ESTIMATING NATURAL EMISSIONS FROM WILDLAND AND PRESCRIBED FIRE

SECTION 1: INTRODUCTION

This paper is prepared for the Policy Committee by the Science and Technology Committee of the Wildland Fire Issues Group. Wildland fires have in the past been considered natural sources while prescribed fires have usually been classified as anthropogenic sources for the purpose of regulation or for assessment of "natural" or "background" air quality impairment. That classification has proven unsatisfactory because aggressive fire suppression (including the use of prescribed fires to reduce fuel hazard) and land use changes have made the current pattern of wildland fires anything but natural. Wildland fires have increased several-fold in the West during the past decade due in part to fuels buildup, and some ecosystems have become unhealthy due to the suppression of inherent natural disturbance. A major increase in prescribed burning is expected in order to help restore ecosystem health and integrity and remedy problems caused by fire exclusion.

What *is* Natural?

A clearer definition of "Natural" is necessary in order to consider the tradeoffs between wildland fires and prescribed fires and to account for the air quality impairment from fires that are part of nature rather than part of economic development.

"Natural" is commonly defined as being "present in or produced by nature"[1]…"with relatively little modification by humans.[2]" Few wildlands in the United States are without significant modification by humans, either by exploitation, fire suppression, or the invasion of exotic species. So, in creating a category of natural emissions, we can choose between these general conceptual approaches: 1) prehistoric or pre-settlement historical conditions, consisting of native vegetation and natural fire regimes at some point in history; 2) current "potential"[3] vegetation patterns and fire regimes assuming no human presence; 3) natural fire regimes based on current actual vegetation conditions but without fire suppression; 4) future natural fire regimes, based either on current, potential, or actual future vegetation.

Or, we could modify these choices to specify some level of human modification of the fire regime

1 Webster's New Third Edition
2 The Concise Oxford Dictionary of Ecology. 1994
3 "Potential" vegetation is that which would occur naturally as an expression of climate and natural disturbance.

such as: a) inclusion of human-caused fires in addition to natural ignitions, b) some level of fire suppression, similar to a current, historic, or specified future level of effort, c) some level of prescribed burning or vegetation management designed to reduce wildland fire severity or to maintain current or desired future vegetation conditions. Finally, we could modify any of these choices to consider current or future land use, such as by limiting our inclusion of prescribed-burning emissions as "natural" to the portion of the land base that is managed exclusively or predominantly to maintain natural conditions.

Most critical to the definition of "natural" is the decision whether to include some level of prescribed burning. Prior fire suppression and it's attendant fuel buildup and ecosystem change, rapid environmental change and extreme weather events, and the changing social value placed on the long-term sustainability of ecosystems all argue for increased prescribed fire. Most experts presume that there will be a rapid increase in the use of fire in an "initial", or catch-up phase of ecosystem restoration. The initial phase may last several decades, before a "maintenance" phase is reached. Prescribed fire is successfully used to reduce the severity and damage caused by future wildland fires, although it can seldom be claimed that there is a direct reduction in the total area burned or emissions resulting from prescribed burning in the short term.

In summary, there is a matrix of choices as to what is included in the category of "natural wildland fire and prescribed fire emissions". Focus may be on the past, present, or future. Focus may be on current (heavily modified) vegetation conditions or fire regimes or potential (natural) conditions and events. We can include some, all, or no prescribed burning as natural events. Or, we can include only the burning that is done solely to restore ecosystem health as natural fires. For the purposes of this paper, "natural fire frequency" will be defined as the fire frequency necessary to sustain an ecosystem in a "natural" or nearly natural condition in the future.

Historic Fire Regimes

Most any approach to estimating natural emissions from fire will look to historic fire frequencies for guidance. Historic fire frequency can be defined in numerous ways and called by various terms (fire frequency, fire return interval, natural fire rotation, ecological fire rotation). Fire frequency can vary greatly by vegetative cover type, site-specific meteorology, stand age, aspect, and elevation. Fire frequency is often defined as a range that reflects site variation. For example a given area of ponderosa pine ecosystem may have a defined fire rotation of 7 to 15 years. The dryer southwestern slopes will have an average fire rotation of approximately 7 years whereas the northern slopes will have an average fire rotation of approximately 15 years. Even within the average site fire rotation interval there can be significant temporal variation depending on weather and ignition potential.

The specific fire regime for each ecosystem varies greatly. Heinselman (1978) recognized the importance of fire frequency and severity in shaping different ecosystems and developed 7 fire regime classifications for all North American ecosystems:

1. No or very little natural fire occurrence (>500 year fire return interval) - e.g., tundra, desert, temperate rain forest.
2. Frequent, low intensity surface fires (1-25 year fire return interval) - e.g.; ponderosa pine, Douglas-fir, Southeastern pine species.
3. Infrequent, low-intensity surface fires (>25 year fire return interval) - e.g., subalpine forest, most eastern deciduous forests, sand pine scrub.
4. Infrequent, high-intensity surface fires (>25 year fire return interval) - e.g., redwood.
5. Short return interval, stand-destroying crown fires (25-100 year fire return intervals) - e.g., chaparral, sagebrush-grass, boreal forests.
6. Variable regimes with frequent, low-moderate intensity surface fire and long return interval, high-intensity crown fires (100-300 year fire return intervals) - e.g., lodgepole pine, western white pine, pinyon-juniper.
7. Very long return interval high-intensity crown fires (>300 year fire return interval) - e.g., spruce-fir, cedar-hemlock, grand fir.

Any change in fire regime will be reflected by some change in the ecosystem. In order to sustain a functional ecosystem, the fire regime needs to be sustained within the natural range of variation. The natural fire regime for an ecosystem may not be the same as the historic fire regime, because neither the current fuel condition nor the climate is the same as in the past. Nor will they be the same in the future.

Geography and Timing of Historic Emissions

Historic wildfire emissions did not occur evenly over the landscape or over the course of time. Most air pollutant sources are reasonably predictable and constant from year to year, and the geographic pattern of emissions is fairly steady. Wildland fire and prescribed fire emissions, however, vary widely over space and time. Estimating the average annual emissions from natural fires is not an adequate description of a source that is generally concentrated in a few weeks of the year, and varies by orders of magnitude from one year to the next, and even from one decade to the next. Some sense of that variability should be conveyed as part of the estimate of natural emissions.

- Intra-Annual variability. Wildland fire occurrence and severity depends on the health of vegetation, the density of ignition sources, and a series of long and short-duration weather events known cumulatively as “fire danger”. Natural emissions from wildland fires occur unevenly during the year and are usually concentrated in a few weeks or months of “fire season”, which of course varies across the country according to vegetation and climatic zone.

