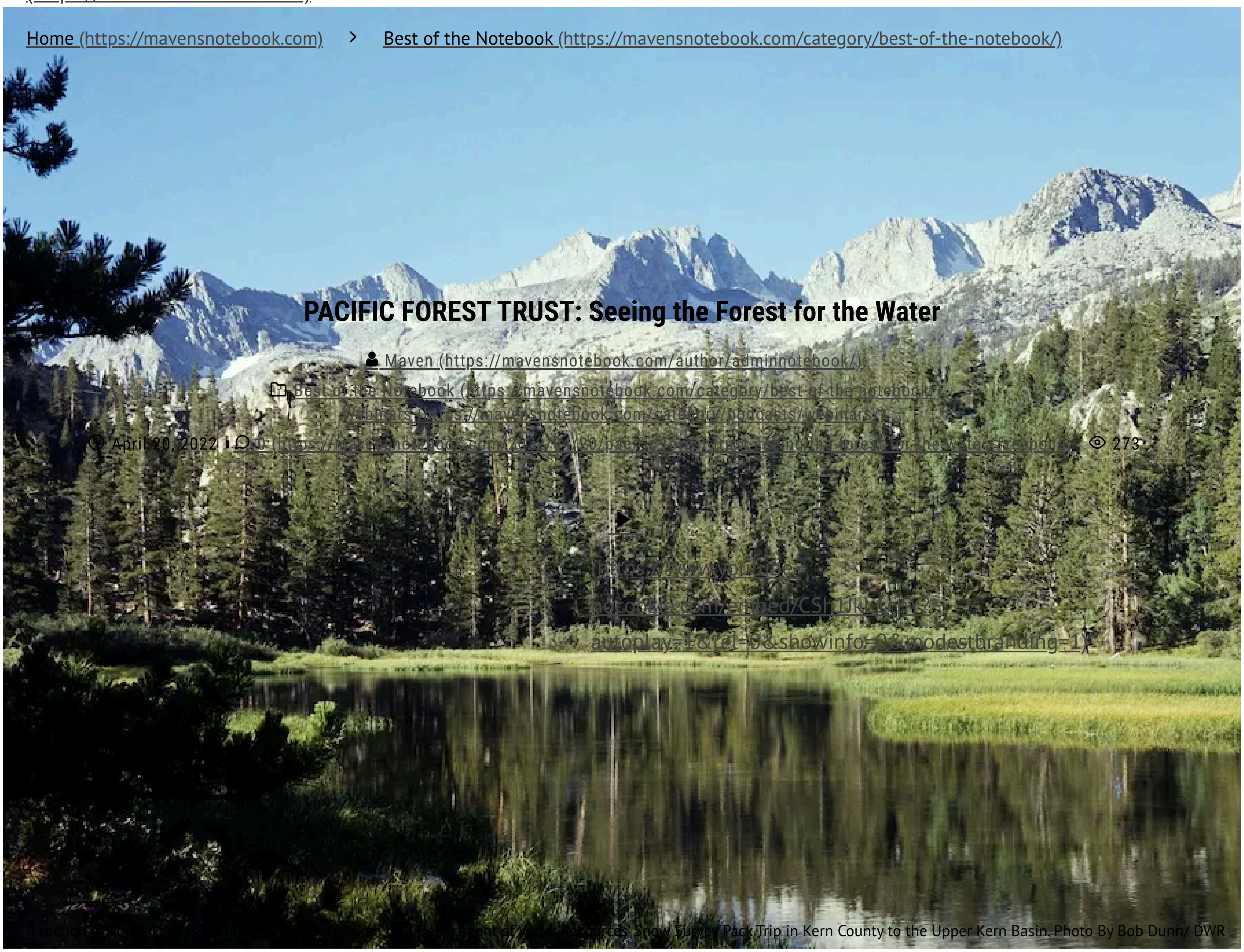

PACIFIC FOREST TRUST: Seeing the Forest for the Water

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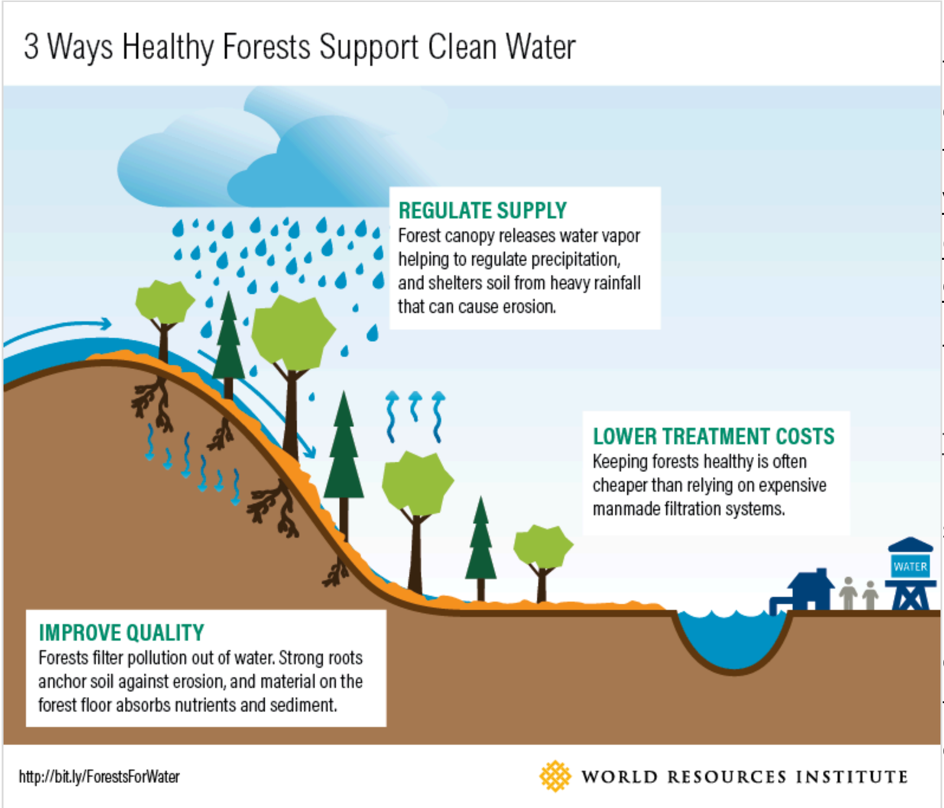
... Department of Water Resources Snow Survey Pack Trip in Kern County to the Upper Kern Basin. Photo By Bob Dunn/ DWR

When an ecologist, a geographer, and an engineer walk into a watershed bar, what do they talk about?

(https://i0.wp.com/mavensnotebook.com/wp-content/uploads/2022/04/Forest-Water-World-Resources-Institute.png?ssl=1)Most of us recognize that when you ask resource managers, 'What do you need out of forests? What do you value out of forests?' the top priority is almost always water. And so that leads to the question, if water is an absolute top priority, do we



manage our forest watersheds for that function? If we do, what do we do? If we don't, Why not? And what are the practices that we're doing that don't support watershed (https://mavensnotebook.com/glossary/watershed/) function?

Those were the questions posed at a recent webinar from the Pacific Forest Trust (https://www.pacificforest.org/) that brought together three pre-eminent scientists with deep experience in the management and science of forest hydrology and watershed function to discuss their work understanding how forests function as watersheds and the effects of land management.

The Pacific Forest Trust is an accredited non-profit conservation land trust that advances forest conservation and stewardship solutions. Its mission is to sustain America's forests for their public benefits of wood, water, wildlife, and people's well-being, in cooperation with landowners and communities.

Laurie Wayburn, Co-founder and President of the Pacific Forest Trust, was the moderator for the webinar.

The panelists:

