The Questionable Practice of Slash Burning
Part II: Environmental Effects and Alternatives

In Part I of this article ("The Questionable Practice of Slash Burning," NCAP NEWS 4 (3):17-21), Roger Hart described human health hazards posed by the chemicals and particulates of slash burn smoke. The formation of carcinogenic polynuclear aromatic hydrocarbons (PNAHs) was raised as a special concern. In Part II, Hart discusses (a) the effects of slash burning on forest productivity and fish habitat, (b) the apparent violation of state and federal laws by slash burn smoke and runoff and (c) alternatives to slash burning.

by Roger Hart

Many forest managers claim clearcutting followed by slash burning is the most profitable means of harvesting and regenerating conifer forests in the Pacific Northwest. "Slash burning imitates the natural cycle of wildfires in nature," we are often told. This article will indicate that forest managers routinely underestimate the true costs of slash burning, and that slash burns can be more harmful to the forest environment than wildfire.

Dwight Barnett, a soil scientist who studied the issue for the Waldport Ranger District of the Siuslaw National Forest, concludes, "Slash burning does not duplicate nature. Slash burns occur more frequently (at least twice as often) as wildfire, and they may be just as severe, or even more severe."[1] The fuel load in slash burns is directly over the soil, whereas wildfire combustion occurs mostly in the crowns, leaving trunks of large diameter green trees standing and in many cases still alive. An average forest floor contains 5 to 20 tons/acre fuel over the soil; slash concentrations vary from 20 to 200 tons/acre over the soil.[2] Because slash burn fuel concentrations are up to forty times that of forest floor, surface fire intensity and soil damage is correspondingly greater in a slash burn.

In the first section of this article I focus on the evidence for damage to tree environments and fish habitats resulting from slash burning. Then I discuss legislation pertinent to slash burning and point out that a number of federal and state statutes are probably routinely violated by slash burning. Finally, I briefly discuss alternative slash disposal methods, that, once both outright and hidden costs of slash burning are considered, will prove to be viable methods that cut down on nutrient loss, erosion, and damage to fish habitat.

Effects on Forest Productivity

Organic, decaying matter holds water, stores nutrients, and provides food for microbes and fungi which, in turn release nutrients for use by the trees. Seedlings planted in topsoil with 7% organic matter grow two to three times faster than seedlings planted in subsoil with only 1% organic matter.[3] Three principal reasons tree growth is diminished after slash burning relate to degradation of this organic matter (Fig. 1):

1) *Lack of moisture retention.* Severe burning in which most of the organic matter is consumed decreases the capacity of soil to hold water by as much as 4.6 times and up to fifteen years after the burn.[4] In addition, microclimate humidity decreases and soil temperature increases by up to 20°F to a depth of two inches after slash burning because of the decrease in insulation and shading provided by litter and foliage.[1] Burned areas suffer more extreme temperature fluctuations than do unburned areas. These changes can stunt or kill seedlings.[5] Survival rates of eastern Oregon yellow pine seedlings were found to be twice as high in slash covered areas as in burned areas.[6] The survival rate of true fir seedlings in northern California was best in shaded areas. [7] Even Douglas fir, commonly reputed by forest managers to require open sun, has survival rates twice as high in shaded seed beds compared to unshaded ones.[8] Conifer regneration by natural seeding on burned soil resulted in 72-89% lower density compared to unburned soil in Montana's Mission range.[4] Even more importantly, after fifteen years, Douglas fir trees averaged 2.2. feet tall and .5 inches in diameter on burned soil compared to 13.9 feet all and 4.4. inches in diameter on unburned soil.[4]

2. *Volatilization and leaching of nutrients.* Nutrient loss takes place by leaching from the soil as a result of increased runoff but more importantly, by volatilization especially during hot burns of 800-1000°C. Phosphorous, potassium, and sulfur are lost, but the loss of nitrogen is by far the most critical. Unlike agricultural soils in which some nitrogen is available from the mineral components of soil, nitrogen in forest soil is provided through the nitrogen fixing activities of microbes and flora.