- Inter-Annual Variability. Wildland fire occurrence and severity varies greatly from year to year, so simply describing natural emissions as an annual average value is inadequate. This variability can make it difficult to deal with wildland fire emissions in a standard regulatory practice that sets annual standards or calculates background levels over at most a few years. Ecosystems with naturally short fire return intervals, such as grasslands, may experience a year or two without ignition, then concentrate emissions in a single year with double or triple the average value. Ecosystems with long fire return intervals such as spruce or coastal Douglas-fir might experience several decades with minimal fire activity, then concentrate enormous activity in a few severe fire events. Natural emissions during a severe fire year may exceed the average annual emissions by two orders of magnitude, making it difficult to estimate baseline emissions or to measure trends in air quality. Background estimates of natural emissions from wildland fire should at least describe the extremes as well as the annual mean to be meaningful.

In summary, wildland fire is highly variable in place and time. Historic fire regimes are well known and described for all major ecosystem types. These historic frequencies can be used as a starting point for definition of natural emissions although historic fire frequency results in much more emissions than would be acceptable in today's society. Burning to maintain natural ecosystem conditions may not need to occur any more frequently than the middle to upper end of the historical average fire frequency. Some areas may be maintained adequately even if the infrequent end of the natural fire frequency range is increased although potential long term effects of this sort of ecological manipulation are largely unknown. On the other hand, the environment is not static. Climate change, for example, will in some cases change the frequency of fire necessary to maintain any given ecosystem in the future.

SECTION 2: POSSIBLE APPROACHES FOR ESTIMATING ACCEPTABLE EMISSIONS FROM PRESCRIBED FIRE

The discussion that follows proposes a number of potential approaches to estimating a "natural" or acceptable[4] emissions background value from prescribed fire. The alternatives were developed by the Science and Technology committee of the EPA Wildland Fire Policy Group and undoubtedly **do not represent all possible approaches**. They provide a starting point for further discussion but **more thought and analysis are needed before a preferred approach is chosen**.

Option 1. Fire necessary to restore and sustain desired ecosystem characteristics.

The conceptual foundation of estimating fire necessary to restore and sustain desired ecosystem characteristics probably makes the most intuitive sense as an approach to estimating an acceptable emission background although the emissions value predicted from this approach can be quite high. There are a number of possible ways in which to calculate this value.

a. Historic frequency. Current vegetation types and historic fire frequencies across all wildlands are used. This approach is closest to estimating emissions from fire playing a natural role in ecosystems but acres burned per year and resulting emissions are very high. As an example, Figure 1 shows what emissions from this approach would look like for 10 states in the West.[5]

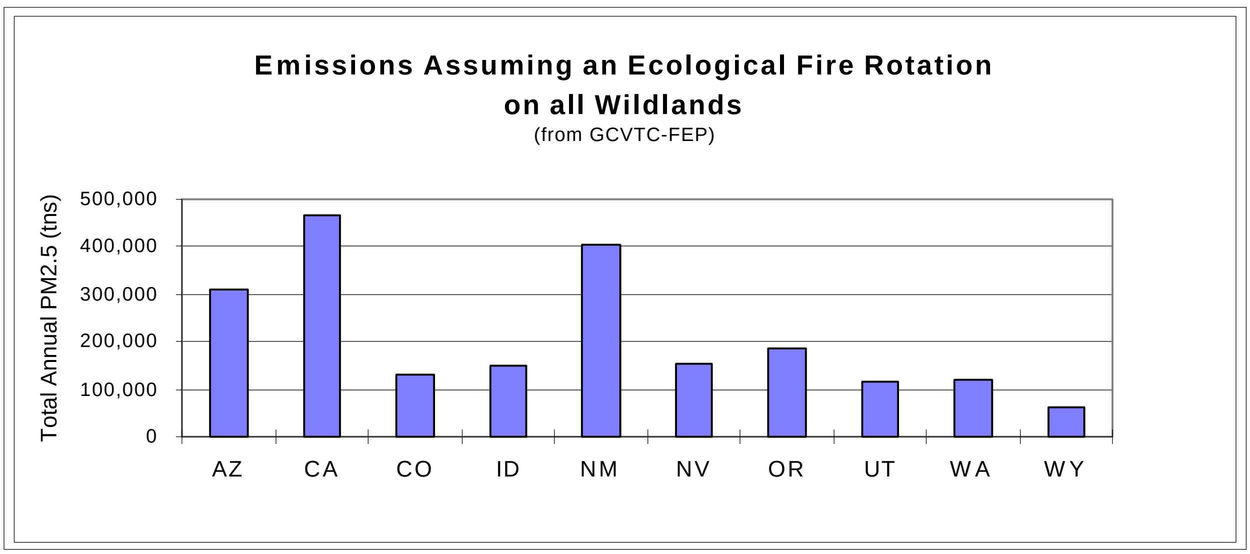

Figure 1: Emissions predicted for 10 states in the west if fire were to occur at historic frequencies in existing vegetation.

4 The S & T Committee preferred the term "acceptable" rather than natural since truly natural emissions are not necessarily what would result from a preferred approach.
5 See Section 3 of this paper for an overview of the Grand Canyon Visibility Transport Commission - Fire Emissions Project from which most of the examples are drawn.

b. Scientifically defined. With this approach, fire necessary to restore and sustain desired ecosystem characteristics would be defined by the scientific community. Presumably this value could be tempered from the previous estimate by extending fire rotations when appropriate, by prioritizing where fire was most needed, and by factoring in when alternatives to fire could be used and to what extent without serious ecological consequences. An estimate of this sort has not been compiled so there is no way of knowing the magnitude of the resulting emissions. A scientifically defined estimate could take a number of years to develop. The result would provide an excellent estimate of emissions from vital forest burning and a complete view of the assumptions inherent to the estimate.

c. Local manager defined. Local managers could be queried for their estimates of future fire needs for ecosystem management. This value would be much lower than the historic frequency estimate since managers would temper their estimates with what could realistically be accomplished and with their intimate knowledge of where extensive prescribed fire was or was not appropriate in their area. The data collection job is quite difficult with this approach and assumptions inherent to the estimates could vary dramatically by local area and be largely unquantified. A method similar to this was used to estimate emissions from future burning in the 10 western states, the results are shown in Figure 2 and give an indication of the magnitude of emissions that would be predicted if such a process were to be used again.