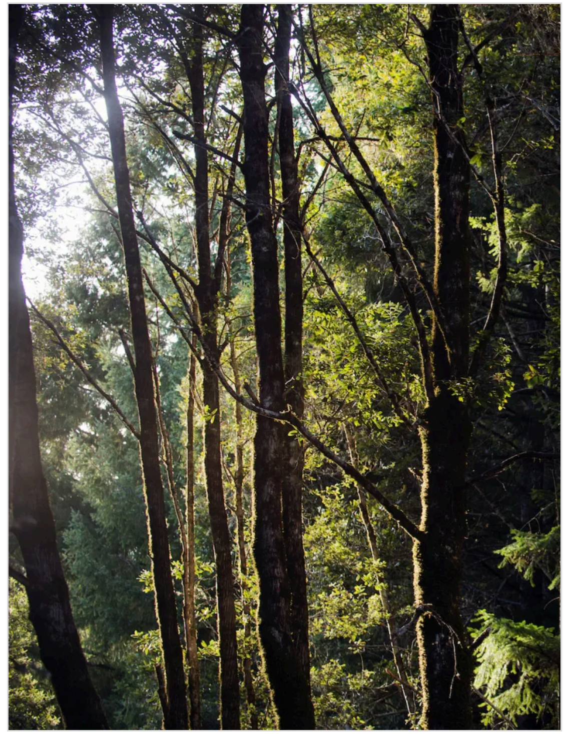
> **Dr. Jerry Franklin** (https://www.washington.edu/news/people/jerry-franklin/) is a professor emeritus at the University of Washington's School of Environmental and Forest Sciences and a world-renowned forest ecologist who has been called "the father of new forestry." He is a leading authority on sustainable forest management and maintaining healthy forest ecosystems and was responsible for integrating ecological and economic values into harvest strategies.
>
> **Dr. Roger Bales** (https://www.rogerbales.com/) is a distinguished professor of engineering and a founding faculty member at UC Merced and has been active in water- and climate-related research for over 35 years. Currently, his work focuses on California's efforts to build the knowledge base and implement policies that adapt our water supplies, critical ecosystems, and economy to the impacts of climate warming. He has served as Director of the Sierra Nevada Research Institute, the Southern Sierra Critical Zone Observatory, and the UC Water Security and Sustainability Research Initiative.
>
> **Dr. Julia A. Jones** (https://ceoas.oregonstate.edu/people/julia-jones) is a professor in the Department of Geosciences at Oregon State University. She teaches graduate and undergraduate courses related to spatial statistics, landscape ecology, and geographical analysis of watershed dynamics. Her research interests include the hydrological effects of road networks in National Forest land, roadside plants, physical stream processes, and the spatio-temporal analysis of ecological and physical processes at landscape to regional scales.

Here's what they had to say, edited for clarity.

QUESTION: Ms. Wayburn turned first to Jerry Franklin, noting that he has been called 'the father of modern forest ecology,' otherwise known as Obi-Wan Kenobi of the forest. And of the trio that walked into the bar, he's the ecologist. Ms. Wayburn asked him to talk about how forests function as watersheds, why that is a good proxy for overall forest health and function, and his thoughts on how we've managed them (or not) for watershed function.

Dr. Jerry Franklin: I want to begin by saying that arguably the most important service provided by forests and forest landscapes is their role in providing us with a well-regulated flow of high-quality water. And I think that's going to be very true in this century.

It's probably a much more important service than, for example, the provision of wood. And we certainly want, as a society, well-regulated flows of high quality water, and that's what we typically get from a properly forested landscape. We don't want the water, but we want to do whatever we can to mitigate the potential for flood flows; we certainly don't want to do things that result in extremely low flows or intermittent flows. And forests are absolutely critical in participating in the hydrologic cycle that results in having a well-regulated flow of high quality water.



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Northern California's Grizzly Creek Redwoods State Park along Highway 36 in Humboldt County. Photo taken October 2, 2013. Carl Costas / DWR

Unfortunately, of course, we have grossly modified the ability of our forest landscapes to do that – at least most of our forest landscapes. We've done it in a number of ways. I will note, however, that we have made progress in recent years in dealing with the streams and rivers themselves, the channels through which the water flows, the network. And we've realized, I think largely because of the importance of the stream itself for fish, to begin to deal with it.

But unfortunately, dealing with streams and channels by using buffers, which is one of the typical approaches used in restoring structural complexity, is insufficient. So we have to be aware that in terms of stream flows, we have to be concerned about the condition of the entire watershed because it's that entire watershed that's going to be intercepting precipitation, transpiring water, and so forth. And we have modified the bulk of our forest landscapes in ways that make the forest quite injured in terms of its ability to play a proper role.

It's equally true in the moist forested regions, such as the forests of Western Washington and Western Oregon, and in the very dry forests in the interior regions and the Sierra Nevada. And the problem is basically one of densification, although we've done it in different ways.

With the dry forest or the frequent fire forest landscape, we've done a whole series of things, including, of course, the exclusion of fire, but we also did a tremendous amount of activity and logging and prevention of the natural fire regime in those areas. And as a consequence, we've converted those forests to dense fire-prone stands, which definitely are not the kind of conditions that existed originally, which was much more open, old tree-dominated forest systems that did a wonderful job of regulating the hydrologic cycle.

