Bibliography Pertinent to Disturbance and Rehabilitation of Alpine and Subalpine Lands in the Southern Rocky Mountains

By

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BIBLIOGRAPHY PERTINENT TO DISTURBANCE AND REHABILITATION OF ALPINE AND SUBALPINE LANDS IN THE SOUTHERN ROCKY MOUNTAINS

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PREFACE

Rehabilitation of disturbed lands and preservation of natural beauty have become responsibilities attached to any program of drastic landscape disturbance. To be successful, landscape rehabilitation must be preplanned and based upon the best information available concerning natural landscapes, their rehabilitation potentials and actual reclamation procedures. We must also be able to recognize ecosystems where chances for rehabilitation are poor or nil in light of our present knowledge.

The need for information on rehabilitation potentials and procedures is especially acute in the alpine and subalpine areas of the Rocky Mountains where natural systems are relatively poorly understood and pertinent research has originated primarily within the last twenty years. Rehabilitation success in these lands has usually been limited.

The objective of this bibliography is to provide an introduction to available literature on alpine and subalpine natural systems and the disturbance susceptibilities and reclamation techniques appropriate to these systems. Emphasis is given to the Southern Rocky Mountains and especially Colorado although several special references from other areas are included. References are segregated into seven sections covering different aspects of the literature on high-elevation lands. Cross references are included at the ends of each section. Most literature cited here is available in the libraries of Colorado State University or the University of Colorado. Sources not readily available have been avoided. Microfilm or photocopy order numbers are included in the references to nearly all doctoral dissertations. These microfilms or photocopies may be ordered from

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Ordell Steen

William Berg

CONTENTS

SUBJECT INDEX

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SECTION I

GENERAL, AESTHETICS, PHILOSOPHY

1

Ackerman, D. H. 1973. Environmental impact study: a tool for sound mineral development. Min. Congr. J. 59:16-22.

Outlines the program sponsored by American Metal Climax to assess future environmental impact of the Kirwin mine in northwest Wyoming. Included analyses of potential impact on wildlife, streams, vegetation, and local communities. Concludes that preplanning is good business.

2

Beardsley, W. 1967. Cost implications of camper and campground characteristics in Central Colorado USDA For. Serv. Res. Note RM-86.

Campground occupancy is determined by physical setting, not size or construction investment. The presence of water nearby was particularly important.

3

Billings, W. D. 1952. The environmental complex in relation to plant growth and distribution. Quart. Rev. Biol. 27:251-265.

The environment of plants is a dynamic whole, changing in time and space and made up of a complex of interrelated factors. The distribution of plant species and communities must be studied by considering each factor in relation to others. The distribution of each species in this environmental complex is according to its own genetically determined tolerance limits, including the limits of its ecotypes and biotypes.

4

Bradley, M. D. 1973. Decision-making for environmental resources management. J. Environ. Manage. 1:289-302.

Natural resource management is analyzed as a decisionmaking process to elucidate the forces and resistances acting upon decisionmakers. Three general models of the decision-making process are reviewed.

5

Coates, W. E. 1973. Landscape architectural approach to surface mining reclamation. pp. 26-41 in National Coal Association. First research and applied technology symposium on mined-land reclamation. Bituminous Coal Research, Inc. Monroeville, Pa.

Although concerned specifically with coal mined areas, outlines a philosophy for managing surface mined areas. Surface mining operations must have as its goal not only mineral extraction but also land rehabilitation. A simultaneous extraction-rehabilitation procedure has several advantages over traditional practices.

6

Copeland, O. L. and P. E. Parker. 1972. Land use aspects of the energy crisis and western mining. J. For. 70:671-675.

To meet energy and resource demands, severe landscape disruption is inevitable. Mining developments, through preplanning and careful execution, must preserve or restore acceptable surface environments.

7

Foss, P. O. (ed.). 1974. Environment and Colorado: a handbook. Environmental Resources Center, Colo. St. Univ., Fort Collins. 197p.

A collection of 28 brief articles concerned with ecological systems, social and economic aspects of environmental quality, environmental threats, pollutants, major environmental issues, use and preservation of energy resources, and protection of environmental quality.

8

Kuchler, A. W. 1953. Some uses of vegetation maps. Ecology 34:629-636.

Vegetation maps have been used for a great variety of purposes, especially in Europe. These include problems in forestry, agriculture, land management and planning, geology, etc. Concludes that such maps may be expensive, but they are less expensive than to do without them.

9

Laird, A. M. 1973. Mined land reclamation and public relations. Can. Min. Metall. Bull. 66:47-50.

Outlines a typical reclamation program for a new mining operation in British Columbia. This includes characterizations of the area to be disturbed, characterization of mine and mill wastes, experimental revegetation, long term reclamation, and public relations.

10

Leopold, A. 1949. The land ethic. in A Sand County Almanac and sketches here and there. Oxford Univ. Press, New York.

Land use must be based on more than economics; it must consider what is ethically and esthetically right--what preserves the integrity, stability, and beauty of the biotic community. When based solely on economics, land use eliminates many members of the community which are necessary to the healthy functioning of the whole, of which man is a part. We must extend our social conscience to the land and change our role from conquerors to members and citizens of the land-community.

11

Leopold, Luna B. 1969. Quantitative comparison of some aesthetic factors among rivers. USGS Circular No. 620, 12p.

A scheme to rank landscapes according to their relative physical, biological, and human interest uniqueness is applied to some Idaho rivers. Several landscape features may be graphically combined to represent particular aspects. Unique qualities of a landscape may enhance its value to society.

12

Litton, Burton V., Jr. 1968. Forest landscape description and inventories. A basis for land planning and design. USDA For. Serv. Res. Paper PSW-49, 64p.

Summarizes means of recording and expressing the visual attributes of landscapes. Landscapes are analyzed according to factors such as distance, form, spatial definition, light, etc. Seven compositional types are described including panoramic, feature, and focal landscapes. Bibliography.

13

Madole, R. F. (ed.). 1973. Environmental inventory and land use recommendations for Boulder County, Colorado. Inst. Arct. Alp. Res. Occas. Pap. No. 8. Univ. of Colo. 228p.

A collection of reports on bedrock geology, surficial deposits, vegetation, climate, mineral resources, soils, water resources, air pollution, wildlife, natural hazards, and land use and tenure in this diverse county which includes both plains and high mountains.

14

Mittman, H. 1974. Landscape management considerations in revegetation of high-altitude disturbed lands. pp. 76-79 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent., Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Each landscape has an identifiable visual character describable in terms of the basic concepts, elements, principles, and variables of landscape management. This character of the landscape must be incorporated into the design of human activities to minimize their visual impact.

15

Odum, E. P. 1969. The strategy of ecosystem development. Science 164:262-270.

Summarizes some of the principal features of ecological succession and their relevance to human ecology and landscape planning.

16

Olgeirson, E. R. 1974. Ecological problems in the revegetation of high-altitude disturbed lands: highways. pp. 71-75 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Revegetation programs must be built upon an ecological base, an understanding of natural systems and inclusion of landscape units larger than just the immediate impacted area. Revegetation efforts are confronted with many unanswered questions.

17

Paller, W. and D. A. Schultz. 1973. Planning approaches to surface mining on the national forests. pp. 68-81 in National Coal Association. First research and applied technology symposium on mined-land reclamation. Bituminous Coal Res., Inc., Monroeville, Pa.

Planning for mining development must be comprehensive to coordinate mining activities with other local resource uses and minimize impacts on them, to analyze impacts and influences on the resources of the overall land area, to include inventory and rehabilitation studies, and to develop a long range monitoring program to detect possible noncatastrophic but cumulative resource degradation. Examples are cited from an Idaho phosphate mine development.

18

Peterson, G. L. and E. S. Newmann. 1969. Modeling and predicting human response to the visual recreation environment. J. Leisure Res. 1:219-237.

A conceptual model is presented for developing quantitative preference functions to evaluate characteristics of the visual environment and predict preferences. The model allows for differences in people's response to the same environment.

19

Shafer, E. L., Jr., J. F. Hamilton, Jr. and E. A. Schmidt. 1969. National landscape preferences: a predictive model. J. Leisure Res. 1:1-19.

A quantitative model is developed to predict relative public preference for various landscape photographs. Six variables or landscape characteristics accounted for 66% of the variation in preference scores. An attempt to quantify aesthetics. (See Vol. 2 p. 195 for comments.)

20

Stankey, G. H. 1973. Visitor perception of wilderness recreation carrying capacity. USDA For. Serv. Res. Paper INT-142.

Analysis of visitor attitudes about recreation use; their perception of and reaction to problems such as crowding, littering, construction, and management actions to alleviate such problems.

21

Thirgood, J. V. 1973. Planned reclamation. pp. 92-97 in National Coal Association. First research and applied technology symposium on mined-land reclamation. Bituminous Coal Res. Inc., Monroeville, Pa.

Reclamation should be considered an integral part of the total mining activity and planned before operations begin. Its aim, in most instances should be compatibility with surrounding lands. This requires resource inventory, creation of suitable topography, and natural or assisted revegetation.

22

USDA Forest Service. 1973. Natural forest landscape management, Vol. 1. USDA For. Serv. Handbook 434. 77p.

Landscape management considers the visual harmony or disharmony among landscape parts and the design of management practices to produce visually acceptable landscapes. This report outlines the basic concepts and principles of landscape management and treats aspects such as form, texture, variety, and contrast.

23

Ward, R. T. 1974. A concept of natural vegetation baselines. pp. 2-4 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Revegetation of disturbed landscapes requires knowledge of the natural vegetation, how its parts fit together and how it is integrated with the environment. Natural environments, and thus vegetations, are characterized by gradual change and microscale variation, not broad uniform areas with sharp boundaries. Gradient analysis techniques can be used to establish vegetation baselines.

24

Williamson, R. M. and W. F. Currier. 1971. Applied landscape management in plant control. J. Range Manage. 24:2-6.

Natural landscape beauty can be maintained in a plant control program such as pinyon-juniper removal by recognition of landscape management principles.

SECTION II

CLIMATE, GEOLOGY, HYDROLOGY

25

Baker, F. S. 1944. Mountain climates of the western United States. Ecol. Monogr. 14:223-254.

Characterizes precipitation and temperature climates for 28 areas of mountainous western United States. Includes changes of temperature and length of growing season with elevation, the percentage of precipitation falling in each month, changes of total precipitation with elevation, and relation of total annual snowfall to elevation.

26

Barry, R. G. 1972. Climatic environment of the east slope of the Colorado Front Range. Occasional Paper No. 3. Inst. Arct. Alp. Res., Univ. Colo., Boulder. 206p.

Climatic data for years 1952-1970 are presented for four sites (elevations: 7,200; 8,500; 10,000; and 12,300 feet) in montane and subalpine forests and alpine tundra. Tables include mean daily maximum, minimum, mean, and range of temperatures; relative humidity by month; mean daily wind speed and gust speed; solar radiation; and total monthly precipitation. Synoptic climatological analyses of temperature and precipitation data are included.

27

Barry, R. G. 1973. A climatological transect of the east slope of the Front Range, Colorado. Arct. Alp. Res. 5:89-110.

This report is a tabulation and discussion of climatic data (1952 to 1970) recorded at four ridge sites from 2195 m to 3750 m elevation. Data are presented on wind speeds, temperature, precipitation, radiation, and synoptic climatology.

28

Becker, C. F. and J. D. Alyea. 1964. Precipitation probabilities in Wyoming. Wyo. Agric. Exp. Stn. Bull. 416, Univ. Wyo., Laramie.

Average monthly and annual precipitation for 73 Wyoming stations from 3,500 to 9,000 feet. Table of precipitation probabilities for one-week periods for each station.

29

Benedict, J. B. 1970. Downslope soil movement in a Colorado alpine region: Rates, processes, and climatic significance. Arct. Alp. Res. 2:165-226.

Describes soil movement processes and resulting landforms; moving soils are classified according to their surface expression and sorting. Average maximum rates of modern movement range from .4 to 4.3 cm/year with variations related to ground water levels and slope angle. Radiocarbon dating indicates rates of past movement.

30

Bergen, J. D. 1969. Cold air drainage on a forested mountain slope. J. Appl. Meteorol. 8:884-895.

Volume and flow velocity of nocturnal cold air are related to the net radiation balance of the slope. Local mean speed varies as the one-half power of temperature drop which varies as the two-thirds power of estimated net radiation loss.

31

Bergen, J. D. 1969. Nocturnal air temperature on a forested mountain slope. USDA For. Serv. Res. Paper RM-52.

Nocturnal temperature patterns on a forested subalpine mountain slope may be divided into two periods: 1) "a period of uniform cooling over the entire slope with a relatively constant temperature gradient down the slope" and 2) "a period of increasing downslope gradient with little temperature change near the crest of the hillside." A point of nearly constant temperatures halfway up the hillside is identified with a "center of divergence for cold air moving off the slope."

32

Berry, J. W. 1968. Climates of the states--Colorado. Climatography of the United States No. 60-5. Environmental Sci. Serv. Adm., U. S. Dept. Commerce, Washington, D. C.

A general characterization of the climate of Colorado followed by tables of mean temperature and precipitation for about 90 recording stations. Normals, means, and extremes of temperature, precipitation, relative humidity, wind, and other statistics are presented for five (low elevation) stations. Maps of temperature and precipitation isolines are included.

33

Bethlahmy, N. 1971. Maximum peak flows for selected return periods for watersheds west of the continental divide in Idaho and Montana. USDA For. Serv. Res. Paper INT-113.

Maximum peak flows can be estimated from long term average water yields. Expected maximum peak flows are tabulated by return periods (mean annual, 5, 10, and 20 years) and average annual yield of these Idaho and Montana watersheds.

34

Brown, H. E. and J. R. Thompson. 1965. Summer water use by aspen, spruce, and grassland in western Colorado. J. For. 63:756-760.

Water use, considered as difference between spring and fall soil moisture, averaged 19.2, 14.9, and 8.9 inches for the aspen, spruce, and grassland types respectively. These differences cannot be attributed solely to vegetation type however.

35

Caldwell, M. M. 1968. Solar ultraviolet radiation as an ecological factor for alpine plants. Ecol. Monogr. 38:243-268.

Finds only a modest change in total U.V. with elevation and little effect of U.V. on plant growth. Alpine plants have no greater capacity to filter U.V. than lower elevation plants and are equally sensitive.

36

Craddock, G. W. and C. K. Pearse. 1938. Surface runoff and erosion on granite mountain soils in Idaho as influenced by range cover, soil disturbance, slope, and precipitation intensity. USDA Circ. 482.

The wheatgrass range type controls erosion more effectively than the downy chess, lupine-needlegrass, or annual weed cover types. Deteriorated ranges constitute a flood and erosion hazard.

37

Croft, A. R. and R. B. Marston. 1950. Summer rainfall characteristics in northern Utah. Trans. Geophys. Union 31:83-93.

Characterizes summer torrential rains or cloudbursts at high elevations in the Wasatch Mountains of northern Utah. Data are presented for frequency, depth, intensity, and areal extent in addition to a comparison of mountain and valley stations.

38

Del Rio, S. M. and contributors. 1960. Mineral resources of Colorado--first sequel. Mineral Resources Board, State of Colorado. Publishers Press, Denver. 764p.

History of mineral development in Colorado and mineral resources by counties. Chapters on molybdenum, uranium, rare earths, thorium, beryllium, oil shale, coal, petroleum and natural gas.

39

Doty, R. D. 1971. Contour trenching effects on streamflow from a Utah watershed. USDA For. Serv. Res. Paper INT-95. 19p.

Contour trenching over about 15 percent of a watershed (6,200-9,000 ft.) reduced peak spring flow and peak summer flow but not annual water yields nor snowmelt runoff.

40

Dourojeanni, A. C. 1969. Hydrologic soil study of an alpine watershed. M.S. Thesis, Colo. State Univ., Ft. Collins.

An analysis of hydrologic soil properties in an alpine/subalpine watershed of the Colorado Front Range. The watershed was partitioned into 13 hydrologic units based on soil type and landform. Total water storage in the upper meter of the soil is related to landform, slope, and soil bulk density.

41

Dyrness, C. J. 1967. Erodibility and erosion potential of forest watersheds. pp. 599-610 in W. E. Sopper and H. W. Lull (eds.), Forest Hydrology. Pergamon Press. New York.

Reviews some literature dealing with forest soil erosion, stressing resistance of soil particles to detachment and transport and soil infiltration rates. Soil erodibility indices are strongly influenced by parent material, organic matter, climate, and soil chemical characteristics.

42

Farmer, E. F. and J. E. Fletcher. 1971. Precipitation characteristics of summer storms at high elevation stations in Utah. USDA For. Serv. Res. Paper INT-110.

Long term (10 or more years) precipitation data from 25 stations are analyzed for record consistency, precipitation zones, intensity-duration-frequency characteristics, 24 hour depths, monthly depths and number of storms, storm occurrence by hour of day, and storm occurrence by storm duration.

43

Farmer, E. F. and B. P. Van Haveren. 1971. Soil erosion by overland flow and raindrop splash on three mountain soils. USDA For. Serv. Res. Paper INT-100.

Erosion of bare soil by overland flow in a laboratory simulation was most affected by rainfall intensity, slope steepness, and percentage by weight of particles greater than 2 mm.

44

Frank, E. C. 1973. Snow amount in relation to streamflow and herbage production in western Colorado. J. Range Manage. 26:32-34.

Peak snowpack is correlated with water yield and peak discharge but not herbage production of mountain grasslands.

45

Frank, E. C. and R. Lee. 1966. Potential solar beam irradiation on slopes: tables for 30° to 50° latitude. USDA For. Serv. Res. Paper RM-18. 116p.

Daily integrated and total annual potential insolation and a radiation index based on annual values are tabulated for combinations of latitude (two degree intervals), aspect, and slope (0 to 100 per cent in 10 per cent intervals).

46

Gary, H. L. and G. B. Colthorp. 1967. Snow accumulation and disappearance by aspect and vegetation type in the Santa Fe Basin, New Mexico. USDA For. Serv. Res. Note RM-93.

Of four vegetation types studied (Douglas fir, aspen, spruce-fir, and high elevation grassland), snow accumulated most rapidly and deeply under spruce-fir but had the greatest water equivalent on the grass plots. Snow melting continued longest under spruce-fir.

47

Gates, D. M. and R. A. Janke. 1966. The energy environment of the alpine tundra. Oecol. Plant. 1:39-61.

Characterizes the radiation budget of the alpine, the spectral distribution of solar radiation, and factors affecting it with emphasis on the ultraviolet. Includes an analysis of the energy budget of alpine plants with data from Niwot Ridge near Boulder, Colorado. Temperatures of sunlit leaves may be well above air temperatures. Describes a wind velocity profile and the effects of wind on plant temperatures. Discusses the consequences of this environment for plant activities.

48

Geiger, R. 1950. The climate near the ground. Harvard Univ. Press, Cambridge. 482p.

A relatively thorough treatment of the characteristics of the climate near the ground (below 2 meters). Treats the influence of ground properties on the climate of this boundary layer; the temperature, humidity and wind relationships and optical phenomena within this layer; and the influences of topography, plants, animals, and man. Includes chapters on cold air drainage and microclimatic effects of different exposures.

49

Haase, E. F. 1970. Environmental fluctuations on south facing slopes in the Santa Catalina Mountains of Arizona. Ecology 51:959-974.

The warmest and driest aspects based on means were S, SSW, SW and SE respectively, but this order may change with time of year. Drought conditions were the most intense on SW aspect.

50

Haeffner, A. D. 1971. Daily temperatures and precipitation for subalpine forest, central Colorado. USDA For. Serv. Res. Paper RM-80. 48p.

Tabulation of daily precipitation and temperature data at two sites near Fraser, Colo.; one at 9,070 feet from 1939 to 1971, the other at 10,620 feet for a shorter period. Monthly summaries included.

51

Haeffner, A. D. and C. F. Leaf. 1973. Areal snow cover observations in the Central Rockies, Colorado. USDA For. Serv. Gen. Tech. Report RM-5.

Photographic estimates of snow cover extent is tabulated by dates for 6 watersheds and over 90 subunits. Also summarizes use of these data for hydrologic analyses of subalpine watersheds.

52

Hamon, W. R. 1961. Estimating potential evapotranspiration. Am. Soc. Civ. Eng., J. Hydraul. Div., 87(HY3):107-120.

Develops equation to estimate average potential evapotranspiration from mean temperature converted to saturation water vapor density and day time hours.

53

Hoover, M. D. and C. F. Leaf. 1967. Process and significance of interception in Colorado subalpine forest. pp. 213-224 in Sopper, W. E. and H. W. Lull (eds.). Forest Hydrology. Pergamon Press. New York.

Increased streamflow after timber harvest are not due, apparently to reduced interception but to reduced evaporation and sublimation of snow on tree crowns, less evaporation due to rapid melt in open areas, and reduced transpiration.

54

Ives, Ronald L. 1938. Weather phenomena of the Colorado Rockies. J. Franklin Inst. 226:691-755.

Winter cyclones are the source of most of Colorado's moisture. Three types of summer storms are described: two convection caused (regional and valley) and cyclonic.

55

Ives, R. L. 1942. Atypical subalpine environments. Ecology 23:89-96.

Subalpine wet meadows and rain forests consistently occur at the heads of valleys which have a largely local air circulation and a localized diurnal storm cycle (see Ives, 1938).

56

Ives, J. D. and R. G. Barry (eds.) 1974. Arctic and alpine environments. Methuen, London. (About 980p.)

Should be available by Fall 1974. Includes a number of articles which should be of interest: Topo- and micro-climatology in alpine areas by R. G. Barry and C. C. VanWie; Alpine hydrology by H. D. Slaymaker; Alpine Quarternary glaciation by H. Heuberger; Alpine timberlines by P. Wardle; Arctic and alpine vegetation: plant adaptations to cold summer climates by W. D. Billings; The geomorphic processes of the alpine environment by N. T. Caine; Alpine soils by J. L. Retzer; Prehistoric occupation of the alpine zone in the Rocky Mountains by W. M. Husted; articles on the impact of twentieth century technology by J. D. Ives, W. S. Osburn, Jr., and L. Muller-Wille and by W. S. Osburn, Jr.; in addition to others on the alpine and several similar titles for the arctic tundra.

57

James, J. W. 1967. Nocturnal temperature inversions in an inland valley in the California Coast Range. pp. 13-26 in H. E. Wright and W. H. Osburn (eds.). Arctic and alpine environments. Indiana Univ. Press.

Although data from low elevations (1013 to 1615 feet), indicates large temperature differences which may arise under certain conditions between ridge tops and valley bottoms. Minimum temperatures on the ridge top in this study averaged 21° F higher than those in the valley bottom, 600 feet below.

58

Johnson, K. L. (ed.). 1963. Watershed analysis of the Little South Fork of the Cache LaPoudre River. Coop. Watershed Management Unit, Colo. State Univ., Fort Collins.

Physical description, climate, hydrology (streamflow and surface runoff measurements), land ownership, resource management and recommendations for management of this Colorado high elevation watershed.

59

Johnston, R. S. and R. D. Doty. 1972. Description and hydrologic analysis of two small watersheds in Utah's Wasatch Mountains. USDA For. Serv. Res. Paper INT-127. 53p.

"The climate, geology, soils, and vegetation are included in a description of two small watersheds (7,500 to 8,400 feet) characteristic of the high elevation aspen type of northern Utah. Precipitation, soil water use, evapotranspiration, and quantity and quality of streamflow on these relatively undisturbed catchments are graphically illustrated and discussed."

60

Judson, A. 1965. The weather and climate of a high mountain pass in the Colorado Rockies. USDA For. Serv. Res. Paper RM-16. 28p.

Characterizes the temperature, snowfall, snow densities and crystal types, snowpack, wind speeds and directions, correlation of surface winds with winds aloft, and major storm types on Berthoud Pass (11,315 ft. m.s.l.). Average (1950-1964) temperatures, precipitation, snowfall and windspeeds are presented for each month of the year.

61

Kittredge, J. 1948. Forest Influences. (The effects of woody vegetation on climate, water, and soil, with applications to the conservation of water and the control of floods and erosion.) McGraw-Hill, Inc., New York. 394p.

