World Trends In Forests, Forest Use, Wood Supply
The Irony of California Forestry
The Challenge to Our Profession

Robert F. Powers[1]

Keynote

For nearly a quarter century the Forest Vegetation Management Conference (FVMC) has been a forum for the effective exchange of vegetation management philosophies, methodology and research. Why this conference is successful traces to three factors. The first is broad spectrum membership from industry, government, and academia as well as private individuals interested in the subject of forest land management. The second is the exceptionally strong commitment and professionalism of a cadre of officers, committee chairs, and directors who ensure that the organization remains fresh and vital. The third is the commitment of the University of California Cooperative Extension—most recently, Sherry Cooper—to oversee the essential details of meeting arrangements and the timely publication of each year's *Proceedings*. Other organizations strive to emulate the success of the FVMC.

The first meeting of the FVMC was held October 1979, in Redding, California. One of those early papers: "*Principles of Herbicides, and Conifer Tolerances*" was delivered by Jim McHenry of the University of California at Davis. If anyone at that 1979 meeting had an inkling of what this fledgling get-together might grow to be, it had to be Jim. Jim McHenry had uncommon vision and worked quietly and diplomatically to see that presentations would be vital and of high caliber. He also worked to see that manuscripts would eventually be submitted for publication in an annual *Proceedings*. Jim passed away on November 8 of last year. Among the pioneers of the FVMC, he deserves as much credit as anyone for the vision and persistence that brought what might easily have become a one-shot conference to the polished institution that it is today. Jim was recognized for his contributions to forest vegetation management by receiving a Lifetime Achievement Award at the 21st Annual Meeting, January 18, 2000. He is missed, but his legacy continues. In my view, the FVMC stands as the premier annual professional forestry event in the West.

The first two FVMC's were simply oral presentations by such capable experts as Drs. Dost, Newton, and Radosevich. But there is a problem with stopping at oral summaries. Beyond listener's memories and a few scribbled notes, there is little tangible to serve as detailed reference material in the future. In 1981, a newly-formed slate of officers mailed a questionnaire to those attending the first two conferences. Among the questions were whether a formal account should be published. Of 113 respondents, 109 favored a published *Proceedings*, and this was drafted into FVMC by-laws (Aune 1988). Formal publication began with the 3rd Annual FVMC. The first publication was more a compendium of typed papers of differing font and format—some even with company letterheads—than the clean, crisp professional *Proceedings* we have come to expect today. Regardless, the content was good

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and stood as desk reference material for many years. The keynote, "*Enhancing forest productivity through intensive management*" (Walstad 1981) seems as timely today as it must have seemed then.

Since the beginning, 421 papers have been presented at the FVMC. Who produced them? I separated them into nine categories based on the main affiliation of lead authors (Figure 1). Of these, one-third are by USDA Forest Service authors (Research and National Forest Systems combined). About one-fifth are from the academic sector. Forest industry professionals account for one-sixth of total submissions, followed in a close grouping by regulators, consultants and contractors, and manufacturers and suppliers. Authors identified with predominantly environmental, legal and medical interests make up the smallest group. Seen collectively, a broad array of interests have been presented to this professional forum. Put bluntly, the FVMC is not simply comprised of like-thinking *nozzleheads*.

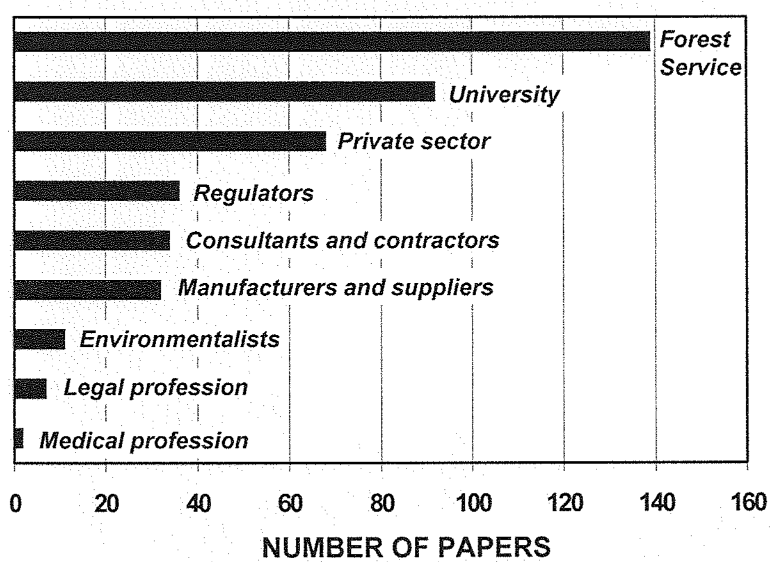

Figure 1. Distribution of 421 presentations at the Forest Vegetation Management Conference by affiliation of lead author. Beginning in 1981, papers were published in the *Proceedings*.

One aspect of an evolving organization like the FVMC might be a shift in authorship affiliation over time. This might indicate a maturing of the professional membership (expertise spread more broadly), a change of direction (diminution of certain affiliations and the rise of others), or an awareness of emerging issues. I examined author affiliation for three periods with similar numbers of papers—1979-1989, 1990-1999, and 2000 to the present (Table 1). One trend is the rise in papers by industrial forestry professionals (from 9 percent in the earliest period to 20 percent in the most recent period). I think this indicates the professional growth of the practicing forester—someone who's more sophisticated in all aspects of forest vegetation management than his counterpart in 1979, and who is viewed as an authority by his peers. This is paralleled by the declining percentages for Forest Service and University authors.

