LINCOLN COUNTY

BIOMASS UTILIZATION AND MANAGEMENT STUDY

Annotated Bibliography

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INTRODUCTION

This document is an annotated bibliography, prepared for the Lincoln County Regional Development Authority Study for Pinyon-Juniper Uses. The bibliography has been developed to address biomass utilization, technology processes, distribution and estimation, among other topics related to pinyon-juniper. The bibliography was complied from Range Management journals, USDA documents, and personal libraries. The bibliography is divided into the following categories, and alphabetized per category:

- Technology
- Products and Residues
- Direct Combustion
- Gasification
- Distribution
- Biomass Estimation
- Economics
- Silviculture and Harvesting
- Fire
- Wildlife Utilization
- Ecology
- Miscellaneous Topics

TECHNOLOGY

Barlow, J. and G. Tomberlin. 1994. Biomass fuel combustion with inclined fluidized bed technology. In: Proceedings, Bioenergy 1994, the Sixth National Bioenergy Conference. Reno-Sparks, NV. 1994 October 2-6. Western Regional Biomass Energy Program. U.S. Department of Energy. Denver, CO. p. 161-68.

Abstract: Biomass combustion in small-scale units has been limited because of economics of scale and low combustion efficiency. Improved agitation of fuel during combustion and improved combustion control using the inclined fluidized bed suggests that unit sizes as low as 10 million BTU per hour are feasible. Acceptable emission rates of NOx and CO have been attained in the small units.

Bergman, R. and J. Zerbe. 2001. Primer on wood biomass and energy. USDA Forest Service Technology Marketing Unit, Forest Products Laboratory.

Abstract: This report explains the advantages of biomass fuels and the importance of life cycle costing. The report covers micro-, small-, medium- and large-scale units.

Bioenergy Update. June 2000. New modular biopower system. General Bioenergy, Florence, AL.

Abstract: U.S. DOE funding made it possible to develop a modular power unit that is practical as a stand-alone power source or as a distributive power generator connected to the grid. This system uses fluidized bed combustion with a transfer coil and flash evaporator to eliminate the need for a boiler. The generator is driven by a simple steam engine, which reduces maintenance costs.

Bioenergy Update. May 2003. Brelsford Engineering Inc. develops improved dilute acid cellulose hydrolysis processes for "Ethanol from Cellulose." General Bioenergy, Florence, AL.

Abstract: A new, two-stage process to convert cellulose and hemicellulose into monosaccharides. Fermentation is used to convert the sugars into fuel alcohol. The process has been proven on softwoods with lignin as residue. Brelsford will work with Genahol, the licensee of the process, to establish local conversion facilities.

Bridgewater, T. PhD. and C. Peacocke, PhD. 1995. Biomass fast pyrolysis. In: Proceedings, Second Biomass Conference of the Americas. Portland, OR. 1995 August 21-24. p. 1037-46.

Abstract: The article provides an overview of the process and organizations involved in research and development of fast pyrolysis conversion systems.

Castleman, J.M., C. Gottschalk, and R.Q. Vincent. 1994. Fluidized bed combustion and gasification: a guide for biomass waste generators. In: Proceedings, Bioenergy 1994, the Sixth National Bioenergy Conference. Reno-Sparks, NV. 1994 October 2-6. Western Regional Biomass Energy Program. U.S. Department of Energy. Denver, CO. p. 673-80.

Abstract: This guide stresses the importance of matching the biomass resource to a suitable conversion technology. Physical state, moisture content, ash analysis, combustion temperature, and the type of products desired all influence the choice of technology.

Ferris, Joyce M. 1996. Fuel and operating flexibility demonstrated by three fluidized bed agricultural waste fired projects in California. In: Proceedings, Bioenergy 1996, the Seventh National Bioenergy Conference. Nashville, TN. 1996 September 15-19. Southeastern Regional Biomass Energy Program, Tennessee Valley Authority, Muscle Shoals, AL. p. 409-14.
Abstract: This article is based on case studies of three operating plants. Flexible operation demands a tolerance of a wide spectrum of biomass fuels without significant loss of efficiency.

Graham, Robert G., B. Freel, and D. Kravetz. 1996. The commercial conversion of wood to liquids via RTP® for fuel, chemical and power applications. In: Proceedings, Bioenergy 1996, the Seventh National Bioenergy Conference. Nashville, TN. 1996 September 15-19. Southeastern Regional Biomass Energy Program, Tennessee Valley Authority, Muscle Shoals, AL. p. 590-97.
Abstract: Ensyn Technologies, Greeley, Ontario Canada, has four operating plants in the United States and Canada. Their technology has been established and proven. Biomass is converted to a liquid in a fluidized bed with rapid heating and cooling. High value chemicals (smoke flavoring and hydroxyacetaldehyde) can be extracted and the remainder used as boiler fuel. Ensyn retains ownership of the processing equipment. They will lease to developers who can show economic viability.

Sanders, C.F., C.R. Purvis, and P.A. Bray. 1994. Demonstration of a 200-kilowatt biomass fueled power plant. In: Proceedings, Bioenergy 1994, the Sixth National Bioenergy Conference. Reno-Sparks, NV. 1994 October 2-6. Western Regional Biomass Energy Program. U.S. Department of Energy, Denver, CO. p. 521-28.
Abstract: Fluidized bed combustion provides energy to drive air compressors that force air through heat exchangers, that in turn drive the generator. Energeo, through funding from EPA, DOD, DOE and others propose this 200kw unit as a basic system for use in the developing world. Estimates show that 200kw can supply power to a community of 300 people.

U.S. Department of Energy. 1981. Western sun biomass energy cogeneration.
Abstract: This report includes case studies of 13 industries benefiting from cogeneration. Cogeneration is an excellent option for developments that require both power and thermal energy.

PRODUCTS AND RESIDUES

Barger, R.L. and P.F. Ffolliot. 1972. Physical characteristics and utilization of major woodland tree species in Arizona. Research paper RM-83. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station Ogden, UT. 79 p.
Abstract: Woodland species, principally pinyon and juniper, cover over 51 million acres in Arizona and adjoining states. The occurrence, physical characteristics, and utilization potential of pinyon, juniper, and Gambel oak are reported here. Products for which they may be especially suited include veneer, particleboards, charcoal, pulp and chemical extractives. In addition, pinyon is valuable for Christmas trees and nuts. The report is a reference handbook of all available information relating to stand and stocking characteristics and physical and chemical properties of the species.

Bioenergy Update. June 2002. Faswall® wood concrete. General Bioenergy, Florence, AL.
Abstract: Describes the combination of “pin chips” and Portland cement into a durable, fire- resistant, vermin-resistant building block suitable for commercial and residential structure construction. The company has an operating plant near Little Rock, Arkansas. Residential and commercial buildings have been erected in North Carolina, Texas and New Mexico, demonstrating that the building system is suitable for a variety of climates.

Bioenergy Update. 2000. New biomass refinery piloted. General Bioenergy, Florence, AL.
Abstract: Changing World Technologies is operating a 15-ton per day pilot plant at the Philadelphia Naval Shipyard. The system depolymerizes and separates products into gases, fluids and solids with heat recovery as a by-product. Wet feedstocks are acceptable, and there is no drying requirement.

Bristol, D., D.J. Noel, B. O’Brien, and B. Parker. 1993. Biomass ash utilization. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 736-41
Abstract: With careful analysis of the ash from burning biomass, most of the ash can serve a useful purpose. Currently, wood ash is returned to the harvest area and applied to the soil. Other uses include a treatment to deodorize sewage sludge; use as a component of landfill leachate treatments; and use as an additive for composting. The beneficial use of ash is environmentally and socially sound, and can be financially attractive.

Chum, H.L. 1993. Chemicals and products from biomass conversion: an overview. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 1201-11.

Abstract: Biomass can provide many products used in commerce and industry. Proper management results in a reliable, sustainable biomass resource that will become more important as petroleum resources are exhausted

Fitzpatrick, S.W. 1993. The thermochemical conversion of cellulosic biomass to high value chemicals and fuel additives. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 1385-1408.
Abstract: Conversion of cellulose and hemicellulose into levulinic acid, formic acid, and furfural can be performed on a continuous basis. The products are commodity chemicals with great potential of converting levulinic acid into environmentally acceptable pesticides and fuel additives. Small units are modular, making it possible to develop economically viable facilities in rural communities.

Ffolliot, P, F., G.J. Gottfried, and W.H. Kruse. 1999. Past, present, and potential utilization of pinyon-juniper species. In: Monsen, Stephen B.; Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18; Provo, UT. USDA, Forest Service, Rocky Mountain Research Station, Ogden, UT. Proc. RMRS-P-9. p. 254-259.
Abstract: Pinyon-juniper species in the Interior West are a sizeable wood fiber resource for products that can be made from smaller, irregular stems, and those that capitalize on the unique physical and chemical characteristics of the species. However, large-scale utilization of these species is largely influenced by management programs implemented to improve the range condition, hydrologic behavior, and wildlife habitat conditions of the woodlands. The past, present, and potential utilization of pinyon-juniper species is presented in this paper, specifically solid wood, chemical, and specialty pinyon products.

Himmelblau, D.A. 1995. Phenol-formaldehyde resin substitutes from biomass tars. In: Proceedings, Second Biomass Conference of the Americas. Portland, OR. 1995 August 21-24. p. 1141-50.
Abstract: Approximately 320,000 tons of phenol-formaldehyde was used in 1992 by forest industries in North America. An air fluidized single bed reactor can be used to produce tars that can substitute for a major portion of the phenol-formaldehyde resins used to make exterior-grade plywood, OSB and particle board. Testing of sample boards using the substitute resins was carried out at Louisiana State University. Adhesive properties of the substitute resins were satisfactory.

Jagtoyeu, M., and F. Derbyshire. 1993. Wood as feedstock for activated carbons. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 1292-95.
Abstract: Activated carbons are employed over a broad range of applications, including the improvement of air and water quality. This paper explains the search

for explanations of the different qualities of biomass resulting in varied levels of effectiveness of all manner of biomass resources.