Effects of forests on solar radiation, air temperature, wind, atmospheric moisture, precipitation, evaporation, soil temperature, litter, soil moisture, runoff and stream flow, floods, erosion, etc.

62

Kruse, E. G. and H. R. Haise. 1973. Water use by native grasses in high altitude Colorado meadows. USDA Agri. Res. Serv. ARS-W-6.

Growing season evapotranspiration totals in high mountain meadows ranged from 58.9 to 70.5 cm. and averaged about 82 percent of evaporation from Class A pans. A simple equation utilizing only two climatic variables gave good estimates of evapotranspiration in these meadows.

63

Leaf, C. F. 1966. Sediment yields from high mountain watersheds, central Colorado. USDA For. Serv. Res. Paper RM-23.

Sediment yields correlate well with annual peak discharge and total annual flow. Sediment yields from a logged watershed were relatively large immediately after treatment but abated in subsequent years.

64

Leaf, C. F. 1969. Aerial photographs for operational streamflow forecasting in the Colorado Rockies. West Snow Conf. Proc. 37:19-28.

Snow depletion-meltwater runoff curves analyzed for three Colorado subalpine watersheds.

65

Leaf, C. F. 1971. Areal snow cover and disposition of snowmelt runoff in central Colorado. USDA For. Serv. Res. Paper RM-66. 19p.

Snow pack depletion--runoff relationships are characteristic for individual watersheds but may vary considerably among adjacent watersheds. Differences between south and north facing slopes diminish at high elevations. Watershed efficiencies varied among years and during seasons and on one watershed averaged 39 percent over an 11 year periods.

66

Leaf, C. F. and G. E. Brink. 1972. Annual streamflow summaries from four subalpine watersheds in Colorado. USDA For. Serv., Gen Tech. Report RM-1.

Tables of daily flow for East St. Louis Creek at Fraser Experimental Forest and three watersheds near Steamboat Springs, Colorado.

67

Leaf, C. F. and G. E. Brink. 1973. Hydrologic simulation model of Colorado subalpine forest. USDA For. Serv. Res. Paper RM-107.

Describes a computerized simulation model to predict probable hydrologic changes resulting from watershed management in the Colorado subalpine. The model is used to simulate snowmelt and water yield from a 667 acre watershed at Fraser Experimental Forest.

68

Lee, R. 1963. Evaluation of solar beam irradiation as a climatic parameter of mountain watersheds. Colo. State Univ., Hydrol. Paper No. 2. 50p.

Describes methods, both graphical and mathematical, to derive potential solar beam irradiation for any surface [Tables of potential solar beam irradiation are presented in Frank and Lee (1966)]. In addition, two methods of deriving potential insolation on a watershed are described. The first breaks the watershed into facets, the second utilizes a theoretical intercepting surface. Over 90 percent of the differences in water yield among 12 watersheds in three areas of the U. S. were associated with potential insolation differences.

69

Love, L. D. 1952. (revised 1960). The Fraser Experimental Forest: its work and aims. USDA For. Serv., Rocky Mt. For. Range Exp. Stn., Stn. Paper 8. 16p.

Presents highlights of Forest Service research since 1937 at this experimental forest. Includes effects of timber cutting on water and sediment yield, snowmelt, streamflow, tree growth and regeneration, etc.

70

Love, L. D. and B. C. Goodell. 1960. Watershed research on the Fraser Experimental Forest. J. For. 58:272-275.

Summarizes past watershed research at this Colorado experimental forest, particularly the effects of timber cutting on snow accumulation and melt and stream flow.

71

Lovering, T. S. and E. N. Goddard. 1950. Geology and ore deposits of the Front Range, Colorado. U.S. Geol. Surv. Prof. Paper 223. 319p.

A comprehensive review of the physiography, geology, and ore deposits of these mountains. Includes a description of Front Range mines and the ore they have produced.

72

Lull, H. W. and L. Ellison. 1950. Precipitation in relation to altitude in central Utah. Ecology 31:479-484.

Precipitation increases linearly with elevation from 5,500 to 10,000 feet; differences are most pronounced in winter and least in summer.

73

Marcus, S. R. 1973. Geology of the montane zone of central Colorado with emphasis on Manitou Park. USDA For. Serv. Res. Paper RM-113. 20p.

Petrology, structure, geologic history, and physiography of Colorado Front Range, Sangre de Cristo Mountains, Spanish Peaks, and Wet Mountains. The Manitou Park area is discussed in detail.

74

Marr, J. W., J. M. Clark, W. S. Osburn, and M. W. Paddock. 1968. Data on mountain environments III. Front Range, Colorado, four climax regions, 1959-1964. Univ. of Colo. Studies, Ser. in Biol. No. 29, 181p.

Tabular presentation of meteorological data by day, month, and year for four sites from 7,200 feet to 12,300 feet elevation west of Boulder. Includes air and soil temperatures, winds, precipitation, snow depth, soil moisture, and relative humidity. Numbers 27 and 28 of the Series in Biology contain similar data for earlier periods and in one case (#27) additional sites.

75

Martinelli, M., Jr. 1959. Some hydrologic aspects of alpine snowfields under summer conditions. Geophys. Res. 64:451.

Alpine snowfields are an important source of summerstream flow in Colorado. Ablation rates, density, etc. are characterized for five such snowfields. Snowdrift size is a function of the shape and size of barriers to winds.

76

Martinelli, M., Jr. 1964. Watershed management in the Rocky Mountain alpine and subalpine zones. USDA For. Serv. Res. Note RM-36, 7p.

Removing timber from 39% of a watershed near Fraser, Colorado, increased water yield by 23% due primarily to greater spring runoff. Alpine summer snowfields are an important source of summer streamflow. Relatively few storms account for most of the snow that accumulates in these fields. Snow fences may appreciably increase snow depth.

77

Meeuwig, R. O. 1970. Sheet erosion on intermountain summer ranges. USDA For. Serv. Res. Paper INT-85.

Erosion magnitudes resulting from simulated rain applied to small plots in Utah, Idaho, and Montana depends primarily on proportion of soil surface protected from direct raindrop impact. Tables and figures may aid land manager in assessment of potential sheet erosion on similar sites.

78

Meeuwig, R. O. 1971. Soil stability on high elevation rangeland in the Intermountain area. USDA For. Serv. Res. Paper INT-94, 10p.

Erosion is more related to plant and litter cover than any other variable but is greatly affected by slope gradient. Organic matter decreases erosion of clay soils but tends to increase erosion of sandy soils.

79

Meiman, J. and G. Leavesley. 1974. Little South Poudre watershed climate and hydrology 1961-1971. Synop. Coll. For. Nat. Resour. Colo. State Univ., Fort Collins. 22p.

This report summarizes in graphs and charts the daily observation data presented in a larger report by the same authors (Little South Poudre watershed climate and hydrology 1961-1971. Basic data. College of Forestry and Natural Resources, Colo. State Univ., Fort Collins. 102p.). This 105 square mile watershed lies in the high elevations (nearly 80 percent between 8,300 and 11,300 feet) of the Colorado Front Range. Data from two meteorological base stations (8120 and 9000 feet elevation) include temperature maximums, minimums, and means; precipitation monthly means and ranges and annual totals; and monthly solar radiation totals. Snow water content measurements are presented from four snow courses and streamflow data from several gauging stations.

80

Mueggler, W. F. 1971. Weather variations on a mountain grassland in southwestern Montana. USDA For. Serv. Res. Paper INT-99.

Weather data collected during five growing seasons summarized for four stations (7,100 and 8,200 feet elev. but tabulated only for 7,100 feet elev.). Data include solar radiation, air temperature, soil temperature, relative humidity, wind, precipitation and soil moisture.

81

Parsons, W. J. and G. H. Castle. 1959. Aerial reconnaissance of mountain snow fields for maintaining up-to-date forecasts of snowmelt runoff during the melt period. West. Snow Conf. Proc. 27:49-56.

Describes a method of making current runoff forecasts from frequent measurements of snow covered area and a single snow course survey.

82

Retzer, J. L. 1965. Significance of stream systems and topography in managing mountain lands. pp. 399-411 in C. T. Youngberg (ed.), Forest-soil relationships in North America. Oregon State Univ. Press, Corvallis.

Management of mountain lands must consider, in addition to soils, characteristics of streams and slopes and recognize maturity of topography. Several management problems related to these characteristics are briefly discussed.

83

Richmond, G. M. 1965. Glaciation of the Rocky Mountains. pp. 217-230 in H. E. Wright, Jr. and D. G. Frey (eds.). The Quaternary of the United States. Princeton University Press, Princeton.

Five distinct Pleistocene glaciations are recognized and described for the Rocky Mountains. These extended as far south as latitude 33 degrees with an average end moraine elevation of 10,200 to 11,400 feet in the south and 4,200 to 5,400 feet at latitude 49 degrees. Bibliography.

84

Rocky Mountain Association of Geologists. 1972. Geologic atlas of the Rocky Mountain region. Denver, Colorado. 331p.

This collection of several papers with abundant regional maps forms a "compendium of the mappable geology" of the Rocky Mountain region of the United States. Topics include regional geography, tectonics, regional geophysics, historical geologic systems from Cambrian through Pleistocene, and economic geology. Each paper includes a list of selected references.

85

Salisbury, F. B. and G. G. Spomer. 1964. Leaf temperatures of alpine plants in the field. Planta 60:497-505.

Under clear skies, alpine plant temperatures are dependent on radiation and may be as much as 22° C above air temperatures.

86

Salisbury, F. B., G. G. Spomer, M. Sobral, and R. T. Ward. 1968. Analysis of an alpine environment. Bot. Gaz. 129:16-32.

The alpine environment near Rocky Mountain National Park, Colorado is described in terms of the variability and cycles (with periods from hours to seasons) of light intensity, air temperature, wind, precipitation, and atmospheric humidity.

87

Slaymaker, H. O. 1972. Sediment yield and sediment control in the Canadian cordillera. pp. 235-274 in H. O. Slaymaker and H. J. McPherson (eds.). Mountain geomorphology: geomorphological processes in the Canadian cordillera. Tantalus Research Ltd., Vancouver.

Characterizes sediment yield rates, contributing factors and control principles for large, intermediate, and small watersheds. Bibliography.

88

Soons, J. M. 1967. Erosion by needle ice in the Southern Alps, New Zealand. pp. 217-227 in H. E. Wright and W. H. Osburn (eds.). Arctic and alpine environments. Indiana Univ. Press.

Sediment yields in runoff plots may be high even though precipitation is low due apparently to needle ice activity.

89

Thornbury, W. D. 1965. Regional geomorphology of the United States. John Wiley and Sons, Inc. New York. 609p.

A standard text and reference on this subject. The regional classification closely follows Fenneman's classification but incorporates information acquired since 1931. The bibliography is not exhaustive but provides a good introduction.

90

Trask, P. D. 1950. Dynamics of sedimentation. pp. 3-40 in P. D. Trask (ed.). Applied sedimentation. John Wiley and Sons, New York.

A general and broad review of sediment dynamics: erosion, transport, and deposition; major areas of deposition (as lakes, continental shelf, etc.); and classification of sediments.

91

Turner, G. T. and E. J. Dortignac. 1954. Infiltration, erosion and herbage production of some mountain grasslands in western Colorado. J. For. 52:858-860.

Thurber's fescue meadows provide good watershed protection but the bluegrass type permits greater runoff and thus subjects lower lands to gullying. The needlegrass type is subject to deterioration and erosion.

92

USDA Forest Service. 1959. Forest and range hydrology handbook. USDA Forest Service Category 2 Handbook 2534. 272p.

Relatively nontechnical discussions relating to hydrologic analyses and management of watersheds. Includes watershed characteristics, hydrologic processes affected by soil and plant cover, watershed survey methods, effects of land treatments, evaluation of channel changes and structures, sedimentation studies, and hydrologic measurements.

93

Vanderwilt, J. W. 1947. Mineral resources of Colorado. State Colo. Miner. Resour. Board. Colo. Min. Assn., Denver.

Part I briefly describes the metal mining districts of Colorado according to location, accessibility, general geology, ore deposits, and mine production; the nonmetalic mineral resources of Colorado and their characteristics; and the fuel reserves of Colorado including coal, petroleum, and oil shale. Part II summarizes the geology and ore deposits of Colorado mining districts. Part III reports on strategic mineral resources.

94

Weimer, R. J. and J. D. Haun. 1960. Guide to the geology of Colorado. Geological Soc. of Amer., Rocky Mt. Assoc. of Geologists, and Colo. Scientific Soc. 310p.

A collection of several papers and detailed field trip descriptions relating to Colorado geology. Includes major geologic features, geologic history, stratigraphy, lithology, etc. Field trips include most areas of mountainous Colorado. Bibliographies.

95

Williams, P., Jr. and E. L. Peck. 1962. Terrain influences on precipitation in the intermountain west as related to synoptic situations. J. Appl. Meteorol. 1:343-347.

Analyzes precipitation distribution patterns of several years with regard to different storm types in northwest Utah. Low elevation stations received more precipitation than high elevation stations during storms associated with a "cold low" aloft.

See also 7, 13, 98, 116, 128, 146, 149, 150, 166, 194, 201, 203, 207, 227, 257, 258, 273, 274, 288, 294, 295, 299, 300, 304, 421, 432, 446, 450

SECTION III

SOILS AND SUBSTRATES

96

Black, R. F. 1950. Permafrost. pp. 247-275 in P. D. Trask (ed.), Applied sedimentation. Wiley and Sons. New York.

A review of literature considering the extent, origin, and characteristics of permafrost; its engineering and biological significance; recognition and prediction of permafrost; and its implications for construction, water supply, sewage disposal, mining, etc. Little direct reference to alpine.

97

Crocker, R. L. and J. Major. 1955. Soil development in relation to vegetation and surface age at Glacier Bay, Alaska. J. Ecol. 43:428-448.

Changes in soil properties are related to vegetation development, following deglaciation, from initial colonization of bare areas to development of spruce dominated forests. Organic carbon continuously increases, bulk density decreases, litter accumulates, pH declines rapidly at first but then changes little, and total nitrogen increases beneath alder (and dryad) but then decreases following spruce establishment.

98

DeBano, L. F., J. F. Osborn, J. S. Krammes, and J. Letey, Jr. 1967. Soil wettability and wetting agents: Our current knowledge of the problem. USDA For. Serv. Res. Paper PSW-43. 13p.

A nonwettable soil layer is apparently widespread in the western United States, especially on burned watersheds. This layer forms when hydrophobic substances, originating from plant litter, volatolize and subsequently condense on soil particles. Plant species differ greatly in their contribution to nonwettability. A nonwettable layer impedes infiltration, water movement and evaporation. Greater runoff, water erosion and dry-creep erosion result. Many wetting agents to improve wettability are commercially available but differ little in effect. Application of a wetting agent to nonwettable soils increased grass seed germination.

99

Fahey, B. D. 1974. Seasonal frost heave and frost penetration measurements in the Indian Peaks region of the Colorado Front Range. Arct. Alp. Res. 6:63-70.

Maximum frost heaving of 25 to 30 cm. occurred at the surface of frost boils but was less in vegetated areas. Maximum heaving is favored by absence of snow, low vegetation cover, and water table near the surface. Mean frost penetration rates during first four months of freezing was 1.4 cm/day while thaw averaged 1.6 cm/day from mid May into August.

100

Faust, R. A. and T. J. Nimlos. 1968. Soil microorganisms and soil nitrogen of the Montana alpine. Northwest Sci. 42:101-107.

Surface soils have high total nitrogen due to restricted microbial oxidation of organic matter but low levels of ammonium and nitrate. Psychrophile bacteria (those which grow relatively rapidly at low temperatures) make up 6 to 21 percent of the bacterial populations in well drained soils and 50 percent in poorly drained soils.

101

Fox, C. J. and J. Y. Nishimura. 1961. Soil survey of Trout Creek watershed, Colorado. USDA, SCS, and U.S. Forest Service. Series 1958, No. 5. 48p. plus maps.

A description of the soil types and soil management units in this 58 square mile watershed at elevations mostly between 8,400 and 9,700 feet. Fifteen soil series and land types are mapped and described according to general features (extent, relief, vegetation, fertility, water storage capacity, etc.), profile characteristics, and uses. Representative soil series of each of five great soil groups found in this watershed are described. Based on this and other information, soil management areas are described and management recommendations developed.

102

Fox, C. J. and J. Y. Nishimura. 1965. Soil management report Taylor River area, Gunnison National Forest. USDA Forest Service, Regional Office Denver. Div. of Watershed Mgmt. 87p.

Descriptions for broad planning purposes of soil management areas and their suitabilities and limitations for various uses in approximately 880 square miles of high elevation lands near Gunnison, Colorado. Each of seven broad management areas is characterized and mapped, its present use described and recommendations provided for its future management. The suitabilities of the many soil types for timber, range, recreation, and engineering uses along with their value for water production and wildlife habitat are discussed. Brief descriptions of the geology, climate, vegetation and soils of this area are provided. This is an interim report and a published survey should be available by 1976 or 1977.

103

Gary, H. L. 1968. Soil temperatures under forest and grassland cover types in northern New Mexico. USDA For. Serv. Res. Note RM-118.

Mean monthly and mean annual soil temperatures for one year at seven depths under Douglas fir, aspen, spruce-fir, and grassland types on south and north facing slopes near Santa Fe. Temperatures were more related to vegetation type than elevation, aspect, or snow cover.

104

Goodman, G. T., C. E. R. Pitcairn, and R. P. Gemmell. 1973. Ecological factors affecting growth on sites contaminated with heavy metals. pp. 149-173 in R. J. Hutnik and G. Davis, Ecology and Reclamation of Devastated Land. Vol. II. Gordon and Breach. New York.

Discusses factors which limit germination, establishment, and growth of plants on metalliferous mine workings and old mine wastes. Metal tolerant clones are superior to commercial nontolerant seed varieties.

105

Gradwell, M. W. 1960. Soil frost action in a snow-tussock grassland. New Zealand J. Sci. 3:580-590.

Ice needles occurred only on bare loamy soil and not beneath fescue tussock litter. One-half to two inches of litter or two to three inches of scree prevented needle ice growth.

106

Grubb, Hayes F. 1965. The feasibility of vegetating mine tailings at Climax, Colorado. MSc. Thesis, Colo. State Univ. Fort Collins.

Tailings from the Climax Molybdenum Mine (11,000 feet elev.) are deficient in N-P-K, unstable, and have a wide range of pH. Barley and other species such as timothy, smooth brome, western wheatgrass, Russian wildrye, clovers, etc. can be established if fertilizers and lime added.

107

Hoff, C. C. 1957. A comparison of soil, climate, and biota of conifer and aspen communities in the Central Rocky Mountains. Am. Midl. Nat. 58:115-140.

Soils of aspen forests are generally less rocky, less acid, more moist and contain more organic carbon than those of conifer forests. No consistent differences in relative humidity, air temperature, or light intensity were found. Aspen is a "soil improving" tree species.

108

Ives, J. D. and B. D. Fahey. 1971. Permafrost occurrence in the Front Range, Colorado Rocky Mountains, U.S.A. J. Glaciol. 10:105-111.

Permafrost probably occurs as scattered patches in wet, winter snow-free sites near timberline but becomes more extensive and very deep at the highest elevation snow-free sites where it may form a continuous zone.

109

Johnson, D. D. and J. J. Cline. 1965. Colorado mountain soils. Advan. Agron. 17:233-281.

A description of the general soil patterns of mountainous Colorado based on five regional subdivisions (lower montane, upper montane, subalpine, and mountain parks and meadows) is followed by descriptions of each of the major soil types such as alpine meadow, brown podsolic, brown forest soils, etc. A typical profile and the variation of each type is characterized.

110

Johnson, W. M. 1940. Infiltration capacity of forest soils as influenced by litter. J. For. 38:520.

Removal of forest litter from Colorado ponderosa pine forest floors significantly reduced infiltration and thus increased runoff.

111

Johnson, W. M. and D. R. Smith. 1966. Pot tests of productivity and nutritive status of three alpine soils in Wyoming. USDA For. Serv. Res. Note RM-75.

Alpine soils developed on glacial till are more fertile than those developed on volcanic ash or breccia. Phosphorus was the most limiting element in soils from till although other soils are deficient primarily in nitrogen. Ash soils should be accepted as naturally unproductive due to poor soil moisture holding characteristics.

112

Kersten, M. S. 1959. Frost penetration: relationships to air temperatures and other factors. Highw. Res. Bd. Bull. 225:45-62.

Describes equations to predict depth of freeze from air temperature and several soil characteristics including moisture content and thermal conductivity. Includes field observations from Minnesota.

113

Linell, K. A. and C. W. Kaplan. 1959. The factor of soil and material type in frost action. Highw. Res. Bd. Bull. 225: 81-126.

Soil frost behavior is affected by grain size, void characteristics, soluble salts, mineral type, organic matter content, compaction, moisture content, thermal properties of the soil, etc.

114

Lunt, O. R. 1972. Problems in nutrient availability and toxicity. pp. 271-277 in V. B. Youngren and C. M. McKell (eds.). The biology and utilization of grasses. Academic Press, New York.

A brief review of nutrient availability and toxicity problems related to grass establishment and growth. Toxicities associated with acid soils are generally more important than those due to specific heavy metals. Acid soils are usually deficient in phosphorous, molybdenum, magnesium and calcium and contain toxic levels of aluminum and manganese. Most grass species, however, contain considerable genetic variability in relation to tolerance of toxic elements and nutrient supply. Nitrogen is considered a major factor determining grass species distributions.

115

Lutz, H. J. and R. F. Chandler, Jr. 1946. Forest Soils. John Wiley and Sons, Inc. New York. 514p.

A general soils text emphasizing forest soils. Includes chapter on soil formation, organic matter, physical properties, chemical properties, classification, and erosion.

116

Meeuwig, R. O. 1971. Infiltration and water repellency in granitic soils. USDA For. Serv. Res. Paper INT-111.

Hydrophobic compounds released by decomposition of plant litter and absorbed on mineral surfaces may be a major limiting factor for the ability of such soils to absorb high-intensity summer rainfall. Water repellency tends to develop in a continuous layer under pine litter in the Carson Range of Sierra Nevada.

117

Mortvedt, J. J., P. M. Giordano, and W. L. Lindsay (eds.). 1972. Micronutrients in Agriculture. Soil Science Society of America. Madison, Wisc. 666p.

A summarization discussion of micronutrients in soils and their availability to plants. Among many subjects discussed are plant uptake, functions of micronutrients in plants, climatic and soil conditions promoting deficiencies, soil and plant analysis, and methods to correct deficiencies. Toxicities caused by Al and Mn are also covered.

118

Nimlos, T. J. and R. C. McConnell. 1962. The morphology of alpine soils in Montana. Northwest Sci. 36:99-112.

The Ptarmigan series comprises well drained, acid, and stony soils with minimal profile development and well developed turf. The Hopleys series is similar but alkaline. The Beartooth series comprises imperfectly to poorly drained acid soils with a peaty horizon overlying a gleyed horizon.

119

Nimlos, T. J. and R. C. McConnell. 1965. Alpine soils in Montana. Soil Sci. 99:310-321.

The two well drained series have in common an organic surface, an A1 with characteristics of a mollic epipedon, low C/N ratios, dark colors, and high base saturation. The poorly drained series is strongly acidic with evidence of gleying. It has low oxidation rates, low temperatures, poor aeration and undecomposed organic matter on the surface.

120

Nimlos, T. J., R. C. McConnell, and D. L. Pattie. 1965. Soil temperature and moisture regimes in Montana alpine soils. Northwest Sci. 39:129-137.

Soil temperatures decreased with depth and were lower under a sedge hummock than a fellfield or dry meadow community. One inch temperatures closely followed air temperature. Available soil moisture increased from fellfield to dry meadow to sedge hummock communities. Alpine soils contain abundant total nitrogen but it is concentrated in unavailable organic form.

121

Nimlos, T. J., R. W. Steele, G. M. Blake, and R. D. Tabor. 1964. Soil temperatures in the Lubrecht Experimental Forest. Montana Forestry Notes, Montana State Univ. No. 1.

Soil temperatures of six forested sites are related to soil moisture and air temperature.

122

Nishimura, J. Y. 1974. Soils and soil problems at high altitudes. pp. 5-9 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent., Inf. Ser. No. 10, Colorado State Univ., Fort Collins.