Following slash burns, the natural rotation of nitrogen-fixing "weed species" such as red alder, snowberry, and shiny leaf is suppressed by herbicides in an attempt to promote conifer growth. Nitrogen loss after slash burning ranges from 150 kg/hectare for a mild burn to 745 kg/hectare for a severe burn corresponding to up to 20% of the total nitrogen in the top eight inches of soil.[1] In the absence of nitrogen-fixing tree species, the only source of nitrogen is free-living bacteria and lichens and they provide only about 1 kg per hectare per year.[1] Thus it would take free-living nitrogen fixers up to 800 years to replace the nitrogen lost in a single severe slash burn. After a careful consideration of all the factors involved, Dwight Barnett concluded nitrogen loss from slash burns could decrease timber yield by up to six percent but would vary depending on the depth and stability of the soil as well as the severity of the burn. Barnett cautions that a true cost of the damage to soil caused by slash burning cannot be made because of uncertainties in the roles played by organic matter, microbes and mycorrhizae, but estimates the replacement

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of nitrogen alone by fertilizer would cost between $57 and $258 an acre.[1] These estimates do not allow for loss of fertilizer by leaching, so the actual nitrogen cost per acre of slash burning can be twice as high.

3. *Destruction of mycorrhizae.* Even in mild slash burns, mycorrhizae that symbiotically grow on conifer roots are destroyed. These fungi (*Ascomycetes* ssp. and *Basidiomycetes* spp.) that populate Douglas fir root tips are dependent on the Douglas fir for photosynthesis products such as carbohydrates, amino acids and other organic compounds. The fungi in turn translocate water and nutrients to the trees. The soil of an old-growth Douglas fir stand in Oregon has been estimated to contain 3,700 lb/acre of fungal mycelia and 4,800 lb/acre of mycorrhizae root tips.[9] Because of their dependency on the trees, the Douglas fir mycorrhizae are slow to reinoculate a slash burn compared to *Endogonacae* fungi that stimulate grass, weed, ferns and maple roots or the *Actinomycetes* bacteria that form nitrogen-fixing nodules on the roots of red alder. Thus, unless a slash burn is immediately planted with mycorrhizal-inoculated Douglas fir, seedling growth can be slowed down for up to ten years after a slash burn.[10-12]

Effects on Fish Habitat

The Fish habitat near slash burns is adversely affected in three ways:

1. *Increased sedimentation and clogging of spawning grounds.* Organic residues from microbes, water, mycorrhizae, and tiny roots all act to bind soil together, and the branches and logs of slash act as dams against downslope mass movement. Their removal by burning can increase total surface erosion up to twelve times.[13]

Soil erosion takes place by landsliding, dry ravel (downward movement of soil by gravity alone), and overland flow of water. Studies have shown that up to 65% of dry ravel actually occurs *during* a slash burn.[13] Buffer zones may reduce landsliding and dry ravel, but the complex branching geometry of erosion gullies and rills prevents effective buffering against leaching of fine sediment from ravel deposits by overland flow. A large number of small rills and gullies deliver the fine sediment to larger brooks which cut through buffer strips and deliver the sediment to creeks, streams, and rivers. Partial cutting without slash burning (see alternatives) is probably the most effective means of preventing overland flow delivery of ravel deposits into watersheds.

Erosion results in an increase in the suspended sediment load of streams. In one study, suspended sediment increased 67 times to about 150 ppm after a slash burn (see Fig. 2).[14] Fish mortality under these conditions has been reported as 22 percent of the total population.[15] In extreme cases, sediment load may range as high as 70,000 ppm immediately downstream from improperly logged areas.[16]

The increase in suspended sediment may only temporarily degrade fish habitat, but siltation of spawning gravels poses a long term threat of immense proportions. The sediment load carried by streams from slashburned clearcuts settles out downstream in low velocity deep water pools, behind logs and rocks, and shallow gravel beds. According to George Brown, Chairman of the Department of Forest Engineering at Oregon State University, "Siltation of spawning gravel is one of the most important impacts of erosion on fish habitat. Circulation of water through the gravels may be significantly reduced, thus lowering the dissolved oxygen concentration in the vicinity of eggs and increasing the concentration of carbon dioxide and toxic products normally borne away by subgravel water.[17] Salmon alevin emergence from eggs is inversely proportional to the percent of fine sediment in the spawning beds. [15] In a gravel bed with 30% sediment, for example, less than 40% of the salmon eggs hatch; in sediment-free gravel over 90% of the eggs hatch.