Joyner, H.S., B.M. Vaughan, D.H. White, and D. Wolf. 1993. MSW and biomass to liquid fuels by packaged liquefaction plants. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 964-78.
Abstract: Binder to process coal fines and finely divided biomass into fuel pellets.

Klass, D.L. 1998. Biomass for renewable energy, fuels and chemicals. Academic Press.
Abstract: This is a comprehensive review of historical and current use of biomass and the conversion technologies available through 1998.

Miller, R.K. 1997. Southwest woodlands: cultural uses of the "forgotten forest." Journal of Forestry. 95(11):24-28.
Abstract: Article discusses traditional and cultural (both historic and current) Native American uses of woodland species not primarily used for lumber, including pinyon and juniper.

Ortiz, L., J.L. Miguez, and E. Granada. 1996. Briquetting biomass: current situation of the Spanish market. In: Proceedings, Bioenergy 1996, the Seventh national Bioenergy Conference. Nashville, TN. 1996 September 15-19. Southeastern Regional Biomass Energy Program, Tennessee Valley Authority, Muscle Shoals, AL. p. 747-54.
Abstract: Briquetting biomass fuels corrects one of the problems associated with transport and combustion of low density feedstock. The densification process converts the biomass into a clean, uniform fuel. Transportation costs are also reduced. Densification machines, costs, feedstock quality, and the quality of the product are discussed.

Pickering, W.H. PhD. 1995. Densified fuels from wood waste. In: Proceedings, Second Biomass Conference of the Americas. Portland, OR. 1995 August 21-24. p. 1190-99.
Abstract: Densified fuel burns with a hot flame when supplied with ample combustion air. Stoves that burn pellets easily meet EPA standards because volatile organic compounds are almost completely burned. The economics of pelleted wood are attractive. Assuming a retail price of $3.00 per 40lb. bag, the cost per million BTU is $8.82. Industrial bulk sales would be about $4.40 per million BTU, which is competitive to natural gas, propane, and #2 stove oil.

Reed, T.B. and W.L. Mobeck. 1993. Commercial production of the oil absorbent 'sea sweep'. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 1485-93.
Abstract: Made from "pin chips," a waste wood product. 'Sea Sweep' is an environmentally acceptable absorbent for oil spills. It is made by heating pin chips

in an atmosphere of pyrolysis vapors of 300-350ºC, followed by rapid cooling. Disposal is easy, as used chips have a heat value of 17,300BTU per pound as fuel, equal to or better than coal.

Rezende, M.E., A.L. Vanya Pasa, R. Sampio, and P. Macedo. 1993. Commercial charcoal manufacture in Brazil. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 1456-70.
Abstract: World production of charcoal reached 21.4 million tons in 1989 (FAO, 1991). Major use is for home cooking. Brazil has used masonry kilns of low efficiency to obtain charcoal for their steel industry. Progress is now being made in the development and use of new technology to obtain 400kg of wood tar, 140kg of acetic acid, 60kg of crude methanol, and significant amounts of low BTU gases for heating. Forest management practices now are based on sustainable yield to maintain the steel industry.

Scherry, R.W. 1952. Plants for man. Prentice Hall. New York, 270 p.
Abstract: This book covers several topics, including the conversion of pinene to camphor.

U.S. Department of Energy 1992. A handbook for small-scale densified biomass fuel pellets manufacturing for local markets.
Abstract: The handbook includes financial analysis, stove availability, equipment suppliers, etc. Pinyon-juniper could be used for industrial fuels.

White, D.H. PhD., D. Wolf, PhD., H.S. Joyner, PhD., and B.M. Vaughan. 1995. Modular plants producing fuels for biomass cogeneration plants. In: Proceedings, Second Biomass Conference of the Americas. Portland, OR. 1995 August 21-24. p. 507-14.
Abstract: Thermo-mechanical liquifaction was first performed by the U.S. Bureau of Mines. The concept was further refined at the Department of Chemical Engineering, University of Arizona. Continuous liquifaction of a wide spectrum of biomass resources has been proven at the University of Arizona, and is now being commercialized. The bio-crude from the process has been refined into high value products such as clean oil, asphalt additives and modifiers, organic binders, char and by-products of heat recovered as steam. The process can be designed as a portable model.

Young, J.A. and J.D. Budy. 1979. Historical use of pinyon-juniper woodlands. Journal of Forest History. 23:113-21.
Abstract: Traditional uses include fuelwood, charcoal, fence posts, etc. Estimates of present-day value related to estimates of standing resources.

Young, J.A. and T.J. Svejcar. 1999. Harvesting Energy from 19th Century Great Basin Woodlands. In: Monsen, Stephen B. and Stevens, Richard, compilers. Proceedings:

ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo, UT. Proc. RMRS-P-9. USDA, Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 47-50.

Abstract: The pinyon-juniper woodlands of the Great Basin were a vital source of structural wood and energy products for the mining industry from the 1860's to the 1930's. Pinyon and juniper were cut extensively for fuel wood and for the production of charcoal, the only available fuel or energy source for the smelters of central Nevada. Firewood and fence post for ranches were also important uses of pinyon and juniper. Deforestation by cutting, promiscuous burning continued unabated until the 1920's and 1930's, when fossil fuels, substitute types of structural wood, and fire control combined to decrease disturbance in this vegetation type.

DIRECT COMBUSTION

Badger, P.C. and C.D. Stephenson. 1992. Case studies of three industrial wood fired boilers. National Fertilizer and Environmental Research Center, Southeastern Regional Biomass Energy Program, Tennessee Valley Authority, Muscle Shoals, Alabama.

Abstract: The paper describes facilities, operations, the number of employees and the problems encountered at three TVA industrial boilers. The benefits of wood fuel are multiple.

Hollenbacher, R. 1992. Biomass combustion technologies in the United States. Biomass Combustion Conference. Reno, NV. 1992 January 28-30. U.S. Department of Energy Regional Biomass Energy Program.

Abstract: This report covers all systems, from pile burners to suspension and fluidized bed systems, and the advantages and disadvantages of each. The paper includes tables and discussions on the effect of moisture content in fuel, flame temperature on NO formation, and ash deformation temperatures.

LeBlanc, J.D. 1993. Three biomass power plants in New England: first five years of challenges and solutions. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 1754-63.

Abstract: Presents guidelines for generating electricity from biomass fuels in stand-alone plants. Three 16mw plants in different locations using varying biomass supply were monitored.

Wiltsee, G.A. Jr., C.R. McGowin, and E.E. Hughes. 1993. Combustion technologies for power generation. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 347-67.

Abstract: Presents an outline of state of the art combustion systems. Includes analyses for fuel classes, moisture content, alkali content, and comparison to coal.

GASIFICATION

Arizona State University, Tempe AZ. Department of Chemical, Bio and Materials Engineering. Circulating fluidized bed gasification.
Abstract: Synthesis gas was successfully generated from over 100 sources of biomass, including chips of pinyon and juniper. The gasifier design uses a novel circulating system to heat the bed material. The bed material can be selected to capture products released when gasifying hazardous materials or synthetic substances, such as polyvinyl chloride.

Forest Industries. 1980. Georgia hospital powered by wood chips.
Abstract: In a project funded by the Georgia Forestry Division, Applied Engineering Co., Braverburg SC, designed an air blown, updraft gasifier capable of handling green whole tree chips. This unit was used to supply producer gas to a 500hp boiler at Northwest Regional Hospital, Rome GA. The producer gas, valued at $2.04 per million BTU, replaced natural gas at $3.50 per million BTU. With a 125-year history of success, this technology is still a viable alternative to fossil fuel use.

Mansour, M.N, K. Durai-Swamy, and G. Voelker. 1995. MTCI/Thermochem steam reforming process for biomass. In: Proceedings, Second Biomass Conference of the Americas. Portland, OR. 1995 August 21-24. p. 543-52.
Abstract: Synthesis gas is produced in a fluidized bed system using pulse heaters imbedded in the bed material. Overall efficiency is enhanced by the recovery of waste heat. Steam reforming avoids formation of dioxins and converts any chlorinated compounds into salt and clean gas.

Menville, R.L. Jr. 1996. Gasification process developments offer new opportunities for biomass to energy. In: Proceedings, Bioenergy 1996, the Seventh National Bioenergy Conference. Nashville, TN. 1996 September 15-19. Southeastern Regional Biomass Energy Program, Tennessee Valley Authority, Muscle Shoals, AL. p. 289-96.
Abstract: Biomass is carried through an externally heated tube where it is broken down into synthesis gas and ash. The gas is cleaned and the mixture can be used as fuel or feedstock for the production of methanol or other high value products. The system has low maintenance costs and a simple payback of less than 2 years when competing against natural gas at $4.50 per million BTU.

Ochs, S., T. Sichz, and J.L. Kuester. 1994. Biodiesel by indirect liquifaction. In: Proceedings, Bioenergy 1994, the Sixth National Bioenergy Conference. Reno-Sparks, NV. 1994 October 2-6. Western Regional Biomass Energy Program. U.S. Department of Energy. Denver, CO. p. 27-34.
Abstract: This process uses a novel circulating fluidized bed gasifier to generate synthesis gas. The mixture of gases is used as feedstock in a reformer process to produce a clean hydrocarbon liquid equal to diesel fuel. Over 100 biomass sources

have been successfully converted into synthesis gas including pinyon pine and juniper wood chips.

St. Walley, R.M., C.S. St. Walley, and C.B Rickey. 1996. Operation of a piston engine with a downdraft channel gasifier. In: Proceedings, Bioenergy 1996, the Seventh National Bioenergy Conference. Nashville, TN. 1996 September 15-19. Southeastern Regional Biomass Energy Program, Tennessee Valley Authority, Muscle Shoals, AL. p. 612-19.
Abstract: This paper describes a gasifier based on an experimental model at Purdue University. The modular gasifier is relatively simple to operate and can be used to power engines, gas turbines, or heating equipment.

DISTRIBUTION

Burkhardt, J.W. and E.W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. J. Range Management 22(4):264-270.