High elevation soils vary greatly in depth, rockiness, water holding capacity, fertility, and susceptibility to erosion and must be evaluated prior to disturbance. Maximum slope for grass establishment is generally 66 percent. A good seedbed is best prepared from topsoil. Subsoils are usually nitrogen deficient. Seeding in the alpine has, in most cases, not proven practical.

123

Parr, J. F. 1968. The soil microbiological equilibrium: nature and duration of changes induced by cultural practices. pp. 28-37 in G. W. Bergtson (symp. chairman). Forest fertilization--theory and practice. Tenn. Valley Auth., Knoxville, Tenn.

The nature of microbiological populations, their associations and interactions, are affected by the soil environment. Fertilizer application, burning, etc. may upset microbiological populations for long periods and thus affect the growth and nutrition of crops and trees. Bibliography.

124

Peterson, H. B. and R. F. Nielson. 1973. Toxicities and deficiencies in mine tailings. pp. 15-25 in R. J. Hutnik and G. Davis (ed.) Ecology and Reclamation of Devastated Land. Vol. I. Gordon and Breach. New York.

Although a great deal of variability exists among various mine and mill wastes, tailings from heavy metal operations often have toxic substances, nutrient deficiencies, low pH, high salts, and physical properties unfavorable for plant growth. Each site must be studied separately.

125

Pettibone, H. C. and C. D. Kealy. 1971. Engineering properties of mine tailings. J. Soil Mech. Found. Div. ASCE 97:1207-1225.

Reports the mineralogical and physical properties of eight separated mine backfill materials and a series of samples from a tailings pond as related to their possible use in construction programs.

126

Price, L. W. 1971. Vegetation, microtopography, and depth of active layer on different exposures in subarctic alpine tundra. Ecology 52:638-647.

An analysis of the relationship of vegetation, microtopography, and exposure to depth of permafrost in an alpine tundra area of the Yukon Territory. Depth to permafrost is largely related to microtopography and vegetation cover.

127

Retzer, J. L. 1956. Alpine soils of the Rocky Mountains. J. Soil Sci. 7:22-32.

Three alpine soils groups (alpine turf, alpine meadow, and alpine bog) are described by a modal profile, occurrence and drainage, depth of permafrost, etc. In addition, exchangeable cations, available phosphorus, pH, organic carbon, and particle size are described for alpine turf soils from various parent materials.

128

Retzer, J. L. 1962. Soil Survey--Fraser alpine area, Colorado. USDA For. Serv. and Soil Cons. Serv. in cooperation with Colo. Agr. Expt. Sta. Series 1956, No. 20. 47p.

Describes ten soil series plus five other mapping units (rock slides, etc.) in the alpine and subalpine areas near Fraser, Colorado. Includes profile characteristics, topography, permeability, use, etc. of each series. Soil management areas are defined and soils classified according to suitability for various uses. Aspects of watershed management are discussed.

129

Retzer, J. L. 1963. Soil formation and classification of forested mountain lands in the United States. Soil Sci. 96:68-74.

Vegetation modifies mountain soils both physically and chemically. Together with effects of terrain, this provides several problems for classification of soils on steep mountainous lands.

130

Retzer, J. L. 1965. Present soil forming factors and processes in arctic and alpine regions. Soil Sci. 99:38-44.

Reviews features of cryopedogenic soils of North America. Permafrost is an important component of these landscapes and, in addition to the arctic, is found on mid latitude mountains above 10,500 feet. Well drained cryopedogenic soils from various regions have remarkable similar morphologies. Profiles are distinctive but poorly developed due to low temperatures and immaturity. Carbon/nitrogen ratio range from 13 to 26. Normal pH values for surface soils are about 4.5 except where developed from basic parent materials.

131

Schramm, J. R. 1958. The mechanism of frost heaving of tree seedlings. Proc. Am. Phil. Soc. 102:333-350.

Describes the mechanism by which seedlings are lifted in a study on fine coal mine wastes.

132

Skoropanov, S. G. 1968. Reclamation and cultivation of peatbog soils. Translated from Russian by N. Kaner. Israel Program for Scientific Translations, Ltd. Jerusalem.

Description of bog soils in Russia and their reclamation for agricultural purposes including drainage, fertilization, influence of agricultural plants on fertility, etc.

133

Smith, D. 1966. Pot test of nutritive status of two high elevation soils in Wyoming. J. Range Manage. 19:38-40.

Yield of domestic oats, grown in the greenhouse on two high elevation Wyoming soils increased with addition of phosphorus but not nitrogen, potassium, or micronutrients. Twenty years of protection from grazing did not increase productive capabilities of these soils.

134

Smith, D. R. 1969. Vegetation, soils, and their interrelationships at timberline in the Medicine Bow Mountains, Wyoming. Univ. Wyom., Laramie, Agric. Exp. Stn., Sci. Monogr. 17. 13p.

A *Geum* turf community on high elevation coarse textured soils of high organic matter is distinguished from but intergrades with a *Deschampsia* meadow community at lower elevations on finer textured soils of lower organic matter content. Production is analyzed. Twenty three soil series are tentatively described. In general, soils are moderately deep, acid, highly base unsaturated, and have accumulated organic matter.

135

Tew, R. K. 1968. Properties of soil under aspen and herb-shrub cover. USDA For. Serv. Res. Note INT-78. 4p.

Soils under aspen stands have higher organic matter content and more rapid cycling of bases than on adjacent herb-shrub sites. Soils on south facing slopes have poorer aggregation and moisture holding capacity than those on other aspects and are, consequently, more susceptible to erosion.

136

USDA Forest Service. 1961. Handbook on soils. USDA For. Serv. Category 2 Handbook 2512.5. 298p.

A guide to the principles and basic procedures used to analyze physical landscape features of the environment pertinent to wild lands management. Includes chapters on soil forming minerals and rocks; soil morphology; physical characteristics of soils; soil moisture; chemical properties of soils; plant nutrients and soil fertility; biologic and organic properties of soils; principles, kinds, and effects of soil erosion; and geomorphology. Each chapter considers several aspects of the respective topic in addition to basic definitions and a brief bibliography.

137

Woodmansee, R. G. 1972. Soil descriptions and simulation model of potassium cycling in Colorado forests. Ph.D. Thesis. Colo. State Univ., Fort Collins. 172p. 73-13,054.

Soils of lodgepole pine, Douglas fir, and Engelmann spruce-subalpine fir forests in the Colorado Front Range were analyzed for profile (color, texture, structure, consistence, thickness, stoniness, and root context) and chemical characteristics (pH, organic carbon, nitrogen, C.E.C., phosphorous, calcium, magnesium, potassium, and sodium). All horizons exhibited low fertility.

See also 13, 56, 149, 150, 171, 175, 176, 179, 197, 200, 201, 207, 220, 234, 238, 247, 260, 262, 265, 269, 286, 320, 450.

SECTION IV

NATIVE SPECIES AND VEGETATION

138

Amundsen, C. C. 1967. The subalpine forests of Wild Basin, Front Range, Colorado. Ph.D. Thesis, Univ. of Colorado, Boulder. 141p. 68-2672.

Recognizes four forest types. Representative sites of the lodgepole pine subclimax type occur on dry south facing slopes, have little or no litter or live plant cover, form all aged stands, and have insignificant spruce and fir reproduction. Lodgepole pine stands successional to spruce-fir are even aged and found on mesic, recently disturbed sites. A successional forest of mixed limber pine and Douglas fir was found on a north facing slope. Subalpine fir is the most abundant tree species in climax spruce-fir forests but Engelmann spruce has the greatest basal area. Several factors perpetuate the mixture of spruce and fir in these forests. Differences in structure and productivity of these subalpine forests could not be consistently related to a geographic or environmental characteristic.

139

Bamberg, S. A. 1961. Plant ecology of alpine tundra areas in Montana and adjacent Wyoming. M.A. Thesis. Univ. of Colo., Boulder. 163p.

Alpine tundra vegetation types of Montana and northern Wyoming are described and related to environmental factors. These types are separated into two groups according to types of substrate, igneous or sedimentary. Types are further separated according to soil moisture and snow duration differences. Frost action and animal disturbance are important.

140

Bierly, K. F. 1972. Meadow and fen vegetation in Big Meadows, Rocky Mountain National Park. MSc. Thesis, Colorado State Univ., Fort Collins. 102p.

Describes the natural vegetation of this subalpine wetland area and its variation along gradients of moisture, nutrients, and soil type. Includes analyses of the responses of individual species to these gradients. Seven vegetation types are recognized.

141

Billings, W. D. 1973. Arctic and alpine vegetations: similarities, differences, and susceptibility to disturbance. Biosci. 23:697-704.

A general characterization of arctic and alpine environments, floras, life forms, vegetations, ecotypes, and susceptibilities to disturbance. Degree of disturbance depends not only on the kind and intensity of disruption but also on kind of vegetation, soil, permafrost, and animal life. Most arctic and alpine vegetations recover very slowly from disturbance.

142

Billings, W. D. 1974. Adaptations and origins of alpine plants. Arct. Alp. Res. 6:129-142.

Summarizes the adaptations of alpine tundra plants to the environment of cold, short growing seasons. Includes morphological characteristics, seed dormancy and germination, seedling establishment, vegetative growth, photosynthesis and respiration, etc. Most alpine floras evolved relatively recently from forest, grassland, and desert floras.

143

Billings, W. D. and L. C. Bliss. 1959. An alpine snowbank environment and its effects on vegetation, plant development and productivity. Ecology 40:388-397.

Productivity of snowbank sites is high due to high available moisture but if snow lies very late, the growing season becomes too short for plant and soil development. Most plant growth begins immediately after or prior to snow melt and is very rapid. Full bloom may be achieved in three weeks and seed production in six to eight weeks.

144

Billings, W. D. and H. A. Mooney. 1959. An apparent frost hummock sorted polygon cycle in the alpine tundra of Wyoming. Ecology 40:16-19.

Wind erosion and frost heaving may cause degradation of peat hummocks in the alpine. After degradation and subsequent flooding, the peat mounds reform until they are again susceptible to erosion.

145

Billings, W. D. and H. A. Mooney. 1968. The ecology of arctic and alpine plants. Biol. Rev. Cambridge Phil. Soc. 43:481-529.

A comprehensive review of the adaptations of these plants. Includes life form, morphology, and physiological ecology (seed dormancy and germination, seedling establishment, pigmentation, photosynthesis and respiration, annual growth cycle, productivity, etc.)

146

Bliss, L. C. 1956. A comparison of plant development in microenvironments of arctic and alpine tundras. Ecol. Monogr. 26:303-337.

A comparative study suggests that the Wyoming alpine tundra is a more severe environment for plant development than the arctic tundra due to high winds, vapor pressure deficits, surface soil temperatures, UV radiation, and low soil moisture. Phenology and growth of several species correlate with microenvironment.

147

Bliss, L. C. 1958. Seed germination in arctic and alpine species. Arctic 11:180-188.

A greater proportion of alpine than arctic plant seeds germinated. Some seeds germinate equally well in light and dark while germination of others is reduced in dark. Viable seed and seedlings are common in many alpine plants.

148

Bliss, L. C. 1960. Transpiration rates of arctic and alpine shrubs. Ecology 41:386-389.

Transpiration rates for species of willow, alder, and dwarf birch were directly related to air temperature, vapor pressure deficit, and wind speeds below 6 mph but inversely related to cloud cover and wind speeds above 6 mph.

149

Bliss, L. C. 1962. Adaptations of arctic and alpine plants to environmental conditions. Arctic 15:117-144.

Reviews several earlier works on alpine and arctic tundra environment (soils, light, temperature, wind, and snow cover) and some aspects of the adaptation of plants to these environments. Includes Russian work.

150

Bliss, L. C. 1966. Plant productivity in alpine microenvironments on Mt. Washington, New Hampshire. Ecol. Monogr. 36:125-155.

Solar radiation, temperature, wind, atmospheric moisture, and winter snow cover are the most important environmental factors affecting community development. Soils of this alpine are low in exchangeable bases, available calcium, potassium and phosphorus. Addition of high amounts of nitrogen, phosphorus, and potassium significantly increased yields. Species phenologies are generally controlled by local microenvironments and most shoot and flower development is completed in the first 20 to 30 days of the growing season, relying on reserves of previous years.

151

Bollen, W. B., K. C. Lu, J. M. Trappe, and R. F. Tarrant. 1969. Influence of sitka alder on soil formation and microbiological succession on a landslide of alpine origin at Mount Rainier. USDA For. Serv. Res. Note PNW-103.

Sitka alder increased soil carbon, soil nitrogen, and microbial populations over a three year period.

152

Bonde, E. K. 1965. Studies in the germination of seeds of Colorado alpine plants. Univ. of Colo. Studies. Series in Biology No. 14. pp. 1-16.

Long continued dormancy is an important factor in seeds of only a few alpine species and can usually be overcome without special treatment. After 22 months, the germination percentages of only four of 19 species tested declined.

153

Bonde, E. K. 1965. Further studies on the germination of seeds of Colorado alpine plants. Univ. of Colo. Studies Series in Biol. No. 18. Univ. of Colo., Boulder.

Seeds from 59 alpine species were tested in December and May-June and were classified into eleven categories according to germination percentages and change in germination percentage between time periods.

154

Bonham, C. D. and R. T. Ward. 1970. Phytosociological relationships of alpine tufted hairgrass (*Deschampsia caespitosa* (L.) Beauv.) Arct. Alp. Res. 2:267-275.

Tufted hairgrass dominates many wet to dry-mesic alpine habitats in the southern Rocky Mountains especially on north facing slopes having loam to sandy acidic soils, where cold melt-water is supplied throughout the summer. These sites also have continuous snowcover from October to late June. Importance of associated species is related to hairgrass density and moisture conditions.

155

Brink, V. C. 1959. A directional change in the subalpine forest-heath ecotone in Garibaldi Park, British Columbia. Ecology 40:10-16.

Establishment of trees in subalpine heath seems a reflection of recent climatic change. Trees are establishing in only one community type (neither very dry nor wet) and only where snow disappears early.

156

Brink, V. C. 1964. Plant establishment in high snowfall alpine and subalpine regions of British Columbia. Ecology 45:431-438.

Failure of plant establishment on many bare areas is due to rapid, surficial soil movement resulting from frost action and snow glide. Nitrogen deficiencies and summer drought also inhibit seedling establishment.

157

Choate, G. A. 1963. The forests of Wyoming. USDA For. Serv. Res. Bull. INT-2. 47p.

Statistics on extent of forested areas, timber volumes, timber uses, water, recreation, and grazing in Wyoming national forests.

158

Churchill, E. D. and H. C. Hanson. 1958. The concept of climax in arctic and alpine vegetation. Bot. Rev. 24:127-191.

A literature review on the concepts of vegetation dynamics especially as they apply to arctic and alpine tundra. Discusses with examples several types of vegetation change which occur within a community (non-cyclic replacement, phasic cycle replacement, directional, etc.) as well as spatial changes corresponding to environmental gradients. Reviews European as well as American concepts and literature.

159

Clausen, J. 1965. Population studies of alpine and subalpine races of conifers and willows in the California High Sierra Nevada. Evolution 19:56-58.

Horizontal alpine and erect subalpine growth form races have evolved in three conifer and two willow species.

160

Cochran, P. H. and C. M. Berntsen. 1973. Tolerance of lodgepole and ponderosa pine seedlings to low night temperatures. For. Sci. 19:272-280.

Young seedlings of lodgepole pine are more resistant to low night temperatures than those of ponderosa pine although this difference disappears after age two months. Mortality of both species at temperatures of 20° F or less was reduced by previous exposure to temperatures just above freezing. Photoperiod appears more important than low temperature preconditioning in producing frost hardiness. These results account for some of the distribution patterns of these two species.

161

Conrad, P. W. and W. T. McDonough. 1972. Growth and reproduction of red elderberry on subalpine rangeland in Utah. Northwest Sci. 46:140-148.

Red elderberry is found on subalpine sites from the Southern Rocky Mountains west to the Sierra Nevada and north to southern Idaho. Growth and reproduction studies were conducted in field and laboratory. Reproduction by seed is essentially nonexistent but vegetative reproduction is vigorous. Stem debarking, bud removal, and severe climatic conditions cause great variation in stem density but do not appear detrimental to the species. Livestock and browsers seldom utilize elderberry until fall.

162

Cooper, W. S. 1908. Alpine vegetation in the vicinity of Long's Peak. Bot. Gaz. 45:319-337.

Separates high mountain vegetation into alpine grassland and forest; the former into dry meadows and wet meadows. A diagram of hypothesized succession is included.

163

Costin, A. B. 1967. Alpine ecosystems on the Australasian region. pp. 55-87 in H. E. Wright, Jr. and W. H. Osburn (eds.). Arctic and alpine environments. Indiana Univ. Press.

Characterizes the extent, climate, and vegetation of alpine tundra areas of North Borneo, New Guinea, Australia, New Zealand, and the Subantarctic Islands. Bibliography.

164

Cox, C. F. 1933. Alpine plant succession on James Peak, Colorado. Ecol. Monogr. 3:299-372.

Characterizes the alpine climate and vegetation which is segregated into alpine scrub forest, grassland, and desert. Lists important species of each type and the adaptations of several species. Succession proceeds by various pathways to an alpine meadow climax dominated by Kobresia.

165

Daubenmire, R. F. 1941. Some ecological features of the subterranean organs of alpine plants. Ecology 22:370-378.

The root system of 24 alpine species is described and illustrated. There is apparently no strikingly uniform root adaptations to the alpine environment.

166

Daubenmire, R. F. 1943. Vegetational zonation in the Rocky Mountains. Bot. Rev. 9:325-393.

An overview of the vegetation of the Rocky Mountains from New Mexico to Alberta in terms of climax associations or elevational zones. Climatic changes associated with elevation are described. Drought and low temperatures are suggested as important factors related to elevational limits of species.

167

Daubenmire, R. F. 1954. Alpine timberlines in the Americas and their interpretation. Butler Univ. Bot. Stud. 11:119-136.

After reviewing several theories to account for alpine timberlines, concludes that the most promising one views timberline as a point on a scale of diminishing heat supply. Wind, snow, etc. may locally alter timberline.

168

Daubenmire, R. F. 1968. Soil moisture in relation to vegetation distribution in the mountains of northern Idaho. Ecology 49:431-438.

Climax vegetation types closely reflect soil moisture regimes, and not necessarily elevation. Grassy parks represent areas of soil drought to which germination characteristics of grasses are adapted. Rooting depth seems a primary adaptation to soil moisture stress.

169

Davis, C. B. 1967. The woody shrubs of Colorado. MSc. Thesis, Colo. State Univ., Fort Collins. 377p.

A taxonomic key to and description of the shrub species of Colorado. Includes range maps and line drawings.

170

Day, R. J. 1972. Stand structure, succession, and use of southern Alberta's Rocky Mountain forest. Ecology 53:472-478.

A post fire successional sequence from a lodgepole pine to a subalpine fir-Engelmann spruce community is hypothesized. A well planned program of fire prescription and control is needed.

171

Despain, D. G. 1973. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecol. Monogr. 43:329-355.

Vegetation patterns and seedling establishment are influenced by parent material, soil moisture, elevation, aspect, snow accumulation, etc. Soils of major vegetation types analyzed for available water, organic matter, potassium, calcium, magnesium, texture and morphology.

172

Dix, R. L. 1974. Regional ecological systems of Colorado. pp. 7-17, in P. O. Foss (ed.) Environment and Colorado: a handbook. Environmental Resources Center, Colorado State University, Fort Collins.

An overview of the principal vegetation patterns in Colorado in terms of four regions: the Great Plains, Foothills, Southern Rocky Mountain (montane, subalpine, and alpine), and Intermountain Regions. Some major community and environmental gradients within each region are briefly considered.

173

Dixon, H. 1935. Ecological studies on the high plateaus of Utah. Bot. Gaz. 97:272-320.

General descriptions of vegetation types from low elevation desert to subalpine forests and alpine meadows.

174

Dixon, H. N. 1969. The growth of lodgepole pine in the Colorado Front Range as related to environment. Ph.D. Thesis, Univ. of Colorado, Boulder. 120p. 69-19,528.

Growth rate differences between two lodgepole pine stands at 10,000 feet elevation are related to soil moisture differences. Radial and terminal growth begins in late June and ceases in early August. Onset of growth was not affected by microclimate.

175

Douglas, G. W. 1972. Subalpine plant communities of the western North Cascades, Washington. Arct. Alp. Res. 4:147-166.

Brief descriptions of the structure, composition, and environmental relations of major subalpine forest and non-forest communities of this area. Soil descriptions include pH, morphology, drainage, effects of snow, etc.

176

Eddleman, L. E. 1967. A study of phytoedaphic relationships in the alpine tundra of northern Colorado. Ph.D. Thesis, Colorado State Univ. 160p. 67-13,195.

The vegetation and soils of seven different alpine plant communities are described. Development of plant communities is controlled principally by duration of snow cover, soil moisture, and soil stability.

177

Ek-Jander, J. and G. Fahraeus. 1971. Adaptation of Rhizobium to subarctic environment in Scandinavia. pp. 129-137 in T. A. Lie and E. G. Mulder. Biological nitrogen fixation in natural and agricultural habitats. Plant and Soil, Special volume.

White clover rhizobia strains from northern Scandinavia were better adapted to low temperatures than were strains from southern Scandinavia.

178

Ellison, L. 1954. Subalpine vegetation of the Wasatch Plateau, Utah. Ecol. Monogr. 24:89-184.

Describes the natural vegetation of this subalpine area and the changes it has undergone due to grazing by livestock. Emphasis is given to the upland herb association and the effects on it of overgrazing. Forest and shrub communities are less extensive. Successional trends are described.

179

Fonda, R. W. and L. C. Bliss. 1969. Forest vegetation of the montane and subalpine zones. Olympic Mountains, Washington. Ecol. Monogr. 39:271-301.

Five montane and two subalpine major forest community types are described including herbaceous species composition and associated environment. Morphology and fertility of forested soils in these mountains are discussed.

180

Foreman, E. M. F. 1971. Growth, flowering, and vivipary in arctic and alpine populations of *Deschampsia caespitosa* (L.) Beauv., *Poa alpina* L. and *Trisetum spicatum* (L.) Richt. Ph.D. Thesis, Univ. of Colorado, Boulder. 360p. 72-3648.

Flowering and incidence of vivipary were studied in three alpine grasses under controlled conditions of light intensity, photoperiod, and temperature. Asexual reproduction may replace flowering and sexual reproduction when environment condition for flower development are marginal. Genetically controlled variation within these species was noted in relation to leaf length and color,degree of tillering, growth rates, ability to survive cold treatment or adverse photoperiods, degree of vivipary, etc. Each species probably includes ecotypes.

181

Fowells, H. A. (ed.). 1965. Silvics of forest trees of the United States. USDA Forest Serv. Agr. Handbook No. 271.

Reviews available literature on over 100 U.S. forest tree species. Includes range, habitat characteristics (climate, soils and topography, and associated trees and shrubs), life history (seed production, seedling development, growth and yield, reaction to competition) and races and hybrids for each species.

182

Franklin, J. F., W. H. Moir, G. W. Douglas, and C. Wiberg. 1971. Invasion of subalpine meadows by trees in the Cascade Range, Washington and Oregon. Arct. Alp. Res. 3:215-224.

Massive tree invasion of meadows near the forest tundra boundary seem related to recent climatic change. This invasion was most intense about 40 years ago and has essentially ceased since 1945. Snow free period is probably the most critical factor to tree establishment.

183

Greene, J. G. 1971. Clonal variation in *Populus tremuloides* Michx. on the east slope of the Front Range, Boulder County, Colorado. Ph.D. Thesis, Univ. of Colorado, Boulder. 333p. 72-3655.

Aspen exhibits a great deal of interclonal variation in the Colorado Front Range, particularly with respect to time of leaf flush and fall, type of coloration, shape and size of leaves, leaf serration, and dormant bud pubescence. Several characters vary with elevation: time of leaf flush, length of growth activities, rate of leaf development, shape and thickness of leaves, and growth rates.

184

Griggs, R. F. 1938. Timberlines in the northern Rocky Mountains. Ecology 19:548-564.