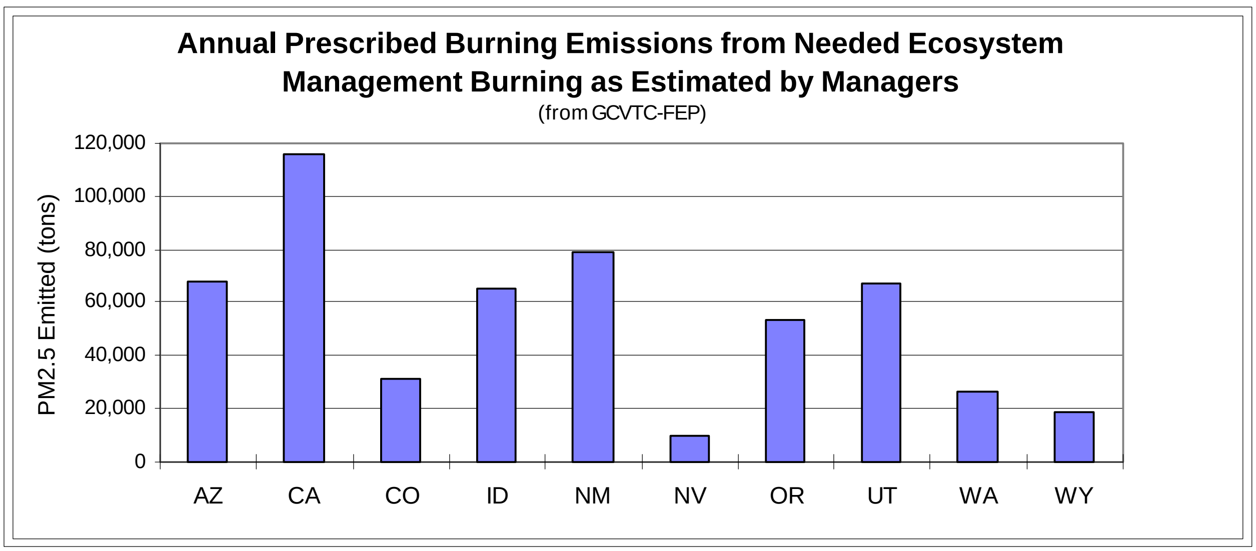

Figure 2: Local land manager estimates of fire needs for ecosystem management compiled into statewide PM2.5 emissions.

d. Agency defined by ecotype. This approach is similar to the one above but rather than querying local managers, agency leaders provide general estimates of fire required based on agency vision for ecosystems by vegetation type or ecotype. In this way, overarching agency or organizational visions are reflected in the emissions estimates. The data collection job for this method is much easier than the previous approach and assumptions inherent to the estimates are more consistent and easier to elucidate. The overall emissions estimates would likely be of the approximate magnitude seen in Figure 2 although this is uncertain. Also, potential local area variations would be lost with this approach.

e. Underlying land management goal determines whether an area qualifies for "ecosystem management burning". For this approach, existing land classifications, agency planning documents, and overriding land management goals would be used to determine whether fire within an area could qualify for the "ecosystem management" designation. Agencies use various terms to describe lands managed primarily for natural processes such as wilderness, administratively withdrawn, habitat conservation areas, late successional reserves, riparian reserves, national monuments, designated unroaded areas, remote and semi-remote recreation areas, municipal watersheds, wild and scenic river corridors, research natural areas, etc. Prescribed fire needed within these areas would qualify for the "acceptable emission" designation. Fire needed on lands managed for multiple uses, including commodity production goals, would not. Once these land categories were geographically delineated, historic fire frequencies would be applied to calculate the acceptable emissions background. The approach could be unpopular since it would exclude a majority of state and private lands. In addition, much of the Federal lands where fire is presently needed most are in areas designated with commodity production as a valid land use. Table 1 displays the area in the 10 western states that currently fall into either the "Withdrawn" or natural processes designation, the multi-use including commodities designation, and lands which could not be or were not placed in either of these categories.

Table 1: Distribution of wildlands in the 10 western states by general land classification category. (From GCVTC-FEP)

	Withdrawn Areas		Multi-use Areas		Undefined Areas		Total
	acres	percent	acres	percent	acres	percent	acres
All Owners	73,971,020	14%	423,456,343	77%	50,208,894	9%	547,636,258
Acres Burned if Ecological Rotation	3,263,023	9%	28,795,287	82%	3,021,916	9%	35,080,225
LANDS EXISTING BY OWNER							
BIA	0	0%	35,598,312	100%	0	0%	35,598,312
BLM	19,331,012	14%	99,719,427	71%	20,964,605	15%	140,015,044
FS	40,436,471	35%	59,962,866	52%	14,094,769	12%	114,494,107
FWS	3,074,919	100%	0	0%	11,403	0%	3,086,322
NPS	10,007,431	98%	0	0%	245,754	2%	10,253,185
OFED	0	0%	1,761,810	21%	6,506,824	79%	8,268,634
SPO	1,121,186	0%	226,413,928	96%	8,385,540	4%	235,920,654

BIA: Bureau of Indian Affairs
BLM: Bureau of Land Management
FS: Forest Service
FWS: Fish and Wildlife Service
NPS: National Park Service
OFED: Other Federal
SPO: State, Private, and other.

Option 2. Fire necessary to manage fuels to a condition where they can be dealt with most effectively from a wildfire control standpoint.

Many types of vegetation where fuel buildups have reached unnaturally high loadings are in a condition where fire suppression action is very difficult or ineffective. Some of these vegetation types could be brought into a more manageable and controllable condition through prescribed fire and/or mechanical fuel reduction. Another approach to estimating an acceptable emissions background from fire is to estimate the area of wildlands where fuels could be brought into a more manageable condition through the use of prescribed fire and how much fire would be required to accomplish this goal. Fire behavior analysts refer to a graph called the hauling chart (Figure 3) to determine manageability of active fires. Fires that plot out in the lower left corner of the chart are the most manageable and can generally be actively and effectively suppressed with hand tools. Fires that plot out toward the upper right of the chart are the least manageable and even aerial suppression techniques may be ineffective. In many areas, especially the short fire rotation timber types, this approach would accomplish results similar to burning for ecosystem management and could be more acceptable to the public.

No example of what emission totals might look like from this estimation method are available.

