BIOENERGY AND WATERSHED RESTORATION IN THE MOUNTAINOUS REGIONS OF THE WEST: WHAT ARE THE ENVIRONMENTAL/COMMUNITY ISSUES?

R. L. Graham[1], D. D. Huff[1], M. R. Kaufmann[2],
W. D. Shepperd[2], and J. Sheehan[3]

ABSTRACT

Throughout the western mountainous regions, wildfire risks are elevated due to both fire suppression activities which have changed the forest structure making it more susceptible to stand-killing fires and the expansion of human structures (houses, light commercial) into these same forests. By providing a market for currently noncommercial but flammable materials (small trees, tops, and branches), new and existing bioenergy industries could be a key factor in reducing the regional forest fuel loads. Although bioenergy would appear to be an ideal answer to the problem in many ways, the situation is complicated and numerous issues need resolution. A public fearful of logging in these regions needs assurance that harvesting for bioenergy is an environmentally and socially responsible solution to the current fuel build up in these forests. This is especially important given that biomass harvesting cannot pay its own way under current energy market conditions and would have to be supported in some fashion.

This paper outlines options for controlling wildfire risk and the environmental and social issues that need to be addressed before the public can intelligently evaluate the role of biomass harvesting in fire reduction solutions. In particular biomass harvesting could have significant effects on the nutrient cycling regimes of these stands and the hydrology of these forested watersheds. Given the importance of water in the dry West, the latter is of special significance. Unfortunately, there is a paucity of information on either of these topics.

Keywords: fuels, fire management, watershed restoration, biomass energy, community, sustainability, environment

[1]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6335; [2]USFS Rocky Mountain Research Station, Ft. Collins, CO 80526; [3]Plumas Corporation, Quincy, CA 95971

INTRODUCTION

Across the western dry mountainous regions there is increasing recognition of the fire risks posed by current forest conditions of continuous canopy coverage, deep tree crowns, and substantial quantities of dead branches and trees (Sampson, 1997). These risks are exacerbated by the influx of homes and businesses into forested areas which not only increase the probability of fires igniting, but also the losses when fires do occur.

The current conditions are generally believed to be artifacts of historic management (fire suppression and logging that stimulated regeneration) and that prior to European settlement these forests were more varied, open, and dominated by fire-resistant tree species and subject to mild but comparatively frequent fires. However, in some regions of the west, there is considerable uncertainty as to pre-European settlement conditions and the role of Native Americans in creating forest structure. Surveyor notes and historic photos suggest more open forest conditions across much of the central Rockies and the Sierra Nevada but historic photos may be biased as open stands would have been more readily photographed than dense stands. Historic fire return intervals across the region vary considerably - from 3 to 60 years depending on forest type and location. Nonetheless, there is general agreement that current forest conditions are undesirable and more fire resilient forests are needed.

There are basically three options for managing current forest flammability at the stand level - do nothing to reduce fuel loads but rely on an aggressive fire fighting strategy, remove potential fuel through mechanical means (e.g., logging) or remove potential fuel through controlled fires (i.e., prescribed burns). The latter two approaches can be used in combination within a stand. The three approaches have advantages and disadvantages which are outlined in Table 1.

Current and more fire resilient stand conditions are depicted in Figure 1 which shows a typical ponderosa pine stand in the Front Range of Colorado before and after being thinned to reduce fuel load. Such thinning is intended to move the stand towards a pre-European condition in which fires stay mostly in the understory and stand killing fires are limited to small patches rather than the thousand acre conflagrations that can occur under current conditions.

Bioenergy is a solution to one of the most vexing problems of reducing forest flammability through mechanical means - what to do with the flammable materials such as tops and limbs, small trees and cull trees that need to be removed, but are generally not merchantable for conventional forest products (Helms and Tappeiner, 1996). If left in the stand this material creates a highly hazardous forest fire condition and the volume of material that would be produced if vast acreages of western forest were treated precludes any thought of landfilling the material. Over the past year at least two studies have examined the feasibility of a bioenergy industry based on forest fuel thinnings and both concluded the volume of wood in the examined region was sufficient to support some industry (Neos Corp. 1997, NREL 1998).