Timberline in the Rockies interpreted as static since (1) trees of all ages occur at highest cripple line, (2) the occasional occurrence of trees exceeding 1,000 years in age close to timberline and (3) development of timber atoll which suggests that conditions unchanged for many centuries.

185

Griggs, R. F. 1956. Competition and succession on a Rocky Mountain fellfield. Ecology 37:8-20.

Presents a potential invasion sequence for common alpine fellfield plants and describes characteristics of several species.

186

Haferkamp, M. R. and P. O. Currie. 1973. Effect of fertilizer on root strength of Sherman big bluegrass (*Poa ampla* Merr.). Agron. J. 65:511-512.

Sherman big bluegrass is subject to pullup by grazing animals after seeding and this greenhouse study was designed to determine if resistance to pullup could be increased by fertilization. Nitrogen additions increased root strength, number of shoots, foliage weight, and root system weight and length. Resistance to pullup was thus increased.

187

Harrington, H. D. 1954. Manual of the plants of Colorado. Sage Books, Denver. 666p.

A standard manual for the taxonomic description and identification of Colorado native plants.

188

Hayward, C. L. 1952. Alpine biotic communities of the Uinta Mountains, Utah. Ecol. Monogr. 22:93-118.

Discusses plant and animal species which occur in each of several alpine communities: open water, wet meadows, dry meadows, rock slides, dry ridges in glaciated valleys, high unglaciated ridges, krummholz, etc. Dipterans, spiders, and ants are the best represented invertebrates while vertebrate animals are poorly represented.

189

Heifner, M. A. 1974. Ecological studies in Colorado alpine willow marshes. MSc. Thesis, Colo. State Univ. Fort Collins. 66p.

Describes the species composition and major determining environmental factors of these willow marshes. They are dependent on a reliable influx and retardation of water but do not occur where snow lies late in the growing season.

190

Hitchcock, A. S. 1950. Manual of the grasses of the United States. USDA Misc. Publ. No. 200. 1051p. (Second edition revised by A. Chase)

A taxonomic key and description of all grass species known to grow in the continental United States, excluding Alaska.

191

Holch, A. E., E. W. Hertel, W. O. Oakes, and H. H. Whitwell. 1941. Root habits of certain plants of the foothills and alpine belts of the Rocky Mountain National Park. Ecol. Monogr. 11:327-345.

Deep taproots predominate in the foothills region although shallow wide spreading root systems are also common. Alpine plants generally have shallow roots and rhizomes. The climate of the two areas is characterized.

192

Holding, A. J. and J. F. Lowe. 1971. Some effect of acidity and heavy metals on the Rhizobium-leguminous plant association. pp. 153-166 in T. A. Lie and E. G. Mulder (eds.). Biological nitrogen fixation in natural and agricultural habitats. Plant and Soil, Special volume.

A review of the effects of the complex of factors associated with soil acidity on the legume-Rhizobium association. Low success of Rhizobium in acid and wet soils cannot be adequately explained by hydrogen ion considerations alone. Heavy metal toxicity may be important.

193

Holway, J. G. and R. T. Ward. 1963. Snow and meltwater effects in an area of Colorado alpine. Am. Midl. Nat. 69:189-197.

As snow lies progressively later into the growing season, plant development is delayed, some species do not complete their life cycle, and some species are replaced by others. The artificial application of cold meltwater delayed flowering for most species from a week to over a month.

194

Holway, J. G. and R. T. Ward. 1965. Phenology of alpine plants in northern Colorado. Ecology 46:73-83.

Growth initiation started as early as May in relatively snow-free sites and as late as early August in snow accumulation areas. Dormancy began in most species by mid-September. The duration of phenological phases for most species was quite stable even at different sites. Snow cover is considered the primary factor influencing phenology. Includes description of climate.

195

Hurd, R. M. 1961. Grassland vegetation in the Big Horn Mountains, Wyoming. Ecology 42:459-467.

Characterizes the vegetation, flora, production, and effects of grazing on ranges between 7,000 and 8,500 feet. Idaho fescue is the most important species. Grasses and sedges accounted for 65% of the total vegetative cover but forbs increased in importance on sedimentary derived soils as opposed to granitic derived soils.

196

Janke, R. A. 1968. The ecology of *Vaccinium myrtillus* using concepts of productivity, energy exchange, and transpiration resistance. Ph.D. Thesis, Univ. of Colorado, Boulder, 109p. 68-14,385.

The abundance of *Vaccinium myrtillus* generally increases from 8,000 to 11,500 feet elevation in the Colorado Front Range but it disappears abruptly near timberline. At low elevations, its productivity is higher on north than south facing slopes but little difference was noted at high elevations. Late lying snowbanks reduce its productivity in forests but increase it in openings. Transpiration resistances are relatively low and the species seems well adapted for keeping leaf temperatures low but not for conserving water.

197

Johnson, P. L. and W. D. Billings. 1962. The alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns. Ecol. Monogr. 32:105-135.

Cryopedogenic activity requires: 1) temperature alterations across the freezing point, 2) a frost susceptible substrate and 3) an adequate supply of moisture. Three major vegetation types are recognized: *Geum* turf on summits and upper slopes; hairgrass meadows on lower slopes; and sedge bogs on wet mineral bog and peat soils.

198

Johnson, W. M. 1962. Vegetation of high altitude ranges in Wyoming as related to use by game and domestic sheep. Wyom. Agric. Exp. Stn. Bull. 387. 31p.

Seven major vegetation types are distinguished in the alpine and subalpine sheep ranges of Wyoming. Each is briefly described as to occurrence, species composition, plant cover, and grazing use. Species associations are considered.

199

Kelly, G. W. 1970. A guide to the woody plants of Colorado. Pruett Publ. Co., Boulder. 180p.

Nontechnical descriptions of the trees and shrubs native to Colorado. Includes descriptions of appearance, common habitat, and uses of each. Several photographs.

200

Klikoff, L. C. 1965. Micro-environmental influences on vegetation pattern near timberline in the central Sierra Nevada. Ecol. Monogr. 35:187-211.

Distinguishes several community types based on floristics and environment including rock, gravel, dry meadow, moist meadow, wet meadow and forest communities. Soils are organic or mineral, low in nutrients, commonly sandy and shallow, with active frost phenomena in wet areas. Air and soil temperature regimes of the communities are compared.

201

Kuramoto, R. T. and L. C. Bliss. 1970. Ecology of subalpine meadows in the Olympic Mountains, Washington. Ecol. Monogr. 40:317-347.

Describes the vegetation and environment of eight subalpine meadow types which occur as openings in the upper limits of subalpine forest. Micro-environment factors (radiation, wind, precipitation, atmospheric and soil moisture and temperature) were measured in three of the communities. Soils are generally weakly developed due to frequent fires, erosion, and short growing seasons. Physical and chemical soil characteristics are described. The majority of these meadows are fire caused but once established, microenvironments may limit tree establishment.

202

Langenheim, Jean. 1956. Plant succession on a subalpine earthflow in Colorado. Ecology 37:301-317.

Community-types, studied approximately 30 years after an earthflow at 9,500 feet elevation, are apparently related to substrate stability and degree of soil development. *Chaenactic alpina, Rosa woodsii,* and *Senecio atratus* communities represent pioneer stages; succession culminates in a big sagebrush or trembling aspen community.

203

Langenheim, J. H. 1962. Vegetation and environmental patterns in the Crested Butte area, Gunnison County, Colorado. Ecol. Monogr. 32:249-285.

The coincidence of major community types (sagebrush, aspen, lodgepole pine, spruce-fir, upland herb, alpine, fescue, etc.) with principal environmental features (elevation, aspect, soil parent material) was determined from map overlays. The species composition, structure, and some successional characteristics of each community type are generally described.

204

Larson, S. A. 1930. Forest types of the Northern Rocky Mountains and their climatic control. Ecology 11:631-672.

Characterizes the climate and flora of the major climax forest zones. Lower elevational limits are imposed by deficient moisture and upper limits by low temperatures.

205

Lawrence, D. B., R. B. Schoenike, A. Quispel, and G. Bond. 1967. The role of *Dryas drummondii* in vegetation development following ice recession at Glacier Bay, Alaska, with special reference to its nitrogen fixation by root nodules. J. Ecol. 55:793-813.

Dryad is the first plant species to attain dominance on deglaciated areas. Root nodules are shown to fix nitrogen, and dominance by this plant increases soil nitrogen considerably but not as effectively as *Alder*. Dryad also stabilizes the soil surface against erosion and begins the development of a humus layer, thus speeding up succession.

206

Major, J. and S. A. Bamberg. 1967. Comparison of some North American and Eurasian alpine ecosystems. pp. 89-118 in H. E. Wright, Jr. and W. H. Osburn (eds.). Arctic and Alpine environments. Indiana Univ. Press.

Compares regional climate, fauna, and flora of various alpine areas in North America and Eurasia. Bibliography.

207

Marr, J. W. 1967. Ecosystems of the East Slope of the Front Range in Colorado. Univ. of Colo. Studies, Ser. in Biology No. 8. 115p.

Summarizes geology, soils, climate, and natural vegetation of the major plant community types of the Front Range. Includes detailed data on principal species, etc. from specific sites representing the 30 community types.

208

Marr, J. W. and B. E. Willard. 1970. Persisting vegetation in an alpine recreation area in the Southern Rocky Mountains, Colorado. Biol. Conserv. 2:97-104.

Summarizes climate, geology, flora, fauna, and principal plant communities of Trail Ridge alpine. Summarizes much of Willard's dissertation. (Willard 1963).

209

May, D. E. 1973. Models for predicting composition and production of alpine tundra vegetation from Niwot Ridge, Colorado. M.A. Thesis, Univ. of Colorado, Boulder. 99p.

A description of vegetation gradients and types and their controlling environmental factors. Major vegetation gradients are related to soil moisture, snow cover, and substrate stability. Six major vegetation types were distinguished: dry sedge meadow, dry fellfield, moist shrub, moist meadow, snowbank community, and wet meadow. Moist sites are more productive (144 to 450 g/m^2) than either dry or wet sites. Regression analyses identified soil moisture, snow cover, pebbles, calcium, and ammonium as most correlated to vegetation distribution.

210

McKell, C. M. (ed.). 1972. Wildland shrubs--their biology and utilization. USDA For. Serv., Gen Tech. Report INT-1. 494p.

A collection of several papers organized by eight sections: continental aspects of shrub distribution, utilization, and potentials; present and possible uses of shrubs; genetic potentials; synecology; physiology; nutritive quality; regeneration; and future of shrubs in arid lands. Concerned primarily with arid land shrubs.

211

McMinn, R. G. 1952. The role of soil drought in the distribution of vegetation in the northern Rocky Mountains. Ecology 33:1-15.

Plant associations are correlated with different intensities of soil drought from a grassland association to a grand fir association.

212

Merkle, J. 1954. An analysis of the spruce-fir community of the Kaibab Plateau, Arizona. Ecology 35:316-322.

A description of tree, shrub, and herb species composition of these forests at 8700 to 9200 feet elevation. Heavy summer browsing by deer resulted in the death of large numbers of aspen sprouts.

213

Miller, P. C. 1964. Factors influencing the vegetation patterns of the White River Plateau in northwestern Colorado. Ph.D. Thesis, Univ. of Colorado, Boulder. 232p. 65-4260.

Subalpine vegetation between 10,000 and 11,000 feet in this area is formed of spruce-fir forests and meadows of which three types are recognized. Short forb-grass and tall forb meadows occur where more snow accumulates than on fescue meadow sites. The present pattern of forest and meadow appears stable since meadow soils become too dry for successful tree seedling establishment. Describes age structure of spruce and fir populations killed by spruce beetle.

214

Miller, R. L. and G. A. Choate. 1964. The forest resources of Colorado. USDA For. Serv. Resource Bull. INT-3.

Statistics on extent of forested areas, timber volume, timber use, water, recreation, and grazing in Colorado national forests.

215

Mitchell, W. W. 1968. On the ecology of Sitka alder in the subalpine zone of south-central Alaska. pp. 45-56 in J. M. Trappe et al. (eds.). Biology of Alder. USDA For. Serv., Pacific Northwest Forest and Range Exp. Station.

Sitka alder, which is an important colonizer on deglaciated terrain, etc. is also a dominant, enduring component of the subalpine zone of Alaska. Nitrogen contents of soils under alder are some of the highest recorded for Alaska and pH values are some of the lowest (to 3.3).

216

Moir, W. H. 1967. The subalpine tall grass, *Festuca thurberi*, community of Sierra Blanca, New Mexico. The Southwest. Nat. 12:321-328.

Composition and environment of the Thurbers fescue association of southern New Mexico which occurs conspicuously on ridges above the closed subalpine forest. The Kentucky bluegrass meadows may be a grazing derivative of the fescue meadows.

217

Moir, W. H. 1969. The lodgepole pine zone in Colorado. Am. Midl. Nat. 81:87-98.

Climax lodgepole pine forests (those not being replaced by other tree species) occur in the Colorado Front Range between about 8,200 and 9,300 feet. They are found on deep well drained soils with few associated shrub and herbaceous species.

218

Mooney, H. A. 1963. Physiological ecology of coastal, subalpine, and alpine populations of *Polygonum bistortoides*. Ecology 44:812-816.

Bistort occurs from alpine tundra to coastal grasslands. Four populations representing extremes were compared for seasonal growth cycle, mode of reproduction, chromosome complement, metabolic activity and growth in a uniform environment.

219

Mooney, H. A. and W. D. Billings. 1965. Effects of altitude on carbohydrate content of mountain plants. Ecology 46:750-751.

Plants use up carbohydrate reserves more rapidly if transplanted to a lower elevation. Within the natural elevational range, carbohydrate reserves are highest near the lower elevational limits of the species.

220

Morgan, M. D. 1969. Ecology of aspen in Gunnison County, Colorado. Am. Midl. Nat. 82:204-228.

Describes the understory, reproduction, soils, and successional status of these aspen stands. Understory vegetation is lush and soils are fertile but immature.

221

Neff, D. J. 1957. Ecological effects of beaver habitat abandonment in the Colorado Rockies. J. Wildl. Manage. 21:80-84.

Effects of abandonment on erosion were minimal in an inherently stable area which was quickly invaded by grasses and sedges. Beaver populations should be maintained, however to ensure necessary aquatic habitat for other wildlife.

222

Noble, D. L. 1972. Effects of soil type and watering on germination, survival, and growth of Engelmann spruce: a greenhouse study. USDA For. Serv. Res. Note RM-216. 4p.

Germination, seedling survival, and seedling growth of Engelmann spruce were compared from two forest soil types (a Sol Brun Acide and a Podzol) and five watering treatments. Both germination and survival were affected by watering differences but only survival was affected by soil differences. Root growth but not top growth nor total dry weight was affected by watering treatments.

223

Olgeirson, E. 1974. Vascular plants on a spruce bald in Colorado. Madrono 22:360-363.

A high elevation spruce bald, developed by clearcutting practices, is maintained by an environment unfavorable to tree seedling establishment. Soil instability is a dominant factor related to vegetation patterns and tends to maintain grasses, favor weeds, and permit introduction of species typical of the alpine.

224

Oosting, H. J. and J. F. Reed. 1952. Virgin spruce-fir of the Medicine Bow Mountains, Wyoming. Ecol. Monogr. 22:69-91.

Describes the vegetation of these subalpine forests in terms of numbers and percent cover of herbaceous and shrub species and density, diameter, and size class distributions of the two tree species. Considers the spruce-fir community to be floristically uniform and ecologically simple. Reviews literature on reproduction, seedling establishment, growth, etc. of Engelmann spruce and subalpine fir.

225

Osburn, W. S., Jr. 1958. Ecology of winter snow free areas in the alpine tundra of Niwot Ridge, Boulder County, Colorado. Ph.D. Thesis. Univ. of Colo. 96p. 59-833.

Describes a successional sequence following gopher destruction of alpine kobresia meadows. Cushion plants invade and become dominant after disturbance ceases but as humus builds up, kobresia regains dominance. The distribution of moisture in the soil profile determines the type of plants which dominate these snow free areas.

226

Patten, D. T. 1963. Light and temperature influence on Engelmann spruce seed germination and subalpine forest advance. Ecology 44:817-818.

Light Increases germination of spruce seeds at low temperatures which may, in part, explain its role in initiating forest advance onto high elevation grasslands.

227

Patten, D. T. 1963. Vegetational pattern in relation to environment in the Madison Range, Montana. Ecol. Monogr. 33:375-406.

Distributions of nine vegetation types are related to environmental factors (temperature, precipitation, evaporation, wind, soils, geology, topography, animals, and fire) to account for vegetation patterns, especially forest vs. grassland and sagebrush. Soil temperatures may be high enough in the open to kill conifer seedlings. Forest soils have greater moisture availability, are more acidic and shallower, reach wilting percentage later, and have lower nitrogen content than those of open areas. Discusses origins of present patterns.

228

Paulsen, H. A. 1960. Plant cover and forage use of alpine sheep ranges in the central Rocky Mountains. Iowa State J. Sci. 34:731-748.

Describes the vegetation characteristics and plant species composition of alpine meadow and alpine turf communities and the principal species utilized by sheep in Wyoming, Colorado, and New Mexico. Herbage production averaged 363 and 626 pounds per acre on turf and meadow sites respectively. Grazing was usually light since sheep are usually dispersed while grazing.

229

Paulsen, H. A. 1969. Forage values on a mountain grassland--aspen range in western Colorado. J. Range Manage. 22:102-107.

Characterizes herbage production, cattle preference and nutritional value of the major forage species of Thurber's fescue grasslands of Black Mesa, Colorado.

230

Paulsen, H. A. 1970. Competition and successional patterns on Thurber fescue grasslands of western U.S.A. XI Int. Grassl. Congr. Proc. 11:662-665.

Herbicides, fertilizers (nitrogen and phosphorus), and water were applied to a high elevation grassland in western Colorado to elucidate some ecological relationships. Fertilizer application increased grass but not forb cover and seedling establishment. Thurber fescue recovered rapidly from manipulation and maintains dominance due to early and vigorous growth. Discusses phenology, seed production, seed germination, and seedling establishment of major species.

231

Pelton, J. 1956. A study of seed dormancy in eighteen species of high altitude Colorado plants. Butler Univ. Bot. Stud. 13:74-84.

Seeds of 18 plant species collected between 9,500 and 10,000 feet, were segregated into four groups based on dormancy characteristics.

232

Pearcy, R. W. and R. T. Ward. 1972. Phenology and growth of Rocky Mountain populations of *Deschampsia caespitosa* at three elevations in Colorado. Ecology 53:1171-1178.

Phenological (date of inflorescence emergence, anthesis, etc.) and height growth characteristics differed significantly among 20 populations of hairgrass collected at elevations from 3,148 to 12,168 feet and grown in common gardens. The significance of these differences to survival is discussed.

233

Petersen, B. W. 1968. Pollination of some tundra plants with miniature flowers on Niwot Ridge in Boulder County, Colorado. Ph.D. Thesis, Univ. of Colorado, Boulder. 117p. 68-12,422.

Pollinating agents for seven alpine species with small flowers consisted of a beetle, ants, bumblebees, a butterfly, and a syrphid fly. One species was mostly self pollinated although self pollination occurred readily in all species. Ants are important pollinators of alpine plants.

234

Reed, R. M. 1971. Aspen forests of the Wind River Mountains, Wyoming. Am. Midl. Nat. 86:327-343.

Recognizes a nonsuccessional aspen community characterized by canopy, understory species, soils (fertile A1 and well developed B2) and environment.

235

Reynolds, H. G. 1966. Use of openings in spruce-fir forests of Arizona by elk, deer, and cattle. USDA For. Serv. Res. Note RM-66.

Cattle used openings more than adjacent forest, elk use differed little, and deer preferred adjacent forest areas. Maintenance of natural openings and creation of small ones by cutting should improve deer and elk habitat.

236

Root, R. A. and J. R. Habeck. 1972. A study of high elevation grassland communities in western Montana. Am. Midl. Nat. 87:109-121.

The occurrence of grassy balds within the subalpine forest zone is related to the inability of tree seedlings to become established on these areas of annual summer drought.

237

Sayers, R. L. and R. T. Ward. 1966. Germination responses in alpine species. Bot. Gaz. 127:11-16.

Seed germination percentages were relatively high for alpine avens, hairgrass, spike trisetum, stonecrop, and pasque flower but zero for spike woodrush. The effects of moisture stress, low temperatures, light, etc. are considered.

238

Scott, D. and W. D. Billings. 1964. Effects of environmental factors on standing crop and productivity of an alpine tundra. Ecol. Monogr. 34:243-270.

An analysis of plant production in an alpine tundra of southeast Wyoming. Considers total standing crop, correlation to environmental factors, above and below ground comparisons, weekly net productivity of selected species, rates of photosynthesis and respiration (in field and lab), effects of nutrients and fertilization, etc. Above ground summer standing crop was most related to altitude, winter snow cover, moisture regime, soil movement, percent clay, extractable potassium, and available subsoil water. Alpine tufted hairgrass responded to Hoagland's solution and nitrogen fertilization.

239

Spomer, G. G. 1964. Physiological ecology studies of alpine cushion plants. Physiol. Plant. 17:717-724.

The growth habit of alpine cushion plants, which often lose the cushion form when transplanted to low elevations, seems governed by low temperatures and not radiation, wind, or moisture stress. The effects of growth regulators on internode elongation and dormancy were tested.

240

Spomer, G. G. and F. B. Salisbury. 1968. Eco-physiology of *Geum turbinatum* and implications concerning alpine environments. Bot Gaz. 12:33-49.

Dormancy in alpine avens appears to be regulated by soil temperature changes, with five weeks of freezing temperatures required to break dormancy. Roots may be important in regulating dormancy. Low soil temperatures may be important in determining the lower limits of alpine tundra.

241

Stahelin, R. 1943. Factors influencing the natural restocking of high altitude burns by coniferous trees in the central Rocky Mountains. Ecology 24:19-30.

Examination of tree reproduction on eight burned areas from 9,000 to 11,000 feet elevation in Colorado revealed that abundance of seed trees, exposure, plant cover, and soil type are among the most important factors affecting rate of restocking. A sedge and grass turf effectively limits tree seedling establishment. Reproduction is favored by north exposures, a plant cover of vaccinium, and light gravelly soils.

242

Stewart, W. D. P. 1967. Nitrogen fixing plants. Science 158:1426-1432.

Biological agents which fix nitrogen include: 1) legume-Rhizobium (bacteria) associations, 2) non-leguminous root nodule bearing plants, (13 genera of flowering plants including *Alnus* and *Shepherdia*), 3) plants bearing leaf nodules, 4) blue-green algae and 5) free-living nitrogen-fixing bacteria and possibly some fungi, actinomycetes, and yeast. Discusses the structure and physicology of nodules and includes a section on some biochemical aspects.

243

Stone, E. L. 1968. Microelement nutrition of forest trees: A review. pp. 132-175 in G. W. Bengtson (symp. chairman). Forest fertilization--theory and practice. Tenn. Val. Auth. Knoxville, Tenn.

Discusses the visual symptoms of deficiency and excess, analysis of concentrations in plant tissues, soil criteria of deficiency and excess, soil analyses and control of deficiency, and consequences for forestry of six micronutrients: boron, copper, iron, manganese, molybdenum, and zinc. Bibliography.

244

Strasia, C. A., M. Thorn, R. W. Rice, and D. R. Smith. 1970. Grazing habits, diet and performance of sheep on alpine ranges. J. Range Manage. 23:201-208.

Whiproot clover, dwarf clover, American bistort, alpine avens, and red and sheep fescues accounted for about 67% of the diet of sheep on Wyoming alpine range. The proportion of forbs was related to their availability.

245

Thilenius, J. F., D. R. Smith, and G. R. Brown. 1974. Effect of 2,4-D on composition and production of an alpine plant community in Wyoming. J. Range Manage. 27:140-142.

2,4-D applied to a hairgrass meadow community altered the composition of the community from forb to grass dominance. Total standing crop was not affected nor was digestible dry matter content.

246

Tranquillini, W. 1964. The physiology of plants at high altitudes. Annu. Rev. Plant Physiol. 15:345-362.

A review of research (esp. European) on the physiological characteristics of plants in relation to alpine environments. Includes transpiration, water consumption, frost resistance, photosynthesis, chlorophyll destruction, etc.

