University of Nevada, Reno

Fuel Analysis in Upper Elevation Pinyon-Juniper Woodlands of Lincoln County, Nevada

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in
Geography

by

Jonathan W. Cheek

Dr. Franco Biondi/Thesis Advisor

December, 2009

University of Nevada, Reno
Statewide • Worldwide

THE GRADUATE SCHOOL

We recommend that the thesis
prepared under our supervision by

JONATHAN W. CHEEK

entitled

Fuel Analysis In Upper Elevation Pinyon-Juniper Woodlands Of Lincoln County, Nevada

be accepted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

Franco Biondi, Advisor

Jason Sibold, Committee Member

Robin Tausch, Graduate School Representative

Marsha H. Read, Ph. D., Associate Dean, Graduate School

December, 2009

ABSTRACT

Wildland fires are an important component of the Great Basin ecosystem, and their behavior is greatly controlled by forest fuels. Understanding changes in fuel conditions through time can enable managers to better manage fire use. Using data from permanent plots located within Mount Irish and the Clover Mountains of Lincoln County, Nevada, I studied current fuel conditions and their past changes in relation to historic stand composition and structure, climate variability, fire occurrence, and human impacts. My objectives were to quantify current surface and crown fuel, canopy bulk densities, and to use a regionally-specific vegetation simulator to: (1) reconstruct forest structure; (2) estimate changes in canopy fuels at each study site from time of settlement through the present (2007 at Mount Irish and 2008 at the Clover Mountains) and near future (2050); and (3) estimate changes in potential crown fire behavior over time. *Pinus ponderosa, Pinus monophylla, Juniperus osteosperma, Juniperus scopulorum,* and *Abies concolor* are tree species at the two study sites. Current fuel characteristics were quantified by: down dead woody debris (planar intercept method), litter and duff bulk density (collection and weighing), and canopy biomass and bulk density (allometric equations and Fuel Management Analysis Plus program). Percent cover for herbaceous and shrub vegetation was estimated using a Braun-Blanquet (1965) cover class system. The Clover Mountains have significantly higher amounts of 10-hr surface fuel and lower bulk densities of litter, and combined litter and duff (103.4 kg/m^3 at Mount Irish, 63.8 kg/m^3 at the Clover Mountains), which favor a higher rate of surface fire spread compared to Mount Irish. Both study sites have similar herbaceous cover percentages, but the Clover Mountains have higher percent cover of shrub vegetation, which also favors surface fire spread. Combining all species, canopy bulk density is significantly greater ($P \leq 0.05$) at Mount Irish (0.195 kg/m^3) compared to the Clover Mountains (0.085 kg/m^3). This indicates that Mount Irish is more susceptible to a severe crown fire. Forest simulation modeling using USDA Forest Vegetation Simulator (FVS) began in 1900 at the Clover Mountains and in 1850 at Mount Irish, and modeled changes in canopy fuels (canopy biomass, canopy bulk density) and potential fire behavior (crowning index) through 2050. Simulations were relatively accurate, as assessed by comparing the simulation output in the year 2007 for Mount Irish and in the year 2008 for the Clover Mountains with field data collected in those years. I used a regionally calibrated simulator for the Great Basin (Utah variant) and I added regeneration by species and density in the correct historical sequence. Potential crown fire behavior was assessed with FVS in terms of crowning index (CI), the windspeed necessary to sustain a crown fire. Crowning index values decreased by 47.5% at Mount Irish and by 60% at the Clover Mountains over the modeled periods, indicating that both sites are becoming more susceptible to crown fire. If management goals are to prevent this type of destructive fire, then careful examination of available options to modify existing fuel loads is recommended.

Acknowledgements

I greatly appreciate and thank my committee members Dr. Franco Biondi, Dr. Jason Sibold, and Dr. Robin Tausch for their assistance and support throughout the duration of this project. In addition, I would like to thank the following for fieldwork sampling and analysis assistance: Megan Bradley, Jeff Crawford, Kelli Hoover, Mackenzie Kilpatrick, Michael Koch, Katie Mann, Alex Mensing, Kevin Rock, Kurt Solander, and Scotty Strachan. I would also like to thank Dr. Nicole Vaillant (Fire Ecologist, USDA Forest Service) for her assistance with FMAplus and FVS software, and Dr. Scott Mensing for providing access to his laboratory. Research support for this project was provided by Cooperative Agreement No. FAA070002, with the Bureau of Land Management, Department of the Interior, U.S. Government, under the Great Basin Cooperative Ecosystem Studies Unit Agreement with the University of Nevada, Reno. The opinions and conclusions contained in this document are those of the authors and should not be interpreted as representing those of the U.S. Government. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government.

TABLE OF CONTENTS

APPENDICES

INTRODUCTION

The Great Basin contains unique ecosystems that are under the influence of wildland fire. Understanding the driving forces behind wildfires is crucial to manage forest dynamics to protect areas of historical and economic significance, to maintain ecological biodiversity, to reduce the alteration of natural fire regimes, and to aid fire management.

Juniperus osteosperma is the most widespread conifer in Nevada while *Pinus monophylla* is the most common and widely distributed pine in the state (Charlet 1996). Significant expansion of these dynamic woodland communities within the past 130 to 150 years has been observed throughout the Intermountain West, with grazing, fire suppression, and climate changes being the major causes (Miller et al. 1994; Miller et al. 2001; Tausch et al. 1999). As these woodlands expand, the historic fire regime is being altered within the Great Basin. This has been observed through significant increases in the length of mean fire return intervals (Miller et al. 2001). Climatic episodes, such as the oscillations of the warm El Nino and cold La Nina, also influence the fire regime in the southwestern United States (Brown et al. 2008; Swetnam et al. 1990). Wet and dry climatic cycles affect forest fuel characteristics by promoting combustible biomass during wet periods, and then burning during dry periods (Brown et al. 2008; Westerling et al. 2003; Westerling et al. 2006). The dry climate of The Great Basin has a unique affect on fuels by intensifying the accumulation of fuels through very slow decomposition rates (Sackett et al. 1996).

Ecologists have recognized that ecosystems are not static and that changes in ecosystem structure are not unlimited or entirely unpredictable, but are generally constrained within certain limits. Veblen (2003a), Landers et al. (1999), Floyd et al. (2000), and Swetnam et al. (1999) suggest that managers need to understand the historical range of variability (HRV) of these ecosystems. This concept is used to describe the typical magnitude of change that may occur over centuries or millennia within ecosystems. The HRV may pertain to climate (Veblen 2003a; Stephenson 1999; Swetnam 1990; Romme et al. 2003; Miller et al. 1994, 2001; and Tausch 1999), anthropogenic (i.e. pre- and post-Euro-American settlement) land use and impacts (Veblen 2003a; Landers et al. 1999; Floyd et al. 2000; Swetnam et al. 1999; Miller et al. 1994, 2001; Tausch 2007, and Baker 2004), fire regimes (Cissel et al. 1999; Veblen 2003a; Floyd et al. 2000; Stephenson 1999; Swetnam et al. 1999; and Romme et al. 2003, 2007), species composition and stand structure (Veblen 2003a; Landers et al. 1999; Stephenson 1999; Swetnam et al. 1999; Romme et al. 2003, 2007; Miller et al. 1994, 2001, 2008; Tausch 1999; and Tausch et al. 2007), and spatial and temporal species variation (Veblen 2003a; Landers et al. 1999; Swetnam et al. 1999; Romme et al. 2003, 2007; Miller et al. 2008; and Tausch et al. 2007). This concept is particularly useful because it plays a key role in resource planning and management decisions by recognizing historic ecosystem structures and how they have been influenced by natural and anthropogenic processes. Flannigan et al. (2000) describe the impacts of climate change on forest fires and how this will impact forests in the United States. Veblen (2003a) observed extreme fire events of the 20th century in Patagonia, Argentina that were outside the HRV due to ecological changes attributed to Euro-American land use practices. Floyd et al. (2000) and Romme et al. (2003) observed similar 20th century extreme fire events in Mesa Verde National Park, Colorado that were within the HRV, suggesting that human activities have not altered the Mesa Verde fire regime. Restoration efforts may be needed in situations observed by Veblen (2003a), but not in circumstances observed by Floyd et al. (2000) and Romme et al. (2003). Therefore, the HRV of particular areas is critical in determining appropriate management strategies.

In the American southwest, Miller et al. (2008), Tausch et al. (2007), and Baker et al. (2004), have documented pinyon and juniper woodland expansion into shrub-steppe communities and how it influences fire severity and frequency. Pinyon-juniper trees associated with the woodland expansion have continuously increased in density and cover, which has caused a decrease in understory biomass (Miller et al. 2001). However, minimal work has been performed from a landscape perspective to determine how topographic factors, such as aspect and elevation, influence stand-level rates of development and structural characteristics (Johnson et al. 2006). Thus, minimal information exists on the mechanisms influencing tree establishment within the expanding pinyon-juniper woodlands in the Great Basin (Chambers 2001).

As a way to reconstruct tree population, increment core samples have been used to determine species establishment (Miller et al. 2008) and tree age (Brown et al. 1982). Miller et al. (2008) note that pinyon and juniper expansions began after 1850, with the most rapid expansion and tree establishments occurring between 1900 and 1920 in Nevada. Romme et al. (2003, 2007), Miller et al. (1994), Tausch (1999), and Heyerdahl et al. (2001) suggest that woodland expansion in both time and space was connected to a reduction of fire frequency, the introduction of livestock grazing, and climate. Livestock influenced woodland expansion throughout the Great Basin by reducing herbaceous vegetation cover and other fine fuels resulting in a decrease in fire occurrence that allowed trees to establish (Miller et al. 1994, 2001; Tausch et al. 2007). Chambers (2001) also notes how the reduction in herbaceous cover promotes an increase in shrub cover, which act as nurse plants and promotes the establishment of tree seedlings. Although there has been a reduction in fire frequency, Baker et al. (2004) discuss that nearly all observed fires in these expanding woodlands since Euro-American settlement have been high-severity fires, and suggest that high-severity fires were the typical fire type in historic pinyon-juniper woodlands. Miller et al. (2001), Tausch et al. (2007), and Romme et al. (2007) note that woodland expansion has caused a shift in biomass from surface and ground fuels to canopy fuels, with an increase in fuel continuity. This type of fuel transition will result in infrequent high intensity crown fires. Therefore, determining historic and current fuel conditions can assist in predicting future fire behavior.

The "fire exclusion/fuel buildup" perspective is the dominant view of current wildfire management problems among political leaders, resource managers, and the general public (Veblen 2003b). This perspective suggests that unnatural fuel buildup has resulted from suppression of formerly frequent fires. The effect of the increased fuel buildup may lead to more catastrophic fires. However, this perspective is supported in some ecosystems, but not in others (Veblen 2003b). Therefore, the use of the fire exclusion/fuel buildup perspective must be used on a site to site basis. Schoennagel et al. (2004) give an example of a subalpine forest in the Rocky Mountains and Sherriff et al. (2006) show higher elevation ponderosa pine dominated forests on the eastern slope of the northern Colorado Front Range where the fire exclusion/fuel buildup perspective is not supported. However, Schoennagel et al. (2004) also give an example where the perspective is supported in low-elevation ponderosa pine forest. Escobedo et al. (2001) acknowledge that fuel buildup due to fire exclusion is site-specific and related to the types of fuels measured. In Sequoia National Park, Knapp et al. (2005) note that fire suppression in the past 120 years has allowed fuel to accumulate without the presence of historically common surface fires.

Many ecologists have studied the effect of fuels on fire behavior. Brown et al. (1973) state that forest fuels are the most influential factor in the ignition, buildup, and behavior of fire. Westerling et al. (2003) note that fire dynamics and, especially, large-scale fires in the Great Basin are dominated by fine fuels. Sackett et al. (1996) note that rapid accumulation and extremely slow decomposition of fuels in the American southwest increases fire severity due to the dry climate.

Fuel characteristics determine the rate of combustion (Johnson et al. 2001) and supply the basis for assessing fire outcome (Sackett et al. 1996). These characteristics include: surface area to volume ratio, fuel moisture timelag class (discussed later), packing ratio, and fuel load. Surface area to volume ratio is important because as more surface area is present for combustion, heating of the whole fuel particle is faster, and moisture is driven off more quickly. The packing ratio is the fuelbed compactness and is calculated by dividing the bulk density of the fuelbed by the fuel particle density. Combustion will not occur if the packing ratio is too high because not enough oxygen can reach the fuel (van Wagtendonk 2006). In addition, higher packing ratios release and gain moisture at a slower rate compared to lower packing ratios (Stephens et al. 2004). If the packing ratio is too low, fire has difficulty spreading as the distance from particle to particle increases (van Wagtendonk 2006) and flaming combustion would produce larger flame lengths because moisture evaporates more quickly with lower packing ratios, which explains why ponderosa pine needles support surface fires more than white fir (Stephens et al. 2004) and pinyon pine needles (van Wagtendonk et al. 1998). Fuel load is the amount of fuel that is potentially available for combustion. Fuel load influences the amount of energy released and fire spread rates depending on fuel particle size, packing ratio, and whether or not it is dead or live fuel. The rate of fire spread may actually decrease as fuel loads increase because the extra fuel converts to a greater heat sink, and more heat is required for combustion (van Wagtendonk 2006).

Fuels are broken down into three classifications: ground, surface, and canopy fuels and are categorized based on the location of the uppermost fuel layer through which they burn, with each layer influencing fire behavior differently (Johnson et al. 2001). Ground fuels, most commonly ignited by passing surface fire (Scott et al. 2001), include duff, roots, peat, and rotten buried logs (Johnson et al. 2001), which are located in the upper soil layer (DeBano et al. 1998). Duff is both the fermentation layer, where decomposition has begun but the particles can still be recognized, and the humus layer, where organic material is compressed and in all states of decay (Brown 1974; van Wagtendonk et al. 1998). Duff accumulation is the result of the difference between duff production and decomposition (van Wagtendonk et al. (1998). Fire spread is usually slow within ground fuels because of its compactness, and burning typically occurs through smoldering combustion (Pyne et al. 1996, Johnson et al. 2001). The impacts of slow ground fires can be much more severe compared to fast moving surface fires with high flame lengths. Tree basal injury, tree death through cambium mortality, and loss of fine root hairs can be caused by a ground fire smoldering for days through deep, accumulated duff (Stephens et al. 2004; van Wagtendonk 2006).

Surface fuels contain needles, leaves, live and dead grass, forbs, dead and down branch wood and logs, shrubs, and trees less than 1.8 m tall (Johnson et al. 2001; Scott et al. 2001). Majority of wildland fires ignite in and are carried by surface fuels (Pyne et al. 1996). Litter, also referred to as downed woody material (Brown 1974), consists of recently fallen and partially decomposed tree leaves, fallen twigs, bark, and branches that still retain their morphological characteristics (Brown 1974; van Wagtendonk et al. 1998). A component of litter are fine fuels which are porous (van Wagtendonk 2006) and are fast-drying dead fuels that are less than 1 cm in diameter, ignite readily, and are consumed quickly by fire (DeBano et al 1998). The ratio of surface area to volume of fine fuels is a useful indicator of fuel flammability (Brown 1970). The behavior of surface fires varies depending on the characteristics of the surface fuel complex (Scott et al. 2001).

Canopy fuels consist of overstory and understory trees, large shrubs, and snags (Pyne et al 1996). When canopy fuels ignite, a crown fire is the result. Crown fires advance from top to top of trees or shrubs, mostly independently of the surface fire (DeBano et al. 1998), and are usually carried by wind (Wolf 2003). Three types of crown fire exist. Passive crown fires are the least severe in that they burn surface fuels and single trees or groups of trees (van Wagtendonk 2006), but a solid flame is not consistently maintained in the canopy (Scott et al. 2001). Active crown fires burn in the canopies in concurrence with a surface fire (van Wagtendonk 2006), and are dependent on heat from the surface fuels for continued spread (Scott et al. 2001). Wind may assist a passive crown fire to become an active crown fire. Rarest are independent crown fires which spread the fastest and spread far ahead of or in the absence of surface fire (van Wagtendonk 2006). These short lived fires require a combination of steep slope, high windspeed, and low foliar moisture content (Scott et al. 2001). Crown fire spreads faster and causes more severe and lasting damage than a surface fire burning under the same conditions (Scott et al. 2002)

Ladder fuels typically occur in denser stands, sometimes as a result of fire suppression, where there is a continuous fuel layer between ground fuels and canopy fuels, and may promote large, catastrophic fires (Schoennagel et al. 2004). These fuels allow fire to be carried from surface fuels into canopy fuels (Pyne et al 1996). However, ladder fuels may not exist or may play a limited role, particularly in less dense forests such as those in the Great Basin. Low crowns down to or near the ground may act as ladder fuels (van Wagtendonk 1996) in pinyon-juniper woodlands (Robin Tausch, personal communication) within the Great Basin.

These fuel classifications can affect each other depending on interactions between dominant vegetation types and stand structure. For example, the suppression of understory species caused by dominant tree encroachment reduces the susceptibility of a site to fire due to the decrease in surface fuels. Crown fires become more common as the trees mature with larger and denser crowns (Miller et al. 2001). The transition from a surface to a crown fire can be very severe and can greatly influence fire behavior (Van Wagtendonk 1996). This phenomenon is referred to as torching, and is an important interaction. Dry surface fuels, low humidity and high temperatures, heavy accumulations of dead and downed litter, canopy base height, fuel availability in crowns, fuel moisture content, local weather conditions, and the presence of ladder fuels determine if a surface fire will transition to a crown fire (Hall et al. 2006; Beighley et al. 1990).

The amount of dead fuel that is capable of combustion in a given fire is determined mostly by fuel moisture. Abiotic factors that determine fuel moisture include the size, quantity, composition, location, arrangement, compactness, and continuity of dead fuels (Pyne et al. 1996; Johnson et al. 2001; DeBano et al. 1998; and Westerling et al. 2003). Finer fuels have a higher ignition potential than heavier fuels because they typically lose moisture more rapidly (Westerling et al. 2003). Fuel sizes are categorized into classes based on the equilibrium moisture content, which is related to the moisture of the surrounding air (Pyne et al. 1996) and is dependent on fuel particle size or its depth in duff (van Wagtendonk 2006). The diameter size classes are 0-0.64 cm, 0.64-2.54 cm, 2.54-7.62 cm, and >7.62 cm, and are also considered 1-, 10-, 100-, or 1000-hour time lag classes (Martin et al. 1981; Brown et al. 1982). The time lag interval is defined as the time required for dead fuel to lose 63% (1-1/e) of the difference between its initial moisture content and the equilibrium moisture content in an atmosphere of constant temperature and relative humidity (Pyne et al. 1996). The more a dead fuel can retain its fuel moisture, the lower the rate of burning and fuel consumption will be (Johnson et al. 2001). Quantity is the amount of all fuel sizes located within an area. As the quantity of fuels increases, along with low moisture content, so does the potential for fire to increase in size and intensity. The composition of litter and dead fuel (needles, pine cones, rotten wood, grass, etc.) affects the amount of time for the fuel to gain or lose moisture (Pyne et al. 1996). The location of dead fuel determines the amount of moisture that a fuel may contain. If a fuel is not located under a canopy, direct solar radiation will lower the moisture content and cause the fuel to become more susceptible to combustion (Pyne et al. 1996). The arrangement of litter within surface fuels also determines the moisture content. If the arrangement of litter is compact, air circulation will be limited and fuel aeration will occur at a slower rate. When litter is not compact, the fuel is able to dry at a faster rate, thus increasing the probability of combustion (DeBano et al. 1998; Pyne et al. 1996). Arrangement can also be viewed as a biotic factor influenced by species composition. For example, *P. ponderosa* needles on the forest floor usually burn more rapidly and efficiently than *P. monophylla* and *J. osteosperma* because their longer needles pack together less tightly and form more porous fuelbeds than short and flat needles (DeBano et al. 1998; van Wagtendonk et al. 1998). Fuel continuity (connectivity) influences the rate of surface fire spread. If fuel distribution is discontinuous, the rate of fire spread will decrease. Sando et al. (1972) state that fuel amount and continuity may be the most important fuel characteristics influencing fire behavior. Miller et al. (2000) note that fuel load, fuel moisture, and bulk density of a fuel bed directly influences fuel continuity and suggest that fire suppression may increase fuel continuity and can result in qualitatively different fire patterns and behavior.

Topography (slope steepness, aspect, and elevation) is another abiotic factor that influences the susceptibility of fuels to combust. Topography influences fuel moisture (Heyerdahl et al. 2001; Pyne et al. 1996) and plays a significant role in stand structure and development (Johnson et al. 2006). Aspect affects fuel characteristics through variations in the amount of solar radiation that different aspects receive. An aspect facing the sun will have a lower humidity and higher fuel temperature resulting in a higher probability of fuel combustion (Pyne et al. 1996). Aspect can contribute local variation in fire frequency by directly affecting fuel moisture through solar radiation and the duration of time that snow exists, and indirectly affecting fuel type (Heyerdahl et al. 2001). Elevation influences local climate and affects fuel availability. The amount of precipitation and snow melt, and differences in temperature differ among elevations causing variations in fuel availability (Pyne et al. 1996), fuel type, and fuel moisture (Heyerdahl et al. 2001). Slope steepness directly affects flame length and the rate of spread of a surface fire (Heyerdahl et al. 2001; Pyne et al. 1996). The steeper the slope, the longer the flame length and faster fire spread rate will be. Steep slopes, along with wind, enhance heat transfer by convection and are conducive to hurling embers into the air which produce spot fires ahead of a flaming front (van Wagtendonk 2006).

Quantifying forest fuel is important in predicting potential fire behavior. A common inventorying technique is to determine the bulk density of surface, ground, and crown fuels. Bulk density for ground and surface fuel is referred to as fuelbed bulk density and is calculated by dividing “oven-dry weight of organic material by sample volume” (Stephens et al. 2004). Ground fuels are distinguished by higher bulk density than surface and canopy fuels (Scott et al. 2001). The importance of fuelbed bulk density is that it acts as a heat sink (van Wagtendonk et al. 1998) and influences fuel moisture, fire behavior, and the available time for combustion. Higher fuelbed bulk densities will result in a less intense, slower rate of fire spread because moisture is released at a slower rate (Stephens et al. 2004) and more fuel must be raised to ignition temperature (van Wagtendonk et al. 1998; van Wagtendonk 2006). In contrast, lower fuelbed bulk densities result in fuel drying faster due to higher porosity (van Wagtendonk et al. 1998) and fuel becoming available for combustion for longer periods (Stephens et al. 2004). In addition, the flaming combustion associated with lower fuelbed bulk densities may produce larger flame lengths because moisture evaporates more quickly. Differences in leaf morphology and decomposition rates may explain the differences between lower and higher fuelbed bulk densities (Stephens et al. 2004).

Canopy bulk density (CBD) is used to describe the bulk density of canopy fuel of a stand, not an individual tree (Scott et al. 2001), and is defined as the “dry weight of the available canopy fuel per unit of canopy volume, including the spaces between the tree crowns”. A high fuel load does not necessary mean a high bulk density (Scott et al. 2002). Higher CBD, lower crown base heights, and higher wind speeds than those needed for passive crown fires are required for active crown fires. Once an active fire occurs, the critical spread rate decreases rapidly as crown bulk density increases from 0.01 to 0.05 kg/m^3. As a result, the actual spread rate needed to initiate crown fire spread becomes less. Fire is able to spread more easily from tree to tree as canopies become denser. There is little additional effect on the critical spread rate after CBD reaches 0.15 kg/m^3. CBD can be effectively reduced by thinning, but may contribute to active surface fuel if the thinned debris is not removed (Stephens et al. 2005).

Van Wagner (1968) began to use the line intercept method for measuring forest fuels for forest fuel management. The technique is “rooted in probability-proportional-to-size concepts” (Sikkink et al. 2008). Van Wagner states that collecting and weighing is the least troublesome way to measure fine fuel. However, he notes that larger-sized fuel estimates would be simplified by tallying all the pieces that intersected a sample line. The method contains three assumptions: (1) the pieces are cylindrical, (2) all pieces are horizontal to the ground, and (3) the pieces are randomly oriented. With these assumptions come potential errors. Van Wagner (1968, 1982) and Brown (1974) discuss in detail how to avoid these errors through sampling layout design. The line intersect method is more advantageous than ‘quadrant sampling’ in that there is no need to delineate the quadrants and determine which objects are in each quadrant (Kaiser 1983).

Brown (1971, 1974) developed the planar intercept method, which is an expansion of Van Wagner’s (1968) line intercept method and has the ability to be applicable to a wider range of fuel conditions than the line intercept method. The method can calculate weights and volumes of downed woody material for all diameter size classes, average diameter of debris larger than 7.6 cm, and depth of fuel and forest floor litter. “Fuel weight is estimated by counting the number of intercepts of woody fuel particles in different size classes with a sampling plane. The intercepts are then multiplied by factors derived from physical properties of woody fuels of Rocky Mountain conifer species (van Wagtendonk et al. 1998)”. Potential errors and bias, similar to those encountered in the line intercept method, can occur but can be eliminated through sampling layout design (Brown 1971; Hood et al. 2006). The advantage of the planar intercept method is that it does not take much time to complete a plot, is non-destructive, and avoids the costly task of collecting and weighing large quantities of forest debris. Compared to destructive sampling, the planar intercept method is more efficient for estimating the volume of large size fuel, but it can be effectively used for small fuels as well such as needles and twigs (Brown 1971, 1974). When comparing sampling techniques to estimate surface fuel loading in montane forests, Sikkink et al. (2008) state that the planar-intercept method estimated 1-hr through 1000-hr fuels best compared to other tested methods, and recommend that although the method does not measure shrubs or herbaceous vegetation, the "planar-intercept technique continue to be used when measures of fuel loadings require high precision and accuracy". Escobedo et al. (2001) followed Brown's (1974) planar intersect method to compare fuel loadings to fire frequencies. They found that areas experiencing higher frequencies of fires tend to accumulate less downed woody fuels than sites with lower fire frequencies. However, time since last fire may influence the amount of smaller fuels present. These findings appear to support Veblen's (2003b) fire exclusion/fuel buildup perspective.

Estimation, rather than attempting to quantify, gives better results for herbaceous and shrub cover. Indirect methods must be used to describe vegetation cover in natural plant communities because the distribution of individuals is mostly irregular (Braun-Blanquet 1965). However, direct measurements have been conducted involving cutting and weighing as well. Brown et al. (1982) describe a technique (relative-weight estimate method) that involves a combination of estimation, and clipping and weighing. Although this method requires little training or experience, the accuracy of the method has not been fully evaluated. Rittenhouse et al. (1977) estimated crown biomass of big sagebrush (Artemisia tridentatea Nutt.) from linear measurements of crown width and area. Plant height, longest crown diameter, and its perpendicular diameter were recorded. Plants were then cut at ground level and air dried to a constant weight. Foliage was removed and oven dried at 60° C. They then ran regression and correlation statistics for various expressions of width and cover versus photosynthetic biomass and woody biomass, obtaining strong relationships.

Hood et al. (2006) estimated fuel bed loadings in areas of Jeffrey pine-white fir, ponderosa pine-Gambel oak, and pinyon-juniper stands to predict fire behavior and explain post-fire effects in fuel treated areas. They compared the cover-depth method, involving fuel collection and drying, to the planar intercept method (Brown 1974; Brown et al. 1982). The cover-depth method estimated higher duff and litter loadings, and lower woody fuel loadings than the planar intercept method for most sites. Van Wagtendonk et al. (1998) discuss equations that will predict litter and duff weights based on depth, and stress the importance of having accurate estimates of fuel depth and weight for predicting fire behavior. They show that fuelbed bulk density can be estimated by predicting litter and duff weight from litter and duff depth. Bulk density was calculated from weight and depth of litter and duff components.

Research on estimating canopy fuel load and canopy bulk density has involved both direct and indirect methods. A variety of indirect methods have been developed to estimate canopy fuel characteristics because direct, non-destructive direct measurement of many canopy fuel characteristics is not possible (Reinhardt et al. 2006). The effectiveness of computer programs using input field data of crown measurements (Sando, et al. 1972), various types of surveying equipment (Keane et al. 2005), relationships among cross-sectional areas, diameter breast height, and crown biomass (Snell et al. 1978), and allometric equations (Snell et al. 1978; Scott et al. 2002; Keane et al. 2005; Tausch 2009) to estimate canopy characteristics have been examined and compared to direct measurements. Keane et al. (2005) discuss that the most popular method for estimating canopy bulk density uses the measurements of tree diameter, tree height, and crown base height for all trees in a stand to calculate crown biomass distribution from allometric crown biomass equations.

Previous work estimating vertical distribution of canopy fuel assumed that available fuel is uniformly distributed within a tree's crown. Reinhardt et al. (2006) did not make this assumption when comparing several indirect methods for estimating canopy fuel load and canopy bulk density to values derived from destructively measured plots which involved collection, drying, and weighing. Instead, they summed available fuel masses in 1-meter vertical layers across all trees and divided by the volume of that layer to obtain a vertical fuel profile for each stand. CBD is the highest bulk density found in any 3 m deep canopy layer. FMAplus (Carlton 2004) also develops vertical fuel profiles, and USDA Forest Vegetation Simulator (FVS, Dixon 2003) and FMAplus also use maximum running means to calculate CBD. Reinhardt et al. (2206) conclude that the maximum running mean using adjusted allometric equations provided the highest correlation (r^2 = 0.996) between observed and predicted canopy bulk density, and the adjusted allometric equations provided the highest correlation (r^2 = 0.985) between observed and predicted canopy fuel load.

The study objectives were to quantify current surface and crown fuel, canopy bulk densities, and to use a regionally-specific vegetation simulator to: (1) reconstruct forest structure; (2) estimate changes in canopy fuels at each study site at 10-year intervals from time of settlement through the present (2007 at Mount Irish and 2008 at the Clover Mountains) and near future (2050); and (3) estimate changes in potential crown fire behavior over time at Mount Irish and the Clover Mountains.

MATERIALS AND METHODS

Study Areas

The Mount Irish study site (N 37˚ 38' 41", W 115˚ 24' 04") is located within the Mount Irish Mountain Range on the western side of Lincoln County (approximately 19 km northwest of Hiko). The mountain range makes up the eastern hydrographic boundary between the Great Basin Interior Drainage and the Colorado River Basin (Appendix A, Figure 1), and is well within the boundaries of the Great Basin ecosystem (Jamieson 2008). Ponderosa pine (*Pinus ponderosa*), single-needle pinyon pine (*Pinus monophylla*), Utah juniper (*Juniperus osteosperma*), Rocky Mountain juniper (*Juniperus scopulorum*), and white fir (*Abies concolor*) are tree species located within the study site. Bradley (2009) reported that the total basal area of these species combined among all twelve permanent plots is 14.5 m^2/ha with ponderosa pine making up 35.1% (5.10 m^2/ha), pinyon pine making up 34.8% (5.05 m^2/ha), Utah and Rocky Mountain juniper making up 14.5% (2.10 m^2/ha), and white fir making up 15.6% (2.27 m^2/ha) of the total basal area. Mountain mahogany (*Cercocarpus sp.*), bitterbrush (*Purshia sp.*), and sagebrush (*Artemisia sp.*) are the dominant shrub species. Elevation ranges from approximately 2400 to 2660 m. The study area is mostly confined by steep, rocky cliffs and the geology consists of limestone, dolomite, shale, and quartzite (Stewart et al. 1978). Climate data were obtained from the PRISM (Parameter-elevation Regressions on Independent Slopes Model; Daly et al. 2008) dataset over the 1895 to 2006 period (Appendix A, Table 1). Monthly data for two 4x4 km cells show that the annual average total precipitation is 288 mm with the months of January (30 mm), February (34 mm), and March (30 mm) accounting for 32.6% of the annual average total precipitation and

June being the driest month (12.2 mm). The site experiences the highest temperatures (Appendix A, Figure 3) from July through September (19.5 – 20.7˚C), and the lowest ones from December through February (-1.5 - -0.1˚C). Average annual temperature is 9.0˚C.

Human impact within the Mount Irish study site appears to be minimal. Native American presence and activity is evident due to the presence of artifacts (arrow heads and flakes of stone tools) and the presence of petroglyphs at the eastern base of Mount Irish. Logan City was founded as a mining town in 1865, reached a peak population of 300, and was abandoned in 1869 when new mining prospects developed in Pioche, Nevada. Because mining activity near the study site is documented, year 1860 was designated as the Euro-American settlement date. The landscape surrounding Logan City is scattered with ruins and artifacts. Evidence of Euro-American disturbance within the Mount Irish study site includes ax cuts on trees, cut stumps, and small mining pits. The rugged terrain and lack of water suggests that grazing by livestock was unlikely. Jamieson (2008) conducted a fire history study which showed fire as possibly being the most influential disturbance within the study site. Fire scars were mostly collected from ponderosa pine, but several were also collected from pinyon pine and white fir. The mean fire return interval prior to EuroAmerican settlement (1550 through 1860) was 4.48 years, with a minimum and maximum return interval of 1 and 31 years respectively. The mean fire return interval following settlement could not be estimated because the number of fire scars to analyze was minimal; only two fires (1883 and 1916) were apparent in the fire scar record after 1860. Fires were likely small and patchy, but relatively frequent prior to 1860 and less frequent after 1860. Fire scars were present in plots 2, 9, 11, and 12, and within 50 meters of plots 6, 9, 10, and 12 at Mount Irish (Appendix B, Table 2).

The Clover Mountains study site (N 37˚ 27' 33", W 114˚ 28' 02") is located within the Clover Mountain Range on the eastern side of Lincoln County (approximately 17 km southeast of Caliente). Unlike Mount Irish, the Clover Mountains are not within the hydrographic boundary of the Great Basin (Appendix A, Figure 1). Rather, they are within the Colorado River Watershed, but are within the ecological boundaries of the Great Basin. Ponderosa pine (*P. ponderosa*), single-needle pinyon pine (*Pinus monophylla*), and few Utah Juniper (*Juniperus osteosperma*) are tree species located within the study area while Manzanita (*Arctostaphylos sp.*) and Gambel Oak (*Quercus gambelli*) are the dominant shrub species. Bradley (2009) reported that the total basal area of these species combined among all twelve permanent plots is 13.8 m^2/ha with ponderosa pine making up 66.7% (9.21 m^2/ha), pinyon pine making up 33.0% (4.55 m^2/ha), and Utah juniper making up 0.3% (0.04 m^2/ha) of the total basal area. The combination of the above species is indicative that the Clover Mountains may be located in a climatic transitional area between the Great Basin and the Colorado Plateau where greater precipitation occurs in late summer than does at Mount Irish and other areas further north and west. Elevation ranges from approximately 1900 to 2280 m, with the summit of Ella Mountain representing the highest locality, and the geology consists of rhyolitic flows, shallow intrusive rocks, ash-flow tuff, tuffaceous sedimentary rocks, and silicic ash-flow tuffs (Stewart et al. 1978). A fire lookout tower was built in 1964 on the apex of Ella Mountain and is currently under the management of the Bureau of Land Management. PRISM (Daly et al. 2008) data from 1895 to 2006 (Appendix 1, Table 2) was obtained from four 4x4 km cells covering the site and reveals that the annual average total of precipitation is 408.4 mm with the months of January (44.5 mm), February (54.5 mm), and March (46.3 mm) accounting for 35.6% of the annual average total precipitation and June being the driest month (10.4 mm). The site experiences the highest temperatures in July and August (20.6 – 21.4˚C), and the lowest temperatures from December to February (-1.6 – 0.0˚C). Average annual temperature is 9.1˚C. The Clover Mountains receive significantly more ($P \leq 0.05$) annual precipitation (Appendix A, Figure 2) and, although not significantly different ($P \geq 0.95$), has higher average annual temperatures than Mount Irish (Appendix A, Figures 3).

Unlike Mount Irish, the Clover Mountains study site did not experience mining activity. The town of Caliente was populated by Euro-Americans in 1901 as a result of railroad construction, and as of the 2000 census has an approximate population of 1,100. Livestock grazing is not evident, although access from Caliente is made available via dirt roads throughout the study site. Evidence of Euro-American disturbance within the Clover Mountains includes cut stumps and downed trees. Present human disturbances are associated with recreational activity such as camping and all terrain vehicles, which appear to have minimal disturbance on the surrounding landscape. Kilpatrick (2009) conducted a fire history study using ponderosa pine fire scars at the Clover Mountains. Similar to Mount Irish, fire appears to be the most influential disturbance within the study site. Fires at the Clover Mountains were more widespread as indicated by fire dates being present throughout the study site, but were less frequent than at Mount Irish. The mean fire return interval for the time period (1785-1900) prior to Euro-American settlement is 7.00 years and 9.00 years following settlement (1901-2000). Five fires were recorded following settlement, with two of them (1877 and 1946) being relatively major fire events. The 1946 fire event scarred 55% of recorder trees for a total of 72 trees, while the 1877 fire event scarred 50% of recorder trees. No fires have been recorded on more than one tree since 1946. Thus, this time period (62 years) represents the longest fire free period in the 1675-2007 fire scar record (Kilpatrick 2009). Fires scars were present in plots 10, 11, and 12 at the Clover Mountains (Appendix B, Table 3).

FIELD AND LABORATORY METHODS

Field sampling is imperative for fuel mapping and analysis because it has been suggested that remote sensing cannot accurately depict fuel bed characteristics, fuels are extremely variable across landscapes, and fuel beds are profoundly complex (Ryan et al. 2001). Due to the variability of fuels within diverse landscapes, a well establish method for fuel data collection does not exist. Fuel inventories were conducted at Mount Irish and the Clover Mountains in 2008, and were largely based on Van Wagner's (1968) line intercept method while incorporating elements from Brown's (1974) and Brown et al. (1982) handbooks.

At each site, ten randomly and two strategically selected plots were sampled (Appendix B, Table 1). The two strategically selected plots were established to quantify stands containing unique composition and structure. Each permanent plot was randomly chosen as a rectangle or circle, and was 0.1 ha in size. Rectangular plots were 50 x 20 m, and circular plots had a radius of 17.8 m. Within the circle, five 10 m transects were established and oriented with azimuths: 0°, 72°, 144°, 216°, and 288° (Appendix B, Figure 1). To obtain a more complete spatial coverage of the plot, the 0° and 144° transects began at the origin and the 72˚, 216˚, and 288˚ transects began at 7.8 m from the origin. The rectangular fuel plot inventory also consisted of five 10 m transect lines. Each transect originated along the horizontal axis line with a randomly determined bearing that begins at (0, 10 m) and ends at (50, 10 m) (Appendix B, Figure 2). Elevation, aspect, and slope were recorded for each plot. Iron rebar was hammered flush into the ground at the center of each plot (and at the ends of long axis for rectangular plots) and a few trees were tagged with aluminum identification labels in order to assist in relocating the permanent plots in the future. Photographs were taken at the beginning of each transect at each permanent plot.

Down Dead Woody Debris

The Planar Intersect Method (Brown 1971) was used to tally down, dead woody debris (DWD) at each permanent plot at Mount Irish and the Clover Mountains (Appendix C, Table 1). A transect was 10 m in length and was divided into 1 m sections. Along each transect, sampling planes extending vertically 1.8 m (Brown 1974) were positioned. These sampling planes "resemble guillotines dropped through the downed debris" (Brown 1974). Pieces of woody material were categorized into three diameter size classes (0-0.64 cm, 0.64-2.54 cm, and 2.54-7.62 cm) corresponding to the fuels' equilibrium moisture content. Intersections between woody particles and the sampling plane were then counted. Down woody debris greater than 0.64 cm in diameter that intersected the transect line, and within 1.8 m of the forest floor, were counted along the entire 10 m transect. Pieces larger than 7.62 cm that were encountered were recorded by their diameters (Brown 1982). If the transect intersected the end piece of a portion of fuel greater than 7.62 cm, it was only tallied if the central axis of the woody debris was crossed. A go-no-go gage (Brown et al. 1982) was used to more accurately measure the fuel into appropriate size classes. The planar intersect method was also used to record data (height and diameter at breast height) relating to standing snags which was useful in capturing the absence of trees that were once alive. Two t-tests were performed for each fuel size class to test for significant differences in the quantity of fuel for each fuel size class between the two study sites.

Litter and Duff

Litter (down woody debris < 0.64 cm in diameter) and duff were collected separately within a 100 cm^2 (0.01 m^2) circular PVC frame (circle radius = 5.64 cm) located at two predetermined locations (3.5 m and 6.5 m intervals, Appendix B, Figure 3) along each transect line. Litter and duff were collected separately because each burns differently in a fire. Adding the total number of samples for each litter and duff gives a potential total of 20 samples per plot (a maximum of 10 litter samples and 10 duff samples), hence, potentially 240 samples per site. A ruler was used to estimated litter and duff depth to the nearest centimeter for each collected sample. The ruler eliminated bias associated with visual estimates and provided a source of standardization. Samples were individually placed into paper bags. Each paper bag was taped shut and was labeled with the site I.D., plot number, transect and interval number, and date. Paper bags are more advantageous than plastic bags because they allow for samples to dry out, preventing mold and rot. No. 10 (2mm) and No. 30 (600μm) U.S.A. Standard Test Sieves were used to sort litter and duff samples from inorganic material such as rocks (Appendix B, Figure

4). After sorting, each sample was placed in a paper bag, oven dried at 50˚C for 36 hours, and then weighed individually (Appendix B, Figure 5). Reinhardt et al. (2006) also oven dried their samples at 50˚C for between 24 and 48 hours. The weight (7.026 g) of the paper bag was subtracted from each weighed sample to obtain dry litter and duff weight. Litter and duff bulk densities at each sample location were calculated by dividing the sample weight by the sample volume. Combined bulk densities were computed by first separately combining depth and weights of litter and duff; the combined weight was then divided by the combined volume to obtain combined bulk density (a total of 120 values per site).

Canopy Fuel: Canopy Bulk Density and Canopy Fuel Load

Tree height, crown base height, longest crown diameter and its perpendicular diameter, diameter breast height, and basal diameter were measured for each tree within each plot. A measuring stick with one-tenth meter increments was used to measure tree heights, crown base heights, and crown diameters for smaller trees, and a clinometer was used to measure tree heights and crown base heights for taller trees. A measuring tape was used to assist in measuring large crown diameters. Using a measuring tape required two crew members, one at each end of the tape, to accurately obtain the necessary measurements. If the canopies of two different trees overlapped each other, each individual canopy was measured. In addition, only canopies of trees rooted within the plot boundary were measured; even if the canopy extended outside the designated boundary. The use of clinometers, measuring sticks, and measuring tapes eliminated any potential bias and provided a source of standardization. These measurements were used to estimate canopy biomass at each plot.

Biomass estimates for individual *P. monophylla* (single-leaf pinyon pine), *J. osteosperma* (Utah juniper), and *J. scopulorum* (Rocky Mountain juniper) were obtained using structural equations (Tausch 2009) which are based on allometric concepts (Appendix E, Table 1). Allometric relationships are usually represented by a two-parameter power function:

$$Y = aX^b$$

where X is the dimension measured (Tausch et al. 1988), Y is the morphological, physiological, or ecological variable of interest, and a and b parameters are known as the allometric coefficient and the allometric exponent respectively (Packard et al. 2008a). The values for the dependent and independent variables are usually transformed to their logarithms resulting in the allometric equation being expressed as:

$$\log Y = \log a + b\log X.$$

The method of ordinary least squares is then used to fit a straight line to the data, and the parameters in the allometric equation are then estimated by back-transformation to the arithmetic scale. Potential problems and biases are associated with this approach (Packard et al. 2008a; Packard et al. 2008b; Tausch et al. 1988) which can lead to conclusions that are not well supported by the original data (Packard et al. 2008a).