Table 1. Options for reducing forest flammability.

Option	advantages	disadvantages
Do nothing proactive but respond aggressively to wildfires	No cost if no fire	Continued forest stress due to excessive competition; insect and disease outbreaks as a result of stress; continued loss of landscape structure: continued modification of the understory High risk of fire and subsequent impacts - undesirable air emissions - loss of property - loss of life - costs for fighting wildfire ($200-600M/yr in the US) - costs of forest rehabilitation - loss of forest habitat at least temporarily - possible water quality impacts - impacts on biota both directly (death in fire) and indirectly - loss of habitat and/or change in habitat at a stand and a landscape level - loss of stored carbon to the atmosphere (greenhouse gas effect)
Prescribed fire	Best mimics natural ecosystem processes Low risk of negative ecological impacts at the stand-level unless fire gets away	Logistically very difficult to accomplish if the stand has a significant fuel load; may require multiple burns to reduce fuel load to an acceptable level; Difficult to schedule Risk of fire escaping; especially problematic in built-up areas Expensive with no product to offset cost Produces undesirable air emissions Loss of stored carbon to the atmosphere (greenhouse gas effect)
Mechanical removal	Treatment may be able to pay for itself - partially if not wholly Potential for excellent control of stand and landscape structure Little to no risk to property or human life Comparatively easy to schedule	Poorly managed treatment could result in - soil compaction - tree scarring - introduction of non-native plants - high grading (removal of largest and most valuable trees) - poor landscape structure Uncertain impacts on understory (could be positive or negative) Possible construction of new roads and their ensuing environmental problems Disturbance of wildlife during treatment Creation of high fire risk if small material is not removed or treated In some regions, treatment will in and of itself encourage regeneration and therefore require subsequent treatment - most likely a prescribed burn