In the Douglas Fir moist forest landscapes, we simply cut down all the natural forests and replaced them with plantations composed of very dense stands of conifers, which are very heavy water users and utilize more water than the natural forest did.

So in the case of both kinds of landscapes that have been dramatically altered, particularly the stream flows and the low flows that are so important, those summer low flows are often critical from the standpoint of water quality and their ability to support fish.

Obviously, we need to think about how we begin to modify that forest cover to restore it to a condition so it can function as it did, historically, prior to all the modifications that we did. There are ways for us to begin to do that. And most profoundly with developed approaches to restoration on the east side, the dry forests in the Sierra and forests that can help us do that.

Ms. Wayburn: One of the things you're pointing out is the impact of forest structure or forest management impacts on the structure, water flow, quantity, flow regimes, and water quality. Many people think of stream buffers as sufficient to deal with water issues around water quality, and they are not really thinking about forests as storage in and of themselves.

QUESTION: One of the areas that Dr. Bales has focused on is helping us understand that the whole forest stores water, not simply wet meadows. Many of us have heard of the importance of wet meadows in the near term. In the last few years, and in California in particular, there has been a big emphasis on wet meadow restoration within forests, but less discussion about the forest itself that feeds the wet meadows. Would you share some of your work about understanding the balances between trees, temperature, precipitation, and evaporation – all of which add up to water in forests?

Dr. Roger Bales: I'd like to discuss some of the work we're doing in the Sierra Nevada, and I'm going to put it in a multi-benefit analysis framework for forest restoration.

I'm working with two partnerships to provide better wildfire protection through fuels treatments and better restoration, mainly on public lands. I started researching water in the Sierra Nevada back in the 1980s when we were assessing acid deposition in mountain lakes. Then with the maturing of satellite data in the 1990s, I worked on snow cover, snowmelt processes, and improving estimates of water storage in watersheds, along with predictions of runoff.

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Shortly after my spouse and I came to start UC Merced in 2003, we established the Southern Sierra Critical Zone Observatory, where, by now, dozens of scientists have done research on water, vegetation, soils, and climate processes. It's the place where we're able to take a systems view of the watershed.

We were fortunate to have measurements at the right place at the right time to learn from the four-year dry period that began in fall 2011. It was a great experiment for researchers. We saw declining water use by the forest as the drought progressed, along with the gradual depletion of root accessible water storage in areas with up to 100% conifer mortality.

Our productive mixed conifer forests are possible because they can draw stored water from several meters down. They've experienced multi-year dry periods in the past, but our 21st-century dry periods are becoming more severe than those of the past millennia. They are hotter and the trees need more water.

From these small watershed studies, we've developed tools to predict the drought resiliency of our mountain forests. We now have credible independent measurements of annual forest water use, scaled across the state at a 30-meter resolution for drought, wildfire, or management actions.

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The beautiful and lush Indian Valley in the Sierra Nevada Mountains of Northern California. Dale Kolke / DWR

Therefore, our response variables are evapotranspiration (https://mavensnotebook.com/glossary/evapotranspiration/) and runoff, which is estimated as precipitation minus evapotranspiration. We think we're bringing to the table probably the best estimates of evapotranspiration that are available or have been available.

Let me briefly mention the meadows and riparian areas, which provide important habitats and can have high biodiversity. The upslope forest discharges water through the subsurface to keep streams flowing and meadows wet. Yet, in the summer dry period, as the level of that subsurface water in the forest drops due to both drainage and use by the trees, streamflow declines, and meadows also dry up. Another challenge with riparian areas is that they have so much fuel compared to the surrounding forest that they become the corridors for high severity wildfire. We see this across the Sierra Nevada.

Now back to multi-benefit analysis. This is very important for water. Regional partnerships bring together multiple stakeholders who have an interest in healthy functioning watersheds.

There are at least three different types of interests in these partnerships.

> **First are the people as the state and nation.** We all have an interest in wildfire protection and how smoke affects health, recreation, and so forth.
>
> **The second are the property right holders.** I'm not focusing so much on landowners, but those with water rights as water rights are property rights. So water supply and hydropower providers benefit because if a forest has fewer trees, it uses less water, which can translate into more runoff. These agencies then pass on the additional water and electricity to downstream users.
>
> **The third would be the rural communities.** I call this out as a special category because our state's committed to rural communities, and they are part of what makes California what it is.