2. *Elevation of stream temperature.* For the most part, trout and anadromous salmon are accustomed to water temperatures between 45° and 60°F. Clearcutting followed by slash burning increases the incidence of sunlight reaching the watershed and produces blackened forest litter that efficiently absorbs solar radiation. Maximum stream temperatures of 83°F were measured following clearcutting in the Alsea watershed study. The annual maximum was increased by 28°F and the monthly maximum by 14°F.[18] Increased temperature lowers the capactiy of water to hold dissolved oxygen. Furthermore, warm water can induce growth of bacteria pathogenic to fish. For example, *Columnaris*, a warm water bacteria that attacks gill tissue, nearly eliminated a run of sockeye salmon by a small temperature rise in the Columbia River.[19]

Table 1. Summary of likely slash burn smoke composition at various optical densities.

Visibility(1)	Particulates mg/m^3	Nitrogen Oxides mg/m^3	Carbon Monoxide mg/m^3	Non-Methane Hydrocarbons mg/m^3	Chlorine mg/m^3	Lead ug/m^3	Benzo[a]Pyrene ug/m^3	Benzo[b]Flouranthene ug/m^3
10 meters	50.00	20.20	240.50	7.500	.36(6)	70.00	1.250(8)	7.92(8)
100 meters	5.00	2.02	24.05(4)	.750(5)	.04	7.00(7)	.130	.79
1 kilometer	.50(2)	.20	2.41	.075	.004	.70	.013	.08
10 kilometers	.05	.02(3)	.24	.008	.0004	.07	1.001	.01

1. *Calculated using an estimates visibility of 100 meters in smoke 5 mg/m^3 particulate (see Part I of this article NCAP News 4(3):21). A visibility of 10 meters means objects more than 10 meters distant are not visible in the smoke. At a visibility of 100 meters, the smoke is ten times less dense than at a visibility of 10 meters.*
2. *The EPA standard for particulates is .15 mg/m^3 over a 24 hour period.*
3. *The nitrogen oxide concentrations were calculated for a mild burn volatilizing 300 lb/acre of nitrogen. Losses three times higher have been reported in severe burns and three times lower in low temperature burns. The calculation assumes all nitrogen is volatilized as nitrogen dioxide. Nitric acid, ammonia, nitrogen oxide, and nitrous oxide are all possible products of volatilization. The current OSHA ceiling for nitrogen dioxide is 9 mg/m^3, NIOSH has recommended the ceiling be lowered to 1.8 mg/m^3.[36] The OSHA ceiling for nitric oxide is 30 mg/m^3 and nitric acid 5 mg/m^3.[36] The annual standard is .1 mg/m^3.[33]*
4. *The eight hour standard is 10 mg/m^3, the one hour standard 40 mg/m^3.[33]*
5. *The three hour standard is .16 mg/m^3.[33]*
6. *Chlorine may be present as hydrogen chloride, chlorine gas, phosgene (CLCO), or chlorine dioxide. The chlorine may be present as a thermal degradation product of herbicides (see Part I of this article, NCAP NEWS 4(3):21).*
7. *The quarterly lead standard is 1.5 ug/m^3.*
8. *Benzo[a]Pyrene and Benzo[b]Flouranthene are two of many carcinogenic polyaromatic hydrocarbons detected in slash burn smokes. Standards have not yet been established.*