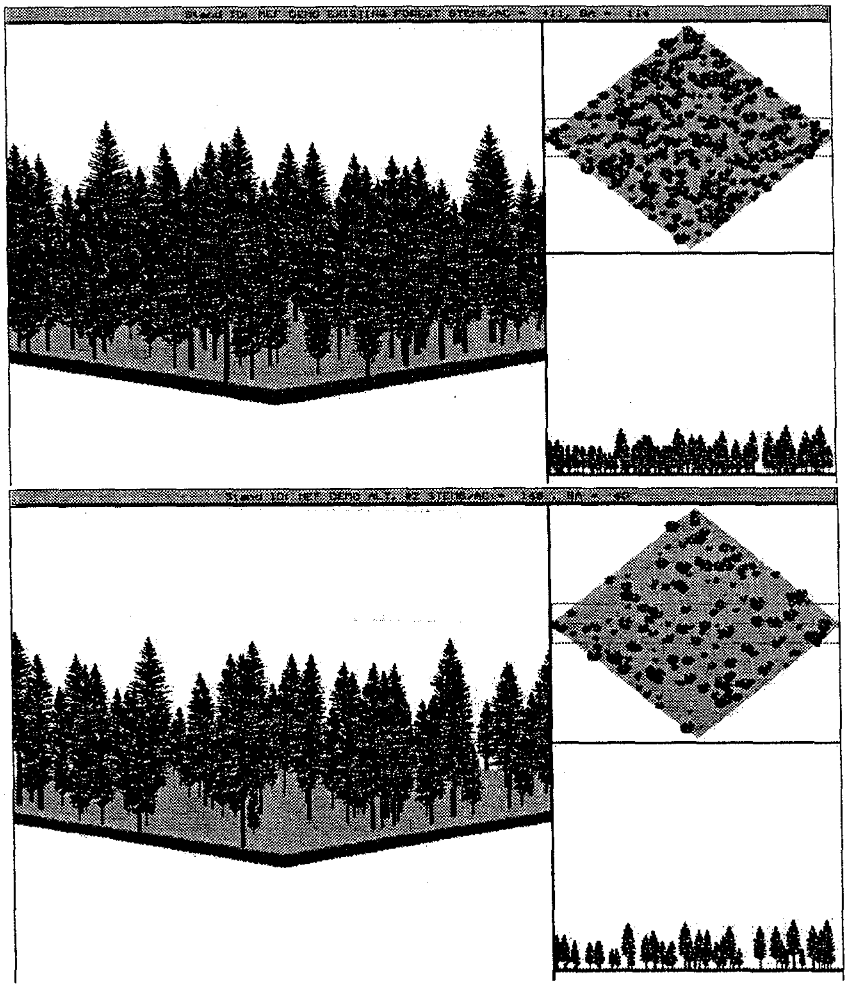

Figure 1. Example of Front Range Ponderosa Pine stand before and after thinning to improve fire resilience.

Reducing forest flammability is not without controversy. To begin with, there is no consensus across government agencies, private land holders, environmental groups and forest communities as to what the desired forest condition should be, other than less flammable. Furthermore there are probably multiple ways of achieving the same set of forest conditions and these ways need to be examined from a social, economic and environmental standpoint.

Prescribed burning is commonly perceived as the "natural" solution and advocated as the solution of choice by some environmental groups. And indeed successful prescribed burns do mimic historic natural processes and present minimal ecosystem impacts. Restoring fire in some fashion to these ecosystems is clearly desirable from an ecosystem function perspective. Furthermore, skilled practitioners of prescribed burning may be able to burn at fairly low costs. Sampson (1997) cites costs of $12-$25 per acre in Idaho National forests.

Dave McCandliss (Sierra National Forest, CA, personal communication) working in commercial timber stands with heavy undergrowth records an average cost of \$70/acre for a first time burn in the Kings River area of the Sierra National Forest in California. Given that much of the land would need two or three burn treatments to reduce the fuel load this is a cost of ~ \$36 to \$210/acre. (The first burn is used to kill the understory vegetation and tree ingrowth while the subsequent burns are used to consume up the fuel). It should be noted that some stands have progressed to the point that it is impossible to apply prescribed burning without some prior removal of flammable material.

Prescribed burning does however has some significant environmental and social problems particularly if viewed from a regional perspective. Foremost of these are the air quality problems associated with smoke from prescribed burning. The deep duff layer that has built up on the forest floor of many of these forests after decades without fire means that prescribed fires may smolder and burn for days after ignition. Wind directions change with time and communities receiving the smoke downwind may object and the smoke can present immediate health hazards. If the impacted airshed includes a heavily populated area (for instance the Sacramento or San Joaquin Valley) with its own set of air pollutants, the resultant soup of pollutants and smoke may be highly undesirable and regional air boards may prohibit fire ignition depending on the current pollutant conditions. For example, a quarter of the days for which forest conditions would permit prescribed burning in the Kings River Ranger district of the Sierra National Forest in California currently can't be used for burning because of air quality conditions in the San Joaquin Valley. If one takes a global perspective, prescribed burning releases large amounts of greenhouse gases - CO_2, CO, and methane. Sampson (1997) estimated, using fire models, that prescribed burning would release 1 to 20 tons of carbon/acre depending on initial stand conditions. While bioenergy would also release carbon, the net impact of the atmosphere is less because it could displace fossil carbon.