While they still dominate the papers because they are seen as being "on the cutting edge of science," the private sector is emerging as authoritative, too. And that's a healthy sign. It also means that the private sector has been applying what others have said and is sharing their experiences with peers.

Table 1. Distribution of papers published in the Proceedings of the Forest Vegetation Management Conference by affiliation of the lead author by decade

Affiliation of lead author	Number by affiliation in—			Percentage by affiliation in—		
	1979-89	**1990-99**	**2000-03**	**1979-89**	**1990-99**	**2000-03**
Private sector	13	28	27	*9.1*	*19.4*	*20.0*
USDA Forest Service	48	51	40	*33.8*	*35.4*	*29.6*
University	36	34	22	*25.4*	*23.6*	*16.3*
Legal profession	7	0	0	*4.9*	*0.0*	*0.0*
Manufacturers/suppliers	17	10	7	*12.0*	*6.9*	*5.2*
Consultants/contractors	8	9	15	*5.6*	*6.2*	*11.1*
Regulators	10	7	19	*7.0*	*4.9*	*14.1*
Medical profession	2	0	0	*1.4*	*0.0*	*0.0*
Environmentalists	1	5	5	*0.7*	*3.5*	*3.7*
Total	*142*	*144*	*135*			

Consultants, contractors and those from regulating agencies have essentially doubled their percentages between the first period and the present. Largely, I think, this reflects the technical complexity of rules and regulations governing the way that forests are managed. The modern skills needed to practice forestry in California with its myriad agencies and zone regulations are daunting. Not only do we need to be aware of changing rules (the regulators), but we also need to turn to experts (consultants and contractors) to ensure we can comply effectively and efficiently. Although low in absolute numbers, the greatest proportional increase in authored papers over the life of the FVMC belongs to the environmentalists. This is another healthy sign because it indicates that our group is open to views that may run counter to traditional forestry. The future of active forest management in California may depend on it.

Forests? In *California*?

As witnessed by 84 remarkable paired photographs, California's forestland is better stocked now than it was a century ago (Gruell 2001). In fact, many may be surprised to learn that California is 40 percent forested, ranking second among states in total forest area. While its 40.2 million acres is dwarfed by Alaska, California has more forestland than Oregon, Washington, or Idaho (Figure 2), and 6.4 million acres is capable of mean annual volume increments (mai) of 120 ft^3 per acre per year at culmination (USDA Forest Service 2003). California ranks behind only Oregon (10.8 million acres) and Washington (9.9 million acres) in forest area with very high growth potential. The state stands sixth nationally in land with a production potential of 85 ft^3 mai and higher (Oregon, Mississippi, Alabama, Washington, and Louisiana exceed it). More than half (58 percent) of California's forests are publicly owned

(Figure 3). The remainder is split between forest industry (8 percent) and private non-industrial landowners (34 percent) (USDA Forest Service 2003). Sixteen percent of California's forestland is dedicated to parks and wilderness, thereby reserving it permanently from timber harvest. Of the forestland remaining, over half (17.8 million acres) is classified as timberland (that capable of producing at least 20 ft^3 mai per acre and not reserved for other purposes). Timberland ownership is 58 percent public, 16 percent forest industry, and 26 percent private non-industrial.

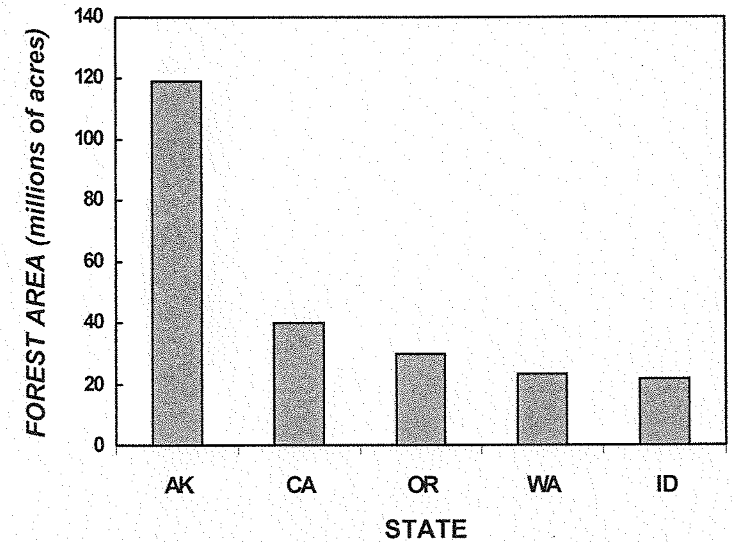

Figure 2. Forest land area of the western states. California ranks second to Alaska.

