Range Management Research, Fort Valley Experimental Forest

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Abstract—*Range management research at the Fort Valley Experimental Forest during the past 100 years has provided scientific knowledge for managing ponderosa pine forests and forest-range grazing lands in the Southwest. Three research time-periods are identified: 1908 to 1950, 1950 to 1978, and 1978 to 2008. Early research (1908-1950) addressed ecological effects of livestock grazing on pine regeneration and forage plant growth. In later years (1950-1978) the research scope broadened to include the multiple uses of forest resources (trees, understory vegetation, livestock, wildlife, etc.), environmental and socio-economic impacts, and tree, forage, and animal interactions and interrelationships. Currently (1978-2008) research is focused on biodiversity, ecosystem restoration, and ecology of invasive non-native species.*

Introduction

The purpose of this paper is to document the first 100 years of range management research at the U.S. Forest Service's Fort Valley Experimental Forest (FVEF) and to explain the significance of this research on the field of range ecology and management. Although we emphasize the work done at FVEF in the ponderosa pine forest, we also touch on other research projects in nearby experimental plots in other vegetation types such as pinyon-juniper and chaparral communities.

The paper has three sections, each reflecting a distinct time period and Forest Service range research focus. The FVEF was established in 1908 in northern Arizona to provide alternatives for protecting and managing forest and range resources. For the period from 1908 to 1950, forest grazing was used primarily for regional economic stability. During this first period, range research focused largely on how domestic livestock grazing impacted forage grasses and ponderosa pine regeneration. From 1950 to 1978, the focus of range research changed from livestock production to multiple use emphasizing timber, forage, and animal interactions in

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ponderosa pine, pinyon-juniper, and chaparral vegetation types. The period from 1978 to 2008 represents yet another era, wherein the focus shifted to biodiversity, ecosystem restoration, and ecology of invasive non-native plant species.

Range research at Fort Valley during the 100-year history included: (1) ecological baseline information and management practices, (2) tree overstory and understory plant relationships, (3) plant-animal relationships, and (4) environmental issues, concerns, and evaluations. Our goal is to highlight range research techniques and practices developed at FVEF and nearby sites and touch on key researchers and some of their significant contributions.

Ecological Effects of Livestock Grazing: 1908 to 1950

In the early years of the FVEF, field researchers often spent their winters in Tucson and summers at Fort Valley. Later they were housed all year at each location conducting their respective research. On site U.S. Forest Service (USFS) scientists were often accompanied by Washington Office personnel who reviewed, coordinated, and assisted in research progress and/or conducted their own independent field research. Some of the noted early scientists and administrators were: G.A. Pearson, R.R. Hill, W.R. Chapline, C.L. Forsling, E.W. Nelson, M.W. Talbot, F. Haasis, C.K. Cooperrider, H.O. Cassidy, E.C. Crafts, R. Price, J.F. Arnold, R.H. Canfield, G. Glendening, C.F. Cooper, B.I. Judd, K.W. Parker, H. Weaver, and A.W. Lindenmuth.

During the period from 1908 to 1950, the livestock industry was strong and grazing lands were utilized mainly for immediate economic returns with limited regard for biodiversity. Range research focused on baseline studies to determine how plant species recovered from past overuse, response of forage plants to the current-day grazing practices, the impacts of grazing on pine regeneration, and determining range condition and trend. The use of grazing exclosures and permanent measurement plots was essential for building baseline information; several of these original projects are discussed here.

R. R. Hill, a USFS Grazing Examiner, divided his time among the first USFS grazing reconnaissance on the Coconino National Forest (1912) and a study to determine the effects of intense livestock grazing on tree regeneration from 1910 to 1914 (Hill 1917). In 1912, he established a study to examine how understory vegetation recovered when protected from livestock grazing. He worked with M.W. Talbot, W.R. Chapline, and G.A. Pearson to select five livestock exclosure sites on the Coconino National Forest, locally known as the "Hill plots." Permanent quadrats were established inside and outside the exclosures, and the vegetation was mapped periodically between 1912 and 1941. Early reports (Arnold 1950, Glendening 1941, Hill 1921, Hill 1923, Merrick 1939, Talbot and Hill 1923) concluded that the herbaceous understory vegetation requires several decades to recover from "severe livestock" grazing. As described below (time period 1978-2008), this early research resumed in 2002 (Bakker and Moore 2007, Bakker and others *these proceedings*).