Prescribed burning is also logistically very difficult to implement across large areas at the frequencies needed to reduce fuel load and maintain that reduction. The forest conditions needed for a safe prescribed burn (large fuels are wet and small fuels are dry) limit the number of days a prescribed burn can be ignited. Thus within a region large acreages would need to be burned at essentially the same time. For example, a single ranger district in a National forest might have 100,000 acres that need to be treated (i.e. burned three times to reduce fuel loads and then reburnt every 10 years to maintain that reduced load). If the goal was to bring that district into a fire resilient condition in 10 years, then 30,000 acres would need to be burnt every year for 10 years, thereafter 10,000 acres would need to be burnt annually. With a skilled practitioner of prescribed burning and 12 full-time fire-fighters for lighting and controlling fires, a ranger district is doing well in the southern Sierra Nevada to burn 2,000 acres a year. The gap between what is currently practicable and what's needed is considerable in many areas. Furthermore the number of individuals with the skills to successfully burn a stand which has not experienced fire in a half a century are limited. These difficulties are dwarfed in some areas by the risk of a fire getting away. Simply fighting a wildfire costs anywhere from \$150 to \$600/acre not including the costs of structures that burn, the loss of timber values, or rehabilitation. Sampson (1996) records that the average cost over the last 15 years for fighting forest fires on National Forest land is $215/acre and the associated timber losses are $1000-$2000/acre. In areas where there are buildings nearby the risk of an escaped burn may preclude the use of prescribed fire.

Thus, prescribed burning is unlikely to work as the sole solution for reducing fire risk. However, mechanical removal of fuels is not without its own set of challenges. Among these is its close association with logging for timber and the negative perceptions resulting from that association (Louis Blumberg, Wilderness Society, presentation at Western Biomass Coalition Meeting, Sacramento, CA, April 1st, 1998; Sampson 1997). Logistically, economically and environmentally, mechanical removal of fuels is best done simultaneously with logging for timber if logging is to take place. Disturbance to the stand in terms of soil compaction, noise (which affects wildlife), damage to residual trees and vegetation are all reduced if the stand is only entered once. Logging can both subsidize and reduce the cost of removing the fuel material by making the harvesting action more efficient. Furthermore, even if fuel removal is the only objective for entering a stand, the cost of the removing the fuel is reduced if merchantable material from cut trees can be taken off the site at the same time. In other words, it makes good economic sense to produce saw logs, pulp chips and/or bioenergy chips from a tree if the tree is to be removed for fire reasons in the first place. Nonetheless, the taking of merchantable material from a site presents public acceptance problems as mechanical fuel removal can be viewed as (or used as) an excuse for more logging. If a bioenergy industry is to develop in the west based on utilizing wood extracted to reduce flammability the public needs assurance that biomass harvesting is an environmentally and socially responsible forest management action and is appropriate in the larger context of watershed management and restoration.

In the remainder of this paper we provide a brief overview of the issues that need to be addressed to evaluate the environmental and social sustainability of bioenergy based on forest management activities in mountainous western regions. We will use Figure 1 to provide a structure to the discussion and to reference the complex relations between the various issues.

ENVIRONMENTAL ISSUES

Harvesting for bioenergy raises environmental issues both at a stand and at a landscape/regional level. We will first address stand effects that need to be investigated and then landscape/regional effects. The linkages between these and between social issues are illustrated in Figure 2.

Stand-level Effects

Nutrient cycling. Removing flammable material for its energy value through mechanical means (hereafter referred to as biomassing) has nutrient budget and nutrient cycling