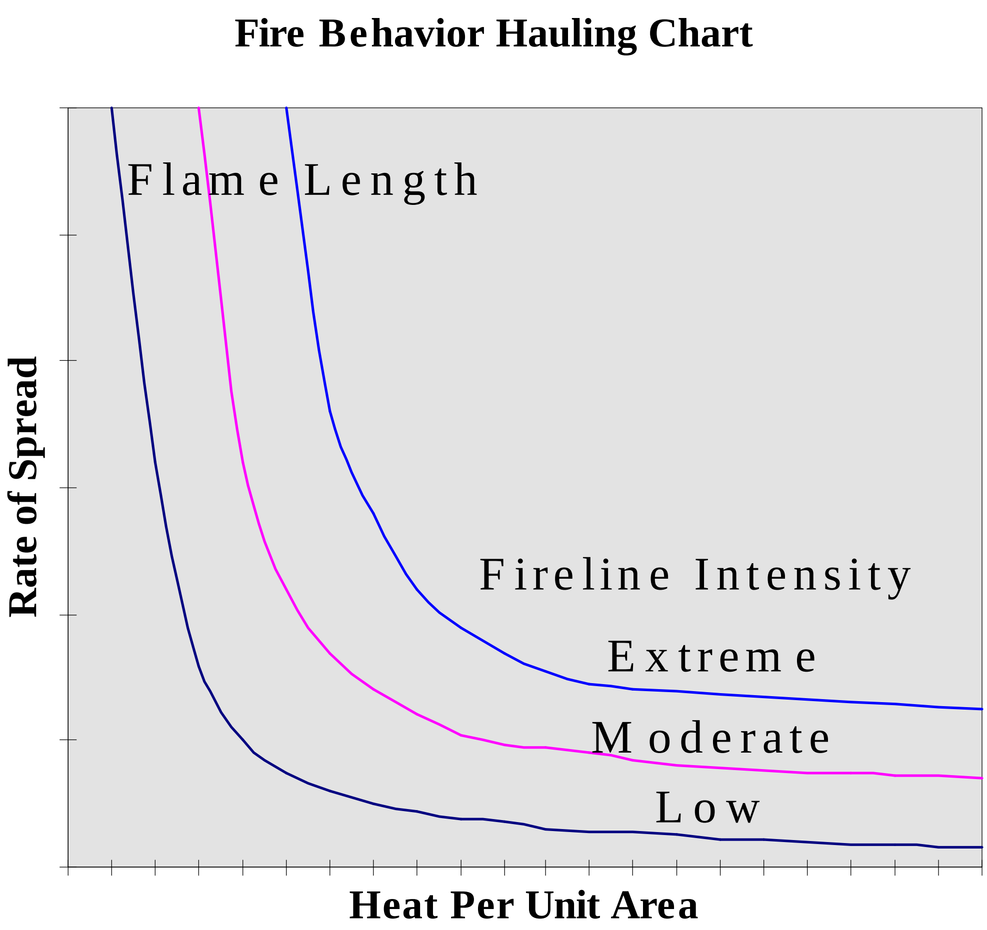

Figure 3: Fire behavior or fireline intensity is related to rate of spread, heat per unit area, and flame length.

Option 3. No net increase in emissions.

An acceptable emissions background could be calculated using the sum of emissions from recent (10-20 years prior) wildfire and prescribed fire. This value would become an emissions cap. Emissions from prescribed burning would be allowed to increase substantially as long as wildfire emissions could be kept to a minimum. Any part of the cap consumed by wildfire emissions would not be available to prescribed burning.

This method of estimating a natural emissions background may not allow for the increase in prescribed fire that land managers believe is needed to restore fire to a more natural role. In addition, a few bad wildfire years resulting from unfavorable meteorology would mean that prescribed fire could only be used very little if at all.

The State of Oregon has used the no net increase concept to manage predicted prescribed fire emissions increases in the northeastern corner of the state. They used the sum of wildfire emissions from 1980-1993 plus prescribed fire emissions from 1987-1993 (prescribed burning records were not available for 1980-1986) to establish the emissions cap. They then apportioned the total emissions cap into wildfire and prescribed fire by using 1940-1980 wildfire to quantify emissions if wildfire were playing a more natural or historic role in the area. These emissions are reserved for future wildfire. All of the remaining emissions up to the cap are available to current and future prescribed fire (Figure 4).

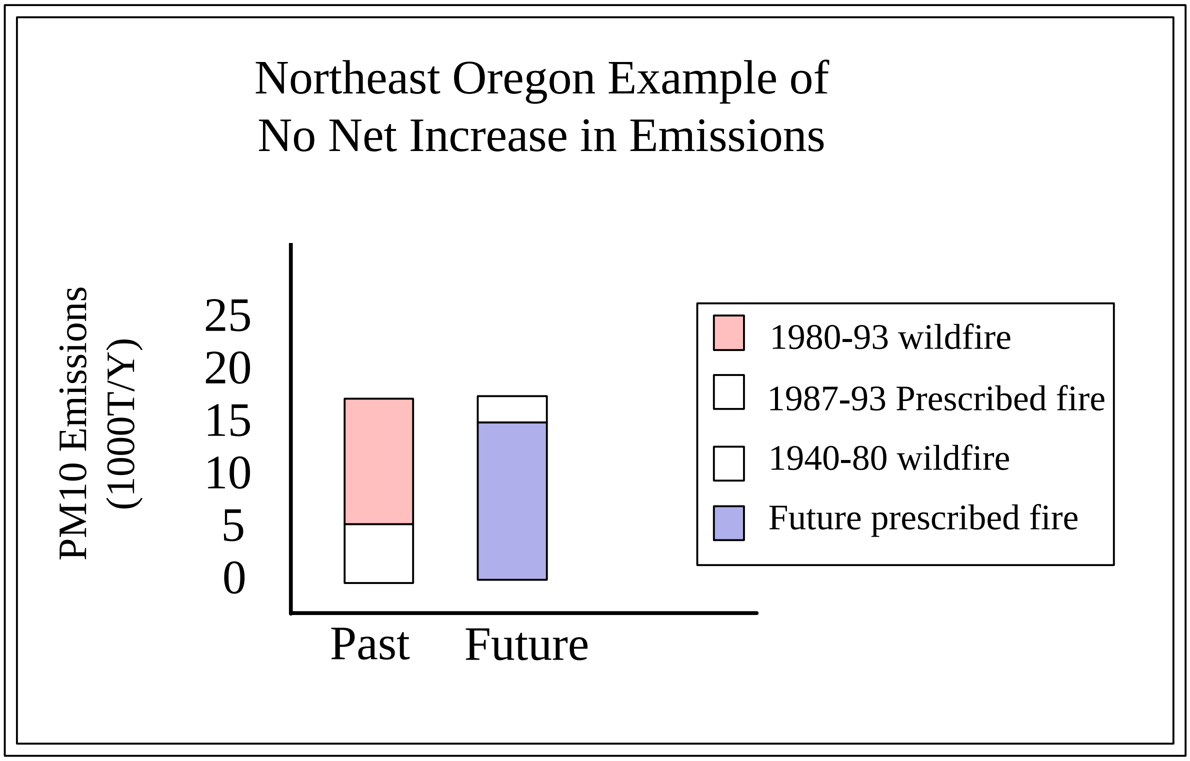

Figure 4: Distribution of emissions from prescribed burning and wildfire under the northeast Oregon "no net increase" management scheme.

Option 4. No change from current.

This is the control or no action alternative. Under this scenario, the acceptable emissions background would be estimated using recent wildfire emissions. No provisions for increases in prescribed fire or recognition that wildfires are becoming less controllable would be included in the estimate. This approach is undesirable because it does not recognize the need to use fire to manage for ecosystem health or the fact that wildfires will burn more area and be more severe until society begins to reduce the fuel buildups seen in many ecosystems in the country.

Approximate annual emissions from the sum of prescribed fire and wildfire are shown in Figure 5 below. This graphic is probably not a good picture of what future emissions under this option might look like though as wildfires are becoming more uncontrollable so are likely underestimated for future years.

