The Wildland/Science Interface

by Steve Pyne

A long narrow road winds steeply up into thickly-wooded backcountry to an exclusive enclave of costly structures, all well beyond the periphery of settlement. It's the formula for the worst-case scenario of the wildland/urban interface, except that this is no subprime landscape stuffed with trophy homes. It's a telescope complex atop Mount Graham, and on the Sky Islands of Arizona the scene is repeated four times. Call it the wildland/science interface.

Fire management accepts as axiomatic that it is science-based or at least science-informed and that good science is the antidote to the toxins of politics, land development, and a Smokey-blinkered populace that doesn't understand the natural ecology and inevitability of fire. Science is better than experience or history, and more science is better still. Science, preferably natural science, since even social science is tainted with the implied values of its human doers, is the solution. At Mount Graham, however, it is the problem. And the challenge is not simply that "science" here underwrites its own version of the WUI and opens paved roads to remote sites that complicate fire management and compromise biodiversity. The real challenge is the assumption that science stands apart from the scene it describes and from its Olympian perch can peer objectively outward and advise wisely.

The Mount Graham International Observatory suggests instead, that science's lofty perch is not removed from land management and that science, too, has its self-interests that can influence what it sees, does, and says. Science, in brief, is not an ungrounded platform for viewing the universe of fire and recording its observations. It is sited, and that siting determines what it sees, and decisions over such sites make science and its caste of practitioners as motivated by their own values and ambitions as loggers, ranchers, real estate developers, and ATV recreationists. Science has its own dynamic apart from nature, its own presence on the land, and its own politics. The 1.83 meter primary mirror of the VATT telescope, while nominally looking out, is also a reflecting lens that looks back on its viewers.

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The Sky Islands, as their name hints, are ideal for astronomical observatories. They sit atop high mountains amid a dry climate surrounded by dark deserts (the exception is Tucson, but the city has adopted light abatement measures). The costs of constructing and operating such facilities favor clustering, and the region is dense with telescopes. Mt Lemmon in the Santa Catalinas holds one for the Steward Observatory, Mt Hopkins in the Santa Ritas hosts the Whipple Observatory's MMT for the Smithsonian Institution Astrophysical Observatory, Kitt Peak in the Boboquivaris has a compound of 22 instruments including the famous National Solar Observatory, and in the Pinaleños three telescopes sit in a concrete aerie atop Mt Graham. In recent years wildfires have threatened them all.

The fires have come almost annually. In 2002 and 2003 the Bullock and Aspen fires together burned 85% of the Santa Catalinas. In 2004 the Nuttall fire complex burned 29,000 acres of Mount Graham. In 2005 the Florida Peak fire in the Santa Ritas threatened both the MMT telescope and cabin inholdings in Madera Canyon, and forced evacuations. In 2007 the Alambre fire moved up the slopes of Kitt Peak before being contained at 7,000 acres and over $2 million in suppression costs. But such scenes are hardly news: the same dynamic is playing out across the country, and for that matter, throughout the industrial world, as a revanchist vegetation meets an outmigration of urbanites. Matter and antimatter - the astrophysicists needn't peer into nebulae at the fringes of an expanding universe to detect such explosions, they need only look around them.

But the deeper collision is occurring within the domain of cultural values not subatomic particles. The observatories break up public wildlands into incommensurable blocks: they are in this respect no different from a private inholding or a clearcut. Only four Sky Islands have roads that extend to their summits; all lead to observatories. So long as Science seemed a greater good, as incontestable in its claims to public land as to public money, there were few objections.

Certainly there were no doubts from the scientific or university communities. They were the good guys, far removed from grubby commodity producers and selfish summer homeowners. Their motives were unimpeachable. They were studying the heavens. Theirs were the highest values of civilization.