G.A. Pearson established permanent silviculture plots at Fort Valley (USFS permanent sample plots) in 1909. In 1914, understory plots within the silviculture plots were added to quantify woody and herbaceous plant composition, secondary plant succession, and effects of livestock, rodents, and other possible forms of competition on pine seedling survival (Haasis 1923, Pearson 1923,1933,1942). All plants were charted on 24 plots, then half of the plots were denuded and all plot pairs were remapped five years later (1919). These plots were remeasured again in 1996 (Bakker and others 2002) and results are discussed in a later section (time period 1978-2008).

In 1927 on USFS allotments northwest of Flagstaff (locally known as the "Cooperrider-Cassidy" or "Wild Bill-Willaha" plots), C.K. Cooperrider and H.O. Cassidy studied biological factors responsible for injury to ponderosa pine regeneration and grazing impacts on herbaceous vegetation. After nine years, they observed that cattle, sheep, game animal browsing, and tip moths did the most injury to seedlings more than three years old, whereas rodents damaged younger seedlings (Cooperrider 1938). The herbaceous composition data were never published; however, measurements resumed in 2006 (Laughlin and Moore *these proceedings*) and are discussed later (time-period 1978 to 2008).

In the 1940s, J.F. Arnold remeasured the "Hill" plots to further describe the ponderosa pine-bunchgrass successional patterns and forage yields (Arnold 1950, Bakker and Moore 2007, Clary 1975, Milchunas 2006). He used plant life-form classifications to evaluate range condition and trend and showed bunchgrass survival was reduced by removing the plant apex (Arnold 1955).

G.A. Pearson spent the final years of work summarizing his career. After Pearson's retirement in 1945, G.S. Meagher (Timber Management Research Leader) returned to Fort Valley in 1946 to help complete G.A. Pearson's (1950) monograph. Other research during this time period included the development of Range Utilization Standards (USDA Forest Service 1937), shrub invasion control, flood control surveys, and the Cooperative Western Range Survey. These efforts from 1936 to 1941 were in cooperation with the Soil Conservation Service, Bureau of Agriculture Economics, and Corp of Engineers. In the 1940s, range study plots were established throughout the National Forest Region to provide information on range recovery, utilization, condition, and trend, which provided benchmark data for future measurements. In addition, the Wild Bill allotment was used to test the widely used line intercept method (Canfield 1941).

Multiple Use Era: 1950 to 1978

From 1950 to 1978, the USFS research emphases changed from single-use livestock production to multiple-use. Arriving in 1956, Don Jameson, plant physiologist and range scientist, assisted Elbert H. Reid (Range Management Research Assistant Director) in initially establishing the Southwest Chaparral Woodland and Forest Range Project (SCWFRP) on the Northern Arizona University (NAU) campus in Flagstaff, AZ (Arizona State College before 1966). This initiative was to provide basic and applied range management information and focused on timber, forage, and animal interactions in the ponderosa pine, pinyon-juniper, and chaparral range

types. Research approaches involved plant physiology, ecology, plant and animal (livestock and wildlife) nutrition, economics, and environmental sciences.

Much of Jameson's early research was concerned with plant physiological responses to tissue removal and resistance of plants to heat and desiccation (Jameson and Huss 1959, Jameson 1961a, 1962, 1963). Later he studied the effects of natural growth inhibitors on herbaceous vegetation, plant competition, and plant patterns (Jameson 1961b, 1965a, 1966a, 1966b, 1967, 1968, 1970). Jameson initiated a large-scale ecological study in the nearby pinyon-juniper type that provided a method of comparing the ability of different soils (sedimentary vs. basaltic) to produce native vegetation following tree overstory removal. Herbage yields were determined based on soils, annual precipitation, pretreatment tree canopy cover, and pretreatment nitrates (Clary and Jameson 1981, Jameson 1965b, Jameson and Dodd 1969). In his last years at Flagstaff, Don became the local expert on the newly developed computers and computer modeling. One of his many contributions was the modeling of optimum stand selection for juniper control (Jameson 1971).