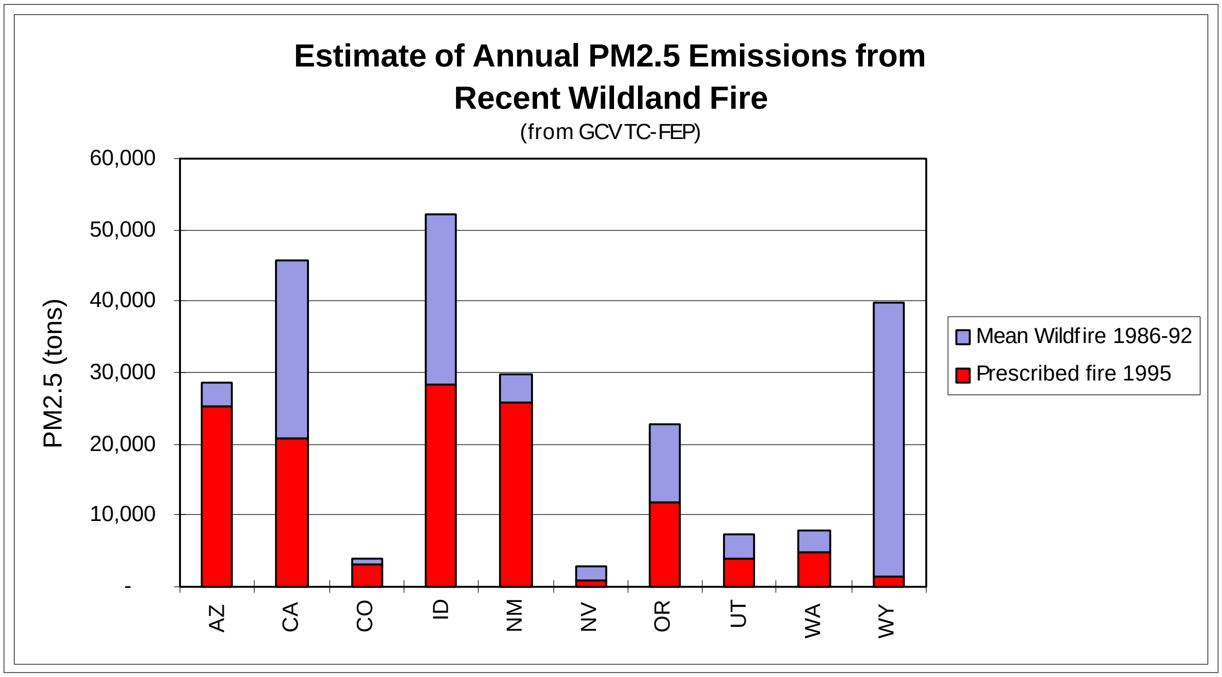

Figure 5: Recent emissions from wildfire and prescribed fire.

Possible Implications of the Alternatives for Estimating an Acceptable Emissions Background

Table 2 represents the estimated effect of each option for estimating an acceptable emissions background on seven test criteria. A "0" in the table means the option will adversely impact this criteria and a "1" indicates a positive impact. A "?" was also used when the effect of the estimation scheme could not be predicted. The table shows how all alternative result in a negative effect on visibility in that all will result in an increase in emissions from fire over time. PSD increment consumption effects were unknown since EPA has not promulgated a rule that addresses PSD and wildland fire.

Option Number	Regional Haze/Visibility: Downtrend	Regional Haze/Visibility: Equity	PSD: Increment consumption	NAAQS: Risk of exceedence	Ecosystem Health	Public Acceptability : Life and Property	Public Acceptability : Smoke Impacts
1	0	0	?	?	1	1	0/1
2	0	0	?	?	1	1	0
3	0	1	?	0/1 (cap)	0/1	0/1	0/1
4	0	1	?	?	0	0	1

SECTION 3: EXAMPLE OF ASSESSING WILDLAND FIRE AND PRESCRIBED FIRE EMISSIONS - GCVTC FIRE EMISSIONS PROJECT

Overview of the Fire Emissions Project

The Fire Emissions Project or FEP, provides an example of a recent prescribed fire emissions inventory that included many of the concepts presented above.

The FEP was initiated when the Grand Canyon Visibility Transport Commission requested information be compiled about prescribed fire and wildland fire in the west so this source's contribution to haze impacts in the Colorado Plateau could be assessed. More specifically, the Commission requested:

- quantification of emissions from prescribed fire and wildland fire in the west,
- spatial and temporal resolution of burning,
- management practices and their effect on emissions,
- ability to distinguish ecosystem burning from activity fuel burning,
- alternatives for prescribed fire and their effect on emissions.

The Forest Service took the lead in responding to this request and worked with a steering committee of project advisors composed of representatives of the EPA, WGA, BLM, NPS, FWS, CDF, BIA, two tribes, and the GCVTC executive director.

Methods Overview

For the FEP, a spatially-resolved inventory of prescribed burning during one current and two future years (1995, 2015, and 2040) for 10 western states was compiled.

Underlying Land Management Categories

Land allocation categories were used in the FEP to better describe options for future land management and prescribed fire use on the landscape. The categories used were Congressionally Reserved areas, Administratively Withdrawn, Riparian Reserves, Matrix lands, and Undefined lands. NPS used a different classification scheme using Wilderness, Administratively Endorsed as suitable for wilderness designation, Riparian Reserve, and Undefined as all NPS land is Congressionally Reserved under the definitions that follow.

- Congressionally Reserved (CR): These are lands that have been reserved by act of Congress for specific land allocation purposes. Examples include Wilderness areas, National Parks and Monuments, Wild and Scenic Rivers, National Wildlife Refuges, and other lands with congressional designations. Lands in this allocation type are managed primarily for natural ecosystem processes. Serious restrictions or total prohibition of the use of mechanical treatments in these areas probably exists.

- Administratively Withdrawn (AW): Administratively withdrawn areas are areas identified in current agency plans for some special protection. They may include recreational and visual protection areas, back country, special study areas, or areas set aside for endangered species habitat protection. Also included in this classification were wilderness study areas and areas administratively endorsed as suitable for wilderness designation. Administratively Withdrawn lands may be available for very limited commodity production (timber, range) but they are managed primarily for other values. As with CR areas, natural ecosystem processes are emphasized to the greatest extent possible. Limited mechanical treatments may be used but generally only if judged to not be in conflict with natural ecosystem processes.

- Riparian Reserves (RR): Riparian reserves are areas along rivers, streams, wetlands, ponds, lakes, and unstable or potentially unstable areas where the conservation of aquatic and riparian-dependent terrestrial resources receives primary emphasis. The main purpose of the reserves is to protect the health of the aquatic system and its dependent species. As with CR and AW lands, Riparian Reserves are managed primarily for protection of natural ecosystem processes. Riparian Reserves may be subject to management restrictions concerning the use of mechanical treatments, fire, or both. Riparian Reserve areas may be in large blocks or may be interspersed in Matrix or Undefined lands as buffers along rivers and streams.

- Matrix (MX): Matrix lands are lands outside the other categories where a mix of management practices are appropriate. These are the areas where timber, range, and other commodity production activities are most appropriate. Matrix lands also include non-forested areas that may be technically unsuited for timber or other commodity production. Fire and/or mechanical treatments are generally appropriate on matrix lands. Matrix lands may include all those left after other lands are classified into one of the proceeding categories unless the agency wished to use the Undefined land classification.