Abstract: Western juniper invasion of sagebrush-bunchgrass vegetation in southwestern Idaho was verified. The invasion started about 1860 and is continuing at present. Juniper was found to be climax on rocky ridges and rimrocks where soil development is limited. Seral juniper stands were found on the deeper soils of valley slopes and bottoms. These sites were previously occupied by productive sagebrush-grass stands. It appears that juniper control would be more beneficial on invaded sites than on climax juniper sites.

Harper, K.T. and J.N. Davis. 1999. Biotic, edaphic and other factors influencing pinyon-juniper distribution in the Great Basin. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 51-54.

Abstract: Drought and severe frost events during the growing season often limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides throughout the Great Basin and across the Colorado Plateau. Dramatic zone inversions may arise to confound more common patterns and place pinyon-juniper woodlands above the mountain brush zone. Such a zone inversion occurs on a grand scale in Spanish Fork Canyon, Utah County, Utah, where Utah juniper and Colorado pinyon have an ecological advantage of Gambel oak and associated mountain brush species. Utah juniper and associated pinions are insensitive to differences in geologic parent materials and soils derived therein. Regional floristic patterns and climatic changes associated with differences in elevation exert a far stronger impact. Woodland successional processes proceed more quickly on deep deposits off volcanic ash and alluvium or lacustrine deposits than on soils derived in place from consolidated bedrock of volcanic or sedimentary origin.

Mitchell, J.E. and T.C. Roberts. 1999. Distribution of pinyon-juniper in the western United States. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 146-154.

Abstract: The extent of pinyon-juniper woodlands in the western United States, as determined from advanced very high-resolution radiometer (AVHRR) data, has been appraised at approximately 55.6 million acres. There is presently no complete national inventory to which this total can be compared; however, Forest Service plot-based estimates and independent GAP predictions are consistent with the AVHRR acreage in Utah where adequate inventory data exist. An assessment by the BLM has yielded higher pinyon-juniper coverage for their own lands than that

derived from AVHRR data. Spatial discrepancies remain between the AVHRR and GAP coverages; however, the importance of algorithms in classifying remotely sensed data is noted.

Neilson, R.P. Perspectives on patterns of climate and pinyon-juniper in the interior west. USDA Forest Service, Corvallis, OR 97339

Abstract: Pinyon and juniper distributions in the west are clearly related to large-scale distribution and temporal dynamics of regional airmass gradients. The distributional patterns of pinyon species also bear interesting relationships to those of ponderosa pine and various species of oak. The pines and oaks appear to have similar ecological constraints, but differ in that the oaks have the capability to reproduce both asexually (clone) and sexually. This paper reviews work on the regional and elevational patterns of distribution of some of the pines and oaks and their relationship to regional airmass gradients and the mode of reproduction. Implications with regard to local to regional diversity patterns are also discussed. Simulations with a new biogeography model, MAPSS, are able to reiterate many of the spatial patterns of both horizontal and elevational ecotones in the region under the present climate. Simulations under global warming scenarios are discussed in terms of the expected climate shifts and their similarities to mid-Holocene climate shifts and the possible implications to regional biotic complexity at a range of scales.

Nevada Dept of Conservation and Natural Resource's Technical Working Group. 2002. Nevada Natural Resources Status Report. http://dcnr.nv.gov/nrp01/content.htm

Abstract: Land cover and land use types were mapped by Utah State University in collaboration with the BLM and USFS using circa 1990 satellite images (Gap Analysis Program, circa. 1995). Not surprisingly, the analysis shows that about 81 percent, or 57.5 million acres, of Nevada's landscapes can be described as rangeland (Table 4-1). Forestland, including pygmy conifer (pinyon and juniper) woodlands, covers about 8.5 million acres, or 12 percent of the state. Wetlands and riparian zones cover about 0.7 percent of the state's land area. The estimate of 0.5 million acres for this land cover type probably underreports the actual amount.

O'Brien, R.A. and S.W. Woudenberg. 1999. Description of pinyon-juniper and juniper woodlands in Utah and Nevada from an inventory perspective. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 55-60.

Abstract: Forests composed mostly of pinyon and/or juniper species cover more than 45.3 million acres in the intermountain west. About 40 percent (18.0 million acres) of that area is in Nevada and Utah, where roughly 71 percent of the total forest land is pinyon-juniper and juniper forest type. The net volume of pinyon and juniper species in the two states is estimated at over 10.3 billion cubic feet, or about 137.5 million cords. Juniper makes up about 63 and 47 percent, respectively, of the pinyon-juniper volume in Utah and Nevada. Fifty-eight percent of the total number of pinyon and juniper trees in Nevada, and 49 percent in Utah, are pinyon. About 53 percent of pinyon and juniper stands in Utah, and about 67 percent in Nevada, are estimated to be between 40 and 120 years old. Almost 20 percent of stands in Utah and 9 percent of stands in Nevada are over 200 years old. Only about 6 percent of Utah stands, and less than 1 percent of Nevada stands, show evidence of chaining.

Tausch, R.J., N.E. West, and A.A. Nabi. 1981. Tree age and dominance patterns in Great Basin pinyon-juniper woodlands. Journal of Range Management 34(4):259-64.
Abstract: Prior studies of pinyon-juniper woodlands at a few locations have indicated considerable historical expansion of the trees and loss of understory. Whether these changes are a widespread phenomenon and related to pervasive, rather than local influences was the question asked by this research. An objective sampling of 18 randomly selected mountain ranges in the Great Basin was undertaken. Tree age and dominance in the pinyon-juniper woodlands showed definite geographical, elevational, and historical trends. The oldest, most tree-dominated woodlands were located in areas of intermediate topography where disturbances may have been less frequent. Populations of both trees (*Pinus monophylla* and *Juniperus osteosperma*) were progressively younger and less dominant in both upslope and downslope directions from the intermediate elevations. Tree densities have also historically increased within the oldest woodlands. Pinyon density has increased faster than that of juniper. Approximately 40 percent of the sampled plots had their trees establishing during the last 150 years. These changes generally coincide with the introduction of heavy livestock grazing, tree utilization by the mining industry, and fire suppression that followed settlement of the region. Associated climatic trends were also investigated. The relative importance of these influences on the changes in tree age and dominance cannot be determined without further research. The loss of understory, coincident with increasing tree dominance, has reduced forage production and made the woodlands progressively less susceptible to fire. Barring some major environmental change or management action, this forage reduction and decreased frequency of burning will continue until trees dominate much more area.

Tueller, P.T., C.D. Beeson, R.J. Tausch, N.E. West, and K.H. Rea. 1979. Pinyon-juniper woodlands of the Great Basin: distribution, flora, vegetal cover. Research paper INT-229. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 22 p.
Abstract: A map of the pinyon-juniper woodland type in the Great Basin was developed from LANDSAT-1 imagery and from field checking of boundaries. A floristic list of 240 positively identified species associated with pinyon-juniper woodlands in the Great Basin is provided. Variations in total vegetal cover and in the relative proportions of pinyon and juniper are related to latitude, longitude, and elevation.

Vasek, F.C. 1996. The distribution and taxonomy of three western junipers. Brittonia 18:350-372.

Abstract: This paper presents the accumulated information with the hope that an increased understanding of morphologic units and their geographic ranges will promote correct identification. *Juniperus osteosperma* occurs primarily in the Great Basin area from western New Mexico and central Wyoming to the eastern base of the Sierra Nevada and higher mountains of California's Mojave Desert. *J. osteosperma* is arborescent in habit, usually has one stem at the base and 5 to eight stems at 5 feet above ground, has a maximum height of 30 feet, an average height of 13 feet, and gray-brown or weathering ash-white bark.

West, N.E. 1999. Distribution, composition, and classification of current juniper-pinyon woodlands and savannas across western North America. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 20-23.
Abstract: Pinyon-juniper woodlands involve vegetation dominated by about seven species of Pinus and 17 species of Juniperus scattered over more than 75 million acres of the southwestern United States and Mexico. The junipers are more widespread latitudinally, longitudinally, and elevationally than the pinyons. The understory is much more diverse and reflects largely local climatic patterns. Grasslands and shrub steppes have successionally preceded pinyon-juniper savanna to woodland on sites with gentle slopes and fine soil textures. Excessive livestock grazing and direct fire control are the major factors that have led to present tree dominance. Tree dominance can be regarded as a sign of ecosystem degradation on sites formerly occupied by native herbs and shrubs. On many sites, trees will be eventually replaced by introduced herbs following fire storms unless proactive management is undertaken.

BIOMASS ESTIMATION

Bolsinger, C.L. 1989. California's western juniper and pinyon-juniper woodlands: area, stand characteristics, wood volume and fenceposts. Resource Bulletin PNW-RB166. USDA Forest Service. Pacific Northwest Research Station, Portland, Oregon. 37 pages.

Abstract: The results of a statewide inventory of western juniper and pinyon-juniper woodlands are presented. Included are statistics on area of woodland by type and ownership; area of rangeland with scattered juniper and pinyon trees; wood volume by ownership, species and tree size; juniper fenceposts; tree and stand age distribution; stand characteristics, including overstory and understory; and a discussion of resource potential and changes in western juniper and pinyon- juniper woodlands since 1945.

Chojnacky, D.C. 1985. Pinyon-juniper volume equations for the central Rocky Mountain states. Research Paper INT-339. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 27 p.

Abstract: Gross cubic foot volume equations are now available for pinyon-juniper and several other woodland species in Nevada, Idaho, Utah, Colorado, Wyoming, and South Dakota. The volume equations are based on data collected as a subsample of woodland inventories conducted by Federal and State land management agencies. In these inventories, volumes of 4,705 trees were estimated by a visual sampling method. Use of the equations requires a measurement of a tree's diameter at the root collar (DRC), total height, and number of basal stems. Thirteen equations, applicable to different parts of a species range, are presented for Utah juniper, western juniper, Rocky Mountain juniper, oneseed juniper, singleleaf pinyon, pinyon, Gambel oak, bur oak, mountain mahogany, and a group of woodland hardwoods. A test of several equations against some local volume data revealed prediction errors up to 20 percent or more in half the cases. However, the equations should be adequate for use in large statewide woodland inventories.