Arriving in 1962, Henry Pearson (ruminologist, nutritionist, and range scientist) mainly focused his research efforts on the "Wild Bill Range" (Pearson and Jameson 1967). This study estimated livestock gains from forage intake and nutritional plant values (Figure 1) for cattle grazing in different ponderosa pine stand densities (Clary and Pearson 1976, Pearson 1964, 1972). Grazing intensity was also calculated for maximum livestock profits on ponderosa pine ranges (Pearson 1973). Prior to study initiation, the prevalent dense ponderosa pine stands were thinned or clear-cut to specific tree stand densities: 80, 60, 40, 20, and zero (clear-cut units) sq ft basal area/acre (Figure 2). The original stand density (untreated unit) averaged 110 ft^2 basal area per acre. Three events were touted as reasons for the exceptionally high densities (thousands of seedlings per acre) of the 40+ year-old spindly ponderosa pine: (1) limited livestock control during 1918 (allowing overgrazing and grass competition reductions), (2) exceptionally high ponderosa pine seed yields during the spring of 1919, and (3) unusually high rainfall during June 1919 (normally a dry month). The new pine seedlings flourished when the July summer monsoons began.

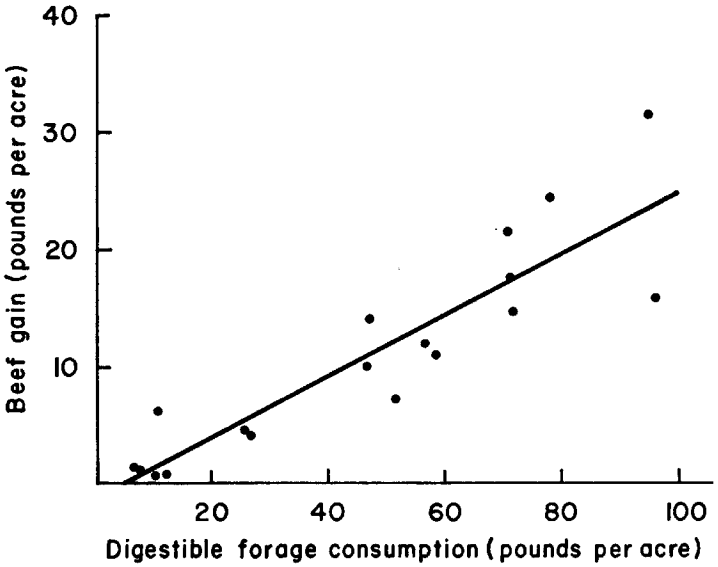

Figure 1. Estimated livestock gains based on forage intake and nutritional plant values (Pearson 1972).