3. *Chemical poisoning of fish habitat.* Numerous toxic chemicals enter the fish habitat after slash burning because infiltration of rainfall decreases and total runoff increases by up to 35%.[1] Apparently the increase in runoff results from a combination of factors: 1) organic matter is reduced in the soil, 2) soil grains are coated by a tarry residue left after volatilization of organic matter, and 3) salts such as sodium chloride and calcium carbonate from a "hardpan" as their ions are released from organic matter. A study of streams draining a 240 acre experimental Douglas fir watershed showed a surge of chemicals during the first rains following slash burning.[20] Both nitrate and ammonia, formed by combustion of nitrogen in organic matter, increase. Ammonia concentrations in streams draining slashburned clearcuts have been measured as high as 7.6 ppm, and at that level are probably toxic to fish and are fifteen times higher than the permissible level established by the Federal Water Pollution Control Administration.[20]

Polyaromatic hydrocarbons and resin acids are also released. Polyaromatic hydrocarbons are highly carcinogenic but may not pose an immediate threat to fish populations. On the other hand, dehydroabietic acid (DHA) is *lethal* to sockeye salmon at concentrations as low as 2 ppm.[21] As of yet, no studies of DHA have been made in either soil on slash burn sites or adjacent streams. It is, however, a major component of slash burn smoke and concentrations as high as .3 ± .1 mg/m³ have been measured.[22] Because DHA is emitted at concentrations up to 100 times that of PAHs, it is likely that DHA will be detected, when looked for, in the same sites PAHs have been detected, e.g., in burned litter and estuary shellfish.

In current practice, slash burn sites are routinely sprayed by herbicides to kill and desiccate live shrubs and plants thereby insuring a more successful (and hotter) burn. Studies show the herbicide levels in streams draining sprayed forest land often are high enough to kill salmon fry. The highest concentrations are recorded during the first heavy rains following herbicide application. In one careful study, three researchers measured 143 ppm of 2,4,5-T in stream water and 3.73 ppm in fish 32 days after the watershed had been sprayed with 2.2. lbs/acre of 2,4,5-T.[23] In another study of a Washington powerline right-of-way, 2,4-D and picloram were applied at 6 and 1.5 lbs/acre respectively in two stages in July and August. During the first significant storm in September, nearby streams contained .83 ppm 2,4-D and .116 ppm picloram.[24] Significant levels continued through October.

In summarizing the effect of slash burning on fish habitat, we are left with a picture of drastic increases of temperature, and of suspended sediment load and siltation of spawning gravels accompanied by a chemical flush of ammonia, nitrate, DHA, PAH and herbicides coinciding with the fall runs and spawning rituals of coho and chinook salmon. The 1983 return of wild salmon to streams in the Oregon coast range was the lowest in recorded history. The extent and nature of damage to fish habitat by clearcutting and slash burning will probably never be adequately assessed or compensated.

Slash Burning and Environmental Laws

Slash burning apparently violates numerous state and federal ordinances, guidelines, and regulations regarding forest productivity, protection of watersheds and fish habitats, and maintenance of air quality.