We also talk about natural versus working lands. Our so-called natural forests and grasslands are also important though as working lands. They face three large drivers for change:

> **First is the overriding need for better fire protection.** With wildfires severity depending on climate and fuel, our immediate management actions are mainly aimed at fuel levels. Many of our forests are too dense with too many stems per acre and are vulnerable to high severity wildfire.
>
> **The second key consideration is habitat**, which depends on more than just fire protection. At a minimum, fuels need to be done to maintain the biodiversity that life on earth so heavily depends on. In California, we have the 30 by 30 initiative to help us move in that direction.
>
> **Third, we're asking more of our working lands**. We want them to sequester more carbon and thus take carbon dioxide out of the atmosphere. A recent report suggests that by more actively managing the state's forests and developing fossil fuel replacements from forest biomass, we can meet about half of California's carbon sequestration needs.

[Water supply reliability] and cobenefits are integral parts of these three drivers for change.
So how do we sustainably manage our forests going forward? I think of sustainability as a three-legged stool:

> **The first leg is ecological integrity and resilience.** We need to restore the health of these watersheds, the health that existed prior to the massive in-migration of the 1800s to California. We've been borrowing from our natural capital, and the bill is now due.

The second leg of the stool is human well-being or ecosystem services or watershed benefits. That is the water as well as recreation, forest products, jobs, income, and so forth that people depend on. So a very [active area] of our research is studying benefits, especially water benefits, that far outweigh the costs of restoration that's going on now.

The third leg of the stool is environmental justice or equity. This can include equity for rural communities but also equity for future generations. What sort of landscapes are we leaving to our children?

I have two closing thoughts. First, through multi-benefit partnerships that include water interests as key partners, we have the resources to manage our watersheds sustainably, even in a warming climate. And second, though our knowledge of how to do those isn't perfect, it's actionable.

Ms. Wayburn: A couple of things that you're pulling out there. Number one is the ecological integrity that benefits water and habitat and reduces fire risk that, when done right, will also enhance net carbon stores as well as benefit both humans and wildlife.

QUESTION: Dr. Julia Jones brings a unique perspective of the longer-term impact of management on forests for watershed function. We, as human beings, think long-term may be in decades, and of course, forests live for centuries and sometimes millennia. So the question of what is long-term is certainly one we can think about. But to the degree that we can think long-term, Julia has done that. And she's really put some time into this question of the difference in response between planted forests and natural forests and how they function in terms of water yield, timing, and quality. Could you tell us what you have learned from these longer-term evaluations of how forests respond as watersheds under management?

Dr. Julia Jones: I have benefited greatly in my scientific life from long-term experiments on watersheds. And I'd like to acknowledge that some of the key experiments that I've continued to look at, which now have 70-year histories, were ones that Jerry worked on in the early part of his career.

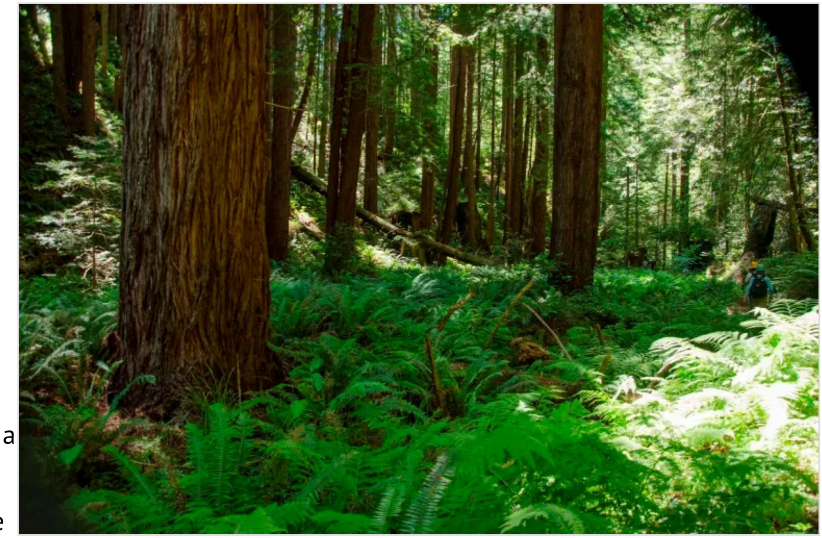
Much of the science I'll talk about has been conducted on public forest lands, national forests, and US Forest Service experimental forests. These long-term experiments can tell us about change over our entire lifetimes and also give us a window into how the watershed functions and how that may change over hundreds of years.