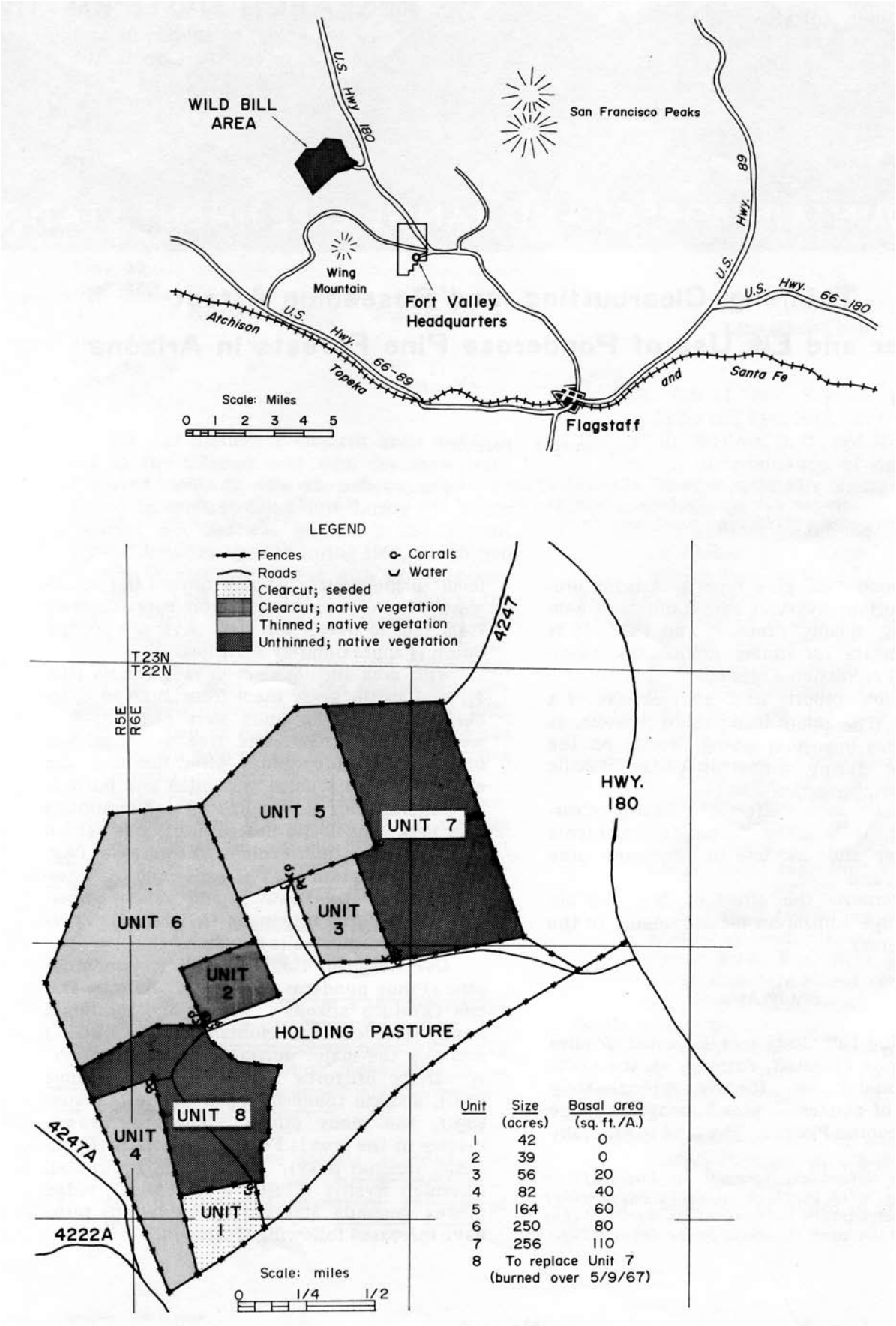

Figure 2. Map of the Wild Bill study area. Top: Location of study area relative to the Fort Valley Headquarters. Bottom: Eight experimental pastures by acreage and stand density (Pearson and Jameson 1967).

Several basic and applied studies branched out to include management and technical methods for timber, livestock, and wildlife (Pearson 1963, 1967a, 1968, Pearson and others 1971). *In vitro* digestibility techniques (Figure 3) for livestock and wildlife research were described in the 1968 national symposium in Flagstaff and Fort Valley (Pearson 1964, 1965a, 1967b, 1967c, 1970). Using rumen fistulated cattle (Figure 4), this nutrition research was a first for the USFS (claimed to be "cutting edge" research by Washington Office Range Division Chief Ken Parker in 1964), resulting in Pearson's appointment to the 17-state Western Range Livestock Nutrition Committee. Rumen studies resulted in microbial descriptions for mule deer, white-tailed deer, pronghorn, and bison (Pearson 1965b, 1967d, 1969a, 1969b). A 7-foot snowfall in December 1967 precipitated a study determining why pronghorn, which were provided highly nutritious alfalfa hay after extended periods without food, died from starvation more than those not provided any supplemental feed. Rumen microbial examinations indicated that the limited rumen absorption of nutrients was confounded by the increased acid production from the high quality hay causing the pronghorn to die from acute acid indigestion (Pearson 1969b). Similar results occurred earlier in mule deer herds of northern Utah (Doman and Rasmussen 1944). Other techniques developed and tested included freeze branding, remote cattle weighing and recording (Pond and Pearson 1971), forage sample storage (Pond and Pearson 1970), remote livestock water developments (Pearson and others 1969), rumen microbial techniques (Pearson 1965a, 1965b, 1967b), and remote radio telemetry (Lascano and others 1970).

Figure 3. *In vitro* digestibility techniques for range livestock and wildlife research (Pearson 1970).

Figure 4. Bill Kruse assisting with rumen fistulated cattle (Pearson 1970).

A May 1967 lightning strike ignited the White Horse wildfire north of the Fort Valley headquarters, burning about 800 acres of forest land, including two experimental pastures on the "Wild Bill Range" (Pearson and others 1972). The unthinned ponderosa pines were decimated by the resulting crown-fire, but the adjacent thinned pines were virtually undamaged due to the fire going across the pasture as a ground fire. Ponderosa pine radial growth increased on trees with crown scorch less than 60% but decreased where it was more than 60% (Figure 5). Burning initially enhanced herbaceous plant growth and nutritive values after the fire.