Chojnacky, D.C. 1986. Pinyon-juniper site quality and volume growth equations for Nevada. Research Paper INT-372. USDA, Forest Service, Intermountain Research Station, Ogden, UT. 7 p.

Abstract: In recent years, land managers have become increasingly aware of the potential value of the 42 million acres of pinyon-juniper (P-J) woodlands in the Rocky Mountain States. Inventories of P-J recently were done for the first time in Nevada, Idaho, Utah, Colorado, New Mexico, and Arizona. However, these inventories were conducted without procedures to estimate site quality and wood volume growth because adequate methods were unavailable. As an attempt to fill this information void, this study was initiated using more intensively measured subsample of plots from the Nevada P-J inventory. The study was an exploratory effort to develop site quality and stand growth equations for use in P-J inventories.

Chojnacky, D.C. 1987. Volume and growth prediction for pinyon-juniper. Gen. Tech. Rep. INT-215. USDA Forest Service, Intermountain Research Station, Ogden, UT. p. 207-215.
Abstract: Summarizes the author's recent work in volume and growth prediction for pinyon-juniper trees. Two volume models are compared, volume conversions to different utilization standards are explained, and prediction errors are examined. Three stand growth prediction measures are discussed: (1) current annual growth, (2) a mean annual volume growth (MAI) for uneven-aged stands, and (3) a potential MAI for fully stocked stands. An appendix lists tables of equations developed.

Chojnacky, D.C. 1987. Estimating singleleaf pinyon and Utah juniper volumes for several utilization standards. Western Journal of Applied Forestry 2(2):51-55.
Abstract: Ratio equations were developed to estimate singleleaf pinyon (Pinus monophylla) and Utah juniper (Juniperus osteosperma) volume for several utilization standards. The equations were constructed to estimate outside-bark volume between 1.5 and 6 inches. Data for the equations was collected from 61 locations throughout the Great Basin.

Frolich, M.. 2001. Energy potential - pinyon-juniper woodlands. [Occasional paper].
Abstract: Estimates of energy production on a sustainable basis using data for standing biomass, regrowth estimates, and energy analyses. Estimates were based on information generated by the U.S. Forest Service.

Grier, C.C, K.J. Elliott, and D.G. McCullough. 1992. Biomass distribution and productivity of pinus edulis and juniperus monosperma woodlands of north-central Arizona. Forest Ecology and Management. 50(3-4):331-50.
Abstract: Above-ground biomass distribution, leaf area, above-ground net primary productivity and foliage characteristics were determined for 90- and 350-year old *Pinus edulis-Juniperus monosperma* ecosystems on the Colorado Plateau of northern Arizona. These ecosystems have low biomass, leaf area and primary productivity compared with forests in wetter environments. Biomass of the 350-year-old pinyon-juniper stand examined in this study was 54.1 mg ha-1; that of the 90-year-old stand was 23.7 mg ha-1 year-1 for the mature stand; tree productivity was about 80% of these values for both stands. Projected ecosystem leaf area (LAI) of the stands was 1.72 m2 m-2 and 1.85 m2 m-2, respectively. Production efficiency (dry matter production per unit leaf area) was 0.129 kg m-2 year-1 for the young, and 0.160 m-2 for the mature stand. Production efficiency of the study site was below the 0.188 kg m-2 year-1 reported for xeric, pure juniper stands in the northern Great Basin. Biomass of pinyon-juniper ecosystems of northern Arizona is generally below the 60-121 mg ha-1 reported for pinyon- juniper stands of the western Great Basin in Nevada. A climatic gradient with summer precipitation decreasing between southeast Arizona and northwest Nevada occurs in the pinyon-juniper region. Great Basin pinyon-juniper ecosystems lie at the dry-summer end of this gradient while pinyon-juniper ecosystems of the Colorado Plateau lie at about middle of this gradient. In spite of wetter summers, pinyon-juniper ecosystems of northern Arizona are less productive than those of the Great Basin.

Jones, R. 1980. Pinyon and juniper forest volume inventory for Lincoln County, Nevada. Nevada Division of Forestry.

Abstract: In 1980, the NDF undertook an inventory of the pinyon-juniper stands in the Caliente and Pioche areas to examine the economic viability of locating a cement board plant within the area. The study was limited to all areas with a slope of less than 30 percent. Sampling points were located on a map, and then visited and measured using the "Estimating Pinyon/Juniper Cordwood With the Line-Intersect Method." The mean volume of wood inventoried was 2.98 $\pm$ 0.38 cords per acre, and the range of volumes measured at the transects was 0-18.8 cords per acre. A vegetation map was used to extrapolate values, measured from transects, to the area as a whole. The results of the study showed that a cement board plant could run 310 days a year, for 141 years, if it utilized 25 cords of pinyon-juniper biomass per day.

Mason, L.R. and S.S. Hutchings. 1967. Estimating foliage yields on Utah juniper from measurements of crown diameter. J. Range Management 20(3):161-166.

Abstract: This study indicates that tree foliage yield can be approximated from crown measurements. The relation between crown and foliage production is improved by including ratings of foliage denseness (sparse, medium, and dense) and soil characteristics. Such estimates are needed to fully evaluate site potential and condition of rangeland occupied by trees.

Meeuwig, R.O. and J.D. Budy. 1981. Point and line-intersect sampling in pinyon-juniper woodlands. Gen. Tech Rep. INT-104. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 38 p.

Abstract: Two probability proportional to size (pps) sampling methods have been adapted for use in pinyon-juniper woodlands. Procedures are described for estimating biomass, stand basal area, canopy cover, tree density, and growth rates, using either point sampling or line-intersect sampling. Both sampling methods are supported by regression equations for estimating above-ground biomass, cordwood, slash, fine fuels, and foliage of singleleaf pinyon and Utah juniper. Regression equations for predicting decadal growth rates in terms of stand basal area above-ground biomass, and cordwood are also presented.

Meeuwig, R.O., E.L. Miller, and J.D. Budy. 1979. Estimating pinyon and juniper fuel and biomass from aerial photographs. Research Paper INT-274. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 9 p.

Abstract: Regression equations were developed for estimating mass of various fuel components per unit crown area of singleleaf pinyon (Pinus monophylla) and Utah juniper (Juniperus osteosperma). Techniques are described for using these equations for estimating fuel loading, fuelwood volumes, and potential slash production from aerial photographs.

Miller, E.L., R.O. Meeuwig, and J.D. Budy. 1981. Biomass of singleleaf pinyon and Utah juniper. Research Paper. INT-273. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 18 p.

Abstract: The pinyon-juniper woodland forest of the western United States has a long history of use largely because of the scarcity of timber in this region. For centuries this woodland has provided people with nuts, fuelwood, fenceposts, and poles. This project was performed to develop prediction equations that use measurable, independent tree variables to estimate above ground biomass as related to resource potentials and quantity of fuels. Also, it was performed to obtain data for analysis of growth relations and site quality of pinyon-juniper in Nevada. The results showed that aboveground biomass was closely correlated with crown diameter for both species, and stem diameter at stump height for pinyon and diameter at breast height for juniper.

Montes, N., T. Gauquelin, W. Badri, V. Bertaudiere, and El H. Zaoui. 2000. A non-destructive method for estimating above-ground forest biomass in threatened woodlands. Forest Ecology and Management. 130(1-3):37-46.

Abstract: Current techniques for calculation of biomass in agroforestry require felling of many trees. Such methods are not well suited to the natural environment, especially if the environment is subject to anthropic degradation and if the wood supply to local populations is at stake. The method we describe here was used in a socioeconomic and ecological study of the biomass of a thuriferous juniper woodland (*Juniperus thurifera L*.) in the High Central Atlas mountains (Morocco). This computerized method reconstructs the different component volumes of a tree from two orthogonal-view photographs. Then, using the volume and the density of each component, it estimates the biomass of the tree. Regression curves were established between dendrometric parameters for 102 trees (tree height X crown projection area) and their estimated biomass by this computer method. A second-order polynomal equation gave the best regressions with a high coefficient of determination (R2=0.96). To validate the method, the biomass of seven trees (cut in a previous study) was compared with those obtained from our regression equations, while in a second study, the biomass of three trees, estimated from photographs using the computer program, was compared with values obtained after felling and weighing the same trees. The results show that the method is reliable with a mean error percentage varying between 2.5 and 7.5 per tree. For young trees, the accuracy of the biomass could be improved, for example, by using a tree morphology classification.

Tausch, R.J. and P.T. Tueller. 1989. Evaluation of pinyon sapwood to phytomass relationships over different site conditions. J. Range Management 42(3):209-212.

Abstract: Detailed studies of competitive interactions in the pinyon-juniper (*Pinus monophylla-Juniperus ostesperma)* ecosystem require accurate estimates of biomass from physical measurements of the plant species involved. Relationships between green leaf biomass (phytomass) and trunk sapwood area were evaluated on 6 plots on a western Nevada mountain range. Four of the plots covered a range of environmental conditions from the lower to the upper edge of the woodland belt in 100-m elevation increments. The remaining 2 covered canyon and mountain top environments. The sapwood area to phytomass relationship was first individually analyzed for each of the 6 plots and the results compared. The ratio for grams of phytomass per cm^2 of sapwood area for the tree in each plot with the highest value

ranged from 1.5 to over 2 times the tree with the lowest value. The highest average plot ratio was only 10% greater than the lowest average plot ratio. Individual regression slopes for the 6 plots did not significantly differ and the data were combined for the remaining analyses. The regression relationship for trees with less than 40 cm^2 sapwood area differed from the overall relationship. The slope values for the sapwood area to foliage biomass relationship for the western Nevada data averaged about 2/3 the slope values for a data set from a mountain range in southwestern Utah. These differences were significant between a subset of young trees from each site with up to 40 cm^2 sapwood area ($P \leq 0.01$) and for an analysis between all the samples trees from each site ($P \leq 0.10$).