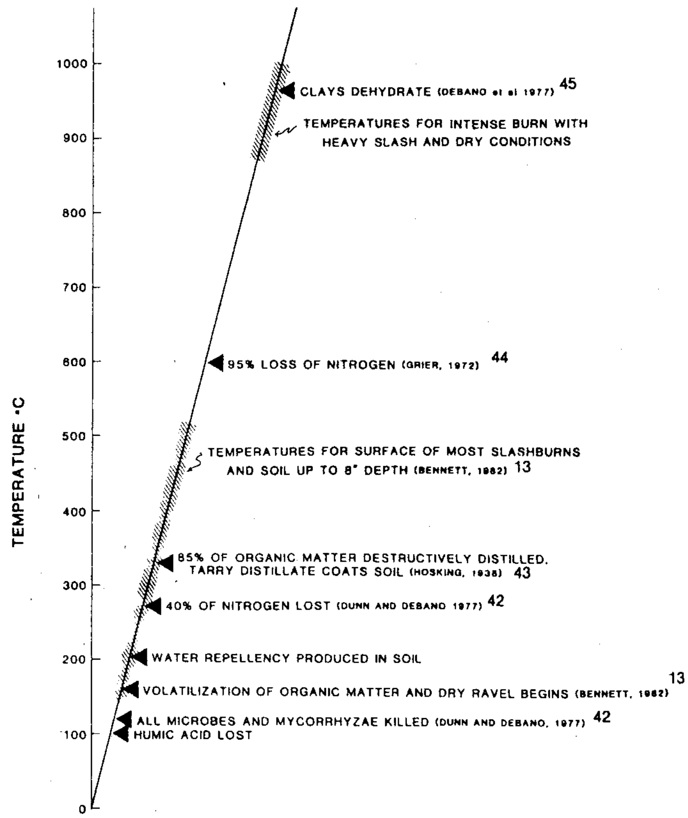

Fig. 1. Slashburn effects on forest soil as a function of temperature.

The Oregon Forest Practices Act states, "Operations on forest land shall be planned and conducted in a manner which will provide adequate consideration to treatment of slashing . . . to maintain productivity of forest land. . . ."[25]. Yet, as documented above, there is evidence that slash burns, especially hot ones, deteriorate productivity through loss of nitrogen, organic matter, beneficial fauna, and moisture retention capability.

Water quality and fish habitat are protected by the Federal Water Pollution Control Act 1956, 1970. The Oregon Forest Practices Acts states, "During and after harvesting operations, streambeds and streamside vegetation shall be maintained in as near natural state as possible in order to maintain water quality and aquatic habitat."[25] The law is very stringent against erosion and directs, "Leave stabilization strips of undergrowth vegetation along all class II streams in widths sufficient to prevent washing of sediment into class I streams below." A class II stream is any headwater stream or minor drainage that feeds into class I streams. In a watershed with a dense tributary system of class II streams, partial cutting is the only means of complying with this regulation.

Furthermore, states the Act, ". . . It is the responsibility of the landowner to determine whether or not chemicals are contaminating streams or other bodies of water."[25] One possible interpretation of this statute suggests streams draining slash burns that were treated with herbicides should be analyzed at the parts per billion range not only during the burn but also during the first fall rains when the runoff chemical flush first enters the streams. The law is not explicit about the chemicals generated by slash burning itself, such as ammonia, nitrate, dehydroabietic acid and polyaromatic hydrocarbons. A liberal interpretation of the term "applied," however, would also require the forest landowner to analyze for *these* chemicals in samples from streams and lakes both during the actual burn and during the fall flush of chemicals.

The stated purpose of the Federal Clean Air Act of 1965 as amended in 1970 is, "to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population. . . ."[26] Numerous sources of smoke emission such as automobile combustion, wigwam sawdust burners, municipal incinerators, private woodstoves, and cigarette smoking are strictly regulated by law. As of yet, the same controls have not been placed on slash burning despite evidence suggesting it violates air quality in two respects: 1) as a significant contributor to the global environment of suspended particulates noxious gases (carbon monoxide, nitrogen oxides, chlorine and hydrocarbons) and carcinogens (polyaromatic hydrocarbons), and 2) as a local health hazard to residents of forested regions who suffer respiratory stress, headaches, malaise, and sometimes pneumonia from inhaling suspended particles and noxious gases (see Part I).

Slash Burning and the World

Let's first consider the global impact of slash burn pollution. The total amount of slash needed to burn to meet silviculture requirements has been estimated at 150 million tons.[27] The emission of suspended particulates from slash burning has been estimated at between 10 and 60 gms of particulates for every kilogram of slash burned.[28] With an average emission rate of 40 gm/kg,[29] burning of this much slash would produce a particulate mass comparable to eruptions of Mt. St. Helens or El Chichon. Fine (less than one micron) particulates produced during low temperature smoldering phases are usually abundant in slash burn smoke,[30] and of special concern because they stay suspended in the atmosphere for long periods and if inhaled are deposited in the alveoli of the lungs. Studies suggest 13% of all submicron particulates in Oregon are from slash burns, and up to 67% during the peak burn month of August.[31]