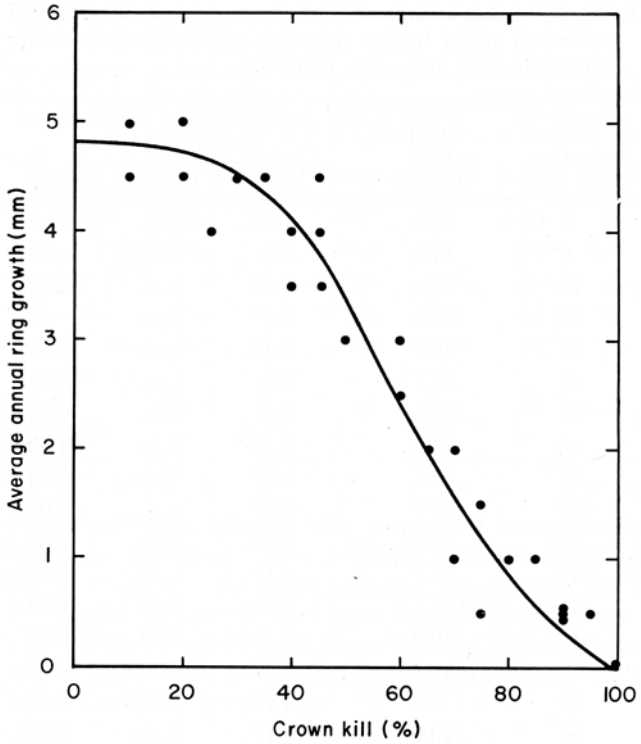

Figure 5. Ponderosa pine radial growth increased on trees with crown scorch less than 60%, but decreased where it was more than 60% as a result of the White Horse fire that burned two experimental pastures on the "Wild Bill Range" in 1967 (Pearson and others 1972).

Arriving in 1966, Floyd Pond (ecologist and range scientist) focused his research on the chaparral range type; however, he also studied plant responses in forested ranges using grazing and clipping studies (Pond 1960). He also found that plant dry matter yield reductions occurred with increased frequency and intensity of harvesting (Pond 1961).

Range scientist Warren Clary, assigned to the nearby Beaver Creek Multiple Resource Evaluation Project, was the longest tenured range scientist at the Flagstaff headquarters (1960–1976). The Beaver Creek Project (Figure 6), a cooperative Rocky Mountain Station (RM) and National Forest System (NFS) Region 3 effort located south of Flagstaff, was established to make multiple resource evaluations of land and vegetation treatments designed to increase overland water yields (Figure 7). Clary first focused on the sampling needed to evaluate herbaceous productivity on the newly formed project.