In Oregon, we have a number of paired watershed experiments established as early as the 1950s. These paired watershed experiments involve establishing a reference watershed in mature or old-growth forests and then imposing a treatment, usually cutting some or all of the forest with roads or maybe not roads, or maybe with a riparian buffer or not, and then examining how the streamflow changes in the treated watershed relative to the reference old-growth or mature forest.

Experiments of this type were also established throughout much of the eastern United States on Forest Service experimental forests in the 1950s. And experiments of this type have been established elsewhere around the world, including more recently in intensively managed non-native tree plantations in South America.

From these long-term experiments, we can learn how past management and current management affect water yield and streamflow. Essentially, the basic results are that old native forests both provide more moderated stream flows and higher and generally predictable water yield, as well as storing more carbon and having a lot more biodiversity than our planted forests, which are typically single species and highly managed.

This varies a little bit with geography. For example, in the Pacific Northwest in Oregon, replacing old forests with planted the young forests has reduced summer water yield by as much as 50% from July to September, compared to what the old forests are producing. And in South America, the replacement of native forests with intensively managed species of non-native eucalyptus or radiata pine – those plantations have been shown to evapotranspire 90 to 95% of incoming precipitation with rather dramatic effects on streamflow to downstream communities, both aquatic communities and human communities that depend on those for water sources.



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Caspar Creek Experimental Watershed, Jackson State Demonstration Forest. Photo by USFS

This has become a global political issue, which means that there's a lot of attention focused now on forest restoration. And so the question then becomes, how can we restore forests for water? Interestingly, that is a conversation that is really just beginning. So this webinar is rather prescient in that respect because the effect of forest restoration on water really depends on the type of restoration you're referring to.

There are lots of different things that people do with forests that are called restoration. Most notably, in the middle of the last century, there were many cases where forests were planted as a form of reclamation of degraded lands with the goals of producing timber, for example, or reducing erosion. But in the vast majority of cases, we now see after decades that those forests also have reduced streamflow and that has led to a shift in the forest restoration concepts. So now, the contemporary guidelines for forest restoration focus more on rehabilitation or reconstruction, where rehabilitation is defined as desired structure and species composition and processes, and reconstruction is the reestablishment of native plant communities.

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The Cleveland Fire plantation shows the need for treatments in this 22 year old plantation that now has quite a bit of fuel, with interlocking crowns and crowns near the ground. Photo by the USFS.

The most interesting experiments looking at this that I know of are actually in South America, where intensively managed forest plantations of non-native eucalyptus have been cut down, and native tree species have been planted or allowed to seed in an effort to restore the structure, the species composition, and the watershed function of native forests. Those experiments aren't very old; there are maybe ten years of post-treatment record, but they show very promising increases in water yield, including during the dry season, which is characteristic of some of those areas.

That's leading to a lot of creative forest management ideas in South America about promoting the reintroduction of native species as part of managed forest landscapes. But it remains unclear how those experiments will evolve in terms of their water yield or streamflow over the longer time period as those forests grow and as the climate continues to change.

I will also comment that in Chile, where some of these experiments are underway, for 20 years, they have had a policy of using very generous riparian forest buffers in their managed forest landscapes. But these reductions in water yield and streamflow have occurred despite the existence of the riparian forest buffers. That is echoed in Oregon; in Western Oregon, where intensively managed, planted Douglas fir forests have been clear cut, but a narrow riparian buffer has been retained of the fast-growing densely planted Douglas fir forests, we don't see any increase or very little increase in water yield after the clear cutting. This gets back to what Roger was saying about the subsurface flow of water throughout the whole watershed and how we really need to consider the entire watershed and its vegetation structure when we're thinking about watershed function.

Ms. Wayburn: All three of you have flagged that the current density of our forests is not helpful in terms of watershed function. If we look at the history of forest management, it tends to go in one direction, then another direction, and then another direction. And at present, there's a tremendous amount of interest in forest thinning and the relationship of thinning to fire. So you've all three flagged that reducing current densities would help watershed function. And since funding for things like thinning tends to be a political decision, the concern that many might have is that we might say, 'we've thinned it, we've taken care of the problem. Everything will be better now.'