247

Viereck, L. A. 1962. Plant succession and soil development on gravel outwash of the Muldrow Glacier, Alaska. Ph.D. Thesis, Univ. of Colorado, Boulder. 153p. 62-6295.

Describes a successional sequence on gravel outwash in alpine tundra of Alaska. A pioneer stage is dominated by dryad but this is succeeded first by a meadow stage, then a shrub stage, and finally a climax tundra of low shrubsedge tussock-mors. Silt and clay accumulate in the gravel as succession proceeds and moisture availability increase. Soils of climax tundra have high organic matter and low pH.

248

Ward, R. T. 1969. Ecotypic variation in *Deschampsia caespitosa* (L.) Beauv. from Colorado. Ecology 50:519-522.

Plants collected at 9,000 feet elevation had similar leaf lengths but longer stems and flowered approximately one month later than plants from 11,000 feet. Considerable non-genetic plasticity was also noted.

249

Wardle, P. 1965. A comparison of alpine timberlines in New Zealand and North America. New Zealand J. Bot. 3:113-135.

A comparison of tree lines primarily in New Zealand and Colorado, their characteristics and principal tree species. Discusses ecological characteristics of important tree species as related to timberline environments and suggests that upper timberline is set by inability of trees to produce new shoots during summer and harden them before winter.

250

Wardle, P. 1968. Engelmann spruce (*Picea engelmanni* Engel.) at its upper limits on the Front Range, Colorado. Ecology 49:483-495.

Discusses factors which produce the krummholz growth form and limit the elevational extent of Engelmann spruce. Temperature, wind, winter snow depth and duration, and soil temperature changes are related to elevation changes from forest to krummholz.

251

Weber, W. A. 1972. Rocky Mountain Flora (4th edition). Colorado Assoc. Universities Press, Boulder. 438p.

"A field guide for the identification of the ferns, conifers, and flowering plants of the Southern Rocky Mountains from Pikes Peak to Rocky National Park and from the plains to the Continental Divide." Identification keys are accompanied by line drawings of several species.

252

Whipple, S. A. 1973. The species composition and age structure of subalpine forests of the Front Range. M.Sc. Thesis. Colo. State Univ., Fort Collins, Colo. 109p.

A description of species composition and forest dynamics along major environmental gradients within lodgepole pine and Engelmann spruce/subalpine fir forests especially near Fraser, Colorado.

253

Whitfield, C. J. 1933. The vegetation of the Pikes Peak region. Ecol. Monogr. 3:75-105.

Brief description of vegetation types (alpine, subalpine, montane, etc.), and climatic changes associated with increasing elevation.

254

Whittaker, R. H. and W. A. Niering. 1965. Vegetation of the Santa Catalina Mountains, Arizona: A gradient analysis of the south slope. Ecology 46:429-452.

Describes the principal plant community types along an elevation gradient from Sonoran desert to subalpine forest. Distribution of species, growth forms, and life forms demonstrate changes in community characteristics along gradients of elevation and topographic moisture.

255

Willard, B. E. 1963. Phytosociology of the alpine tundra of Trail Ridge, Rocky Mountain National Park, Colorado. Ph.D. Thesis, Univ. of Colo., Boulder. 269p. 64-1949.

Describes with species lists etc. the major plant communities of the Trail Ridge alpine tundra. Includes fellfields, snowbed, marsh, alpine turf, and zootic associations.

256

Younkin, W. 1970. A study of the vegetation of alpine rock outcrops in northern Colorado. MSc. Thesis, Colorado State University, Fort Collins. 109p.

Rock outcrops in alpine tundra contain within a relatively small area many plant species seldom found in the open tundra due to the protection and variety of habitats afforded by these outcrops. This report is a description of the environment and vegetation of rock outcrops in Rocky Mountain National Park of Colorado.

See also 3, 34, 56, 85, 97, 100, 107, 134, 261, 262, 263, 269, 281, 286, 291, 310, 329, 351, 358, 429, 444, 448, 451, 452.

SECTION V

DISTURBANCE

257

Anderson, H. W. 1954. Suspended sediment discharge as related to streamflow, topography, soil and land use. Trans. Am. Geophys. Union 35:268-281.

High annual sediment discharge from 29 watersheds in western Oregon was related to high annual streamflow, steep slopes, erodible soils, and land development (especially roadbuilding). A map of erosion potential is presented for western Oregon.

258

Anderson, H. W. 1971. Relative contributions of sediment from source areas, and transport processes. pp. 55-63 in J. T. Krygier and J. D. Hall (symposium directors). Forest land uses and stream environment. Contin. Educ. Publ., Oreg. State Univ., Corvallis.

Past use of West Coast forested lands has increased sediment discharge by factors ranging from 1.24 to over 4. Roadbuilding greatly influences sediment production and landslides. Stream turbidity is significantly related to soil characteristics including silt and clay content.

259

Anderson, H. W. and C. H. Gleason. 1959. Logging effects on snow, soil moisture, and water losses. West. Snow Conf. Proc. 27:57-65.

Three methods of logging all increased maximum snow accumulation and reduced annual water losses.

260

Barth, R. C. 1970. Revegetation following a subalpine wildfire. MSc. Thesis. Colo. State Univ., Fort Collins. 139p.

Three years after an intense fire, soil on burned site had less organic matter, potassium, phosphorus, and calcium but the same pH as on unburned site. Aspect, herbaceous density, and slope position were significant to establishment of lodgepole pine seedlings. The change in abundance of several shrub, forb, and grass species during the three year period is described. Artifically seeded timothy, bluegrass, and bromegrass established on the burned site.

261

Billings, W. D. 1969. Vegetational pattern near alpine timberline as affected by fire-snowdrift interactions. Vegetatio 19:192-207.

Very high elevation sites on which forests have been destroyed by fire may remain as meadows with little tree reproduction almost indefinitely. Snowdrift patterns are also modified by forest destruction, and late lying snow blown into adjacent forest may kill the trees and inhibit their reproduction.

262

Bollinger, W. H. 1973. The vegetation patterns after fire at the alpine forest-tundra ecotone in the Colorado Front Range. Ph.D. Thesis, Univ. of Colorado, Boulder. 358p. 73-32,513.

Increased insolation and wind and reduced winter snow cover and soil moisture after fire destruction of high elevation forests limit tree reproduction and tend to perpetuate these areas as meadows. Rich forb communities which develop a thick turf on these sites also hinder forest invasion. Tree seedling establishment is limited to areas beneath "nursemaid" shrubs which maintain a favorable environment. Describes effects of fire on soils of these areas.

263

Bonham, C. D. 1972. Vegetation analysis of grazed and ungrazed alpine hairgrass meadows. J. Range Manage. 25:276-279.

Frequency values of eight plant species generally indicate whether or not hairgrass meadows have been grazed. The most important discriminating species include alpine timothy, cinquefoil (*Potentilla diversifolia*), American bistort, alpine bluegrass, and marsh marigold.

264

Burden, D. F. and P. F. Randerson. 1972. Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. J. Appl. Ecol. 9:439-457.

Direct recording and comparative studies proposed as two basic approaches to study of effects of trampling intensity on environmental change. These two approaches illustrated with examples from three areas in England.

265

Challinor, J. L. and P. L. Gersper. 1973. Vehicle perturbation effects upon a tundra soil-plant system: I. Effects on morphological and physical environmental properties of the soils. Agron. Abstr. 1973. pp. 96-97.

Effects of weasel vehicle tracks recorded near Barrow, Alaska, included increased bulk density, increased temperature, accelerated and deeper thaw, decreased moisture, and an intensified reducing environment.

266

Clark, B. D. 1968. Basic waste characteristics at winter recreation areas. U. S. Dept. Interior, Fed. Water Pollution Control Adm., Northwest Region. Report No. PR-7.

An analysis of water use and wastewater discharge by six Oregon and Washington ski areas. Water use is a function of the number of full time employees and number of fixture-units. Per capita water use varies according to type of resort area and type of guest.

267

Dix, R. L., R. E. Gilbert, and S. J. Kerr. 1972. A preliminary reconnaissance of mining practices and environmental impacts in Colorado. Rocky Mountain Center on Environment. Denver, Colorado. 33p.

An evaluation of mining practices in Colorado, their environmental impact and current reclamation progress. Includes recommendations concerning mined land reclamation and mining techniques to minimize damage and visibility.

268

Dotzenko, A. D., N. T. Papamichos, and D. S. Romine. 1967. Effect of recreational use on soil and moisture conditions in Rocky Mountain National Park. J. Soil Water Conserv. 22:196-197.

Heavy recreational use decreases soil moisture and organic matter content and increases bulk density although high organic matter soils are less subject to bulk density increases.

269

Douglass, G. W. and T. M. Ballard. 1971. Effects of fire on alpine plant communities in the North Cascades, Washington. Ecology 52:1058-1064.

Soils and species composition of burned and unburned sites in alpine and treeline communities are compared. Soil pH and humus form are consistently altered by fire. Fire alters the composition and diversity of plant communities.

270

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. Bot. Rev. 26:1-78.

A literature review of the effects of grazing on plant, plant community, and site characteristics. Includes all major U.S. rangeland areas from the True Prairie and Desert Grassland to mountain ranges with a brief discussion of the subalpine.

271

Ellison, L. and C. M. Aldous. 1952. Influence of pocket gophers on vegetation of subalpine grassland in central Utah. Ecology 33:177-186.

When pocket gophers are present, soil is loosened, grasses and sedges and rhizomatous species tend to increase but total production remains unchanged. Pocket gophers increase erosion once started by vegetation denudation.

272

Ellison, L., A. R. Croft and R. W. Bailey. 1957. Indicators of condition and trend on high range watersheds of the Intermountain Region. USDA Agr. Handbook No. 19. 66p.

Outlines principles for judging high elevation range condition (soil stability, vegetation cover, presence of desirable species, etc.) and the direction of its change. Several characteristics indicate condition: vegetation and litter cover, soil movement, soil remnants, erosion pavement, lichen lines, gullies, vegetation composition, etc.

273

Fredriksen, R. L. 1971. Comparative chemical water quality--natural and disturbed streams following logging and slash burning. pp. 125-134 in J. T. Krygier and J. D. Hall (symposium directors) Forest land uses and stream environment. Continuing Education Publications, Oregon State Univ., Corvallis.

Nutrient loss from a clearcut and burned Douglas fir forest in western Oregon was 1.6 to 3.0 times that from a similar undisturbed forest. Ammonia and manganese concentrations in streams exceeded federal water quality standards for 12 days. Annual nitrogen loss from the disturbed areas averaged 4.6 pounds per acre compared to .16 pounds for the undisturbed area.

274

Freethey, G. W. 1969. Hydrogeologic evaluation of pollution potential in mountain dwelling sites. M.Sc. Thesis. Colo. State Univ., Fort Collins.

Geologic, hydrologic, and topographic characteristics of 28 dwelling sites in the Colorado Front Range were evaluated for their relation to presence of biological contamination and as a means to predict pollution potential of future mountain homesites.

275

Gonsior, M. J. and R. B. Gardner. 1971. Investigation of slope failures in the Idaho batholith. USDA For. Serv. Res. Paper INT-97.

Slope failures were often associated with road construction and related to steepness of natural ground slope and fill slope, high void ratios (lack of adequate compaction), and inadequate control of surface and subsurface flow. Recommendations are made for construction in similar mountainous terrain.

276

Green, G. W., A. H. Lachenbruch, and M. C. Brewer. 1960. Some thermal effects of a roadway on permafrost. U.S. Geol. Surv. Prof. Paper 400-B: p. B141-B144.

Roadways in permafrost terrain increase the seasonal range of temperatures and depth of thaw. Winter temperatures are lower and summer temperatures higher than in adjacent undisturbed ground.

277

Haupt, H. F. 1959. Road and slope characteristics affecting sediment movement from logging roads. J. For. 57:329-332.

Seven road and slope characteristics were analyzed for relation to degree of erosion and sedimentation from Ponderosa pine logging roads in southwestern Idaho. Four characteristics (a slope obstruction index, cross ditch interval, embankment slope length, and product of cross ditch interval and road gradient) significantly affected sediment flow distance.

278

Hornbeck, J. W. 1968. Protecting water quality during and after clearcutting. J. Soil Water Conserv. 23:19-23.

Excessive damage to water quality can be avoided in logging operations in the eastern U.S. if roads are carefully constructed with minimum slope and away from stream channels and surface disturbance by equipment is minimized.

279

Lomnicki, A. 1971. The management of plant and animal communities in the Tatra Mountains National Park. pp. 599-604 in E. Duffey and A. S. Watt (eds.), The scientific management of animal and plant communities for conservation. Blackwell Scientific Publ., Oxford.

Reviews the damaging effects of man's activities in these Polish mountains and management policies for restoration.

280

Lutz, H. J. 1945. Soil conditions of picnic grounds in public forest parks. J. For. 43:121-127.

Trampling increased soil density while it drastically reduced permeability in two Connecticut state parks.

281

Marr, J. W. 1964. Utilization of the Front Range tundra, Colorado. pp. 109-118 in D. J. Crisp (ed.). Grazing in terrestrial and marine environments. Blackwell Scientific Publ., Oxford.

Reviews some of the major plant communities of the Front Range tundra, native animals found there, the effects of grazing by these and domestic animals on the vegetation, and natural and artificial revegetation. Many processes, including frost heaving and animal grazing may produce bare soil areas which may then be maintained by needle ice activity. Rehabilitation of disturbed areas is slow and attempts at revegetation have had little success.

282

Meeuwig, R. O. 1965. Effects of seeding and grazing on infiltration capacity and soil stability of a subalpine range in central Utah. J. Range Manage. 18:173-180.

Disked and seeded plots had lower infiltration capacities and soil stability than unseeded plots after seven years. Even moderate grazing can have pronounced residual effects on infiltration and soil stability.

283

Megahan, W. F. and W. J. Kidd. 1972. Effect of logging roads on sediment production rates in the Idaho batholith. USDA For. Serv. Res. Paper INT-123.

Sediment production rate (in Ponderosa pine and Douglas fir forests) attributed to erosion within the area disturbed by road construction averaged 770 times greater than that for similar, undisturbed lands in the vicinity. Erosion control measures should be applied immediately after road construction.

284

Morris, A. J. 1972. Soil compaction and recreational visitor use patterns in a forest campground. MSc. Thesis, Colo. State Univ., 125p.

Degree of soil compaction most related to soil moisture content but soil type, compactive force, and ground cover are also important.

285

Odegard, G. J. 1974. Nutrient and biomass distribution following clearcutting in a lodgepole pine forest ecosystem. Ph.D. Thesis. Colorado State Univ., Fort Collins. 182p.

Soils, vegetation, and logging residues were analyzed from three lodgepole pine sites near Fort Collins (a 1965 clearcut, a 1972 clearcut, and a control) to determine the effects of forest clearcutting on distribution of biomass and nutrients. Baseline data were recorded from the 1972 clearcut sites. Biomass of the 01 horizon was nearly doubled by clearcutting on the 1972 site. Mineral soil nutrient levels in the 1972 clearcut site demonstrated no immediate response to clearcutting although the 1965 clearcut site had lower soil nutrient levels than the control site. Clearcutting reduced total understory biomass by 52 percent on the 1972 site. Apparently understory biomass subsequently increases; the 1965 clearcut had a higher total understory biomass and nutrient reserve than the control site. Tree bole harvesting removed about five percent of the total nitrogen, and seven, ten and six percent of the available phosphorous, potassium, and calcium respectively. Since most nutrients of a tree are stored in needles, branches, and twigs however, whole tree removal would more than double nutrient losses from the site. Bibliography.

286

Olgeirson, E. 1974. Parallel conditions and trends in vegetation and soil on a bald near tree line, Boreas Pass, Colorado. Arct. Alp. Res. 6:185-203.

Recognizes two types of soil-vegetation units (regressional and undisturbed). Five undisturbed units "include forb and grass meadows underlain by alpine meadow soils and grass dominated sods underlain by alpine turf soils." Each is briefly described. Four regressional units represent vegetation and soil responses to forest removal with soil instability and increased erosion.

287

Packer, P. E. 1967. Forest treatment effects on water quality. pp. 687-699 in W. E. Sopper and H. W. Lull (eds.) Forest Hydrology. Pergamon Press, New York.

Summarizes research relating timber harvesting operations to stream water quality. Roads which are inadequately drained or located too close to streams are the main cause of water quality deterioration.

288

Packer, P. E. and H. F. Haupt. 1965. The influence of roads on water quality characteristics. Proc. Soc. Am. For. 1965:112-115.

High rates of sediment production and stream turbidity may result from roadbuilding activities (especially on coarse grained granitic soils) unless roads are properly constructed and drained. Stream sediments may have several detrimental effects on aquatic life. A brief literature review indicates important factors contributing to sediment movement distances from roads and thus widths of protective strips required along drainage ways.

289

Patton, D. R. 1973. A literature review of timber-harvesting effects on stream temperatures: research needs for the southwest. USDA For. Serv. Res. Note RM-249. 4p.

Forest cutting may raise water temperatures of shallow, low volume streams. This affects fish by influencing metabolic rates, oxygen content of water, hatching and development time, and migration. Research is needed on how logging affects water temperatures.

290

Phillips, R. W. 1971. Effects of sediment on the gravel environment and fish production. pp. 64-74 in J. T. Krygier and J. D. Hall (directors). Forest land uses and stream environment. Contin. Educ. Publ., Oreg. State Univ., Corvallis.

Summarizes research on effects of sediment on fish survival (especially Pacific Northwest). Suspended sediment blocks light and damages gill membranes. Settled sediment reduces oxygen supply to egg, forms barrier to fry emergence, and reduces food supply.

291

Pond, F. W. and D. R. Smith. 1971. Ecology and management of subalpine ranges on the Big Horn Mountains of Wyoming. Wyo. Agric. Exp. Stn. Res. J. 53.

Briefly describes the major vegetation types in the subalpine of the Big Horn Mountains and the major cattle and sheep forage species together with the growth and development, phenology, and nutritive value of these species. Heavy grazing reduced production more on granitic than sedimentary derived soils; it also reduced water infiltration and litter while it increased soil temperatures. Effects of range pitting, fertilization, and weed control are considered.

292

Reid, C. P. P., G. J. Odegard, J. C. Hokenstrom, W. J. McConnell, and W. E. Frayer. 1974. Effects of clearcutting on nutrient cycling in lodgepole pine forests. Coll. For. Nat. Resour., Colo. State Univ., Fort Collins. 321p.

This report analyzes some effects of clearcutting on nutrient distribution and water quality within the lodgepole pine forest ecosystem and thus provides insights into some consequences of this harvest technique. Two forest sites were clearcut on different dates (1965 and 1972) while another served as an undisturbed control. Understory biomass was drastically reduced during and immediately after tree harvest but nutrient levels in mineral soil reflected no immediate apparent change. Bole clearcutting removed approximately five percent of the total nitrogen pool of the site and seven, ten, and six percent of the available phosphorous, potassium, and calcium respectively. A considerable quantity of nutrients were deposited on the forest floor. Whole tree (branches, needles, etc. in addition to boles) removal would have more than doubled nutrient losses from the site. A diverse subordinate vegetation developed in years subsequent to the 1965 harvest and served to reduce nutrient losses from the soil. Clearcutting resulted in increased water yield from the sites and thus increased nutrient losses from the soils. Nitrate nitrogen losses were the most dramatic. Such nutrient losses may result in eutrophication of mountain streams and impoundments.

293

Rickard, W. E. and C. W. Slaughter. 1973. Thaw and erosion on vehicular trails in permafrost landscapes. J. Soil Water Conserv. 28:263-266.

A hand cleared controlled access trail was much more stable than tractor cleared trails in permafrost terrain of central Alaska. Bulldozed trails result in considerable soil movement. Surface organic matter should be left intact and traffic restricted to low ground pressure vehicles.

294

Ross, R. N. 1971. Snow and soil-water response to logging. MSc. Thesis. Colorado State Univ., Fort Collins. 85p.

Snow accumulation and melt rates significantly greater in clearcut and selectively cut areas than in uncut area. Soil moisture depletion was not significantly different between treatments.

295

Russell, R. L. 1973. Hydrology criteria for ski area development, in National Winter Sports Symposium. U.S. For. Serv., Denver, Colo. 15p.

The hydrologic effects of ski area development include changes in water quality and water quantity. Erosion and sedimentation are the major water quality effects and a method to predict erosion rates is illustrated. Chemical water quality and water temperature are also affected by ski area development. Water quantity is generally increased by forest canopy removal and plans must be made to accommodate this extra water in stream channels.

296

Rutherford, W. H. 1954. Interrelationships of beavers and other wildlife on a high altitude stream in Colorado. MSc. Thesis, Colo. State Univ., Fort Collins.

Two watersheds in Colorado, one with and the other without beaver influence, are compared for wildlife species and vegetation production.

297

Settergren, C. D. 1967. The effects of fire on wildland hydrology. Ph.D. Thesis, Colo. State Univ., Fort Collins. 229p. 68-2586.

Mathematical models developed from data in literature to predict watershed responses to forest fires. Literature review.

298

Strickler, G. S. 1961. Vegetation and soil condition changes on a subalpine grassland in eastern Oregon. USDA For. Serv. Pacific Northwest For. and Range Expt. Sta., Res. Paper 40. 46p.

A comparison of 1938 and 1957 photographs and quantitative data from systematically placed plots illustrate changes in soil and vegetation conditions which occurred after good management principles were applied to overgrazed subalpine sheep range in the Wallawa Mountains. Allotment boundary changes, grazing period changes, use of specific areas for bedgrounds, and open herding of sheep resulted in significant improvements. Erosion was retarded and plant density, vigor and litter increased, although vegetation composition was little affected.

299

Striffler, W. D. and E. W. Mogren. 1971. Erosion, soil properties, and revegetation following a severe burn in the Colorado Rockies. pp. 25-36 in C. W. Slaughter, R. J. Barney, and G. M. Hansen. Fire in the northern environment--a symposium. USDA For. Serv., Pacific Northwest For. and Range Exp. Stn.

The Comanche Burn killed all above ground vegetation. Subsequent localized erosion was common but soil losses from the area were small. Movement was directly related to percent slope, percent rock cover, and rainfall intensity. Soil physical properties were little affected but nutrient losses occurred. Tree reproduction increased with seed source and moisture but decreased as shrub and herbaceous densities increased. Establishment of subordinate vegetation was favored by deep, moist soils.

300

Swanston, D. N. 1971. Principal mass movement processes influenced by logging, road building, and fire. pp. 29-39 in J. T. Krygier and J. D. Hall (symposium directors) Forest land uses and stream environment. Contin. Educ. Publ., Oregon State Univ., Corvallis.

Four classes (1. debris avalanches, flows, and torrents; 2. slumps and earth flows; 3. deep seated soil creep; 4. dry creep and sliding) of soil mass movement are the dominant erosion processes in the western states. They characteristically occur on steep slopes and except for the last, under high soil moisture. Roadbuilding is the most damaging of the three activities considered and slope failures result primarily from slope loading, inadequate provisions for drainage, and bank cutting.

301

Tiedemann, A. R. 1973. Stream chemistry following a forest fire and urea fertilization in north-central Washington. USDA For. Serv. Res. Note PNW-203.

Urea fertilization at 78 kg./ha. of a burned forest area between about 1,000 and 8,000 feet elevation caused immediate increases in stream nitrate levels but these were within acceptable limits for municipal water supplies.

302

USDA. 1968. Restoring surface mined land. USDA Miscellaneous Publ. No. 1082.

Characteristics of surface mining operations in the U.S. Includes summary analysis of ownership, age, duration, erosion, water quality, plant cover, etc. Principles for mined-land conservation include preplanning, stabilization, water quality control, minimizing visual impact, etc.

303

U. S. Forest Service. 1973. Planning considerations for winter sports resort development. USDA For. Serv. in cooperation with National Ski Areas Association. 55p.

General discussion of principles involved in ski area development on national forest and adjacent lands. Includes Forest Service policies regarding development, recommendations to provide quality skiing, and methods to identify and lessen environmental impacts.

304

Wentz, D. A. 1974. Effect of mine drainage on the quality of streams in Colorado, 1971-72. Colo. Water Resour. Circ. No. 21. Colo. Water Conserv. Bd., Denver.