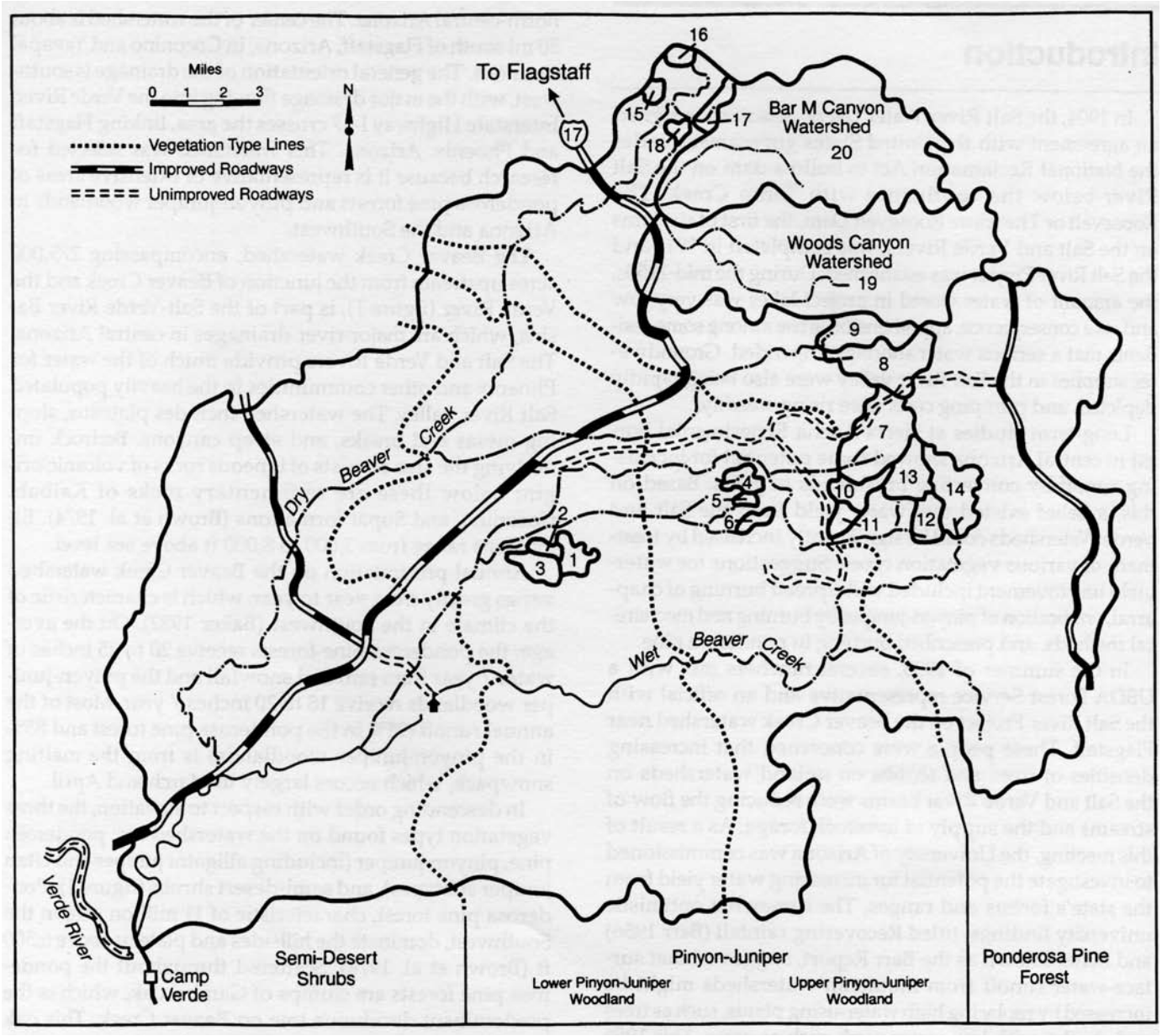

Figure 6. Map of the Beaver Creek Watershed.

Figure 7. Cattle grazing in a Beaver Creek ponderosa pine forest opening.

Clary and colleagues (Peter Ffolliott, Fred Larson, Art Tiedemann, and Bill Kruse) studied the impact of ponderosa pine and pinyon-juniper modifications, such as cabling, sawing, and herbicide treatments on timber growth, forage yields, and their interrelationships with soil, hydrologic response, and wildlife habitat (Clary 1964, Clary and Ffolliott 1966, Clary and Jameson 1981, Clary and Larson 1971, Clary and others 1974, 1978, Ffolliott and Clary 1975, 1982). Each treatment approach produced a different combination of effects.

The economic effectiveness of tree overstory modifications on forage value, livestock carrying capacity and distribution on the landscape, trade-off relationships, and optimum combinations of timber products (such as sawtimber, pulpwood, and fuelwood) and livestock were studied (Figure 8; Clary 1978, 1983, 1987, 1988, Clary and Grelen 1978, Clary and others 1974, 1975, 1978). Cooperators Don Neff and Clay McCulloch, Arizona Game and Fish Department, and Hudson G. Reynolds, USFS RMRS Wildlife Biologist, examined the effects of treatments on forage and habitat for deer, elk, small mammals, and livestock (Clary 1972, Reynolds and others 1970).

Arriving in 1965, range technician William (Bill) Kruse eventually became the only range researcher at the Flagstaff location following Clary's departure in 1976. He was later transferred to Green Valley, Arizona, as superintendent of the Santa Rita Experimental Range (Ffolliott and others 2003). He returned to Flagstaff as a range scientist following completion of his MS degree. Some of his accumulated wisdom and experience was expressed in Kruse and Baker Jr. (1998) and in two book chapters: "Grazing systems of the southwest" (Kruse and Jemsion 2000) and "Livestock grazing in riparian areas: environmental impacts, management practices and management implications" (Clary and Kruse 2004).