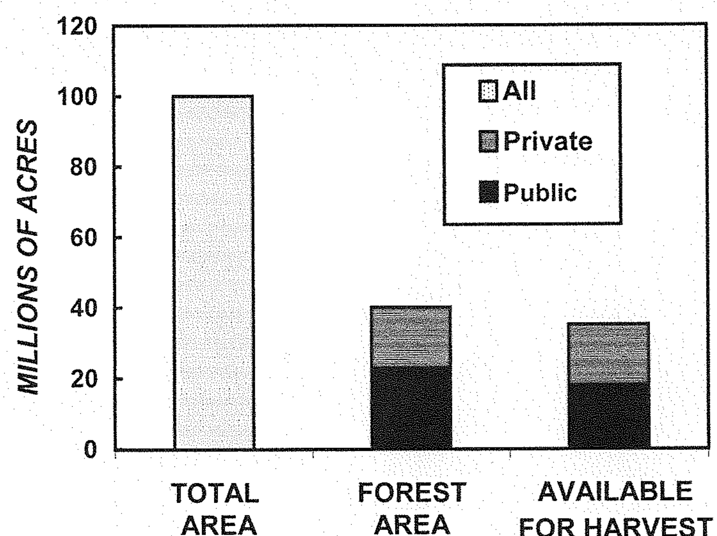

Figure 3. Land area of California in public and private forests and the forest area available for harvest.

Timber harvest on private lands, whether industrial or non-industrial, is governed by the strongest forest practices act in the nation. The Z'Berg-Nejedly Forest Practices Act (1973) sets legal standards for private forest management that exceed those for most nations in the world (Dicus and Delfino 2003). The history of California's Forest Practices Act has been described very well by Gasser (1996). The Act creates a 9-member Board of Forestry (the majority of whom may not have financial connections to the forest products industry) whose role is to oversee timber harvest policy on non-federal lands. The Board of Forestry is the policy arm of the California Department of Forestry, which is the enforcement branch. The Act requires that a Timber Harvest Plan be prepared for each operation by a state-registered professional forester. The Act is the functional equivalent of an environmental impact report required for such activities under the California Environmental Quality Act.

Environmentalists displeased with forestry operations condoned by the Act organized a strong ballot initiative in 1990 to ban such practices as clearcutting. A fierce political battle ensued among proponents and opponents. Competing initiatives were developed, but a voting public most likely wearied and confused by the claims of each side approved neither. But in the aftermath of the failed initiatives, the Board of Forestry adopted regulations in 1993 that went beyond those of the 1973 Act, including sustained yield planning (a Non-Industrial Timber Management Plan option for smaller landowners) and the requirement that landowners manage for late seral conditions on at least 15 percent of their forest holdings. Rules were added concerning cumulative impacts and archaeological sites, and bolstering the habitat protection standards already in place. A major addition was to give standing to other Resource Agency departments concerning the rules. They include the California Department of Water Resources and the California EPA State Water Resources Control Board. Thus emerged the strongest and most detailed forest practices act in the nation.

In 1994, 30 seasoned forestland managers from both private and public sectors were polled on how well the Act was working (Gasser 1996). There was general agreement on several points.

Positive Aspects

- Soil and water resources are far better protected under provisions of the Act than they were before 1973. Contributing factors were location, construction, and maintenance of roads, improved erosion control devices, application of erosion hazard ratings, and classification of streams and riparian buffers.
- A more holistic assessment of cumulative impacts including impacts on riparian zones and forest fauna.
- A sense of a better process for resolving problems.
- Mandated restocking of logged areas to ensure a future forest.
- A new emphasis on long-term monitoring and long-range planning.

Negative Aspects

- Prescriptive rules reduce management flexibility.
- Too much time is spent on rule compliance at the sacrifice of land management.
- Regulation is seen as open-ended and a means for achieving political ends.
- Costs of timber harvest plans are growing. Achieving the last increment of environmental protection is not worth the cost.

- Adding multiple departments leads to turf battles within the Resources Agency that detract from the goal of good land stewardship.
- Costs are not equitable and the burden is particularly heavy on the non-industrial private forest landowner. Expensive timber harvest plans encourage landowners into harvesting more than they otherwise might.

Emerging Concerns

- Emphasizing late seral stage forests, along with the requirement to regenerate at final harvest, is leading to a sere shift to older age classes with young forests relegated to burns and agricultural conversions.
- California forests are becoming overstocked, not understocked, accelerating fuel loadings and setting the stage for wildfire.
- Carrying higher tree inventories may reduce forest productivity and the quality of harvested products.
- Some streams may be over-protected, reducing their quality in the long run.
- Sustained yield plans are being developed to comply with regulation, not enlightened forest practices.
- Public education is a key tool not addressed well by the Board of Forestry.

A more recent analysis by Dicus and Delfino (2003) found that in many respects, state regulations now exceed the environmental protection standards of national (Sustainable Forestry Initiative) and international (Forest Stewardship Council) certification bodies. The authors warn that the Act may have unintended consequences:

> *"The ever-increasing cost to landowners of complying with the (Forest Practices Regulations) leads to less active forest management, which in turn could lead to a degradation in forest health and conversion of forestlands to alternative activities such as development of subdivisions."*

More than half of California's timberland is publicly owned, and through 1990 more than a third of the state's timber harvest came from public land. Those in the private sector who felt constrained by the cost of a timber harvest plan could turn to federal timber supplies. But despite a high volume of growing stock (USDA Forest Service 2003), harvests have plummeted. Of the nearly 2 billion board feet harvested in 2000 (half the state harvest in 1990), only 13 percent came from public timberland and by 2001 it was 8 percent (California Board of Equalization 2003). Thus, timber harvests are down and a higher proportion of the timber that is cut has come from private lands. Although public timber sales continue, absolute harvests are down in all counties, regardless of the proportion of public or private ownership (Figure 4). Largely this mirrors the national decline in timber harvests. Today, timber harvesting on National Forest lands is one one-fifth of the 30-year average from 1960 to 1990 (Figure 5). A fall in West Coast production has accelerated harvesting in the South where 85 percent of forest holdings are private and largely unaffected by Forest Service policy. A serious consequence of all of this is that many companies are making investments elsewhere because they do not see themselves on a level playing field with other states and countries. A probable scenario with the current course is that California forests will be *less* managed, trees will become weakened, fuels will build.