Van Wagtendonk, J.W., J.M. Benedict, and W.M. Sydoriak. 1996. Physical properties of woody fuel particles of Sierra Nevada conifers. Int. J. Wildland Fire. 6(3):117-123.
Abstract: A study of the physical properties of Sierra Nevada conifer fuel particles showed that an average diameter, squared, quadratic mean diameter, surface-area-to-volume ration, and specific gravity varied significantly by species for all four time lag fuel diameter size classes. The nonhorizontal angle was not significantly affected by size class, and the developmental stage of overstory did not affect any of the properties. These values are used to calculate fuel weight and predict fire behavior. Regional variation in physical properties can result in fuel weight estimates for the Sierra Nevada that differ from under 40.8 percent to over 8.3 percent from those calculated from Rocky Mountain values. These differences made small changes in predicted fire behavior.

Waconda, J. 1999. Woodland inventory procedures and analyses conducted for management planning purposes on Indian lands. In: Desired Future Conditions for Pinyon-Juniper Ecosystems. Gen. Tech. Rep. RM-258. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 130-135.
Abstract: The purpose of this paper is to describe standard Bureau of Indian Affairs (BIA), Albuquerque Area Office (AAO) Branch of Forestry planning, implementation, and data analysis procedures used in previous woodland inventory projects. The paper also addresses several unusual situations encountered on these projects. When planning inventories, BIA employs a national categorization system that prioritizes reservations based on forest resource acreages and regional resource value standards. Standard woodland inventory project design includes obtaining remote sensing imagery, preparing specialized forest maps, and selecting a sampling method and design to address the data accuracy requirements. Continuous Forest Inventory (CFI) systems or temporary plot systems are generally used with a single-unit, fixed area circular plot design. Equivalent diameter at root collar is calculated and current growth estimates are based on pinyon growth rates. The AAO also collects tree mortality information for fuelwood management. Insect and disease problems are also included in the inventory data.

ECONOMICS

Bledsoe, F.N. and J.M. Fowler. 1992. Economic evaluation of the forage-fiber response to pinyon-juniper thinning. Bulletin 753. Las Cruces, NM. New Mexico State University Agricultural Experiment Station. 129 p.

Abstract: Extensive model testing has revealed that basal area is a key woodland management variable and can be used to jointly manage forage and fiber production on pinyon-juniper woodlands. Economically efficient thinning regimes vary according to climate, site productivity and product prices. Xeric sites require basal area of zero to maximize long run returns, whereas mesic sites are economically efficient at basal areas of approximately 40 square feet per acre. Forage production can be increased from virtually no production to approximately 500 pounds per acre within four years of thinning on xeric sites. Mesic sites show increases up to 750 pounds per acre within four years of thinning. Even larger increases can be realized on both xeric and mesic sites when thinned areas are seeded.

Chadwick, J.H, D.R. Nelson, C.R. Nunn, and D.A. Tatman. 1999. Thinning versus chaining: which costs more? In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 290-292.

Abstract: In 1990, 320 acres of pinyon-juniper were chained as part of a big game winter range improvement project in Spanish Fork Canyon. Areas were double-chained: units were chained in one direction, seed was broadcast aerially, and the units chained in the opposite direction. In conjunction with the chaining, 40 acres were thinned and seeded with the same mix in order to compare implementation costs and results between the two treatments. Trees were dragged and hand-piled in drainage ways and seed was raked into the soil so as to better simulate the effects of chaining. Per-acre cost for thinning was considerably greater than for chaining.

Clemmer, S. and D. Weichert. 1994. The economic impacts of renewable energy use in Wisconsin. Department of Administration, Division of Energy and Intergovernmental Affairs, Wisconsin Energy Bureau, Madison, WI.

Abstract: This report addresses the accumulated, tangible socioeconomic benefits of the commercial utilization of a local or regional energy resource for the local or regional economy. Such utilization generates three times more jobs, earnings and sales in Wisconsin than an equal investment in imported fossil fuel usage. The report also addresses the avoidance of costs associated with the control of CO_2 and NOx, which is significant.

Henderson, D.E. and M.L. Baughman. 1987. Whole tree harvesting of the pinyon-juniper type: economic and institutional considerations. In: Everett, RL, compiler. Proceedings: Pinyon-juniper Conference. Reno, NV. 1986 January 13-16. Gen.

Tech. Rep. INT-215. USDA Forest Service, Intermountain Research Station, Ogden, UT. p. 192-195.
Abstract: As public land management agencies are faced with tighter fiscal constraints, capabilities to effectively implement desired land management practices may be lessened. Such conditions require innovative partnerships between the public and private sectors. Such partnerships should seek to accomplish agency objectives while providing adequate economic incentives to the private sector. Under proper conditions, public land management of the pinyon-juniper type could be accomplished by the private sector. This discussion focuses on the various economic and institutional considerations, which may be prerequisite to effective public/private sector relationships. Within this discussion, a model management framework is outline, necessary institutional relationships defined, and economic benefits assessed.

Le Baron, A. 1968. Estimating profits from sales of pinyon-juniper products. Utah Resources Series 43. Utah Agricultural Experiment Station.
Abstract: Limited economic viability for posts, charcoal, cordwood. Christmas trees have more promise.

Morris, G. 1993. Commercialization analysis for fuels from pinyon-juniper biomass. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 1833-38.
Abstract: The report identifies commercially feasible energy markets to promote sustainable operations for alternative land uses for pinyon-juniper woodlands. Analyses include harvest costs, processing costs, hauling, etc.

Murphy, P.M. 1987. Specialty wood products from pinyon-juniper. Gen. Tech. Rep. INT-215. USDA, Forest Service, Intermountain Research Station. Ogden, UT. p. 166-172.
Abstract: Feasibility studies utilizing pinyon-juniper woodlands for providing specialty wood products show mixed promises. Current costs of chipping and hauling proved too high for feasible production of oriented-structure board. A cement board plant proved feasible at one location in eastern Nevada. However, the present slump in the housing market and the high interest rates on money will have a negative effect on this project.

Nevada State Energy Office. 2000. Energy for Nevada, report to the legislature on the status of energy in Nevada for the year 2000.
Abstract: Pinyon-juniper woodlands are a potential energy feedstock that would provide a basis for economic development associated with the creation of new industries.

Quinn, M.W., J. Whittier, S. Haase, C. High, D. Swanson, and E. Wood. 1994. Economic impact of industrial wood energy use in thirteen western states. In:

Proceedings, Bioenergy 1994, the Sixth National Bioenergy Conference. Reno-Sparks, NV. 1994 October 2-6. p. 395-401.
Abstract: A 1992 analysis indicated that industrial wood energy was directly linked to 1,538 jobs with a net of 3,250 full-time employees when secondary jobs were added. Operations, both direct and indirect, totaled over $950 million annually, and net federal tax revenues from wood energy facilities were estimated at over $25 million. A wide variation in the use of wood was noted over the thirteen state area.

Schmidt, L.A. 1995. Pinyon-juniper fuelwood markets in the southwest. Flagstaff, AZ. Gen. Tech. Rep. RM-258. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 214-217.
Abstract: This study estimates the commercial harvest and sale of pinyon-juniper fuelwood from state, private, and public forests in Arizona, Colorado, New Mexico, Nevada, and Utah. The demand for fuelwood peaked five or six years after the 1973 oil embargo. Reports and personal interviews suggest there is less fuelwood consumed today than there was during early 1970 and 1980. There is a strong public awareness for better air quality. Many cities and towns have "no-burn" days during winter temperature inversions. Persons residing in these communities cannot use the same amount of fuelwood they used in the past, before the restrictions were in effect. A surge of interest by the sagebrush rebellion groups has seemingly reduced availability of fuelwood from public and some state woodlands.

Swan, L. 1995. Western Juniper: An evolving case study in commercialization, ecosystem management, and community development. Flagstaff, AZ. Gen. Tech. Rep. RM-258. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 179-183.
Abstract: This article is intended to stimulate exploration and marketing of juniper and pinyon products. Ultimately, the objectives are to better utilize fiber harvested for ecosystem management purposes, and improve local community and tribal economies. The evolving case history of western juniper (*Juniperus occidentalis*) commercialization efforts, from an unofficial coordinator's perspective, is offered as an example of what could be done in the Southwestern United States.

Whittier, J. S. Haase, D.L. Lynch, C. Jones, G. Jones, and B. Dettman. 1996. Market potential for biomass co-fire in the four corners region. In: Proceedings, Bioenergy 1996, the Seventh National Bioenergy Conference. Nashville, TN. 1996 September 15-19. Southeastern Regional Biomass Energy Program, Tennessee Valley Authority, Muscle Shoals, Alabama, 1996. p. 187-94.
Abstract: The use of forest thinnings to co-fire with coal is not viable when low sulfur coal is in plentiful supply. The average cost of whole tree wood chips for a power plant was $3.15 per million/BTU.

Young, J.A. and R.A. Evans. 1981. Something of value- energy from wood on rangelands. Rangelands 3(1):10-12.
Abstract: This article addresses problems of costs and perceptions of the harvest of non-commercial woodlands.

Young, J.A., R.A. Evans, J.D. Budy, and A. Torell. 1982. Cost of controlling maturing western juniper trees. Journal of Range Management 35(4):437-42.

Abstract: A cost evaluation was conducted of four alternatives for improvements on maturing western juniper (*Juniperus occidentalis*) woodlands. The alternatives were: (a) the use of picloram (4-amino-3,5,6-trichloropicolinic acid) to kill the trees with no further treatment, with a total cost of $78/ha ($31/acre); (b) picloram with sufficient limbing and/or removal of trees to allow passage of a rangeland drill for seeding at a cost of $448/ha ($179/acre); (c) mechanical clearing and burning of the trees at a cost of $595/ha ($237/acre); and (d) wood harvesting and slash disposal at a cost of $2,080/ha ($832/acre). The picloram and limb, mechanical and wood-harvesting treatments provide mechanically seedable sites, but of considerably different quality in terms of ease of seeding and chances of seedling establishment. The mechanical treatment requires a large capital investment, while the wood-harvesting treatment requires a large amount of labor. Based on equivalent energy values, the wood-harvesting operation would produce a profit for the landowner who could afford to invest the labor. For a specific woodland, a combination of treatments would be most cost effective.