Sampling of numerous stream sites in Colorado (data tabulated for each) for temperature, specific conductance, pH, stream bottom conditions, aquatic biota, sulfate, and dissolved trace elements, indicates that approximately 450 miles of streams in 25 different areas are adversely affected by metal-mine drainage. These expanses are mapped. Copper and zinc appear to present the greatest toxicity dangers. Includes background discussion on Colorado metal and coal deposits, the process of acid formation and trace element liberation, and the consequences of mine drainage.

305

Willard, B. E. and J. W. Marr. 1970. Effects of human activities on alpine tundra ecosystems in Rocky Mountain National Park, Colorado. Biol. Conserv. 2:257-265.

High soil moisture sites are most easily damaged, tall herb communities next and fellfield communities least easily damaged. Turf communities are most resilient.

306

Willard, B. E. and J. W. Marr. 1971. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. Biol. Conserv. 3:181-190.

Trampling by visitors to Rocky Mountain National Park alpine tundra kills plants and initiates erosion processes. Fellfields which have been disturbed for only a single season of trampling, may show nearly complete recovery after two years of protection. Longer periods of disturbance, however may require several years for recovery. Kobresia meadows resist disturbance due to a strong turf but once the turf is broken, extremely long periods are required for re-establishment.

307

Zoghet, M. F. 1969. Alpine surface soil movement. Ph.D. Dissertation. Colo. State Univ., Fort Collins. 161p. 70-5511.

Erosion rates in undisturbed alpine tundra are slow but accelerate greatly after ground cover is disturbed by sheep, etc. Wind is one of the most important contributors to soil erosion. Total sediment yield in micro runoff collectors was best correlated to snow deposition and litter cover.

See also 53, 69, 70, 76, 92, 123, 141, 178, 201, 216, 225, 255, 390, 424, 435, 447, 450.

SECTION VI

REHABILITATION AND REVEGETATION

308

Alexander, R. R. 1966. Stocking of reproduction on spruce-fir clearcuttings in Colorado. USDA For. Serv. Res. Note RM-72.

Reproduction subsequent to harvest related to seedbed condition, aspect, slope, amount of slash, vegetation abundance, soil texture, width and direction of cut strip and number of years since cutting.

309

Alexander, R. R. 1968. Natural reproduction of spruce-fir after clearcutting in strips, Fraser Experimental Forest. USDA For. Serv. Res. Note RM-101.

Reproduction on all clear cut areas was sufficient for stand replacement but was primarily that which survived logging. Subsequent reproduction was scarce due partly to limited seed supply and competition from ground vegetation.

310

Alexander, R. R. 1974. Silviculture of subalpine forests in the Central and Southern Rocky Mountains: The status of our knowledge. USDA For. Serv. Res. Paper RM-121. 88p.

A "comprehensive summary of available knowledge on timber management applicable to Rocky Mountain subalpine forests." A general discussion of climate, geology, soils, and vegetation, is followed by detailed discussions of the spruce-fir and lodgepole pine forest types. Includes descriptions of insects and diseases, past cutting history, regeneration requirements (seed supply, germination, and establishment), site quality, growth and yield, and management of old growth. Bibliography.

311

Allison, F. E. 1966. The fate of nitrogen applied to soils. Advan. Agron. 18:219-258.

A review of research on the fate of nitrogen fertilizers applied to soils. Chief loss in agriculture is due to leaching although biological denitrification contributes to gaseous loss. Heavy applications of urea or ammonia may under some conditions, result in large losses.

312

Appleby, A. P. and R. G. Brenchley. 1968. Influence of paraquat on seed germination. Weed Sci. 16:484-485.

Germination of several grass species including Kentucky bluegrass and perennial ryegrass was reduced when paraquat was applied directly to seeds on soil surface. Alfalfa and red clover were not affected by 1 lb./acre. A layer of soil .25 inches thick over the seeds protected them from paraquat.

313

Arakine, H. R. and A. R. Schmid. 1949. Cold resistance of various legumes and grasses in early stages of growth. Agron. J. 41:182-185.

Timothy, Kentucky bluegrass, and smooth brome have sufficient survival under cold conditions to be planted in late fall. Legume survival under cold temperatures was low.

314

Armbrust, D. V. and J. D. Dickerson. 1971. Temporary wind erosion control: cost and effectiveness of 34 commercial materials. J. Soil Water Conserv. 26:154-157.

Six materials (a resin in water emulsion and five liquid polymers) met criteria of cost, erosion control, no deleterious effects on plant germination and growth, and ease of application. All have to be applied as a pre-emergence spray with a herbicide to control weeds.

315

Aulityky, H. 1967. Significance of small climatic differences for the proper afforestation of highlands in Austria. pp. 639-653 in W. E. Sopper and H. W. Lull (eds.) Forest Hydrology. Pergamon Press, New York.

Microenvironments (temperature, radiation, precipitation, wind, etc.), vegetation, and physiological behavior of tree species are related to determine suitable areas for afforestation near timberline in the Austrian Alps.

316

Barnett, A. P., E. G. Diseker, and E. C. Richardson. 1967. Evaluation of mulching methods for erosion control on newly prepared and seeded highway backslopes. Agron. J. 59:83-85.

Reports tests of several mulching methods to control erosion on highway backslopes subjected to two storm intensities. "Whisker dams" and surface mulch were superior techniques under high intensity storms. Asphalt spray decreased this effectiveness.

317

Bell, A. V. 1974. The tailings pond as a waste treatment system. The Can. Min. Metall. Bull. 67:73-78.

Management considerations which should be included in the planning design and operation of a tailings system.

318

Berg, W. A. 1972. Vegetative stabilization of mine wastes. pp. 24-26 in Colo. Min. Assoc. 1972 Min. Yearb., Denver, Colorado.

A range of problems are encountered in vegetative stabilization of mine tailings and spoils in the western states. These include instability, nutrient deficiencies, acidity, salinity, toxicity, and low moisture availability. Two major approaches to tailings stabilization have been to cover them with soil or establish vegetation directly. Revegetation problems on spoils are less complex but highly visible.

319

Berg, W. A. 1974. Grasses and legumes for revegetation of disturbed subalpine areas. pp. 31-35 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Foxtails (meadow and creeping) and smooth brome establish well and are persistent in the Colorado subalpine. Other species that establish well but are not persistent include timothy, slender wheatgrass, tall fescue, orchardgrass, and ryegrass. Several other grass species show promise or may have special uses. A limited number of legumes are marginally adapted to high elevations: alfalfa, white clover, cicer milkvetch, birdsfoot trefoil, etc.

320

Berg, W. A., E. M. Barrau and L. A. Rhodes. 1975. Plant growth on acid molybdenum mill tailings as influenced by liming, leaching, and fertility treatments. pp. 207-222 in M. J. Chadwick and G. Goodman (eds.) The ecology of resource degradation and renewal. Blackwell Scientific Publications Ltd., Oxford.

Tailings from the Climax Molybdenum mine were limed, fertilized, and leached in a glasshouse to determine the effects of these treatments on plant growth on these tailings. As plant growth media, the tailings are extremely acid and low in many nutrients. Very high liming rates were required to neutralize the tailings; in addition, sulfide oxidation continued after liming so that long term vegetative stabilization of the tailings may require maintainance liming. Leaching after liming increased plant growth. Fertilization with nitrogen, phosphorous, and potassium was required for plant growth on the tailings. A plant growth response was also noted on some tailings to manganese, zinc, and copper application. Limited field studies at this high elevation site (3400 m) demonstrates that growth of most perennial grasses is poor on the tailings although cereal rye made fair to good growth.

321

Bethlahmy, N. and W. J. Kidd. 1966. Controlling soil movement from steep road fills. USDA For. Serv. Res. Note INT-45. 4p.

Erosion on steep terrain of loose weathered granitic material near Boise, Idaho, was effectively controlled by combined seeding, straw mulching, and netting.

322.

Blaser, R. E. 1963. Principles of making turf mixtures for roadside seedings. Highw. Res. Rec. 23:79-84.

Variable microclimate, seed emergence and growth rate differences, differential responses to soil fertility and lime, etc. are reason to use mixtures of seeds. These mixtures should be simple and aggressive species used sparingly.

323

Bleak, A. T. 1959. Germination characteristics of grass seed under snow. J. Range Manage. 12:298-302.

High seedling mortality of seeds planted in the subalpine in late summer or fall is often traceable to winter-killing. Viability of pre-germinated smooth brome and Tualatin oatgrass seeds was significantly decreased beneath snowcover. Probable damage was due to low temperatures and dessication due to freezing.

324

Bolstad, R. 1971. Catline rehabilitation and restoration. pp. 107-116 in C. W. Slaughter, R. J. Barney, and G. M. Hansen. Fire in the northern environment--a symposium. USDA For. Serv., Pacific Northwest Forest and Range Exp. Station.

Bulldozer action on sloping permafrost terrain in Alaska has resulted in severe erosion. Standard water bars and berm dikes combined with seeding and fertilization effectively reduced such erosion.

325

Bowns, James E. 1972. Low level nitrogen and phosphorus fertilization on high elevation ranges. J. Range Manage. 25:273-276.

Thirty and sixty pounds/acre of available nitrogen and phosphorus increased production, crude protein, and phosphorus content of subalpine meadows. Effects on production carried over into second year.

326

Brink, V. C., I. R. Mackay, S. Freyman, and D. G. Pearce. 1967. Needle ice and seedling establishment in southwestern British Columbia. Can. J. Plant Sci. 47:135-139.

Needle ice activity may cause serious damage to late seedings, especially on certain soil types. Increased seeding rates may compensate for this damage. Needle ice activity may be very important to erosion of non- or sparsely-vegetated slopes.

327

Brooks, C. R. and R. E. Blaser. 1963. Effect of fertilizer slurries used with hydro-seeding on seed viability. Highw. Res. Rec. 53:30-34.

Germination of clovers, redtop, perennial ryegrass, oats, etc. was not reduced by fertilizer slurries as used in hydro-seeders. Fertilizer, however, aggravates moisture stress in fescue and apparently reduces germination.

328

Brown, J. A. 1974. Cultural practices for revegetation of high-altitude disturbed lands. pp. 59-63 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Describes the revegetation progress and problems on the Climax Molybdenum Company's property at Climax, Colorado (11,300 to 13,500 feet elev.). A mixture of seven grasses plus white Dutch clover has been developed for disturbed subalpine areas. Several seeding methods are used depending on site characteristics. Nitrogen and phosphorus fertilization of subsoils has been necessary. Engelmann spruce, lodgepole pine, and trembling aspen have been successfully transplanted.

329

Brown, R. W. 1973. Transpiration of native and introduced grasses on a high elevation harsh site. pp. 467-481 in Hutnik, R. J. and G. Davis (eds.). Ecology and Reclamation of Devastated Land, Vol. I. Gordon Breach, New York.

Two introduced grasses (smooth brome and intermediate wheat-grass) had higher transpiration rates and less ability to control transpiration in response to environmental fluctuations than a native grass (kings fescue) at high elevations of northern Utah. In these terms, kings fescue is the best adapted of these species to high elevation harsh sites.

330

Brown, R. W., R. H. Ruf, Jr., and E. E. Farmer. 1971. Suitability of *Ceanothus prostratus* for the revegetation of harsh sites. USDA For. Serv. Res. Note INT-144. 12p.

Squaw carpet, a prostrate shrub forms "extensive trailing lateral branches that root at the nodes when in contact with the soil." It forms dense mats under natural conditions in relatively dry forest types from 3500 to 8500 feet elevation on coarse granitic soils primarily in the Sierra Nevada. It supports nitrogen fixing organisms in root nodules. In this study, rooted stem cuttings were planted on harsh sites (road cuts, logged areas, mine tailings, etc.) throughout the Intermountain region from 4,410 to 10,260 feet elevation. Percent survival was low at all locations but plantings were considered successful at several sites below 7,000 feet. Considerable variability was noted within the species.

331

Carleton, A. E., R. D. Austin, J. R. Stroh, L. E. Wiesner, and J. G. Scheetz. 1971. Cicer milkvetch (*Astragalus cicer* L.). Seed germination, scarification and field emergence studies. Mont. Agric. Exp. Stn. Bull. 655. Mont. State Univ.

Cicer tolerates higher pH than alfalfa but is equally tolerant to low pH. Productive at high elevations. It has low seed germination and slow seedling growth rate. Mechanical scarification increases germination but it must be more intense than for alfalfa. Scarified seed loses viability quickly. Best seeding dates were early May at Bozeman and mid-April at Bridger.

332

Carpenter, L. H. and G. L. Williams. 1972. A literature review on the role of mineral fertilizers on big game range improvement. Colo. Div. Game Fish Parks Spec. Rep. No. 28.

Reviews literature on effects of nitrogen fertilization on native rangelands with particular emphasis to its significance for wildlife. Includes effects on yield, vegetation composition, chemical content of plants, plant vigor and growth, palatability, etc.

333

Chepil, W. S., N. P. Woodruff, F. H. Siddoway, and D. V. Armbrust. 1963. Mulches for wind and water control. USDA Agric. Res. Serv. ARS 41-84.

Well anchored vegetative mulch was superior to all other mulches in cost and effectiveness of controlling wind and water erosion. Cutback asphalt, asphalt emulsion, and latex emulsion restricted percolation of water into soil when applied in quantities sufficient to control erosion. Includes recommendations for spreading and anchoring vegetative mulch.

334

Chepil, W. S., N. P. Woodruff, F. H. Siddoway and L. Lyles. 1960. Anchoring vegetative mulches. Agric. Eng. 41:754-755, 759.

A disk packer is the best implement for anchoring mulches. If packer is not used, 4000 lb/acre of prairie layer, 5000 to 6000 lb/acre of wheat straw with 500-1000 gal/acre of rapid curing asphalt is recommended.

335

Cook, C. W. 1973. Rehabilitation of surface mined land. pp. 55-58 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

General guidelines and considerations pertinent to rehabilitation of disturbed lands.

336

Cook, C. W., I. B. Jensen, G. Coltharp, and E. M. Larson. 1970. Seeding methods for Utah roadsides. Utah Agric. Exp. Stn., Resour. Ser. 52. 23p.

Guidelines for establishing grass stands on roadway cuts and fills in Utah. Discusses topsoiling, fertilizers, seeding methods, mulches, species to seed (smooth brome, intermediate wheatgrass, pubescent wheatgrass, orchard grass, meadow fescue, and Italian ryegrass are recommended for high elevations), weed control, and maintenance practices.

337

Cook, C. W., R. M. Hyde, and P. L. Sims. Guidelines for revegetation and stabilization of surface mined areas in the western states. Colo. State Univ. Range Sci. Ser. No. 16.

Guidelines for establishing vegetation on disturbed lands include general recommendations for seeding methods, topsoiling, fertilization, mulching, weed control, and management during vegetation establishment and specific recommendations for revegetation of regions from plains grassland to alpine. Includes tables on number of seeds per pound for several species and use of various herbicides to control weeds. Topsoiling, fall seeding with a drill, and nitrogen fertilization is recommended in both the subalpine and alpine. Several species of fescues, wheatgrasses, bluegrasses, and others are recommended for seeding in these regions.

338

Cooper, C. S., A. E. Carleton, and R. F. Eslick. 1971. Birdsfoot trefoil for Montana. Mont. Agric. Exp. Stn., Mont. State Univ., Bozeman Bull 652. 14p.

Birdsfoot trefoil does better on low phosphorus soils than most legumes but has slow establishment and growth rates and is not as drought tolerant or winter hardy as alfalfa. It reseeds better than alfalfa.

339

Cresswell, C. F. 1973. Changes in vegetational composition, nutritional status, and microbial populations with the establishment of vegetation on gold-mine dumps on the Witwatersrand. pp. 335-359 in R. J. Hutnik and G. Davis (eds.), Ecology and reclamation of devastated land. Vol. II. Gordon and Breach, New York.

Describes problems and techniques to establish vegetation on gold mine dumps in South Africa. Describes the changes which have occurred during the seven years since establishment of vegetation and some characteristics of these wastes.

340

Cuany, R. L. 1974. Plant breeding and its role in supplying new plant materials. pp. 44-54 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Outlines the role and methods of breeding for improved plant materials for high altitude revegetation. Includes choice of species, methods of recombination and evaluation, etc. A breeding program for smooth brome is described.

341

Currier, W. F. 1973. Basic principles of seed planting. pp. 225-232 in National Coal Association. Research and applied technology symposium on mined-land reclamation. Bituminous Coal Research, Inc., Monroeville, Pa.

Basic principles for successful seed planting include: use adapted species, reduce plant competition, prepare a good seedbed, cover seed to proper depth, be sure of even seed distribution, seed at proper time, be sure of sufficient plant nutrients. Broadcasting and drilling methods are discussed in relation to these principles.

342

Dahl, O. 1967. Trees, shrubs, roses and vines for Wyoming high altitudes. Agric. Ext. Serv., Univ. Wyo., Laramie Bull. 477. 30p.

A guide for selection of trees and shrubs for home landscaping at elevations from 6,000 to 8,000 feet. Includes mostly ornamentals.

343

Dean, K. C. and R. Havens. 1973. Methods and costs for stabilizing tailing ponds. Min. Congr. J. 59:41-46.

Evaluated several physical, chemical, vegetative, and combined vegetative methods for stabilization effectiveness, maintenance, and cost. The chemical-vegetative procedure is the most economical and its use is recommended.

344

Doran, C. W. 1952. Adaptability of plants for reseeding high mountain parks in western Colorado. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 10.

Compares the vigor and general suitability of several grass and four legume species for reseeding high elevation ranges. Includes a brief description of the salient features of each species. Intermediate wheatgrass, smooth brome, quackgrass, timothy, meadow foxtail, and Kentucky bluegrass were rated as excellent for general suitability.

345

Dudeck, A. E., N. P. Swanson, L. N. Mielke, and A. R. Dedrick. 1970. Mulches for grass establishment on fill slopes. Agron. J. 62:810-812.

Of eleven mulch treatments applied to slopes seeded with smooth brome in eastern Nebraska, excelsior mat resulted in lowest soil temperatures, highest soil moisture, and highest yields of grass seedlings.

346

Dyrness, C. T. 1970. Stabilization of newly constructed road backslopes by mulch and grass-legume treatments. USDA For. Serv. Res. Note PNW-123. 5p.

Fall seeded grasses and legumes did not provide erosion control in Oregon mountains until June. Mulching may therefore be necessary for first few months.

347

Eaman, T. 1974. Plant species potentials for high altitude revegetation. pp. 39-43 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Species potentially valuable for high altitude revegetation must be perennial, environmentally adapted, and available. Rocky Mountain revegetation studies have relied primarily on smooth brome, orchard grass, timothy, intermediate wheatgrass, pubescent wheatgrass, slender wheatgrass, Kentucky bluegrass, mountain brome, Russian wildrye, blue wildrye, and big bluegrass. Tufted hairgrass, sheep fescue, Thurber fescue, and Parry oatgrass are potentially valuable natives.

348

Echols, J. W. and R. L. Cuany. 1974. Seed supplies and plant materials work group summary. pp. 83-87 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent., Inf. Ser., No. 10, Colo. State Univ., Fort Collins.

Seed of grasses used for forage and soil conservation is often in short supply and expensive. A critical need exists for new plant materials and a screening of desirable types. Several grasses, sedges, legumes, forbs, and shrubs have potential for high elevation reclamation. Includes a table of recommended seeding rates for over 50 grasses and legumes and their typical purity and germination percentages.

349

Elliot, C. R., E. C. Stacey, and W. J. Doran. 1961. Creeping red fescue. Can. Dep. Agric., Res Branch, Publ. 1122.

Description and general characteristics, adaptations, varieties, and use of creeping red fescue in Canada. It is a perennial turf grass which "thrives under cool, moist conditions and is not affected by frost." Red fescue is suitable for reclaiming burned over areas in northern Alberta and British Columbia.

350

Ellison, L. 1949. Establishment of vegetation on depleted subalpine range as influenced by microenvironment. Ecol. Monogr. 19:95-121.

New seedlings establish best where some vegetation is already present since temperatures are less extreme, frost heaving less common, and soil moisture more persistent in these areas than in bare openings.

351

Ellison, L. and W. R. Houston. 1958. Production of herbaceous vegetation in openings and under canopies of western aspen. Ecology 39:337-345.

Smooth brome, blue wildrye, tall coneflower and cowparsnip were seeded in openings and under canopies. Plots in open were more productive than those under aspen. Brome was the most successful species and cowparsnip the least.

352

Gates, D. H. 1962. Revegetation of high altitude, barren slopes in northern Idaho. J. Range Manage. 15:314-318.

Erosive, acidic, low nutrient steep slopes were fertilized, mulched and seeded to smooth brome, slender wheatgrass, orchardgrass, timothy, mountain brome, and Idaho fescue. All mulches were considered failures except native hay which contained viable native seed. Fertilizers had little effect. Concluded that indigenous grasses are superior to introduced species.

353

Gomm, F. B. 1962. Reseeding studies at a small high altitude park in southeastern Montana. Mont. Agric. Exp. Stn. Bull. 568, 16p.

Establishment of seeded species increased with intensity of cultivation and from north to south exposures. Fertilizers had no effect on number of seedlings established in seeding year. Fall seedlings were concluded better than spring seedings. Only smooth brome and meadow foxtail stands had increased after four years. Three species of wheatgrass, mountain brome, orchardgrass, and Kentucky bluegrass maintained their original stands during the four years.

354

Grable, A. R., F. M. Willhite, and W. L. McCuistion. 1965. Hay production and nutrient uptake at high altitudes in Colorado with different grasses in conjunction with alsike clover or nitrogen fertilizer. Agron. J. 57:543-547.

Yield of six grass species (smooth brome, orchardgrass, meadow foxtail, timothy, reed canarygrass, and intermediate wheatgrass) was increased about equally by 200 lb./acre nitrogen application or alsike clover. However, alsike clover disappeared after two years. Most orchardgrass was winterkilled.

355

Graybeal, N. 1973. An analysis of vegetation on ski slopes at the Winter Park Ski Area. MSc. Thesis, Colo. State Univ., Fort Collins. 108p.

Vegetation cover on slopes of this Colorado ski area increased with time since slope preparation but was not necessarily higher on seeded than nonseeded slopes nor correlated with elevation. Orchardgrass, Canada rye, and alsike clover, species often included in ski slope seeding mixtures, were recorded below but not above 10,100 feet.

356

Hafenrichter, A. L., J. L. Schwendiman, H. L. Harris, R. S. MacLauchlan, and H. W. Miller. 1968. Grasses and legumes for soil conservation in the Pacific Northwest and Great Basin states. USDA Soil Conservation Serv. Agric. Handbook 339.

Summarizes 32 years of systematic testing of a large number of grasses and legumes for conservation. Pertinent characteristics (favorable soils and soil moisture regime, pH tolerance, disease susceptibility, germination rate, seed production rate, frost resistance, etc.) for each of several species segregated into groups: 1) rapid developing, short lived grasses; 2) rapid developing, long lived grasses for subhumid areas; 3) saline and alkaline tolerant grasses; 4) drought tolerant long lived bunch grasses; 5) drought tolerant long lived sod grasses; 6) the bluegrasses; 7) fine leaved grasses for cover, erosion control, and recreation areas; and 8) legumes.

357

Hanson, A. A. 1972. Grass varieties in the United States. Agricultural Handbook No. 170. USDA Agr. Res. Serv. 124p.

Working guide to status of named and experimental grass varieties in U.S. Includes development agency and individuals, method of breeding, and description of general adaptations, morphology, growth and production, and disease resistance, etc.

358

Harrington, H. D. 1946. Results of a seeding experiment at high altitudes in Rocky Mountain National Park. Ecology 27:375-377.

Roadcuts seeded to 24 native species. After six years, 15 offered particular promise: golden banner, scorpion weed, purple fringe, ticklegrass, hairgrass, fringed brome, spike trisetum, alpine bluegrass, waxflower, yarrow, raspberry, etc. Seeded scorpion weed survived better than when transplanted. Time and labor available to collect such seed limits such programs.

359

Hauch, R. D. 1968. Nitrogen source requirements in different soil-plant systems. pp. 47-57 in G. W. Bengtson (symp. chairman). Forest fertilization--theory and practice. Tenn. Val. Auth., Knoxville, Tenn.