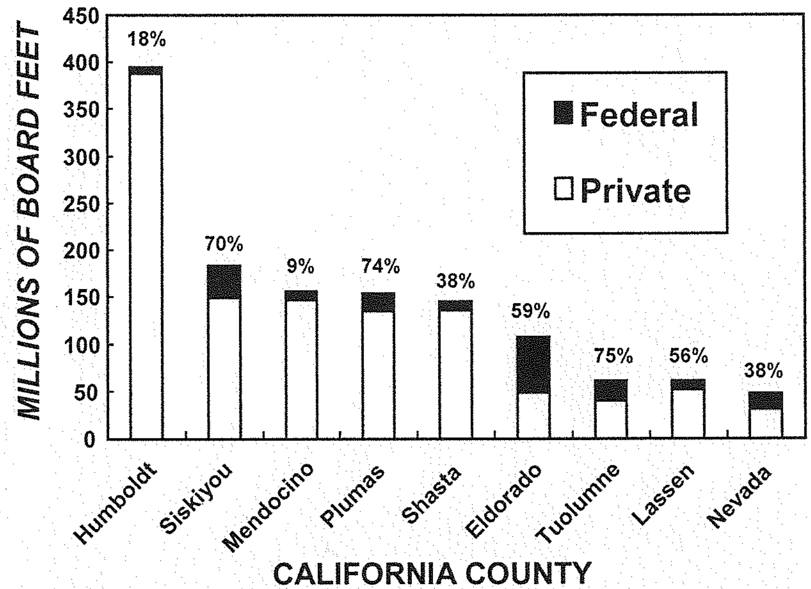

Figure 4. Timber harvested in 2000 for nine northern California counties. Proportion of county timberland in National Forest is shown as percentages. State total harvest was 1.97 billion board feet. Source: California Board of Equalization (2003).

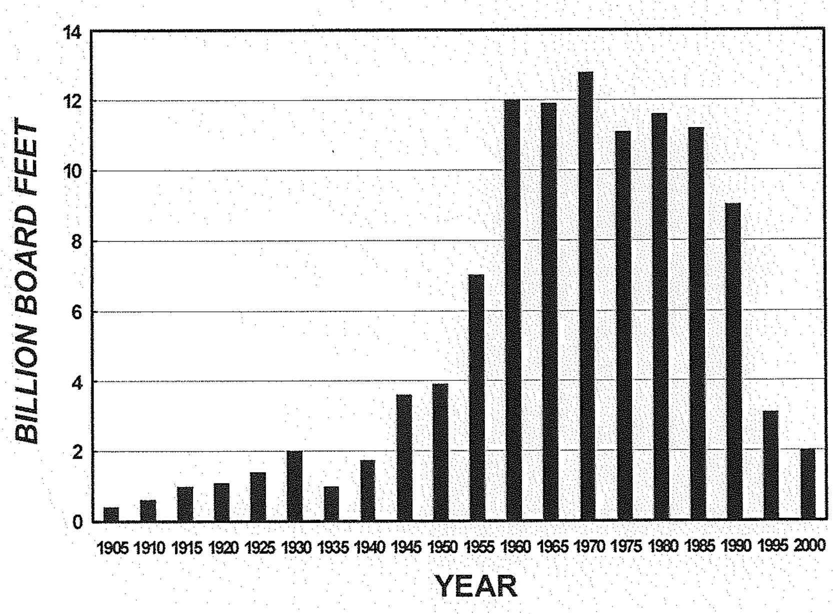

Figure 5. National Forest timber sold between 1905 and 2000.

Scaling Up Nationally

The Rocky Mountains divide U.S. forestland nearly in two—51 percent is east of the Rockies, and 49 percent is west (Table 2). Pacific Coast states account for over one-quarter of U.S. forestland. Of this, nearly half is in Alaska (Haynes 2003). Two-thirds of U.S. forestland is classified as timberland, and many have the perception that the lion's share is federal. While this is true for the Pacific Coast states, it is not so nationally. The private, non-industrial sector accounts for 58 percent of our nation's forestland (Table 2). Both nationally and in the West, the lowest share is owned by forest industry.

Table 2. Area of forestland and timberland in the United States by region and ownership. Areas estimated after 1997. From Haynes (2003)

Distribution of Forest	**1953**	**1997**	**2010**	**2020**	**2050**
	------------*millions of acres*------------				
Total Forestland					
North	160.8	170.3	172.1	171.0	163.8
South	226.0	214.1	213.2	212.6	210.5
Rocky Mountains	141.6	143.2	144.3	144.2	142.5
Pacific Coast	227.8	219.3	216.3	213.9	207.1
Total	*756.2*	*747.0*	*745.9*	*741.7*	*723.8*
Timberland ownership					
Public	145.4	146.1	146.1	146.1	146.1
Industrial	59.0	69.9	66.4	66.1	64.9
Non-industrial	304.4	290.8	289.6	287.0	278.1
Total	*508.9*	*503.8*	*502.1*	*499.2*	*489.0*
Timberland Pacific Coast					
Public	52.4	43.0	43.0	43.0	43.0
Industrial	11.2	12.1	12.0	12.0	11.8
Non-industrial	19.8	17.1	15.9	15.3	14.5
Total	*83.4*	*72.2*	*71.0*	*70.3*	*69.3*