Although large trees are more important, the allometric equations give equal weight to small and large trees resulting in overestimates of large tree biomass, whereas the equations used by Tausch (2009) do not. Tausch's equations (Tausch 2009) are structural, and while still generally based on allometric concepts, have a different interpretation that is based on the derivation of a Functional Crown Volume. This volume, which is linearly related to the biomass components, avoids the potential biases associated with the analysis of allometric equations with log-transformed data. These equations will be referred to as 'Tausch equations' throughout the remainder of this paper. The equations were derived from five data sets of pinyon pine from the Virginia Range (western NV), Pine Grove Hills (western NV), the Needle Range (southwestern Utah), and the Sweetwater Mountains (western NV) and from one data set of Utah juniper from Pine Grove Hills (western NV). Required variables in the equations include longest crown diameter and the diameter perpendicular to longest crown, tree height, and crown base height. Although the equations are species specific to single-leaf pinyon pine and Utah juniper, the Utah juniper equations were also used for Rocky Mountain juniper. Using a species specific equation as a surrogate for similar species of similar growth form has been conducted in other studies (Gholz et al. 1979; Cruz et al. 2003; Gray et al. 2003; Perry et al. 2004).

Tree foliage and half of 1-hr fuels (diameter ≤ 0.64 cm) are assumed to contribute to a crown fire (Scott et. al 2002; Reinhardt et al. 2006). Larger fuels do not burn quickly enough to contribute to fire spread (Keane et al. 2005; Scott et. 2002). Therefore, the estimated available biomass for these two fuel classes was used to estimate current canopy bulk density. CBD can range from zero in areas without a canopy, to about 0.4

kg/m^3 in very dense stands (Scott et al. 2002), directly affects crown fire spread (van Wagtendonk 2006), and is important for sustaining active crown fire (Fule et al. 2001a). Values of 0.05 kg/m^3 or higher have been observed with both passive and active crown fires in ponderosa pine forests of Arizona (Fule et al. 2001a; Fule et al. 2001b). For rare independent crown fires to occur, steep topography, very high wind speeds, and bulk densities greater than 0.05 kg/m^3 are required (van Wagtendonk 2006). To obtain canopy bulk density per plot, I originally used a method referred to as both "load over depth" and "mean crown length" (Cruz et al. 2003; Reinhardt et al. 2006). Fule et al. (2001a) used this method to calculate CBD for ponderosa pine in Arizona. The following equation represents this method:

$$\mathrm{CBD} = \mathrm{CFL}/\mathrm{CL}$$

where CBD is the canopy bulk density (kg/m^3), CFL is the canopy fuel load (kg), and CL is the canopy volume (m^3). To obtain canopy volume, the average crown length for each plot was multiplied by the plot area. However, this method is not consistent with the methods used in FMAplus and FVS to calculate canopy bulk density.

FMAplus (Carlton 2004) was used to calculate canopy bulk densities for ponderosa pine and white fir. The calculations made in FMAplus are based on diameter at breast height, oven dry weights, foliage to branchwood ratios, and specific gravity for each species. FMAplus uses Brown's (1978) equation for grand fir in place of white fir; making adjustments for the difference in specific gravity (23.1 lbs/ft^3 for grand fir, and 24.3 lbs/ft^3 for white fir). In addition, FMAplus was also used to calculate pinyon pine and juniper species canopy bulk densities, and were compared to the values obtained by the Tausch equations. FMAplus uses the "maximum running mean method" (Reinhardt et al. 2006) which differs from the "load-over-depth. Therefore, the maximum running mean method was used with the Tausch equations to estimate canopy bulk density which provided consistency and allowed comparison between FMAplus and the Tausch equations. The maximum running mean requires creating a vertical fuel profile for each plot by summing available fuel masses in (1m or 1ft, depending on desired method) vertical layers across all trees from the ground to the top of the tallest tree, and dividing by the volume of that layer. From these values the effective canopy bulk density for the plot is the maximum canopy bulk density value found by the 3 m (Reinhardt et al. 2006) or 13 ft (FMAplus, FVS) running mean throughout the canopy. The maximum running mean method is more accurate than the load over depth method because it does not assume a uniform vertical distribution of canopy fuel (Scott et al. 2001). The load over depth method may be appropriate in single-storied stands because it assumes a uniform vertical distribution of available canopy fuel within a forest canopy. However, in multi-storied stands, the load over depth method is less accurate (Perry et al. 2004) than the maximum running mean method (Reinhardt et al. 2006).

Since FMAplus uses a 13-foot running mean, the same approach was used with the Tausch equations to estimate pinyon pine and juniper species canopy bulk densities. Effective canopy bulk densities were then converted to metric units.

Available canopy fuel loads (foliage, 1-hr, 10-hr, and 100-hr size classes) for pinyon pine and juniper species were calculated from three sets of equations: 1) Tausch equations containing trees that had the necessary input variables measured in the field; 2)

FMAplus containing trees that had the required input measurements; 3) and Tausch equations which contained the same trees as in FMAplus. Canopy fuel loadings for ponderosa pine and white fir were computed using FMAplus. Table 3 (Appendix E) lists the number of stems used in each method.

Herbaceous and Shrub Vegetation

Estimation, rather than attempting to quantify, gives better results for herbaceous and shrub cover in natural plant communities because the distribution of individuals is mostly irregular (Braun-Blanquet 1965). The percentage of herbaceous and shrub cover was separately estimated within a 1 m^2 circle area (circle radius being 0.564 m), which is appropriate in a Mediterranean type climate (Braun-Blanquet 1965), centered at four locations (2.5, 4.5, 6.5, and 8.5 m) along each transect (Appendix B, Figure 3). Thus, each permanent plot had a total of 20 estimates. Each estimate was assigned a whole number value (Appendix F, Table 1) according to the Braun-Blanquet cover classes: 0: 0%, 1: <5%, 2: 5-25%, 3: 25-50%, 4: 50-75%, and 5: 75-100% (Braun-Blanquet 1965). The 0% cover class was added to the five original Braun-Blanquet cover classes in order to account for areas containing no herbaceous and/or shrub cover. These cover classes provide completely satisfactory estimates in small sized test areas; up to 10 m^2 (Braun-Blanquet 1965). A quantitative comparison for herbaceous and shrub cover between Mount Irish and the Clover Mountains is not possible because the cover classes do not have the same percentage intervals. Therefore, each cover class was color coded to represent percentage of herbaceous (Appendix F, Tables 2 and 3) and shrub cover (Appendix F, Tables 4 and 5). From these color coded percentages, visually qualitative comparisons were made for each herbaceous and shrub vegetation between both study sites.

Canopy Fuel Reconstruction and Potential Crown Fire Behavior

Reconstruction of canopy fuel and potential crown fire behavior through time was performed by closely following the methodology of a study conducted in Grand Canyon, Arizona. Fule et al. (2004) used the FVS (Dixon 2003; Van Dyck 2000; Reinhardt et al. 2003) to model changes in canopy biomass, CBD, and species composition, and utilized the Nexus (Scott 1999) computer program to model potential fire behavior from 1880 through 2040 on the North Rim of Grand Canyon National Park. FVS only runs simulations into the future and requires tree diameter at breast height as an input. A non-destructive method to obtain growth data is provided through increment cores (Bakker 2005). To quantify canopy fuel in 1880, Fule et al. (2004) determined which trees predated 1880 using tree ring data, and estimated past tree DBH by subtracting the radial growth measured on increment cores since 1879. Fule et al. (1997) previously used this method, referred to as the conventional diameter reconstruction method (Bakker 2005), to reconstruct historical DBH for ponderosa pine in Arizona. To estimate past DBH for trees without increment cores, local species-specific relationships between tree diameter and basal area increment were developed. Fule et al (2004) found that canopy biomass and CBD increased roughly in parallel with each other.

Forest Vegetation Simulator (FVS, Dixon 2003) is a statistical model that simulates tree and forest growth, tree mortality and regeneration, and the impacts of a wide range of silvicultural treatments, and was used to simulate changes in canopy fuels at each study site beginning in the year settlement occurred at Mount Irish (1860) and the Clover Mountains (1900) and ending in 2050. Year 2050 was chosen because difficulty exists in predicting future climate changes and disturbance regimes (Fule et al. 2004). Required minimum inputs at the beginning of each simulation include tree species and diameter at breast height.

Increment borers were used to extract tree cores from each live tree within all permanent plots. Tree increment cores and diameter measurements were collected at the base and diameter breast height of each tree during the summer of 2007 at Mount Irish and 2008 at the Clover Mountains. Increment cores were then surfaced with increasingly finer grit sand paper until the cell wall structure was easily visible and then dated (Stokes et al. 1968), but not crossdated.

To reconstruct DBH of individual trees, breast cores were measured from the outer ring towards the pith at annual intervals using a Velmex measuring system with 0.001 mm precision and MEDIR software. Cores were only measured if DBH was also measured in the field. From these measurements, DBH of individual trees at a historical date of interest was reconstructed using the conventional method (Bakker 2005) by measuring the radial increment between the outer ring and the historical date of interest and subtracting twice this measurement from the current diameter (Bakker 2005; Fule et al. 1997):

$$G = \mathrm{DIAM} - (I_H \times 2)$$

where G is the DBH at the historical date of interest, DIAM is the DBH at time of coring, and I_H is the radial increment between the outer ring and the historical date of interest. This method assumes that radial growth has been symmetric and that the chronological and geometric centers are equal (Bakker 2005). Cores that were not measureable (i.e. rot) were eliminated. A total of 293 cores from Mount Irish (Appendix G, Table 1) and 352 cores from the Clover Mountains (Appendix G, Table 2) were measured. DBH reconstruction for trees without increment cores (i.e. rot or a core was simply not taken) was determined through local species-specific relationships between known current DBH values and breast ages of individual trees. A total of 65 trees from Mount Irish (Appendix G, Table 3) and 55 trees from the Clover Mountains (Appendix G, Table 4) had historic DBH values estimated through these relationships.

Forest Vegetation Simulator was used to simulate forest change (i.e. basal area, tree density, fuel biomass) at each study site at 10-year intervals beginning at time of Euro-American settlement. Users of the program are able to choose the variant that is most applicable to a specific geographic area. The variants in FVS contain equations such as tree growth and mortality that were developed for a specific geographic area. FVS does not contain a Great Basin variant (Appendix G, Figure 1), thus, the Utah variant which covers all forested areas in Utah was used because it resembles the Great Basin vegetation and climate more closely than the other variants. The Utah variant contains ponderosa pine, pinyon pine, and white fir. Western juniper is the only juniper species and was used in place of Utah and rocky mountain juniper. The Fire and Fuels Extension (Reinhardt et al. 2003) to FVS was used to simulate changes in fuel characteristics (i.e. CBD, fuel biomass) and potential crown fire behavior (i.e. crowning index). FVS allows the user to adjust moderate and severe (90th and 97th percentiles) fire weather conditions such as fuel moisture and maximum temperature to give a better representation of climate at a study site. FireFamily Plus (Bradshaw et al. 1999) is a statistical software package designed to analyze distributions of fire-related weather variables. The moderate and severe fire weather conditions were calculated for July and August 1986-2008 at the Kane Springs weather station (KNSN2; elevation 1336 m) for the Clover Mountains simulation (Appendix G, Table 6) and for 1976-2000 at the Las Vegas, Tonopah weather station (KBJN; elevation 1756 m) for the Mount Irish simulation (Appendix G, Table 5) using FireFamily Plus. Each weather station was chosen due to its close proximity to each study site. Calculated July and August weather data values were chosen because these months represent the most severe fire weather.

FVS simulations began with reconstructed conditions at time of settlement for the Clover Mountains (1900) and at 10 years prior to settlement (1860) at Mount Irish. Simulation started prior to settlement at Mount Irish because reconstructed DBH values were calculated back in time at 25 year intervals from year 2000. Tree density and basal area at year 2007 for Mount Irish and 2008 at the Clover Mountains in the simulations were compared against field data that were collected at both study sites to account for reconstruction accuracy. Establishment dates were determined by basal increment core analysis or through local species-specific relationships between known current base diameters and base ages of individual trees. Based on individual tree establishment dates, regeneration data by species per decade were added to each study site.

Potential crown fire behavior was assessed in terms of the crowning index (CI), which is the 6-meter open windspeed required to sustain an active crown fire and is dependent on canopy bulk density, slope steepness, and surface fuel moisture. Active crown fires occur at lower wind speeds as stands become denser. Lower index numbers indicate that crown fire can occur at lower wind speeds. Therefore, crown fire hazard is greater at lower index values (Reinhardt et al. 2003). Flame length and torching index (windspeed required for a passive crown fire) are other descriptors of fire behavior, however, they are dependent on assumptions of historic values of crown base height which are impossible to estimate. Therefore, the CI is viewed as a more reliable variable describing historic and future crown fire behavior (Fule et al. 2004).

RESULTS

Plots at Mount Irish have elevations ranging from 2457 to 2595 m, slopes ranging from 4 to 46%, and are located on southern, western, and northern aspects. Plots at the Clover Mountains have elevations ranging from 1995 to 2218 m, slopes ranging from 20 to 54%, and are located on all aspects.

Down Dead Woody Debris

Each permanent plot has a total of fifty 1-m intervals (five, 10-m transects). Thus each study site, each containing twelve plots, has 600 1-m intervals where DWD was tallied. The t-Test for this situation contained 600 observations (Appendix C, Table 2, Column A). Histograms for each fuel size class at each study site are located in Appendix C (Figures 1 through 6), and show that mean and max counts for each fuel size class at the 1-meter intervals are higher at the Clover Mountains compared to Mount Irish.

The second test involved 12 observations with each observation representing the total amount of fuel by size class for each permanent plot. With twelve observations at each study site, a t-Test was performed for each fuel size class (Appendix C, Table 2, and Column B). Histograms for each fuel size class at each study site are located in Appendix C (Figures 7 through 12), and show that the mean and max counts for each fuel size class at the permanent plots are higher at the Clover Mountains compared to Mount Irish.

The amount of 10-hr (0.64 – 2.54 cm) down woody debris at the Clover Mountains study site is significantly greater at a significance level of 95% confidence level than at Mount Irish. There are no significant differences in the amount of 100- and 1000-hr (2.54 – 7.62cm, > 7.62 cm) fuels between Mount Irish and the Clover Mountains. Tests for significant differences were conducted within each study site to determine if aspect may possibly contribute significantly to differences in the amount of fuel for each size class between plots with northern and southern aspects (Appendix C, Tables 3 and 4). There are no significant differences in the quantity of down, dead woody debris within each size class between north facing and south facing plots at either Mount Irish or at the Clover Mountains. In addition, at each study site there is not a significant difference in the quantity of DWD among all size classes between plots containing fire records and plots not containing fire records.

Litter and Duff

Mount Irish and the Clover Mountains each had 120 potential samples for each litter and duff; 240 samples combining the two. Table 1 (Appendix D) lists the weights and depths of samples taken from every 1-meter interval along each 10-meter transect at each site. Table 2 (Appendix D) lists the bulk density for each sample collected at the Clover Mountains and Mount Irish. Not every 1-meter interval contained fuel. Combing all 12 plots at each site, the Clover Mountains had more intervals that did not include duff and Mount Irish had more intervals that did not include litter (Appendix D, Table 3). Table 4 (Appendix D) shows the total number of litter and duff samples collected at each site. There is not a significant difference between Mount Irish and the Clover Mountains in the number of litter and duff samples collected.

Litter and duff are deeper on average at the Clover Mountains compared to Mount Irish (Appendix D, Table 5). Figure 1 and 2 (Appendix D) show the average fuelbed depths per plot for each site. Litter is significantly deeper at a significance level of 90% confidence level at the Clover Mountains compared to Mount Irish ($P = 0.058$), while duff depth is not significantly deeper (Appendix D, Table 6). Although not statistically significant (Appendix D, Table 7), the Clover Mountains study site has a heavier litter and duff fuel load (Appendix D, Table 8). Total area of collected samples per plot was $0.1m^2$ (10 locations, each being $0.01m^2$). Weights per plot were converted to kg/m^2. The weights for all plots combined was calculated by summing the weights of all plots and dividing by 12 (twelve $1m^2$ areas) to get total weight from $kg/12m^2$ to kg/m^2. Total litter and duff weights of collected samples at the Clover Mountains when combining all plots together is 1.243 and 0.392 kg/m^2 respectively compared to 1.201 and 0.278 kg/m^2 respectively at Mount Irish. Figure 3 and 4 (Appendix D) show total fuelbed sample weights per plot, while figure 5 (Appendix D) shows the total fuelbed weights for each study site. Table 9 (Appendix D) and Figure 6 and 7 (Appendix D) show fuelbed bulk densities for both study sites. Bulk densities per plot were calculated by dividing the total weight of each plot by the total volume of the collected samples within each plot. Bulk densities per study site include data from all plots regardless if a plot did not contain duff (i.e. plots 3, 8, and 12 at Mount Irish and plots 8, 9, 10, and 12 at the Clover Mountains). Bulk densities per study site were computed by dividing the total weight of the twelve plots by total volume of collected samples of all plots combined. Bulk densities for litter and for litter and duff combined are significantly lower at a significance level of 95% confidence level at the Clover Mountains compared to Mount Irish (Appendix D, Table 10). Tests for significant differences were conducted within each study site to determine if aspect significantly contributes to differences in fuelbed bulk densities between plots with northern and southern aspects (Appendix D, Tables 11 and 12). There are no significant differences in fuelbed bulk densities between north facing and south facing plots at either Mount Irish or at the Clover Mountains.

Studies in southwestern Colorado, northern California (Hood et al. 2006), and Sierra Nevada (van Wagtendonk et al. 1998) report similar fuelbed bulk densities for specific forest types (Appendix D, Table 13). Although these studies are not specific to the Great Basin ecosystem, the fuelbed bulk densities they report offer a comparison on specific species. Van Wagtendonk et al. (1998) report a litter bulk density of 78 kg/m^3 for white fir stands which is almost identical to the litter bulk density of 77 kg/m^3 for plot 12 at Mount Irish which is dominated by white fir and ponderosa pine. Litter bulk densities for ponderosa pine stands at the Clover Mountains range from 29 to 87 kg/m^3 which is similar to 36 kg/m^3 reported by van Wagtendonk et al. (1998). Van Wagtendonk et al. (1998) also report a litter bulk density of 71 kg/m^3 for western juniper while densities for litter at Mount Irish for plots dominated by pinyon-juniper range from

61 to 168 kg/m^3. Duff bulk densities for ponderosa pine dominated plots at Mount Irish range from 142 to 179 kg/m^3 compared to 155 kg/m^3 reported by van Wagtendonk et al. (1998). When combining litter and duff bulk densities for ponderosa pine, van Wagtendonk et al. (1998) and Hood et al. (2006) report bulk densities of 118 and 128 kg/m^3 respectively; Mount Irish ranges from 111 to 135 kg/m^3. Hood et al. (2006) found that bulk density was most variable in pinyon-juniper stands compared to Jeffrey pine-white fir and ponderosa pine-Gambel oak stands. This is evident at Mount Irish and the Clover Mountains as well. Pinyon-juniper stands at Mount Irish have combined litter and duff bulk densities ranging from 63.5 to 141.3 kg/m^3; a difference of 77.8 kg/m^3. These values vary more compared to ponderosa pine and ponderosa pine-white fir dominated stands at Mount Irish that have combined bulk densities ranging from 77.2 to 135.0 kg/m^3 (a difference of 57.8 kg/m ^{3}), and ponderosa pine dominated stands at the Clover Mountains that have combined bulk densities ranging from 33.9 to 86.0 kg/m^3 (a difference of 52.1 kg/m^3).

Tests for significant differences were conducted between plots containing a fire record and plots not containing a fire record at each study site (Appendix B, Table 2 and 3). Significant differences were tested for depths, weights, and bulk densities for litter, duff, and combined litter and duff. Results show that there are no significant differences for each of these characteristics between plots containing fire records and plots not containing fire records at neither Mount Irish nor at the Clover Mountains.

Canopy Fuel: Canopy Bulk Density and Canopy Fuel Load

Current canopy bulk densities and canopy fuel loads (foliage, 1-Hr, 10-Hr, and 100-Hr size classes) for pinyon pine and juniper species were calculated with three different methods; twice using the Tausch equations and once using FMAplus. The first estimates using the Tausch equations used all trees containing the required Tausch input variables. Trees that had missing data (i.e. tree height or crown diameter) were omitted from the calculations (Appendix E, Table 2). The second estimates were conducted using FMAplus. Contrast to the Tausch equations, FMAplus requires diameter at breast height. The third estimates used the Tausch equations containing the same trees that were used in FMAplus. For the remainder of this paper 'Tausch*' represents this third method. Every tree that was present in the FMAplus calculations was also present in the Tausch* equations. Therefore, the trees in the Tausch methods that were not part of the FMAplus calculations were omitted, resulting in the Tausch* method. This allowed for direct comparison between the Tausch* equations and FMAplus. Table 3 (Appendix E) lists the number of stems used to estimate canopy fuel load and canopy bulk density in each of the three methods.

Tables 4 through 8 (Appendix E) compare the three methods used to obtain Mount Irish canopy fuel loads for foliage, 1-hr, 10-hr, and 100-hr size classes for each species and all species combined. Tables 9 through 12 (Appendix) compare the three methods used to estimate canopy fuel loads at the Clover Mountains. The tables show fuel loads per plot as well as per study site. Using the calculated canopy fuel loads for all species combined from FMAplus (Appendix E, Table 4 and 9), Mount Irish has significantly more canopy foliage biomass at the 90% significance level (P = 0.057) compared to the Clover Mountains (Appendix E, Table 13). The average foliage biomass per plot at Mount Irish is 844 kg/0.1 ha with plot 6 (pinyon-juniper dominated) having the highest foliage fuel load of 1334 kg/0.1 ha (Appendix E, Table 4). The average foliage biomass per plot at the Clover Mountains is 586 kg/0.1 ha with plot 11 (ponderosa pine dominated) having the highest foliage fuel load of 1105 kg/0.1 ha (Appendix E, Table 9). There are no significant differences between the two study sites for 1-hr ($P = 0.15$), 10-hr ($P = 0.62$), and 100-hr ($P = 0.13$) canopy fuel loads for all species combined (Appendix E, Table 13). In addition, there are no significant differences of fuel loads between Mount Irish and the Clover Mountains for ponderosa pine. For pinyon pine, there are no significant differences for fuel loads between the three methods for each study site, or between the two sites. However, for juniper species, a significant difference at the 95% significant level does exist between the Tausch* equations and FMA for 1-hr fuel loads at Mount Irish. This significant difference can is attributed to the biases and potential problems associated with allometric equations (Tausch et al. 1988; Packard et al. 2008a; Packard et al. 2008b). Mount Irish does have a significantly higher amount of foliage, 1-hr, 10-hr, and 100-hr fuel load for juniper species than the Clover Mountains. This is due to the fact that only two juniper species were encountered at the Clover Mountains.

FAMplus creates vertical fuel profiles with outputs being in English units. Vertical fuel profiles for pinyon pine and juniper species, as well as both species combined, were also created for the Tausch and Tausch* methods in order to determine the canopy bulk density for each plot. Vertical fuel profiles (Appendix E, Figure 1) using the Tausch and Tausch* equations for pinyon-pine and juniper species were created in

English units in order to visually compare them to the profiles created in FMAplus. From these vertical fuel profiles, the canopy bulk densities were determined from the maximum 13-foot running mean. The values in English units were then converted to metric units.

Table 14 (Appendix E) compares pinyon pine and juniper species canopy bulk density values obtained from the three methods. The pinyon-juniper canopy bulk density analysis will focus on the Tausch* equations that contain the same trees as in FMAplus because the allometric derived equations that Tausch (2009) used are species specific to the Great Basin. Pinyon pine occurs in nine plots with canopy bulk densities ranging from 0.036 to 0.183 kg/m^3 per plot at Mount Irish, and in eight plots with canopy bulk densities ranging from 0.008 to 0.203 kg/m^3 per plot at the Clover Mountains. Juniper species are present in all plots with canopy bulk densities ranging from 0.008 to 0.229 kg/m^3 per plot at Mount Irish, and in two plots with canopy bulk densities of 0.004 kg/m3 and 0.007 kg/m^3 per plot at the Clover Mountains. The combination of pinyon pine and juniper species takes place in nine plots with canopy bulk densities ranging from 0.061 to 0.322 kg/m^3 per plot at Mount Irish, and in two plots with canopy bulk densities of 0.072 kg/m^3 and 0.131 kg/m^3 per plot at the Clover Mountains.

When comparing pinyon pine, juniper species, and the combination of pinyon pine and juniper species canopy bulk density values obtained from the Tausch* equations to those from FMAplus, no significant differences exist at the Clover Mountains. However, a significant difference at a significance level of 95% confidence level does exist between the two methods for pinyon pine canopy bulk density at Mount Irish (Appendix E, Table 15). Approximately seventy five percent of the FMAplus calculations are greater than the Tausch* calculations; 31 of 42, and correlations range from 0.654 to 1.000 between the two methods for canopy bulk density (Appendix E, Table 16). This significant difference can is attributed to the biases and potential problems associated with allometric equations (Tausch et al. 1988; Packard et al. 2008a; Packard et al. 2008b). The correlation value of 1.000 is associated with the Clover Mountain pinyon pine and the combination of Clover Mountain pinyon pine and juniper. Each of these categories has only two canopy bulk density values (only two plots contained pinyon pine and pinyon pine-juniper). These comparisons support the use of FMAplus to calculate canopy bulk densities for both ponderosa pine and white fir.

White fir is not present at the Clover Mountains while ponderosa pine does exist at both study sites (Appendix E, Table 17). White fir is found within five plots at Mount Irish with canopy bulk densities ranging from 0.0016 to 0.0737 kg/m^3 per plot. Ponderosa pine is also found within five plots at Mount Irish with canopy bulk densities ranging from 0.0064 to 0.0929 kg/m^3 per plot. The Clover Mountains has seven plots containing ponderosa pine with canopy bulk densities ranging from 0.0064 to 0.1041 kg/m^3 per plot. These min and max values for ponderosa pine canopy bulk density are similar to previously reported min and max values of 0.01 kg/m^3 and 0.76 kg/m^3 (Cruz et al. 2003), and mean value of 0.166 kg/m^3 for ponderosa pine forests in the western United States (Reinhardt et al. 2006).

Two graphs were created for each study site (Appendix E, Figures 2 and 3 for Mount Irish, Figures 4 and 5 for the Clover Mountains) showing canopy bulk densities for each species (Appendix E, Table 18). Values for ponderosa pine and white fir in each graph were calculated using FMAplus. However, values for pinyon pine and juniper species in the first graph for each site (Appendix E, Figures 2 and 4) were calculated using FMAplus while the values in the second graph for each site (Appendix E, Figures 3 and 5) were calculated using the Tausch* equations. Pinyon pine canopy bulk densities are consistently higher at Mount Irish, and are higher in six of eight plots containing pinyon pine at the Clover Mountains when using FMAplus compared to using the Tausch* equations. As mentioned above, the difference in the values of pinyon pine canopy bulk density at Mount Irish between the two methods is statistically significant. FMAplus calculated pinyon pine at plot 6 as having the highest canopy bulk density (0.269 kg/m^3) among all species at all Mount Irish plots. This value is approximately 60% greater than the value (0.111 kg/m^3) calculated using the Tausch* equation. The Tausch* equation calculated juniper species at plot 7 as having the highest canopy bulk density (0.229 kg/m^3) among all species at all Mount Irish plots. This value is approximately 35% greater than the value (0.149 kg/m^3) calculated using FMAplus. FMAplus calculated pinyon pine at plot 4 as having the highest canopy bulk density (0.255 kg/m^3) among all species at all plots at the Clover Mountains. This value is approximately 40% greater than the value (0.153 kg/m^3) calculated using the Tausch* equation. The Tausch* equation calculated pinyon pine at plot 8 as having the highest canopy bulk density (0.203 kg/m^3) among all species at all plots at the Clover Mountains. This value is approximately 7% greater than the value (0.189 kg/m^3) calculated using FMAplus. Again, the difference in the values between the Tausch* equations and FMAplus is attributed to the biases and potential problems associated with allometric equations (Tausch et al. 1988; Packard et al. 2008a; Packard et al. 2008b).

Combining the permanent plot canopy bulk densities for each species gives the canopy bulk density for each species at each study site. These values were calculated using FMAplus because the Tausch* method does not calculate canopy bulk densities for ponderosa pine or white fir. Mount Irish has higher canopy bulk densities compared to the Clover Mountains for white fir, juniper species, pinyon pine, and all species combined (Appendix E, Table 19 and Figure 6). The reason that white fir canopy bulk density is higher at Mount Irish is because white fir does not exist at the Clover Mountains. Canopy bulk density for ponderosa pine is higher at the Clover Mountains.

Combining all species at each permanent plot gives a total canopy bulk density for each plot and study site (Appendix E, Table 20). Figures 7 and 8 (Appendix E) show canopy bulk density values when combining all species in relation to pinyon pine densities (trees/ha) per plot. Plots 6 and 7, both dominated by pinyon pine and juniper species, have the highest canopy bulk densities (0.3844 and 0.3684 kg/m^3 respectively) at Mount Irish, while plots 4 and 8, both dominated by pinyon pine, have the highest canopy bulk densities (0.2627 and 0.1890 kg/m^3 respectively) at the Clover Mountains. Canopy bulk density at Mount Irish (0.1954 kg/m^3) is significantly greater ($P \leq 0.05$) (approximately 56%) compared to the Clover Mountains (0.0849 kg/m^3).

Tests for significant differences were conducted within each study site to determine if aspect significantly contributes to differences in canopy bulk densities between plots with northern and southern aspects (Appendix E, Tables 21 and 22). FMAplus canopy bulk density values of combined species (Appendix E, Table 20) were used to test for significant differences, resulting in no significant differences in canopy bulk densities between north facing and south facing plots at neither Mount Irish nor at the Clover Mountains.

Tests for significant differences were also conducted for canopy fuel loads and canopy bulk densities in relation to fire occurrences. Plots containing fire records have significantly less 1-hr canopy biomass than plots not containing fire records at both Mount Irish ($P \leq 0.05$) and the Clover Mountains ($P \leq 0.05$). In addition, when combining all species together, canopy bulk densities are significantly lower at plots containing fire records compared to plots not containing fire records at both Mount Irish ($P = 0.005$) and the Clover Mountains ($P = 0.119$).

Herbaceous and Shrub Vegetation

Table 6 (Appendix F), for Mount Irish, and Table 7 (Appendix F), for the Clover Mountains, have herbaceous and shrub cover classes arranged next to each other for visual comparison. The number of observations for each cover class for herbaceous (n=240), and shrub (n=240), and herbaceous and shrub cover combined (n=480) are listed with accompanying percentage of observations and cumulative percentages (Appendix F, Table 8). Herbaceous cover does not appear to differ much between Mount Irish and the Clover Mountains. The majority of the herbaceous estimates at each site are in cover classes 0 and 1 (65% for Mount Irish; 75% for the Clover Mountains). Forty nine percent of the herbaceous observations are associated with cover class two at Mount Irish compared to 45% at the Clover Mountains. Shrub cover does appear to differ between the two sites. Approximately 45% of shrub cover at the Clover Mountains is in cover class 3 or higher compared to approximately 11% at Mount Irish. Cover class zero at Mount Irish accounts for the highest percentage (47%) of shrub observations compared to cover class 2 accounting for 24% at the Clover Mountains. Combining the number of herbaceous and shrub estimates, approximately 91% of herbaceous and shrub cover combined is in cover class 2 or lower at Mount Irish compared to approximately 75% at the Clover Mountains. However, the majority of observations at each site are in cover class 1; 35% at Mount Irish and 29% at the Clover Mountains.

Canopy Fuel Reconstruction and Potential Crown Fire Behavior

FVS simulations incorporated a total of 358 (293 measured, and 65 from local species-specific relationships) individual tree DBH values for Mount Irish and 407 (352 measured, and 55 from local species-specific relationships) for the Clover Mountains. Species-specific relationships between breast age and DBH for tree species at Mount Irish are shown in Figures 2 through 5 (Appendix G) and at the Clover Mountains in Figures 6 and 7 (Appendix G). The relationship between ponderosa pine breast age and DBH at the Clover Mountains (Appendix G, Figure 7) is difficult to examine due to cohorts of trees (plots 3, 11, and 12) that are similarly aged, but vary greatly in DBH and breast age. Power relationships exist between breast age and DBH for pinyon pine at each site and for white fir and juniper species at Mount Irish, and linear relationships exist for ponderosa pine at both sites. R^2 values for these relationships are 0.74 for pinyon pine and 0.51 for ponderosa pine at the Clover Mountains, and 0.70 for pinyon pine, 0.75 for juniper species, 0.45 for ponderosa pine, and 0.12 for white fir at Mount Irish. Reconstructing DBH values resulted in 135 (out of 358) trees at Mount Irish having DBH values pre-dating 1850, and 136 (out 0f 407) trees pre-dating 1900 at the Clover mountains. The DBH values of these trees in 1850 at Mount Irish and in 1900 at the Clover Mountains were inputted into FVS.

Determining establishment dates for each species per decade is necessary to account for density-dependent mortality (Fule et al. 2004). Establishment dates for the majority of trees at each study site were determined through basal increment core analysis. However, twenty-two establishment dates at Mount Irish and ten at the Clover Mountains (Appendix G, Table 7) were estimated using species-specific relationships between known current base diameters and base ages of individual trees. These relationships are shown in Figures 8 through 11 (Appendix G) for Mount Irish and in Figures 12 and 13 (Appendix G) for the Clover Mountains. The relationship between ponderosa pine base age and base diameter at the Clover Mountains (Appendix G, Figure 13) is difficult to examine due to cohorts of trees (plots 3, 11, and 12) that are similarly aged, but vary greatly in base diameter and base age. Regeneration data based on establishment dates by species per decade (Appendix G, Tables 8 and 9) were added in FVS to account for density-dependent mortality. Regeneration densities per species per decade in FVS were increased by 40% at Mount Irish and by 50% at the Clover Mountains. Simulation data at year 2007 for Mount Irish and 2008 for the Clover Mountains were checked against field data for each study site. Simulation values for tree density (trees per hectare) and basal area (m^2 per hectare) were within ±31% at Mount Irish and within ±20% at the Clover Mountains (Appendix G, Table 10). Values of added regeneration densities, and comparisons between FVS simulation outputs and field data are similar to the values of a study conducted in Grand Canyon (Fule et al. 2004). The Grand Canyon study reported added regeneration densities of 40%, and simulation values within ±20% of field values for tree density and basal area.

Crowning index values (Appendix G, Table 11) decreased from 120 to 63 km/hr from 1850 to 2050 at Mount Irish, a 47.5% decrease, and from 127 to 51 km/hr from 1900 to 2050 at the Clover Mountains, a 60% decrease. CI value at Mount Irish was 75 km/hr in 2007 (a 37.5% decrease from 1850) and at the Clover Mountains was 67 km/hr in 2008 (a 47% decrease from 1900). The largest percent decrease in CI in a cycle (each cycle being 10 years) prior to 2010 was 8.33% (1970-1980) at Mount Irish and 12.12% (1920-1930) at the Clover Mountains. FVS simulations predict that the greatest percent decrease in CI in a single cycle at each study site will be 12.21% (2000-2010) at Mount Irish and 12.66% (2030-2040) at the Clover Mountains.

The FVS simulations also show changes in fuel biomass and canopy bulk density at Mount Irish (Appendix G, Table 12) and at the Clover Mountains (Appendix G, Table 13). These changes are represented by combining all plots together, which shows temporal changes for each study site. The current biomass and canopy bulk density values in the FVS outputs are not as accurate as those obtained from the Tausch* equations and FMAplus. This is because the only inputs into FVS were tree species and DBH. Data pertaining to crown dimension, tree height, and crown base height were not entered into FVS because these measurements are impossible to determine back in time. Therefore, the FVS model assumes these measurements at the beginning of each simulation based on species-specific relationships with DBH. However, the temporal trend of fuel biomass and canopy bulk density is meaningful. An inverse relationship is evident between CI and CBD (Appendix G, Figures 14 and 15), and between CI and fuel biomass (Appendix G, Figures 16 through 19). CBD increased by 59.3% from 1850 to 2050, and by 51.3% from 1900 to 2050 at Mount Irish, and increased by 70.4% from

1900 to 2050 at the Clover Mountains. Biomass increased by 63.2 to 79.4% from 1850 to 2050, and by 45.9 to 64.7% from 1900 to 2050 as CI decreased by 45.7 and 40.6% respectively at Mount Irish (Appendix G, Table 14). Biomass increased by 69.8 to 83.3% from 1900 to 2050 as CI decreased by 59.8% at the Clover Mountains (Appendix G, Table 14). When comparing the FVS outputs for percent changes in CI and fuel biomass between the two study sites, the Clover Mountains are transitioning at a faster rate into an ecosystem more prone to severe crown fires. In 1900, Mount Irish had a CI value of 106 km/hr compared to 127km/hr at the Clover Mountains. In 2000, Mount Irish CI value decreased to 75 km/hr, while the CI value at the Clover Mountains decreased at a faster rate to 67 km/hr. Continuing into the future (2050), Mount Irish is predicted to have a CI value of 63 km/hr compared to a value of 51 km/hr at Mount Irish.

DISCUSSION

Down Dead Woody Debris

The amount of down dead woody debris is an indication of surface fuel continuity. The more connected surface fuels are, the more easily fire can advance across the landscape. However, fuel continuity is only a fraction of what it takes for fires to spread; fuel moisture, compactness, type, and size also contribute to the spread of surface fires. The significantly greater amount of 10-hr (0.64 – 2.54 cm) down woody debris fuel at the Clover Mountains suggests that the surface fuel is more continuous compared to Mount Irish. Larger fuel size classes do not contribute as much to the flaming front of a surface fire as do smaller size classes. This is because larger fuels have higher surface to volume ratios. Although the Clover Mountains have higher 10-hr fuel continuity, if the packing ratio (compactness) is too high, not enough oxygen will be able to reach the fuel. Thus, combustion may not be initiated and fire spread will not occur.

The fact that there are no significant differences in the quantity of DWD between plots containing fire records and plots not containing fire records is surprising. One would think that plots which have experienced a recent fire would have significantly greater 100- and 1000-hr size classes of DWD because as large trees burn, tree mortality will increase, and then these dead trees will fall to the forest floor. Consumption of these size classes by the flaming front of a fire would be low. Thus, remnants of these size classes would be expected unless the last fire was severe enough to consume entire trees or not severe enough resulting in little recruitment of dead trees. Another explanation may be that enough time has elapsed since last fire for the DWD to decompose. However, some plots that have experienced recent fire within the two study sites do contain higher quantities of 100- and 1000-hr DWD fuel sizes. Plot 10 dominated by ponderosa pine at the Clover Mountains experienced a fire in 1946 and has the most (n=7) tallies for the 1000-hr (diameter > 7.62 cm) and the second most tallies (n=25) for the 100-hr (2.54 < diameter < 7.62 cm) DWD size classes among all plots. In contrast, some plots not experiencing a recent fire at the Clover Mountains (plots 2, 3, and 8 dominated by pinyon pine, ponderosa pine and, pinyon pine respectively) account for the only plots without 1000-hr DWD tallies. Natural mortality caused by drought or insect damage may also explain for the higher quantities of larger sizes of DWD at plots that have not experienced a recent fire such as plot 1 at the Clover Mountains.

Litter and Duff

Fuelbed fuel loads and bulk densities are variables that influence the connectivity of burnable areas (Miller et al. 2000). Mount Irish has significantly higher litter and combined (litter and duff) bulk densities compared to the Clover Mountains. The fact that the Clover Mountains have more plots dominated by ponderosa pine compared to Mount Irish supports why Mount Irish has higher bulk densities. The compact nature of juniper species and pinyon pine needles is indicative of higher fuelbed bulk densities. Although the plots at the Clover Mountains do contain larger quantities of pinyon pine, the plots at Mount Irish contain larger numbers of both pinyon pine and juniper species. Thus, having more juniper species and less ponderosa pine at Mount Irish explains why bulk densities are lower at the Clover Mountains. All else being equal, as fuelbed weight increases, rate of fire spread may actually decrease because more fuel must be raised to ignition temperature. Although Mount Irish has higher litter and combined bulk densities, the rate of fire spread at the Clover Mountains may actually be higher. More porous fuelbeds (i.e. fulebeds associated with ponderosa stands) will have lower bulk densities and will burn with greater intensity than denser fuelbeds (i.e. fuelbeds associated with juniper species stands). Although not statistically significant, the Clover Mountains has deeper duff than Mount Irish. This suggests that deep duff surrounding the bases of trees may smolder for longer periods and generate enough heat that may kill trees through cambium mortality and loss of fine root hairs (van Wagtendonk 2006). Although difficult to predict without experimental tests, comparing the fuelbed characteristics between the two study sites suggest that the rate and severity of fire spread through the fuelbed may be higher at the Clover Mountains than at Mount Irish.

Combining this with the fact that the Clover Mountains has significantly greater amount of 10-hr down dead woody debris as mentioned above, supports the suggestion that the Clover Mountains may have a higher rate of surface fire spread.

The fact that there are no significant differences for depths, weights, and bulk densities for litter, duff, and combined litter and duff between plots containing fire records and plots not containing fire records at each study site is unexpected. One would expect duff depths and weights to be significantly lower in plots which have experienced a recent fire event. An explanation may be that enough time has elapsed since last fire for adequate decomposition from litter to duff to occur. However, some plots do exhibit the expected fuelbed characteristics. For example, plot 7 dominated by pinyon-juniper at Mount Irish and plot 3 dominated by ponderosa pine at the Clover Mountains have the deepest duff depths (1.2 and 2.3 cm respectively) and the heaviest duff weights (0.1315 and 0.1295 kg respectively) among all plots. Each of these plots does not have a record of fire occurrence.

Canopy Fuel: Canopy Bulk Density and Canopy Fuel Load

Foliage and half of 1-hr fuels are assumed to directly influence the rate of crown fire spread. Mount Irish has significantly more canopy foliage biomass at the 90% significance level compared to the Clover Mountains. Although not indicative of a higher canopy bulk density, this does suggest that the rate of crown fire spread at Mount Irish may be higher than at the Clover Mountains.

When analyzing the canopy fuel data, canopy bulk density for all species combined is approximately 56% greater at Mount Irish. This difference between the two study sites may be attributed to the greater amount of foliage biomass at Mount Irish. The Clover Mountains also have more herbaceous cover, suggesting less canopy biomass than at Mount Irish.

Based on the observed canopy bulk density of 0.05 kg/m^3 (Fule et al. 2001a; Fule et al. 2001b) associated with passive and/or active crown fires in ponderosa pine forests in Arizona, both study sites appear to be capable of sustaining these types of crown fires. Combining all species, the canopy bulk density at Mount Irish and the Clover Mountains is 0.1954 kg/m^3 and 0.0849 kg/m^3 respectively. Eleven plots at Mount Irish and nine plots at the Clover Mountains have canopy bulk densities greater than 0.05 kg/m^3 (Appendix E, Table 20). Van Wagtendonk (2006) states that there is little additional effect on the critical spread rate after canopy bulk densities reach 0.15 kg/m^3. When combining all species together, eight plots at Mount Irish and two plots at the Clover Mountains have canopy bulk densities greater than 0.15 kg/m^3. The higher number of plots containing these higher canopy bulk density values at Mount Irish suggests that canopy fire spread may be more continuous across the landscape at Mount Irish compared to the Clover Mountains. FMAplus outputs show that pinyon pine has higher canopy bulk densities (0.112 kg/m^3 at Mount Irish and 0.075 kg/m^3 at the Clover Mountains) when compared to other tree species (Appendix E, Table 19).