Then the science-industrial complex met the Wilderness, the American Indian Religious Freedom, and the Endangered Species Acts. They spiraled together with particular force at Mount Graham when in 1984 the University of Arizona, heading a consortium, petitioned to create a cluster of seven telescopes, one of them an enormous 6-dish, rail-mounted interferometer, at the summit. That catalyzed an opposition. An Apache Survival Coalition declared the peak a sacred mountain. Advocates for roadless areas wanted access limited rather than enlarged. And enthusiasts for wilderness and biodiversity noted that the mountain was a Pleistocene relic of Englemann spruce and cork-bark fir with 17 protected species, including a unique subspecies of red squirrel that inhabited the summit, and could go nowhere else; expanding the facility over two peaks would diminish its required habitat and perhaps introduce other disturbances. Under terms of the ESA environmental groups protested and eventually brought suit.

The controversy – "scopes vs. squirrels" - became more bitter as the years passed, not lessened by the inability of the science community to admit that they were in fact upsetting a biotic order. Compared to the 156 billion light-years width of a Hubble universe, Earth is less than a flyspeck and the addition of a few acres of telescopes on the Pinaleños tiny beyond infinitesimal. But compared to the habitat of the red squirrel and public claims on a patch of land that could not enlarge or go elsewhere, it was a significant, probably irreversible disturbance. The University of Arizona and the astronomical community refused to accept that fact or to place themselves within the scene. The Mount Graham International Observatory was only a place for viewing. MGIO was not itself within the panorama viewed.

The controversy dragged on for years, a bitter war of bureaucratic attrition. On-site protests, charges of fudged reports on the biological status of the squirrel in particular, intervention by the state's politicians, backroom deals, legal suits, court injunctions, appeals – from the time the UofA proposed a complex akin to that on Kitt Peak until three telescopes actually arose on Emerald Peak and an adjacent knob, a decade of rancor passed. Throughout, the tendency was to interpret the feud along familiar tropes such as jobs vs. environment, or the perversion of biological science by politics, greed, and hubris. For environmentalists, Mt Graham joined Glen Canyon as a martyred landscape. Yet the contest might as equally be viewed as one between sciences, and between science and wildland management, and between institutions of science. One science, astronomy, and a nominally science-supporting institution, the UofA, turned to politics to overturn the claims of another science and its non-governmental auxiliary. The winner was the more powerful: Astronomy meant Big Science. Conservation biology only acquired a name in 1978. Deep sky met deep biology, and sky won.[1]

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In retrospect, it should have been obvious that Mt Graham would become a point of convergence for controversy, as much a focal point for gathering environmental themes as the lenses of the observatory were for light and microwave radiation in the night sky. That applies not only to its ecological status but to its human history.

The mountain is like a living natural-history cabinet of southwestern species. The Chihuahuan Desert laps against its eastern flank; the Sonoran Desert, its western. The floodplain of the Gila River runs along its north, and high desert along its south. So steep is the mountain that life zones become wafer-thin, stacked like poker chips and tucked away into niches amid the deeply crenulated flanks. From Fort Grant on its southern shoulder to peak of Mt Graham six horizontal miles rises 6,000 feet, or better than one foot of rise for each six feet of run. Forest types appear like thin-sections from rocks; only along the rough-rolling summit is there breadth enough to create the semblance of a forest, and those 3,000-plus acres of Engleman spruce and cork-bark fir are a relic biota, a Pleistocene refugee as distinct as the California condor, and as endangered.

The mountain's human history has been as mixed. Major mines bore into the mountains to the north. Ranching overran the lowlands as soon as mines developed and the indigenous tribes were pacified. Mormon settlers colonized the Gila River floodplain for irrigation agriculture, establishing regional entrepots like Safford and Thatcher. Military posts dot the region; Fort Grant was part of Gen. George Crook's famous campaign to contain the Apaches, blocking potential escape routes from the San Carlos Reservation to Mexico. The Mormons and the military, from the north and south respectively, converged on the summit. Settlers developed flume-transport logging that ate away at the northern canyons. The Army established a hill station, along with a hospital and heliograph lookout, along the summit, with a wagon road to supply it. The settlers deposited a small cluster of cabins at Columbine, while Fort Grant evolved into a state prison, which continues to supply labor for forest-related projects. In 1902 Mt Graham became a forest reserve; and after the U.S. Forest Service acquired control over the reserves in 1905, a national forest in 1907. The federal government went from suppressing Apaches to suppressing fire; Heliograph Peak became a fire lookout; fires all but disappeared. Although formally vanquished, the Apaches continued to identify sacred springs like the Bear Wallow cienega on the top, and ritually revisit them. Then the University of Arizona and Big-Science astronomy staked a claim.