More than 3 million tons of submicron particulates would be produced by the burning of this much slash, the equivalent of thirteen years' output of Earth's municipal incinerators.[32] The carbon monoxide would be equivalent to 37 years' output of all internal combustion gasoline engines in the Portland-Vancouver area.[33] The nitrogen oxides produced would be equivalent to those produced in two centuries by all the woodstoves in the Portland-Vancouver area.[33] These few examples of slash burn impact are given to illustrate that all the slash that "needs" to be burned cannot be burned. Guidelines are needed to determine which slash burns are absolutely necessary and which can be replaced by alternative methods.

Analysis of slash burn smoke has been made by airplanes flying through the plumes, by instrumentation hung from cables, and by ground-based air samples. The results of these tests are presented in Table 1. The highest concentration of particulate matter was measured from suspended cable at the Tenas 10 clearcut in western Washington and, reached a maximum of 56,167 ug/m^3 in the early stages of the burn.[34] This concentration is 375 times the EPA 24 hr standard of 150 ug/m^3.[32] High particulate concentrations were measured for three hours. During this same period the non-methane hydrocarbon three hour standard was exceeded by up to 49 times and the carbon monoxide 8 hr standard by twenty-six times.

An average particulate density of 100 ug/m^3 was measured over a forty hour period on private property in Lincoln County.[36]* In the same sample, Benzo(a)pyrene concentrations averaged .31 ng/m^3, dibenzo(a,h)anthracene .11 ng/m^3 and Benzo(b)fluoranthene 1.9 ng/m^3. All of these substances are highly carcinogenic PAHs.[32]

In Table 1, I have indicated the approximate concentrations of substances in slash burn smoke assuming the concentration of each substance varies linearly with the total suspended particulate concentration. The results indicate that when visibility is less than 10 meters, as it was at the Tenas 10 burn, slash burn smoke is a highly toxic combination of nitrogen oxides, carbon monoxide, hydrocarbons, and chlorine capable of causing pulmonary edema from nitrogen oxide and chlorine gases and increased risk of angina pectoris and coronary infarction by high levels of carbon monoxide and nitrogen oxide.[36] At a visibility of 100 meters, carbon monoxide and hydrocarbons are above standards and nitrogen oxides may be concentrations sufficient to cause pulmonary edema and chronic lesions in the lungs.[36] At a visibility of one kilometer, the 24 hr standard for total suspended particulates is probably violated and standards for nitrogen oxides could be violated.

The Benefits of Slash Burning

The principal benefit cited for slash burning is reduction of replanting costs. The latter benefit depends on access of sites to tree planters. A savings of $30/acre has been reported in heavy slash with dense branches above head level.[27] In moderate slash the savings is only $5/acre. These savings are minor compared to the actual cost of slash burning which ranges as high as $584/acre (see Fig. 4) or the cost of replanting which ranges as high as $335/acre.[1] Reduction of disease and pests is another cited benefit of slash burning, yet no cost estimate of the benefits have ever been made. In fact, up to $110/acre is spent on animal control (tubing and traps) even after slash burning.[1] Thus, it appears the costs of slash burning outweigh the benefits even without considering possible

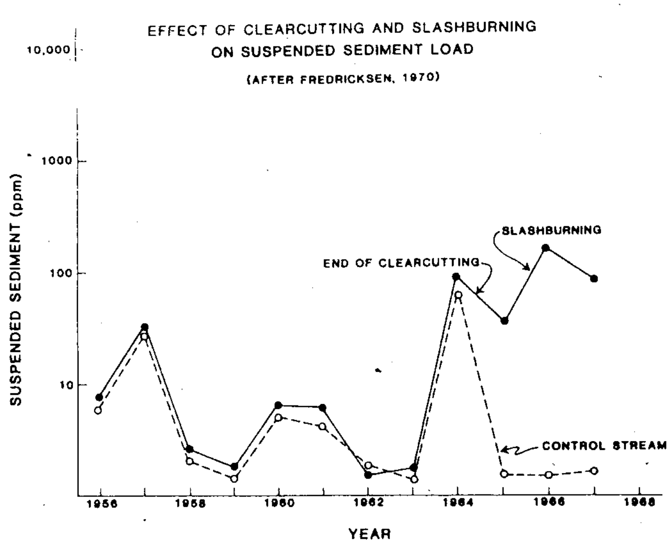

Fig. 2. Increase of stream suspended sediment load after clearcutting and slash-burning.