However, there is not a published threshold canopy bulk density value that determines exactly when a crown fire occurs or is sustained. This is because the conditions needed for crown fire occurrence is widely variable. Canopy bulk density is only a fraction, although a good indicator, of what is needed to initiate crown fire and its spread. Fuel moisture, canopy base height, and wind speed, are other variables that contribute to crown fire propagation.

High lightning strike density has been found to be a good predictor of wildfire. Dilts et al. (2009) observed that the eastern half of Lincoln County has higher fire density and higher lightning strike density compared to the western half, and state that a gradient from ignition-limited to ignition-saturated areas exists going from the western to the eastern portion of Lincoln County. The storm activity associated with the North American monsoon may have more influence on the Clover Mountains compared to Mount Irish, which explains for the higher lightning strike densities at the Clover Mountains. These results (Dilts et al. 2009), along with species compositions between the two study sites, strengthen the suggestion that the Clover Mountains are located within a climatic transitional zone between the Great Basin and the Colorado Plateau. Although current canopy bulk density calculations indicate that crown fire may be more severe at Mount Irish, the chances for an ignition may actually be greater at the Clover Mountains. Thus, ignitions may be more of a limiting factor for fire occurrence at Mount Irish compared to the Clover Mountains.

The fact that permanent plots that have experienced a recent fire have significantly lower canopy bulk densities than plots which have not experienced a recent fire is not surprising. Severe fires will reduce tree densities resulting in reduced available fuel loads. This may explain why the Clover Mountains has a significantly lower canopy bulk density when compared to Mount Irish. The last major fire event at the Clover Mountains occurred in 1946 (Kilpatrick 2009), while fire events at Mount Irish subsided drastically after 1860 (Jamieson 2008).

Permanent plots that have experienced a recent fire event have significantly less 1-hr (diameter < 0.64 cm) canopy biomass than plots not experiencing recent fire events at both Mount Irish and the Clover Mountains. This too is not surprising because foliage and a portion of the 1-hr canopy biomass are directly consumed in the flaming front of a crown fire. If a fire is not severe enough to consume larger portions of the trees, then the foliage and 1-hr canopy biomass will be reduced or even eliminated while leaving larger canopy fuel size classes intact. A significant difference in foliage does not exist between plots with and without recent fire activity possibly due to the fact these woodland species are fire adapted and resprout foliage quickly after fire.

Herbaceous and Shrub Vegetation

Shrub and herbaceous vegetation contributes to surface fuel connectivity, thus surface fire spread. The percent cover of herbaceous vegetation appears to be similar between Mount Irish and the Clover Mountains. However, percent cover of shrub vegetation appears to be greater at the Clover Mountains. This suggests that a greater connectivity of this type of surface fuel exists and the potential for surface fire spread is greater at the Clover Mountains compared to Mount Irish.

Canopy Fuel Reconstruction and Potential Crown Fire Behavior

Accuracy is important when attempting to model ecological changes through time. Great care was taken in order to assure accuracy at every step in reconstructing forest fuel biomass and potential fire behavior. Although a Great Basin variant does not exist in FVS, the Utah variant most closely resembled the Great Basin ecology and climate. The most accurate data were the direct measurements taken in the field at each study site. These measurements allowed for comparisons between field measurements and forest reconstruction for tree density and basal area. Site specific data on regeneration density by species and decade were inputted into the model resulting in simulated densities and basal areas in 2007 at Mount Irish and in 2008 at the Clover Mountains being within ±31 and ±20% respectively of field-measured values. The fact that simulation for the Clover Mountains is closer to the current field measurements than the simulation for Mount Irish is quite interesting. The Utah variant in FVS may be better suited and resemble ecological characteristics and processes better for the Clover Mountains than for Mount Irish. This would make sense because the Clover Mountains are in closer proximity to the geographical areas represented in the Utah variant.

Current fuel biomass and canopy bulk density values reported in FVS are lower than the values obtained through allometric equations in FMAplus and the allometric derived equations specific to the Great Basin (Tausch 2009). An explanation is the fact that FVS only requires tree species and DBH as model inputs. Crown ratio, tree height, and crown base height, which are required in FMAplus and the Tausch equations, are optional inputs in FVS. However, it is impossible to determine what the historic values of these variables are, and thus were not entered into FVS. Therefore, the fact that the CBD values reported in FVS differ from FMAplus and the Tausch equations is not surprising. However, it is important to observe how fuel biomass and canopy bulk density change through time in relation to crowning index. These relationships are indicative as to whether the fire exclusion/fuel buildup perspective is valid at Mount Irish and the Clover Mountains. An interesting observation among both study sites is how CI decreases as canopy foliage and 1-hr fuel biomass increases. Since foliage and 1-hr fuels contribute directly to the flaming front of a crown fire, one would expect the potential for crown fire occurrence to increase in parallel to an increase in biomass of these canopy fuel types. The results obtained from the FVS simulations at Mount Irish and the Clover Mountains do support the fire exclusion/fuel buildup perspective as indicated by the CI decline through time. The windspeed needed to sustain an active fire decreased at both Mount Irish and the Clover Mountains as CBD and fuel biomass increased. An explanation as to why the crowning index is decreasing and fuel biomass is increasing at a faster rate at the Clover Mountains compared to Mount Irish may be related to differences in the quantity and composition of tree species between each study site FVS simulation.

An assumption in this model is that there has not been a disturbance such as fire since Euro-American settlement. However plot 11 at Mount Irish, and plots 10, 11, and 12 at the Clover Mountains have evidence of post settlement fire occurrence. Running separate simulations for each of these plots beginning in the decade following fire would help validate the fire exclusion/fuel buildup perspective at each study site. Simulations of each permanent plot would also be beneficial to observe how fuel biomass and potential fire behavior has changed temporally and spatially within each study site. In addition, future projections of crowning index and fuel biomass may be more accurate if simulations started in 2007 for Mount Irish and 2008 for the Clover Mountains. Field-measured data pertaining to crown ratios, tree heights, crown base heights, etc. could be entered into the model and would give a more accurate description of forest structure at the beginning of the simulations.

CONCLUSION

Results suggest that continuity of surface fuels and rate of surface fire spread at the Clover Mountains is greater than at Mount Irish. Although a published threshold value describing when crown fires occur or when they are sustained does not exist, both study sites appear to be capable of sustaining passive and/or active crown fires based on CBD values of 0.05 kg/m^3 (Fule et al. 2001a; Fule et al. 2001b). However, CBD is approximately 56% greater and appears to be more continuous across the landscape at Mount Irish suggesting that a crown fire will be more severe compared to the Clover Mountains. FVS outputs show that crown fire potential is increasing in parallel with increasing fuel biomass through time at each study site. If left unmanaged, both sites could experience crown fires with undesirable consequences across the landscape. As a management goal, restoration of forest stands should rely on detailed research within Lincoln County and the Great Basin as a whole. Prescribed thinning and/or burning are two management activities that may be beneficial for restoring current forests to pre-Euro-American conditions. However, the applicability of thinning and/or burning, as well as other activities should be carefully analyzed to determine which management activity would be most appropriate, especially under future climate change scenarios.

REFERENCES

Baker, William L.; Shinneman, Douglas J. 2004. Fire restoration of pinyon-juniper woodlands in the western United States: a review. *Forest Ecology and Management.* 189: 1-21.

Bakker, Jonathan D. 2005. A new, proportional method for reconstructing historical tree diameters. *Canadian Journal of Forest Research*. **35**: 2515-2520.

Beighley, M.; Bishop, J. 1990. Fire behavior in high-elevation timber. *Fire Management Notes*. **51** (2), 23-28.

Bradley, Megan. 2009. Pre- and post-settlement stand development of woodland ecosystems in Lincoln County, Nevada. MS Thesis, University of Nevada, Reno.

Bradshaw, L.; Brittain, S. 1999. FireFamily Plus. Software available from USDA Forest Service, Rocky Mountain Research Station, MT.

Braun-Blanquet, Josias. *Plant sociology: the study of plant communities*. Hafner Publishing Company. New York. 1965.

Brown, Arthur A.; Davis, Kenneth P. *Forest fire: Control and use*. 2nd Ed. McGraw-Hill Book Company. New York. 1973.

Brown, J.K. 1970. Ratios of surface area to volume for common fine fuels. *Forest Science*. **16**(1): 101-105.

Brown, J.K. 1971. A planar intersect method for sampling fuel volume and surface area. *Forest Science*. 17: 96-102.

Brown, J.K. 1974. Handbook for inventorying downed woody material. Ogden: USDA Forest Service, Intermountain Forest and Range Experiment Station General Technical Report INT-16.

Brown, J.K. 1978. Weight and Density of Crowns of Rocky Mountain Conifers. USDA Forest Service Research Paper INT-197.

Brown, J.K.; Oberheu, R.D.; Johnston, C.M. 1982. Handbook for inventorying surface fuels and biomass in the interior west. Ogden: USDA Forest Service, Intermountain Forest and Range Station General Technical Report INT-129.

Brown, Peter M.; Heyerdahl, Emily K.; Kitchen, Stanley G.; Weber, Marc H. 2008. Climate effects on historical fires (1630-1900) in Utah. *International Journal of Wildland Fire*. **17**: 28-39.

Carlton, D. 2004. Fuels Management Analyst Plus Software, Version 3. Fire Program Solutions, LLC, Estacada, Oregon.

Cissel, John H.; Swanson, Frederick, J.; Weisburg, Peter J. 1999. Landscape management using historical fire regimes: Blue River, Oregon. *Ecological Applications*. **9**(4): 1217-1231.

Chambers, Jeanne C. 2001. Pinus monophylla establishment in an expanding Pinus-Juniperus woodland: Environmental conditions, facilitation and interacting factors. *Journal of Vegetation Science*. 12: 27-40.

Charlet, David A. *Atlas of Nevada conifers: a phytogeographic reference*. Reno: University of Nevada Press, 1996.

Cruz, Miguel G.; Alexander, Martin E.; Wakimoto, Ronald H. 2003. Assessing canopy fuel stratum characteristics in crown fire prone fuel types of western North America. *International Journal of Wildland Fire*. **12**: 39-50.

Daly, C.; Gibson, W.; Daggett, M.; Smith, J.; Taylor, G. 2008. Near-real-time monthly high-precipitation climate data set for the conterminous United States. Spatial Climate Analysis Service, Oregon State University. Corvallis, OR.

DeBano, Leonard F.; Neary, Daniel G.; Ffolliott, Peter F. *Fire's Effects on Ecosystems*. New York: John Wiley and Sons, 1998.

Dilts, Thomas E.; Sibold, Jason S.; Biondi, Franco. 2009. A weights-of-evidence model for mapping the probability of fire occurrence in Lincoln County, Nevada. *Annals of the Association of American Geographers*. **99**(4): 712-727.

Dixon, Gary E. (comp). 2003. Essential FVS: A User's Guide to the Forest Vegetation Simulator. Internal Report. USDA Forest Service, Forest Management Service Center, Fort Collins, CO.

Escobedo, Francisco J.; Ffolliott, Peter F.; Gottfried, Gerald J.; Garza, Florentino. 2001. Fire frequency effects of fuel loadings in pine-oak forests of the Madrean Province. USDA Forest Service, Rocky Mountain Research Station, Research Note RMRS-RN-10.

Flannigan, M.D.; Stocks, B.J.; Wotton, B.M. 2000. Climate change and forest fires. *The Science of the Total Environment*. Vol: 262, Issue: 3: 221-229.

Floyd, Lisa M.; Romme, William H.; Hanna, David D. 2000. Fire history and vegetation pattern in Mesa Verde National Park, Colorado, USA. *Ecological Applications*. 10: 1666-1680.

Fule, Peter Z.; Covington, W. Wallace; Moore, Margaret M. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. *Ecological Applications*. **7**(3): 895-908.

Fule, Peter Z.; McHugh, Charles; Heinlein, Thomas A.; Covington, W. Wallace. 2001a. Potential fire behavior is reduced following forest restoration treatments. In: Proceedings of the RMRS-P-22. USDA Forest Service, Ogden, UT, pp. 28-35.

Fule, Peter Z.; Waltz, Amy A.M.; Covington, W. Wallace. 2001b. Measuring forest restoration effectiveness in hazardous fuels reduction. *Journal of Forestry*. **99**(11): 24-29.

Fule, Peter Z.; Crouse, Joseph E.; Cocke, Allison E.; Moore, Margaret M; Covington, W. Wallace. 2004. Changes in canopy fuels and potential fire behavior 1880-2040: Grand Canyon, Arizona. *Ecological Modelling*. **175**: 231-248.

Gholz, H.L.; Grier, C.C.; Cambell, A.G.; Brown, A.T. 1979. Equations for estimating biomass and leaf area of plants in the pacific northwest. Oregon State University, School of Forestry, Research Paper 41.

Gray, K.L.; Reinhardt, E.D. 2003. Analysis of algorithms for predicting canopy fuel. In: Proceedings of the Second International Wildland Fire Ecology and Fire Management Congress and Fifth Symposium on Fire and Forest Meteorology, November 16-20, 2003, Orlando, FL. American Meteorological Society.

Hall, Sonia A.; Burke, Ingrid C. 2006. Considerations for characterizing fuels as inputs for fire behavior models. *Forest Ecology and Management*. Volume 227, Issues 1-2: 102-114.

Heyerdahl, Emily K.; Brubaker, Linda B.; Agee, James K. 2001. Spatial controls of historical fire regimes: a multiscale example from the interior west, USA. *Ecology*. **82**(3): 660-678.

Hood, Sharon; Wu, Ros. 2006. Estimating fuel bed loadings in masticated areas. USDA Forest Service Proceedings, RMRS-P-41.

Jamieson, Leia P. 2008. Fire history of pinyon-juniper/ponderosa pine ecosystem in the intermountain west. MS Thesis, University of Nevada, Reno.

Johnson, Dustin D.; Miller, Richard F. 2006. Structure and development of expanding western juniper woodlands as influenced by two geographic variables. *Forest Ecology and Management*. Vol. 229, Issues, 1-3: 7-15.

Johnson, Edward A.; Miyanishi, Kiyoko. 2001. *Forest Fires: Behavior and Ecological Effects*. San Diego: Academic Press, 2001.

Kaiser, Lee. Unbiased estimation in line-intercept sampling. 1983. *Biometrics*. **39**(4): 965-976.

Kilpatrick, M. 2009. Tree-ring based fire history of the Clover Mountains, Lincoln County, Nevada. M.S. Thesis. University of Nevada, Reno, Nevada, U.S.A.

Keane, Robert E.; Reinhardt, Elizabeth D.; Scott, Joe; Gray, Kathy; Reardon, James. 2005. Estimating forest canopy bulk density using six indirect methods. *Canadian Journal of Forest Research*. **35**: 724-739.

Knapp, Eric E.; Keeley, Jon E.; Ballenger, Elizabeth A; Brennan, Teresa J. 2005. Fuel reduction and coarse woody debris dynamics with early season and late season prescribed fire in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management*. **208**: 383-397.

Landers, Peter B.; Morgan, Penelope; Swanson, Frederick J. 1999. Overview of the use of natural variability concepts in managing ecological systems. *Ecological Applications*. 9: 1179-1188.

Martin, Robert E.; Frewing, David W.; McClanahan, James L. 1981. Average biomass of four Northwest shrubs by fuel size class and crown cover. Res Note PNW-374. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Miller, Carol; Urban, Dean L. 2000. Connectivity of forest fuels and surface fire regimes. *Landscape Ecology*. **15**: 145-154.

Miller, Richard F.; Wigand, Peter E. 1994. Holocene Changes in Semiarid Pinyon-Juniper Woodlands. *BioScience*, **44**, 465-474.

Miller, Richard F.; Tausch, Robin J. 2001. The role of fire in pinyon and juniper woodlands: a descriptive analysis. In: Gallery, K., Wilson, T. (Eds), Fire Conference 2000: The First National Congress on Fire Ecology, Prevention and Management. Tall Timbers Research Station, Tallahassee, FL, pp. 15-30.

Miller, Richard F.; Tausch, Robin J.; McArthur, Duran E.; Johnson, Dustin D.; Sanderson, Stewart C. Age structure and expansion of pinyon-juniper woodlands: A regional perspective in the intermountain west. 2008. USDA, Forest Service, RMRS-RP-69.

Packard, Gary C.; Boardman, Thomas J. 2008a. Model selection and logarithmic transformation in allometric analysis. *Physiological and Biochemical Zoology*. **81**(4): 496-507.

Packard, Gary C.; Birchard, Geoffrey F. 2008b. Traditional allometric analysis fails to provide a valid predictive model for mammalian metabolic rates. *The Journal of Experimental Biology*. **211**: 3581-3587.

Perry, David A.; Jing, Huang; Youngblood, Andrew; Oetter, Doug R. 2004. Forest structure and fire susceptibility in volcanic landscapes of the eastern high cascades, Oregon. *Conservation Biology*. **18**(4): 913-926.

Pyne, Stephen J.; Andrews, Patricia L; Laven, Richard D. *Introduction to Wildland Fire*. New York: John Wiley and Sons, 1996.

Reinhardt, Elizabeth D.; Crookston, Nicholas L. (Eds.). 2003. The fire and fuels extension to the Forest Vegetation Simulator. USDA Forest Service General Technical Report RMRS-GTR-166, Rocky Mountain Research Station, Fort Collins, CO., USA, 209 pages.

Reinhardt, Elizabeth; Scott, Joe; Gray, Kathy; Keane, Robert. 2006. Estimating canopy fuel characteristics in five conifer stands in the western United States using tree and stand measurements. *Canadian Journal of Forest Research*. **38**: 2803-2814.

Rittenhouse, L.R.; Sneva, F.A. 1977. A technique for estimating big sagebrush production. *Journal of Range Management*. **30**(1): 68-70.

Romme, William H.; Floyd-Hanna, Lisa; Hanna, David D. 2003. Ancient pinyon-juniper forests of Mesa Verde and the West: A cautionary note for forest restoration programs. USDA, Forest Service, Proceedings RMRS-P-29.

Romme, William; Allen, Craig; Bailey, John; Baker, William; Bestelmeyer, Brandon; Brown, Peter; Eisenhart, Karen; Floyd-Hanna, Lisa; Huffman, David; Jacobs, Brian; Miller, Richard; Muldavin, Esteban; Swetnam, Thomas; Tausch, Robin; Weisberg, Peter. Historical and modern disturbance regimes of pinon-juniper vegetation in the western U.S. 2007. Colorado Forest Restoration Institute. The Nature Conservancy.

Ryan, Kevin C. et al. 2001. Southern Utah Fuels Management Demonstration Project Study Plan. Version 4. USFS-Missoula Fire Sciences Lab.

Sackett, Stephen S.; Hasses, Sally M. 1996. Fuel loadings in southwestern ecosystems of the United States. In: Ffolliott, P. F.; DeBano, L. F.; Baker, M. B., Jr.; Gottfried, G. J.; Solis-Garza, B.; Edminster, C. B.; Neary, D. G.; Allen, L. S.; Hamre, R. H.; tech. cords. Effects of fire on Madrean Province ecosystems. General Technical Report. RM-289. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 187-192.

Sando, Rodney, W.; Wick, Charles H. 1972. A method of evaluating crown fuels in forest stands. Research Paper. NC-84. Saint Paul, MN: USDA, Forest Service, North Central Forest Experimental Station.

Schoennagel, Tania; Veblen, Thomas T.; Romme, William H. 2004. The interaction of fire, fuels, and climate across Rocky Mountain forests. *BioScience*. **54**, **7**, 661-676.

Scott, Joe H. 1999. NEXUS: a system for assessing crown fire hazard. Fire Management Notes **59**(2): 20-24.

Scott, Joe H.; Reinhardt, Elizabeth D. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. USDA Forest Service, Research Paper RMRS-RP-29. Rocky Mountain Research Station, Fort Collins, CO.

Scott, Joe H.; Reinhardt, Elizabeth D. 2002. Estimating canopy fuels in conifer forests. *Fire Management Today*. **62**(4): 45-50.

Sherriff, Rosemary L.; Veblen, Thomas T. 2006. Ecological effects of changes in fire regimes in pinus ponderosa ecosystems in the Colorado Front Range. *Journal of Vegetation Science*. **17**: 705-718.

Sikkink, Pamela G.; Keane, Robert E. 2008. A comparison of five sampling techniques to estimate surface fuel loading in montane forests. *International Journal of Wildland Fire*. **17**: 363-379.

Snell, Kendall A.; Brown, James K. 1978. Comparison of tree biomass estimators-DBH and sapwood area. *Forest Science*. **24** (4): 455-457.

Stephenson, Nathan L. 1999. Reference conditions for giant sequoia forest restoration: structure, process, and precision. *Ecological Applications*. **9**(4): 1253-1265.

Stephens, Scott L.; Finney, Mark A.; Schantz, Heidi. 2004. Bulk density and fuel loads of ponderosa pine and white fir forests: impacts on leaf morphology. *Northwest Science*. **78**(2), 93-100.

Stephens, Scott L.; Moghaddas, Jason J. 2005. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. *Forest Ecology and Management*. **215**: 21-36.

Stokes, Marvin A.; Smiley, Terah L. *An Introduction to Tree-ring Dating*. University of Chicago Press, Chicago, 1968.

Stewart, John H.; Carlson, John E. 1978. Geologic Map of Nevada. U.S. Geological Survey, scale 1:500,000.

Swetnam, Thomas W.; Betancourt, Julio L. 1990. Fire-Southern Oscillation Relations in the Southwestern United States. *Science*, **249**, 1017-1020.

Swetnam, Thomas W.; Allen, Craig D.; Betancourt, Julio L. 1999. Applied historical ecology: Using the past to manage for the future. *Ecological Applications*. 9: 1189-1206.

Tausch, Robin J.; Tueller, Paul T. 1988. Comparison of regression methods for predicting singleleaf pinyon phytomass. *Great Basin Naturalist*. **48**: 39-45.

Tausch, R.J. 1999. Transitions and thresholds: Influences and implications for management in pinyon and juniper woodlands. Pages 61-65 in S.B. Monsen, R. Stevens, R.J. Tausch, R. Miller, and S. Goodrich. Proceedings: Ecology and management of pinyon-juniper communities within the interior west. Proceedings: RMRS-P-9, USDA, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Tausch, Robin J.; Hood, Sharon. 2007. Pinyon/Juniper Woodlands. USDA, Forest Service, General Technical Report. RMRS-GTR-202.

Tausch, Robin, J. 2009. A structurally based analytic model for estimation of biomass and fuel loads of woodland trees. *Natural Resource Modeling*. In Press.

Van Dyck, Michael G. 2000. Keyword reference guide for the forest vegetation simulator. USDA Forest Service Forest Management Service Center, Fort Collins, CO.

Van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. *Forest Science*. 14: 20-26.

Van Wagner, C.E. 1982. Practical aspects of the line intercept method. Canadian Forestry Service, Petawawa National Forestry Institute, Information Report PI-X-12.

van Wagtendonk, Jan W. 1996. Use of a Deterministic Fire Growth Model to Test Fuel Treatments. Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildlife Resources.

van Wagtendonk, Jan W.; Benedict, James M.; Sydoriak, Walter M. 1998. Fuel bed characteristics of Sierra Nevada conifers. *Western Journal of Applied Forestry*. **13**(3): 73-84.

van Wagtendonk, Jan W. 2006. Fire as a physical process. Pages 38-57 in: N.G. Sugihara, J.W. van Wagtendonk, J. Fites-Kaufman, K.E. Shaffer, and A.E. Thode, editors. Fire in California's ecosystems. University of California Press, Berkeley, USA.

Veblen, Thomas T. 2003a. Historic range of variability of mountain forest ecosystems: concepts and applications. *The Forestry Chronicle*. Vol. 79, NO. 2.

Veblen, Thomas T. 2003b. Key issues in fire regime research for fuels management and ecological restoration. Pages 259-276 in: P. Omi and L. Joyce (technical eds). Fire, Fuel Treatments and Ecological Restoration: Conference proceedings, 2002 16-18 April; Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 475p.

Westerling, A.L.; Gershunov, A.; Brown, T.J.; Cayan, D.R.; Dettinger, M.D. 2003. Climate and wildfire in the western United States. *Bulletin of the American Meteorological Society*. May 2003: 595-604.

Westerling, A.L.; Hidalgo, H.G.; Cayan, D.R.; Swetnam, T.W. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildlife Activity. *Science*. **313**: 940-943.

Wolf, Tom. *In Fire's Way: a Practical Guide to Life in the Wildfire Danger Zone*. Albuquerque: University of New Mexico Press, 2003.

Appendix A: Climate

Figure A-1: The Mount Irish and the Clover Mountains study sites in relation to the Great Basin Hydrographic Boundary. Mount Irish lays on the boundary while the Clover Mountains are located outside. However, both study sites are within the ecological boundaries of the Great Basin.

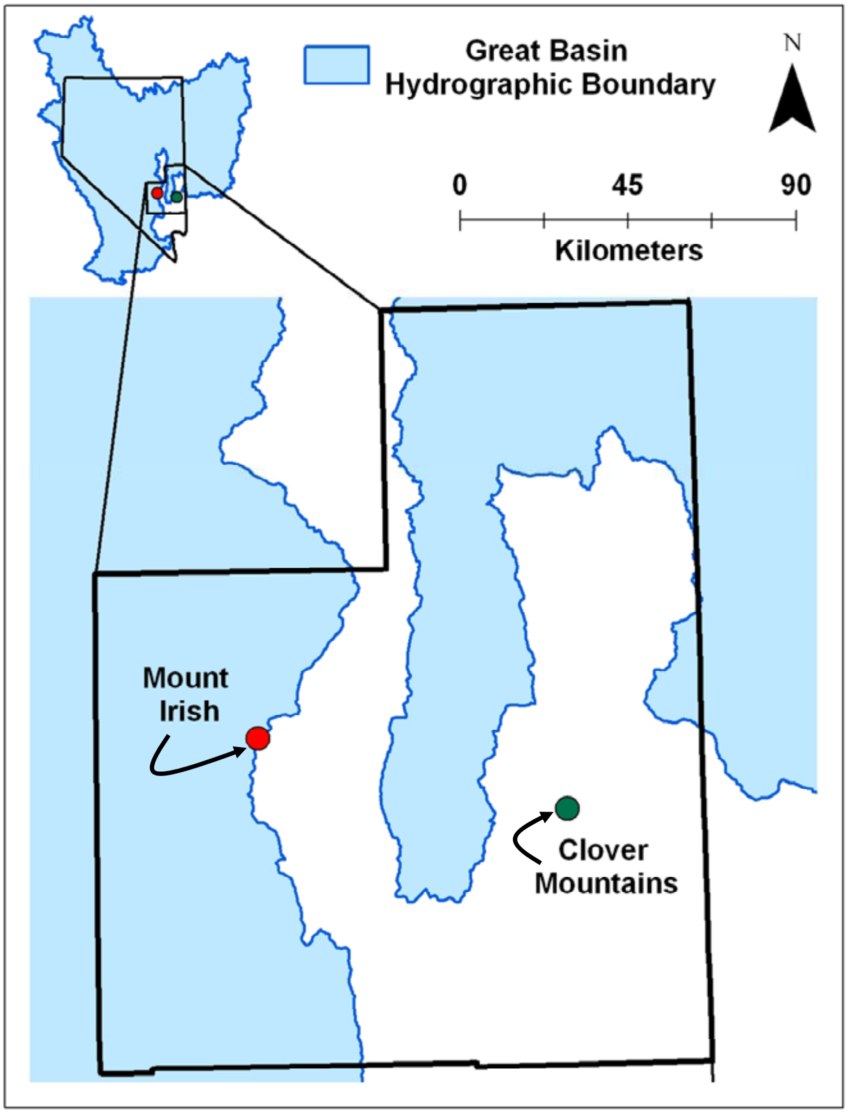


Figure A-2: Average annual precipitation at Mount Irish and the Clover Mountains obtained from PRSIM dataset over the 1895 to 2006 period. Climate data were obtained from two 4x4 km cells (N 37˚ 39' 27", W 115˚ 25' 51"; N 37˚ 36' 57", W 115˚ 25' 51") for Mount Irish and from four 4x4 km cells (N 37˚ 26' 57", W 114˚ 28' 21"; N 37˚ 29' 27", W 114˚ 28' 21"; N 37˚ 26' 57", W 114˚ 25' 51"; N 37˚ 29' 27", W 114˚ 25' 51") for the Clover Mountains.

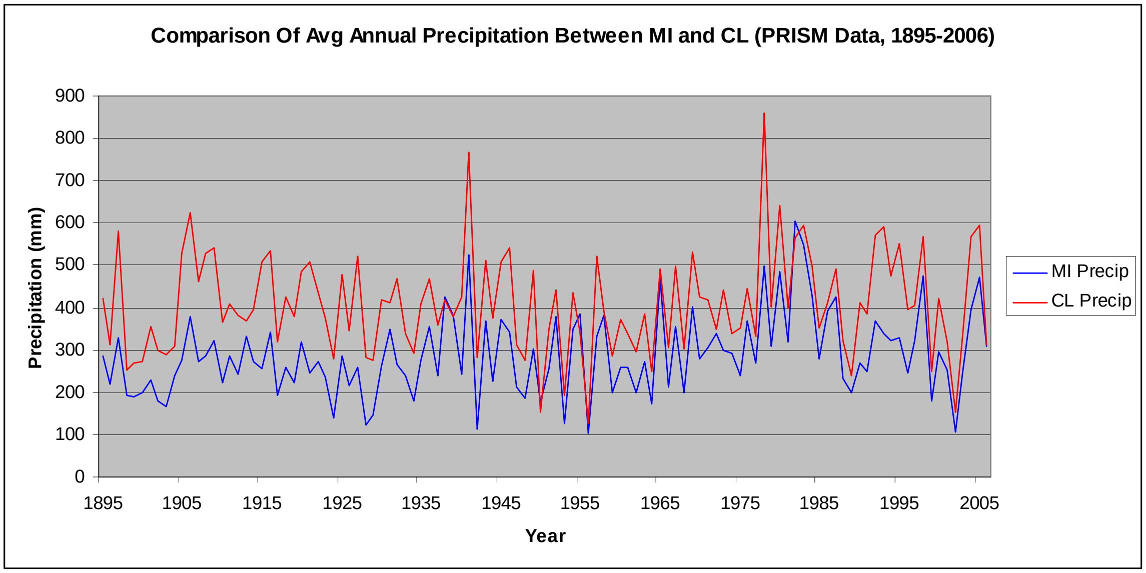


Figure A-3: Average annual temperature at Mount Irish and the Clover Mountains obtained from PRISM dataset over the 1895 to 2006 period. Climate data were obtained from two 4x4 km cells (N 37˚ 39' 27", W 115˚ 25' 51"; N 37˚ 36' 57", W 115˚ 25' 51") for Mount Irish and from four 4x4 km cells (N 37˚ 26' 57", W 114˚ 28' 21"; N 37˚ 29' 27", W 114˚ 28' 21"; N 37˚ 26' 57", W 114˚ 25' 51"; N 37˚ 29' 27", W 114˚ 25' 51") for the Clover Mountains.

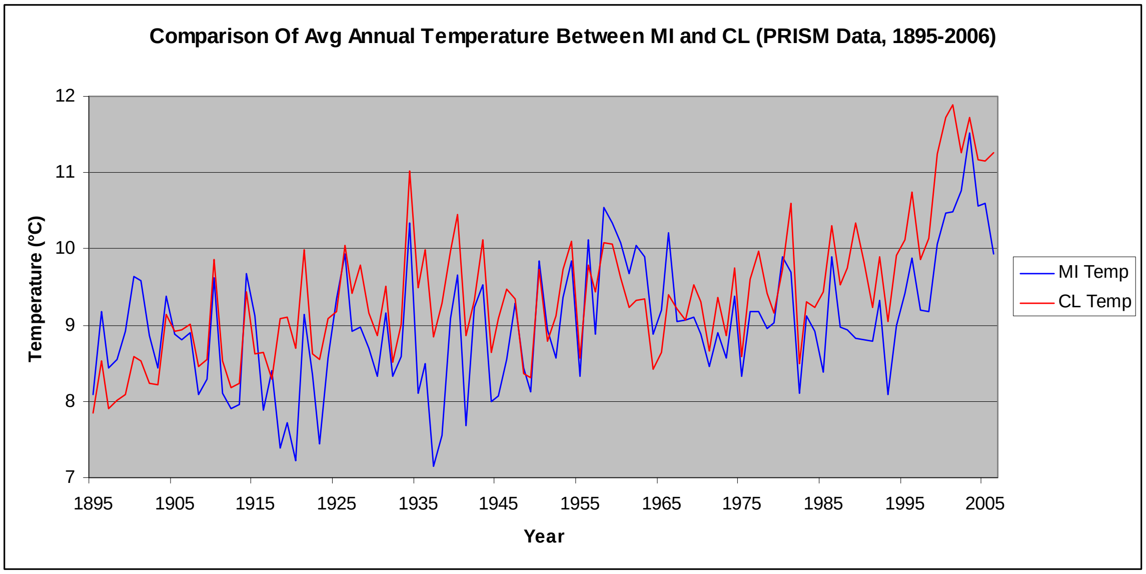


Table A-1: Temperature and precipitation data (1895-2006) at Mount Irish obtained from PRISM.

Mount Irish Climate (PRISM, 1895-2006)				
	Temperature (˚C)			Precipitation (mm)
	Avg. Min	Avg. Max	Avg. Temp	Mean
Jan	-8.0	5.1	-1.5	30.0
Feb	-6.8	6.6	-0.1	34.0
Mar	-4.5	10.2	2.8	30.0
Apr	-1.4	14.9	6.7	23.3
May	2.6	20.1	11.4	19.1
Jun	7.3	25.9	16.6	12.2
Jul	11.5	29.8	20.7	26.6
Aug	10.6	28.5	19.5	29.9
Sep	15.4	24.4	19.9	21.3
Oct	1.4	17.4	9.4	20.2
Nov	-3.8	10.6	3.4	19.6
Dec	-7.2	5.9	-0.7	21.9
Annual Avg	1.4	16.6	9.0	24.0
Annual Average Total				288.1

Table A-2: Temperature and precipitation data (1895-2006) at the Clover Mountains obtained from PRISM.

Clover Mountains Climate (PRISM, 1895-2006)				
	Temperature (˚C)			Precipitation (mm)
	Avg. Min	Avg. Max	Avg. Temp	Mean
Jan	-7.6	4.3	-1.6	44.5
Feb	-5.7	6.6	0.4	54.5
Mar	-2.9	9.7	3.4	46.3
Apr	0.8	14.6	7.7	30.3
May	4.4	19.7	12.1	21.4
Jun	9.5	25.9	17.7	10.4
Jul	13.4	29.5	21.4	26.7
Aug	12.7	28.4	20.6	39.8
Sep	7.7	24.3	16.0	28.3
Oct	2.2	17.5	9.9	33.7
Nov	-3.7	10.6	3.4	33.9
Dec	-8.0	5.1	-1.4	38.8
Annual Avg	1.9	16.3	9.1	34.0
Annual Average Total				408.4

Appendix B: Methods

Figure B-1: Circular plot layout.

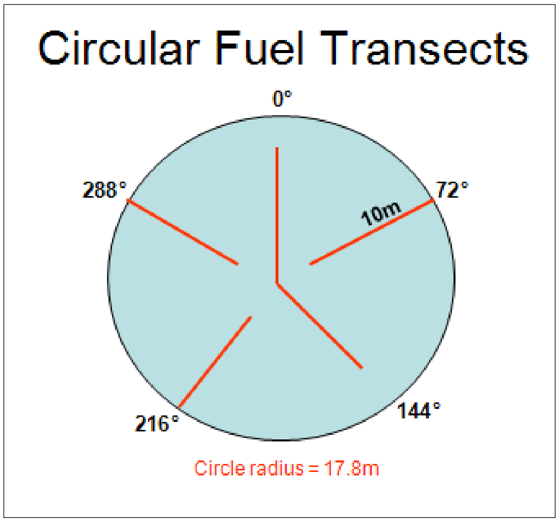


Figure B-2: Rectangular plot layout.

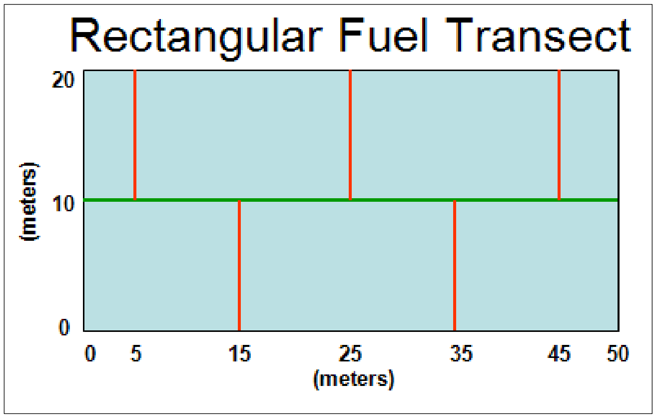


Figure B-3: Locations of herbaceous and shrub cover estimates, and litter and duff collection along each 10 meter transect line.

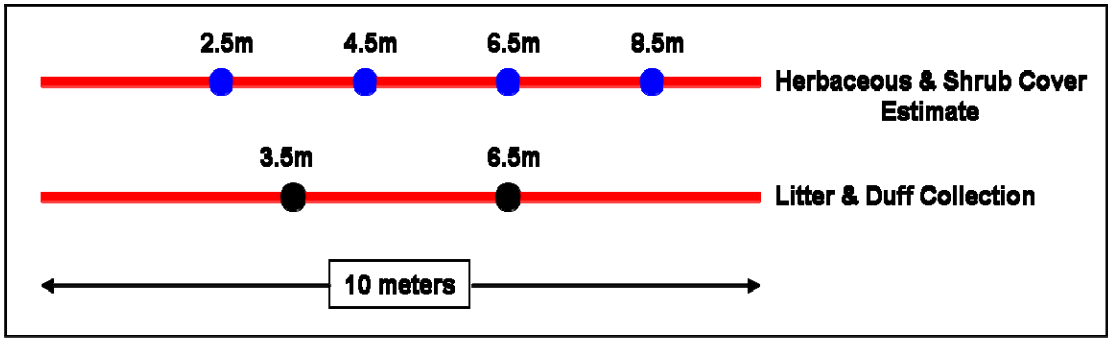


Figure B-4: U.S.A. Standard Test Sieves that were used to sort litter and duff samples from inorganic material such as rocks.

Figure B-5: Litter/duff sample being weighed following oven drying at 50˚C for 36 hours.

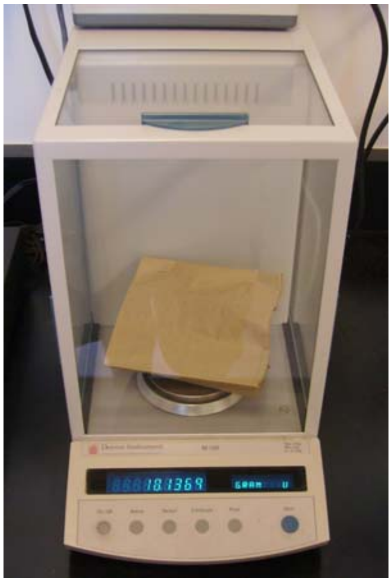


Table B-1: Permanent plot locations and characteristics for the Mount Irish and the Clover Mountains study sites. The northing and easting values refer to UTM Zone 11S.

Mount Irish								
Plot ID	**Northing**	**Easting**	**Shape**	**Long Axis Direction (°)**	**Elevation (m)**	**Slope (%)**	**Aspect (°)**	**Forest Type**
MIP01	4166938	640910	Rectangle	12	2485	35	300	PIMO-ABCO-JUOS
MIP02	4167043	640387	Rectangle	276	2480	33	140	PIMO-JUOS-PIPO
MIP03	4167742	640976	Circle	-	2595	40	350	Mixed
MIP04	4166809	640639	Circle	-	2515	34	290	PIMO-JUOS
MIP05	4166520	641061	Rectangle	250	2516	14	160	PIMO-JUOS
MIP06	4166579	640499	Rectangle	242	2457	20	190	PIMO-JUOS
MIP07	4167298	640511	Rectangle	60	2500	35	230	PIMO-JUOS
MIP08	4167387	640910	Circle	-	2540	35	200	PIMO-JUOS
MIP09	4167607	640565	Circle	-	2520	42	330	PIPO
MIP10	4166746	640487	Circle	-	2485	8	190	PIMO-JUOS
MIP11	4167641	640489	Rectangle	0	2484	46	0	PIPO
MIP12	4166873	640549	Circle	-	2497	4	340	ABCO-PIPO
Clover Mountains								
Plot ID	**Northing**	**Easting**	**Shape**	**Long Axis Direction (°)**	**Elevation (m)**	**Slope (%)**	**Aspect (°)**	**Forest Type**
CLP01	4148067	724008	Circle	-	2142	50	115	PIMO
CLP02	4149152	724147	Rectangle	142	2218	50	325	PIMO
CLP03	4148747	725132	Circle	-	2099	20	5	PIPO
CLP04	4148544	724172	Rectangle	13	2173	38	154	PIMO
CLP05	4149015	724596	Rectangle	60	2180	45	197	PIMO
CLP06	4148479	724606	Rectangle	117	2093	49	338	PIPO
CLP07	4147904	724271	Circle	-	1995	37	120	PIMO
CLP08	4148279	725051	Circle	-	2117	54	190	PIMO
CLP09	4149314	723940	Circle	-	2151	35	130	none
CLP10	4149644	723573	Rectangle	48	2139	50	0	PIPO
CLP11	4148502	724687	Circle	-	2062	43	13	PIPO
CLP12	4149948	723566	Rectangle	9	2098	25	235	PIPO

Table B-2: List of permanent plots where fire occurred at Mount Irish. Fire years within 50 meters refer to fire scars that were collected outside, but within 50 meters, of the permanent plot. Fire years were obtained from fire scars.

Plot #	Fire Years	Fire Years Within 50 meters
2	1759, 1794, 1836	
6		1693, 1689, 1713, 1738, 1742, 1746, 1915
9	1676	1500, 1634, 1676, 1859
10		1836
11	1751, 1778, 1859, 1860	
12	1628, 1827	1781

Table B-3: Same as Table B-2, but for the Clover Mountains.

Plot #	Fire Years
10	1790, 1838, 1877, 1946
11	1861, 1881, 1933
12	1611, 1715, 1764, 1807, 1844, 1860, 1946

Appendix C: Down Dead Woody Debris

Table C-1: Down, dead woody debris tallies by permanent plot and study site.

MOUNT IRISH			
Plot #	**Diameter Size**		
	0.64-2.54 (cm)	**2.54-7.62 (cm)**	**> 7.62 (cm)**
1	44	5	2
2	27	4	3
3	51	9	1
4	42	8	2
5	73	19	3
6	29	4	2
7	69	13	1
8	26	12	3
9	29	3	1
10	147	16	1
11	72	8	2
12	39	12	1
Combined	**648**	**113**	**22**
CLOVER MOUNTAINS			
Plot #	**Diameter Size**		
	0.64-2.54 (cm)	**2.54-7.62 (cm)**	**> 7.62 (cm)**
1	95	25	6
2	124	9	0
3	153	8	0
4	114	14	1
5	144	26	1
6	48	1	2
7	111	15	1
8	82	3	0
9	127	5	3
10	85	25	7
11	130	8	1
12	98	9	3
Combined	**1311**	**148**	**25**

Table C-2: t-Test results showing differences in the quantity of down, dead woody debris between the Clover Mountains and Mount Irish. The fuel size class with diameters of 0.64 – 2.54 cm are the only size class that differs significantly between the two study sites.