Nitrogen for fertilization is available in a wide variety of sources with different physical and chemical characteristics. Most solid sources are water soluble, although some form alkaline and others neutral or acid solutions upon hydrolysis. Nitrogen sources differ in nitrification rates, possible loss of nitrogen, and root damage from nitrite or ammonia. Ammonium forms are generally taken up by plants more rapidly than nitrate forms which should not be used where leaching is extensive or on heavy wet soils. Slow release nitrogen sources are at least theoretically not as subject to losses which reduce fertilizer efficiency as are the rapid release sources. Bibliography.

360

Haupt, H. F. 1959. A method for controlling sediment from logging roads. USDA For. Serv. Interm. For. Range Exp. Stn. Misc. Publ. No. 22.

Describes techniques to control sediment from logging roads on unstable soils in ponderosa pine forests of southwestern Idaho. These methods are applied just after abandonment and before vegetation is established and rely primarily on cross-ditches.

361

Heede, B. H. 1966. Design, construction and cost of rock check dams. USDA For. Serv. Res. Paper RM-20. 24p.

Describes major types of rock check dams, criteria used in their design, methods of construction, and costs. Includes several recommendations for design and construction.

362

Heede, B. H. 1967. Gully development and control in the Rocky Mountains of Colorado. Ph.D. Thesis. Colo. State Univ., Fort Collins. 299p. 67-13,197.

Gullies are classified into continuous and discontinuous channels based on channel morphology and stage of development. This classification is useful as a guide for erosion control. Rock check dams are very successful for stabilizing gullies if criteria of flow, channels and design are considered. Vegetation establishment is recommended.

363

Herbel, C. H. 1972. Using mechanical equipment to modify the seedling environment, pp. 369-381 in McKell, C. M. et al. (ed.). Wildland Shrubs--their biology and utilization. USDA For. Serv. Gen. Tech. Report INT-1.

Evaluates several methods of site modification for reseeding including ripping, pitting, furrowing, water-ponding, soil firming and plowing. Pitting and furrowing formed good seedbeds on medium to heavy textured soils.

364

Herrington, R. B. and W. G. Beardsley. 1970. Improvement and maintenance of campground vegetation in central Idaho. USDA For. Serv. Res. Paper INT-87.

Camp units in lodgepole pine forest receiving water, fertilizer, and seed over two year treatment period demonstrated substantially increased ground cover. Kentucky bluegrass, hard fescue, Dutch clover and sodar wheatgrass were broadcast at 40 pounds per acre.

365

Hodder, R. L. 1970. Revegetation methods and criteria for bare areas following highway construction. Final report for Montana State Highway Comm. 97p.

Reports results from investigations on several problems related to revegetation of highway construction areas in Montana. Includes studies of seed germination (germination of most reduced by hydroseeder fertilizer slurries), effects of mulches on soil moisture and temperature, effectiveness of mulches for stabilization, use of fertilizers, effects of time of seeding soil bacterial inoculations, native shrub propogation, adapted species, and other problems. Study sites are primarily semiarid.

366

Hodder, R. L. and B. W. Sindelar. 1971. Tubelings--a new dryland planting technique for roadside stabilization and beautification. Mont. Agric. Exp. Stn., Mont. State Univ. Bozeman Res. Report No. 18. 19p.

Plants are grown in deep paper tubes reinforced by plastic mesh sleeves called tubelings and then inserted into auger holes. This procedure eliminates need for irrigation during establishment and results in greater survival and growth rates of several tree, shrub, and vine species on arid sites.

367

Hull, A. C. 1943. Hand collection and cleaning of seed of native forage plants. Interm. For. Range Exp. Stn. Res Paper No. 4.

Describes an efficient method for hand collection of native seed.

368

Hull, A. C., Jr. 1966. Emergence and survival of intermediate wheatgrass and smooth brome seeded on a mountain range. J. Range Manage. 19:279-283.

Planting depth (.5 and 1.0 in.) showed no correlation to percent emergence and survival but fall seedings were better than spring seedings at 8,400 feet in southeastern Idaho. 1.2 percent of wheatgrass and .4 percent brome survived first season. Frost heaving accounted for approximately 50 percent of losses.

369

Hull, A. C., Jr. 1973. Duration of seeded stands on terraced mountain lands, Davis County, Utah. J. Range Manage. 26:133-136.

Depleted mountain rangelands from 7,400 to over 9,000 feet elevation were seeded to 37 species from 1936 to 1939. By 1971 only smooth brome, tall oatgrass, intermediate wheatgrass, and red fescue had fair to excellent stands. Native plants have reinvaded the seeded areas.

370

Hull, A. C., Jr. 1974. Species for seeding mountain rangelands in southeastern Idaho, northeastern Utah, and western Wyoming. J. Range Manage. 27:150-153.

Mixtures had higher yields and maintained better stands than single species. High seedling mortality resulted from summer drought, frost heaving, plant competition, and pocket gophers. Smooth brome, meadow foxtail, and creeping foxtail are adapted for seeding most mountain rangelands but smooth brome did not maintain stands above 9,000 feet. Legumes show promise, although alfalfa was reduced by livestock.

371

Hull, A. C., Jr. 1974. Seedling emergence and survival from different seasons and rates of seeding mountain rangelands. J. Range Manage. 27:302-304.

An analysis of factors affecting emergence and survival of seeded grasses (intermediate and slender wheatgrasses, meadow foxtail, smooth brome, and timothy) on a subalpine range in Idaho. More seedlings emerged from seeding rates of 25 than 10 pounds per acre. Maximum emergence and survival was obtained from June seedings followed closely by July and then November, October, September and August. Small seedlings were often killed by drought or frost.

372

Hull, A. C., Jr., D. F. Hervey, C. W. Doran, and W. J. McGinnies. 1958. Seeding Colorado rangelands. Colo. State Univ. Exp. Stn. Bull. 498-S. 46p.

Includes methods to eliminate competing vegetation and seedbed preparation, planting techniques and equipment, recommended planting seasons, stand management, and recommendations for specific vegetation types. The ponderosa pine zone should be seeded to crested and Fairway wheatgrasses and Russian wildrye in early spring or mid to late fall. Timothy, orchardgrass, and smooth brome are best for aspen type and smooth brome, timothy and intermediate wheatgrass for subalpine meadows. Thurbers fescue is well adapted to high elevation parks but has poor seedling vigor.

373

Hull, A. C., Jr. and R. C. Holmgren. 1964. Seeding southern Idaho rangelands. USDA For. Serv. Res. Paper INT-10. 31p.

Summarizes available information and range reseeding experience with over 230 species planted at 79 locations. Discusses removal of competing vegetation, seeding procedures, (method, depth, season, rate), selection of species (brief discussion of establishment characteristics of several grasses and alfalfa), recommendations for specific range types (sagebrush, juniper, mountain brushlands, Ponderosa pine, mountain meadows, and other high elevation ranges). Includes table of adaptations of the 237 species to particular range types.

374

Jackobs, J. A., O. N. Andrews, Jr., C. L. Murdock, and L. E. Foote. 1967. Turf establishment on highway right-of-way slopes--a review. Highw. Res. Rec. No. 161:71-103.

A literature review on factors affecting turf establishment on roadside slopes. Includes discussion of several soil characteristics, cultural practices, and effect of climate and adapted species (for Illinois). Numerous references.

375

Johnson, T. W., Jr., G. H. Schubert, and D. P. Almas. 1973. Rehabilitation of forest land: the Rocky Mountain-Intermountain region. J. For. 71:144-147.

Regeneration of forests in the Rocky Mountain and Intermountain regions is hampered by competition from grasses and shrubs. Several recommendations to alleviate this competition are presented.

376

Johnson, W. H., O. K. Hedden, and J. D. Wilson. 1966. How liquid mulches affect moisture retention, temperature, and seedling growth. Agric. Eng. 47:196-199, 211.

Wax mulch increased soil temperatures by 1.5 to 2.0° F at 2 inch depth. Liquid asphalt mulch reduced soil drying and thus increased early growth of corn.

377

Jolliff, G. D. 1969. Campground site--vegetation relationships. Ph.D. dissertation. Colo. State Univ., Fort Collins. 151p. 70-5486.

Discusses several factors pertinent to revegetation of deteriorated campgrounds in Rocky Mountain National Park. Nitrogen fertilization is essential for grass establishment. Growth is limited by low soil moisture due to poor water infiltration and high evapotranspiration. Percent survival and yield of seeded stands was highest for intermediate wheatgrass and lower for smooth brome and tall fescue respectively.

378

Jones, J. R. 1967. Regeneration of mixed conifer clearcuttings on the Apache National Forest. Arizona. USDA For. Serv. Res. Note RM-79.

The most common obstacles to regeneration are inadequate seed supply, pests such as rodents, inadequate soil moisture, herbaceous competition, browsing by deer and elk, and other factors.

379

Julander, Odell, J. B. Low, and O. W. Morris. 1959. Influence of pocket gophers on seeded mountain range in Utah. J. Range Manage. 12:219-224.

Yields and plant cover of a subalpine site seeded to timothy, orchardgrass, tall oatgrass and smooth brome were reduced when pocket gophers were not controlled. Where dense gopher populations are present, they must be controlled for good grass stand establishment.

380

Kay, B. L. 1972. New mulch materials tested for hydroseeding. Univ. Calif., Davis, Agric. Exp. Stn., Agron. Prog. Rep. No. 39.

Washed dairy waste, ground paper mulch, wood fiber, rice hulls, and barley straw were tested. Wood fiber is the best commercially available material for hydroseeding.

381

Kay, B. L. 1972. Hydroseeding limitations and alternatives. Univ. Cal., Davis., Agric. Exp. Stn., Agron. Prog. Rep. No. 43.

Hydroseeding equipment may severely damage seeds and thus reduce germination percentages. Seeds should not be placed into water until just prior to seeding. Wood fiber should not be used where not really needed since it contributes to seeding failure by preventing seedlings from reaching mineral soil.

382

Kay, B. L. and M. B. Jones. 1972. Pellet-inoculated legume seeds are okay in hydromulching. Univ. of Calif., Davis. Agric. Exp. Stn., Agron. Prog. Rep. No. 44.

Inoculated seeds of subclover will remain effectively inoculated in a hydromulching slurry for 30 minutes.

383

Kidd, W. J., Jr. and H. F. Haupt. 1968. Effect of seedbed treatment on grass establishment on logging roadbeds in central Idaho. USDA For. Serv. Res. Paper INT-53. 9p.

Seeding following deep scarification yielded denser stands than seeding before scarification or braodcasting. Wood chip mulch reduced plant density. Intermediate and crested wheatgrass and smooth brome were the most successfully seeded.

384

Klock, G. 1973. Mission Ridge--a case history of soil disturbance and revegetation of a winter sports area development. USDA For. Serv. Res. Note PNW-199. 10p.

The development and slope stabilization program of a Washington ski area illustrate slope revegetation problems and sound management practices. Construction impact was minimized. Slope fertilization, with a thin layer of soil over seed and fertilizer, was necessary for successful grass establishment using orchard grass, timothy, hard fescue, crested wheatgrass, and common ryegrass.

385

Larse, R. W. 1971. Prevention and control of erosion and stream sedimentation from forest roads. pp. 76-83 in J. T. Krygier and J. D. Hall (symposium directors), Forest land uses and stream environment. Contin. Educ. Publ., Oregon. State Univ., Corvallis.

Reviews some aspects of road planning, construction and maintenance to minimize damaging effects of erosion (especially for Pacific Northwest). Planning and route selection are probably the most important elements although many design features reduce erosion. Regular maintenance is necessary to prevent deterioration.

386

Larson, M. M. 1959. Regenerating aspen by suckering in the Southwest. USDA Rocky Mt. For. Range Exp. Stn. Res. Note 39.

Browsing is greatest deterrent to successful regeneration of cutover areas. These areas should be protected for adequate regeneration and height growth of suckers.

387

Lawrence, T. 1963. The influence of fertilizer on winter survival of intermediate wheatgrass following a long period of drought. J. Br. Grassl. Soc. 18:292-294.

Extent of winterkill in Saskatchewan ranged from four percent with no fertilizer to 90 percent with 66 pounds of applied nitrogen per acre.

388

Lewis, R. D. and R. L. Lang. 1957. Effect of nitrogen on yield of forage of eight grasses grown in high altitude meadows of Wyoming. Agron. J. 49:332-335.

Yield of common, Lincoln, and Manchar bromegrass; orchardgrass; timothy; intermediate wheatgrass; meadow foxtail; and reed canarygrass was increased by nitrogen application.

389

MacConnell, W. P. and D. L. Mader. 1969. Turf: The risky years are after six. Ski Area Manage. 8(2):34-35.

Yield of grasses on Massachusetts ski slopes increased with nitrogen but not phosphorus or potassium application.

390

Marr, J. W., D. L. Buckner, and D. L. Johnson. 1974. Ecological modification of alpine tundra by pipeline construction. pp. 10-23 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent., Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Describes a program to rehabilitate a short pipeline route in Colorado alpine. Alpine turf was carefully removed, preserved, and replaced in its original position along the route and vehicular traffic was minimized. Replaced turf should be level with or slightly depressed from surrounding surfaces. Pocket gopher activity reduced rehabilitation. Includes an anlaysis of the reaction of several plant species to this disturbance.

391

McGinnies, W. J., D. F. Hervey, J. A. Downs, and A. C. Everson. 1963. A summary of range grass seeding trials in Colorado. Agric. Exp. Stn., Colo. State Univ., Tech. Bull. 73. 81p.

A large number of native and introduced grasses are evaluated for their ability to establish and persist on particular range sites from plains uplands to high mountain grasslands. Species which provide initial establishment but die out can be distinguished. Seed source and ecotype differences are observed. Smooth brome, meadow foxtail, slender wheatgrass, red fescue, timothy, Thurber's fescue, Kentucky bluegrass are recommended for high mountain grassland reseeding.

392

McKell, C. M. 1972. Seedling vigor and seedling establishment, pp. 74-89 in V. B. Youngner and C. M. McKell (ed.). The biology and utilization of grasses. Academic Press. New York.

Seedling vigor has been variously defined but usually refers to rate of size increase. It is a function of several factors including seed size, germination rate, seed age, growth rate, root development rate, and resistance to unfavorable conditions. Vigor can be increased by genetic selection, treatment with growth regulation, and fertilization. Vigorous seedlings, reduced competition, and a favorable environment are prerequisites for successful establishment. Bibliography.

393

McQuilkin, W. E. 1949. Direct seeding of trees. pp. 136-146 in USDA, Trees--The yearbook of agriculture, 1949. U.S. Government Printing Office, Washington.

Advantages and obstacles to direct seeding as opposed to transplanting, principles, and recommended general techniques. Rodents are a major problem in the western states.

394

Medin, Dean E. and R. B. Ferguson. 1971. Shrub establishment on game ranges in the northwestern United States, pp. 359-368 in McKell, C. M., et al. (ed.) Wildland shrubs--their biology and utilization. USDA For. Serv. Gen. Tech. Report INT-1.

General recommendations pertinent to establishment of shrub species on range sites includes causes of mortality, site evaluation, selection of species, site preparation, planting techniques, and management of newly established stands.

395

Meiman, J. R. 1974. Water and erosion control in relation to revegetation of high-altitude disturbed lands. pp. 24-30 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

A review of water and erosion control at high elevations by vegetation and other techniques such as mulching, diversion structures, contour trenching and furrowing, channel stabilization, etc. Each site has its own peculiar set of requirements and planning must be coordinated with careful observation.

396

Merkel, D. L. and W. F. Currier. 1973. Critical area stabilization in New Mexico. Critical area stabilization workshop. Report No. 7. Sponsored by New Mexico Interagency Range Committee. USDA, ARS. Las Cruces.

Recommendations for evaluation and treatment of disturbed sites include resource inventory, design, plant materials, seeding methods, mulching and fertilizing, and establishment and maintenance. This is a source of general information pertinent to critical area stabilization. Bibliography.

397

Nelson, J. R., A. M. Wilson, and C. J. Goebel. 1970. Factors influencing broadcast seeding in bunchgrass range. J. Range Manage. 23:163-170.

Broadcast seeding on steep or rocky areas exposes seeds to depredation by rodents and birds and environmental fluctuations. Big bluegrass produced the best stands on these eastern Washington sites.

398

Ohlander, C. A. 1964. Effects of rehabilitation treatments on the sediment production of granitic road materials. M.Sc. Thesis. Colo. State Univ., Fort Collins.

Asphalt-straw, Erosionet, chipped slash, and surface holes were tested in conjunction with seeding for road slope stabilization in areas typical of southern and central Idaho. Asphalt straw and Erosionet retarded erosion more than the other treatments and vegetation production was greatest with Erosionet.

399

Packer, P. E. 1967. Criteria for designing and locating logging roads to control sediment. For. Sci. 13:2-18.

Logging roads, especially those which infringe on natural drainage channels, have steep gradients, or lack drainage facilities, are the major contributor to stream channel sediment from forest lands. Erosion of road surfaces is most affected by road grade or steepness and can be reduced by minimizing steepness. Erosion is also affected by percentage of soil aggregates over 2 mm in diameter and can be reduced by graveling, etc. Erosion is greater on south than north facing slopes. A table of recommended distances between cross drains per road grade and substrate type is included. The distance that sediment is transported downslope is most affected by obstruction spacing and kind of obstruction (logs, rocks, brush, etc.), but is also affected by cross drain spacing, distance to first obstruction, road age, and density of plant cover.

400

Peterson, R. A. 1952. Forage plants in a Montana high altitude nursery. J. Range Manage. 6:240-247.

Of 40 plant species seeded on sites typical of Montana subalpine grasslands, all produced fair to excellent seedling stands but only eight species maintained or increased their stands over a ten year period: common and parkland strains of smooth brome, meadow foxtail, meadow brome, Kentucky bluegrass, slender wheatgrass and bearded wheatgrass. First four species are most reliable for reseeding high mountain ranges.

401

Pieper, R. D. 1971. Selection of fertilizer formulations: time and rate of application for establishment and maintenance. pp. 162-173 in W. F. Currier and D. L. Merkel. Proceedings critical area stabilization workshop. Rpt. 7A. N.M. Interagency Range Comm. USDA ARS. Las Cruces.

Reviews several previous studies on fertilization of range and highway right-of-ways. Nitrogen is most limiting for revegetation but phosphorus may be critical for seedling establishment. Optimal application rates vary per site and effectiveness is often subject to soil moisture.

402

Plummer, A. P., D. R. Christensen, and S. B. Monsen. 1968. Restoring big game range in Utah. Utah State Dep. Nat. Resour., Div. Fish Game Publ. No. 68-3. 183p.

Summarizes results of research by Utah Division of Fish and Game and the Intermountain Forest and Range Experiment Station to improve range productivity and find plant species adapted to various sites. Over 400 species have been tested including many shrubs and forbs. Discusses planting techniques and restoration principles and provides a list of adapted species for each of 12 vegetation types from juniper-pinyon to subalpine herblands. Pertinent characteristics of major species as well as viability of native stored seed are described. Recommends a mixture of the following species for subalpine herblands and aspen openings: smooth brome, intermediate wheatgrass, meadow foxtail, subalpine brome, orchardgrass, mountain brome, reed canarygrass, alfalfa, mountain lupine, common cowparsnip, sweetanise, chickpea milkvetch, mountain snowberry, and yellowbrush in addition to other supplementary species. Bibliography.

403

Plummer, A. P., D. R. Christensen, R. Stevens, and K. R. Jorgensen. 1970. Highlights, results and accomplishments of game range restoration studies. Utah State Dep. Nat. Resour., Div. Fish Game Publ. No. 70-3.

Reviews research efforts by Utah Division of Fish and Game and Intermountain Forest and Range Exp. Station on game range restoration. Most research conducted at elevations below 8,000 feet in juniper-pinyon type but includes some information pertinent to higher elevation projects especially on shrubs: shrub seed production and collection; germination characteristics of several grass, forb, and shrub species; site preparation equipment (scalper and dribbler); and techniques of protecting plants from small mammals.

404

Plummer, A. P. and J. M. Fenley. 1950. Seasonal periods for planting grasses in the subalpine zone of central Utah. Interm. For. Range Exp. Stn. Res. Paper 18, 12p.

Late spring and early summer are the best times for seeding at elevations over 10,000 feet. Of six grasses tested, slender wheatgrass, mountain brome, and smooth brome had the highest survival percentages. Poorer establishment in fall than spring related to winterkilling and frost heaving.

405

Plummer, A. P., A. C. Hull, Jr., G. Stewart, and J. H. Robertson. 1955. Seeding rangeland in Utah, Nevada, southern Idaho, and western Wyoming. USDA Handbook 71.

General recommendations for seeding rangeland include: 1. removal of competition, 2. methods of seeding, 3. time of seeding, 4. species for seeding (recommends mixtures) including grasses, legumes, forbs, and shrubs. Includes a seeding guide for specific vegetation types. A mixture of smooth brome, mountain brome, tall oatgrass, orchardgrass, cicer milkvetch, mountain lupine and others recommended for subalpine.

406

Plummer, A. P. and G. Stewart. 1944. Seeding grass on deteriorated aspen range. USDA For. Serv. INT For. Range Exp. Stn. Res. Paper 11. 6p.

Broadcast seeding near the time of leaf fall with bearded wheatgrass, slender wheatgrass, tall oatgrass, mountain bromegrass, smooth bromegrass, blue wildrye, orchardgrass, and timothy produced successful stands under aspen cover in Utah. Seed need not be covered. Six other species were also tested but judged less well adapted for reseeding.

407

de Quervain, M. R. and H. R. in der Gard. 1967. Distribution of snow deposit in a test area for alpine reforestation. pp. 233-239 in W. E. Sopper and H. W. Lull (eds.) Forest Hydrology. Pergamon Press. New York.

Reforestation attempts near timberline in the Swiss Alps is affected by snow deposition and avalanche activity.

408

Range Seeding Equipment Committee, USDA, USDI. 1965. Range seeding equipment handbook. USDA For. Serv. Handbook 2244.01.

Description, advantages, limitations, etc. of revegetation equipment including site preparation, brush burnind, spraying, seeding, and seed covering equipment.

409

Range Seeding Equipment Committee, USDA. 1974. Range seeding equipment committee history 1946-1973. USDA For. Serv. U. S. Govt. Printing Office 1973-799-635/47.

Description and history of equipment developed by the projects of this committee. Includes the rangeland drill, browse seeder, and seed dribbler for attachment on tracked tractors.

410

Roe, A. L., R. R. Alexander, and M. S. Andrews. 1970. Engelmann spruce regeneration practices in the Rocky Mountains. USDA For. Serv. Prod. Res. Paper 115.

Summarizes pertinent information on the requirements and limitations for establishment of Engelmann spruce reproduction and recommended procedures for regeneration (both natural and artificial) on cutover areas.

411

Ronco, F. 1967. Lessons from artificial regeneration studies in a cutover beetle-killed spruce stand in western Colorado. USDA For. Serv. Res. Note RM-90.

Success of artificial regeneration of spruce forests is dependent on many factors including mulching, frost heaving, damping-off fungi, shade, pocket gophers, and frost.

412

Ronco, Frank. 1970. Influence of high light intensity on survival of planted Engelmann spruce. For. Sci. 16:331-339.

High mortality rates of unshaded spruce seedlings planted above 10,000 feet in Colorado may be associated with solarization. Photosynthesis of spruce seedlings was higher in the shade than the open and light intensities for maximum photosynthesis were much lower than those for lodgepole pine seedlings.

413

Ronco, Frank. 1970. Shading and other factors affect survival of planted Engelmann spruce seedlings in central Rocky Mountains. USDA For. Serv. Res. Note RM-163.

Most mortality after planting resulted from light injury but frost and especially gopher losses were high during some years. Includes recommendations to increase survival of planted spruce.

414

Ronco, F. 1972. Planting Engelmann spruce. USDA For. Serv. Res. Paper RM-89.

Guidelines and recommendations for selection of planting stock, planting season, seedling storage, planting site selection, site preparation, planting, and plantation protection. Emphasis must be placed on getting maximum survival rather than getting seedlings in ground at lowest cost.

415

Rudolph, P. O. 1949. First the seed, then the tree. pp. 127-135 in USDA, Trees- the yearbook of agriculture, 1949. U.S. Govt. Printing Office, Washington.