SILVICULTURE AND HARVESTING

Budy, J.D. and R.O. Meeuwig. 1987. Pinyon-juniper silvics and silviculture. Reno, NV. Gen. Tech. Rep. INT-215. USDA, Forest Service, Intermountain Research Station, Ogden, UT. p. 244-248.

Abstract: The pinyon-juniper type, being more xeric than any other timber types in the United States, has unique silvical characteristics. The forage for livestock and wildlife habitat may provide an opportunity to practice multiple-use silviculture. The development of efficient and appropriate silviculture systems is being facilitated by the increased research conducted in the pinyon-juniper type during the past 10 years.

Ellenwood, J.R. 1995. Silvicultural systems for pinyon-juniper. In: Shaw, Douglas W.; Aldon, Earl F.; LoSapio, Carol, technical coordinators. Desired future conditions for pinon-juniper ecosystems: Proceedings of the symposium. 1994 August 8-12; Flagstaff, AZ. Gen. Tech. Rep. RM-258. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 203-208.

Abstract: Silvicultural systems and cutting methods can be applied to pinyon-juniper stands. Several silvicultural systems are available depending upon the objectives of the landowner. Even-aged, uneven-aged, and irregular-aged silvicultural systems are described and compared for managing pinyon-juniper stands. Each system involves the application of treatments to individual stands to achieve a desired condition. Silvicultural treatment can be maintained. A proposed density management regime is presented.

Huber, D.W. 1992. Utilization of hardwoods, fuelwoods, and special forest products in California, Arizona, and New Mexico. In: Ffolliott, Peter F.; Gottfried, Gerald J.; Bennett, Duane A.; [and others], technical coordinators. Proceedings: Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico. Sierra Vista, AZ, 1992 April 27-30. Gen. Tech. Rep. RM-218. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 103-108.

Abstract: Conifers are the major timber species in the western and southwestern United States. Harvesting and processing of these species dominate the resulting wood products industry. In contrast, hardwoods and other nontraditional species are underutilized in spite of some existing sales for fuelwood and special forest products. Systems for management of tree and shrub woodlands are being developed. The Cut-N-Reuse and Retain-N-Reuse paradigms of industrial harvesting show promise for ecosystem manipulation over the traditional Cut-N-Convert method of land management practices. A better understanding of hardwood, fuelwood, and special forest product industries could enhance rural community development and stability.

Kline, J. 1993. My vision of the pinyon/socioeconomic potential of pinyon woodlands. In: Aldon, Earl F.; Shaw, Douglas W., technical coordinators. Proceedings:

Managing pinyon-juniper ecosystems for sustainability and social needs. Santa Fe, NM. Gen. Tech. Rep. RM-236. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 3-8.
Abstract: The desired future condition of the woodlands includes pinyon and juniper trees of varied ages including climax trees with canopies spaced appropriately for maximum production of pinyon nuts. It includes forbs and grasses, both cool and warm season, growing under and around the trees. It includes watershed retention and an abundance of diverse wildlife. The sociological picture includes local residents using the woodlands for economic gain through fuelwood harvests, harvest of wildings, and Christmas tree cutting. It also includes ranchers grazing woodlands where appropriate and land management agencies should perform silvicutural practices, which would make the woodlands more productive for nuts and straight fence posts. This socioeconomic vision means that the rural residents and the land managers will be working together for the common good.

Kropelin, W. 1993. Acquisition of wood fuel at the Joseph McNeil Generating Station. In: Proceedings, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. Burlington, VT. 1993 August 30-September 2. National Renewable Energy Laboratory, Golden, CO. p. 326-33.
Abstract: Describes wood fuel harvest planning, delivery systems, and environmental considerations for a 100mw power plant in Vermont.

Meeuwig, R.O. and R.L. Bassett. 1983. Pinyon-juniper. In: Burns, Russell M., compiler. Silvicultural systems for the major forest types of the United States. Agriculture Handbook No. 445. Washington, DC: USDA Forest Service. p. 84-86.
Abstract: Discusses pinyon-juniper distribution, cover types, soil and climatic requirements, growth rates, volume and yields, and productivity and uses.

Meeuwig, R.O. and J.D. Budy. 1979. Pinyon growth characteristics in the Sweetwater Mountains. Research Paper INT-227. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 26 p.
Abstract: Stem analyses of singleleaf pinyon (*Pinus monophylla*) indicate that height growth rates of dominants and co-dominants are little affected by age or competition. Each tree grows in height at an essentially constant rat throughout most of its life, but height growth rates vary considerably among dominant trees on the same site. This variation is probably due to genetic differences. Diameter growth rate appears to be unaffected by age but it is sensitive to competition. Stand basal area increases at an exponential rate until the understory shrubs are suppressed; then the rate of stand basal area increase becomes relatively constant. Stand biomass accumulation rates follow a similar pattern, tending to become constant after the understory shrubs have been suppressed.

Sorensen, D. 1999. Advantages and effectiveness of rollerchopping. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 293.

Abstract: Rollerchopping is a mechanical method, using a 12-foot wide drum encased with large blades, that can be used to remove trees for improvement of site productivity. Advantages of rollerchopping over other land-clearance methods include treating slash, creating aesthetic sites, leaving soil undamaged, and leaving selected strips, groups, or individual trees.

FIRE

Barney, M.A. and N.C. Frischknecht. 1974. Vegetation changes following fire in the pinyon0juniper type of west-central Utah. J. Range Management 27(2):91-96.

Abstract: The stages of succession following fire began with weedy annuals that reached a peak within 3 to 4 years. Juniper woodlands were well-developed 85 to 90 years following fire. Intermediate stages of succession varied, but followed a general pattern of perennial grasses, perennial grasses-shrubs, and perennial grasses-shrubs-trees. The percentage of dead sagebrush was positively correlated with density of junipers. Thirty-three years was the average minimum age at which Utah juniper produced seed.

Dwyer, D.D. and R.D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. J. Range Management 20(6):359-362.

Abstract: The study of an April 1964 fire in the blue grama-pinyon-juniper vegetation type of New Mexico showed that forage production was reduced significantly the first year on the burned area but recovered by the end of the second. Species composition of herbaceous vegetation was not significantly affected. Loss of live grass crowns was fully recovered by the second year. Litter was significantly less on the burned area all three years of the study. About 24% of the juniper and 13.5% of the pinyon pine were killed by the fire. Cholla less than one ft. tall were damaged more by the fire than those 2 to 3 ft. tall.

Miller, R.F. and J.A.Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. J. Range Management 52:550-559.

Abstract: The recent expansion of juniper into sagebrush steppe communities throughout the semiarid Intermountain West is most frequently attributed to the reduced role of fire, introduction and overstocking of domestic livestock in the late 1880's, and mild and wet climate conditions around the turn of the century. This hypothesis has, however, limited quantitative support. There are few studies of fire history in the sagebrush steppe and none that examine the chronosequence of changes in mean fire intervals, introduction of livestock, and coincident climatic conditions with the initiation of postsettlement juniper expansion. This study was undertaken to test the hypothesis that the postsettlement expansion of juniper was synchronous with the introduction of domestic livestock, reduction in fire frequency, and optimal climate conditions for plant growth.. We documented the fire history and western juniper (*Juniperus occidentalis*) woodland chronology for a sagebrush steppe in a 5,000ha. watershed in south central Oregon. Regional tree ring data were used as proxy data for presettlement climatic conditions. Western juniper age distribution was determined by coring trees across the study area. Fire history was constructed from several small clusters of presettlement ponderosa pine (*Pinus ponderosa*) scattered across the study area. Samples were crossdated to determine fire occurrence to the calendar year. Mean fire intervals were computed for each cluster based on cumulative fire history of each tree sampled within the cluster. Fire events in low sagebrush (*Artemisia arbuscula*) were documented by determining death dates of fire-killed western juniper trees. Records dating the introduction and buildup of livestock during the late 1880's and dates of initial fire suppression were summarized. Western juniper expansion began between 1875 and 1885, with peak expansion rates occurring between 1905 and 1925. The fire record spans 1601 to 1996. Before 1897, mean fire intervals within individual clusters ranged from 12 to 15 years with years between fires varying between 3 to 28. Nearly one-third of the fires in the basin were large and usually preceded by one year of above-average tree ring growth. Two fire events were recorded in the sparsely vegetated low sagebrush site, 1717 and 1855. The last large fire occurred in the study area in 1870 and the last small fire in 1897. The time sequence of wet climatic conditions between 1870 and 1915, introduction of livestock, and the reduced role of fire support the hypothesis that these factors contributed to the postsettlement of western juniper.

Van Wagtendonk, J.W., W.M. Sydoriak, and J.M. Benedict. 1998. Heat content variation of Sierra Nevada conifers. Int. J. Wildland Fire. 8(3):147-158.

Abstract: A study of fuels of Sierra Nevada conifer species showed that percent ash content, heat content with ash, and heat content without ash of needle and duff fuels significantly varied by species, fuel component, and developmental stage of the overstory. Ash and heat contents of woody fuels varied by species and fuel component but not by developmental stage. Bark fuels significantly differed by species, while no factor significantly affected cone fuels. Regional variation in ash and heat content was evident but small. However, the values reported here for heat content of ash for fine fuels averaged 2.50 MJ kg^{-1} higher than the standard values used in fire behavior prediction systems. Using standard values can result in significant under-predictions of fireline intensity of an average of 16 percent for all species, and an average of 47 percent for *Pinus albicaulis*.

WILDLIFE UTILIZATION

Albert, S.K., N. Luna, and A.L. Chopito. 1995. Deer, small mammal, and songbird use of thinned pinyon-juniper plots: preliminary results. In: Shaw, D.W., Aldon, E.F., LoSapio, C. technical coords. Desired future conditions for pinyon-juniper ecosystems. Gen. Tech Rep. RM-258. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 54-64.