Column A (600 observations)				Column B (12 observations)		
Diameter 0.64-2.54 cm						
	CL	**MI**			**CL**	**MI**
Mean	2.19	1.08		Mean	109.25	54.00
Variance	6.68	2.35		Variance	865.66	1163.64
Observations	600	600		Observations	12	12
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
df	975			df	22	
t Stat	9.00591			t Stat	4.248643	
P(T<=t) one-tail	5.50E-19			P(T<=t) one-tail	0.000164	
t Critical one-tail	1.646418			t Critical one-tail	1.717144	
P(T<=t) two-tail	**1.10E-18**			P(T<=t) two-tail	**0.000329**	
t Critical two-tail	1.9624			t Critical two-tail	2.073873	
Diameter 2.54-7.62 cm						
Mean	0.25	0.19		Mean	12.33	9.42
Variance	0.58	0.35		Variance	76.97	25.90
Observations	600	600		Observations	12	12
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
df	1125			df	18	
t Stat	1.48148			t Stat	0.996163	
P(T<=t) one-tail	0.069379			P(T<=t) one-tail	0.166187	
t Critical one-tail	1.646209			t Critical one-tail	1.734064	
P(T<=t) two-tail	0.138759			P(T<=t) two-tail	0.332375	
t Critical two-tail	1.962075			t Critical two-tail	2.100922	
Diameter >7.62 cm						
Mean	0.04	0.04		Mean	2.08	1.83
Variance	0.05	0.04		Variance	5.36	0.70
Observations	600	600		Observations	12	12
Hypothesized Mean Difference	0			Hypothesized Mean Difference	0	
df	1164			df	14	
t Stat	0.419111			t Stat	0.352001	
P(T<=t) one-tail	0.337606			P(T<=t) one-tail	0.36504	
t Critical one-tail	1.646164			t Critical one-tail	1.76131	
P(T<=t) two-tail	0.675212			P(T<=t) two-tail	0.730079	
t Critical two-tail	1.962004			t Critical two-tail	2.144787	

Figure C-1: Histogram for the Clover Mountains showing the number of DWD (0.64cm < Diam. < 2.54cm) observations (n=600 1-meter intervals).

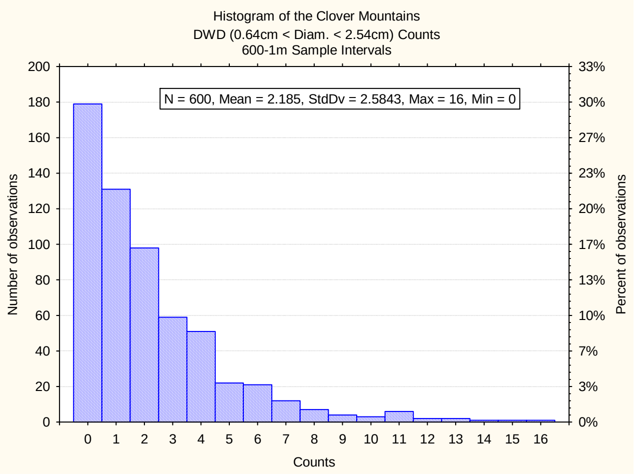


Figure C-2: Same as Figure C-1, but for Mount Irish.

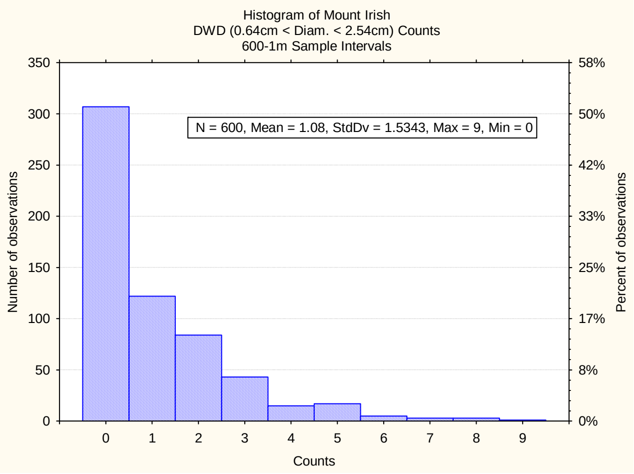


Figure C-3: Histogram for the Clover Mountains showing the number of DWD (2.54cm < Diam. < 7.62cm) observations (n=600 1-meter intervals).

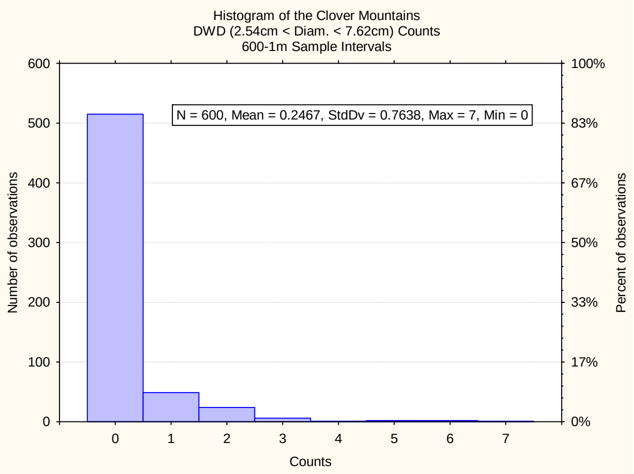


Figure C-4: Same as Figure C-3, but for Mount Irish.

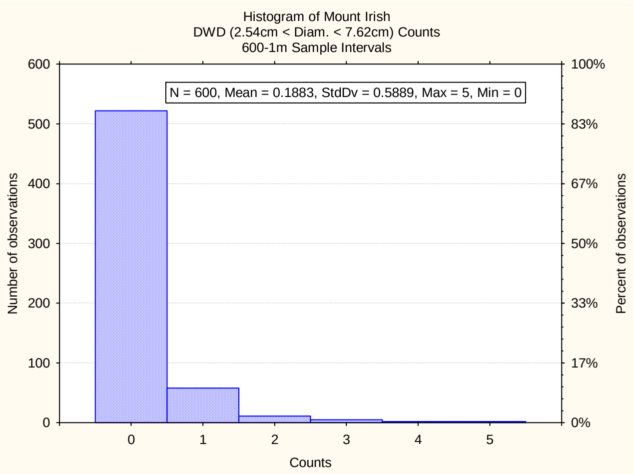


Figure C-5: Histogram for the Clover Mountains showing the number of DWD (Diam. > 7.62cm) observations (n=600 1-meter intervals).

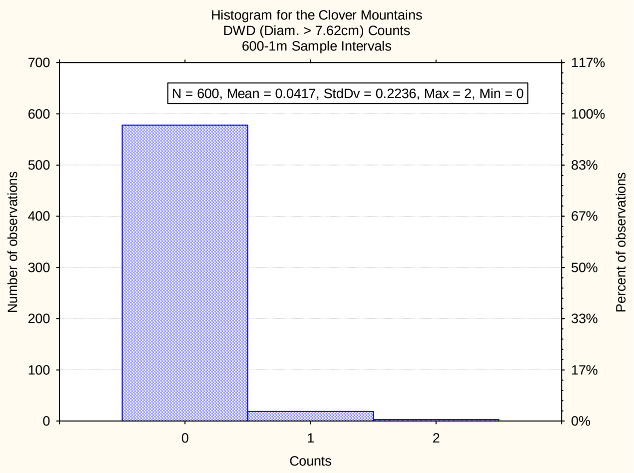


Figure C-6: Same as Figure C-5, but for Mount Irish.

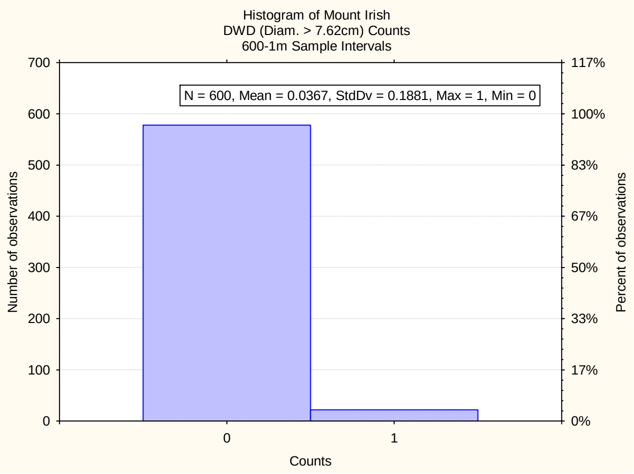


Figure C-7: Histogram for the Clover Mountains showing the number of DWD (0.64cm < Diam. < 2.54cm) observations (n=12 plots).

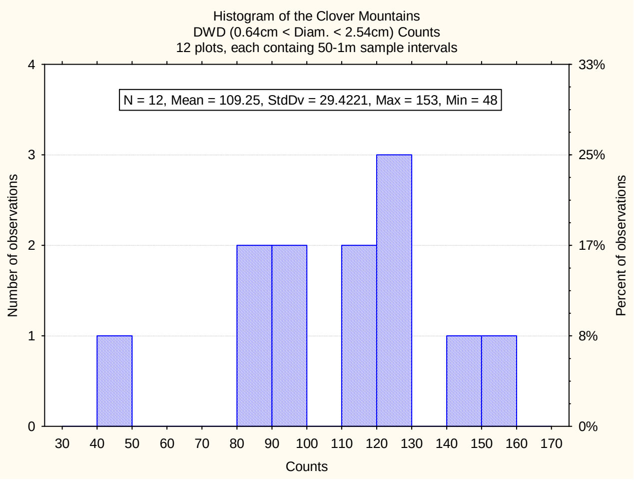


Figure C-8: Same as Figure C-7, but for Mount Irish.

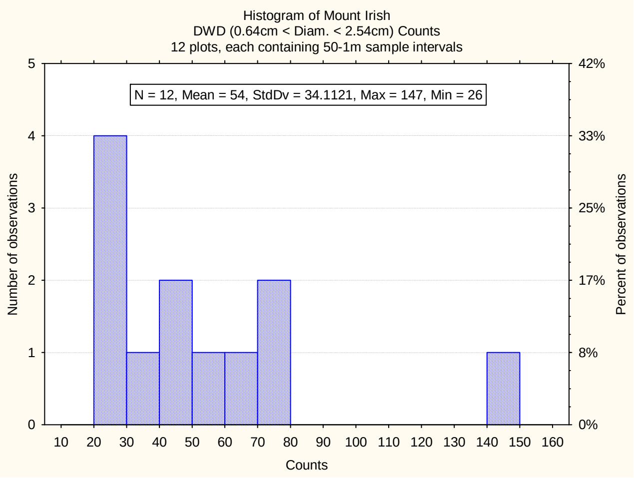


Figure C-9: Histogram for the Clover Mountains showing the number of DWD (2.54cm < Diam. < 7.62cm) observations (n=12 plots).

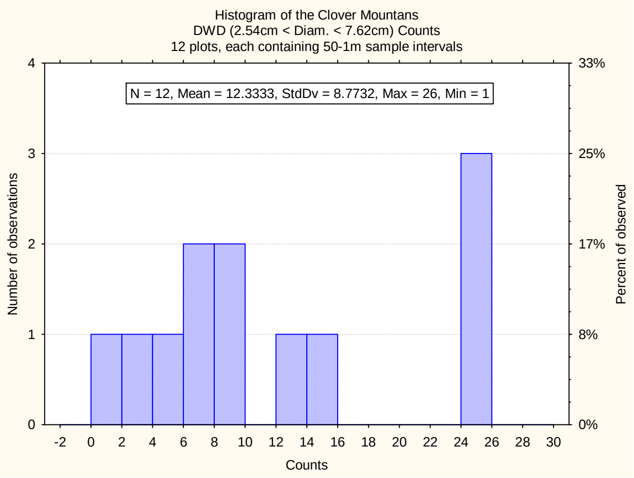


Figure C-10: Same as Figure C-9, but for Mount Irish.

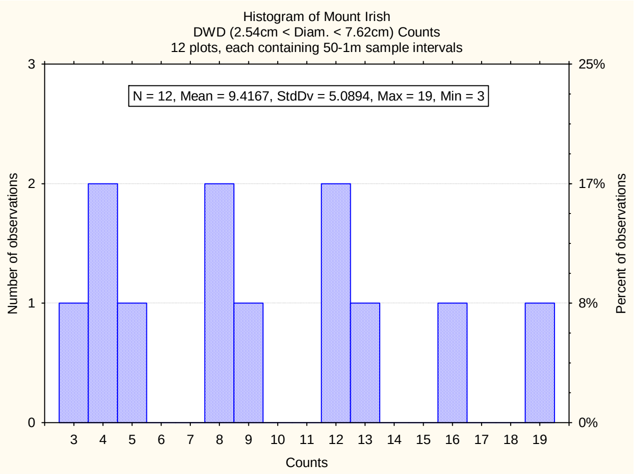


Figure C-11: Histogram for the Clover Mountains showing the number of DWD (Diam. > 7.62cm) observation (n=12 plots).

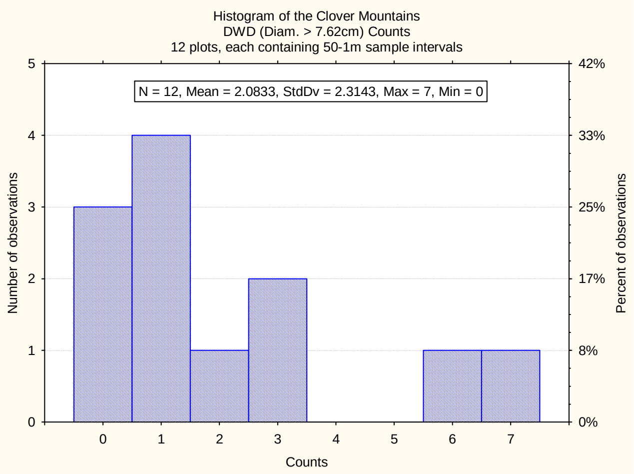


Figure C-12: Same as Figure C-11, but for Mount Irish.

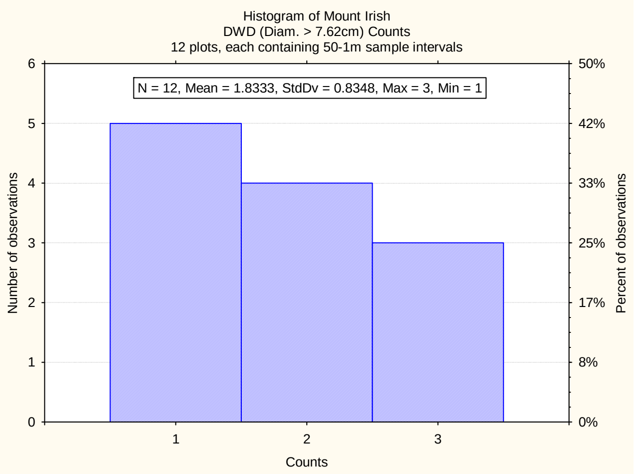


Table C-3: Down, dead woody debris counts by size class between north facing and south facing plots at Mount Irish. There are no significant differences in numbers between north and south facing plots.

North Facing	Plot #	0.64-2.54 (cm)	2.54-7.62 (cm)	> 7.62 (cm)
	1	44.0	5.0	2.0
	3	51.0	9.0	1.0
	4	42.0	8.0	2.0
	9	29.0	3.0	1.0
	11	72.0	8.0	2.0
	12	39.0	12.0	1.0
	Avg	46.2	7.5	1.5
South Facing	**2**	27.0	4.0	3.0
	5	73.0	19.0	3.0
	6	29.0	4.0	2.0
	7	69.0	13.0	1.0
	8	26.0	12.0	3.0
	10	147.0	16.0	1.0
	Avg	61.8	11.3	2.2

Table C-4: Same as Table C-3, but for the Clover Mountains. There are no significant differences in numbers between north and south facing plots.

North Facing	Plot #	0.64-2.54 (cm)	2.54-7.62 (cm)	> 7.62 (cm)
	2	124.0	9.0	0.0
	3	153.0	8.0	0.0
	6	48.0	1.0	2.0
	10	85.0	25.0	7.0
	11	130.0	8.0	1.0
	Avg	108.0	10.2	2.0
South Facing	**1**	95.0	25.0	6.0
	4	114.0	14.0	1.0
	5	144.0	26.0	1.0
	7	111.0	15.0	1.0
	8	82.0	3.0	0.0
	9	127.0	5.0	3.0
	12	98.0	9.0	3.0
	Avg	110.1	13.9	2.1

Appendix D: Fuelbed (Litter and Duff)

Table D-1: List of weights and depths of collected litter and duff samples at the Clover Mountains and Mount Irish. A value of zero refers to no presence of fuel in that particular 1-meter transect interval. The values in the table were used to obtain fuelbed bulk densities. Table 7 provides a summary of those intervals without fuel.

Clover Mountains Litter and Duff Samples								
Plot #	**Transect #**	**Interval**	**Litter Weight (kg)**	**Litter Depth (cm)**	**Duff Weight (kg)**	**Duff Depth (cm)**	**Combined Weight (kg)**	**Combined Depth (cm)**
1	1	3.5	0.001787	0.5	0	0	0.001787	0.5
1	1	6.5	0.022192	4	0.002635	1	0.024827	5
1	2	3.5	0.037164	10	0.007987	3	0.045151	13
1	2	6.5	0.011499	3	0	0	0.011499	3
1	3	3.5	0.027588	3	0	0	0.027588	3
1	3	6.5	0.01339	3	0	0	0.01339	3
1	4	3.5	0.02992	7	0	0	0.02992	7
1	4	6.5	0.004883	2	0.006166	2	0.011049	4
1	5	3.5	0	0	0	0	0	0
1	5	6.5	0	0	0	0	0	0
2	1	3.5	0.031123	2	0.030103	2	0.061226	4
2	1	6.5	0.01016	0.5	0	0	0.01016	0.5
2	2	3.5	0.024596	2	0.009645	0.5	0.034241	2.5
2	2	6.5	0.012192	1	0	0	0.012192	1
2	3	3.5	0.018907	2	0	0	0.018907	2
2	3	6.5	0.009843	1	0	0	0.009843	1
2	4	3.5	0.014032	3	0.008817	0.5	0.022849	3.5
2	4	6.5	0.017572	2	0.013065	2	0.030637	4
2	5	3.5	0.010206	2	0.010838	1	0.021044	3
2	5	6.5	0.011434	3	0.028289	2	0.039723	5
3	1	3.5	0.018272	2	0.007578	2	0.02585	4
3	1	6.5	0.024707	2	0.020719	2	0.045426	4
3	2	3.5	0.027417	5	0.014426	3	0.041843	8
3	2	6.5	0.029177	4	0.013159	3	0.042336	7
3	3	3.5	0.016133	2	0.028763	3	0.044896	5
3	3	6.5	0.016753	3	0.016907	4	0.03366	7
3	4	3.5	0.034418	3	0.012628	3	0.047046	6
3	4	6.5	0.016524	3	0.006755	1	0.023279	4
3	5	3.5	0.012263	2	0	0	0.012263	2
3	5	6.5	0.034943	5	0.008519	2	0.043462	7
4	1	3.5	0.000473	0.5	0	0	0.000473	0.5
4	1	6.5	0	0	0	0	0	0
4	2	3.5	0	0	0	0	0	0
4	2	6.5	0.001355	0.5	0	0	0.001355	0.5
4	3	3.5	0.000067	0.5	0	0	0.000067	0.5
4	3	6.5	0.018891	3	0.005155	1	0.024046	4
4	4	3.5	0.005738	0.5	0	0	0.005738	0.5
4	4	6.5	0.028595	3	0.03711	4	0.065705	7

4	5	3.5	0.008013	1	0	0	0.008013	1
4	5	6.5	0	0	0	0	0	0
5	1	3.5	0.045293	5	0.03353	3	0.078823	8
5	1	6.5	0.018373	1	0	0	0.018373	1
5	2	3.5	0.023679	4	0	0	0.023679	4
5	2	6.5	0.001726	0.5	0	0	0.001726	0.5
5	3	3.5	0.000496	0.5	0	0	0.000496	0.5
5	3	6.5	0.007334	2	0	0	0.007334	2
5	4	3.5	0.003969	0.5	0	0	0.003969	0.5
5	4	6.5	0.004473	0.5	0	0	0.004473	0.5
5	5	3.5	0.008512	0.5	0	0	0.008512	0.5
5	5	6.5	0.017966	4	0	0	0.017966	4
6	1	3.5	0.008826	7	0.011885	4	0.020711	11
6	1	6.5	0.00994	3	0	0	0.00994	3
6	2	3.5	0.016225	5	0	0	0.016225	5
6	2	6.5	0.044144	7	0	0	0.044144	7
6	3	3.5	0.011107	3	0	0	0.011107	3
6	3	6.5	0.002308	0.5	0	0	0.002308	0.5
6	4	3.5	0.011805	5	0.006612	2	0.018417	7
6	4	6.5	0.004423	3	0.003792	1	0.008215	4
6	5	3.5	0.008134	4	0.012572	3	0.020706	7
6	5	6.5	0.017106	8	0.033003	4	0.050109	12
7	1	3.5	0.005574	0.5	0	0	0.005574	0.5
7	1	6.5	0.004456	1	0	0	0.004456	1
7	2	3.5	0.003102	2	0	0	0.003102	2
7	2	6.5	0.002412	0.5	0	0	0.002412	0.5
7	3	3.5	0.004525	3	0	0	0.004525	3
7	3	6.5	0.005887	0.5	0	0	0.005887	0.5
7	4	3.5	0.012505	2	0	0	0.012505	2
7	4	6.5	0.022697	5	0.014324	2	0.037021	7
7	5	3.5	0.008935	3	0	0	0.008935	3
7	5	6.5	0.003423	0.5	0	0	0.003423	0.5
8	1	3.5	0	0	0	0	0	0
8	1	6.5	0.032633	4	0	0	0.032633	4
8	2	3.5	0.000919	0.5	0	0	0.000919	0.5
8	2	6.5	0.013248	2	0	0	0.013248	2
8	3	3.5	0.010638	1	0	0	0.010638	1
8	3	6.5	0.033739	3	0	0	0.033739	3
8	4	3.5	0.010787	1	0	0	0.010787	1
8	4	6.5	0	0	0	0	0	0
8	5	3.5	0.00951	1	0	0	0.00951	1
8	5	6.5	0.000184	0.5	0	0	0.000184	0.5
9	1	3.5	0.018239	1	0	0	0.018239	1
9	1	6.5	0.00384	0.5	0	0	0.00384	0.5
9	2	3.5	0.014658	2	0	0	0.014658	2
9	2	6.5	0.005297	0.5	0	0	0.005297	0.5
9	3	3.5	0	0	0	0	0	0

9	3	6.5	0.021281	2	0	0	0.021281	2
9	4	3.5	0.020211	2	0	0	0.020211	2
9	4	6.5	0.007999	1	0	0	0.007999	1
9	5	3.5	0	0	0	0	0	0
9	5	6.5	0	0	0	0	0	0
10	1	3.5	0	0	0	0	0	0
10	1	6.5	0.005235	1	0	0	0.005235	1
10	2	3.5	0.014927	2	0	0	0.014927	2
10	2	6.5	0.00089	0.5	0	0	0.00089	0.5
10	3	3.5	0.002241	0.5	0	0	0.002241	0.5
10	3	6.5	0.001146	0.5	0	0	0.001146	0.5
10	4	3.5	0.015263	1	0	0	0.015263	1
10	4	6.5	0.00283	0.5	0	0	0.00283	0.5
10	5	3.5	0.006802	0.5	0	0	0.006802	0.5
10	5	6.5	0.000332	0.5	0	0	0.000332	0.5
11	1	3.5	0.081291	6	0.032529	4	0.11382	10
11	1	6.5	0.007289	1	0	0	0.007289	1
11	2	3.5	0.029255	5	0.012606	1	0.041861	6
11	2	6.5	0.023616	4	0.020409	3	0.044025	7
11	3	3.5	0.015465	2	0	0	0.015465	2
11	3	6.5	0.036309	3	0	0	0.036309	3
11	4	3.5	0.007801	1	0	0	0.007801	1
11	4	6.5	0.008918	1	0	0	0.008918	1
11	5	3.5	0.0231	4	0	0	0.0231	4
11	5	6.5	0.019428	2	0	0	0.019428	2
12	1	3.5	0.000343	0.5	0	0	0.000343	0.5
12	1	6.5	0.021606	3	0	0	0.021606	3
12	2	3.5	0.000577	0.5	0	0	0.000577	0.5
12	2	6.5	0	0	0	0	0	0
12	3	3.5	0.012869	1	0	0	0.012869	1
12	3	6.5	0.004795	1	0	0	0.004795	1
12	4	3.5	0	0	0	0	0	0
12	4	6.5	0.002458	0.5	0	0	0.002458	0.5
12	5	3.5	0.002052	0.5	0	0	0.002052	0.5
12	5	6.5	0.000194	0.5	0	0	0.000194	0.5

Mount Irish Litter and Duff Samples

Plot #	Transect #	Interval	Litter Weight (kg)	Litter Depth (cm)	Duff Weight (kg)	Duff Depth (cm)	Combined Weight (kg)	Combined Depth (cm)
1	1	3.5	0.000418	0.5	0	0	0.000418	0.5
1	1	6.5	0.002286	0.5	0	0	0.002286	0.5
1	2	3.5	0	0	0	0	0	0
1	2	6.5	0	0	0	0	0	0
1	3	3.5	0	0	0	0	0	0
1	3	6.5	0.029103	2	0	0	0.029103	2
1	4	3.5	0.000502	0.5	0	0	0.000502	0.5
1	4	6.5	0.000895	0.5	0	0	0.000895	0.5

1	5	3.5	0.006041	0.5	0	0	0.006041	0.5
1	5	6.5	0.015022	1	0.007588	0.5	0.02261	1.5
2	1	3.5	0.001528	0.5	0	0	0.001528	0.5
2	1	6.5	0.002376	0.5	0	0	0.002376	0.5
2	2	3.5	0.035819	2	0	0	0.035819	2
2	2	6.5	0.010053	1	0	0	0.010053	1
2	3	3.5	0.031192	4	0.009251	4	0.040443	8
2	3	6.5	0	0	0	0	0	0
2	4	3.5	0.000732	0.5	0	0	0.000732	0.5
2	4	6.5	0.002199	0.5	0	0	0.002199	0.5
2	5	3.5	0.007563	1	0	0	0.007563	1
2	5	6.5	0	0	0	0	0	0
3	1	3.5	0.000652	0.5	0	0	0.000652	0.5
3	1	6.5	0.011424	1	0	0	0.011424	1
3	2	3.5	0.004155	0.5	0	0	0.004155	0.5
3	2	6.5	0.000951	0.5	0	0	0.000951	0.5
3	3	3.5	0.004168	0.5	0	0	0.004168	0.5
3	3	6.5	0.010113	0.5	0	0	0.010113	0.5
3	4	3.5	0.003577	0.5	0	0	0.003577	0.5
3	4	6.5	0	0	0	0	0	0
3	5	3.5	0.015552	1	0	0	0.015552	1
3	5	6.5	0.02565	2	0	0	0.02565	2
4	1	3.5	0.003253	0.5	0	0	0.003253	0.5
4	1	6.5	0.007273	0.5	0	0	0.007273	0.5
4	2	3.5	0.00047	0.5	0	0	0.00047	0.5
4	2	6.5	0	0	0	0	0	0
4	3	3.5	0.000533	0.5	0	0	0.000533	0.5
4	3	6.5	0.012911	1	0	0	0.012911	1
4	4	3.5	0	0	0	0	0	0
4	4	6.5	0.044295	3	0.025715	3	0.07001	6
4	5	3.5	0.016377	2	0	0	0.016377	2
4	5	6.5	0.005043	0.5	0	0	0.005043	0.5
5	1	3.5	0.014597	2	0	0	0.014597	2
5	1	6.5	0.008768	3	0	0	0.008768	3
5	2	3.5	0.000811	0.5	0	0	0.000811	0.5
5	2	6.5	0.000262	0.5	0	0	0.000262	0.5
5	3	3.5	0.000836	0.5	0	0	0.000836	0.5
5	3	6.5	0.029344	2	0.00559	1	0.034934	3
5	4	3.5	0.001234	0.5	0	0	0.001234	0.5
5	4	6.5	0.008611	0.5	0	0	0.008611	0.5
5	5	3.5	0.001112	0.5	0	0	0.001112	0.5
5	5	6.5	0.033435	5	0.009631	2	0.043066	7
6	1	3.5	0.023729	1	0	0	0.023729	1
6	1	6.5	0.014104	1	0	0	0.014104	1
6	2	3.5	0.06007	4	0.011089	1	0.071159	5
6	2	6.5	0.000793	0.5	0	0	0.000793	0.5
6	3	3.5	0.005904	0.5	0	0	0.005904	0.5

6	3	6.5	0.004416	0.5	0	0	0.004416	0.5
6	4	3.5	0	0	0	0	0	0
6	4	6.5	0	0	0	0	0	0
6	5	3.5	0	0	0	0	0	0
6	5	6.5	0	0	0	0	0	0
7	1	3.5	0.010043	1	0	0	0.010043	1
7	1	6.5	0.025667	1	0	0	0.025667	1
7	2	3.5	0	0	0	0	0	0
7	2	6.5	0.000486	0.5	0	0	0.000486	0.5
7	3	3.5	0.003003	0.5	0	0	0.003003	0.5
7	3	6.5	0.017475	2	0.011188	1	0.028663	3
7	4	3.5	0.026171	1	0.024539	2	0.05071	3
7	4	6.5	0.03516	1	0.073424	6	0.108584	7
7	5	3.5	0.028337	2	0	0	0.028337	2
7	5	6.5	0.037933	2	0.022383	3	0.060316	5
8	1	3.5	0.000453	0.5	0	0	0.000453	0.5
8	1	6.5	0.000933	0.5	0	0	0.000933	0.5
8	2	3.5	0.000359	0.5	0	0	0.000359	0.5
8	2	6.5	0.000688	0.5	0	0	0.000688	0.5
8	3	3.5	0.000487	0.5	0	0	0.000487	0.5
8	3	6.5	0.044671	3	0	0	0.044671	3
8	4	3.5	0	0	0	0	0	0
8	4	6.5	0	0	0	0	0	0
8	5	3.5	0	0	0	0	0	0
8	5	6.5	0.040796	3	0	0	0.040796	3
9	1	3.5	0.00105	0.5	0	0	0.00105	0.5
9	1	6.5	0.045549	2	0.035876	2	0.081425	4
9	2	3.5	0.033159	2	0	0	0.033159	2
9	2	6.5	0.012391	1	0	0	0.012391	1
9	3	3.5	0.011653	1	0	0	0.011653	1
9	3	6.5	0.000992	0.5	0	0	0.000992	0.5
9	4	3.5	0.000452	0.5	0	0	0.000452	0.5
9	4	6.5	0.000349	0.5	0	0	0.000349	0.5
9	5	3.5	0.004317	0.5	0	0	0.004317	0.5
9	5	6.5	0.002733	0.5	0	0	0.002733	0.5
10	1	3.5	0.011389	1	0	0	0.011389	1
10	1	6.5	0.037388	3	0	0	0.037388	3
10	2	3.5	0.01811	3	0.012387	1	0.030497	4
10	2	6.5	0.041696	4	0.022663	2	0.064359	6
10	3	3.5	0.053276	5	0.021025	2	0.074301	7
10	3	6.5	0.044939	5	0.012268	1	0.057207	6
10	4	3.5	0.028543	5	0	0	0.028543	5
10	4	6.5	0.003422	0.5	0	0	0.003422	0.5
10	5	3.5	0.037386	3	0	0	0.037386	3
10	5	6.5	0.0225	3	0	0	0.0225	3
11	1	3.5	0.023639	2	0	0	0.023639	2
11	1	6.5	0.022883	2	0.018556	1	0.041439	3

11	2	3.5	0.024568	3	0	0	0.024568	3
11	2	6.5	0.024955	2	0	0	0.024955	2
11	3	3.5	0.001651	0.5	0	0	0.001651	0.5
11	3	6.5	0.033134	3	0.009871	1	0.043005	4
11	4	3.5	0.016737	2	0	0	0.016737	2
11	4	6.5	0.017305	1	0	0	0.017305	1
11	5	3.5	0.001469	0.5	0	0	0.001469	0.5
11	5	6.5	0.02808	2	0	0	0.02808	2
12	1	3.5	0.003593	0.5	0	0	0.003593	0.5
12	1	6.5	0.018773	1	0	0	0.018773	1
12	2	3.5	0.003176	0.5	0	0	0.003176	0.5
12	2	6.5	0.000505	0.5	0	0	0.000505	0.5
12	3	3.5	0.001679	0.5	0	0	0.001679	0.5
12	3	6.5	0.005679	0.5	0	0	0.005679	0.5
12	4	3.5	0.000849	0.5	0	0	0.000849	0.5
12	4	6.5	0.00489	0.5	0	0	0.00489	0.5
12	5	3.5	0.000996	0.5	0	0	0.000996	0.5
12	5	6.5	0.002341	0.5	0	0	0.002341	0.5

Table D-2: List of litter, duff, and combined bulk density for each sample collected at the Clover Mountains and Mount Irish.

Clover Mountains					
Plot #	**Transect #**	**Interval**	**Litter Bulk Density (kg/m^3)**	**Duff Bulk Density (kg/m^3)**	**Combined Bulk Density (kg/m^3)**
1	1	3.5	35.740	0.000	35.740
1	1	6.5	55.480	26.350	49.654
1	2	3.5	37.164	26.623	34.732
1	2	6.5	38.330	0.000	38.330
1	3	3.5	91.960	0.000	91.960
1	3	6.5	44.633	0.000	44.633
1	4	3.5	42.743	0.000	42.743
1	4	6.5	24.415	30.830	27.623
1	5	3.5	0.000	0.000	0.000
1	5	6.5	0.000	0.000	0.000
2	1	3.5	155.615	150.515	153.065
2	1	6.5	203.200	0.000	203.200
2	2	3.5	122.980	192.900	136.964
2	2	6.5	121.920	0.000	121.920
2	3	3.5	94.535	0.000	94.535
2	3	6.5	98.430	0.000	98.430
2	4	3.5	46.773	176.340	65.283
2	4	6.5	87.860	65.325	76.593
2	5	3.5	51.030	108.380	70.147
2	5	6.5	38.113	141.445	79.446
3	1	3.5	91.360	37.890	64.625
3	1	6.5	123.535	103.595	113.565

3	2	3.5	54.834	48.087	52.304
3	2	6.5	72.943	43.863	60.480
3	3	3.5	80.665	95.877	89.792
3	3	6.5	55.843	42.268	48.086
3	4	3.5	114.727	42.093	78.410
3	4	6.5	55.080	67.550	58.198
3	5	3.5	61.315	0.000	61.315
3	5	6.5	69.886	42.595	62.089
4	1	3.5	9.460	0.000	9.460
4	1	6.5	0.000	0.000	0.000
4	2	3.5	0.000	0.000	0.000
4	2	6.5	27.100	0.000	27.100
4	3	3.5	1.340	0.000	1.340
4	3	6.5	62.970	51.550	60.115
4	4	3.5	114.760	0.000	114.760
4	4	6.5	95.317	92.775	93.864
4	5	3.5	80.130	0.000	80.130
4	5	6.5	0.000	0.000	0.000
5	1	3.5	90.586	111.767	98.529
5	1	6.5	183.730	0.000	183.730
5	2	3.5	59.198	0.000	59.198
5	2	6.5	34.520	0.000	34.520
5	3	3.5	9.920	0.000	9.920
5	3	6.5	36.670	0.000	36.670
5	4	3.5	79.380	0.000	79.380
5	4	6.5	89.460	0.000	89.460
5	5	3.5	170.240	0.000	170.240
5	5	6.5	44.915	0.000	44.915
6	1	3.5	12.609	29.713	18.828
6	1	6.5	33.133	0.000	33.133
6	2	3.5	32.450	0.000	32.450
6	2	6.5	63.063	0.000	63.063
6	3	3.5	37.023	0.000	37.023
6	3	6.5	46.160	0.000	46.160
6	4	3.5	23.610	33.060	26.310
6	4	6.5	14.743	37.920	20.538
6	5	3.5	20.335	41.907	29.580
6	5	6.5	21.383	82.508	41.758
7	1	3.5	111.480	0.000	111.480
7	1	6.5	44.560	0.000	44.560
7	2	3.5	15.510	0.000	15.510
7	2	6.5	48.240	0.000	48.240
7	3	3.5	15.083	0.000	15.083
7	3	6.5	117.740	0.000	117.740
7	4	3.5	62.525	0.000	62.525
7	4	6.5	45.394	71.620	52.887
7	5	3.5	29.783	0.000	29.783

7	5	6.5	68.460	0.000	68.460
8	1	3.5	0.000	0.000	0.000
8	1	6.5	81.583	0.000	81.583
8	2	3.5	18.380	0.000	18.380
8	2	6.5	66.240	0.000	66.240
8	3	3.5	106.380	0.000	106.380
8	3	6.5	112.463	0.000	112.463
8	4	3.5	107.870	0.000	107.870
8	4	6.5	0.000	0.000	0.000
8	5	3.5	95.100	0.000	95.100
8	5	6.5	3.680	0.000	3.680
9	1	3.5	182.390	0.000	182.390
9	1	6.5	76.800	0.000	76.800
9	2	3.5	73.290	0.000	73.290
9	2	6.5	105.940	0.000	105.940
9	3	3.5	0.000	0.000	0.000
9	3	6.5	106.405	0.000	106.405
9	4	3.5	101.055	0.000	101.055
9	4	6.5	79.990	0.000	79.990
9	5	3.5	0.000	0.000	0.000
9	5	6.5	0.000	0.000	0.000
10	1	3.5	0.000	0.000	0.000
10	1	6.5	52.350	0.000	52.350
10	2	3.5	74.635	0.000	74.635
10	2	6.5	17.800	0.000	17.800
10	3	3.5	44.820	0.000	44.820
10	3	6.5	22.920	0.000	22.920
10	4	3.5	152.630	0.000	152.630
10	4	6.5	56.600	0.000	56.600
10	5	3.5	136.040	0.000	136.040
10	5	6.5	6.640	0.000	6.640
11	1	3.5	135.485	81.323	113.820
11	1	6.5	72.890	0.000	72.890
11	2	3.5	58.510	126.060	69.768
11	2	6.5	59.040	68.030	62.893
11	3	3.5	77.325	0.000	77.325
11	3	6.5	121.030	0.000	121.030
11	4	3.5	78.010	0.000	78.010
11	4	6.5	89.180	0.000	89.180
11	5	3.5	57.750	0.000	57.750
11	5	6.5	97.140	0.000	97.140
12	1	3.5	6.860	0.000	6.860
12	1	6.5	72.020	0.000	72.020
12	2	3.5	11.540	0.000	11.540
12	2	6.5	0.000	0.000	0.000
12	3	3.5	128.690	0.000	128.690
12	3	6.5	47.950	0.000	47.950

12	4	3.5	0.000	0.000	0.000
12	4	6.5	49.160	0.000	49.160
12	5	3.5	41.040	0.000	41.040
12	5	6.5	3.880	0.000	3.880

Mount Irish

Plot #	Transect #	Interval	Litter Bulk Density (kg/m^3)	Duff Bulk Density (kg/m^3)	Combined Bulk Density (kg/m^3)
1	1	3.5	8.360	0.000	8.360
1	1	6.5	45.720	0.000	45.720
1	2	3.5	0.000	0.000	0.000
1	2	6.5	0.000	0.000	0.000
1	3	3.5	0.000	0.000	0.000
1	3	6.5	145.515	0.000	145.515
1	4	3.5	10.040	0.000	10.040
1	4	6.5	17.900	0.000	17.900
1	5	3.5	120.820	0.000	120.820
1	5	6.5	150.220	151.760	150.733
2	1	3.5	30.560	0.000	30.560
2	1	6.5	47.520	0.000	47.520
2	2	3.5	179.095	0.000	179.095
2	2	6.5	100.530	0.000	100.530
2	3	3.5	77.980	23.128	50.554
2	3	6.5	0.000	0.000	0.000
2	4	3.5	14.640	0.000	14.640
2	4	6.5	43.980	0.000	43.980
2	5	3.5	75.630	0.000	75.630
2	5	6.5	0.000	0.000	0.000
3	1	3.5	13.040	0.000	13.040
3	1	6.5	114.240	0.000	114.240
3	2	3.5	83.100	0.000	83.100
3	2	6.5	19.020	0.000	19.020
3	3	3.5	83.360	0.000	83.360
3	3	6.5	202.260	0.000	202.260
3	4	3.5	71.540	0.000	71.540
3	4	6.5	0.000	0.000	0.000
3	5	3.5	155.520	0.000	155.520
3	5	6.5	128.250	0.000	128.250
4	1	3.5	65.060	0.000	65.060
4	1	6.5	145.460	0.000	145.460
4	2	3.5	9.400	0.000	9.400
4	2	6.5	0.000	0.000	0.000
4	3	3.5	10.660	0.000	10.660
4	3	6.5	129.110	0.000	129.110
4	4	3.5	0.000	0.000	0.000
4	4	6.5	147.650	85.717	116.683
4	5	3.5	81.885	0.000	81.885
4	5	6.5	100.860	0.000	100.860

5	1	3.5	72.985	0.000	72.985
5	1	6.5	29.227	0.000	29.227
5	2	3.5	16.220	0.000	16.220
5	2	6.5	5.240	0.000	5.240
5	3	3.5	16.720	0.000	16.720
5	3	6.5	146.720	55.900	116.447
5	4	3.5	24.680	0.000	24.680
5	4	6.5	172.220	0.000	172.220
5	5	3.5	22.240	0.000	22.240
5	5	6.5	66.870	48.155	61.523
6	1	3.5	237.290	0.000	237.290
6	1	6.5	141.040	0.000	141.040
6	2	3.5	150.175	110.890	142.318
6	2	6.5	15.860	0.000	15.860
6	3	3.5	118.080	0.000	118.080
6	3	6.5	88.320	0.000	88.320
6	4	3.5	0.000	0.000	0.000
6	4	6.5	0.000	0.000	0.000
6	5	3.5	0.000	0.000	0.000
6	5	6.5	0.000	0.000	0.000
7	1	3.5	100.430	0.000	100.430
7	1	6.5	256.670	0.000	256.670
7	2	3.5	0.000	0.000	0.000
7	2	6.5	9.720	0.000	9.720
7	3	3.5	60.060	0.000	60.060
7	3	6.5	87.375	111.880	95.543
7	4	3.5	261.710	122.695	169.033
7	4	6.5	351.600	122.373	155.120
7	5	3.5	141.685	0.000	141.685
7	5	6.5	189.665	74.610	120.632
8	1	3.5	9.060	0.000	9.060
8	1	6.5	18.660	0.000	18.660
8	2	3.5	7.180	0.000	7.180
8	2	6.5	13.760	0.000	13.760
8	3	3.5	9.740	0.000	9.740
8	3	6.5	148.903	0.000	148.903
8	4	3.5	0.000	0.000	0.000
8	4	6.5	0.000	0.000	0.000
8	5	3.5	0.000	0.000	0.000
8	5	6.5	135.987	0.000	135.987
9	1	3.5	21.000	0.000	21.000
9	1	6.5	227.745	179.380	203.563
9	2	3.5	165.795	0.000	165.795
9	2	6.5	123.910	0.000	123.910
9	3	3.5	116.530	0.000	116.530
9	3	6.5	19.840	0.000	19.840
9	4	3.5	9.040	0.000	9.040

9	4	6.5	6.980	0.000	6.980
9	5	3.5	86.340	0.000	86.340
9	5	6.5	54.660	0.000	54.660
10	1	3.5	113.890	0.000	113.890
10	1	6.5	124.627	0.000	124.627
10	2	3.5	60.367	123.870	76.243
10	2	6.5	104.240	113.315	107.265
10	3	3.5	106.552	105.125	106.144
10	3	6.5	89.878	122.680	95.345
10	4	3.5	57.086	0.000	57.086
10	4	6.5	68.440	0.000	68.440
10	5	3.5	124.620	0.000	124.620
10	5	6.5	75.000	0.000	75.000
11	1	3.5	118.195	0.000	118.195
11	1	6.5	114.415	185.560	138.130
11	2	3.5	81.893	0.000	81.893
11	2	6.5	124.775	0.000	124.775
11	3	3.5	33.020	0.000	33.020
11	3	6.5	110.447	98.710	107.513
11	4	3.5	83.685	0.000	83.685
11	4	6.5	173.050	0.000	173.050
11	5	3.5	29.380	0.000	29.380
11	5	6.5	140.400	0.000	140.400
12	1	3.5	71.860	0.000	71.860
12	1	6.5	187.730	0.000	187.730
12	2	3.5	63.520	0.000	63.520
12	2	6.5	10.100	0.000	10.100
12	3	3.5	33.580	0.000	33.580
12	3	6.5	113.580	0.000	113.580
12	4	3.5	16.980	0.000	16.980
12	4	6.5	97.800	0.000	97.800
12	5	3.5	19.920	0.000	19.920
12	5	6.5	46.820	0.000	46.820

Table D-3: Number of 1-meter intervals where either litter or duff were not present at the Clover Mountains (CL) and Mount Irish (MI).