- Undefined (UN): Undefined lands could not be assigned to any of the above land allocations at the time of the study.

A couple of examples from the Forest Service in the Pacific Northwest give an indication of how these land use categories were used. On Forest Service managed land in Washington, 25 percent of the land base was categorized as matrix whereas in Oregon, about 50 percent of the land was in this category (Figure 6)

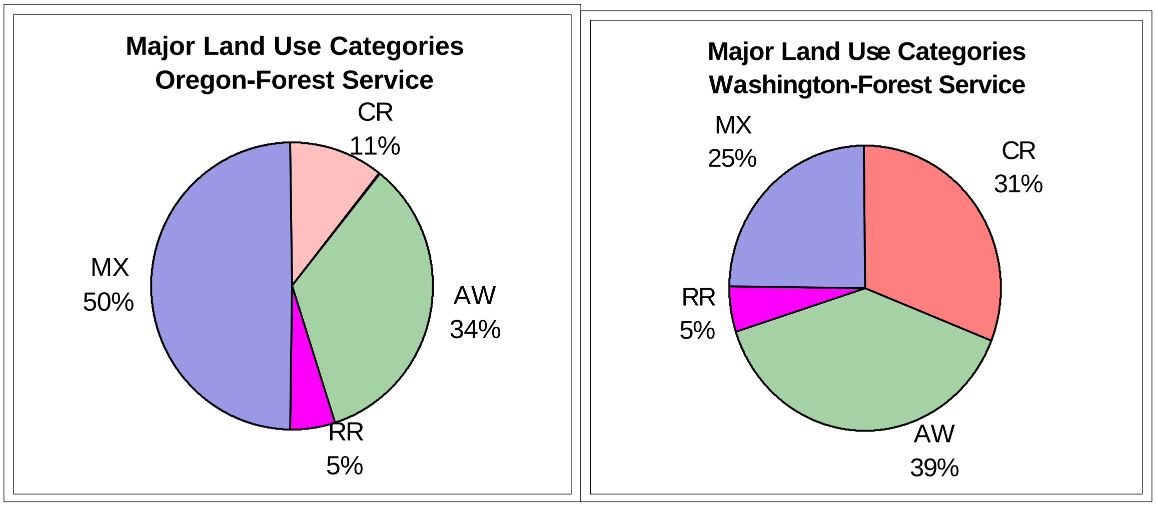

Figure 6: Land use categories assigned on Forest Service managed land in Oregon and Washington during the FEP study.

Vegetative Cover Type

Fourteen vegetative cover types were chosen to characterize the range of species types within the domain and differences or similarities in fire management regimes. These vegetative cover types were spatially mapped throughout the domain using recategorized remote sensed AVHRR (advanced very high resolution radiometry) vegetation data available from the USGS. The cover type categories used in the FEP were: spruce/fir, mixed conifer, Douglas-fir community, ponderosa pine, lodgepole pine, pinyon/juniper woodland, chaparral, aspen/hardwood, cottonwood/willow/riparian, oak brush, sage, desert shrub, annual grass, and perennial grass. In addition, a certain percentage of the area within the vegetative cover types could be defined as composed of broadcast or piled activity fuels.

Within each vegetative cover type, up to three loading categories (high, medium, and low) could be specified by field burners. High loadings were meant to represent an area where fire exclusion, or some natural disturbance (for example bugs, or wind) had resulted in fuel loadings which were higher than would be expected for the particular vegetation type. Low loadings were meant to characterize areas which had recently experienced fire (either wildland fire or prescribed fire. Medium loading was something in between. Areas that were designated as activity fuels could also be classified as high, medium, or low loading. The combination of 14 cover types, 2 activity fuel categories, and up to 3 loading profiles resulted in definition of 43 unique fuel models within the 10 state domain.

Prescribed Fire Fuel Consumption

The type of burning that a manager projected in each vegetative cover type within each land management category, could be associated with up to 5 different categories or types of burning including; initial entry, maintenance, broadcast, pile, or prescribed natural fire (mechanical treatments without fire were also reported). Fuel consumption was estimated using algorithms that relied on an expert-panel-assigned fuel moisture (dry, normal, or wet) believed to be most frequently associated with the type of burning. Emission factors were assigned based on the vegetative cover type.

Field managers were asked to estimate future (2015 and 2040) fire use based solely on what they believed ecosystems need to remain healthy and excluding anticipated (and unquantifiable) future political realities, funding, and personnel restrictions (although perceptions of these undoubtedly influenced the process). In the aggregate, results from the FEP agree with what land managers expect for the future role of fire in ecosystems of the West, and with existing land management and fire use goals laid out in major agency planning documents. The accuracy of the input data is inconsistent between and within the 10 states so, although the methodology is illustrative, the data should be examined at the state or local level to determine accuracy.

Manager estimates for 2015 and 2040 show that fire use is expected to increase quite dramatically in each of the 10 states. Three of the states project fire use needs in the range of one million acres a year. When this study was designed, we presumed that the 2015 burning would reflect the period of "catch-up" or transition burning and that burning in 2040 would reflect less burning or burning at a maintenance level. The data do not show this but instead show acres burned and emissions increasing from 2015 to 2040 (Figures 7 and 8).

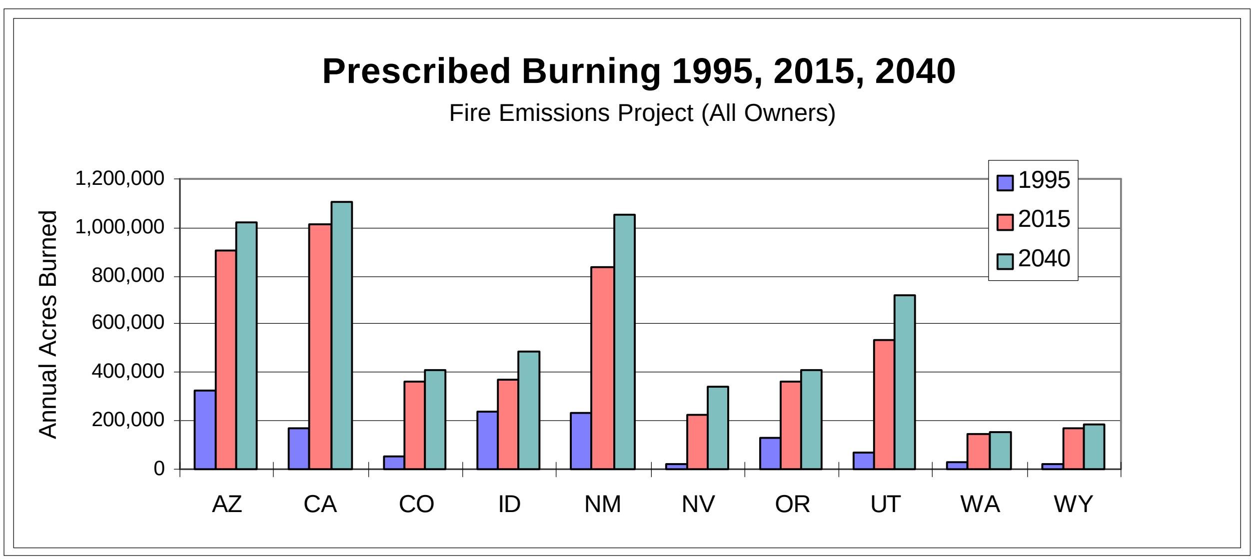

Figure 7: Prescribed fire acres burned by state and year for 10 western states.