By then Mount Graham, despite its extraordinary ruggedness, was becoming an ecological shambles. Logging, grazing, fire control, the introduction of the Abert squirrel by the Arizona Game and Fish Department (as a meat source), all had broken the biological integrity of the mountain refugia and compromised its resilience. In addition to its summit woods, as isolated as though they were on Selkirk Island, the mountain had the northern goshawk, the Mexican spotted owl, and the red squirrel, all threatened or endangered. But underwriting everything was a thickening bloat of combustibles, both choking the old biome and stoking the potential for large fires. The scene worsened with spruce beetles (native) and spruce aphids (exotic) began stripping spruce as part of the living dynamic. The tiles of the old mosaic began falling away.

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Some of this was obvious when the UofA declared its intentions. The potential biological (and cultural) competition was clear from the onset. What all sides failed to consider, however, was fire. It claimed no more than a nominal paragraph in draft assessments.

One reason is that attention was riveted on the summit and its residual woods, widely regarded as an asbestos forest. It had never burned in the memory of American settlement. Later studies demonstrated that the peaks had not burned for 300 years. (In a gesture of historical irony, the last major fire on the heights of Mount Graham had occurred in 1685, two years before Isaac Newton published the *Principia Mathematica*, the foundational opus for modern astronomy.) Lightning kindled no more than 6-12 fires a year, most of which would self-extinguish. People had long ceased to set burns deliberately. Fire seemed a relic from the past, like the heliographs now replaced by microwave repeaters.

The critical concern with fire, moreover, did not reside at the summit but along the lower elevations. Few ignitions would start at the top: lightning would always be accompanied by copious rain, and spruce-fir lack the long needles that make an ideal bed for surface burning. Instead, ignitions would blast up the slopes from lower elevations; and part of what had spared the summits from repeated fires was that those montane woodlands had absorbed routine burns without blowing up and hurling flames to the crestline. That middle landscape was the one most in upheaval: it was fast morphing from a predominantly open Douglas-fir woods to a mixed forest choking with assorted conifers, all as congested as a squirrel midden and as combustible as a crate of excelsior. Much of the change had occurred over the past 60 years. Now, if drought drained those fuels, fires could burn unheedingly across the old borders. The interface between woods had blurred and the interface between woods and scopes had sharpened.

Certainly, this was the reasoning of fire behavior science, which now also found itself on the summit, overlooking a fireshed much as the Large Binocular Telescope does the Milky Way.

Here it appears to challenge the other sciences for space, and in fact might even seem to synthesize them, as it studies the bio-burning of the landscape by the methods of physics. The logic of fire behavior would appear to favor its claims. Fires burn most fiercely where they have more to burn, which at Mt Graham is also where ignition is most common. Fires burn most savagely upslope, and both MGIO and the squirrel's habitat are at the top of the mountain. Add in a warming climate, in which the desert seas will rise, and fire may remake the landscape as thoroughly as glacial ice in the Pleistocene. In time, without aggressive action – not just suppression but preventative intervention – fire might well claim it all, like a sun going into supernova and taking its planets with it.

Then life imitated science. In May, 1996 the Clark Peak fire, kindled from an abandoned campfire, burned 6500 acres, spreading into known squirrel middens and giving the MGIO a thorough scare and inspiring a fire inspection by a scientist who had specialized in the WUI. In June, 2004 lightning sparked two fires, the Gibson and the Nuttall, that together drove through nearly 29,000 acres on the mountain's northeast slopes and nearly converged exactly at the MGIO. All three fires emerged from the mountain's middle zone. In the end, both squirrels and scopes survived. The squirrels took the bigger hit since the beetles and aphids had struck hard even before the burns. Afterwards, the MGIO hardened its structures to prevent embers from entering the interior and burning the scopes from the inside out, and it laid out perimeter protection in the form of a network of sprinklers. Besides, bugs and burns had now insulated it from the threat in ways not possible for the squirrels. The observatory did not live off the lost trees.