CL			MI		
Plot #	**Litter**	**Duff**	**Plot #**	**Litter**	**Duff**
1	2	7	**1**	3	9
2	0	4	**2**	2	9
3	0	1	**3**	1	0
4	3	8	**4**	2	9
5	0	9	**5**	0	8
6	0	5	**6**	4	9
7	0	9	**7**	1	6
8	2	10	**8**	3	0
9	3	10	**9**	0	9
10	1	10	**10**	0	6
11	0	7	**11**	0	8
12	2	10	**12**	0	0
All Plots	13	90	**All Plots**	16	73

Table D-4: Total number of litter and duff samples collected at the Clover Mountains (CL) and Mount Irish (MI).

CL			MI		
Plot #	**Litter**	**Duff**	**Plot #**	**Litter**	**Duff**
1	8	3	**1**	7	1
2	10	6	**2**	8	1
3	10	9	**3**	9	10
4	7	2	**4**	8	1
5	10	1	**5**	10	2
6	10	5	**6**	6	1
7	10	1	**7**	9	4
8	8	0	**8**	7	10
9	7	0	**9**	10	1
10	9	0	**10**	10	4
11	10	3	**11**	10	2
12	8	0	**12**	10	10
All Plots	107	30	**All Plots**	104	47

Table D-5: Average fuelbed depths at Mount Irish and the Clover Mountains.

Mount Irish Average Fuelbed Depth Per Plot			
Plot #	**Litter Depth (cm)**	**Duff Depth (cm)**	**Combined Depth (cm)**
1	0.55	0.05	0.60
2	1.00	0.40	1.40
3	0.70	0.00	0.70
4	0.85	0.30	1.15
5	1.50	0.30	1.80
6	0.75	0.10	0.85
7	1.10	1.20	2.30
8	0.85	0.00	0.85
9	0.90	0.20	1.10
10	3.25	0.60	3.85
11	1.80	0.20	2.00
12	0.55	0.00	0.55
All Plots	1.15	0.28	1.43

Clover Mountains Average Fuelbed Depth Per Plot			
Plot #	**Litter Depth (cm)**	**Duff Depth (cm)**	**Combined Depth (cm)**
1	3.25	0.60	3.85
2	1.85	0.80	2.65
3	3.10	2.30	5.40
4	0.90	0.50	1.40
5	1.85	0.30	2.15
6	4.55	1.40	5.95
7	1.80	0.20	2.00
8	1.30	0.00	1.30
9	0.90	0.00	0.90
10	0.70	0.00	0.70
11	2.90	0.80	3.70
12	0.75	0.00	0.75
All Plots	1.99	0.58	2.56

Figure D-1: Average fuelbed depth per plot at Mount Irish.

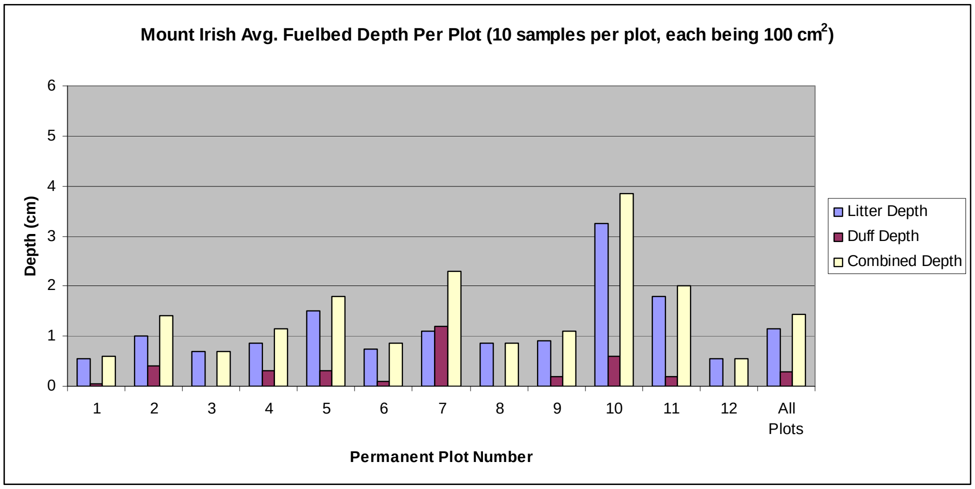


Figure D-2: Same as Figure D-1, but for the Clover Mountains.

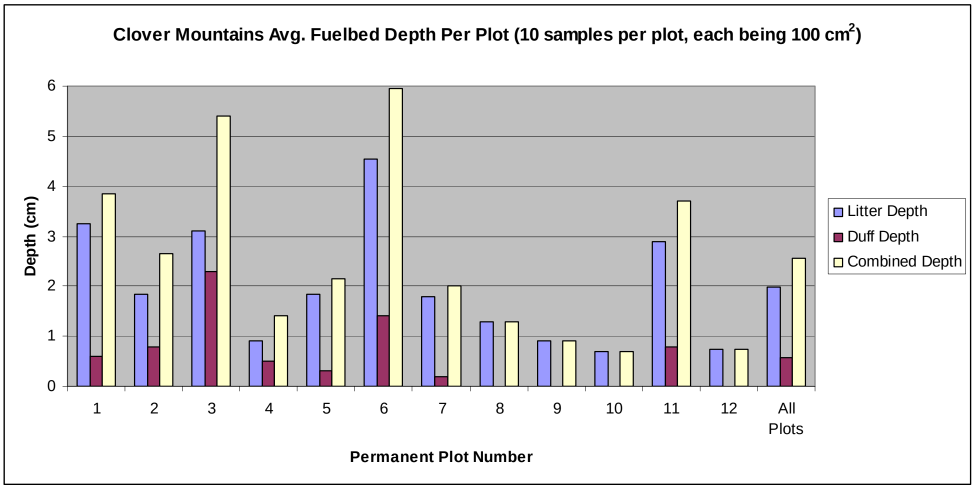


Table D-6: t-Test results showing significant differences in litter and duff depth (cm) between Mount Irish (MI) and the Clover Mountains (CL).

Average Litter Depth		
	CL	**MI**
Mean	1.9875	1.15
Variance	1.484602273	0.573181818
Observations	12	12
Hypothesized Mean Difference	0	
df	18	
t Stat	2.022439487	
P(T<=t) one-tail	0.029123792	
t Critical one-tail	1.734063592	
P(T<=t) two-tail	**0.058247584**	
t Critical two-tail	2.100922037	
Average Duff Depth		
	CL	**MI**
Mean	0.575	0.279166667
Variance	0.482045455	0.117935606
Observations	12	12
Hypothesized Mean Difference	0	
df	16	
t Stat	1.323027768	
P(T<=t) one-tail	0.102211809	
t Critical one-tail	1.745883669	
P(T<=t) two-tail	**0.204423619**	
t Critical two-tail	2.119905285	

Table D-7: t-Test results showing that there are no significant differences in fuelbed weight (g) between the Clover Mountains and Mount Irish.

	Litter		**Duff**		**Combined**	
	CL	**MI**	**CL**	**MI**	**CL**	**MI**
Mean	124.32	120.08	39.21	27.75	163.53	147.84
Variance	4470.13	5195.43	1887.26	1453.00	10677.86	10378.60
Observations	12	12	12	12	12	12
Hypothesized Mean Difference	0		0		0	
df	22		22		22	
t Stat	0.149		0.687		0.375	
P(T<=t) one-tail	0.441		0.250		0.356	
t Critical one-tail	1.717		1.717		1.717	
P(T<=t) two-tail	0.883		0.499		0.712	
t Critical two-tail	2.074		2.074		2.074	

Table D-8: Fuelbed fuel loads at the Clover Mountains and Mount Irish. As indicated by the total values, the Clover Mountains have a heavier fuelbed fuel load. Total area of collected samples per plot is 0.1m^2 (10 locations, each being 0.01 m^2). Weights per plot were converted to kg/m^2. The weight for all plots combined was calculated by summing the weights of all plots and dividing by 12 (twelve 1m^2 areas) to get total weight from kg/12m^2 to kg/m^2.

CLOVER MOUNTAINS					
Litter		**Duff**		**Combined**	
Plot Number	**Litter Weight (kg/m^2)**	**Plot Number**	**Duff Weight (kg/m^2)**	**Plot Number**	**Combined Weight (kg/m^2)**
1	1.484	**1**	0.168	**1**	1.652
2	1.601	**2**	1.008	**2**	2.608
3	2.306	**3**	1.295	**3**	3.601
4	0.631	**4**	0.423	**4**	1.054
5	1.318	**5**	0.335	**5**	1.654
6	1.340	**6**	0.679	**6**	2.019
7	0.735	**7**	0.143	**7**	0.878
8	1.117	**8**	0.000	**8**	1.117
9	0.915	**9**	0.000	**9**	0.915
10	0.497	**10**	0.000	**10**	0.497
11	2.525	**11**	0.655	**11**	3.180
12	0.449	**12**	0.000	**12**	0.449
All Plots	1.243	**All Plots**	0.392	**All Plots**	1.635
MOUNT IRISH					
Litter		**Duff**		**Combined**	
Plot Number	**Litter Weight (kg/m^2)**	**Plot Number**	**Duff Weight (kg/m^2)**	**Plot Number**	**Combined Weight (kg/m^2)**
1	0.543	**1**	0.076	**1**	0.619
2	0.915	**2**	0.093	**2**	1.007
3	0.762	**3**	0.000	**3**	0.762
4	0.902	**4**	0.257	**4**	1.159
5	0.990	**5**	0.152	**5**	1.142
6	1.090	**6**	0.111	**6**	1.201
7	1.843	**7**	1.315	**7**	3.158
8	0.884	**8**	0.000	**8**	0.884
9	1.126	**9**	0.359	**9**	1.485
10	2.986	**10**	0.683	**10**	3.670
11	1.944	**11**	0.284	**11**	2.228
12	0.425	**12**	0.000	**12**	0.425
All Plots	1.201	**All Plots**	0.278	**All Plots**	1.478

Figure D-3: Total fuelbed weight per permanent plot (kg/m^2) at Mount Irish. Refer to Table D-8 for exact values.

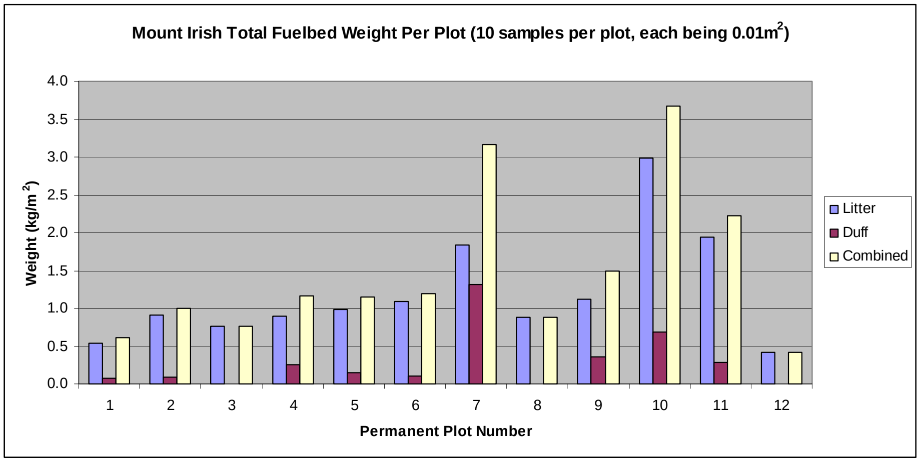


Figure D-4: Same as Figure D-3, but for the Clover Mountains. Refer to Table D-8 for exact values.

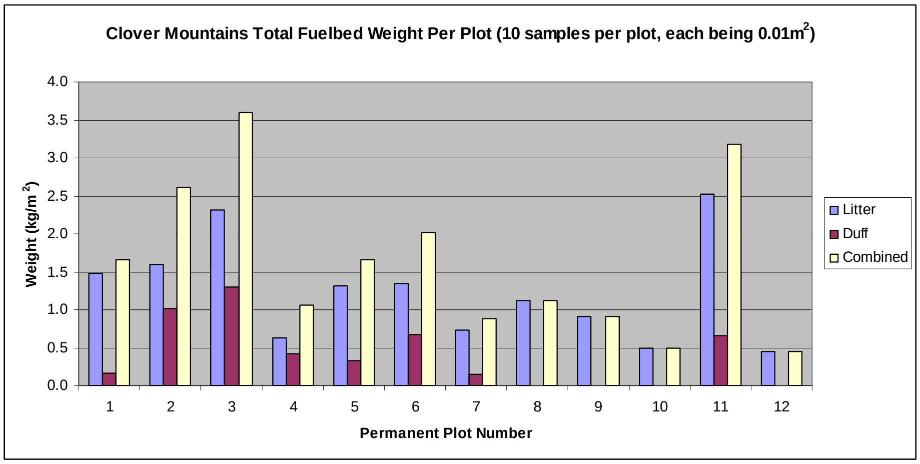


Figure D-5: Total fuelbed weight (kg/m^2) for Mount Irish and the Clover Mountains. Refer to Table D-8 for exact values.

Table D-9: List of fuelbed bulk densities at Mount Irish (MI) and the Clover Mountains (CL). Bulk densities per plot were calculated by dividing the total weight by total volume of the collected samples at each plot. Bulk densities for each study site were computer by dividing total weight by total volume of the collected samples when combining all plots together.

MI Plot #	**Litter Bulk Density (kg/m^3)**	**Duff Bulk Density (kg/m^3)**	**Combined Bulk Density (kg/m^3)**
1	98.667	151.76	103.092
2	91.462	23.128	71.938
3	108.917	0	108.917
4	106.065	85.717	100.757
5	66.007	50.737	63.462
6	145.355	110.89	141.3
7	167.523	109.612	137.308
8	103.985	0	103.985
9	125.161	179.38	135.019
10	91.892	113.905	95.323
11	108.012	142.135	111.424
12	77.238	0	77.238
All Plots	104.421	99.416	103.443
CL Plot #	**Litter Bulk Density (kg/m^3)**	**Duff Bulk Density (kg/m^3)**	**Combined Bulk Density (kg/m^3)**
1	45.669	27.98	42.912
2	86.522	125.946	98.423
3	74.389	56.284	66.678
4	70.147	84.53	75.284
5	71.255	111.767	76.907
6	29.455	48.474	33.93
7	40.842	71.62	43.92
8	85.891	0	85.891
9	101.694	0	101.694
10	70.951	0	70.951
11	87.059	81.93	85.95
12	59.859	0	59.859
All Plots	62.549	68.192	63.815

Figure D-6: Fuelbed bulk densities at Mount Irish.

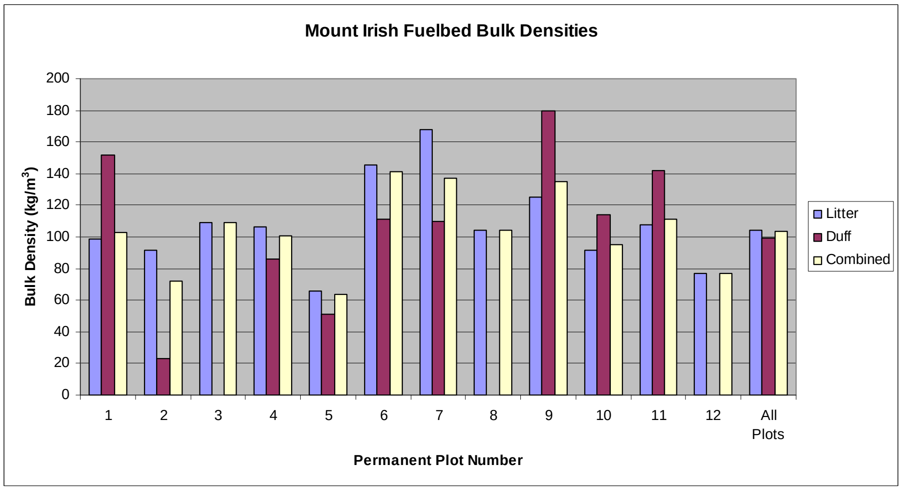


Figure D-7: Same as Figure D-6, but for the Clover Mountains.

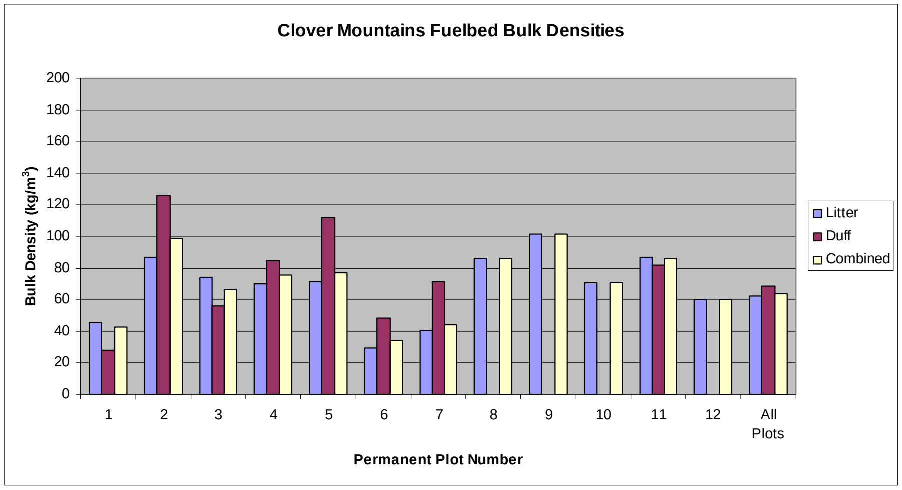


Table D-10: t-Test results showing significant differences in fuelbed bulk densities (kg/m^3) between the Clover Mountains and Mount Irish. Bold values indicate a significant difference.

Litter Bulk Density		
	CL	**MI**
Mean	68.64441667	107.5236667
Variance	455.4232723	780.0597206
Observations	12	12
Hypothesized Mean Difference	0	
df	21	
t Stat	-3.831687797	
P(T<=t) one-tail	0.000485432	
t Critical one-tail	1.720742871	
P(T<=t) two-tail	**0.000970863**	
t Critical two-tail	2.079613837	
Duff Bulk Density		
	CL	**MI**
Mean	50.71091667	80.60533333
Variance	2071.169119	4107.844218
Observations	12	12
Hypothesized Mean Difference	0	
df	20	
t Stat	-1.317410559	
P(T<=t) one-tail	0.101297449	
t Critical one-tail	1.724718218	
P(T<=t) two-tail	0.202594898	
t Critical two-tail	2.085963441	
Combined Bulk Density		
	CL	**MI**
Mean	70.19991667	104.1469167
Variance	474.9274237	637.8238977
Observations	12	12
Hypothesized Mean Difference	0	
df	22	
t Stat	-3.525274699	
P(T<=t) one-tail	0.000952472	
t Critical one-tail	1.717144335	
P(T<=t) two-tail	**0.001904944**	
t Critical two-tail	2.073873058	

Table D-11: List of fuelbed bulk densities for north facing and south facing plots at Mount Irish. There are no significant differences in bulk densities between southern aspects and northern aspects.

North Facing	Plot #	Litter Bulk Density (kg/m^3)	Duff Bulk Density (kg/m^3)	Combined Bulk Density (kg/m^3)
	1	98.667	151.76	103.092
	3	108.917	0	108.917
	4	106.065	85.717	100.757
	9	125.161	179.38	135.019
	11	108.012	142.135	111.424
	12	77.238	0	77.238
South Facing	2	91.462	23.128	71.938
	5	66.007	50.737	63.462
	6	145.355	110.89	141.3
	7	167.523	109.612	137.308
	8	103.985	0	103.985
	10	91.892	113.905	95.323

Table D-12: Same as Table D-11, but for the Clover Mountains. There are no significant differences in bulk densities between southern aspects and northern aspects.

North Facing	Plot #	Litter Bulk Density (kg/m^3)	Duff Bulk Density (kg/m^3)	Combined Bulk Density (kg/m^3)
	2	86.522	125.946	98.423
	3	74.389	56.284	66.678
	6	29.455	48.474	33.93
	10	70.951	0	70.951
	11	87.059	81.93	85.95
South Facing	1	45.669	27.98	42.912
	4	70.147	84.53	75.284
	5	71.255	111.767	76.907
	7	40.842	71.62	43.92
	8	85.891	0	85.891
	9	101.694	0	101.694
	12	59.859	0	59.859

Table D-13: Fuelbed bulk density comparisons for specific forest types between Mount Irish, the Clover Mountains, Sierra Nevada (van Wagtendonk et al. 1998), southwestern Colorado (Hood et al. 2006), and northern California (Hood et al. 2006).

Forest Type	This Study				van Wagtendonk et al. 1998	Hood et al. 2006
	MI Min	MI Max	CL Min	CL Max		
LITTER (kg/m^3)						
PIMO/JUOS	66	168	-	-	-	-
PIPO	108	125	29	87	36	-
ABCO/PIPO	77	77	-	-	-	-
PIMO	-	-	41	87	146	-
Western Juniper	-	-	-	-	71	-
ABCO	-	-	-	-	78	-
DUFF (kg/m^3)						
PIMO/JUOS	51	114	-	-	-	-
PIPO	142	179	0	81	155	-
ABCO/PIPO	0	0	-	-	-	-
PIMO	-	-	0	126	234	-
Western Juniper	-	-	-	-	178	-
ABCO	-	-	-	-	183	-
COMBINED (kg/m^3)						
PIMO/JUOS	63	141	-	-	-	226
PIPO	111	135	34	86	118	128
ABCO/PIPO	77	77	-	-	-	-
PIMO	-	-	43	98	206	-
Western Juniper	-	-	-	-	147	-
ABCO	-	-	-	-	180	-
ABCO/PIJE	-	-	-	-	-	129

Appendix E: Canopy Fuel

Table E-1: Biomass equations for *P. monophylla* and *J. osteosperma*. Equations were developed by Robin Tausch. These equations incorporate crown diameters, crown heights, and tree heights.

One-Hour Stem Biomass:
1-Hr. Inner Hgt. = CrwnHgt – 12.934 (for pinyon) or (-3.9877 for juniper) (dm)
(if < 0 then replace with = 0)
1-Hr. Inner Dia. = AvgDia – (2 * 12.934) or (2 * 3.9877 for juniper) (dm)
(if < 0 then replace with = 0)
1-Hr. Inner Crn. Vol. = 1-HrInHgt * (1-HrInDia)2 * Pi / 6 (dm3)
Func.Vol. 1-Hr. = TotCrnVol – 1-HrInCrnVol (dm3)
1-Hr. Bio. = FuncVol 1-Hr * 0.4407 / 1000 or (0.3932 / 1000 for juniper) (kg)

Ten-Hour Stem Biomass:
10-Hr. Inner Hgt. = CrwnHgt – 9.2246 (for pinyon) or (-6.7603 for juniper) (dm)
(if < 0 then replace with = 0)
10-Hr. Inner Dia. = AvgDia – (2 * 9.2246) or (2 * 6.7603 for juniper) (dm)
(if < 0 then replace with = 0)
10-Hr. Inner Crn. Vol. = 10-HrInHgt * (10-HrInDia)2 * Pi / 6 (dm3)
Func.Vol. 1-Hr. = TotCrnVol – 10-HrInCrnVol (dm3)
10-Hr. Bio. = FuncVol 1-Hr * 0.5785 / 1000 or (0.6336 / 1000 for juniper) (kg)

100-Hour Stem Biomass:
100-Hr. Inner Hgt. = CrwnHgt – 14.9862 (for pinyon) or (-28.4801 for juniper) (dm)
(if < 0 then replace with = 0)
100-Hr. Inner Dia. = AvgDia – (2 * 14.9862) or (2 * 28.4801 for juniper) (dm)
(if < 0 then replace with = 0)
100-Hr. Inner Crn. Vol. = 100-HrInHgt * (100-HrInDia)2 * Pi / 6 (dm3)
Func.Vol. 1-Hr. = TotCrnVol – 100-HrInCrnVol (dm3)
100-Hr. Bio. = FuncVol 100-Hr * 0.8472 / 1000 or (0.7230 / 1000 for juniper) (kg)

Foliage Biomass:
Avg. Crn. Dia. = Sqrt(Dia1 * Dia2) (dm)
Crwn. Hgt. = TreHgt – CrnRise (dm)
Total Crn. Vol. = Pi * AvgCrndia * AvgCrnDia * CrwnHgt / 6 (dm3)
Flg. Inner Hgt. = CrwnHgt – 6.778 (for pinyon) or (-4.6292 for juniper) (dm)
(if < 0 then replace with = 0)
Flg. Inner Dia. = AvgDia – (2 * 6.778) or (2 * 4.6292 for juniper) (dm)
(if < 0 then replace with = 0)
Flg. Inner Crn.Vol. = FlgInHgt * (FlgInDia)2 * Pi / 6 (dm3)
Func. Vol. flg. = TotCrnVol – FlgInCrnVol (dm3)
Flg. Bio. = FuncVolFlg * 1.0741 / 1000 or (2.00 / 1000 for juniper) (kg)

Litter Biomass:
Total Mat Vol = Pi * MatDia * MatDia * (MatDpth / 10) / 6000 (m3)
Trunk Vol. = (Pi * BasDia * BasDia * MatDpth / 4) / 1000000 (m3)
LitterMatVol. = TotMatVol – TrnkVol (m3)
OiFlgBio = 0.4116 + (20.529 * LitMatVol) (kg)
Oi1-HrBio = -1.127 + (8.32 * LitMatVol) (if < 0 then replace with = 0) (kg)
Oi10-Hr.Bio = 0.5413 + (3.233 * LitMatVol) (kg)
TotOiBio = OiFlgBio + Oi1-HrBio + Oi10HrBio (kg)
TotOeBio = -4.455 + (20.248 * LitMatVol) (if <0 then replace with = 0) (kg)
TotOaBio = -4.860 + (12.95 * LitMatVol) (if < 0 then replace with = 0) (kg)
TotLitBio = TotOiBio + TotOeBio + TotOaBio (kg)

Total Tree Biomass:
TotTre. Inner Hgt. = CrwnHgt – 16.44 (for pinyon) or (-28.4825 for juniper) (dm)
(if < 0 then replace with = 0)
TotTre. Inner Dia. = AvgDia – (2 * 16.44) or (2 * 28.4825 for juniper) (dm)
(if < 0 then replace with = 0)
TotTre. Inner Crn. Vol. = TotTreInHgt * (TotTreInDia)2 * Pi / 6 (dm3)
Func.Vol. TotTre. = TotCrnVol – TotTreInCrnVol (dm3)
TotTre. Bio. = FuncVol TotTre. * 3.760 / 1000 or (3.722 / 1000 for juniper) (kg)

Wood Biomass (> 3 in. Dia):
WoodBio. = TotTreBio – (FlgBio + 1-HrBio + 10-HrBio + 100-HrBio) (kg)
(if < 0 then replace with = 0)

Dead Crown Stem Biomass:
DC-1-HrStm = 0.2270 + 0.2742 * FlgDefolVol (for pinyon) (kg)
FlgDefolVol = FlgInVol / 1000 (converts to m3)
= 0.3233 + 0.2525 * FlgDefolVol (for juniper) (kg)
DC-10-HrStm = 0.4227 + 0.3567 * FlgDefolVol (for pinyon) (kg)
= -0.1557 + 0.1441 * FlgDefolVol (for juniper) (kg)
(if < 0 then replace with = 0)

Table E-2: Trees that were omitted from the Tausch equations because data on crown diameter (Diam), tree height (Ht), or crown base height was missing.

<table>
<tr><th colspan="12">Mount Irish</th></tr>
<tr><th>Plot #</th><th>Tree ID</th><th>Spp</th><th>Diam (cm)</th><th>DBH (cm)</th><th>Ht (m)</th><th>Plot #</th><th>Tree ID</th><th>Spp</th><th>Diam (cm)</th><th>DBH (cm)</th><th>Ht (m)</th></tr>
<tr><td>1</td><td>MIP01T035</td><td>PIMO</td><td></td><td></td><td>0.1</td><td>6</td><td>MIP06T071</td><td>PIMO</td><td></td><td></td><td>0.05</td></tr>
<tr><td>1</td><td>MIP01T078</td><td>PIMO</td><td></td><td></td><td>0.25</td><td>6</td><td>MIP06T112</td><td>PIMO</td><td></td><td></td><td>1.4</td></tr>
<tr><td>1</td><td>MIP01T081</td><td>PIMO</td><td></td><td></td><td>0.1</td><td>6</td><td>MIP06T156</td><td>PIMO</td><td></td><td></td><td>0.3</td></tr>
<tr><td>1</td><td>MIP01T082</td><td>PIMO</td><td></td><td></td><td>0.25</td><td>6</td><td>MIP06T005</td><td>JUOS</td><td>18</td><td></td><td>0.9</td></tr>
<tr><td>1</td><td>MIP01T100</td><td>PIMO</td><td></td><td></td><td>0.2</td><td>6</td><td>MIP06T126</td><td>JUOS</td><td>25</td><td>16</td><td>3.8</td></tr>
<tr><td>1</td><td>MIP01T132</td><td>PIMO</td><td>4</td><td></td><td>0.7</td><td>7</td><td>MIP07T105</td><td>PIMO</td><td></td><td></td><td>0.5</td></tr>
<tr><td>1</td><td>MIP01T147</td><td>PIMO</td><td></td><td></td><td>0.1</td><td>7</td><td>MIP07T123</td><td>PIMO</td><td></td><td></td><td>0.1</td></tr>
<tr><td>1</td><td>MIP01T174</td><td>PIMO</td><td></td><td></td><td>0.1</td><td>8</td><td>MIP08T012</td><td>PIMO</td><td></td><td></td><td>0.5</td></tr>
<tr><td>1</td><td>MIP01T208</td><td>PIMO</td><td></td><td></td><td>0.2</td><td>8</td><td>MIP08T094</td><td>PIMO</td><td></td><td></td><td>0.1</td></tr>
<tr><td>1</td><td>MIP01T215</td><td>PIMO</td><td></td><td></td><td>0.1</td><td>8</td><td>MIP08T107</td><td>PIMO</td><td></td><td></td><td>0.4</td></tr>
<tr><td>1</td><td>MIP01T216</td><td>PIMO</td><td></td><td></td><td>0.2</td><td>8</td><td>MIP08T110</td><td>PIMO</td><td></td><td></td><td>0.05</td></tr>
<tr><td>1</td><td>MIP01T226</td><td>PIMO</td><td></td><td></td><td>0.3</td><td>8</td><td>MIP08T158</td><td>PIMO</td><td></td><td></td><td>0.1</td></tr>
<tr><td>1</td><td>MIP01T242</td><td>PIMO</td><td></td><td></td><td>0.4</td><td>8</td><td>MIP08T162</td><td>PIMO</td><td></td><td></td><td>0.35</td></tr>
<tr><td>2</td><td>MIP02T039</td><td>PIMO</td><td></td><td></td><td>0.4</td><td>10</td><td>MIP10T069</td><td>PIMO</td><td></td><td></td><td>0.1</td></tr>
<tr><td>3</td><td>MIP03T085</td><td>PIMO</td><td></td><td></td><td>0.7</td><td>10</td><td>MIP10T078</td><td>PIMO</td><td></td><td></td><td>0.3</td></tr>
<tr><td>3</td><td>MIP03T107</td><td>PIMO</td><td></td><td></td><td>0.2</td><td>11</td><td>MIP11T062</td><td>PIMO</td><td></td><td></td><td>0.1</td></tr>
<tr><td>3</td><td>MIP03T117</td><td>PIMO</td><td></td><td></td><td>0.5</td><td>11</td><td>MIP11T180</td><td>PIMO</td><td></td><td></td><td>0.1</td></tr>
<tr><td>3</td><td>MIP03T130</td><td>PIMO</td><td></td><td></td><td>0.3</td><td>11</td><td>MIP11T266</td><td>PIMO</td><td></td><td></td><td>0.05</td></tr>
<tr><td>3</td><td>MIP03T134</td><td>PIMO</td><td></td><td></td><td>0.2</td><td>11</td><td>MIP11T327</td><td>PIMO</td><td></td><td></td><td>0.05</td></tr>
<tr><td>4</td><td>MIP04T029</td><td>PIMO</td><td></td><td></td><td>0.9</td><td>12</td><td>MIP12T008</td><td>PIMO</td><td></td><td></td><td>0.05</td></tr>
<tr><td>4</td><td>MIP04T035</td><td>PIMO</td><td></td><td></td><td>0.5</td><td>12</td><td>MIP12T146</td><td>PIMO</td><td></td><td></td><td>0.05</td></tr>
<tr><td>4</td><td>MIP04T036</td><td>PIMO</td><td></td><td></td><td>0.15</td><td>12</td><td>MIP12T156</td><td>PIMO</td><td></td><td></td><td>0.2</td></tr>
<tr><td>4</td><td>MIP04T094</td><td>PIMO</td><td></td><td></td><td>0.2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th colspan="12">Clover Mountains</th></tr>
<tr><th>Plot #</th><th>Tree ID</th><th>Spp</th><th>Diam (cm)</th><th>DBH (cm)</th><th>Ht (m)</th><th>Plot #</th><th>Tree ID</th><th>Spp</th><th>Diam (cm)</th><th>DBH (cm)</th><th>Ht (m)</th></tr>
<tr><td>4</td><td>CLP04T043</td><td>PIMO</td><td>14</td><td>7</td><td>2</td><td>7</td><td>CLP07T036</td><td>PIMO</td><td></td><td></td><td>0.4</td></tr>
<tr><td>6</td><td>CLP06T030</td><td>PIMO</td><td>7</td><td></td><td>2.8</td><td>7</td><td>CLP07T042</td><td>PIMO</td><td></td><td></td><td>0.2</td></tr>
<tr><td>6</td><td>CLP06T072</td><td>PIMO</td><td></td><td></td><td>0.6</td><td>7</td><td>CLP07T043</td><td>PIMO</td><td></td><td></td><td>0.1</td></tr>
<tr><td>6</td><td>CLP06T104</td><td>PIMO</td><td></td><td></td><td>0.5</td><td>7</td><td>CLP07T057</td><td>PIMO</td><td></td><td></td><td>0.2</td></tr>
<tr><td>7</td><td>CLP07T010</td><td>PIMO</td><td>13.2</td><td></td><td>2.6</td><td>7</td><td>CLP07T188</td><td>PIMO</td><td></td><td></td><td>0.25</td></tr>
</table>

Table E-3: Number of stems used in calculating canopy bulk density and canopy fuel load. The number of stems used in the Tausch* and FMA methods are equal. The high number of stems associated with the Tausch equations are due to a large number of seedlings that were not used in the Tausch* or FMA methods.

Number of Stems used in Fuel Load and CBD Calculations				
CLOVER MOUNTAINS				
Method Used	PIMO	JUOS	ABCO	PIPO
Tausch	1275	2	0	0
Tausch*	268	2	0	0
FMA	268	2	0	148
MOUNT IRISH				
Method Used	PIMO	JUOS	ABCO	PIPO
Tausch	976	106	0	0
Tausch*	213	56	0	0
FMA	213	56	40	48

Figure E-1: An example of a vertical fuel profile for pinyon pine located in permanent plot 1 at the Clover Mountains. The profiles were created using English units so that visual comparisons could be made with the profiles created in FMAplus. After comparison, values were converted to metric units.

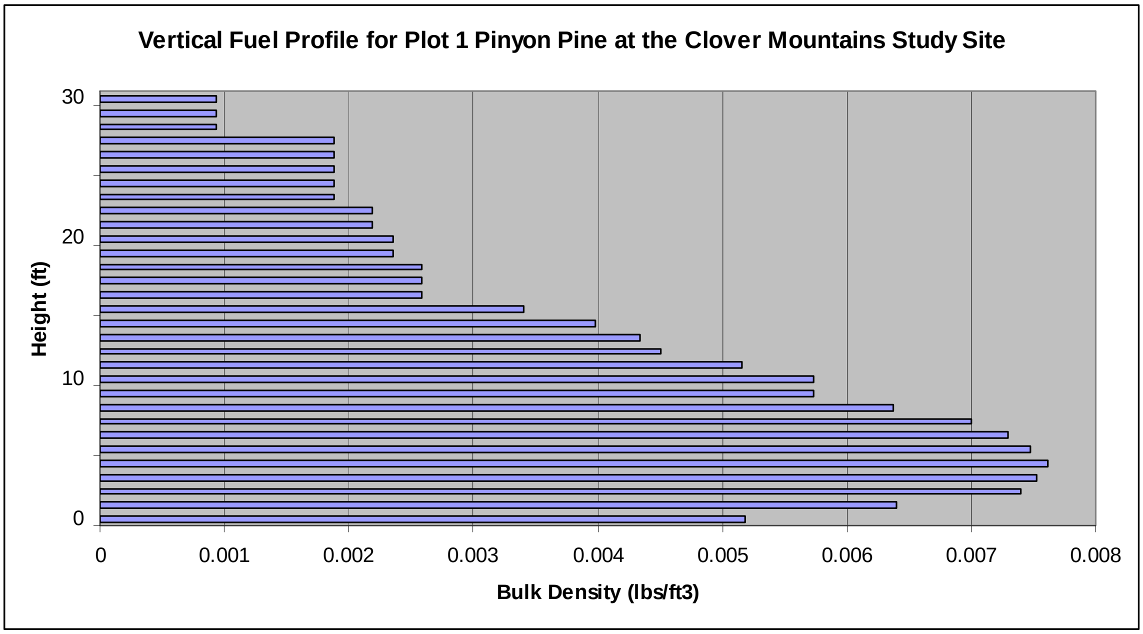


Table E-4: Canopy fuel loads when combining all species (PIMO, JUOS, PIPO, and ABCO) at Mount Irish. Values were obtained using FMA.

FMA Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	1022.216	479.724	690.444	894.439
2	515.592	206.237	497.658	822.705
3	607.501	280.213	596.293	706.136
4	887.714	421.440	520.075	961.690
5	495.416	322.805	302.630	517.833
6	1333.813	759.937	845.122	1573.675
7	1259.837	668.027	717.345	1219.486
8	744.245	412.473	450.582	793.563
9	513.350	47.076	804.771	954.965
10	863.055	598.535	571.634	990.832
11	939.273	89.668	1349.505	1176.894
12	943.757	266.763	986.349	1127.576
Sum (kg/1.2ha)	10125.769	4552.897	8332.407	11739.795
Avg (kg/0.1ha)	843.814	379.408	694.367	978.316

Table E-5: Canopy fuel loads for ponderosa pine at Mount Irish. Values were obtained using FMA.

FMA Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	0.000	0.000	0.000	0.000
2	177.094	15.692	300.388	490.933
3	82.943	2.242	159.161	239.862
4	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000
9	441.615	26.900	766.662	885.472
10	0.000	0.000	0.000	0.000
11	907.889	80.701	1338.296	1163.444
12	203.995	11.209	351.947	504.383
Sum (kg/1.2ha)	1813.537	136.744	2916.455	3284.094
Avg (kg/0.1ha)	151.128	11.395	243.038	273.674

Table E-6: Canopy fuel loads for white fir at Mount Irish. Values were obtained using FMA.

FMA Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	39699.311	3517.660	67338.072	110052.521
2	18593.348	502.523	35679.128	53769.953
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000
8	98997.016	6030.275	171862.841	198496.556
9	0.000	0.000	0.000	0.000
10	203521.785	18090.825	300006.187	260809.398
11	45729.586	2512.615	78896.099	113067.658
12	406541.047	30653.898	653782.326	736196.086
Sum (kg/1.2ha)	813082.094	61307.797	1307564.653	1472392.173
Avg (kg/0.1ha)	67756.841	5108.983	108963.721	122699.348

Table E-7: Canopy fuel loads for pinyon pine at Mount Irish. The Tausch* and FMA equations used the same trees.

Tausch Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	277.942	159.779	179.321	323.809
2	148.880	81.296	94.350	161.277
3	136.714	76.724	87.666	153.386
4	217.669	122.397	139.134	246.723
5	346.054	190.411	219.094	381.368
6	456.556	255.627	292.444	510.830
7	390.886	200.250	241.286	391.199
8	355.311	201.098	228.867	402.511
9	0.057	0.023	0.031	0.045
10	892.637	517.063	578.865	1047.493
11	0.013	0.005	0.007	0.010
12	0.330	0.135	0.178	0.260
Sum (kg/1.2ha)	3223.048	1804.808	2061.243	3618.912
Avg (kg/0.1ha)	268.587	150.401	171.770	301.576
Tausch* Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	254.667	149.704	166.270	304.442
2	136.191	76.010	87.412	151.115
3	128.363	73.298	83.168	146.800
4	199.866	114.953	129.372	232.413
5	309.526	174.869	198.824	351.489
6	433.825	246.147	280.002	492.606

7	363.604	188.968	226.477	369.510
8	336.698	193.368	218.721	387.652
9	0.000	0.000	0.000	0.000
10	863.861	504.956	563.015	1024.218
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
Sum (kg/1.2ha)	3026.601	1722.272	1953.262	3460.245
Avg (kg/0.1ha)	252.217	143.523	162.772	288.354
FMA Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	367.639	260.037	251.071	472.999
2	221.929	156.919	141.227	237.620
3	203.995	147.952	141.227	248.829
4	425.923	304.872	293.663	551.459
5	430.407	304.872	273.488	468.516
6	889.956	641.127	625.435	1179.135
7	721.828	515.592	468.516	795.804
8	477.483	345.222	325.047	564.909
9	0.000	0.000	0.000	0.000
10	807.013	580.601	546.975	950.482
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
Sum (kg/1.2ha)	4546.172	3257.193	3066.649	5469.754
Avg (kg/0.1ha)	378.848	271.433	255.554	455.813

Table E-8: Canopy fuel loads for juniper species at Mount Irish. The Tausch* and FMA equations used the same trees.