Some general principles regarding tree seed production and collection, storage, cleaning, germination pre-treatments, seed viability, and source variability. Only seed from local origin or of proven local adaptability should be used.

416

Rummell, R. S. and C. E. Holscher. 1955. Seeding summer ranges in eastern Oregon. USDA Farmer's Bull. 2091. 34p.

General guidelines for range reseeding and specific recommendations for particular range types from sagebrush to subalpine. Timothy, orchardgrass, mountain brome and pubescent wheatgrass show promise for subalpine meadows while these and other grasses are recommended for logged and burned areas.

417

Schramm, J. R. 1966. Plant colonization studies on black wastes from anthracite mining in Pennsylvania. Tras. Am. Philos. Soc. 56:1-194.

Most general deterrent to colonization is high surface temperatures. Only nitrogen fixing plants and certain ectotrophically microbial species were successful.

418

Simonson, J. L. 1966. Survival and growth of planted pines. M.Sc. Thesis, Colorado State Univ., Fort Collins. 178p.

To determine the relationship of certain environmental factors to survival of planted lodgepole and ponderosa pine seedlings, 300 seedlings of each species were planted at five locations ranging from 8200 to 9200 feet elevation. Microclimate was measured at each plot. Survival of lodgepole pine seedlings was significantly greater on north than south facing slopes and was positively correlated to maximum air temperature and elevation and inversely correlated to evaporation rates and wind speed.

419

Smith, D. R. 1958. The effect of nitrogenous fertilizers on cattle distribution on mountain range. J. Range Manage. 11:248-249.

Urea application to sites normally utilized only lightly by cattle increased their utilization and thus counteracted the tendency for cattle to congregate in limited areas.

420

Smith, J. G. 1963. A subalpine grassland seeding trial. J. Range Manage. 16:208-210.

After 8 growing seasons at 5,700 feet in north central Washington, timothy, pubescent wheatgrass, orchardgrass, blue wildrye, big bluegrass, meadow brome, and slender wheatgrass were rated excellent or good for seeding subalpine areas. Most legumes failed although flat peavine, birdsfoot trefoil, and bramble vetch established stands.

421

Springfield, H. W. 1971. Selection and limitations of mulching materials for stabilizing critical areas. pp. 128-161 in W. F. Currier and D. L. Merkel. Proceedings Critical Area Stabilization Workshop. Report 7A. N. M. Interagency Range Comm. USDA, ARS. Las Cruces.

Advantages and disadvantages of crop residues; wood residues; petroleum products; latex emulsions; plastic films; and gravel, stones and other materials. Straw and white petroleum resin were most effective for summer seeding near Santa Fe. Bibliography.

422

Streeby, L. 1971. Buffer strips--some considerations in the decision to leave. pp. 194-198 in J. T. Krygier and J. D. Hall (symposium directors). Forest land uses and stream environment. Contin. Educ. Publ., Oreg. State Univ., Corvallis.

Buffer strips along streams in disturbed areas are not equally useful under all conditions and areas and do not represent a cure-all for the forest stream environment.

423

Stroh, J. R., A. E. Carleton, and W. J. Seamands. 1972. Management of Lutana cicer milkvetch for hay, pasture, seed, and conservation uses. Mont. Agric. Exp. Stn., Mont. State Univ. Bull. 666. 17p.

Lutana variety of cicer milkvetch does well on all soil textures, infertile soils, and slightly acid to moderately alkaline sites. It is relatively frost tolerant, competitive, less attractive to wildlife than alfalfa, and rapid growing. Its principal range of adaptation is in Rocky Mountains.

424

Swanson, N. P., A. R. Dedrick, and A. E. Dudeck. 1967. Protecting steep construction slopes against water erosion. Highw. Res. Rec. 206:46-52.

Of 13 mulch treatments tested to control erosion with simulated rainfall in Nebraska, the best were jute netting, wood excelsior mat, prairie hay, and fiberglass anchored with asphalt emulsion.

425

Thirgood, J. V. 1969. Land disturbance and revegetation in Canada. Can. Min. J. Dec. 1969. pp. 3-7.

A general review of land disturbance and revegetation activities in Canada with emphasis on mining. Specific examples illustrate trends.

426

Tiedemann, A. R. and G. O. Klock. 1973. First-year vegetation after fire, reseeding, and fertilization on the Entiat Experimental Forest. USDA For. Serv. Res. Note PNW-195.

Seeding after a wildfire in this Washington forest increased vegetation cover by up to one-third. Orchard grass, hard fescue, and timothy provided most of the cover. First year effectiveness of fertilizer is questionable.

427

Townsend, C. E. 1963. Performance of red clover varieties under irrigation in the high altitude meadows of Colorado. Colo. Agric. Exp. Stn. Bull. 515-S. 13p.

Marked differences in persistance were found among the 55 varieties tested at three sites from 6,300 to 9,500 feet. Late flowering type persisted well at all locations and some of the naturalized Swedish varieties performed well at high altitudes.

428

Townsend, C. E. 1974. Legume selection and breeding research in Colorado. pp. 36-38 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent.,Inf. Ser. No. 10, Colorado State Univ., Fort Collins.

Briefly reviews some of the research conducted by the Agricultural Research Service and Colorado State University Experiment Station on legumes for seeding mountain meadows. Native alpine dwarf clovers do not show promise for rehabilitation.

429

Townsend, C. E., A. D. Dotzenko, K. R. Storer, and F. E. Edlin. 1968. Response of zigzag clover genotypes to management practices. Can. J. Plant Sci. 48:273-279.

Zigzag clover is a long lived perennial with strong rhizomes native to mountains of Europe. Significant differences are noted among genotypes in yield, spread, flowering, etc. Proposed that it be used in conjunction with other legumes for meadow improvement.

430

USDA Forest Service. 1974. Seeds of woody plants in the United States. USDA Agriculture Handbook No. 450. 883p.

Part I of this handbook includes several chapters on seed biology and methods of producing and handling seeds. Topics include factors affecting seed production; seed germination and dormancy; within species genetic variation; principles and methods of genetic improvement of seeds; pollen handling; harvesting, processing, and storage of fruits and seeds; presowing treatment to speed germination; seed testing; and tree seed marketing controls. Part II is a compilation of specific data on seeds of 188 genera of woody plants. Information is presented on flowering and fruiting, collection and storage of seeds, pregermination treatments, germination tests, and planting recommendations. Each chapter of both parts includes a bibliography. This handbook supersedes the Woody plant seed manual (USDA For. Serv. 1948. Woody plant seed manual. USDA Misc. Publ. 654. 416p).

431

USDA Forest Service. 1959. Land treatment measures handbook. USDA For. Serv. Category 2 Handbook 2523. 124p.

General recommendations for treatment of Forest Service land disturbed by logging, fire, grazing, road and trail construction, mining, rights-of-way and firebreaks. Also includes recommendations for seeding depleted watersheds, building contour trenches and pits, road slope stabilization, etc.

432

U. S. Environmental Protection Agency. 1973. Processes, procedures, and methods to control pollution from mining activities. EPA-430/9-73-011. U.S. Govt. Printing Office. Washington, D. C. 390p.

This "general overview of available pollution control techniques" includes brief sections on water infiltration control, waste water control, handling pollutants, regrading, revegetation, mine sealing and treatment of mine drainage. Bibliography.

433

USDA Forest Service. 1973. Soil survey, a tool for planning and revegetation on ski slopes. Soils Report. Div. of Watershed Manage., Region 2, Denver. 23p.

Instructions for determining a soil erodibility index (from data on percent silt, percent sand, organic matter content, structure, and permeability) for mountainous areas and recommendations for vegetation establishment on ski slopes of the Rockies. These recommendations include seedbed preparation, fertilization, seeding (including recommended species) mulching, weed control, watering, etc. A section on revegetation of alpine areas is also included; seeding in the alpine has generally not proven practical and removed topsoil and turf should be preserved and carefully replaced.

434

U. S. Soil Conservation Service. 1966. Stabilizing disturbed areas. Range Improv. Notes 11:7-12.

Descriptions, adaptations, and use of Sodar wheatgrass, Fairway wheatgrass, and Durar hard fescue. Durar is adapted to wide range of conditions in areas of over 12 inches precipitation and does well on low fertility soil.

435

Wagar, J. A. 1965. Cultural treatment of vegetation on recreation areas. Proc. Soc. Am. For. 1965:37-39.

Reports results of watering and fertilizing a Utah campground in aspen, lodgepole pine, and Douglas fir forest at 8,000 feet elevation. Watering increased tree growth but not ground cover while fertilizers (nitrogen and phosphate) increased ground cover but not tree growth.

436

Watson, A., N. Bayfield, and S. Moyes. 1970. Research on human pressures on Scottish mountain tundra, soils, and animals. pp. 256-266 in W. A. Fuller and P. G. Kevan (eds.). Productivity and conservation in northern circumpolar lands. Int. Union Conserv. Nature and Natural Resources (new ser.) No. 16. Morges, Switzerland.

Describes the detrimental effect of human trampling and efforts at rehabilitation at a Scottish ski area. Satisfactory plant cover has been established by seeding 5 grasses with lime, fertilizer, and mulch. Natural vegetation establishment is also briefly described.

437

Welin, C. 1974. Cultural problems and approaches in a ski area. pp. 64-70 in Revegetation of high-altitude disturbed lands. Environ. Resour. Cent. Inf. Ser. No. 10, Colo. State Univ., Fort Collins.

Revegetation efforts at the Vail, Colorado, ski area begin immediately after final grading. Fertilizer and seed broadcasting is followed by raking and mulching (2 tons/acre wheat straw). A mixture of various grasses and clover is recommended depending upon elevation. Winter wheat provides a good cover crop. Parabolic waterbars protect the slope against spring runoff.

438

White, D. P. 1965. Survival, growth, and nutrient uptake by spruce and pine seedlings as affected by slow-release fertilizer materials. pp. 47-63 in C. T. Youngberg (ed.). Forest-soil relationships in North America. Oregon State Univ. Press, Corvallis.

Four pine species and white spruce, planted on humus-free and nutrient deficient soils of northern Michigan, were tested for survival, growth, and nutrient uptake with various fertilizer treatments. Fertilizer placed close to roots must be slow releasing. A slow and safe release of soluble fertilizers was provided by use of a perforated sack in direct contact with tree roots. Prepotting with a slow release fertilizer improved survival on adverse sites.

439

Wilson, A. M. 1973. Responses of crested wheatgrass seeds to environment. J. Range Manage. 26:43-46.

The ability of crested wheatgrass seed to germinate at low temperatures and intermittent drought favors establishment on harsh sites. Exposure to favorable moisture conditions and low temperatures hastens subsequent germination.

440

Wilson, A. M., D. E. Wondercheck, and C. J. Goebel. 1974. Response of range grass seeds to winter environments. J. Range Manage. 27:120-122.

Exposure of seeds to five weeks of winter conditions at 1600 feet elevation near Pullman, Washington, had little effect on germination percentages of crested wheatgrass and Siberian wheatgrass but reduced germination of bluebunch wheatgrass, medusahead, smooth brome, and cheatgrass.

441

Wood, G. M., P. Winkelaar, and J. J. Lindsay. 1973. Guide to Vermont ski trail construction and management. Univ. Vermont, Agric. Exp. Stn. Pam. 39. 25p.

Recommendations for slope construction, liming and fertilizing, seeding and seeding mixtures, mulching, and maintenance.

See also 9, 17, 23, 98, 104, 106, 114, 122, 124, 132, 133, 156, 171, 241, 260, 262, 267, 281, 283, 298, 299, 302, 453, 455.

SECTION VII

BIBLIOGRAPHIES

442

Anderson, E. W. and R. W. Harris. 1973. References on grazing resources of the Pacific Northwest. Society for Range Management, Pacific Northwest Section. USDA, SCS, Portland, Ore. 103p.

Includes approximately 700 nonannotated references in four categories: grazing resources; geology, climate, and soils of Pacific Northwest; plant identification publication; and special publications. Not indexed.

443

Barney, C. W. and R. E. Dils. 1972. Bibliography of clearcutting in western forests. Coll. For. Nat. Res., Colo. State Univ., Fort Collins. 65p.

Several hundred nonannotated citations to literature primarily on the ecological and political aspects of clearcutting.

444

Christensen, E. M. and M. J. Hunt. 1965. A bibliography of Engelmann spruce. USDA For. Serv. Res. Paper INT-19.

A briefly annotated bibliography concerned principally with the ecology of spruce and thus supplement Ronco's bibliography on management.

445

Cold Regions Bibliography Section, Library of Congress. Bibliography on Cold Regions Science and Technology. U. S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory.

Comprehensive bibliographies of international scientific literature released annually and dealing with all types of research in cold regions of the world. Many citations especially from U. S. publications are abstracted and author and extensive subject indices are included. Index headings of special interest include "alpine soils," "alpine vegetation," "conservation," etc. This is a good source to literature from areas outside the U. S.

446

DeByle, N. V. and E. Hookans, Jr. 1973. Research related to the Davis County Experimental Watershed: An annotated bibliography. USDA For. Serv. Gen. Tech. Report INT-4.

A bibliography of research conducted at this important watershed experimental forest near Farmington, Utah. Includes 87 articles on climate, soils, infiltration and erosion, erosion control, streamflow, etc.

447

Gibbons, D. R. and E. O. Salo. 1973. An annotated bibliography of the effects of logging on fish of the western United States and Canada. USDA For. Serv., Gen Tech. Report PNW-10.

Includes over 300 references on subjects such as erosion and sedimentation, water quality, influences on salmonids, stream protection, multiple use management, stream improvement, etc. Includes a literature review and author and subject indices.

448

Hoffman, G. R. and G. J. Tomlinson. 1966. A bibliography of vegetational studies of Colorado. Southwest. Nat. 11:228-237.

A list of nearly 200 nonannotated, nonindexed references to studies of natural vegetation in Colorado. Contains reference to many early works.

449

Peterson, H. B. and R. Monk. 1967. Vegetation and metal toxicity in relation to mine and mill wastes. An annotated bibliography useful in evaluating available literature. Utah State Univ. (Logan) Utah Agricultural Exp. Stn. Circular 148. Sept. 1967.

Annotated bibliography of 167 references. Is not segregated into topic sections but contains an author and subject index. Primary emphasis on effects of toxic substances on plant growth.

450

Roberts-Pichette, P. 1972. Annotated bibliography of permafrost-vegetation-wildlife-landform relationships. Can. Dept. Envir., For. Manage. Inst., Inf. Rep. FMR-X-43. 350p.

Nearly 500 annotated references from North American, European, and Russian literature concerned chiefly with disturbance resulting from man's activities and reclamation in arctic lands. A subject index includes the following major headings: arctic general; climate and meteorology; animal ecology; plant ecology; fire; floras; geography, geology, and geomorphology; lichens; man-made changes; oil, pipelines, etc.; permafrost; photogrammetry, surveying, and mapping; plant growth and physiology; and soils.

451

Ronco, F. 1961. Bibliography of Engelmann spruce and subalpine fir. USDA For. Serv. Rocky Mt. For Range Exp. Sta., Res. Paper 57. 58p.

Over 500 references on management aspects of these two forest species with a subject index.

452

Shoup, J. M., L. D. Nairn, and R. H. M. Pratt. 1968. Trembling aspen bibliography. Canada Dept. Forestry and Rural Develop., For. Res. Lab. Liaison and Services Note MS-L-3.

An essentially complete bibliography of trembling aspen through 1966 incorporating approximately 900 references. A subject index is included.

453

Smithberg, M. A. and D. B. White. 1971. Methods and materials for the maintenance of turf on highway rights-of-way. An annotated bibliography. Univ. Minn. Agric. Exp. Stn. Misc. Report 105. 102p.

A well annotated cross referenced bibliography including sections on use of native plants, fertilizers, diseases, erosion control and mulches, salt and alkali problems, etc.

454

Stankey, G. H. and D. W. Lime. 1973. Recreational carrying capacity: An annotated bibliography. USDA For. Serv., Gen. Tech. Report INT-3.

Over 200 annotated references on ecological and social aspects: the concept of carrying capacity; effects on vegetation, soils, water, and wildlife; esthetic resources; and management for carrying capacity. Author index.

455

Stein, W. I. 1964. Selected 1964 publications on reforestation. Western reforestation. Proceedings of the 1964 meeting of Western Reforestation Coordinating Committee. Western Forestry and Conservation Assoc. (Amer. Bank Bldg., Portland, Oregon 97205).

An alphabetical listing by author of literature pertinent to reforestation in the western United States and Canada. This listing is brought up to date through at least the 1971 issue. Not categorized.

456

Tennessee Valley Authority. 1969. Effects of fertilizers on water quality. National Fertilizer Development Center, T.V.A., Muscle Shoals, Alabama.

An annotated and indexed bibliography to several hundred literature sources dealing with "fertilization of agricultural lands and chemical composition of surface and ground waters." Includes literature on natural nutrient cycles; regional water balances; climatic, vegetative, soil, topographic and other factors which affect water movement; and nonwater and water pathways of fertilizer nutrients (volatilization, leaching, microbe fixation, plant uptake, etc.). This bibliography is continued as 1970 supplement to effects of fertilizers on water quality" by the T.V.A. (1971).

457

Vita, S. H. 1971. Pipeline construction in cold regions (excluding the Russian literature). A bibliography. U. S. Dept. Interior Office of Library Services Bibliography Series No. 21.

Over 500 references pertinent especially to arctic pipe line construction and its environmental effects. Includes subject and author index.

458

Weiner, J. and K. Mirke. 1972. Forest fertilization. Institute of Paper Chemistry, Bibliographic Series No. 258. 261p.

A bibliography of several hundred abstracted references to literature concerned with soil fertilization and its effects on tree growth etc. Author and subject indices are included.

COMMON AND BOTANICAL NAMES OF

PLANT SPECIES MENTIONED[1]

Common Name	Botanical Name
Alder, thinleaf	*Alnus tenuifolia* Nutt.
, Sitka	*Alnus sinuata* (Regel) Rydb.
Alfalfa	*Medicago sativa* L.
Aspen, trembling	*Populus tremuloides* Michx.
Avens, alpine	*Geum rossii* (R. Br.) Ser.
Barley	*Hordeum vulgare* L.
Bentgrass	*Agrostis* L.
Birch, dwarf	*Betula nana* L.
Bistort, American	*Polygonum bistortoides* Pursh
Bluegrass, alpine	*Poa alpina* L.
, big	*Poa ampla* Merr.
, Kentucky	*Poa pratensis* L.
Brome, fringed	*Bromus ciliatus* L.
, meadow	*Bromus erectus* Huds
, mountain	*Bromus carinatus* Hook. and Arn.
, smooth	*Bromus inermis* Leyss.
, subalpine	*Bromus tomentellus* Boiss.
Canarygrass, reed	*Phalaris arundinacea* L.
Cheatgrass	*Bromus tectorum* L.
Chess, downy	*Bromus tectorum* L.

[1]Common and Latin plant names are according to Standardized Plant Names (Kelsey, H. P. and W. A. Dayton. 1972. Standardized Plant Names. Second Edition. J. Horace McFarland Co. for American Joint Committee on Horticultural Nomenclature. Harrisburg, Pa.) for all that appear in this manual. For those that do not, Weber's manual (Weber, W. M. 1972. Rocky Mountain Flora. Colorado Associated University Press. Boulder, Colorado) was used as a standard.

Common Name	Botanical Name
Clover, alsike	*Trifolium hybridum* L.
, dwarf	*Trifolium nanum* Torr.
, red	*Trifolium pratense* L.
, whiproot	*Trifolium dasyphyllum* T. and G.
, white	*Trifolium repens* L.
, zigzag	*Trifolium medium* L.
Coneflower, tall	*Rudbeckia laciniata* L.
Cowparsnip, common	*Heracleum lanatum* Michx.
Douglas fir	*Pseudotsuga taxifolia* (Poir) Britt. ex Sudworth
Dryad, Drummond	*Dryas drummondi*
, Mt. Washington	*Dryas octapeta*
Elderberry, red	*Sambucus racemosa*
Fescue, hard	*Festuca ovina duriuscula* (L.) Koch.
, Idaho	*Festuca idahoensis* Elmer
, kings	*Hesperochloa kingii* (S. Wats.) Rydb.
, meadow	*Festuca elatior* L.
, red	*Festuca rubra* L.
, sheep	*Festuca ovina* L.
, tall	*Festuca arundinacea* Vill.
, Thurber	*Festuca thurberi* Vasey
Fir, subalpine	*Abies lasiocarpa* (Hook.) Nutt
Foxtail, creeping	*Alopecurus arundinaceus* Poir.
, meadow	*Alopecurus pratensis* L.
Golden banner	*Thermopsis* R.Br.
Hairgrass, alpine tufted	*Deschampsia caespitosa* (L.) Beauv.
Kobresia	*Kobresia myosuroides* (Vill.) Fiori and Paol.
Lupine, mountain	*Lupinus alpestris* A. Nels. and *Lupinus argenteus* Pursh
Marshmarigold, elkslip	*Caltha leptosepala* DC.
Medusa head	*Elymus caput-medusae* L.
Milkvetch, chickpea	*Astragalus cicer* L.
, cicer	*Astragalus cicer* L.
Needlegrass	*Stipa* L.

Common Name	Botanical Name
Oatgrass, Parry	*Danthonia parryi* Scribn.
, Tualatin	*Arrhenatherum elatius* (L.) Presl.
Oats, domestic	*Avena sativa* L.
Orchardgrass	*Dactylis glomerata* L.
Pasque flower	*Anemone* L.
Peavine, flat	*Lathyrus sylvestris* L.
Pine, limber	*Pinus flexilis* James
, lodgepole	*Pinus contorta latifolia* Engelm
, ponderosa	*Pinus ponderosa* Dougl. ex P. Lawson
Purple fringe	*Phacelia sericea* Hook.
Quackgrass	*Agropyron repens* (L.) Beauv.
Raspberry	*Rubus* L.
Redtop	*Agrostis alba* L.
Ryegrass, Italian	*Lolium multiflorum* Lam.
, perennial	*Lolium perenne* L.
Sagebrush, big	*Artemisia tridentata* Nutt.
Scorpion weed	*Phacelia heterophylla* Pursh
Snowberry, mountain	*Symphoricarpas oreophilus* Gray
Spruce, engelmann	*Picea engelmanni* Parry in Engelm.
Squaw carpet	*Ceanothus prostratus* Benth.
Stone crop	*Sedum* L.
Subclover	*Trifolium subterraneum* L.
Sweet anise	*Osmorhiza occidentalis* (Nutt.) Torr.
Sweet clover	*Melilotus* Juss.
Ticklegrass	*Agrostis scabra* Willd.
Timothy, common	*Phleum pratense* L.
, alpine	*Phleum alpinum* L.
Trefoil, birdsfoot	*Lotus corniculatus* L.
Trisetum, spike	*Trisetum spicatum* (L.) Richt.
Vaccinium	*Vaccinium* L.
Vetch, bramble	*Vicia tenuifolia* Roth
Waxflower	*Jamesia americana* T. and G.

Common Name	Botanical Name
Wheatgrass, bearded	*Agropyron subsecundum* (Link) Hitchc.
, bluebunch	*Agropyron spicatum* (Pursh) Scribn. and Smith
, crested (standard)	*Agropyron desertorum* (Fisch.) Schult.
, crested (Fairway)	*Agropyron cristatum* (L.) Gaertn.
, intermediate	*Agropyron intermedium* (Host) Beauv.
, pubescent	*Agropyron trichophorum* (Link) Richt.
, Siberian	*Agropyron sibiricum* Beauv.
, slender	*Agropyron trachycaulum* (Link) Malte.
, sodar	*Agropyron riparium* Scribn. and Smith
, streambank	*Agropyron riparium* Scribn. and Smith
, thickspike	*Agropyron dasystachyum* (Hook.) Scribn.
, western	*Agropyron smithii* Rydb.
Whortleberry	*Vaccinium* L.
Wildrye, blue	*Elymus glaucus* Buckl.
, Russian	*Elymus junceus* Fisch.
Willow	*Salix* L.
Woodrush, spike	*Luzula spicata* (L.) DC.
Yarrow	*Achillea lanulosa* Nutt.
Yellowbrush	*Chrysothamnus viscidiflorus* (Hook.) Nutt.