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It would seem that fire science also exerts a claim to the summit. Yet science consists of information and ideas; it is not an entity. How can it demand space akin to that of the Heinrich Heitz Submillimeter Telescope or the Mount Graham red squirrel? In fact, it can because it affects fire's management on the ground. Here is another wildland/science interface, where science as a mode of inquiry confronts fire management's need to act, and of the two wildland borders, this is much the trickier.

There are those who say that the barrier should not – does not – exist, that fire management is simply the best application of the best knowledge science produces, and that more science will spark better practices. But there are also those – fire's curmudgeons – who point out that humanity handled free-burning fire, and probably handled it far longer and more successfully, before modern science than after it, and that more money poured into research has not produced savings in fire management's costs or a reduction in area burned by wildfire. Rather than improve performance, science as an intellectual enterprise sits within fire management as the MGIO does on the peaks of the Pinaleños. It not only interrupts the landscape of fire but demands a peak and shoves aside competing claims. What then should be the relationship between knowing and doing, and what is the proper place of science?

From its origins in forestry, fire protection, and later fire management, have insisted that they are science-based. It is their task to counter centuries of misguided folklore and superstition, and they, and they alone, should instruct administrative practice. Yet the record of their accomplishments is at best mixed. Science proved excellent at reducing complex systems into simple matrices and then creating machines (or rules) to apply particular actions. Fire protection became an intellectual complement to silviculture: it could successfully decrease burned area much as tree farmers could pump up cellulose production. But public wildlands are not pine plantations.

Repeatedly, while science showed it could predict fire's behavior, it has failed to understand fire's ecology and overall place in the landscape. In effect, the astronomical sciences of fire triumphed over the biological. (Interestingly that allusion may not be merely emblematic. Astronomy was of course the exemplar of Newtonian mechanics, and a model for what a real science ought to look like. Moreover, it was the Steward Observatory, now overseeing MGIO,

that developed the Laboratory of Tree-Ring Research in the hopes that fluctuations in annual growth rings might chart the effect of sunspot cycles on climate. Those techniques have become the basis for fire histories derived from fire-scarred trees, which are being used to determine the "naturalness" of the contemporary scene and what measures might be taken to restore it.)

The old outcome was generally disastrous. Forestry used its status as an academic science to counter folk wisdom, to condemn western underburning as "Paiute forestry" and cracker-cowboy range burning as wanton vandalism, and to dismiss counterclaims by prairie restorationists and wildlife biologists as the wistful fancies of niche hobbyists. It used science to condemn fire's presence on the land and denounce its practitioners. When experiments in the southern pines showed favorable results from burning, the forestry profession and its state-sponsored expression, the U.S. Forest Service, suppressed them with the same fervor it attacked flames. Eventually, the outsiders were able to replace the "bad science" with their "good science," but the environmental damage had been done.

The response? An ardent appeal for more and better science. If the agencies had had more of the right science, so the apologists claim, they would have applied those findings and could have resisted the perverting pressures of politics. Rather, the story seems to be that the agency did have the best science of its day and applied it with consequences later scientists rejected. Still, one could legitimately discriminate between science as a mode of inquiry and science as a body of positive knowledge, and suggest that its ever-inquiring character was its most basic. The breakdown was not so much the product of science but of its political application. And one could observe, philosophically, that given a couple of decades the scientific community had shown itself capable of righting its errors. The misreading of fire was simply a longer example of fads like cold fusion and polywater, which the community ultimately self-corrected. In the long run science was right. Yet a land agency is not a research institution: it must act, it needs workable knowledge to perform its tasks, and the consequences of error cannot be overturned by the latest journal article. Besides, in the long run, as John Maynard Keynes famously observed, we are all dead.

The reality would seem to argue that local knowledge based on centuries, if not millennia, of practical experience coded into cultural mores was far superior to field- and lab-generated (and later, computer-simulated) data. It just didn't have the same cachet, and it could threaten to undercut the claims to privileged knowledge that led to money and power. Interestingly, the Clark's Peak, Gibson, and Nuttall fires did not obey the fundamental logic of fire behavior by which the most vigorous burning would occur upslope. The steepness of the massif apparently encourages very strong temperature gradients as, at the end of a day, the top cools rapidly while the shoulders remain heated and a violent sundowner wind results. The worst blowups were actually blowdowns. Abstraction met local circumstance, and the facts won.