Tausch Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	212.003	367.452	90.723	188.188
2	50.464	89.429	20.079	28.947
3	85.479	64.423	36.235	73.383
4	195.272	339.442	82.788	165.788
5	92.332	160.716	38.930	71.114
6	212.751	372.445	88.156	153.767
7	599.780	1043.181	253.878	531.820
8	359.765	622.772	155.031	393.598
9	30.292	53.353	12.323	20.893
10	80.169	139.295	33.999	65.659
11	40.422	25.759	15.624	21.873
12	239.432	411.255	105.695	307.506
Sum (kg/1.2ha)	2198.162	3689.521	933.462	2022.536
Avg (kg/0.1ha)	183.180	307.460	77.789	168.545
Tausch* Equations				

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)
1	179.487	310.896	76.966	162.088
2	45.310	79.763	18.374	27.001
3	81.829	57.769	34.969	71.929
4	194.444	337.843	82.525	165.489
5	92.332	160.716	38.930	71.114
6	201.984	352.410	84.488	149.580
7	586.293	1018.150	249.249	526.491
8	330.707	569.895	144.349	380.431
9	25.986	45.311	10.893	19.261
10	80.169	139.295	33.999	65.659
11	29.880	9.736	11.870	17.443
12	238.955	410.319	105.544	307.334
Sum (kg/1.2ha)	2087.376	3492.103	892.156	1963.818
Avg (kg/0.1ha)	173.948	291.009	74.346	163.652

FMA Equations

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)
1	293.663	67.251	136.744	251.071
2	114.327	33.626	53.801	94.151
3	40.351	11.209	17.934	26.900
4	448.340	112.085	219.687	407.990
5	65.009	20.175	29.142	47.076
6	443.857	118.810	217.445	394.540
7	538.009	152.436	248.829	423.682
8	266.763	67.251	127.777	228.654
9	71.734	20.175	38.109	69.493
10	56.043	15.692	24.659	42.592
11	26.900	6.725	8.967	13.450
12	208.478	38.109	85.185	154.677
Sum (kg/1.2ha)	2573.474	663.544	1208.278	2154.276
Avg (kg/0.1ha)	214.456	55.295	100.690	179.523

Table E-9: Canopy fuel loads when combining all species (PIMO, JUOS, and PIPO) at the Clover Mountains. Values were obtained using FMA.

FMA Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	520.075	322.805	403.506	636.643
2	378.848	257.796	201.753	284.696
3	1024.458	91.910	1484.007	1295.704
4	923.581	625.435	699.411	1170.169
5	316.080	206.237	183.820	293.663
6	407.990	71.734	625.435	815.980
7	645.610	464.032	439.374	735.278
8	880.989	647.852	620.952	1060.325
9	0.000	0.000	0.000	0.000
10	226.412	11.209	419.198	585.084
11	1105.159	109.843	1445.898	1246.386
12	605.260	87.426	869.780	912.373
Sum (kg/1.2ha)	7034.462	2896.279	7393.134	9036.302
Avg (kg/0.1ha)	586.205	241.357	616.095	753.025

Table E-10: Canopy fuel loads for ponderosa pine at the Clover Mountains. Values were obtained using FMA.

FMA Equations				
Plot #	**Flg Biomass (kg/0.1ha)**	**1-Hr Biomass (kg/0.1ha)**	**10-Hr Biomass (kg/0.1ha)**	**100-Hr Biomass (kg/0.1ha)**
1	67.251	4.483	112.085	116.569
2	0.000	0.000	0.000	0.000
3	1024.458	91.910	1484.007	1295.704
4	65.009	4.483	107.602	114.327
5	0.000	0.000	0.000	0.000
6	340.739	20.175	576.117	726.312
7	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	226.412	11.209	419.198	585.084
11	1105.159	109.843	1466.073	1246.386
12	546.975	44.834	827.188	831.672
Sum (kg/1.2ha)	3376.004	286.938	4992.271	4916.053
Avg (kg/0.1ha)	281.334	23.911	416.023	409.671

Table E-11: Canopy fuel loads for pinyon pine at the Clover Mountains. The Tausch* and FMA equations used the same trees.

Tausch Equations

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)
1	473.225	265.979	302.882	536.038
2	356.934	177.969	216.658	347.551
3	0.519	0.213	0.280	0.409
4	622.281	343.615	397.286	681.334
5	290.707	158.738	183.037	318.921
6	134.176	83.025	89.346	171.573
7	693.427	397.263	448.312	800.632
8	1124.768	659.912	736.912	1331.863
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	4.123	1.692	2.221	3.252
12	34.837	19.807	22.553	39.482
Sum (kg/1.2ha)	3734.997	2108.212	2399.486	4231.055
Avg (kg/0.1ha)	311.250	175.684	199.957	352.588

Tausch* Equations

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)
1	464.305	262.318	298.077	529.001
2	337.143	169.849	205.998	331.940
3	0.000	0.000	0.000	0.000
4	607.954	337.633	389.435	669.834
5	277.534	153.283	175.877	308.435
6	124.839	79.178	84.295	164.177
7	685.761	394.117	444.184	794.585
8	1119.206	657.630	733.916	1327.475
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	34.824	19.801	22.546	39.471
Sum (kg/1.2ha)	3651.565	2073.810	2354.327	4164.919
Avg (kg/0.1ha)	304.297	172.817	196.194	347.077

FMA Equations

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)
1	452.824	316.080	293.663	522.317
2	378.848	257.796	201.753	284.696
3	0.000	0.000	0.000	0.000
4	858.572	620.952	591.809	1055.842
5	280.213	195.028	168.128	266.763
6	67.251	49.317	49.317	89.668
7	629.918	459.549	432.649	726.312
8	880.989	647.852	620.952	1060.325

9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	58.284	42.592	42.592	80.701
Sum (kg/1.2ha)	3606.899	2589.166	2400.863	4086.623
Avg (kg/0.1ha)	300.575	215.764	200.072	340.552

Table E-12: Canopy fuel loads for juniper species at the Clover Mountains. The Tausch* and FMA equations used the same trees.

Clover Mountains JUOS Canopy Fuel Load

Tausch Equations

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)
1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000
5	41.161	7.159	17.387	30.395
6	0.000	0.000	0.000	0.000
7	21.228	3.740	8.557	11.736
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
Sum (kg/1.2ha)	62.389	10.899	25.944	42.131
Avg (kg/0.1ha)	5.199	0.908	2.162	3.511

Tausch* Equations

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)
1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000
5	41.161	7.159	17.387	30.395
6	0.000	0.000	0.000	0.000
7	21.228	3.740	8.557	11.736
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
Sum (kg/1.2ha)	62.389	10.899	25.944	42.131
Avg (kg/0.1ha)	5.199	0.908	2.162	3.511

FMA Equations

Plot #	Flg Biomass (kg/0.1ha)	1-Hr Biomass (kg/0.1ha)	10-Hr Biomass (kg/0.1ha)	100-Hr Biomass (kg/0.1ha)

1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000
5	35.867	11.209	15.692	24.659
6	0.000	0.000	0.000	0.000
7	15.692	4.483	6.725	8.967
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
Sum (kg/1.2ha)	51.559	15.692	22.417	33.626
Avg (kg/0.1ha)	4.297	1.308	1.868	2.802

Table E-13: t-Test results showing significant differences in canopy fuel loads for all species combined between the Clover Mountains (CL) and Mount Irish (MI). Biomass values used to test for significant difference were calculated using FMA.

FOLIAGE BIOMASS			**1-HOUR BIOMASS**		
	CL	**MI**		**CL**	**MI**
Mean	586.21	843.81	Mean	241.36	379.41
Variance	117379.76	79134.07	Variance	52163.10	49014.37
Observations	12	12	Observations	12	12
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	21		df	22	
t Stat	-2.013052105		t Stat	-1.503452963	
P(T<=t) one-tail	0.028552682		P(T<=t) one-tail	0.073471433	
t Critical one-tail	1.720742871		t Critical one-tail	1.717144335	
P(T<=t) two-tail	**0.057105364**		P(T<=t) two-tail	0.146942865	
t Critical two-tail	2.079613837		t Critical two-tail	2.073873058	
10-HOUR BIOMASS			**100-HOUR BIOMASS**		
	CL	**MI**		**CL**	**MI**
Mean	616.09	694.37	Mean	753.03	978.32
Variance	215141.79	77869.24	Variance	170468.99	75165.06
Observations	12	12	Observations	12	12
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	18		df	19	
t Stat	-0.500909601		t Stat	-1.574672872	
P(T<=t) one-tail	0.31125238		P(T<=t) one-tail	0.065918255	
t Critical one-tail	1.734063592		t Critical one-tail	1.729132792	
P(T<=t) two-tail	0.622504759		P(T<=t) two-tail	0.13183651	
t Critical two-tail	2.100922037		t Critical two-tail	2.09302405	

Table E-14: Comparison of canopy bulk densities (kg/m^3) between Mount Irish and the Clover Mountains using three different methods. (*) Indicates that the same trees were used in each method.

MI PIMO				CL PIMO			
Plot #	**Tausch**	**Tausch***	**FMAplus***	**Plot #**	**Tausch**	**Tausch***	**FMAplus***
1	0.064	0.057	0.098	1	0.103	0.100	0.112
2	0.057	0.052	0.109	2	0.103	0.098	0.141
3	0.038	0.036	0.067	3	0.001	0.000	0.000
4	0.063	0.058	0.157	4	0.156	0.153	0.255
5	0.098	0.088	0.151	5	0.069	0.065	0.091
6	0.115	0.111	0.269	6	0.018	0.017	0.011
7	0.102	0.095	0.228	7	0.128	0.127	0.133
8	0.097	0.091	0.147	8	0.204	0.203	0.189
9	0.000	0.000	0.000	9	0.000	0.000	0.000
10	0.190	0.183	0.194	10	0.000	0.000	0.000
11	0.000	0.000	0.000	11	0.003	0.000	0.000
12	0.000	0.000	0.000	12	0.008	0.008	0.016
All plots	0.067	0.063	0.112	All plots	0.064	0.063	0.075
MI JUOS				**CL JUOS**			
Plot #	**Tausch**	**Tausch***	**FMAplus***	**Plot #**	**Tausch**	**Tausch***	**FMAplus***
1	0.095	0.080	0.090	1	0.000	0.000	0.000
2	0.031	0.028	0.047	2	0.000	0.000	0.000
3	0.028	0.026	0.011	3	0.000	0.000	0.000
4	0.090	0.090	0.163	4	0.000	0.000	0.000
5	0.041	0.041	0.019	5	0.007	0.007	0.006
6	0.097	0.091	0.163	6	0.000	0.000	0.000
7	0.236	0.229	0.149	7	0.004	0.004	0.003
8	0.128	0.114	0.064	8	0.000	0.000	0.000
9	0.027	0.023	0.038	9	0.000	0.000	0.000
10	0.029	0.029	0.013	10	0.000	0.000	0.000
11	0.013	0.008	0.011	11	0.000	0.000	0.000
12	0.055	0.055	0.027	12	0.000	0.000	0.000
All plots	0.071	0.066	0.066	All plots	0.001	0.001	0.002
MI PIMO & JUOS Combined				**CL PIMO & JUOS Combined**			
Plot #	**Tausch**	**Tausch***	**FMAplus***	**Plot #**	**Tausch**	**Tausch***	**FMAplus***
1	0.158	0.135	0.187	1	0.103	0.100	0.112
2	0.085	0.077	0.155	2	0.103	0.098	0.141
3	0.065	0.061	0.079	3	0.001	0.000	0.000
4	0.154	0.148	0.317	4	0.156	0.153	0.255
5	0.138	0.128	0.170	5	0.076	0.072	0.098
6	0.207	0.196	0.384	6	0.018	0.017	0.011
7	0.335	0.322	0.368	7	0.132	0.131	0.136
8	0.225	0.206	0.210	8	0.204	0.203	0.189
9	0.027	0.023	0.038	9	0.000	0.000	0.000
10	0.219	0.212	0.207	10	0.000	0.000	0.000
11	0.013	0.008	0.011	11	0.003	0.000	0.000
12	0.056	0.055	0.027	12	0.008	0.008	0.016
All plots	0.137	0.127	0.175	All plots	0.065	0.063	0.075

Table E-15: t-Tests showing that there is a significant difference between the Tausch* method and the FMAplus method when calculating canopy bulk density for pinyon pine at Mount Irish as indicated by the bold P value. There is not a significant difference between the two methods for juniper species or for pinyon pine combined with the juniper species at Mount Irish. There are no significant differences between the two methods at the Clover Mountains. Each method used the same trees, and a 13-foot maximum running mean to obtain canopy bulk density values. The allometric equation used in each method is the only difference between the two methods.

CL PIMO			**MI PIMO**		
	Tausch*	**FMA**		**Tausch***	**FMA**
Mean	0.096275	0.118538	Mean	0.085722	0.157700
Variance	0.004354	0.006720	Variance	0.001929	0.004112
Observations	8	8	Observations	9	9
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	13		df	14	
t Stat	-0.598378582		t Stat	-2.778235558	
P(T<=t) one-tail	0.279934551		P(T<=t) one-tail	0.007400323	
t Critical one-tail	1.770933383		t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.559869102		P(T<=t) two-tail	**0.014800645**	
t Critical two-tail	2.160368652		t Critical two-tail	2.144786681	
CL JUOS			**MI JUOS**		
	Tausch*	**FMA**		**Tausch***	**FMA**
Mean	0.005500	0.004800	Mean	0.067858	0.066342
Variance	0.000005	0.000005	Variance	0.003700	0.003645
Observations	2	2	Observations	12	12
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	2		df	22	
t Stat	0.319172527		t Stat	0.06130141	
P(T<=t) one-tail	0.389924044		P(T<=t) one-tail	0.475836336	
t Critical one-tail	2.91998558		t Critical one-tail	1.717144335	
P(T<=t) two-tail	0.779848088		P(T<=t) two-tail	0.951672673	
t Critical two-tail	4.30265273		t Critical two-tail	2.073873058	
CL PIMO/JUOS			**MI PIMO/JUOS**		
	Tausch*	**FMA**		**Tausch***	**FMA**
Mean	0.101400	0.116950	Mean	0.165044	0.230833
Variance	0.001776	0.000741	Variance	0.006308	0.010688
Observations	2	2	Observations	9	9
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	2		df	15	
t Stat	-0.438314763		t Stat	-1.513899091	
P(T<=t) one-tail	0.351978788		P(T<=t) one-tail	0.075417785	
t Critical one-tail	2.91998558		t Critical one-tail	1.753050325	
P(T<=t) two-tail	0.703957575		P(T<=t) two-tail	0.150835569	
t Critical two-tail	4.30265273		t Critical two-tail	2.131449536	

Table E-16: Correlations between the Tausch* and FMAplus methods.

MI PIMO				CL PIMO			
Plot #	**Tausch***	**FMAplus***	**R^2**	**Plot #**	**Tausch***	**FMAplus***	**R^2**
1	0.057	0.098	0.654	1	0.100	0.112	0.898
2	0.052	0.109		2	0.098	0.141	
3	0.036	0.067		4	0.153	0.255	
4	0.058	0.157		5	0.065	0.091	
5	0.088	0.151		6	0.017	0.011	
6	0.111	0.269		7	0.127	0.133	
7	0.095	0.228		8	0.203	0.189	
8	0.091	0.147		12	0.008	0.016	
10	0.183	0.194					

MI JUOS				CL JUOS			
Plot #	**Tausch***	**FMAplus***	**R^2**		**Tausch***	**FMAplus***	**R^2**
1	0.080	0.090	0.729	5	0.007	0.006	1.000
2	0.028	0.047		7	0.004	0.003	
3	0.026	0.011					
4	0.090	0.163					
5	0.041	0.019					
6	0.091	0.163					
7	0.229	0.149					
8	0.114	0.064					
9	0.023	0.038					
10	0.029	0.013					
11	0.008	0.011					
12	0.055	0.027					

MI PIMO-JUOS				CL PIMO-JUOS			
Plot #	**Tausch***	**FMAplus***	**R^2**		**Tausch***	**FMAplus***	**R^2**
1	0.135	0.187	0.744	5	0.072	0.098	1.000
2	0.077	0.155		7	0.131	0.136	
3	0.061	0.079					
4	0.148	0.317					
5	0.128	0.170					
6	0.196	0.384					
7	0.322	0.368					
8	0.206	0.210					
10	0.212	0.207					

Table E-17: White fir and ponderosa pine canopy bulk densities (kg/m^3) per permanent plot at Mount Irish obtained from FMAplus. The Clover Mountains study site does not contain white fir.

MI ABCO (FMAplus)	
Plot Number	CBD (kg/m^3)
1	0.0577
2	0
3	0.0609
4	0.0048
5	0
6	0
7	0
8	0
9	0
10	0
11	0.0016
12	0.0737

MI PIPO (FMAplus)	
Plot Number	CBD (kg/m^3)
1	0
2	0.016
3	0.0064
4	0
5	0
6	0
7	0
8	0
9	0.0336
10	0
11	0.0929
12	0.024

CL PIPO (FMAplus)	
Plot Number	CBD (kg/m^3)
1	0.0064
2	0
3	0.1041
4	0.0112
5	0
6	0.024
7	0
8	0
9	0
10	0.0288
11	0.0913
12	0.0721

Table E-18: Canopy bulk density (kg/m3) values per species at each permanent plot at Mount Irish and the Clover Mountains. These values were used in Figures E-2, E-3, E-4, and E-5.

<table>
<tr><th colspan="7">MI CBD</th></tr>
<tr><th>Plot Number</th><th>PIPO (FMA)</th><th>ABCO (FMA)</th><th>PIMO (FMA)</th><th>PIMO (Tausch*)</th><th>JUOS (FMA)</th><th>JUOS (Tausch*)</th></tr>
<tr><td>1</td><td>0.000</td><td>0.058</td><td>0.098</td><td>0.057</td><td>0.090</td><td>0.080</td></tr>
<tr><td>2</td><td>0.016</td><td>0.000</td><td>0.109</td><td>0.052</td><td>0.047</td><td>0.028</td></tr>
<tr><td>3</td><td>0.006</td><td>0.061</td><td>0.067</td><td>0.036</td><td>0.011</td><td>0.026</td></tr>
<tr><td>4</td><td>0.000</td><td>0.005</td><td>0.157</td><td>0.058</td><td>0.163</td><td>0.090</td></tr>
<tr><td>5</td><td>0.000</td><td>0.000</td><td>0.151</td><td>0.088</td><td>0.019</td><td>0.041</td></tr>
<tr><td>6</td><td>0.000</td><td>0.000</td><td>0.269</td><td>0.111</td><td>0.163</td><td>0.091</td></tr>
<tr><td>7</td><td>0.000</td><td>0.000</td><td>0.228</td><td>0.095</td><td>0.149</td><td>0.229</td></tr>
<tr><td>8</td><td>0.000</td><td>0.000</td><td>0.147</td><td>0.091</td><td>0.064</td><td>0.114</td></tr>
<tr><td>9</td><td>0.034</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.038</td><td>0.023</td></tr>
<tr><td>10</td><td>0.000</td><td>0.000</td><td>0.194</td><td>0.183</td><td>0.013</td><td>0.029</td></tr>
<tr><td>11</td><td>0.093</td><td>0.002</td><td>0.000</td><td>0.000</td><td>0.011</td><td>0.008</td></tr>
<tr><td>12</td><td>0.024</td><td>0.074</td><td>0.000</td><td>0.000</td><td>0.027</td><td>0.055</td></tr>
<tr><td>All Plots</td><td>0.014</td><td>0.016</td><td>0.112</td><td>0.063</td><td>0.066</td><td>0.066</td></tr>
<tr><th colspan="7">CL CBD</th></tr>
<tr><th>Plot Number</th><th>PIPO (FMA)</th><th>ABCO (FMA)</th><th>PIMO (FMA)</th><th>PIMO (Tausch*)</th><th>JUOS (FMA)</th><th>JUOS (Tausch*)</th></tr>
<tr><td>1</td><td>0.006</td><td>0.000</td><td>0.112</td><td>0.100</td><td>0.000</td><td>0.000</td></tr>
<tr><td>2</td><td>0.000</td><td>0.000</td><td>0.141</td><td>0.098</td><td>0.000</td><td>0.000</td></tr>
<tr><td>3</td><td>0.104</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td></tr>
<tr><td>4</td><td>0.011</td><td>0.000</td><td>0.255</td><td>0.153</td><td>0.000</td><td>0.000</td></tr>
<tr><td>5</td><td>0.000</td><td>0.000</td><td>0.091</td><td>0.065</td><td>0.006</td><td>0.007</td></tr>
<tr><td>6</td><td>0.024</td><td>0.000</td><td>0.011</td><td>0.017</td><td>0.000</td><td>0.000</td></tr>
<tr><td>7</td><td>0.000</td><td>0.000</td><td>0.133</td><td>0.127</td><td>0.003</td><td>0.004</td></tr>
<tr><td>8</td><td>0.000</td><td>0.000</td><td>0.189</td><td>0.203</td><td>0.000</td><td>0.000</td></tr>
<tr><td>9</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td></tr>
<tr><td>10</td><td>0.029</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td></tr>
<tr><td>11</td><td>0.091</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td></tr>
<tr><td>12</td><td>0.072</td><td>0.000</td><td>0.016</td><td>0.008</td><td>0.000</td><td>0.000</td></tr>
<tr><td>All Plots</td><td>0.019</td><td>0.000</td><td>0.075</td><td>0.063</td><td>0.002</td><td>0.001</td></tr>
</table>

Figure E-2: Canopy bulk densities (kg/m^3) for each species at each permanent plot at Mount Irish. Values for each species were calculated using FMAplus.

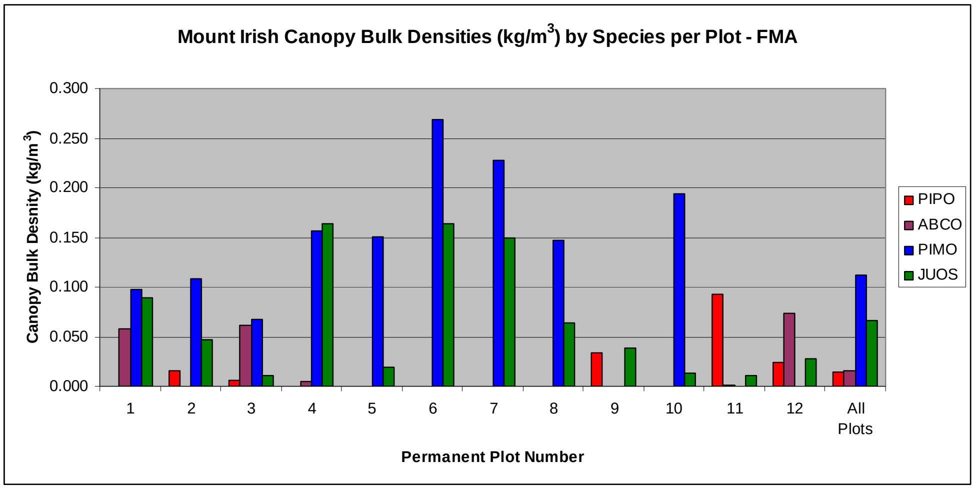


Figure E-3: Canopy bulk densities (kg/m^3) for each species at each permanent plot at Mount Irish. Ponderosa pine (PIPO) and white fire (ABCO) values were calculated using FMAplus. Pinyon pine (PIMO) and Juniper (JUOS) values were calculated using the Tausch equations.

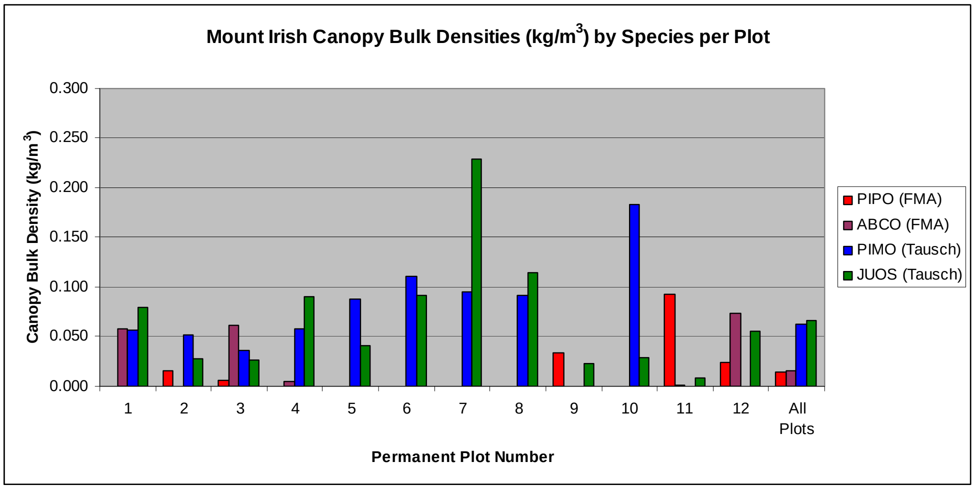


Figure E-4: Canopy bulk densities (kg/m^3) for each species at each permanent plot at the Clover Mountains. Values for each species were calculated using FMAplus.

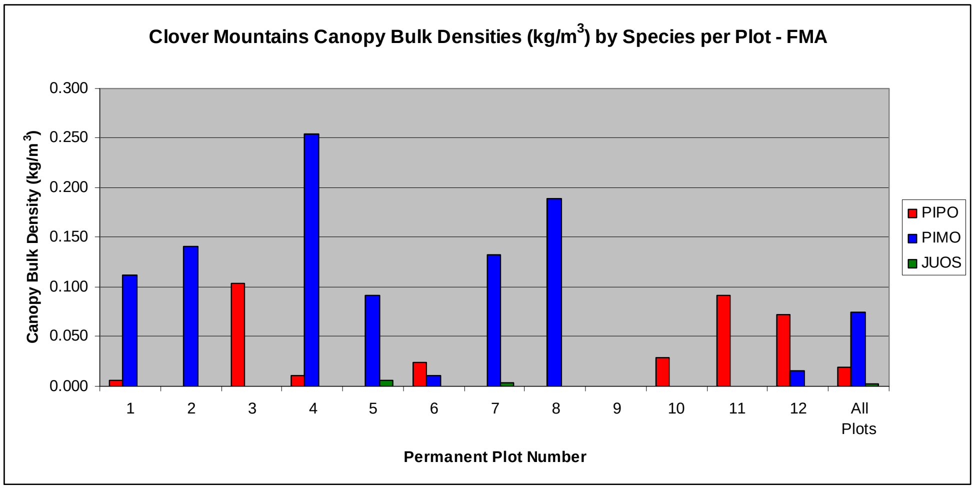


Figure E-5: Canopy bulk densities (kg/m^3) for each species at each permanent plot at the Clover Mountains. Ponderosa pine values were calculated using FMAplus. White fir does not exist. Pinyon pine (PIMO) and Juniper (JUOS) values were calculated using the Tausch equations.

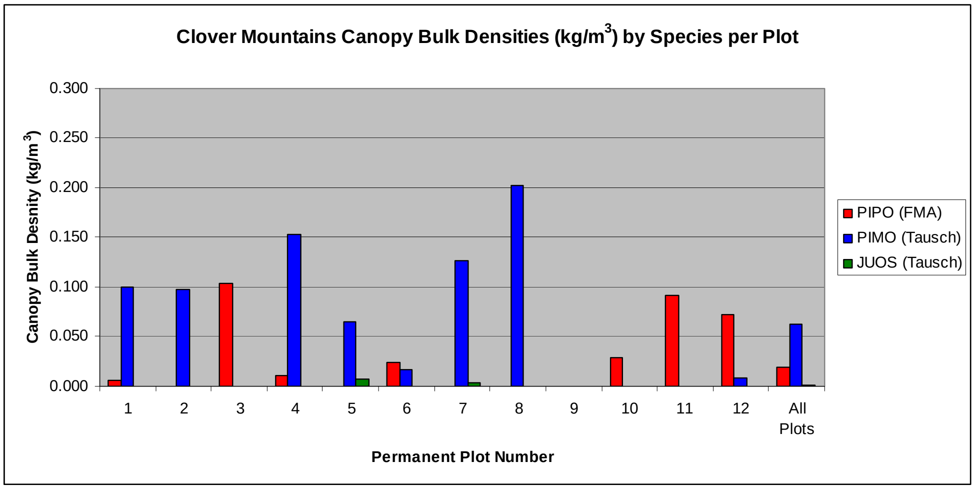


Table E-19: List of canopy bulk densities (kg/m3) by species per study site. Each study site has an area of 1.2 ha (12 plots, each being 0.1 ha). Values were obtained using FMAplus.

	Study Site	
Species	**MI**	**CL**
ABCO	0.016	0.000
PIPO	0.014	0.019
PIMO	0.112	0.075
JUOS	0.066	0.002
All Species	0.195	0.085

Figure E-6: Comparison of canopy bulk densities (kg/m^3) by species for Mount Irish (MI) and the Clover Mountains (CL). Each study site has an area of 1.2 ha. White fir does not exist at the Clover Mountains. Canopy bulk density values were obtained using FMAplus.

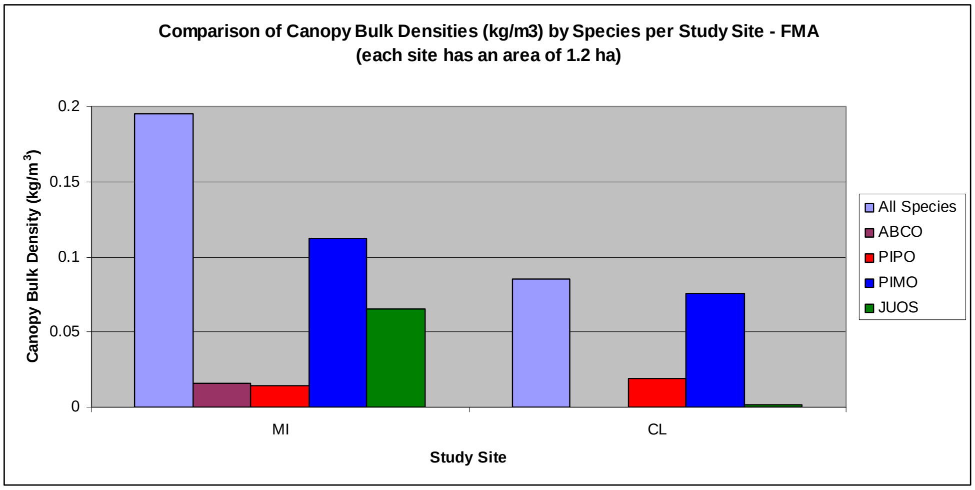


Table E-20: Total canopy bulk densities (kg/m^3) when combining all species at each permanent plot at Mount Irish (MI) and the Clover Mountains (CL) in relation to pinyon pine densities. Pinyon pine densities are for trees ≥ 2.0m.

Mount Irish		
Plot #	**Density (trees/ha)**	**CBD (kg/m3)**
1	190	0.2451
2	90	0.1682
3	70	0.1442
4	160	0.3204
5	300	0.1698
6	300	0.3844
7	420	0.3684
8	200	0.2098
9	0	0.0481
10	590	0.2066
11	0	0.0929
12	0	0.1217
All Plots	193	0.1954
Clover Mountains		
Plot #	**Density (trees/ha)**	**CBD (kg/m3)**
1	410	0.1121
2	510	0.141
3	0	0.1041
4	420	0.2627
5	300	0.0977
6	50	0.0336
7	430	0.1362
8	460	0.189
9	0	0
10	0	0.0288
11	0	0.0913
12	20	0.0737
All Plots	217	0.0849

Figure E-7: Total canopy bulk densities (kg/m^3) when combining all species at each permanent plot at Mount Irish in relation to pinyon pine densities per plot. Refer to Table E-20 for pinyon pine densities (trees/ha).

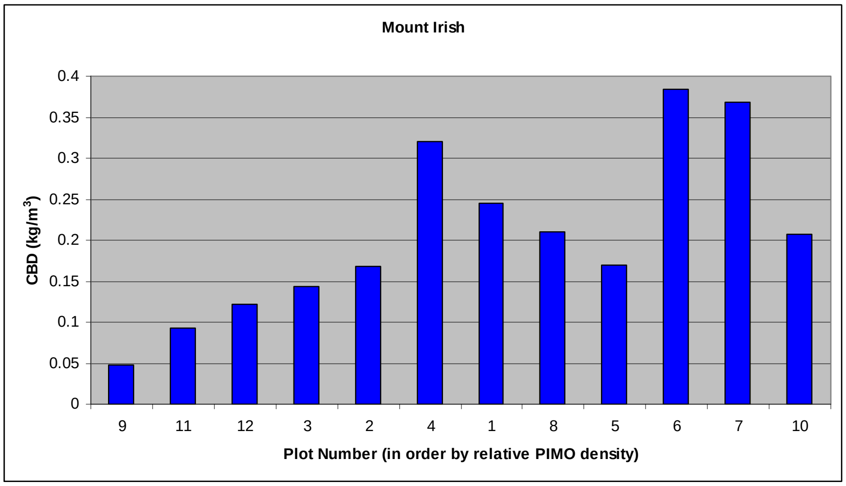


Figure E-8: Same as Figure E-7, but for the Clover Mountains.

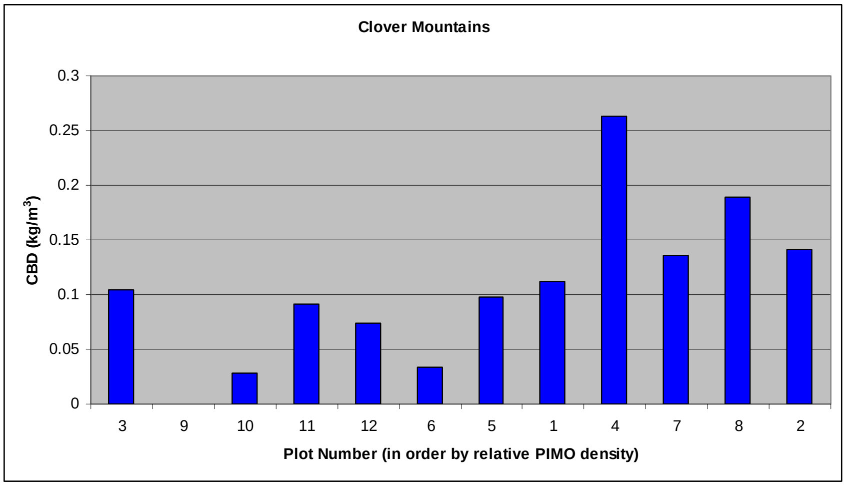


Table E-21: List of canopy bulk densities of combined species for north facing and south facing plots at Mount Irish. There are no significant differences between canopy bulk densities of southern aspects and northern aspects.

North Facing	Plot #	CBD (kg/m^3)
	1	0.245
	3	0.144
	4	0.320
	9	0.048
	11	0.093
	12	0.122
South Facing	2	0.168
	5	0.170
	6	0.384
	7	0.368
	8	0.210
	10	0.207

Table E-22: Same as Table E-10, but for the Clover Mountains.

North Facing	Plot #	CBD (kg/m^3)
	2	0.141
	3	0.104
	6	0.034
	10	0.029
	11	0.091
South Facing	1	0.112
	4	0.263
	5	0.098
	7	0.136
	8	0.189
	9	0.000
	12	0.074

Appendix F: Herbaceous and Shrub Vegetation

Table F-1: Cover classes used to estimate herbaceous and shrub cover at each permanent plot. The original classes of 1 through 5 are from Braun-Blanquet (1932). Class 0 was added to account for areas containing no cover.

Cover Class	Percent Cover	Color Code
0	0	🟦
1	<5	🟦
2	5 to 25	🟩
3	25 to 50	🟨
4	50 to 75	🟧
5	75 to 100	🟥

Table F-2: Percent of herbaceous cover class at each predetermined location for each permanent plot at Mount Irish. Estimates were taken within a 1 m^2 circle. Refer to Table F-1 for color coded percentages.

Mount Irish												
Plot #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
HERBACEOUS COVER CLASSES	2	1	2	1	0	1	2	1	1	1	1	2
	2	2	2	2	1	0	1	1	0	1	2	4
	1	1	0	1	1	0	2	2	1	0	1	3
	2	2	1	2	0	0	2	1	1	1	1	2
	2	1	2	2	1	0	2	2	0	1	1	2
	2	1	2	1	1	1	2	1	1	1	1	2
	2	1	1	1	1	1	1	2	1	0	1	2
	2	1	2	2	1	0	1	1	1	2	1	2
	2	0	1	1	1	2	1	1	2	0	1	2
	2	1	1	1	1	1	0	1	2	0	1	2
	4	1	1	1	0	2	1	1	2	0	1	3
	4	0	1	1	0	2	1	0	2	0	1	3
	3	1	2	3	1	1	1	1	2	1	2	2
	3	1	4	2	1	3	1	1	1	1	1	2
	2	1	2	0	1	1	0	0	1	0	1	2
	2	1	2	0	1	2	1	2	1	2	1	3
	2	1	2	2	0	1	2	1	1	0	0	1
	1	1	3	0	1	0	2	2	1	0	1	1
	2	1	3	1	3	1	2	0	2	1	1	1
	2	1	0	1	0	1	1	0	1	1	1	2

Table F-3: Same as Table F-2, but for the Clover Mountains.

Clover Mountains												
Plot #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
HERBACEOUS COVER CLASSES	1	1	0	2	0	0	1	2	0	1	2	1
	0	1	1	2	0	1	1	3	0	0	1	0
	1	1	1	2	1	0	1	2	0	0	1	1
	0	2	0	3	1	1	2	2	0	0	1	2
	0	1	1	1	2	1	1	1	0	0	1	2
	0	2	0	1	1	2	1	1	0	1	1	2
	0	2	1	1	0	2	1	3	1	0	1	2
	1	2	0	1	0	1	1	1	0	1	1	2
	1	1	1	1	1	2	1	2	0	0	2	2
	0	2	0	1	1	0	1	1	1	0	2	2
	1	5	0	1	2	1	0	1	0	0	2	1
	0	5	1	1	0	2	0	1	0	0	2	0
	1	1	0	0	0	2	2	1	0	0	2	1
	0	2	0	1	0	2	3	1	0	0	1	1
	1	3	1	1	0	1	1	2	0	0	2	2
	1	3	0	1	0	1	2	1	0	0	1	1
	1	4	1	1	1	2	0	1	0	0	1	2
	1	5	1	1	3	1	1	1	0	0	1	2
	1	5	1	1	2	1	0	1	0	0	1	2
	1	2	1	0	0	1	1	1	0	0	1	2

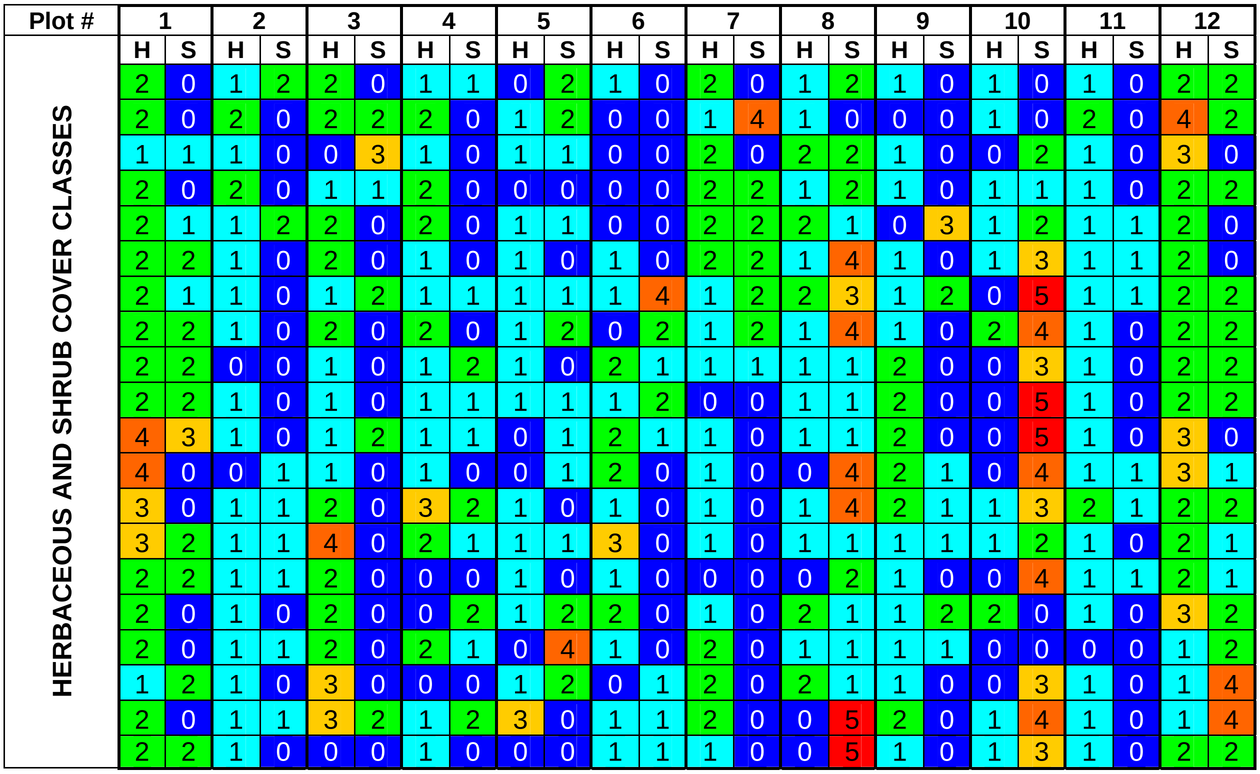
Table F-4: Percent of shrub cover class at each predetermined location for each permanent plot at Mount Irish. Estimates were taken within a 1 m^2 circle. Refer to Table F-1 for color coded percentages.

	Mount Irish											
Plot #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
SHRUB COVER CLASSES	0	2	0	1	2	0	0	2	0	0	0	2
	0	0	2	0	2	0	4	0	0	0	0	2
	1	0	3	0	1	0	0	2	0	2	0	0
	0	0	1	0	0	0	2	2	0	1	0	2
	1	2	0	0	1	0	2	1	3	2	1	0
	2	0	0	0	0	0	2	4	0	3	1	0
	1	0	2	1	1	4	2	3	2	5	1	2
	2	0	0	0	2	2	2	4	0	4	0	2
	2	0	0	2	0	1	1	1	0	3	0	2
	2	0	0	1	1	2	0	1	0	5	0	2
	3	0	2	1	1	1	0	1	0	5	0	0
	0	1	0	0	1	0	0	4	1	4	1	1
	0	1	0	2	0	0	0	4	1	3	1	2
	2	1	0	1	1	0	0	1	1	2	0	1
	2	1	0	0	0	0	0	2	0	4	1	1
	0	0	0	2	2	0	0	1	2	0	0	2
	0	1	0	1	4	0	0	1	1	0	0	2
	2	0	0	0	2	1	0	1	0	3	0	4
	0	1	2	2	0	1	0	5	0	4	0	4
	2	0	0	0	0	1	0	5	0	3	0	2

Table F-5: Same as Table F-4, but for the Clover Mountains.