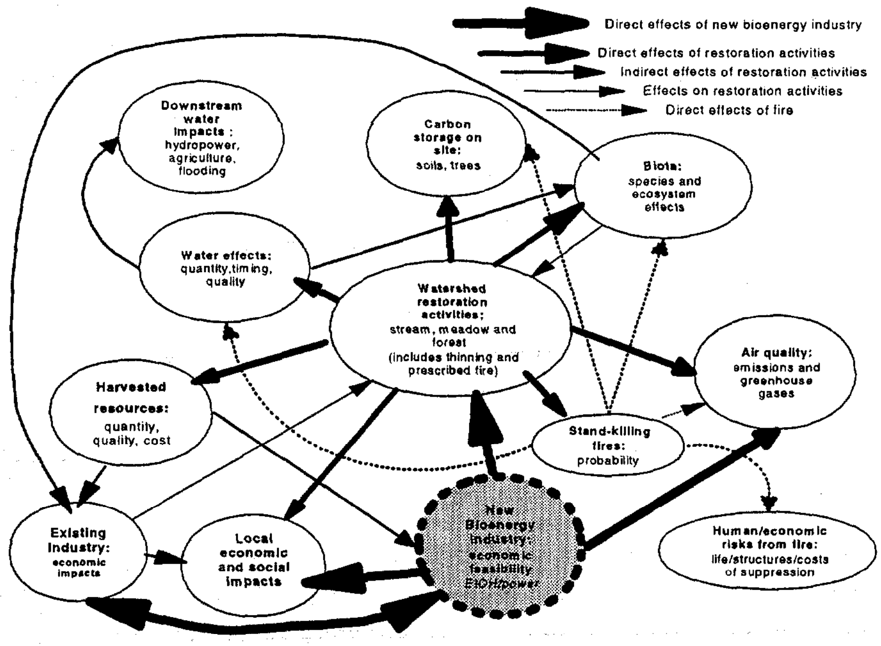

Figure 2. The inter-linkages between environmental and community issues and New Bioenergy industries based on forest management activities in western watersheds.

implications for the stand that are quite different from the effects of prescribed burning. Biomassing removes nutrients from the stand particularly if needles and bark are taken as in the case of whole tree chipping of small trees. An infrequent removal may not be significant if most of the nutrient capital of the stand is in the soil or duff as in the case of the mixed conifer forests of the Sierra Nevada (Helms and Tappeiner, 1996). But repeated removals especially on poor sites may be harmful. The loss of nutrients can be partially compensated by returning the ash from biomass power operations to the forest. Biomassing has the advantage that it does not volatilize forest floor nitrogen as does prescribed burning. However, neither does biomassing cause the needed pulse of soluble exchangable bases (Mg, Ca, K) to the forest soils that prescribed burning does. Unfortunately, there have been comparatively few studies examining nutrient cycling in the dry coniferous forests of the U.S. (Ennes et al., 1997) and none which have specifically addressed biomassing. Even simple budgets identifying the amount of nutrients removed with biomassing are absent. Most of our current understanding of forest nutrient cycles is derived from humid forests. Nutrient cycling and biomassing is clearly an area which needs to be addressed.

Stand health. Biomassing should improve the vigor of the remaining trees by reducing water, light, and nutrient competition. This is especially true for the shade intolerant pine species. Less stressed trees are also better able to resist insect and fungal attacks. One potential risk of biomassing is mechanical damage to trees from the equipment and/or soil compaction. These risks can be reduced through operator care, appropriate equipment (e.g., small maneuverable machinery, wide rubber tracks), and timing of operations (avoiding wet soils).

Disturbance of wildlife. Wildlife are disturbed by noise and dust generated during the biomassing activity, the change in stand structure as a consequence of biomassing and perhaps most importantly, by the need for roads for biomassing. While many animals will simply move out of the stand during the actual biomassing treatment and return when it is over, the environmental conditions in the stand (less brush, less shade, presumably warmer temperatures in the summer and heavier snowpack in the winter) may affect the quality of the habitat for reproduction and foraging. Very little is known on habitat impacts. Roads have many negative environmental impacts (erosion, sedimentation of streams) and there has been public resistance to the development of new roads at least in National Forests. Thus biomassing may be constrained to where roads already exist.

Effect on regeneration and understory. The scarification of soil associated with mechanical site treatment can induce a pulse of regeneration of true firs in western forests. If this regeneration survives it can quickly create a fire risk. There may be ways to reduce the likelihood of these pulses but work is needed to better predict when pulses will occur and how mechanical removal operations contribute to them. Prescribed burning shortly following mechanical removal may be the best solution to this problem. Burning is much easier and less risky following mechanical removal. The impact of biomassing on understory vegetation is largely unknown and probably varies considerably between the different forest types present across the west (Helms and Tappeiner, 1996). In some areas biomassing could stimulate understory growth and like the true fir regeneration this could also create a fire hazard. On the other hand, it could also improve forage for wildlife and/or cattle.