Besides, fire embraces many sciences: which should guide practice? As at Mount Graham the zoologists had to yield to the astronomers, the biologists to the physicists. The general response, however, has been to do more of the same. The solution to the problems of science is more science of the same sort. That the agencies responsible for administering the land are also the ones sponsoring research means that there is no way to segregate the two. Science cannot exist apart from politics because politics pays for the science. It cannot merely observe and analyze from a neutral vantage point because those operations and the vantage point itself deform the scene being examined.

The reality, too, is that major reformations in fire management have come not from new scientific discoveries but from changes in cultural values. Upheavals in social understanding determined the paradigm shifts in fire science, not vice versa. Critical thinkers came to value fire because they saw it as part of wilderness, not because they chronicled its evidence in scarred trees and soil charcoal. Those cultural revolutions further allowed society to sift through the competing claims of the various sciences. The ideas and beliefs that surfaced chose which kind of research to support and which to put on the shelf. Still, perhaps damningly, the most

influential publication of recent decades, Norman Maclean's *Young Men and Fire*, was not written by a fire scientist but by a professor of Renaissance literature at the University of Chicago. After the disastrous 1994 season, the book directly affected the adoption of a common federal fire policy and helped convince fire officers to fight fire differently, one consequence of which has been a willingness to trade burned acres for enhanced firefighter safety.

After nearly a century of evidence, it should be clear that fire science is not adequate to the task before it, and that it will never be adequate. Science, as science, simply can't answer the questions most needed to live on the land. It can improve technology and advise about possible outcomes of decisions, it can overgrow with data, but it cannot decide, and its record is such that acting solely on its existing data will almost certainly lead to errors if not disasters. It should be one scholarship among many, and one epistemology among a throng that includes the impossible-to-codify-and-reduce-to-numbers experiential reality by which people actually live. Yet there it resides like the MGOI, demanding ever more space to do what it deems essential, insisting that it sits above criticism, willfully agnostic about the scientific-industrial complex that supports it.

The critics of fire suppression often point to graphs of increasing expenditures and swelling acres burned to make a case that more money fighting fire doesn't reduce either costs or burned area (Figure 1). Defenders will reply that worsening conditions – climate change, the WUI - are determining the fundamentals, and that these deep-driving circumstances are causing the megaburns that bring larger suppression costs. Yet, in the perverse way of correlations, critics could impishly hint that the rising expenditures are just as likely to be the cause of increased burning. The more we spend, the less control we get. A fire suppression-industrial complex is pushing up costs without regard to results on the ground.

This same logic can be applied to fire science. An uptick in fire research parallels the same upswings in firefighting costs and burned area (Figure 2). The USGS has joined the USFS as a funding agency, and the Joint Fire Science Program, established in 1998, has pumped significant monies into research. The number of scientific articles published shows an exponential rise: in the early 1960s some 13 papers/year were published, and in the early 2000s over 300. Partisans will argue that the growing crises, worsening circumstances, and emerging megafires are the reason for more research funding, and that the proper solution is still more funding for still more studies. Yet this is exactly the logic that long governed suppression. One could just as easily argue that the enhanced investment in science has not made any difference on the ground, or even that an emphasis on fire sciences has diverted attention from the real "drivers" of fire's management. An objective measure of applied fire science – analyzing science as science would natural phenomena – would probably show mixed results much like that from fire suppression. The more we spend, the fewer practical outcomes we get. A fire research-industrial complex is pushing up costs without regard to results on the ground.[2]

Apologists brush off such observations as they might an annoying deer fly. They know that authority goes to power, power goes to money, and the money goes to science. They might further demur that science only observes and analyzes with complete disinterest. In fact, science deflects other forms of inquiry and by counseling practitioners it actively alters the landscape it studies. Over the years it has measured a landscape shaped by decisions informed by past science. It has affected the Pinaleños as fully as the Mount Graham International Observatory. This places science, and its institutions, squarely on the summit; and like the squirrels it has nowhere else to go. If it affects the outcome, then it is part of the problem. If it has no effect, then why is it granted special status and funding?