Despite lessened domestic harvests, national demand for forest products continues to rise and is projected to increase 40 percent by mid-century (Haynes 2003). Following the post-war building boom of World War II, the United States has consumed more forest products than it has produced. Although we maintain an export roundwood market, we import roughly 3-times more than we export (Figure 6). Projections are that domestic demand will be met through three measures: (1) a domestic timber harvest increase of 23 percent (largely as plantations in the South and West reach merchantable size and as prices encourage more harvesting in the non-industrial forestry sector); (2) an 85 percent increase in the use of recycled paper; (3) an 85 percent rise in imports of logs, chips, and wood products (Haynes 2003). Per capita consumption of wood is estimated to be 1,565 lbs per year from 1998 through 2050, up from 1,243 lbs in 1965 (Haynes 2003). Obviously, the public wants wood. But they'd rather that we get it from someone else.

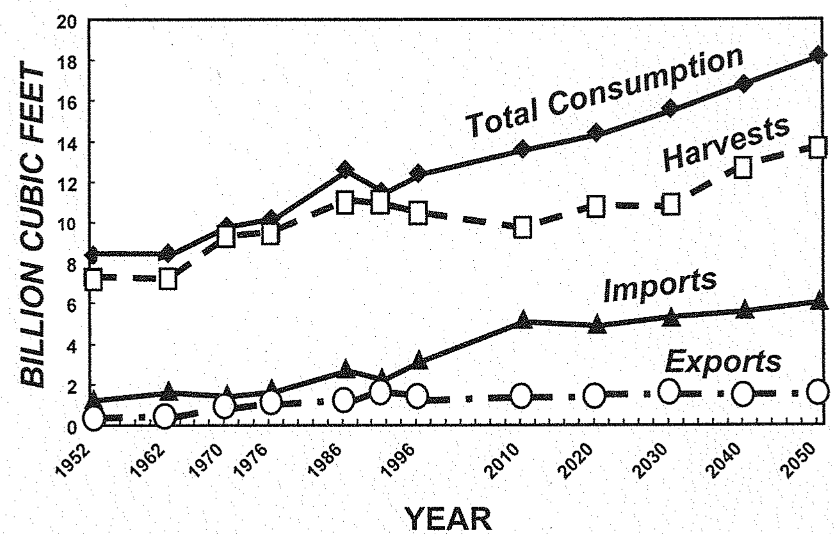

Figure 6. Historical and projected trends in total domestic consumption, harvests, imports and exports for U.S. softwoods. Data beyond 1996 estimated. From Haynes (2003).

One of the "someone's else" is our northern neighbor, Canada. This might seem an export windfall for Canada, but domestic producers were concerned that the U.S. market would be flooded by low-cost Canadian wood. Consequently, a Softwood Lumber Agreement established a tariff-quota system on imported Canadian wood between 1996 and 2001, with the tariff rising in increments as Canadian imports rose above a base level of 14.7 billion board feet. Following the tariff's expiration, U.S. producers sought and obtained continued protection through a 27.2 percent tariff on Canadian imports. Presumably, a less-favorable export market south of Canada leads to lessened harvests in old-growth Canadian forests, particularly in the west—a prospect applauded by the environmental community. But as Adams (2003) points out, our domestic demand continues, and the wood will have to come from somewhere because we are a wood-hungry nation. The tariff seems likely to lead to a depletion of softwood growing stock on private land of the U.S., or an accelerated import from other countries, or both. At the same time, the area of private timberland is projected to shrink by more than 10 million acres by mid-century as landowners turn to more profitable uses of capital (Table 2). The net effect may well be higher gross revenues for U.S. lumber producers and higher expenditures to U.S. consumers (Adams 2003).

Softwood stumpage prices largely reflect the building market, which in turn reflects the state of the national economy. If housing construction slumps, stumpage prices slump as well. But in the long run, people want wood. Or more specifically, things traditionally done *with* wood. As wood grows scarce in the retail market and prices rise to the consumer, alternative products become more attractive. Binkley (1997) showed that with each 1 percent rise in the retail cost of softwood, consumers turn to alternative materials such as cement (up 0.15 percent), structural steel (up 0.3 percent), and brick (up 0.65 percent). Alternative materials may spell short-run savings to the consumer but long-run energy costs to society. Glover et al. (2002) assembled energy costs of producing concrete, steel, and brick. Taking account of the variability in manufacturing costs for primary (raw products) and secondary (recycled) building materials, they estimated the energy costs of comparably sized homes constructed predominantly of steel, concrete, or wood (Figure 7). Homes with wood as the featured material carry far lower energy of manufacturing costs than those made of other materials. And as we shall see, one of the societal costs of energy use is the production of greenhouse gases.