<u>Landscape/regional effects</u>

Water. Water issues are extremely important in the dry west and biomassing could possibly affect not only water quality but the timing and quantity of water coming from these watersheds. Water quality could be affected if biomassing increased sediment loading to streams. Changing stand structure through biomassing potentially affects watershed hydrology in two ways. The reduction of forest canopy will most likely decrease water loss from evapotranspiration. Secondly and perhaps more importantly, opening the stand can increase the amount of water stored in the snowpack. If biomassing increased water flow off site especially in the summer months this could have significant economic and social consequences (Figure 2). Given the enormous value of water, considerable research is needed to better understand hydrologic issues at the watershed scale.

Air. With regards air quality, one is largely interested in understanding the probable emissions associated with biomassing, prescribed burning, or relying on aggressive wildfire control so one can holistically evaluate the tradeoffs of different choices. This includes understanding the extent to which each of the approaches reduces the probable acreage and intensity of wildfires. Thus information is needed on the emissions associated with the equipment used for biomassing and transporting biomass; the emission benefits (compared to the fossil fuel alternatives) of using the bioenergy created from the biomass, and the emissions that would result if prescribed burning or aggressive wildfire control were used instead. A somewhat obscure but perhaps locally important air effect from biomassing is the change it could possibly create in biogenic emissions of hydrocarbons from the forest canopy. If the canopy is reduced there are presumably less of these emissions and since these hydrocarbons are influential in ozone production, biomassing could potentially reduce ozone in valleys such the Sacramento Valley.

Greenhouse gases. As with air, one is primarily interested in understanding the greenhouse gas consequences of choosing biomassing over or in conjunction with the other choices for fire control. Thus the needed information is the greenhouse gas emissions associated with the biomassing operation and transporting biomass; the emission savings associated with using the bioenergy rather than fossil energy, and the emissions that would result if prescribed burning or aggressive wildfire control were used instead. One is also interested in the carbon storage implications of changing the stand structure and the fate of the materials moved offsite for wood products(Sampson 1997).

Landscape integrity. Western forests and their associated ecological and economic values are best managed on a landscape scale (Helms and Tappeiner 1996, Kaufmann et al. 1994). Biomassing associated with thinning and prescribed burning should allow us to more rapidly move towards a more sustainable landscape with the historic heterogeniety of stand structures that existed prior to European settlement. Modeling tools which include both stand and fire processes at the landscape level are needed to project the future consequences of multiple management actions across a landscape.

SOCIAL ISSUES

Local community issues revolve around reduction of fire risk to life and property, effects on existing industries and employment, and quality of life. The relative importance of these three factors varies geographically. In the Front Range of Colorado where there is little forest products industry, no existing biomass power industry but a major tourism/recreation industry and influx of homeowners, aesthetics and reduction of fire risk are perhaps most important. In the Sierra Nevada, a forest products and biomass power industry does exist and grazing is important. Whilst fire risk and quality of life are still important, these other features must be reckoned with. The presence of a forest products industry and the associated logging infrastructure (crews and equipment) makes biomassing more feasible in the Sierra Nevada as does the presence of biomass power plants that can use the material. Some of these facilities already use wood garnered from biomassing and operational biomassing expertise exists.

At a more regional or national level, downstream water impacts on hydropower, reservoir management, agriculture, flooding, and fisheries become important social considerations (Figure 2). In general with the possible exception of flooding, biomassing should produce positive effects but these benefits have never been quantified or examined with rigor.

The need for quantifying the social benefits of biomassing is strong. Current biomassing operations cannot pay their own way. Costs run about $40/dry ton delivered (Northern

Sierra Nevada conditions, Ennes et al.,1997) from biomassing operations and neither existing biomass power plants nor proposed ethanol plants can afford to pay that price for feedstock under current energy market conditions (NREL, 1998). Clearly, the secondary benefits of biomassing have to be quantified if the public is going to be willing to support policies that promote biomassing and bioenergy as part of the solution to western fire problems.

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