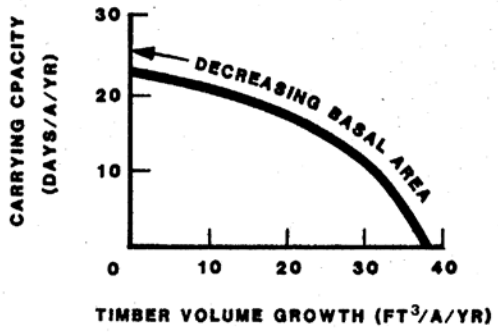

Figure A.--Production possibilities frontier for livestock grazing and wood growth.

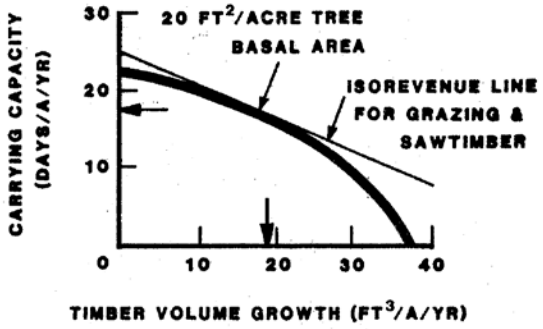

Figure B --Optimum thinning intensity when considering grazing and current sawtimber prices.

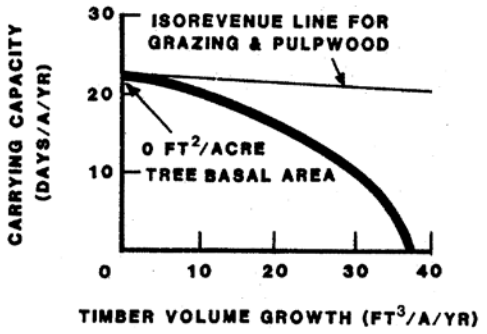

Figure C .--Optimum thinning intensity when considering grazing and current pulpwood prices.

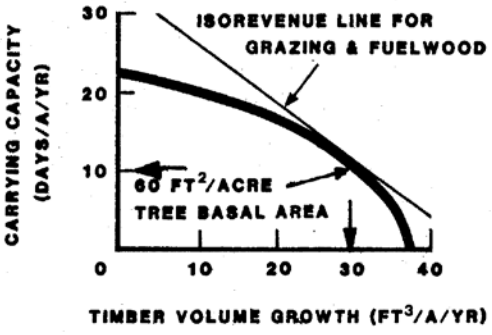

Figure D.--Optimum thinning intensity when considering grazing and current fuelwood prices.

Figure 8. Production possibilities for ponderosa pine ranges based on 1982 product values from the Wild Bill Range.

During the 1950-1978 era of research at Flagstaff, the Agricultural Research Service housed three scientists (Thomas N. Johnsen, Jr., Fred Lavin, and Fred B. Gomm) at the Forest Service Laboratory on the NAU campus. They conducted research on range seeding and noxious plant control across northern Arizona including on or near the Fort Valley headquarters (Johnsen 1980, 1986a, 1986b, Johnsen and Gomm 1981, Lavin 1967, Lavin and others 1968, 1973, 1981).

Biodiversity and Restoration Era: 1978 to 2008

The period from 1978 to 2008 represents yet another era in range-related research at Fort Valley. This era represented a shift from research focused on achieving multiple products to efforts to restore native forest diversity and studies on the ecology of invasive non-native plants. Major efforts have focused on resampling permanent plots, experimenting with cutting and burning treatments designed to restore historic structure and functions, and greater emphasis on understanding how treatments and wild fires influence the growing number of non-native species.

Continued Work on the Hill, Pearson, Cooperrider Permanent Plots

In recent years, there has been an increased interest in quantifying herbaceous vegetation structural and compositional changes in the southwestern ponderosa pine-bunchgrass ecosystems from the early 1900s to present. The rediscovery of the permanent chart quadrats originally established and mapped by R.R. Hill, G.A. Pearson, and C.K. Cooperrider and other scientists between 1912 and 1941 (described in 1908 to 1950 section) provided opportunities to detect and quantify long-term changes in the understory vegetation. With the fine-grained maps showing the location of individual plants, life history (establishment, survival, growth, death) and plant community attributes (composition, cover, etc.) can be quantified. New technologies including geographic information systems and more powerful statistical methods allowed vegetation analyses that were not possible 100 years ago.