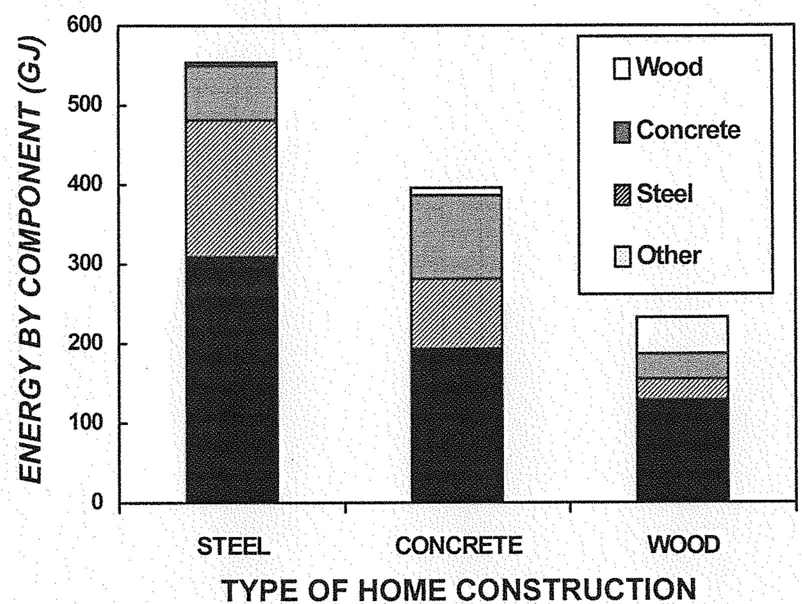

Figure 7. Breakdown of total energy costs of materials for comparably sized homes made principally of steel, concrete, and wood. "Other" materials include aluminum, copper, glass, paper, plaster, plastics, and insulation. Energy units in billions of Joules (GJ). Redrawn from Glover and others (2002).

The Global Setting: Forests in the Larger Scheme

Agencies sometimes differ in their basis for statistical data and this can lead to confusion. For example, FAO (2001) places the forestland of the United States at 558 million acres (Table 3). This seems at odds with the most recent survey of the USDA Forest Service (Haynes 2003), setting total forest cover at 747 million acres with 503 million acres classed as timberland (Table 2). The difference is due to FAO's exclusion of very poor sites and forestland with less than 10 percent canopy cover. When FAO's *Other Wooded Land* is added to that classified as "forest," the U.S. and FAO figures match. The important thing is that the standards followed by each agency be internally consistent so that trends can be examined. FAO data (Table 3) is especially useful in studying world trends. Presumably, data in Table 3 are precise for the United States, provided that we recognize that it includes lightly stocked and low productivity land.

Table 3. Comparative forest biomass of representative nations showing area of forest cover, annual change in forest area between 1990 and 2000, and forest area per capita from 1999 population estimates (FAO 2001).

Country	**Forest biomass**	**Forest area**	**Biomass per acre**	**Annual change**	**Area per capita**
	10^9 tons	*10^6 acres*	*tons*	*percent*	*acres*
Brazil	125.3	1,343.4	93.3	-0.4	7.9
Russia	52.3	2,102.9	24.9	0.0	14.3
Congo	5.1	54.5	95.1	-0.1	19.0
United States	26.9	558.2	48.2	0.2	2.0
Canada	22.3	604.1	36.9	0.0	19.5
Peru	17.6	161.1	109.3	-0.4	6.4
Indonesia	15.7	259.3	60.4	-1.2	1.2
China	11.0	403.8	27.4	1.2	0.2
Australia	9.7	381.7	25.5	-0.2	20.5

Earth's terrestrial surface—where we live—covers 58.5 million square miles. This can be divided into six major biomes: deserts, forests, grasslands and savannas, croplands, wetlands, and tundra (Figure 8). Deserts constitute the most extensive biome—30 percent of the land surface. Less extensive are forests (28 percent), grasslands and savannas (23 percent), and croplands (6 percent). Tundra and wetlands comprise the remainder, with the latter covering slightly more than 1 percent of the land's surface. Wetlands have tremendous ecological value as filters, aquifers, and wildlife habitat. But beyond that, they still would catch the human eye because of their rarity. Forests, on the other hand, are fairly common because they cover more than a quarter of the land and many take them for granted as an endurable resource. Most people understand the value of forests for wildlife habitat, wood products, and recreation. Less appreciated is the role forests have in carbon (C) storage and the regulation of global climate.

The oceans are the predominant sinks of dissolved C, storing an estimated 42 trillion tons (Schimel et al. 1995), mostly as bicarbonate. This is more than 50 times the C stored in the atmosphere as CO_2 and nearly 20-times more than occurs as organic C in Earth's terrestrial vegetation and soil. But forests vastly outweigh all other biomes in their storage of organic C. Of the 2.5 teratonnes (2.7 trillion tons) of C stored in vegetation and the surface meter of soil in

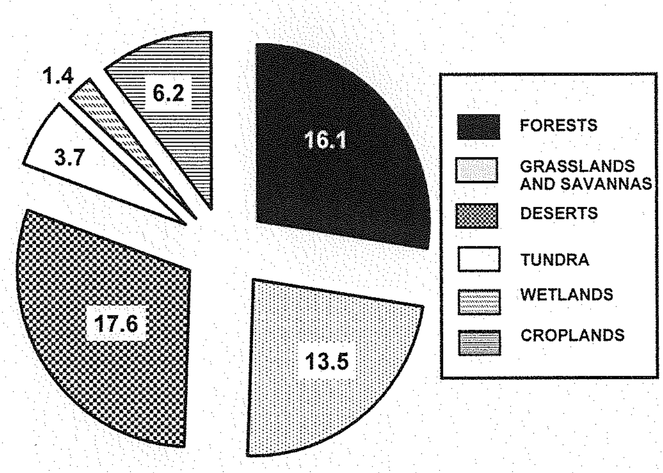

Figure 8. Distribution of the world's terrestrial biomes (millions of square miles). From FAO (2001).

all biomes, nearly half is in forests (Figure 9). Of this, roughly two-thirds of forest C is in the soil and one-third is in the vegetation (FAO 2001). Figured per unit of land area, forests are over three-times more effective as croplands and half-again as effective as grasslands and savannas in C accumulation. Only wetlands exceed forests in C storage efficiency because of their high productivity and the reduced rate of organic decomposition under waterlogged conditions. This means that forests are both a sink (through photosynthesis and humus formation) and a source (through respiration and oxidation) of atmospheric CO_2.