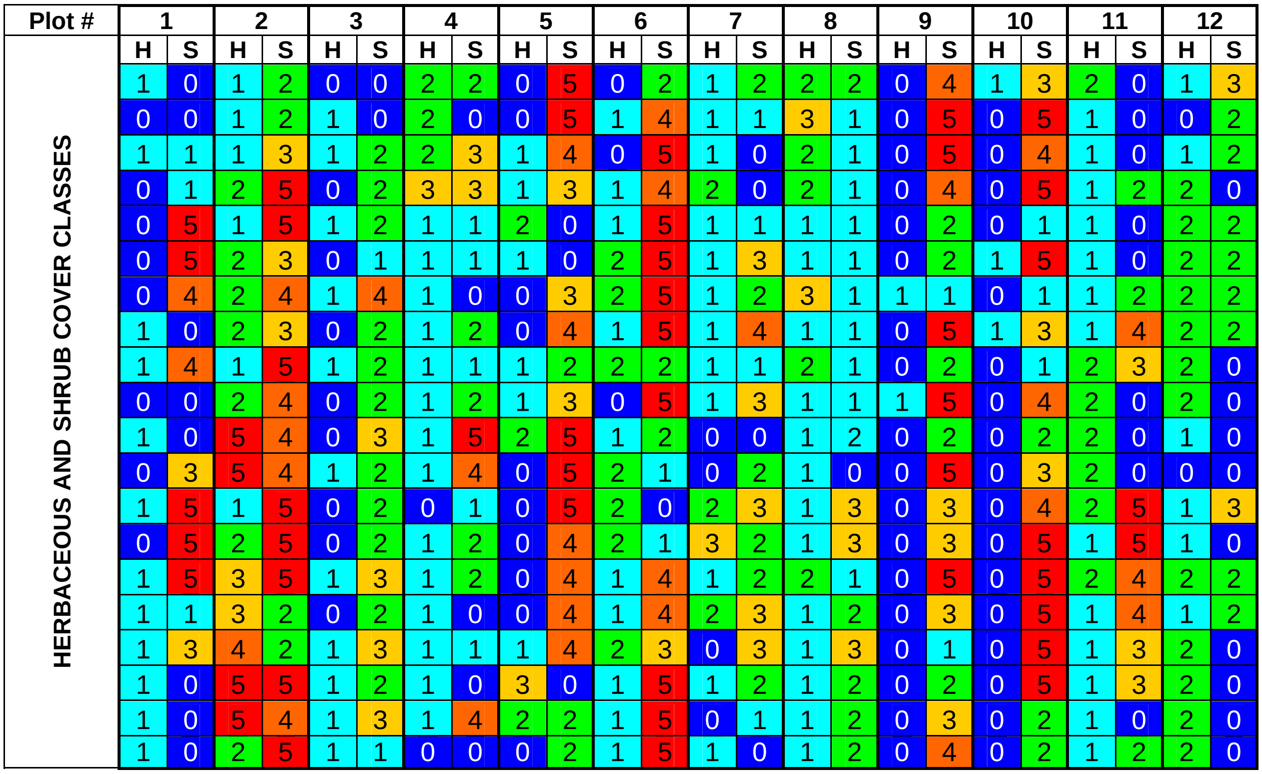
	Clover Mountains Permanent Plot Number											
Plot #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
SHRUB COVER CLASSES	0	2	0	2	5	2	2	2	4	3	0	3
	0	2	0	0	5	4	1	1	5	5	0	2
	1	3	2	3	4	5	0	1	5	4	0	2
	1	5	2	3	3	4	0	1	4	5	2	0
	5	5	2	1	0	5	1	1	2	1	0	2
	5	3	1	1	0	5	3	1	2	5	0	2
	4	4	4	0	3	5	2	1	1	1	2	2
	0	3	2	2	4	5	4	1	5	3	4	2
	4	5	2	1	2	2	1	1	2	1	3	0
	0	4	2	2	3	5	3	1	5	4	0	0
	0	4	3	5	5	2	0	2	2	2	0	0
	3	4	2	4	5	1	2	0	5	3	0	0
	5	5	2	1	5	0	3	3	3	4	5	3
	5	5	2	2	4	1	2	3	3	5	5	0
	5	5	3	2	4	4	2	1	5	5	4	2
	1	2	2	0	4	4	3	2	3	5	4	2
	3	2	3	1	4	3	3	3	1	5	3	0
	0	5	2	0	0	5	2	2	2	5	3	0
	0	4	3	4	2	5	1	2	3	2	0	0
	0	5	1	0	2	5	0	2	4	2	2	0

Table F-6: Percent of herbaceous (H) and shrub (S) cover class at each location for each permanent plot at Mount Irish. Estimates were taken within a 1 m^2 circle. Refer to Table F-1 for color coded percentages.



Plot #	1		2		3		4		5		6		7		8		9		10		11		12	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
HERBACEOUS AND SHRUB COVER CLASSES	2	0	1	2	2	0	1	1	0	2	1	0	2	0	1	2	1	0	1	0	1	0	2	2
	2	0	2	0	2	2	2	0	1	2	0	0	1	4	1	0	0	0	1	0	2	0	4	2
	1	1	1	0	0	3	1	0	1	1	0	0	2	0	2	2	1	0	0	2	1	0	3	0
	2	0	2	0	1	1	2	0	0	0	0	0	2	2	1	2	1	0	1	1	1	0	2	2
	2	1	1	2	2	0	2	0	1	1	0	0	2	2	2	1	0	3	1	2	1	1	2	0
	2	2	1	0	2	0	1	0	1	0	1	0	2	2	1	4	1	0	1	3	1	1	2	0
	2	1	1	0	1	2	1	1	1	1	1	4	1	2	2	3	1	2	0	5	1	1	2	2
	2	2	1	0	2	0	2	0	1	2	0	2	1	2	1	4	1	0	2	4	1	0	2	2
	2	2	0	0	1	0	1	2	1	0	2	1	1	1	1	1	2	0	0	3	1	0	2	2
	2	2	1	0	1	0	1	1	1	1	1	2	0	0	1	1	2	0	0	5	1	0	2	2
	4	3	1	0	1	2	1	1	0	1	2	1	1	0	1	1	2	0	0	5	1	0	3	0
	4	0	0	1	1	0	1	0	0	1	2	0	1	0	0	4	2	1	0	4	1	1	3	1
	3	0	1	1	2	0	3	2	1	0	1	0	1	0	1	4	2	1	1	3	2	1	2	2
	3	2	1	1	4	0	2	1	1	1	3	0	1	0	1	1	1	1	1	2	1	0	2	1
	2	2	1	1	2	0	0	0	1	0	1	0	0	0	0	2	1	0	0	4	1	1	2	1
	2	0	1	0	2	0	0	2	1	2	2	0	1	0	2	1	1	2	2	0	1	0	3	2
	2	0	1	1	2	0	2	1	0	4	1	0	2	0	1	1	1	1	0	0	0	0	1	2
	1	2	1	0	3	0	0	0	1	2	0	1	2	0	2	1	1	0	0	3	1	0	1	4
	2	0	1	1	3	2	1	2	3	0	1	1	2	0	0	5	2	0	1	4	1	0	1	4
	2	2	1	0	0	0	1	0	0	0	1	1	1	0	0	5	1	0	1	3	1	0	2	2

Table F-7: Same as Table F-6, but for the Clover Mountains.



Plot #	1		2		3		4		5		6		7		8		9		10		11		12	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
HERBACEOUS AND SHRUB COVER CLASSES	1	0	1	2	0	0	2	2	0	5	0	2	1	2	2	2	0	4	1	3	2	0	1	3
	0	0	1	2	1	0	2	0	0	5	1	4	1	1	3	1	0	5	0	5	1	0	0	2
	1	1	1	3	1	2	2	3	1	4	0	5	1	0	2	1	0	5	0	4	1	0	1	2
	0	1	2	5	0	2	3	3	1	3	1	4	2	0	2	1	0	4	0	5	1	2	2	0
	0	5	1	5	1	2	1	1	2	0	1	5	1	1	1	1	0	2	0	1	1	0	2	2
	0	5	2	3	0	1	1	1	1	0	2	5	1	3	1	1	0	2	1	5	1	0	2	2
	0	4	2	4	1	4	1	0	0	3	2	5	1	2	3	1	1	1	0	1	1	2	2	2
	1	0	2	3	0	2	1	2	0	4	1	5	1	4	1	1	0	5	1	3	1	4	2	2
	1	4	1	5	1	2	1	1	1	2	2	2	1	1	2	1	0	2	0	1	2	3	2	0
	0	0	2	4	0	2	1	2	1	3	0	5	1	3	1	1	1	5	0	4	2	0	2	0
	1	0	5	4	0	3	1	5	2	5	1	2	0	0	1	2	0	2	0	2	2	0	1	0
	0	3	5	4	1	2	1	4	0	5	2	1	0	2	1	0	0	5	0	3	2	0	0	0
	1	5	1	5	0	2	0	1	0	5	2	0	2	3	1	3	0	3	0	4	2	5	1	3
	0	5	2	5	0	2	1	2	0	4	2	1	3	2	1	3	0	3	0	5	1	5	1	0
	1	5	3	5	1	3	1	2	0	4	1	4	1	2	2	1	0	5	0	5	2	4	2	2
	1	1	3	2	0	2	1	0	0	4	1	4	2	3	1	2	0	3	0	5	1	4	1	2
	1	3	4	2	1	3	1	1	1	4	2	3	0	3	1	3	0	1	0	5	1	3	2	0
	1	0	5	5	1	2	1	0	3	0	1	5	1	2	1	2	0	2	0	5	1	3	2	0
	1	0	5	4	1	3	1	4	2	2	1	5	0	1	1	2	0	3	0	2	1	0	2	0
	1	0	2	5	1	1	0	0	0	2	1	5	1	0	1	2	0	4	0	2	1	2	2	0

Table F-8: List of the number of observations for each cover class for herbaceous, shrub, and combined herbaceous and shrub vegetation at Mount Irish and the Clover Mountains. Cumulative percentages describe the percentage of vegetation that occurs in each cover class.

MOUNT IRISH											
HERBACEOUS				SHRUB				HERBACEOUS & SHRUB			
Cover Class	# Of Obsv. (n=240)	% Of Obsv.	Cumul-ative %	Cover Class	# Of Obsv. (n=240)	% Of Obsv	Cumul-ative %	Cover Class	# Of Obsv. (n=480)	% Of Obsv.	Cumul-ative %
0	37	0.15	0.15	0	112	0.47	0.47	0	149	0.31	0.31
1	118	0.49	0.65	1	51	0.21	0.68	1	169	0.35	0.66
2	70	0.29	0.94	2	50	0.21	0.89	2	120	0.25	0.91
3	11	0.05	0.98	3	9	0.04	0.93	3	20	0.04	0.95
4	4	0.02	1.00	4	13	0.05	0.98	4	17	0.04	0.99
5	0	0.00	1.00	5	5	0.02	1.00	5	5	0.01	1.00
CLOVER MOUNTAINS											
HERBACEOUS				SHRUB				HERBACEOUS & SHRUB			
Cover Class	# Of Obsv. (n=240)	% Of Obsv.	Cumul-ative %	Cover Class	# Of Obsv. (n=240)	% Of Obsv	Cumul-ative %	Cover Class	# Of Obsv. (n=480)	% Of Obsv.	Cumul-ative %
0	73	0.30	0.30	0	43	0.18	0.18	0	116	0.24	0.24
1	108	0.45	0.75	1	31	0.13	0.31	1	139	0.29	0.53
2	47	0.20	0.95	2	57	0.24	0.55	2	104	0.22	0.75
3	7	0.03	0.98	3	35	0.15	0.69	3	42	0.09	0.84
4	1	0.00	0.98	4	30	0.13	0.82	4	31	0.06	0.90
5	4	0.02	1.00	5	44	0.18	1.00	5	48	0.10	1.00

Appendix G: Canopy Fuel Reconstruction

Table G-1: List of trees containing increment cores that were measured to reconstruct historic DBH values at Mount Irish.

Plot #	Tree ID	Species	2007 DBH (cm)	Plot #	Tree ID	Species	2007 DBH (cm)
1	MIP01T001	PIMO	32.5	1	MIP01T003	ABCO	34.5
1	MIP01T013	ABCO	35	1	MIP01T019	ABCO	46
1	MIP01T029	ABCO	36	1	MIP01T034	JUOS	20
1	MIP01T041	PIMO	46	1	MIP01T044	ABCO	31.5
1	MIP01T054	ABCO	29	1	MIP01T056	ABCO	8
1	MIP01T057	ABCO	15	1	MIP01T065	ABCO	17
1	MIP01T104	PIMO	11.5	1	MIP01T107	PIMO	33
1	MIP01T114	PIMO	9	1	MIP01T123	PIMO	8
1	MIP01T150	ABCO	17	1	MIP01T158	PIMO	12
1	MIP01T164	JUOS	26	1	MIP01T166	ABCO	11
1	MIP01T167	PIMO	8	1	MIP01T169	PIMO	7
1	MIP01T173	PIMO	7	1	MIP01T175	ABCO	12
1	MIP01T176	PIMO	6	1	MIP01T177	ABCO	7
1	MIP01T184	PIMO	11	1	MIP01T187	PIMO	6
1	MIP01T189	PIMO	13	1	MIP01T191	ABCO	13
1	MIP01T193	PIMO	15	1	MIP01T205	PIMO	14
2	MIP02T022	PIPO	15	2	MIP02T047	PIMO	8
2	MIP02T064	PIMO	17	2	MIP02T084	PIMO	12
2	MIP02T086	PIMO	18	2	MIP02T088	PIPO	79
2	MIP02T103	PIMO	21	2	MIP02T104	JUOS	11
2	MIP02T110	PIMO	11	2	MIP02T118	PIPO	13
2	MIP02T125	PIMO	10	2	MIP02T126	PIPO	17
2	MIP02T128	PIMO	17	2	MIP02T134	PIMO	14
2	MIP02T142	PIPO	44	3	MIP03T009	PIMO	14
3	MIP03T022	PIMO	17	3	MIP03T025	PIMO	20
3	MIP03T029	PIMO	10	3	MIP03T030	JUOS	14
3	MIP03T033	ABCO	17	3	MIP03T038	ABCO	23
3	MIP03T042	ABCO	44	3	MIP03T043	PIMO	31
3	MIP03T073	ABCO	25	3	MIP03T114	ABCO	47
3	MIP03T121	PIMO	12	4	MIP04T002	PIMO	9.5
4	MIP04T005	PIMO	18	4	MIP04T012	PIMO	8
4	MIP04T028	PIMO	24	4	MIP04T034	PIMO	14.5
4	MIP04T037	PIMO	11.5	4	MIP04T061	PIMO	34
4	MIP04T069	PIMO	31	4	MIP04T079	PIMO	36
4	MIP04T080	PIMO	20	4	MIP04T083	PIMO	5
4	MIP04T087	PIMO	14	4	MIP04T088	PIMO	19
4	MIP04T098	ABCO	14	4	MIP04T102	JUOS	6
4	MIP04T117	PIMO	37	5	MIP05T001	JUOS	15
5	MIP05T002	PIMO	8	5	MIP05T008	PIMO	13
5	MIP05T019	PIMO	18	5	MIP05T020	PIMO	7

5	MIP05T023	PIMO	8	5	MIP05T024	PIMO	5
5	MIP05T031	PIMO	28	5	MIP05T036	PIMO	14.5
5	MIP05T044	PIMO	26	5	MIP05T046	PIMO	8
5	MIP05T048	PIMO	20	5	MIP05T055	PIMO	9
5	MIP05T065	JUOS	17.5	5	MIP05T067	PIMO	16
5	MIP05T073	PIMO	38	5	MIP05T098	PIMO	7.5
5	MIP05T107	PIMO	20	5	MIP05T111	PIMO	8
5	MIP05T112	PIMO	8	5	MIP05T116	PIMO	10
5	MIP05T125	PIMO	22	5	MIP05T126	PIMO	3
5	MIP05T137	PIMO	7	5	MIP05T155	PIMO	14
6	MIP06T016	PIMO	29	6	MIP06T020	JUOS	23
6	MIP06T023	PIMO	40	6	MIP06T033	PIMO	23
6	MIP06T035	PIMO	19	6	MIP06T039	PIMO	30
6	MIP06T041	PIMO	7	6	MIP06T044	PIMO	10
6	MIP06T054	PIMO	7	6	MIP06T058	PIMO	11.5
6	MIP06T065	PIMO	8	6	MIP06T068	PIMO	30.5
6	MIP06T074	PIMO	13.5	6	MIP06T079	PIMO	12
6	MIP06T083	PIMO	41	6	MIP06T086	JUOS	15
6	MIP06T087	PIMO	28	6	MIP06T089	PIMO	24
6	MIP06T092	PIMO	19	6	MIP06T093	PIMO	32
6	MIP06T095	PIMO	35	6	MIP06T097	PIMO	17
6	MIP06T101	PIMO	31	6	MIP06T120	PIMO	6
6	MIP06T130	JUOS	18	6	MIP06T131	PIMO	10
6	MIP06T134	PIMO	21.5	6	MIP06T148	PIMO	14
6	MIP06T149	JUOS	38	7	MIP07T007	PIMO	7
7	MIP07T008	PIMO	9	7	MIP07T011	PIMO	11
7	MIP07T015	JUOS	5	7	MIP07T021	PIMO	8
7	MIP07T027	PIMO	17	7	MIP07T041	PIMO	13
7	MIP07T050	PIMO	8	7	MIP07T052	PIMO	4
7	MIP07T053	PIMO	4	7	MIP07T059	PIMO	16
7	MIP07T062	PIMO	21	7	MIP07T070	PIMO	14
7	MIP07T071	PIMO	19	7	MIP07T075	JUOS	22
7	MIP07T079	PIMO	14	7	MIP07T108	PIMO	19
7	MIP07T120	PIMO	23	7	MIP07T133	JUOS	9
7	MIP07T151	PIMO	27	7	MIP07T154	PIMO	31
7	MIP07T159	PIMO	14	7	MIP07T160	PIMO	19
7	MIP07T162	JUOS	17	7	MIP07T171	JUOS	24
7	MIP07T173	JUOS	33	7	MIP07T191	PIMO	21
7	MIP07T193	PIMO	9	7	MIP07T194	PIMO	15
7	MIP07T196	JUOS	22	7	MIP07T198	PIMO	21
7	MIP07T199	PIMO	16	7	MIP07T202	JUOS	16
7	MIP07T203	PIMO	32.5	7	MIP07T204	PIMO	11
7	MIP07T206	PIMO	15	7	MIP07T207	PIMO	8
7	MIP07T210	JUOS	15	7	MIP07T211	JUOS	16
7	MIP07T213	JUOS	16	7	MIP07T216	JUOS	18
7	MIP07T217	PIMO	11	7	MIP07T223	PIMO	15
7	MIP07T226	PIMO	16	7	MIP07T230	JUOS	13

7	MIP07T233	PIMO	19	8	MIP08T014	JUOS	35.5
8	MIP08T015	JUOS	37	8	MIP08T016	PIMO	33
8	MIP08T018	PIMO	13	8	MIP08T024	PIMO	24
8	MIP08T039	PIMO	25	8	MIP08T045	PIMO	17.5
8	MIP08T054	PIMO	16.5	8	MIP08T061	PIMO	32
8	MIP08T079	PIMO	24	8	MIP08T081	JUOS	17
8	MIP08T084	JUOS	6	8	MIP08T088	PIMO	14
8	MIP08T089	JUOS	24	8	MIP08T106	PIMO	13.5
8	MIP08T111	PIMO	20	8	MIP08T116	PIMO	24.5
8	MIP08T133	PIMO	12	8	MIP08T143	PIMO	8.5
8	MIP08T150	PIMO	10.5	8	MIP08T153	PIMO	23.5
8	MIP08T160	PIMO	15	9	MIP09T006	PIPO	57
9	MIP09T014	PIPO	58	9	MIP09T026	PIPO	48
9	MIP09T037	PIPO	41	9	MIP09T063	PIPO	22.5
9	MIP09T069	PIPO	57.5	9	MIP09T074	PIPO	57
10	MIP10T008	PIMO	10.5	10	MIP10T017	PIMO	20
10	MIP10T028	PIMO	10	10	MIP10T031	PIMO	35
10	MIP10T040	PIMO	10	10	MIP10T067	PIMO	30
10	MIP10T076	PIMO	18	10	MIP10T083	PIMO	24
10	MIP10T085	PIMO	15	10	MIP10T091	PIMO	8
10	MIP10T119	PIMO	9	10	MIP10T125	PIMO	6
10	MIP10T146	PIMO	38	10	MIP10T164	PIMO	14
10	MIP10T166	PIMO	15	10	MIP10T181	PIMO	36
10	MIP10T182	PIMO	15	10	MIP10T183	PIMO	7.5
10	MIP10T190	PIMO	15	10	MIP10T209	PIMO	17
10	MIP10T212	PIMO	5	10	MIP10T215	PIMO	14
10	MIP10T216	PIMO	9.5	10	MIP10T222	PIMO	7.5
10	MIP10T235	PIMO	25	10	MIP10T238	PIMO	20.5
10	MIP10T241	PIMO	23	10	MIP10T246	PIMO	11
10	MIP10T249	PIMO	11	10	MIP10T254	PIMO	6
10	MIP10T257	JUOS	21	10	MIP10T258	PIMO	28
10	MIP10T259	PIMO	13	10	MIP10T266	PIMO	21
10	MIP10T267	PIMO	33.5	10	MIP10T275	PIMO	11.5
10	MIP10T277	PIMO	23	10	MIP10T278	PIMO	25
10	MIP10T295	PIMO	7	10	MIP10T302	JUOS	15
10	MIP10T306	PIMO	9.5	11	MIP11T005	PIPO	7
11	MIP11T006	PIPO	47	11	MIP11T013	PIPO	10
11	MIP11T014	JUOS	8	11	MIP11T015	PIPO	42
11	MIP11T017	PIPO	31	11	MIP11T018	PIPO	10
11	MIP11T051	PIPO	27	11	MIP11T068	PIPO	38
11	MIP11T074	PIPO	22	11	MIP11T075	PIPO	40
11	MIP11T096	ABCO	10	11	MIP11T114	PIPO	27
11	MIP11T115	JUSC	6	11	MIP11T116	PIPO	13
11	MIP11T125	PIPO	35	11	MIP11T126	PIPO	30.5
11	MIP11T128	PIPO	48	11	MIP11T146	PIPO	38
11	MIP11T179	PIPO	41	11	MIP11T183	PIPO	12.5
11	MIP11T209	PIPO	36	11	MIP11T214	PIPO	57

11	MIP11T216	PIPO	36	11	MIP11T221	PIPO	37
11	MIP11T222	PIPO	30	11	MIP11T225	PIPO	39
11	MIP11T248	PIPO	17	11	MIP11T263	JUSC	11
11	MIP11T289	PIPO	42	11	MIP11T339	PIPO	26
12	MIP12T001	JUOS	15	12	MIP12T002	ABCO	24
12	MIP12T003	ABCO	42	12	MIP12T005	JUOS	60
12	MIP12T010	ABCO	44	12	MIP12T026	PIPO	49
12	MIP12T041	ABCO	56.4	12	MIP12T050	ABCO	37
12	MIP12T059	ABCO	30	12	MIP12T060	ABCO	36
12	MIP12T063	ABCO	5.5	12	MIP12T077	ABCO	65
12	MIP12T090	PIPO	34	12	MIP12T099	ABCO	16
12	MIP12T109	PIPO	75	12	MIP12T139	ABCO	35
12	MIP12T153	ABCO	25				

Table G-2: Same as Table G1, but for the Clover Mountains.

Plot #	Tree ID	Species	2008 DBH (cm)	Plot #	Tree ID	Species	2008 DBH (cm)
1	CLP01T002	PIMO	4.5	1	CLP01T011	PIMO	10
1	CLP01T012	PIMO	6	1	CLP01T013	PIMO	10
1	CLP01T028	PIMO	4	1	CLP01T031	PIMO	8
1	CLP01T035	PIPO	50	1	CLP01T044	PIMO	4
1	CLP01T047	PIMO	8	1	CLP01T059	PIPO	13
1	CLP01T074	PIMO	12	1	CLP01T076	PIMO	14
1	CLP01T077	PIMO	16	1	CLP01T105	PIMO	11
1	CLP01T108	PIMO	35	1	CLP01T113	PIMO	6.5
1	CLP01T114	PIMO	11.5	1	CLP01T116	PIMO	9
1	CLP01T117	PIMO	9	1	CLP01T126	PIMO	13
1	CLP01T149	PIMO	9.5	1	CLP01T151	PIMO	14.5
1	CLP01T161	PIMO	32	1	CLP01T174	PIMO	16.5
1	CLP01T178	PIMO	7.5	1	CLP01T180	PIMO	7
1	CLP01T197	PIMO	12.5	1	CLP01T206	PIMO	33
2	CLP02T005	PIMO	6	2	CLP02T006	PIMO	17
2	CLP02T008	PIMO	12	2	CLP02T010	PIMO	14
2	CLP02T011	PIMO	8	2	CLP02T013	PIMO	6
2	CLP02T019	PIMO	23	2	CLP02T025	PIMO	10.5
2	CLP02T033	PIMO	8.5	2	CLP02T034	PIMO	9
2	CLP02T038	PIMO	15	2	CLP02T039	PIMO	10
2	CLP02T040	PIMO	12	2	CLP02T043	PIMO	8.5
2	CLP02T048	PIMO	7.5	2	CLP02T054	PIMO	8
2	CLP02T055	PIMO	6	2	CLP02T057	PIMO	7.5
2	CLP02T063	PIMO	9.5	2	CLP02T065	PIMO	5
2	CLP02T070	PIMO	10	2	CLP02T073	PIMO	7
2	CLP02T075	PIMO	5	2	CLP02T094	PIMO	12.5
2	CLP02T095	PIMO	9.5	2	CLP02T096	PIMO	14.5
2	CLP02T100	PIMO	14.5	2	CLP02T101	PIMO	13.2
2	CLP02T103	PIMO	16.5	2	CLP02T104	PIMO	9

2	CLP02T106	PIMO	10	2	CLP02T107	PIMO	6
2	CLP02T109	PIMO	8.5	2	CLP02T110	PIMO	9.5
2	CLP02T113	PIMO	5	2	CLP02T116	PIMO	6
2	CLP02T125	PIMO	15.5	2	CLP02T131	PIMO	14.5
2	CLP02T138	PIMO	9	2	CLP02T139	PIMO	4
2	CLP02T142	PIMO	11.5	2	CLP02T147	PIMO	6
2	CLP02T151	PIMO	15	3	CLP03T001	PIPO	16.5
3	CLP03T002	PIPO	30	3	CLP03T003	PIPO	34
3	CLP03T004	PIPO	39	3	CLP03T005	PIPO	8
3	CLP03T011	PIPO	59	3	CLP03T012	PIPO	61
3	CLP03T013	PIPO	12	3	CLP03T014	PIPO	27
3	CLP03T015	PIPO	5.5	3	CLP03T016	PIPO	19
3	CLP03T021	PIPO	6.5	3	CLP03T022	PIPO	36
3	CLP03T023	PIPO	36	3	CLP03T024	PIPO	23
3	CLP03T025	PIPO	31	3	CLP03T026	PIPO	35
3	CLP03T028	PIPO	24	3	CLP03T030	PIPO	36
3	CLP03T031	PIPO	41.5	3	CLP03T032	PIPO	43
3	CLP03T033	PIPO	20	3	CLP03T034	PIPO	20
3	CLP03T036	PIPO	47	3	CLP03T037	PIPO	28.5
3	CLP03T038	PIPO	27	3	CLP03T039	PIPO	43
3	CLP03T040	PIPO	36	3	CLP03T041	PIPO	35
3	CLP03T042	PIPO	29.5	3	CLP03T043	PIPO	15.5
3	CLP03T044	PIPO	40	3	CLP03T045	PIPO	22
3	CLP03T046	PIPO	37	3	CLP03T049	PIPO	33
3	CLP03T050	PIPO	14	3	CLP03T051	PIPO	26
3	CLP03T052	PIPO	33.5	3	CLP03T053	PIPO	35
3	CLP03T054	PIPO	36	4	CLP04T005	PIMO	18
4	CLP04T006	PIMO	23	4	CLP04T007	PIMO	21
4	CLP04T016	PIMO	17.5	4	CLP04T020	PIMO	24.5
4	CLP04T021	PIMO	12	4	CLP04T026	PIMO	37
4	CLP04T034	PIMO	14.5	4	CLP04T037	PIMO	8
4	CLP04T043	PIMO	7	4	CLP04T045	PIMO	18
4	CLP04T053	PIMO	18	4	CLP04T054	PIMO	16
4	CLP04T055	PIPO	50	4	CLP04T064	PIMO	35
4	CLP04T074	PIMO	30	4	CLP04T075	PIMO	18
4	CLP04T086	PIMO	14	4	CLP04T087	PIMO	5
4	CLP04T093	PIMO	9	4	CLP04T099	PIMO	33
4	CLP04T100	PIMO	15	4	CLP04T107	PIMO	18
4	CLP04T124	PIMO	24	4	CLP04T128	PIMO	18
4	CLP04T153	PIMO	13	4	CLP04T157	PIMO	20
4	CLP04T160	PIMO	30	4	CLP04T161	PIMO	18
4	CLP04T162	PIMO	23	4	CLP04T166	PIMO	20
4	CLP04T170	PIMO	25	4	CLP04T181	PIPO	8
5	CLP05T001	PIMO	30	5	CLP05T035	PIMO	13.5
5	CLP05T047	PIMO	9	5	CLP05T054	PIMO	5
5	CLP05T059	PIMO	8.5	5	CLP05T081	PIMO	7
5	CLP05T088	PIMO	7	5	CLP05T089	PIMO	6

5	CLP05T118	PIMO	23.5	5	CLP05T152	PIMO	8
5	CLP05T157	PIMO	14	5	CLP05T162	PIMO	7.5
5	CLP05T191	PIMO	10	5	CLP05T200	PIMO	6
5	CLP05T205	PIMO	9	5	CLP05T206	PIMO	15
5	CLP05T212	PIMO	6	5	CLP05T217	PIMO	9
5	CLP05T224	PIMO	23	5	CLP05T251	PIMO	8
5	CLP05T253	PIMO	6	5	CLP05T255	PIMO	5
5	CLP05T257	PIMO	5	5	CLP05T259	PIMO	8
5	CLP05T281	PIMO	6	5	CLP05T286	PIMO	15
6	CLP06T007	PIPO	22.5	6	CLP06T012	PIPO	22
6	CLP06T025	PIPO	74	6	CLP06T036	PIMO	13.5
6	CLP06T061	PIPO	53	6	CLP06T089	PIMO	34
6	CLP06T090	PIMO	14	6	CLP06T092	PIPO	45
6	CLP06T117	PIPO	51.5	6	CLP06T146	PIPO	30
7	CLP07T002	PIMO	14	7	CLP07T003	JUOS	13
7	CLP07T007	PIMO	17	7	CLP07T009	PIMO	21.7
7	CLP07T037	PIMO	16.5	7	CLP07T038	PIMO	9.8
7	CLP07T046	PIMO	2	7	CLP07T048	PIMO	11.3
7	CLP07T049	PIMO	19	7	CLP07T059	PIMO	29.5
7	CLP07T062	PIMO	14.3	7	CLP07T063	PIMO	27
7	CLP07T065	PIMO	12.7	7	CLP07T073	PIMO	16
7	CLP07T079	PIMO	31	7	CLP07T080	PIMO	16
7	CLP07T093	PIMO	8	7	CLP07T094	PIMO	4
7	CLP07T097	PIMO	7	7	CLP07T100	PIMO	5
7	CLP07T102	PIMO	20	7	CLP07T105	PIMO	10
7	CLP07T107	PIMO	16	7	CLP07T109	PIMO	16
7	CLP07T110	PIMO	12	7	CLP07T114	PIMO	20
7	CLP07T118	PIMO	15	7	CLP07T125	PIMO	27
7	CLP07T128	PIMO	19	7	CLP07T134	PIMO	4
7	CLP07T137	PIMO	8	7	CLP07T140	PIMO	30
7	CLP07T149	PIMO	23	7	CLP07T150	PIMO	6
7	CLP07T151	PIMO	5	7	CLP07T178	PIMO	6
7	CLP07T183	PIMO	37	7	CLP07T204	PIMO	17
8	CLP08T002	PIMO	29.5	8	CLP08T007	PIMO	19.5
8	CLP08T008	PIMO	21	8	CLP08T009	PIMO	28
8	CLP08T010	PIMO	23	8	CLP08T011	PIMO	18
8	CLP08T012	PIMO	11.5	8	CLP08T013	PIMO	17
8	CLP08T016	PIMO	29	8	CLP08T020	PIMO	22
8	CLP08T027	PIMO	14	8	CLP08T028	PIMO	18
8	CLP08T029	PIMO	23	8	CLP08T031	PIMO	15.5
8	CLP08T032	PIMO	5	8	CLP08T037	PIMO	23
8	CLP08T038	PIMO	14	8	CLP08T041	PIMO	19
8	CLP08T044	PIMO	7	8	CLP08T046	PIMO	22
8	CLP08T054	PIMO	24	8	CLP08T055	PIMO	31
8	CLP08T060	PIMO	33.5	8	CLP08T063	PIMO	27.5
8	CLP08T070	PIMO	23	8	CLP08T074	PIMO	21
8	CLP08T075	PIMO	24	8	CLP08T077	PIMO	14

8	CLP08T083	PIMO	28.5	8	CLP08T090	PIMO	26.5
8	CLP08T095	PIMO	11	8	CLP08T102	PIMO	25.5
8	CLP08T103	PIMO	11	8	CLP08T106	PIMO	11
8	CLP08T108	PIMO	12	8	CLP08T109	PIMO	24.5
8	CLP08T111	PIMO	18	8	CLP08T112	PIMO	17
8	CLP08T114	PIMO	20	8	CLP08T115	PIMO	24.5
8	CLP08T117	PIMO	21.5	10	CLP10T005	PIPO	55
10	CLP10T012	PIPO	54	11	CLP11T005	PIPO	25
11	CLP11T006	PIPO	31	11	CLP11T009	PIPO	17
11	CLP11T010	PIPO	24	11	CLP11T011	PIPO	15
11	CLP11T012	PIPO	28	11	CLP11T014	PIPO	17
11	CLP11T016	PIPO	12	11	CLP11T020	PIPO	30
11	CLP11T022	PIPO	22	11	CLP11T023	PIPO	10.5
11	CLP11T024	PIPO	8	11	CLP11T026	PIPO	18
11	CLP11T027	PIPO	30	11	CLP11T029	PIPO	14
11	CLP11T030	PIPO	21	11	CLP11T031	PIPO	9
11	CLP11T032	PIPO	28	11	CLP11T033	PIPO	10
11	CLP11T034	PIPO	24	11	CLP11T036	PIPO	37
11	CLP11T037	PIPO	11	11	CLP11T038	PIPO	10.5
11	CLP11T039	PIPO	27	11	CLP11T040	PIPO	31
11	CLP11T042	PIPO	12	11	CLP11T043	PIPO	19
11	CLP11T044	PIPO	13	11	CLP11T045	PIPO	27
11	CLP11T048	PIPO	27	11	CLP11T049	PIPO	11
11	CLP11T052	PIPO	35	11	CLP11T056	PIPO	10
11	CLP11T058	PIPO	37	11	CLP11T061	PIPO	25
11	CLP11T064	PIPO	31	11	CLP11T066	PIPO	36
11	CLP11T070	PIPO	32	11	CLP11T072	PIPO	17
11	CLP11T074	PIPO	27	11	CLP11T079	PIPO	32
11	CLP11T086	PIPO	78	11	CLP11T088	PIPO	23.5
11	CLP11T090	PIPO	11	11	CLP11T091	PIPO	8
11	CLP11T093	PIPO	12	11	CLP11T094	PIPO	25
11	CLP11T095	PIPO	13.5	11	CLP11T096	PIPO	13
11	CLP11T097	PIPO	9.5	11	CLP11T099	PIPO	20.5
11	CLP11T102	PIPO	9	11	CLP11T104	PIPO	12.5
11	CLP11T105	PIPO	17.5	11	CLP11T106	PIPO	27
11	CLP11T108	PIPO	12	11	CLP11T109	PIPO	28.5
11	CLP11T111	PIPO	16	11	CLP11T112	PIPO	13
11	CLP11T113	PIPO	26.5	11	CLP11T114	PIPO	21
11	CLP11T118	PIPO	9	11	CLP11T119	PIPO	22
11	CLP11T121	PIPO	14	11	CLP11T124	PIPO	19
11	CLP11T126	PIPO	31	11	CLP11T127	PIPO	20
11	CLP11T128	PIPO	29	11	CLP11T129	PIPO	24
11	CLP11T130	PIPO	32	11	CLP11T131	PIPO	49
12	CLP12T001	PIPO	66	12	CLP12T003	PIPO	41
12	CLP12T004	PIPO	40	12	CLP12T005	PIPO	32
12	CLP12T007	PIPO	26	12	CLP12T008	PIPO	35
12	CLP12T009	PIPO	42	12	CLP12T010	PIPO	28

12	CLP12T014	PIPO	27	12	CLP12T015	PIPO	17
12	CLP12T016	PIPO	29.5	12	CLP12T017	PIPO	24
12	CLP12T018	PIPO	26	12	CLP12T019	PIPO	14.5
12	CLP12T020	PIPO	21	12	CLP12T021	PIPO	29.5
12	CLP12T022	PIPO	29	12	CLP12T024	PIPO	30
12	CLP12T029	PIMO	25	12	CLP12T033	PIPO	61

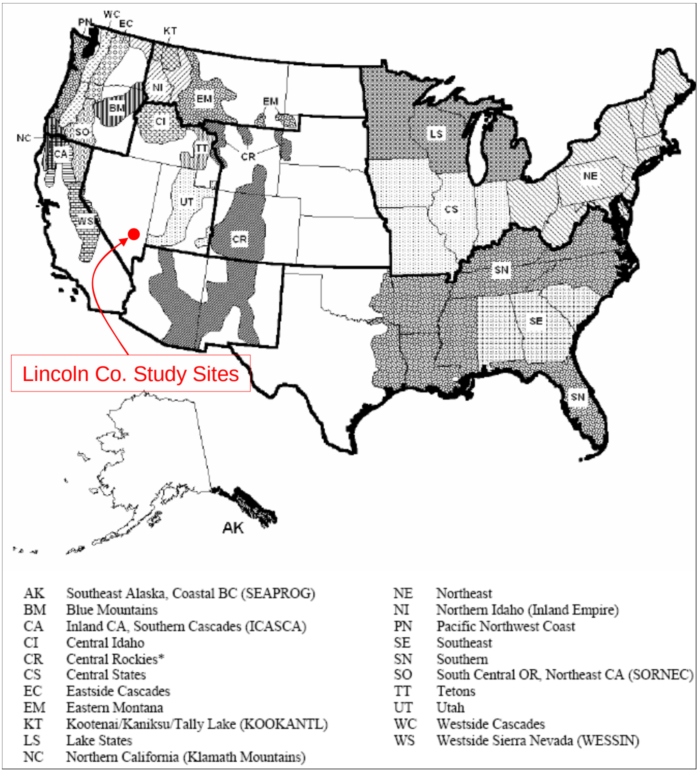
Table G-3: List of trees which historic DBH values were estimated through local species-specific relationships between known DBH values and breast ages of individual trees at Mount Irish.

Plot #	Tree ID	Species	2007 DBH (cm)	Plot #	Tree ID	Species	2007 DBH (cm)
1	MIP01T213	JUOS	60	1	MIP01T069	PIMO	36.5
1	MIP01T064	JUOS	27	1	MIP01T234	ABCO	12
1	MIP01T028	PIMO	4	1	MIP01T090	ABCO	3.5
2	MIP02T092	PIMO	31	2	MIP02T002	JUOS	24
2	MIP02T138	JUOS	14	3	MIP03T102	PIPO	65.5
3	MIP03T095	ABCO	38	3	MIP03T028	PIMO	31
3	MIP03T031	PIMO	27	3	MIP03T050	ABCO	23
3	MIP03T032	JUSC	13	4	MIP04T014	JUOS	45
4	MIP04T051	JUOS	30	4	MIP04T078	JUOS	30
4	MIP04T085	JUOS	28	4	MIP04T110	JUOS	20
4	MIP04T058	PIMO	4	5	MIP05T122	PIMO	12
5	MIP05T004	JUOS	11	5	MIP05T153	PIMO	6
5	MIP05T117	PIMO	5.5	6	MIP06T030	PIMO	37
6	MIP06T073	JUOS	31.5	6	MIP06T001	JUOS	27
6	MIP06T057	PIMO	24	6	MIP06T135	JUOS	20.5
6	MIP06T126	JUOS	16	6	MIP06T110	JUOS	14.5
6	MIP06T122	PIMO	10	7	MIP07T104	PIMO	40
7	MIP07T205	JUOS	26	7	MIP07T219	JUOS	17
7	MIP07T138	PIMO	13	7	MIP07T201	PIMO	12
7	MIP07T013	JUOS	11	7	MIP07T040	JUOS	9
7	MIP07T232	PIMO	7	7	MIP07T042	PIMO	4
8	MIP08T173	PIMO	24.5	8	MIP08T019	PIMO	15
9	MIP09T054	PIPO	54	9	MIP09T001	JUOS	25
10	MIP10T196	PIMO	18	10	MIP10T149	PIMO	16
10	MIP10T030	PIMO	9	10	MIP10T207	PIMO	7
10	MIP10T184	PIMO	6	10	MIP10T186	PIMO	6
10	MIP10T032	PIMO	4	10	MIP10T211	PIMO	4
10	MIP10T041	PIMO	3.5	10	MIP10T042	PIMO	3
10	MIP10T043	PIMO	2	10	MIP10T074	PIMO	2
11	MIP11T149	PIPO	41	11	MIP11T236	PIPO	40
11	MIP11T262	PIPO	32	12	MIP12T104	PIPO	18
12	MIP12T043	ABCO	15	12	MIP12T102	ABCO	4
12	MIP12T101	ABCO	2.5				

Table G-4: Same as Table G3, but for the Clover Mountains.