Abstract: In 1992, three 1-hectare plots were thinned to basal area densities of 7, 13, and 19 m^2/ha. Response of mid-story and understory vegetation and use of the plots by deer, small mammals, and songbirds was also measured. Vegetation increased dramatically on the heaviest thinned plot at 2 years post treatment. Number of species present increased significantly ($p<0.10$) on the treatment plots. Composition of the plant species also changed. Deer use increased in correlation with the amount of trees removed (Rsq=0.948). Overall small mammal abundance increased on all treated plots. However, pinyon mouse density decreased on treated plots. No overall pattern of songbird use of treated or untreated plots emerged from the data. Plot size may have been too small to accurately reflect bird habitat preference. Small thinnings in pinyon-juniper woodlands have less drastic effects on wildlife than chainings and are a viable management tool for multiple resource managers.

Commons, M.L., R.K. Baydack., and C.E. Braun. 1999. Sage grouse response to pinyon-juniper management. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 238-239.

Abstract: The response of Gunnison sage grouse (*Centrocercus minimus*) to management of pinyon-juniper (*Pinus edulis – Juniperus* spp.) was studied in southwestern Colorado during 1994-1997. Near Crawford, CO., numbers of male sage grouse using lek within 100m of live pinyon-juniper were depressed because of increased raptor presence and predation associated with coniferous trees/shrubs. Removal by cutting of pinyon-juniper trees/shrubs in association with brush-beating to reduce height of mountain big sagebrush and deciduous brush resulted in doubling numbers of male sage grouse counted on treatment leks in years 2 and 3 post-treatment. Clearing of young age classes of pinyon-juniper that have spread into sagebrush shrub-steppe appears to have great merit for enhancing sage grouse use of treated areas through increased survival, productivity, and recruitment. This is especially significant in management of small populations of sage grouse in highly fragmented habitats which may be locally threatened with extirpation.

ECOLOGY

Armentrout, S.M. and R.D. Pieper. 1988. Plant distribution surrounding Rocky Mountain pinyon pine and oneseed juniper in south-central New Mexico. J. Range Management 41(2):139-143.

Abstract: Within the pinyon-juniper type, trees and understory vegetation are interspersed with open areas forming a mosaic of vegetational patterns. The objective of this research was to define and describe vegetational zones surrounding Rocky Mountain pinyon (P*inus edulis*) and oneseed juniper (*Juniperus monosperma*). Transects consisting of contiguous frames were laid out from the base of the tree and continued into the interspace area (outside the canopy) for each cardinal direction. Potential zone boundaries were located by calculating a squared Euclidean distance utilizing basal cover estimates of each frame. Zone boundaries were verified by discriminant analysis. Vegetation associated with both pinyon pine and oneseed juniper exhibited 3 zones. Zone 1 consisted of vegetation associated with the tree bole. Zone 2 was, for the most part, located beneath the tree canopy. Zone 3, consisting primarily of interspace, contained mostly perennial grasses and forbs. Mean basal cover of vegetation surrounding oneseed juniper increased from <1% in Zone 1, to approximately 7% in Zone 2, to about 12% in Zone 3. Mean basal cover estimates of vegetation associated with pinyon pine increased from approximately 4% in Zone 1, to 10 and 11% in Zones 2 and 3, respectively. Differences in species composition among zones between tree species were apparent.

Aro, R.S. 1971. Evaluation of pinyon-juniper conversion to grassland. J. Range Management 24(3):188-197.

Abstract: Conversion techniques applied to public lands in Colorado, Utah, Arizona, and New Mexico provided the basis for an evaluation of several methods. Burning was the most effective and the least expensive method studied. Dozing of trees into windrows, followed by seeding of grasses in the cleared areas, was the best mechanical approach examined, but requires careful site selection and economic evaluation. Chaining was the most widely used, but the least effective technique for converting pinyon-juniper woodland to grassland.

Belsky, A.J. 1996. Viewpoint: western juniper expansion: is it a threat to northwestern ecosystems? J. Range Management 49(1):53-59.

Abstract: Many ranchers, rangeland managers and range scientists in the pacific Northwest consider western juniper (*Juniperus occidentalis*) to be an invading weed that reduces water infilatration, dries up springs and streams, increases erosion, reduces biodiversity and reduces the quality and quantity of forage for livestock and wildlife species. Although there is little scientific evidence supporting most of these beliefs, they are currently being used as rationales for controlling juniper on public and private lands. Similar views were held about pinyon-juniper woodlands in the southwest and Great Basin from the 1940's through the 1960's, when efforts were also made to control woodland expansion. Pressures to control the further spread of western juniper and reduce its density in woodlands are increasing.

Because of the paucity of information on the environmental effects of western juniper expansion in the northwest, this paper primarily reviews evidence from earlier studies of pinyon-juniper woodlands in the southwest and Great Basin. These studies rejected earlier assumptions about the deleterious effects of pinyon-juniper expansion on ecosystem properties and call into question current rationales for controlling western juniper in the northwest. These studies also suggest that while the expansion of juniper might alter species composition and decrease herbaceous biomass in grasslands and shrublands, they have few detrimental effects on streamflow, aquatic organisms, soil properties, or wildlife habitat.

Brockway, D.G., R.G. Gatewood, and R.B. Paris. 2002. Restoring grassland savannas from degraded pinyon-juniper woodlands: effects of mechanical overstory reduction and slash treatment alternatives. J. Environmental Management 64:179-197.

Abstract: Although the distribution and structure of pinyon-juniper woodlands in the southwestern United States are thought to be the result of historic fluctuations in regional climatic conditions, more recent increases in the areal extent, tree density, soil erosion rates and loss of understory plant diversity are attributed to heavy grazing by domestic livestock and interruption of the natural fire regime. Prior to 1850, many areas currently occupied by high-density pinyon-juniper woodlands, with their degraded soils and depauperate understories, were very likely savannas dominated by native grasses and forbs containing sparse tree cover scattered across the landscape. The purpose of this study was to evaluate the effectiveness of mechanical overstory reduction and three slash treatment alternatives (removal, clustering, and scattering) followed by prescribed fire as techniques for restoring grassland savannas from degraded woodlands. Plant cover diversity, biomass and nutrient status, litter cover, and soil chemistry and erosion rates were measured prior to and for two years following experimental treatment in a degraded pinyon-juniper woodland in central New Mexico. Treatment resulted in a significant increase in the cover of native grasses, and to a lesser degree, forbs and shrubs. Plant species richness and diversity increased most on sites where slash was either completely removed or scattered to serve as mulch. Although no changes in soil chemistry or plant nutrient status were observed, understory biomass increased over 200 percent for all harvest treatments and was significantly greater than controls. While treatment increased litter cover and decreased soil exposure, this improvement did not significantly affect soil loss rates. Even though all slash treatment alternatives increased the cover and biomass of native grasses, scattering slash across the site to serve as mulch appears most beneficial to improving plant species diversity and conserving site resources.

Clary, W.P., M.B. Baker Jr., P.F. O'Connell, T.N. Johnsen Jr., and R.E. Campbell. 1974. Effects of pinyon-juniper removal on natural resource products and uses in Arizona. Research paper RM-128. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 28 p.

Abstract: Results from six treated and control watersheds, along with other results from the southwestern pinyon-juniper type, suggest that: (1) mechanical methods of pinyon-juniper removal are not likely to increase water yield; (2) removal of

pinyon-juniper overstory by herbicides can increase water yield; (3) there has been no statistical verification of changes in flood peaks or water quality due to treatment; (4) herbage yields increase after virtually all pinyon-juniper treatments, but potential livestock carrying capacity varies greatly due to differences in plant composition; (5) the response by deer to these treatments is, on the average, neutral; (6) the more successful conversion projects just about break even from a benefit-cost standpoint under 1972 economic conditions.

Davenport, D.W., D.D. Breshears, P.W. Bradford, and C.D. Allen. 1998. Viewpoint: sustainability of pinyon-juniper ecosystems – a unifying perspective of soil erosion thresholds. J. Range Management 51(2):231-240.

Abstract: Many pinyon-juniper ecosystems in the western U.S. are subject to accelerated erosion while others are undergoing little or no erosion. Controversy has developed over whether invading or encroaching pinyon and juniper species are inherently harmful to rangeland ecosystems. We developed a conceptual model of soil erosion in pinyon-juniper ecosystems that is consistent with both sides of the controversy and suggests that the diverse perspectives on this issue arise from threshold effects operating under very different site conditions. Soil erosion rate can be viewed as a function of (1) site erosion potential (SEP), determined by climate, geomorphology and site erodibility; and (2) ground cover. Site erosion potential and cover act synergistically to determine soil erosion rates, as evident even from simple USLE predictions of erosion. In pinyon-juniper ecosystems with SEP, the erosion rate is highly sensitive to ground cover and can cross a threshold so that erosion increases dramatically in response to a small decrease in cover. The sensitivity to erosion rate to SEP and cover can be visualized as a cusp catastrophe surface on which changes may occur rapidly and irreversibly. The mechanisms associated with a rapid shift from low to high erosion rate can be illustrated using percolation theory to incorporate spatial, temporal, and scale-dependent patterns of water storage capacity on a hillslope. Percolation theory demonstrates how hillslope runoff can undergo a threshold response to a minor change in storage capacity. Our conceptual model suggests that pinyon and juniper contribute to accelerated erosion only under a limited range of site conditions which, however, may exist over large areas.

Dobrowolski, J.P., R. Lanner, J.C. Malechek, and N. West. 1995. Opinions, options clash on pinyon-juniper woodlands. Utah Science. 56(1):14-21.

Abstract: Editorial article discusses a long-term watershed-scale study proposed by the Tintic Research Station near Eureka, Utah, on pinyon-juniper woodlands managed by the BLM. The study was proposed to determine degraded sites, and whether pinyon and juniper trees can be considered invasive under some conditions. Researches also proposed to examine the role of pinyon-juniper woodlands in ameliorating increasing CO_2 levels. The article included a historical perspective of human utilization of pinyon-juniper woodlands, and studies of seed dispersal.