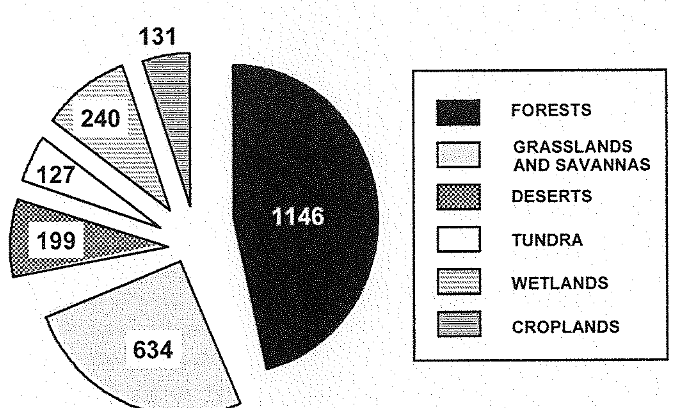

Figure 9. Distribution of the world's carbon stored in terrestrial vegetation and soil to 1 m depth (Gt). One Gigatonne = 1 trillion kg = 1.1 billion tons. Collectively, 2.7 trillion tons of C are stored in terrestrial biomes. From FAO (2001).

Carbon stored above ground in forests spells wood biomass (total dry biomass is slightly over twice the mass of organic C), but biomass is not distributed evenly among forests. Nor is it necessarily related to area in forest cover. The Russian Federation ranks first among nations in forest cover, but it trails Brazil substantially in total standing biomass (Table 3). Brazil, with an area equivalent to that of Canada and the United States combined, has more than twice the standing forest biomass of these combined nations. Australia, with a forest area more than twice that of Peru, has only half the biomass. Climate is the driver and the rule that "location is everything" applies. Countries nearer the equator (Brazil, Congo, Peru) have the greatest biomass per acre. The United States and Canada have similar forest area, but biomass per acre is greater in the U.S. because climate is more favorable throughout the nation.

Nations supporting the highest biomass per acre are targets for accelerated harvests and tend to show net losses of forest area in the past decade (FAO 2001). At present, the forest area of North America is stable or increasing slightly and China's forest area is rising at about 1.2 percent per year because of deliberate government policy. In contrast, Indonesia with a higher population density per unit of forest land is losing its forest cover at the same rate that China's is increasing (Table 3). Tropical nations have lost over 12 percent of total forest cover in the past decade, while non-tropical nations show a net gain of 2.9 percent due largely to afforestation with plantations (FAO 2001). Balancing the pluses and minuses leads to an estimated net loss of 9.4 percent in global forest area over the past decade (FAO 2001). Tropical Asian countries such as Brunai, Malaysia, and Thailand all show annual losses in forest area between 0.2 and 1.2 percent. Micronesia leads the list of Oceania countries with an annual deforestation rate of 1.4 percent (FAO 2001). Although it isn't universally true, many countries with high population densities of less than two acres of forest per capita also have high deforestation rates. High population density per unit of forest can mean exploitation of a dwindling resource. In some cases, exporting products removed at low cost is an important source of revenue. In other cases, raw forest products provide fuel for preparing the next meal. All too often, exploited forests are not replaced.

Earth's climate is warming, probably as a side effect of human activity. The principal effect of human activity on climate is the release of greenhouse gasses, the main culprit being CO_2. Atmospheric releases from coal burning have mounted almost linearly since 1850, but the rate dropped a bit after 1950 with the rise of oil as an alternative fuel source. A gross total of 530 billion tons C probably have been released to the atmosphere since the start of the industrial revolution (Grübler 2002). After oceanic and terrestrial fixation, this translates to a net atmospheric CO_2 increase of about one-third above natural levels. Grübler (2002) estimates current annual atmospheric inputs at about 7.3 billion tons C, with the largest share coming from the burning of coal and oil (about 2.8 billion tons each in 2000). Anthropogenic contributions of C to the atmosphere are small when compared with C sinks and the exchange rates between them. Yet, emissions of C from all anthropogenic sources to the atmosphere have accelerated since 1950, reaching gross inputs of 9 billion tons in 2000 (a bit under 7 billion tons net), and means are sought to reduce them. The U.S. is the world's largest player in anthropogenic C emissions, totaling more than Japan, the European Union, and Russia combined (Flavin 1999).

How are forests involved? According to Grübler (2002), C emitted to the atmosphere from deforestation peaked at about 1.9 billion tons C per year in the 1970s and is holding steady at about 1.3 billion tons C per year. Most of this comes from deforestation in the tropics, but the error of uncertainty is high. Projections are that annual C releases through deforestation will drop to 0.7 tons in the current decade (Yamagata and Alexandrov 2001). Clearly, there is a strong link between forests and C flux. Global forest cover is decreasing, and we may be encouraging it through imports. It doesn't have to be that way.