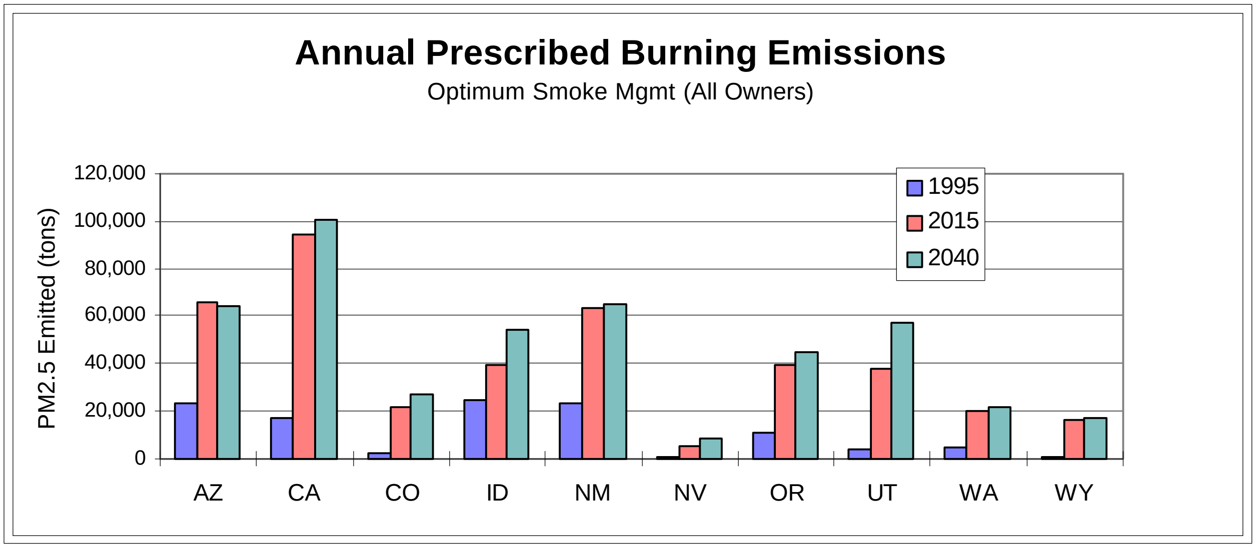

Figure 8: PM2.5 emitted from prescribed burning by state and year for 10 western states.

In addition to gross levels of burning, the FEP data can be sorted and analyzed by a number of factors to better describe what types of burning will increase in the future and which will remain the same. For example Figures 9 - 11 show data for the state of Washington analyzed first by treatment type, then by season, and finally by cover type. Figure 9 shows that all types of fuels treatments are projected to increase dramatically in the future and, although the overall area treated in the state is projected to increase from 2015 to 2040 (figure 8), the area treated with initial entry burning will go down during that time period and the area treated with maintenance fires will increase. Figure 10 shows that although current (1995) burning is primarily in the spring and fall, future burning will need to take advantage of all four seasons.

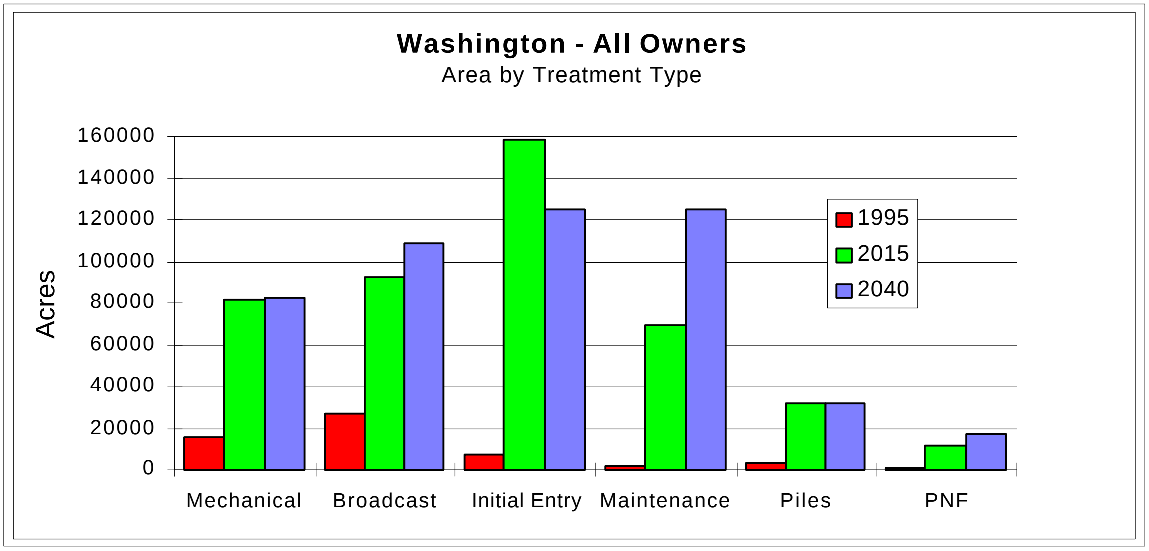

Figure 9: Future burning by type in Washington.