A better explanation for increases in cost and burned area is that America has reclassified the purposes of its public lands, accepts that more burning is advantageous ecologically, and refuses to commit firefighters to go mano a mano with fire in remote, rugged landscapes. Fire officers back off, as federal policy has encouraged them to do. For 30-40 years the major federal land agencies have adopted goals to increase the amount of land burned under their care. The statistics suggest they are doing just that. Be careful what you wish for – and how you study it.

The stronger argument for supporting fire science is that fire management needs to engage its larger culture on terms other than merely as vernacular learning and folklore; the fire guild needs, somewhere, a sense of itself as more than backwoods mechanics and wildland sharecroppers. It needs to connect to high culture in order to truly engage its sustaining society. It needs sophisticated fire science for the same reason that a modern culture needs astronomical observatories. The difference is that observatories tell us little about how to manage Earth, while wildland fire science intends, as its announced ambition, to influence conduct, which is to say, to shape fire practices on the ground. But neither is without cost. Those observatories compete with other values – can literally shove them aside; they claim, and defiantly occupy, the high ground. So, too, fire science can push to the margins other scholarships and forms of knowledge.

Those scopes on the summits will not melt away: their internal logic is to expand. To even appear to criticize Science is to invite charges of philistinism, politicization, and capitulation to faith-based superstition. A steely-eyed survey of fire science's actual achievements, however, would point to marvelous insights into nature and a much-flawed record of practical outcomes. And that, in the end, makes the wildland/science interface a far more troubling conundrum for the fire community than the better publicized wildland/urban interface. It's easier to defend those trashy trophy homes than to dismantle telescopes.

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Yet, unexpectedly, the imperial model of science, in which science informs and management applies, is finding itself constrained. Nationally, a countermove is underway in the guise of adaptive management that blurs the hard border between science and quotidian experience. Science is an experiment in management, practice is a scientific experiment; both need to be constantly calibrated, compared, and adjusted. Granted some space, the concept may return fire management to its ancient status as grounded in experiential knowledge. In principle, it restricts science to standing as one form of information and political input, much as modern fire management identifies suppression as one option among many.

In the Pinaleños the general must always interact with the specific; and here, the alchemy by which principles meet particularities can yield unexpected outcomes. In this case the specifics are the reality of existence at the Mount Graham International Observatory. While the University of Arizona and Big Science got their way - got exclusive right to the site, built an edifice like a Borg cube that can be seen from the White Mountains to the Mexican border – they find themselves denied any larger claim. The road and facilities occupy 8.16 acres. That zone is fenced by stakes and a yellow acrylic rope, beyond which MGIO residents are not permitted to go. The grounds are patrolled by security officers and dogs; they must keep in as well as keep out. Ask anyone about Mount Graham, and they will tell you the place is "political." Of course it's political: it should be. These are public lands and arenas for public values, and in a democracy politics is where competing values must be openly discussed and decided. What tainted the MGIO was that its politics was not open and honest. And what has compromised so much of fire science in the past is that it has confused its data with its values and has dismissed any other scholarship and any other competing values. Science there must be. But it has no claim to the whole of the summit.

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Figure 1. Burned area and USFS expenditures.