From 1996 until 2007, Margaret Moore and associates at NAU, with the original records and old maps from the USFS Fort Valley Archives and the aid of a metal detector, relocated most of the original field plots and have reanalyzed some of these data (Figure 9; Bakker and others 2002, 2006a, 2006b; Bakker and Moore 2007, Bakker and others *these proceedings*, Laughlin and Moore *these proceedings*). Data collections in 1996 on the Pearson understory plots showed species richness reductions and shifts in C_3 and C_4 grasses, although the 'natural' and denuded plot pairs did not differ after 90+ years (Bakker and others 2002). Recent analyses on data from the Hill plots have shown that differences between historical grazing treatments, which may have been evident at one time, have now disappeared once overstory effects such as shading are taken into account. Although herbaceous species richness and cover have declined from 1941 to present, it is due to the overwhelming effect of increasing tree density (Arnold 1950, Bakker and Moore 2007, Clary 1975). Currently, the research team continues to relate shifts in plant composition to physical soil traits, climate, and land-use changes; and to build predictive models using these unique data sets.

GPNA—Restoration Experiment

An experiment was initiated in 1992 on a decommissioned portion of the G.A. Pearson Natural Area on the FVEF to evaluate long-term ecosystem responses to two restoration treatments: thinning only and thinning with prescribed burning (composite treatment). These experiments were similar to the ones initiated on the "Wild Bill Range" in the 1960s and 70s (discussed above), but restoration treatments have a slightly different emphasis on retaining old-growth trees, examining tree spatial pattern, and evaluating restoration of ecosystem functions. Age data were used to document the presettlement forest structure in 1876. Overstory and understory vegetation and ecosystem responses were examined within treatments and further stratified by four patch types (Moore and others *these proceedings*). As expected, the herbaceous standing crop, measured between 1994 and 2004, was significantly higher on the two treated areas (thinned and thinned plus burned) than on the control over the entire post-treatment period, but did not differ between the treatments (Moore and others 2006). Restoring herbaceous species diversity and community composition continues to be more difficult than restoring ecosystem structure such as herbaceous standing crop.

Figure 9. Repeat photographs illustrating the dramatic changes that have occurred in southwestern ponderosa pine forests. Repeat photos of one Hill Plot site called Black Springs in 1941 (left) and 2003 (right). Note circles indicating same stump in middle of both pictures (behind smaller tree in 2003) and forked tree in both photos (right foreground). 2003 photo: J.Bakker

Floristics and Ecology of Non-Native Invasive Plant Species

Carolyn Hull Sieg and colleagues have initiated studies at the FVEF and surrounding areas with new objectives focusing on documenting biodiversity and addressing the ecology of non-native invasive plant species. In 1976, Jack Dieterich and Stephen Sackett initiated a study at Chimney Spring on the FVEF and in 1977 at Limestone Flats on the Long Valley Experimental Forest to examine the effects of reintroducing fire at varying intervals into ponderosa pine forests (Sackett 1980; Sackett and others 1996; Sackett and Haase *these proceedings*). Marking 30 years of burning treatments at Chimney Spring and Limestone Flats, Scudieri and others (*these proceedings*) provide a complete plant species list for each study site in an effort to document important changes since these studies were initiated. Other studies focused on non-native plant invasives include examining the role of disturbances in perpetuating bull thistle (Crisp 2004) and Dalmatian toadflax (Dodge and others *In press*), and how plant communities have changed following recent wildfires (Kuenzi and others 2008, Sabo and others *In press*). Their work has documented the presence of several non-native species that have been used in past seeding projects to enhance livestock forage (Fowler and others 2008), and also a number of new invaders that pose problems for perpetuating productive native plant communities. Given the number of recent arrivals, land managers will be forced to prioritize which non-native species they cannot afford to ignore (Sieg and others 2003).

Summary

Several important range management research methods and land management recommendations were developed during the 100-year history of the FVEF. Although multidisciplinary studies were common since FVEF was established in 1908, the research focus has gradually evolved over the years. Until the early 1950s studies largely focused on the ecological effects of livestock grazing on ponderosa pine regeneration and forage plants. In the multiple-use era, from 1950 to 1978, studies shifted from single-use livestock production to multiple-use management questions. The most recent era of range-related research at FVEF, beginning in 1978, is characterized by increasing emphasis on biodiversity, ecosystem restoration, and ecology of invasive plant species. Many sampling and fundamental management techniques for forested rangelands came from these studies. The research results originating from FVEF and nearby experimental plots had widespread implications and applications to forests and ranges throughout the Southwest.

Acknowledgments

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