Turning Towards Home

A concept emerging from the 1997 Kyoto Protocol (United Nations 1998) is that nations may receive "carbon credits" if they can demonstrate practices that acquire atmospheric carbon faster than they are losing it through anthropogenic impacts (Yamagata and Alexandrov 2001). Forests sequester nearly half of Earth's terrestrial organic carbon (Figure 9), so forest management obviously plays a major role. Unmanaged forests either reach a steady state in which C respiration balances fixation and the forest senesces and releases C (Powers 2001, Waring and Schlesinger 1985), or—particularly in western regions—the forest is consumed in wildfire. The net impact on atmospheric C thus ranges from benign to sizable pulse releases.

On the other hand, managed forests rapidly acquire C, storing between one-quarter to one-third below ground in roots and their decay products, and this is the main means by which C is added to the soil. Therefore, carbon credits could be an effective lever in garnering support for intensive forestry practiced in a careful, sustainable way (Powers 1999, 2001). A simple web check using the keyword "carbon credits" shows that international carbon brokerage has caught the imagination of entrepreneurs in response to the Kyoto Protocol. Objective managers should be skeptical of the scientific basis of carbon brokerage claims. But conservatively, reduced deforestation, fast-growing plantations, and agroforestry could contribute 12 to 15 percent towards offsetting global C emissions. This is a selling point for active forest management and the expansion of plantations to non-stocked sites.

Fire—prescribed or wild—consumes vegetation, releases greenhouse gases, and affects soil properties. Even mild underburns in thinned pine forests can reduce soil organic C and nitrogen for long periods (DeLuca and Zouhar 2000). California's pine-oak-mixed conifer zone has the highest fire return interval (5-10 years) of any Sierra Nevada forest (Skinner and Chang 1996), and probably of any forest timber zone in western North America. The problem is exacerbated by a woody shrub understory. On poor sites, severe shrub competition can suppress stand development to the point that a forest never emerges (see McDonald and Powers, this volume), leaving the hammer cocked and the finger on the trigger for the next conflagration. Even if site quality is high enough that trees eventually overtop shrubs, dead fuels stretch from the ground to the tree canopy, creating ladders ripe for combustion. Data from brush-choked stands of pole-sized pines at Whitmore (Shasta County) and Challenge Experimental Forest (Yuba County) show that for understory fuels alone, C levels vary between 14 and 19 tons per acre (Powers, unpublished). Computer simulations of global change phenomena indicate that fire severity and C losses will increase in the west because of higher fuel loadings from more frequent wet-dry El Niño-La Niña cycles (Bachelet et al. 2001). Lacking vegetation control, the stage is set for wildfire and pulses of C to the atmosphere. Therefore, the problem is apt to worsen.

Is There Hope for California?

I believe that forest management is absolutely essential to California's well-being, but that active management teeters on a knife edge. Ensuring that active management continues depends on a more positive attitude by the public and the regulatory bodies representing them. Is it less responsible to harvest wood in a state that has the strongest environmental regulations in the nation than it is to import wood from regions with fewer environmental safeguards? The answer seems straightforward, but perhaps as professionals we need another tack in describing what forests do for society and what will happen if active management declines. Perhaps the persuasive key is the single thread that links all of us, *carbon*. California forests—trees, understory, soil—are immense reservoirs of carbon. Managed reasonably and proactively, forests will continue to acquire C through rapid growth. There is no risk that we will run out of forests because of overcutting. Sustained yield plans, mandated by the strongest forest practices act in the land, ensure that California harvests will not exceed growth.

Harvested wood products detain organic C from becoming CO_2 for decades. And the thinned forest that remains will acquire atmospheric CO_2 at an even more rapid rate. Even if residues are burned for energy production, the release of C to the atmosphere is benign because that's where it came from originally. Further, the contribution of wood residues to energy production will offset to some degree the energy traditionally produced by the burning of fossil fuels. New forests (again, mandated by law after final harvest) will begin to acquire C rapidly. This will occur both above ground in boles and crowns, and below ground in new root systems growing alongside the old roots from the previous stand. The trick in establishing a new stand from the standpoint of C is to minimize respiration and oxidation. Residues must be handled wisely so as to lessen the need for high intensity slash burns. This may mean whole tree yarding with residues chipped for energy production, or returned to the site as either a surface mulch, or worked into the soil during site preparation (Powers et al. 1999). Whether managing for C is good business economically awaits the politics of carbon credits. But it *is* good business ecologically. And that may catch the conscience of the public.

Unmanaged forests in California most certainly will burn, and it's not likely that we will return California's present forests to the "open, park-like stands" thought to be common before the onset of European culture and fire control. Many of us make our home in the forest and rural communities, and individual dwellings are now part of the equation. The clock moves ceaselessly forward and the best we can do is to manage forests in such a way that fuel loads are light, fuel ladders are rare, and both natural and societal values are protected. Remedying the problem after the fact is prohibitively costly, and preventative medicine seems much more potent. The first dose of preventative medicine is to establish vigorous stands. As witnessed by 24 years of FVMC history, the key to doing that in California's Mediterranean climate is the early and vigorous control of understory vegetation, particularly woody shrubs. Fortunately, this has been a *raison d'etat* of the Forest Vegetation Management Conference since 1979. And that's why FVMC is important to the practice of forest management in California and in regions beyond.

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