Plot #	Tree ID	Species	2008 DBH (cm)	Plot #	Tree ID	Species	2008 DBH (cm)
1	CLP01T045	PIMO	3	1	CLP01T046	PIMO	2.5
1	CLP01T049	PIMO	3	1	CLP01T050	PIMO	4
1	CLP01T057	PIMO	3	1	CLP01T060	PIMO	4
1	CLP01T061	PIMO	4	1	CLP01T130	PIMO	5
1	CLP01T158	PIMO	11.5	1	CLP01T195	PIMO	43.5
1	CLP01T201	PIMO	4	2	CLP02T003	PIMO	4
2	CLP02T007	PIMO	4	2	CLP02T018	PIMO	3
2	CLP02T024	PIMO	5	2	CLP02T031	PIMO	4
2	CLP02T091	PIMO	4	2	CLP02T099	PIMO	4
2	CLP02T124	PIMO	5.5	2	CLP02T153	PIMO	3.5
2	CLP02T181	PIMO	3.5	3	CLP03T029	PIPO	4.5
3	CLP03T035	PIPO	4	4	CLP04T015	PIMO	25
4	CLP04T032	PIMO	22	4	CLP04T042	PIMO	14
4	CLP04T052	PIMO	6.5	4	CLP04T065	PIMO	3
4	CLP04T067	PIMO	4.5	4	CLP04T088	PIMO	3
4	CLP04T092	PIMO	4.5	4	CLP04T097	PIMO	8
4	CLP04T119	PIMO	34	4	CLP04T142	PIMO	17
4	CLP04T144	PIMO	4	4	CLP04T183	PIMO	24.5
5	CLP05T136	PIMO	4.5	5	CLP05T165	PIMO	6
5	CLP05T213	PIMO	5	5	CLP05T214	PIMO	21
7	CLP07T035	PIMO	24.2	7	CLP07T077	PIMO	10
7	CLP07T113	PIMO	3	7	CLP07T132	PIMO	19
8	CLP08T036	PIMO	20.5	8	CLP08T051	PIMO	4
8	CLP08T079	PIMO	8	8	CLP08T100	PIMO	4.5
10	CLP10T007	PIPO	70.5	11	CLP11T001	PIPO	5
11	CLP11T013	PIPO	7	11	CLP11T019	PIPO	9
11	CLP11T080	PIPO	32	11	CLP11T110	PIPO	5
12	CLP12T025	PIMO	32				

Figure G-1: Forest Vegetation Simulator (FVS) geographic variants. As depicted, a variant does no exist for the Great Basin. Therefore, the Utah variant was used in FVS because of its close similarities in vegetation and climate to the Great Basin.



AK	Southeast Alaska, Coastal BC (SEAPROG)	NE	Northeast
BM	Blue Mountains	NI	Northern Idaho (Inland Empire)
CA	Inland CA, Southern Cascades (ICASCA)	PN	Pacific Northwest Coast
CI	Central Idaho	SE	Southeast
CR	Central Rockies*	SN	Southern
CS	Central States	SO	South Central OR, Northeast CA (SORNEC)
EC	Eastside Cascades	TT	Tetons
EM	Eastern Montana	UT	Utah
KT	Kootenai/Kaniksu/Tally Lake (KOOKANTL)	WC	Westside Cascades
LS	Lake States	WS	Westside Sierra Nevada (WESSIN)
NC	Northern California (Klamath Mountains)		

Table G-5: Fuel moisture and max temperature for Las Vegas, Tonopah weather station (KBJN, 1976-2000) located approximately 72 km west of Mount Irish. The percentiles are shown for the months of July and August (7-day analysis periods), the months showing the most severe fire weather. The “1-Hr”, “10-Hr”, and “100-Hr” refer to 1-Hr, 10-Hr, and 100-Hr timelag fuels. These percentiles were manually entered into the Fire and Fuels Extension to FVS for the Mount Irish simulations.

MOUNT IRISH		
Variable	**July-August 90th percentile**	**July-August 97th percentile**
1-Hr moisture (%)	1.93	1.47
10-Hr moisture (%)	3.00	2.00
100-Hr moisture (%)	3.97	3.32
Temperature (˚C)	34.40	36.66

Table G-6: Same as Table G5, but for the Clover Mountains simulation. Weather data is for the Kane Springs weather station (KNSN2, 1986-2008) located approximately 32 km southwest of Elly Mountain within the Clover Mountains.

CLOVER MOUNTAINS		
Variable	**July-August 90th percentile**	**July-August 97th percentile**
1-Hr moisture (%)	1.33	0.83
10-Hr moisture (%)	1.59	1.04
100-Hr moisture (%)	2.47	1.70
Temperature (˚C)	38.33	40.00

Figure G-2: Relationship between pinyon pine breast age and DBH at Mount Irish. Relationship was used to reconstruct historical DBH values for trees without measureable increment cores.

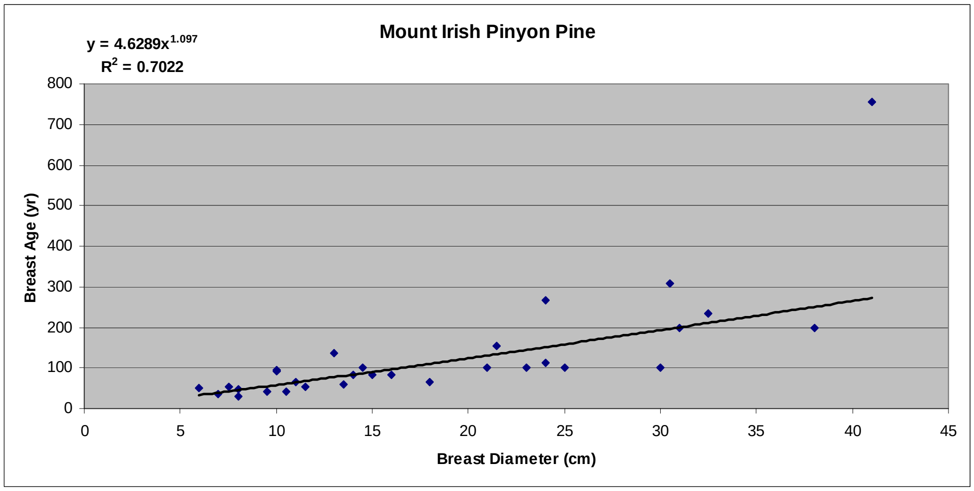


Figure G-3: Relationship between ponderosa pine breast age and DBH at Mount Irish. Relationship was used to reconstruct historical DBH value for trees without measureable increment cores.

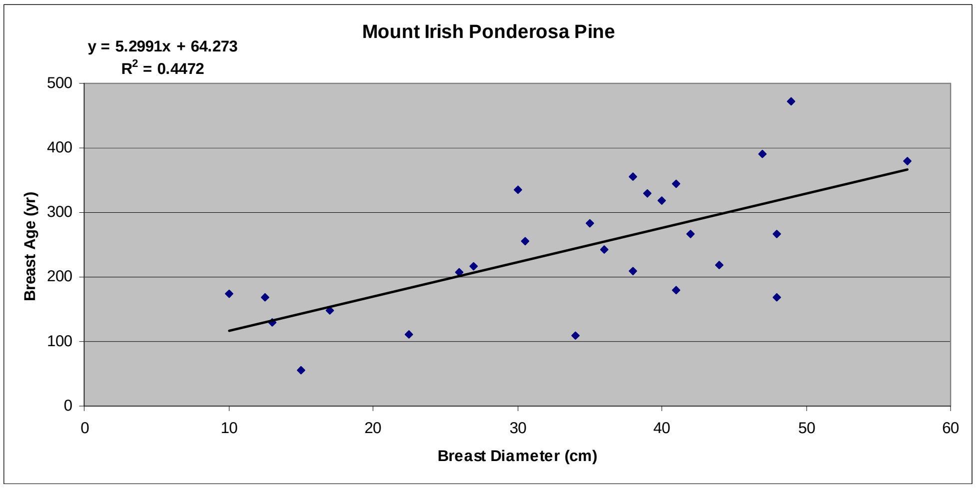


Figure G-4: Relationship between white fir breast age and DBH at Mount Irish. Relationship was used to reconstruct historical DBH value for trees without measureable increment cores.

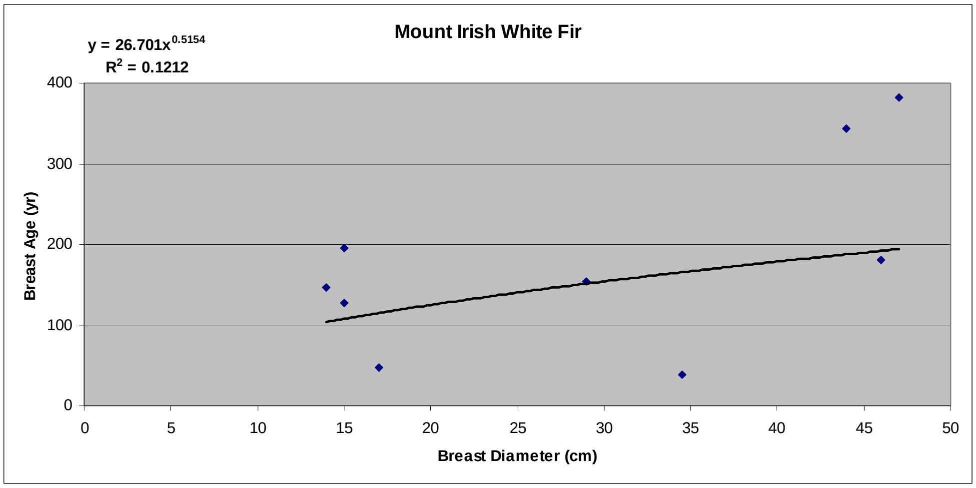


Figure G-5: Relationship between juniper specie breast age and DBH at Mount Irish. Relationship was used to reconstruct historical DBH value for trees without measureable increment cores.

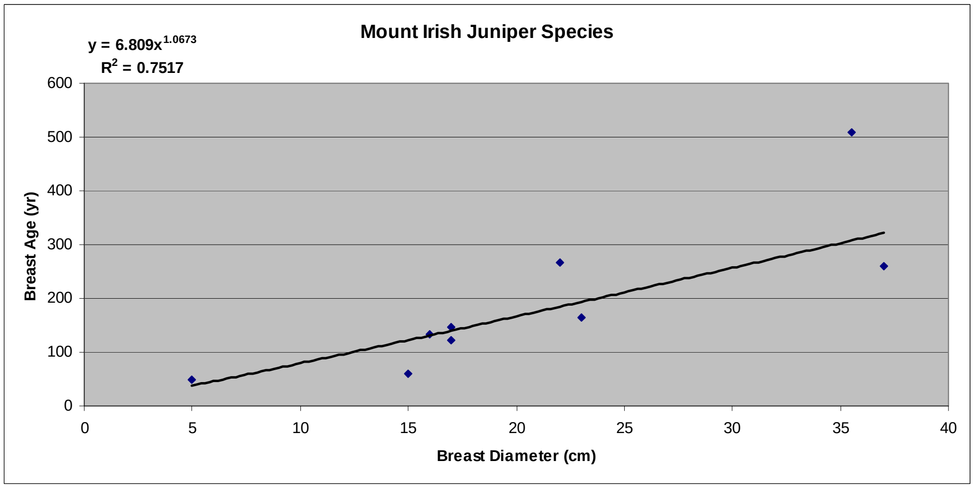


Figure G-6: Same as Figure G2, but for the Clover Mountains.

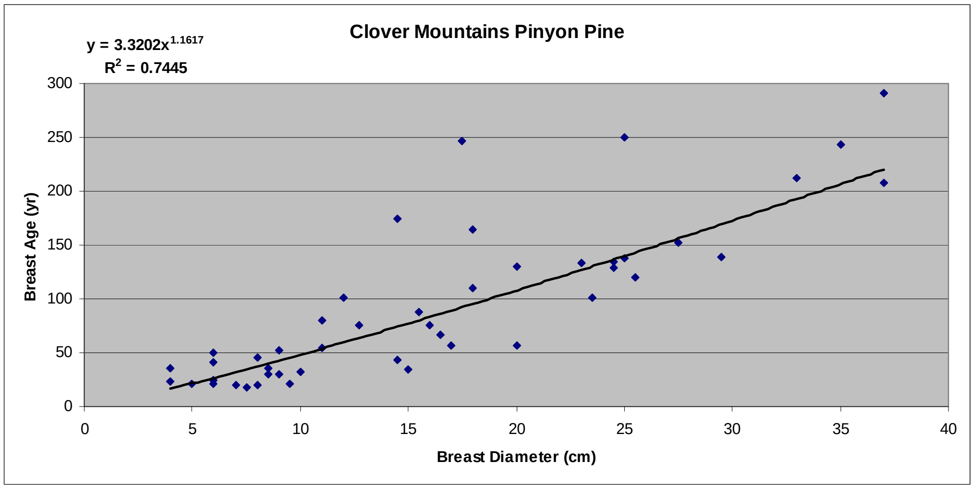


Figure G-7: Same as Figure G3, but for the Clover Mountains.

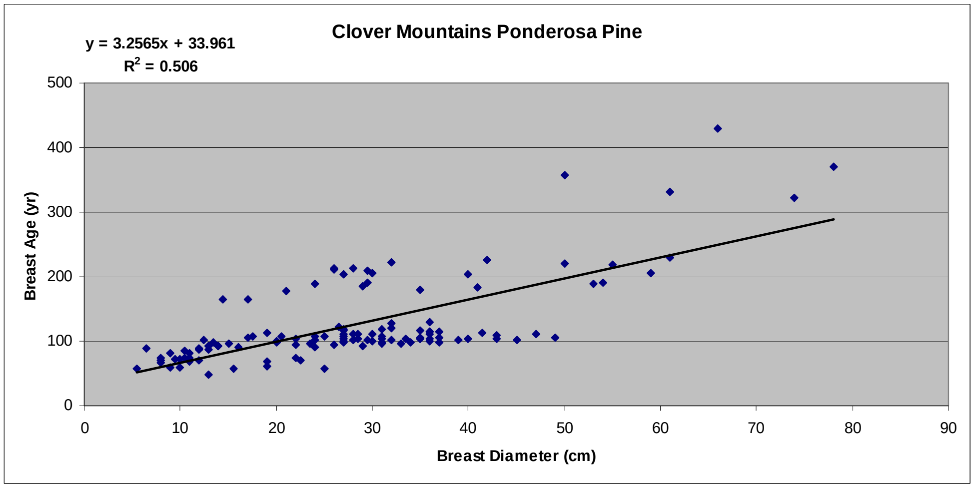


Table G-7: List of trees at Mount Irish and the Clover Mountains with establishment dates derived from local species-specific relationships between known current base diameters and base ages of individual trees.

MOUNT IRISH				CLOVER MOUNTAINS			
Plot #	Tree ID	Species	Base Age	Plot #	Tree ID	Species	Base Age
1	MIP01T028	PIMO	1928	1	CLP01T130	PIMO	1940
1	MIP01T064	JUOS	1662	1	CLP01T201	PIMO	1959
1	MIP01T234	ABCO	1896	4	CLP04T015	PIMO	1873
2	MIP02T002	JUOS	1805	4	CLP04T032	PIMO	1854
2	MIP02T092	PIMO	1760	4	CLP04T042	PIMO	1910
2	MIP02T138	JUOS	1843	4	CLP04T092	PIMO	1945
3	MIP03T032	JUSC	1674	4	CLP04T119	PIMO	1816
3	MIP03T095	ABCO	1820	4	CLP04T142	PIMO	1854
4	MIP04T051	JUOS	1683	4	CLP04T183	PIMO	1867
4	MIP04T078	JUOS	1578	7	CLP07T113	PIMO	1978
4	MIP04T085	JUOS	1825				
4	MIP04T110	JUOS	1705				
6	MIP06T001	JUOS	1813				
6	MIP06T030	PIMO	1782				
6	MIP06T057	PIMO	1816				
6	MIP06T073	JUOS	1745				
6	MIP06T122	PIMO	1869				
6	MIP06T126	JUOS	1834				
7	MIP07T201	PIMO	1869				
9	MIP09T001	JUOS	1843				
10	MIP10T207	PIMO	1910				
11	MIP11T149	PIPO	1697				

Figure G-8: Relationship between pinyon pine base age and base diameter at Mount Irish. Relationship was used to estimate establishment dates for trees without measureable base cores.

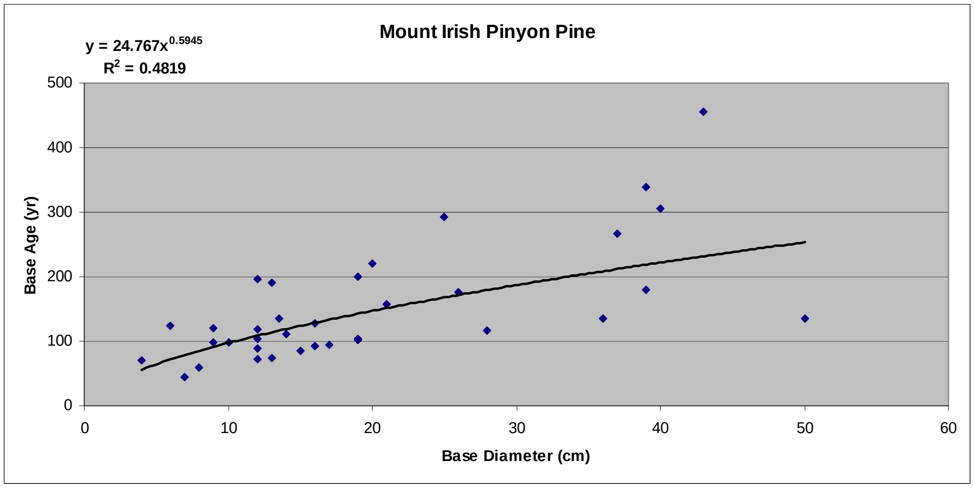


Figure G-9: Relationship between ponderosa pine base age and base diameter at Mount Irish. Relationship was used to estimate establishment dates for trees without measureable base cores.

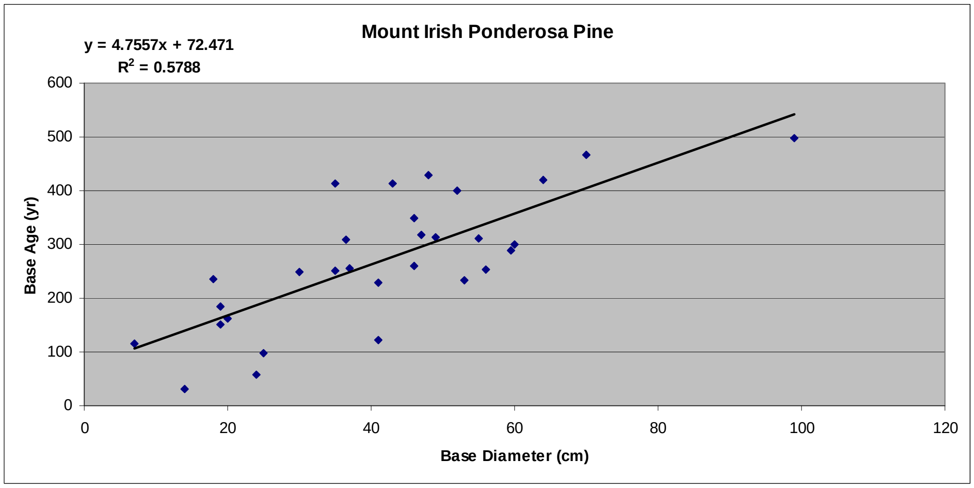


Figure G-10: Relationship between white fir base age and base diameter at Mount Irish. Relationship was used to estimate establishment dates for trees without measureable base cores.

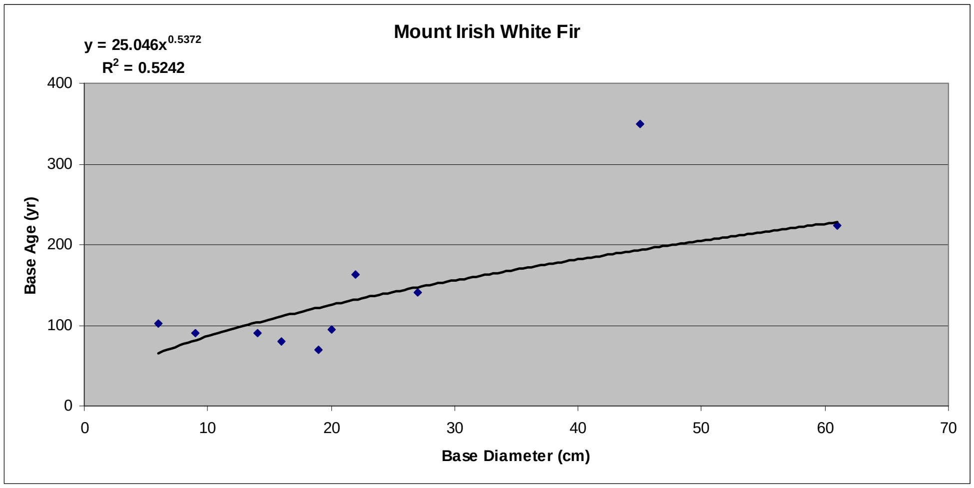


Figure G-11: Relationship between juniper species base age and base diameter at Mount Irish. Relationship was used to estimate establishment dates for trees without measureable base cores.

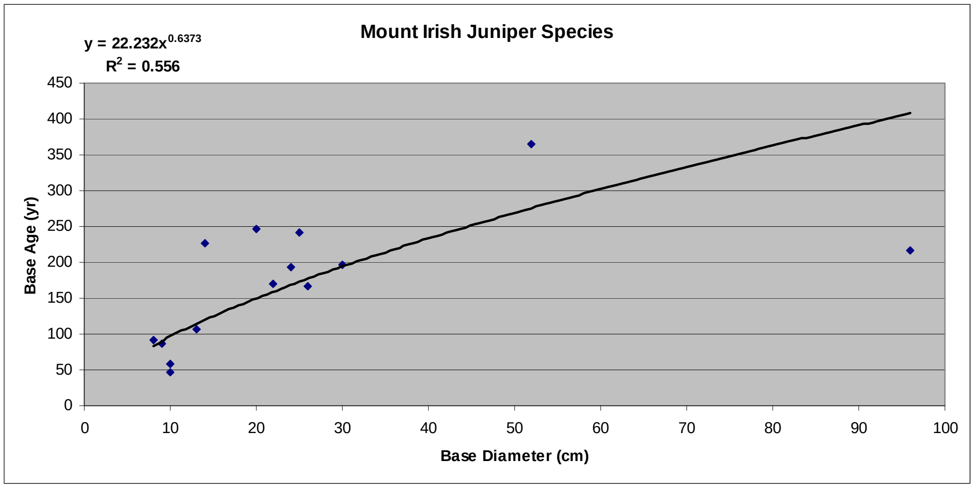


Figure G-12: Same as Figure G8, but for the Clover Mountains.

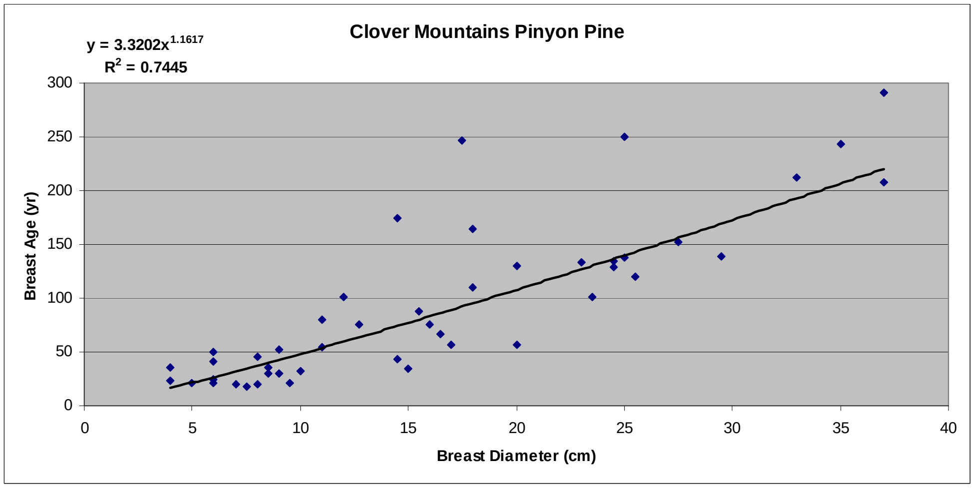


Figure G-13: Same as Figure G9, but for the Clover Mountains.

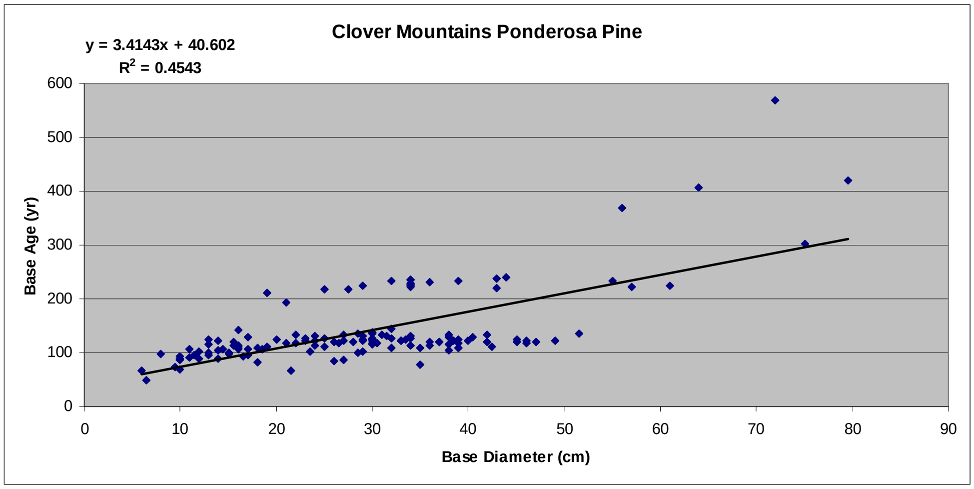


Table G-8: Establishment per species per decade for trees that do not pre-date 1850 at Mount Irish. Regeneration densities in FVS were increased by 40% to account for density-dependent mortality.

MI Regeneration by species per decade														
Sp.	**1850-1859**	**40%**	**1860-1869**	**40%**	**1870-1879**	**40%**	**1880-1889**	**40%**	**1890-1899**	**40%**	**1900-1909**	**40%**	**1910-1919**	**40%**
ABCO	0.0	0.0	1.0	0.4	3.0	1.2	1.0	0.4	2.0	0.8	2.0	0.8	2.0	0.8
Jusp	5.0	2.0	3.0	1.2	1.0	0.4	1.0	0.4	0.0	0.0	2.0	0.8	3.0	1.2
PIMO	6.0	2.4	11.0	4.4	12.0	4.8	11.0	4.4	10.0	4.0	20.0	8.0	21.0	8.4
PIPO	1.0	0.4	0.0	0.0	1.0	0.4	1.0	0.4	1.0	0.4	0.0	0.0	1.0	0.4
	1920-1929	**40%**	**1930-1939**	**40%**	**1940-1949**	**40%**	**1950-1959**	**40%**	**1960-1969**	**40%**	**1970-1979**	**40%**		
ABCO	1.0	0.4	2.0	0.8	1.0	0.4	0.0	0.0	0.0	0.0	1.0	0.4		
Jusp	0.0	0.0	1.0	0.4	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0		
PIMO	17.0	6.8	10.0	4.0	5.0	2.0	5.0	2.0	6.0	2.4	1.0	0.4		
PIPO	0.0	0.0	1.0	0.4	0.0	0.0	1.0	0.4	0.0	0.0	1.0	0.4		

Table G-9: Establishment dates per species per decade for trees that do not pre-date 1900 at the Clover Mountains. Regeneration densities in FVS were increase by 50% to account for density-dependent mortality.

CL Regeneration by species per decade								
Sp	**1900-1909**	**50%**	**1910-1919**	**50%**	**1920-1929**	**50%**	**1930-1939**	**50%**
PIMO	11.0	5.5	13.0	6.5	14.0	7.0	23.0	11.5
PIPO	16.0	8.0	10.0	5.0	5.0	2.5	4.0	2.0
JUOS	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.5
	1940-1949	**50%**	**1950-1959**	**50%**	**1960-1969**	**50%**	**1970-1979**	**50%**
PIMO	24.0	12.0	22.0	11.0	25.0	12.5	6.0	3.0
PIPO	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
JUOS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table G-10: Comparison between FVS simulation values and field data for tree density (trees per hectare) and basal area (m^2 per hectare) at Mount Irish (2007) and the Clover Mountains (2008). Simulation values for density and basal area are within 31% of field data at Mount Irish and within 20% at the Clover Mountains.

	Density (trees/ha)	**Basal Area (m^2/ha)**
MI 2007		
FVS Simulation	205	20.43
Field Data	299	14.46
±%	31	29
CL 2008		
FVS Simulation	269	16.99
Field Data	338	13.77
±%	20	19

Table G-11: Crowning Index (CI) values and percent decrease from decade to decade at Mount Irish (1850-2050) and the Clover Mountains (1900-2050). CI at Mount Irish in 2007 was 74.95 km/hr and at the Clover Mountains in 2008 was 66.70 km/hr.

Year	**Crowning Index (km/hr)**		**Percent Decrease**	
	Mount Irish	**Clover Mountains**	**Mount Irish**	**Clover Mountains**
1850	120.3	-	-	-
1860	117.5	-	2.34	-
1870	114.0	-	3.01	-
1880	112.0	-	1.71	-
1890	109.0	-	2.68	-
1900	106.1	127.2	2.71	-
1910	102.8	117.2	3.10	7.84
1920	101.0	108.6	1.79	7.35
1930	98.2	95.5	2.68	12.12
1940	96.0	85.6	2.32	10.30
1950	94.9	78.0	1.10	8.85
1960	93.1	73.8	1.90	5.44
1970	91.5	70.3	1.70	4.73
1980	83.9	68.6	8.33	2.40
1990	79.0	67.2	5.81	2.15
2000	74.9	66.7	5.17	0.67
2010	65.8	66.7	12.21	0.07
2020	63.7	65.4	3.24	1.88
2030	62.8	60.9	1.31	6.82
2040	62.9	53.2	-0.06	12.66
2050	63.0	51.3	-0.14	3.63

Figure G-14: FVS simulation outputs for crowning index and canopy bulk density values at Mount Irish (1850-2050). The graph shows that there is an inverse relationship between the two variables.

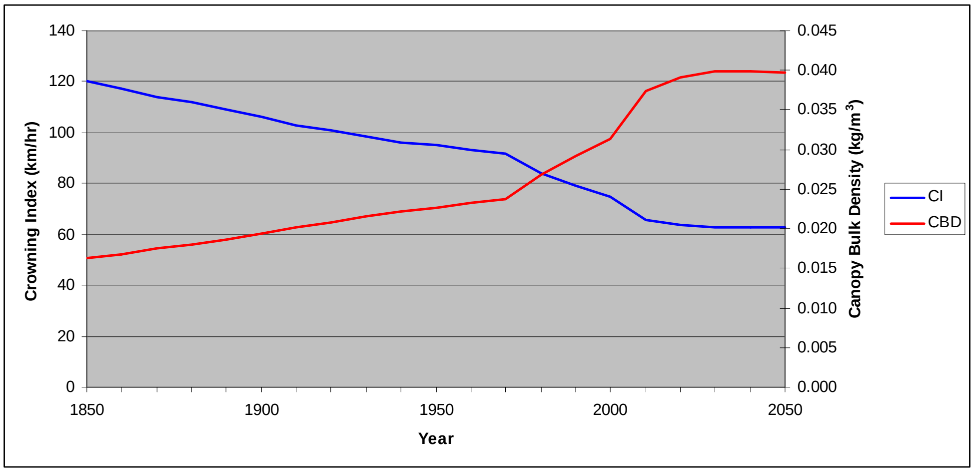


Figure G-15: Same as Figure G14, but for the Clover Mountains (1900-2050).

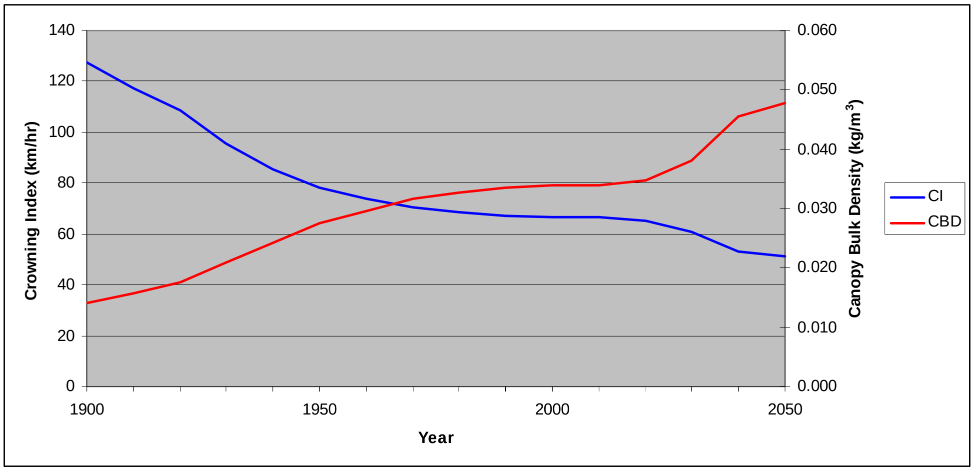


Table G-12: Changes in crowning index (CI), canopy bulk density (CBD), and biomass of total surface fuel (TSF), crown foliage (CF), crown 1-Hr size class (C 1-Hr), crown foliage plus half crown 1-Hr size class (CF &Half 1-Hr), total standing live and dead (TS L&D), total crown and surface biomass (TB C&S) at Mount Irish, 1850-2050.

Year	CI (km/hr)	TSF (kg/m^2)	CF (kg/m^2)	C 1-Hr (kg/m^2)	CF & Half 1-Hr (kg/m^2)	TS L&D (kg/m^2)	TB C&S (kg/m^2)	CBD (kg/m^3)
1850	120	0.698	0.167	0.425	0.380	1.569	2.242	0.0162
1860	118	0.749	0.181	0.469	0.416	1.793	2.466	0.0168
1870	114	0.792	0.197	0.519	0.457	2.018	2.914	0.0175
1880	112	0.833	0.212	0.565	0.495	2.242	3.138	0.0179
1890	109	0.880	0.229	0.618	0.538	2.466	3.363	0.0186
1900	106	0.928	0.246	0.671	0.582	2.690	3.587	0.0194
1910	103	0.981	0.264	0.729	0.629	2.914	4.035	0.0202
1920	101	1.038	0.282	0.783	0.673	3.138	4.259	0.0208
1930	98	1.102	0.301	0.842	0.722	3.587	4.708	0.0216
1940	96	1.165	0.321	0.901	0.771	3.811	4.932	0.0223
1950	95	1.231	0.338	0.955	0.816	4.035	5.380	0.0226
1960	93	1.305	0.359	1.018	0.868	4.483	5.828	0.0232
1970	92	1.595	0.375	1.071	0.911	4.932	6.501	0.0238
1980	84	1.661	0.394	1.132	0.960	5.156	6.949	0.0268
1990	79	1.726	0.408	1.187	1.001	5.604	7.398	0.0291
2000	75	1.802	0.421	1.234	1.038	5.828	7.846	0.0313
2010	66	1.872	0.428	1.268	1.062	6.277	8.070	0.0374
2020	64	1.948	0.438	1.313	1.095	6.501	8.518	0.0392
2030	63	2.020	0.448	1.360	1.128	6.949	8.967	0.0399
2040	63	2.095	0.450	1.386	1.143	7.173	9.415	0.0398
2050	63	2.196	0.455	1.432	1.171	7.622	9.639	0.0398

Table G-13: Same as Table G12, but for the Clover Mountains, 1900-2050.

Year	CI (km/hr)	TSF (kg/m^2)	CF (kg/m^2)	C 1-Hr (kg/m^2)	CF & Half 1-Hr (kg/m^2)	TS L&D (kg/m^2)	TB C&S (kg/m^2)	CBD (kg/m^3)
1900	127	0.694	0.140	0.388	0.335	1.345	2.018	0.0141
1910	117	0.734	0.159	0.442	0.380	1.569	2.242	0.0158
1920	109	0.784	0.182	0.511	0.438	1.793	2.690	0.0175
1930	95	0.836	0.213	0.591	0.509	2.018	2.914	0.0209
1940	86	0.905	0.247	0.678	0.586	2.466	3.363	0.0242
1950	78	0.992	0.286	0.781	0.676	2.690	3.811	0.0275
1960	74	1.085	0.322	0.883	0.764	3.138	4.259	0.0296
1970	70	1.195	0.363	1.001	0.864	3.587	4.932	0.0316
1980	69	1.309	0.399	1.115	0.957	4.035	5.380	0.0326
1990	67	1.439	0.438	1.241	1.058	4.708	6.053	0.0336
2000	67	1.566	0.467	1.353	1.144	5.156	6.725	0.0339
2010	67	1.709	0.493	1.459	1.223	5.828	7.398	0.0339
2020	65	1.850	0.523	1.579	1.313	6.277	8.294	0.0348
2030	61	1.984	0.541	1.676	1.379	6.949	8.967	0.0382
2040	53	2.133	0.554	1.764	1.436	7.398	9.639	0.0455
2050	51	2.300	0.574	1.889	1.519	8.070	10.312	0.0477

Figure G-16: Changes in crowning index (CI) and biomass of crown foliage (CF), crown 1-Hr fuel size class (C 1-Hr), and crown foliage plus half of crown 1-Hr fuel size class (CF & ½ 1-Hr) at Mount Irish, 1850-2050.

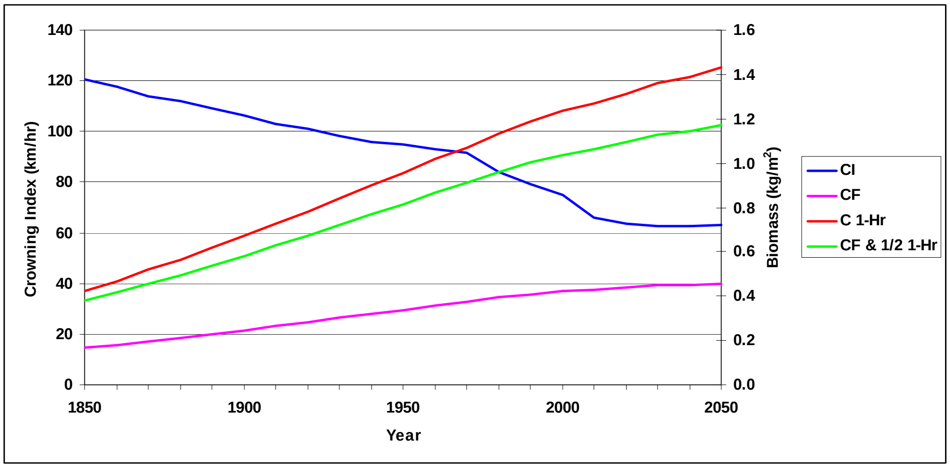


Figure G-17: Same as Figure G16, but for the Clover Mountains, 1900-2050.

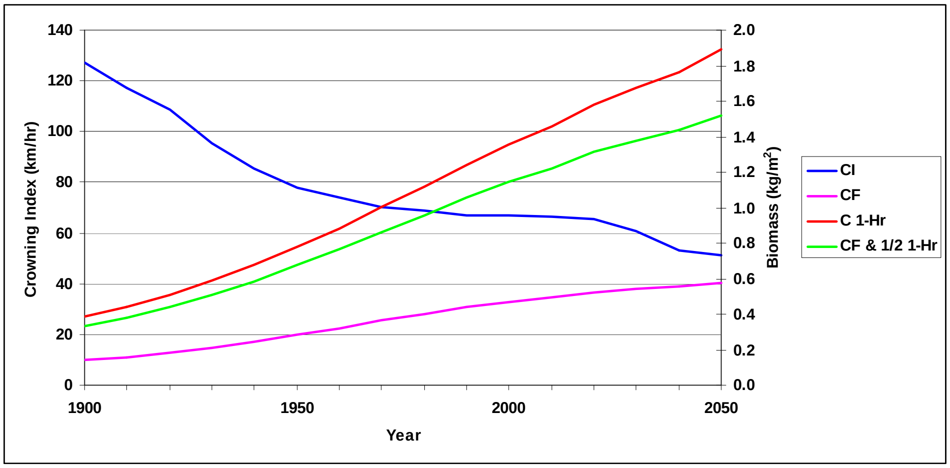


Figure G-18: Changes in crowning index (CI) and biomass of total standing live and dead (TS L&D), total surface (TSF), and total biomass of crown and surface (TB C&S) at Mount Irish, 1850-1900.

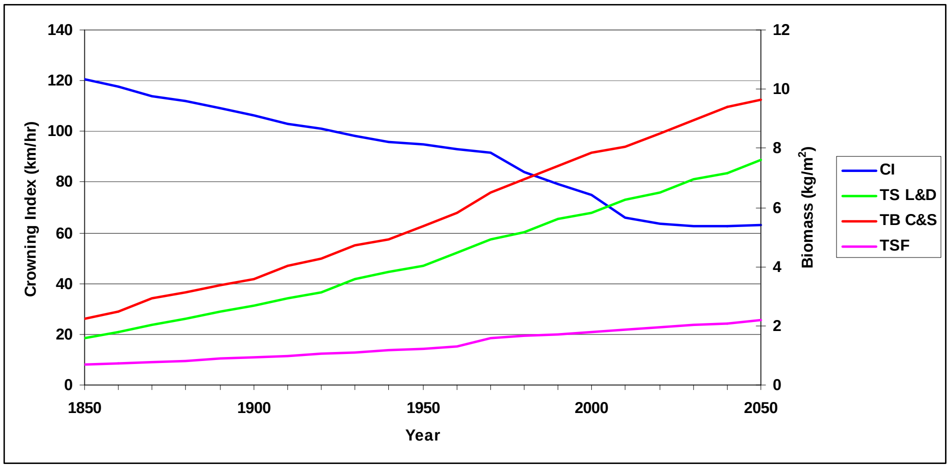


Figure G-19: Same as Figure G18, but for the Clover Mountains, 1900-2050.

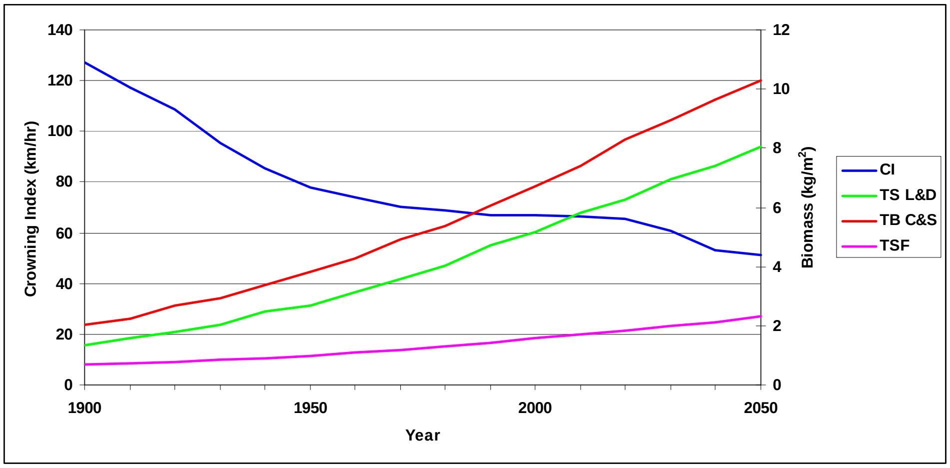


Table G-14: Percent change in crowning index (CI) and biomass of crown foliage (CF), crown 1-Hr fuel size class (C 1-Hr), crown foliage plus half of crown 1-Hr fuel size class (CF & Half 1-Hr), total standing live and dead (TS L&D), total surface (TSF), and total biomass of crown and surface (TB C&S) at Mount Irish, 1850-2050 and 1900-2050, and the Clover Mountains (1900-2050).

Study Site	CI (km/hr)	TSF (kg/m^2)	CF (kg/m^2)	C 1-Hr (kg/m^2)	CF & Half 1-Hr (kg/m^2)	TS L&D (kg/m^2)	TB C&S (kg/m^2)
MI (1850-2050)	-45.7	68.2	63.2	70.3	67.6	79.4	76.7
MI (1900-2050)	-40.6	57.7	45.9	53.1	50.3	64.7	62.8
CL (1900-2050)	-59.8	69.8	75.5	79.4	78.0	83.3	80.4