*Ed. note: The filter was unable to trap particles smaller than .3 microns. EPA estimates that approximately half of smoke particulates are smaller than .3 microns.

deferred costs such as loss of nutrients, organic matter, and soil and damage to fish habitat and destruction of air quality.

Why then is slash burning carried out? Dwight Barnett concludes the practice has become institutionalized partly because slash burning was required by law long before alternative methods became available and partly because comparisons to wildfires were made on cool slash burns lit under unusually wet conditions: "Apparently no one bothered to take a close look at what was happening on the ground or, if they did, their observations and suggestions went unheeded."[1] Now that we have looked at what *does* happen, let us turn to alternatives.

Alternative: Mechanical Clearing

Mechanical clearing of slash uses heavy machinery to pile, crush, bury, or chip slash. Piling of larger slash can be done by traditional yarding methods. The cost of yarding slash can be somewhat offset by its utilization in pulp, paper and particle board processes, and sale of firewood. Improvement in stumpage prices and accessibility to yarding sites will provide incentives for better utilization of yarded slash. The yarding of slash will increase soil disturbance and erosion unless it is done down by high lead, however.

Rolling choppers that crush slash *in situ* have the advantage of avoiding detrimental effects of nitrogen loss, soil erosion, and decrease in water percolation. In addition, the crushed slash provides a favorable micro-climate for conifer seedlings, increases access to tree planters, and minimizes soil compaction.

Burying of slash in large pits avoids nitrogen loss. Soil disturbance is minimized if tractors with rake blades are used. Soil compaction is the largest drawback of this technique, but can be minimized by dragging tilling units behind the tractor. Such tillage not only aerates and decompacts the soil, but mixes nutrients from the underlying mineral soil into the forest litter, increasing overall productivity.

Of all slash treatments, on-site chipping best conserves nutrients, soil quality and micro-climate for establishment of seedlings. Although it is a labor-intensive process, the increased costs of chipping can be offset by using the chips as a mulch to surround new seedlings. This will preserve soil moisture in summer, decrease freezing in winter, and control competitive weeds, thereby saving the costs of two or three applications of herbicides and the accompanying danger to fish populations. A small addition of nitrogen-rich fertilizer will support the microbe populations necessary for rapid and natural decay of the cellulose in the chips.

All of the mechanical disposal methods except high line yarding are limited to slopes less than 35°, the limit for safe operation of heavy equipment. Slash burning on steep slopes is likewise undesirable, however, because of the high likelihood of soil erosion and nutrient loss. On steep slopes partial cutting is an important option.

Alternative Partial Cutting

Slash burning becomes a need following clearcutting because the increased sunlight induces rapid growth of competing species such as blackberry, salmonberry, salal, fireweed, foxglove, and tansy ragweed. In addition, herbicide treatment, particularly of salmonberry and blackberry, leaves dead stands of thick bushes that prohibit tree planting. Thus, slash burning becomes a necessary complement to clearcutting. In some partial cut systems such as the shelterwood