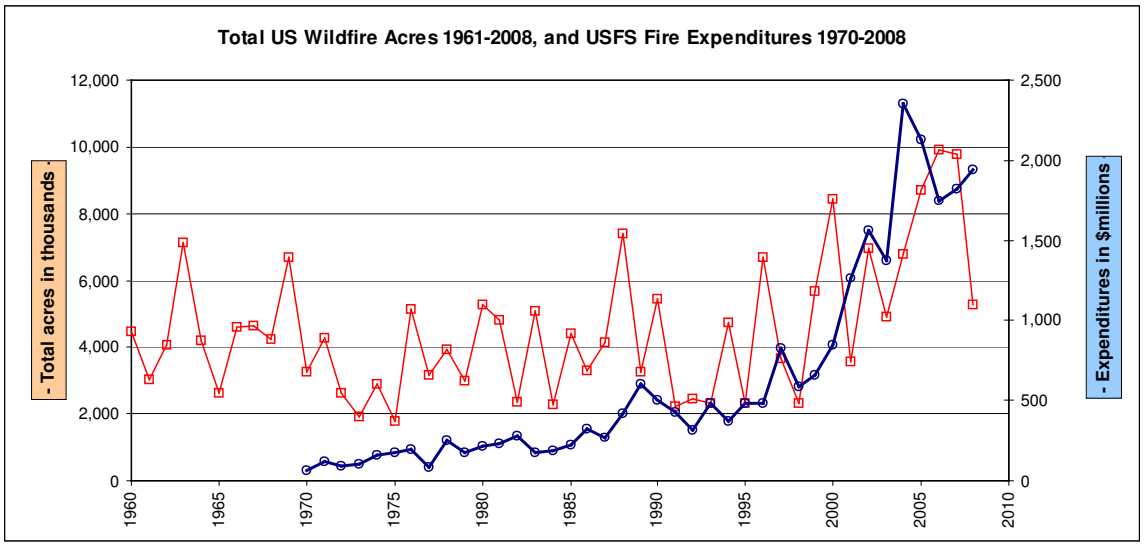
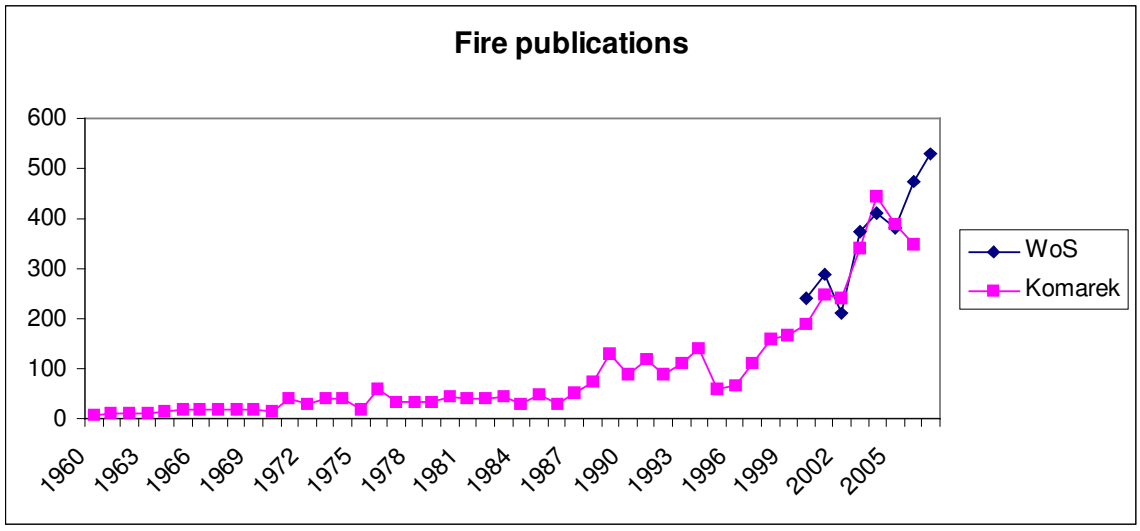


Figure 2. Number of fire publications. Source: Peter Frost, "Hot Topics and Burning Questions" (endnote 2). Data: Web of Science, and Komarek Fire Bibliography.



[1] For an excellent summary of the events, see Paul Hirt, "Biopolitics: A Case Study of Political Influence on Forest Management Decisions, Coronado National Forest, Arizona," in Christopher J. Huggard and Arthur R. Gomez, eds., *Forests Under Fire: A Century of Ecosystem Mismanagement in the Southwest (*Tucson : University of Arizona Press, 2001). For a collection of essays on the topic, see Conrad A. Istock and Robert S. Hoffman, eds., *Storm over a Mountain Island: Conservation Biology and the Mt. Graham Affair* (Tucson: University of Arizona Press, 1995).

[2] Peter Frost, "Hot Topics and Burning Issues: Fire as a Driver of System Processes – Past, Present, Future," Paper presented at postgraduate course offered by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) at Wageningen University, the Global Fire Monitoring Center/Max Planck Institute for Chemistry, and the United Nations University (30 March to 5 April, 2008), p. 2.