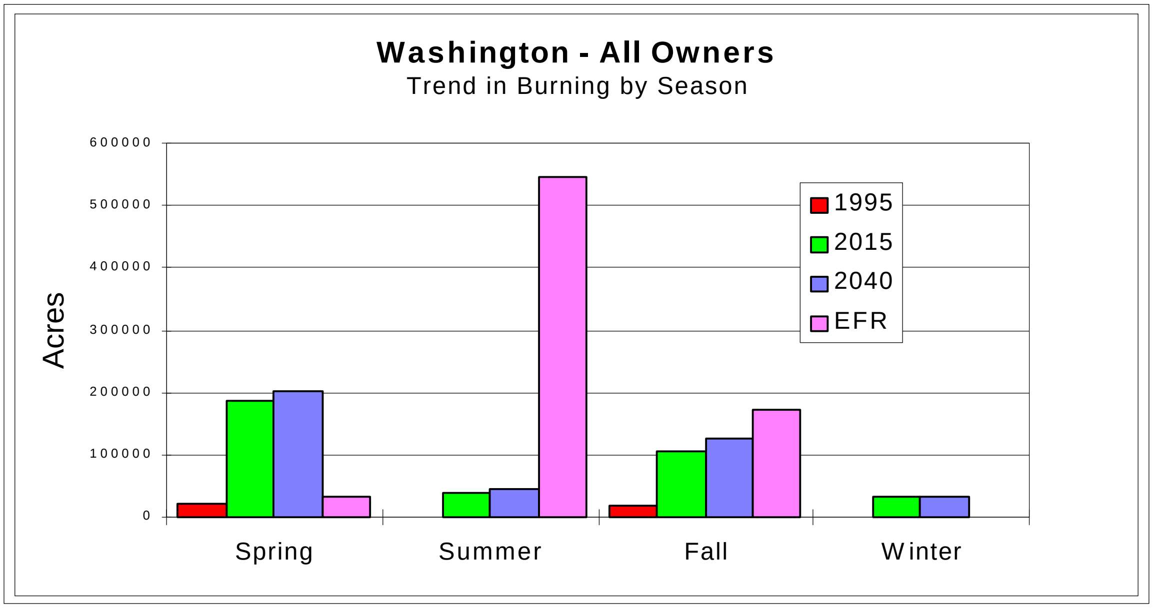

Figure 10: Future burning by season in Washington

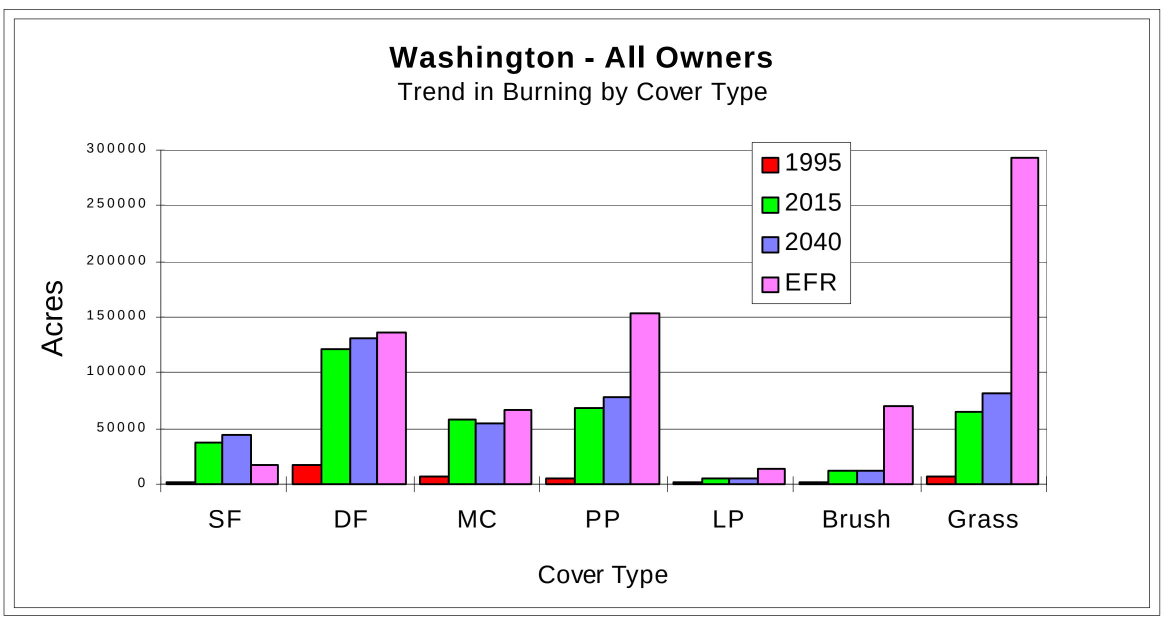

Figure 11: Trend in future burning by vegetative cover type compared to ecological fire frequency in the same cover types.

Natural Fire Frequency
Information about ecological, or natural, fire frequencies by vegetative cover type, agency, and state were compiled as part of the FEP. Fire frequency was recorded as either a range or an average. If a range was given, the mathematical average of the range was later used for calculating emissions. The percent of area burned historically by season was also recorded. A weakness in the natural fire frequency available from the FEP is a single frequency was applied to all areas of a particular vegetative cover within a state for each agency. A more refined analysis would have allowed for frequency to vary within the cover type in different areas of a state. Fuel consumption for natural fire frequency was calculated the same as for the same vegetation type in prescribed fire areas except the fuel moisture was assumed to be in the dry category in all cases.

Manager estimates of prescribed fire use in 2040 are vastly lower than the area that would be expected to burn if fire were allowed to burn at levels estimated by the ecological fire rotation (Figure 12). The reason for the large difference between ecological fire frequency and 2040 prescribed burning is unknown but we speculate the reasons may include limited access, limits on funding and personnel, widespread wildland/urban interface areas, and burning not emphasized in very short rotation types (grasses).

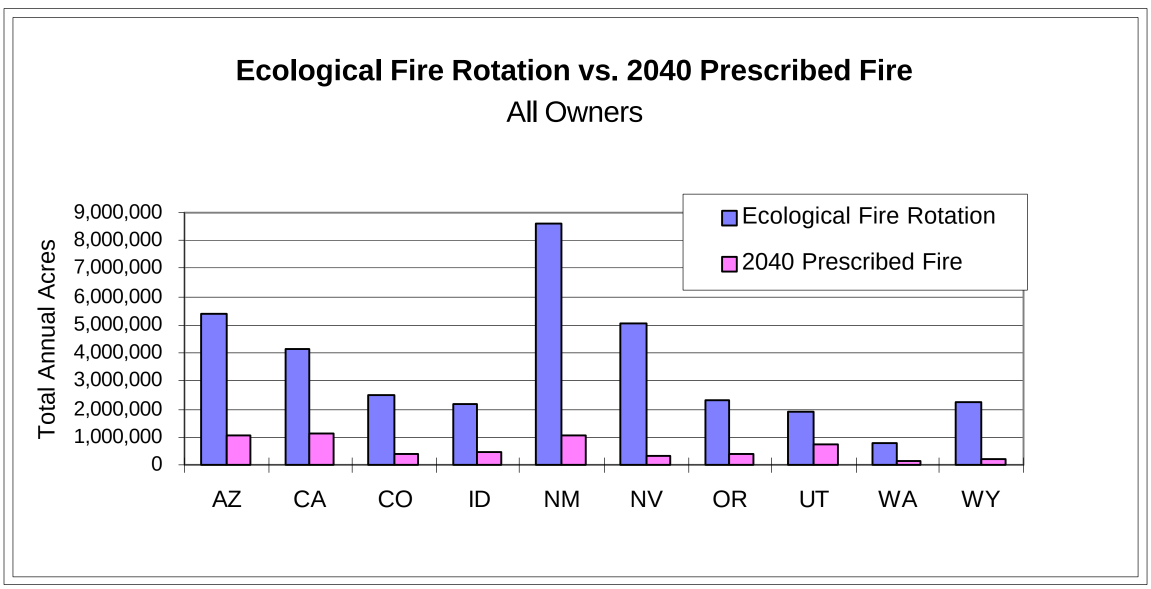

Figure 11: Estimated acres burned per year under the ecological fire rotation scenario and projected 2040 prescribed fire.