THE COST OF SLASHBURNING

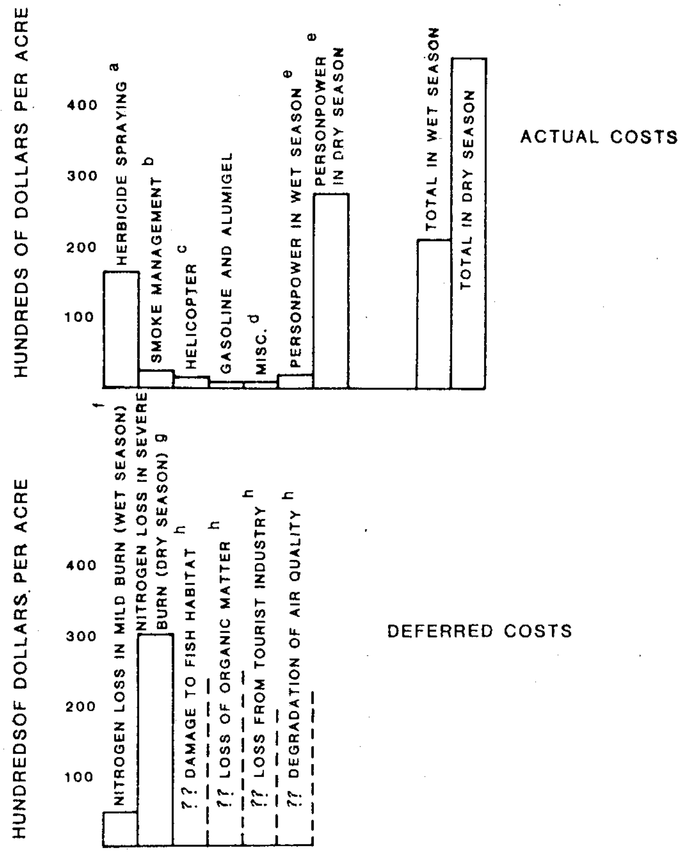

Fig. 3. The Cost of Slashburning.

(a) Assumes two applications, one at spring bud break and a desiccating spray just prior to burning, and uses Jan Newton's figure of $82.86/acre.[37] In some burns, only one herbicide application is used.

(b) Includes daily meteorological observations and evaluation in the burn season, onsite inspection by the state forester, and issuance of permits and guidelines.[38]

(c) Includes igniting and controlling the fire and does not include standby time and waits for false starts.[39]

(d) Includes telephone, office overhead, and person-power involved in filling out permits and requisitions.[39]

(e) Includes fire trail construction, fire watch, and mop-up.[1] (Some private companies reduce costs by allowing slashburns to smolder for several days to a week. This practice produces harmful emission of submicron particulates, carbon monoxide, and nitrogen oxides.)

(f) Assumes 200-700° C temperature, and a nitrogen replacement cost for application of urea at 200 lbs/acre.[1]

(g) Assumes nitrogen loss as high as 1,000 lbs/acre.[1]

(h) Those costs have not been adequately assessed.

system, sufficient timber is left standing to provide shade for seedlings and to prevent growth of high solar intensity species such as salmonberry and blackberry. The immediate profit return from clearcutting is higher than partial cutting because the cost of setting up yarding equipment and road construction is offset by higher timber removal rates. Partial cutting, on the other hand, has the advantage of eliminating nutrient loss, erosion, and damage to fish habitat. Furthermore, natural regeneration from seed trees can reduce or eliminate site preparation and reforestation costs. If the percentage of timber removed is small, the slash does not present as serious a fire hazard, particularly in the humid, lightning-free coast range. Slash deteriorates more rapidly if shaded.

Conclusion

Slash burning is an outmoded silviculture technology that inflicts considerable damage on fish habitat, air quality and forest productivity. Originally, slash burning was carried out under wet conditions. Increased population density has resulted in smoke management guidelines limiting slash burns to the hot dry summer months. Under these conditions, irreparable loss of organic matter and nitrogen occurs, and toxic levels of nitrogen oxides are released into the environment. Soil erosion and sedimentation of spawning gravels follow.

Upon consideration of all the "deferred costs" of slash burning, it is clear that increased utilization of slash as an energy source or the recycling of slash into the forest by chipping or crushing are viable alternatives. Slash burning on a steep slope with shallow soil in dry conditions and heavy slash loads can result in intolerable nutrient and soil loss. Partial cutting is the best alternative under these conditions.

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