Is that approach sufficient? Is combining the approach of fuels thinning and buffers sufficient for watershed function? You indicated that you think more than that is needed. But I also would appreciate some discussion of the role of fire in this. I know it sounds kind of biblical: water, fire, and forest. But there's a conjunction here that I would appreciate if you could comment about how you see the role of thinning from a temporal perspective. Is it enough to do one and you're done? Overall, do we fundamentally need to change what we're doing in the forest landscape? And how does that relate to fire impacts?

Dr. Jerry Franklin: There are all kinds of thinning. And if, in fact, all you're doing is reducing the density of the plantation forests, you're probably not going to have a whole lot of impact because all you're going to do is transfer the leaf area. So it's doing the transpiration from more trees to fewer trees, but they're still going to be evapotranspiring as much essentially.

Further, in the dry forests, we really need to be altering the structure much more significantly than simply reducing the density. First, we need to be thinking about the composition of that forest. It isn't just a matter of thinning any trees; we want, in fact, to reduce the more fire-prone firs in favor of the more fire-resistant pines, for example. And we also want a forest that is predominantly dominated by large trees as opposed to small trees. And those are things that thinning can contribute to, but it has to be explicitly focused on trying to redevelop that low density, old tree-dominated structure that was characteristic of the fire-resistant dry forests.

Dr. Julia Jones: That is consistent with what we are observing in the wet forests of Western Oregon. We had an accidental thinning in one of our paired watershed experiments; about 12% of the basal area, which is sort of the sum of the areas of all the trees, was removed, and it made a short-term difference in the summer deficits. Then by five or six years later, the deficits were just the same as they were in a nearby planted forest watershed that hadn't had thinning, so that corroborates Jerry's comment that if you have a densely planted forest and you thin by taking out the smaller trees, which is what thinning typically does, but you retain this uniform canopy with a complete canopy cover leaf area, you're probably not going to make a long term difference on streamflow.

In fact, some of the research that's just now emerging from the Andrews Forest in Oregon shows that when you have a dense forest canopy, so lots of stems of trees and all the leaf areas up at the top, that actually influences local winds in such a way that you can get downslope winds under the forest canopy that may accelerate, as well as turbulence above the canopy that may accelerate moisture loss from the canopy. So, Jerry's comment that we need forest structures that are more diverse rather than a single canopy is a really important comment.

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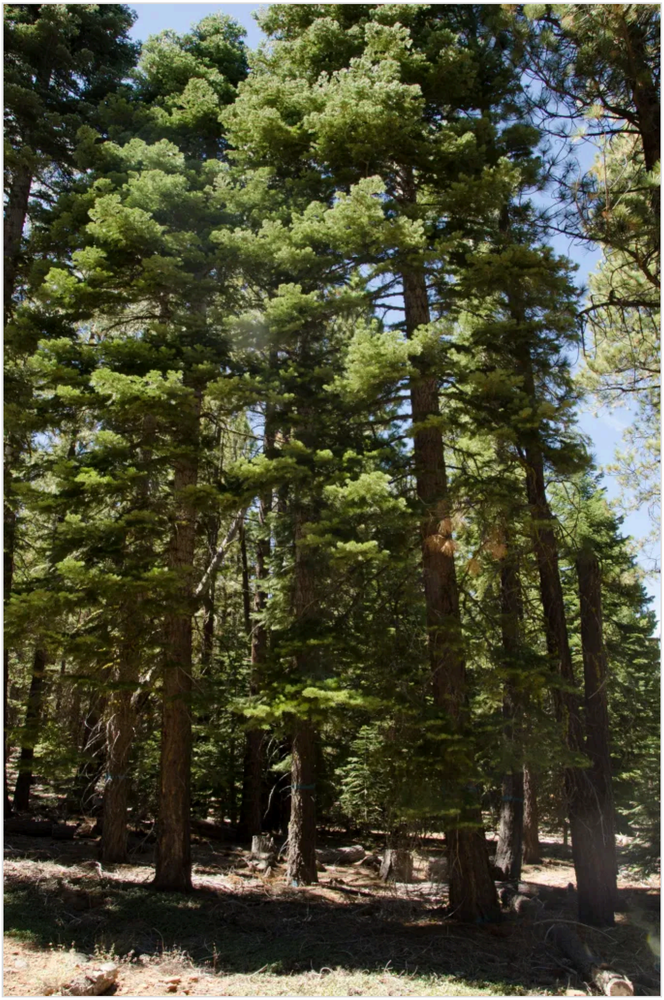
Fuel load management work, including controlled burns, is conducted by CalFire in conjunction with DWR, as part of the fuel load management program which reduces fire risk, protects public safety, and enhances forest and watershed health. Photo by Kelly M. Grow / DWR