Jameson, D.A. 1967. The relationship of tree overstory and herbaceous understory vegetation. J. Range Management 20(4):247-252.

Abstract: For study of the effect of trees on understory vegetation a good mathematical equation is very helpful. This article presents an equation which fits overstory-understory data better than previously used equations.

Kruse, W.H., R.P. Balda, M.J. Simon, A.M. Macrander, and C.D. Johnson. 1978. Community development in two adjacent pinyon-juniper eradication areas twenty-five years after treatment. Journal of Environmental Management 8:237-47.

Abstract: The ecological impacts of two 26-year-old pinyon-juniper removal projects (one to provide a transmission line corridor and the other for range improvement purposes) were evaluated by comparison with an adjacent, undisturbed woodland site in north-central Arizona. In the range improvement project, the trees had been bulldozed to release forage and grasses. Rangeland, avian and mammalian (small and large) assessments of these 2 disturbed woodlands were made to compare them with an undisturbed native woodland. Most tests showed the corridor to be generally different from the native woodland, whilst the range improvement area was not significantly different from either the corridor or the native condition, suggesting it was in an intermediate stage of development. The bird and mammal populations appeared to develop and change with the vegetation changes, leading to a climax pinyon-juniper woodland.

Laycock, W. A. 1999. Ecology and management of pinyon-juniper communities within the interior West: overview of the "Ecological Session" of the symposium. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 7-11.

Abstract: Categories of papers in the "Ecological Session" were history and ecological change, distribution, classification, ecology and physiology, succession and diversity, and disease. Substantial changes have taken place in pinyon-juniper woodlands over the past 150 years. Coinciding with and following early extensive localized harvesting, these woodlands have been dramatically expanding and thickening. Several authors predicted future large, severe fires. Ecological research reported included seed dispersal and banks, seedling establishment, and ecophysiological relations of pinyon and juniper. One model presented illustrated the process of increases in tree density and cover and corresponding decreases in understory. This model would explain most of the processes and results reported in the other papers.

Pieper, R.D. 1990. Overstory-understory relations in pinyon-juniper woodlands in New Mexico. J. Range Management 43(5):413-415.

Abstract: Herbage biomass for blue grama (*Bouteloua gracilis*), pinyon ricegrass (*piptochaetium fimbratium*), New Mexico muhly (*Muhlenbergia pauciflora*), other grasses, and forbs was estimated on 25 pinyon-juniper stands of varying overstory cover on the Fort Stanton Experimental Ranch in southcentral New Mexico. Negative 2nd degree polynomial curves best expressed the relationships between total understory and blue grama biomass and overstory canopy cover. Positive polynomial relationships were shown for cool-season grasses, New Mexico muhly, and pinyon ricegrass. Reducing pinyon-juniper canopy cover would likely increase blue grama production and reduce production of New Mexico muhly and pinyon ricegrass.

Potter, L.D. and J.C. Krenetsky. 1967. Plant succession with released grazing on New Mexico range lands. J. Range Management 20(3):145-151.
Abstract: After 25 years of protection from grazing, grassland plots tripled in percent of ground cover of grasses. Grazed desert grasslands showed continued increases of mesquite. Protection resulted in remarkable increases in grass cover in ponderosa pine and aspen types.

Svejcar, T. 1999. Implications of weedy species in management and restoration of pinyon and juniper woodlands. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 394-396.
Abstract: A survey of the literature was done to determine of the presence of weedy species is a short-term annoyance or a long-term threat on pinyon-juniper lands. The conclusion is that situations differ with no “cookbook” solutions for managers. Six-step guidelines will help managers find answers for site-specific questions.

Tausch, R.J. 1999. Historic pinyon and juniper woodland development. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 12-19.
Abstract: Climate change influences the ecological processes driving regional vegetation change. With the paleological and geomorphological perspective of Holocene history, it is apparent that each vegetation change interaction with the environment sets the conditions for the next vegetation change. Because of interactions between vegetation and environment, particularly for non-tree species, pinyon-juniper woodlands of the Great Basin represent multiple communities and ecosystems. Multiple successional stages occur in repetitive but constantly changing mosaics across the landscape. Tree expansion over the last 150 years has set up the conditions for the possible decline in woodland areas from large fires expected over the next 150 years. To manage these woodlands, better definitions are needed that define a woodland versus other communities, to account for long term patterns of change and interacting cycles of disturbance and succession.

Tausch, R.J. and P.T. Tueller. 1990. Foliage biomass and cover relationships between tree-and-shrub-dominated communities in pinyon-juniper woodlands. The Great Basin Naturalist. 50(2):121-134.

Abstract: Woodlands dominated by singleleaf pinyon (Pinus monophylla) and Utah juniper (Juniperus osteosperma) cover extensive areas in the Great Basin and southwestern U.S. Both species are aggressive and can nearly eliminate the previous shrub-dominated community. Successional pathways from shrub-dominated communities before tree establishment to the tree-dominated communities that follow are known only for a few specific sites. How site growing conditions affect successional patterns needs further study. We compared the relationship of foliage biomass and percentage of cover between paired shrub-dominated and tree-dominated plots over several sites. Sites studied are from different elevation and topographic conditions on one mountain range. Foliage biomass in shrub-dominated plots had about a three-to-one variation over the range of site conditions sampled. Tree-dominated plots varied by about two to one. Cover in shrub-dominated plots had a four-to-one variation; cover in tree-dominated plots varied by about two to one. Total foliage biomass in both tree-and- shrub-dominated plots correlated best with the site index of height at 200 years of age. Variation in percentage of cover in both tree-and shrub-dominated plots correlated best with elevation. Foliage biomass variation in shrub-dominated plots was proportional to the variation in the paired tree-dominated plots. A similar proportional relationship was present for percentage of cover between paired tree-and-shrub-dominated plots. Foliage biomass was more sensitive to topographic differences than to cover. Variation in plant species sampled in the shrub-dominated plots correlated with total foliage biomass of the same plots. Species sampled also correlated with pinyon height at 200 years of age and total foliage biomass in the paired tree-dominated plots.

Tausch, R.J. and N.E. West. 1995. Plant species composition patterns with differences in tree dominance on a southwestern Utah pinyon-juniper site. Desired future conditions for pinyon-juniper ecosystems. Gen. Tech Report RM-258. USDA Forest Service, Rocky Mountain Forest and Range Station, Fort Collins, Co. 8 p.

Abstract: Fourteen plots covering the range from scattered small trees to full tree dominance were sampled from a single site in southwestern Utah. The rate of reduction in understory cover with increasing tree cover was less than the rate of reduction in total understory leaf biomass with increasing tree leaf biomass. Differences were primarily due to changes that occurred in the crowns of the shrubs. Shrub leaf biomass was rapidly reduced as tree leaf biomass increased, but this initially coincided with minimal loss in shrub crown area or height. Forb leaf biomass initially declined but then increased with increasing tree leaf biomass. A tradeoff occurred between shrubs and forbs at later stages of succession on this site. The grasses were not so affected. Rank by natural logarithm of abundance curves for the plots had several straight lines, reflecting strong dominance by the growing trees. Species interactions within the understory can affect the patterns of understory composition as tree dominance increases.

MISCELLANEOUS TOPICS

Aldon, E.F. and T.J. Loring technical coordinators. Ecology, uses and management of pinyon-juniper woodlands. General Technical Report RM-39. USDA Forest Service. Proceedings of the Workshop, March 24-25 1977, Albuquerque New Mexico.
Abstract: Papers included in this report cover ecology, uses and potential, and management strategies. Properties of wood related to extractives, char quality, etc. are also discussed.

Ffolliott, P.F.1992. Multiple values of woodlands in the southwestern United States and northern Mexico. Gen. Tech. Rep. RM-218. US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. p. 17-21.
Abstract: Values of woodlands in the southwestern United States and northern Mexico for wood and livestock production, wildlife resources, watershed management, and recreation and tourism are described. Many of these woodlands continue to be used as they were in the past. Management is becoming more responsive to the multiple values of woodland communities and people's desires for these multiple benefits, however.

Meeuwig, R.O. and R.B. Murray. 1977. Current research on pinyon-juniper in the Great Basin. Western Juniper Ecology and Management Workshop. Bend, OR. 1977 January. p. 97-103
Abstract: Research in progress [at the time of the report] on pinyon-juniper woodlands in the Great Basin is summarized. The program includes woodland inventory techniques, methods of classifying biotic potentials, use and effects of fire, invasion processes, and methods of revegetation of burned and cutover areas. The goal is increased forage production in harmony with woodland product utilization, soil stability, and recreation.

Williams, G., G.F. Gifford, and G.B. Coltharp. 1969. Infiltrometer studies on treated vs. untreated pinyon-juniper sites in central Utah. J. Range Management 22(2):111-114.
Abstract: Based on data from small-plot studies utilizing high intensity simulated rainfall, conversion of pinyon-juniper stands to grassland in central Utah has not necessarily increased infiltration rates or always reduced sediment yields from a given point on treated areas. Of 14 sites studied, two sites indicated improved infiltration rates and two sites indicated decreased infiltration rates on treated as compared with nearby untreated areas; two sites had significantly less sediment from treated areas compared to nearby untreated areas.

Goodrich, S. and N. Gale. 1999. Cheatgrass frequency at two relic sites within the pinyon-juniper belt of Red Canyon. In: Monsen, Stephen B., Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities

within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18. Provo Utah. Proc. RMRS-P-9. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. p. 69-71.
Abstract: Frequency of cheatgrass (*Bromus tectorum*) is reported for two relic sites within a belt of Colorado pinyon (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*), where non-Native Americans and their livestock are likely to have had little effect.

U.S. Department of Energy. 2001. Careers in renewable energy. Energy Efficiency and Renewable Energy Clearing House.
Abstract: This document outlines the requirements of trained operators in alternate energy development.