Then the other thing I'll say is that we need more deliberate experiments to look at the consequences of thinning. So, for example, at the South Umpqua Experimental Forest in southwestern Oregon, we've had about ten years of planning of an experiment that will do thinning in both the slopes of a 50-year-old planted forests and also some in the riparian zone, which is hugely controversial. But this is a place with long-term data on stream temperature. So over the next decade or so, we may gain some insights both into how thinning affects water yield, but also whether it can be done in a way to protect stream temperature and water quality.

Ms. Wayburn: Something that Julia has pointed out has also been corroborated by research in snow systems that have snow as a significant part of their precipitation. Closed-canopy, even-structured forests can lose up to 70% of their snow to evaporation as it sits on top of that dense-packed, even surface. So that more open, diverse structure in forests that have some tough trees that are big and tall, some that are medium, and some that are small with openings actually allows the snow to infiltrate down to the ground and then be held in shaded areas and later melt and release.

But that structure also creates more physical turbulence when there are clouds, mist, and/or fog, so that those forest structures can help 'milk' more precipitation out of the air. So this issue of how you do thinning really matters for a long-term outcome. Roger, can we get your take on that complex issue and the fire issue you flagged? And the riparian versus the whole forest?



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Treated forest area. Photos by the USFS

Dr. Roger Bales: The thinning projects that I'm involved in and in the Central Sierra and Northern Sierra focus on fuels treatments for wildfire protection, but they basically provide benefits to the other ecosystem services too. We've done both our own assessments and interviewed lots of resource managers, and fuels treatments have lots of secondary benefits, including more water available for runoff.

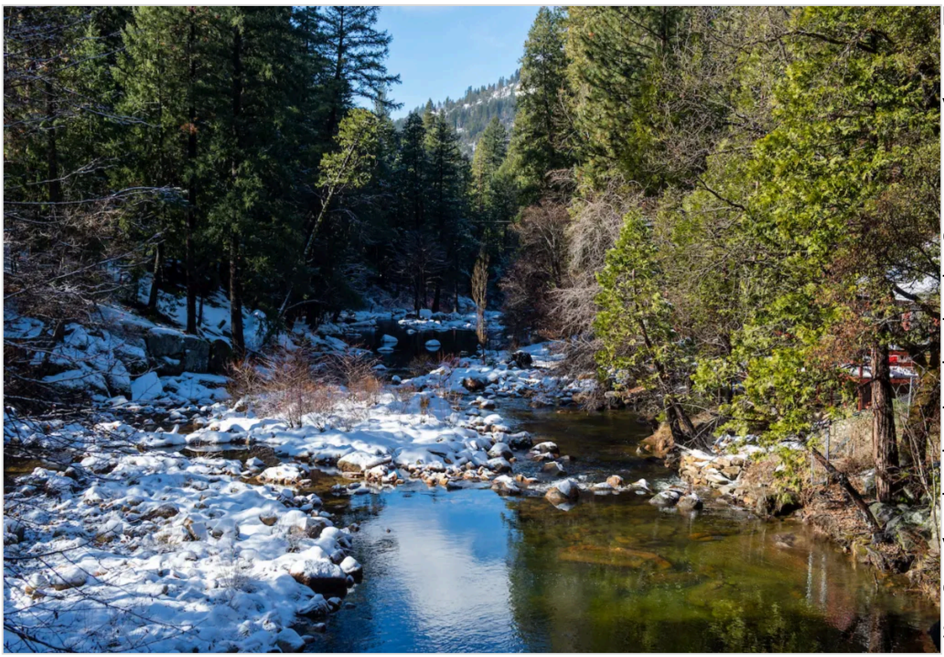
As for restoration treatments, the scenarios I've been using working with people for planning involved maybe removing half of the biomass of the small trees, but leaving 75% of the canopy in place – the large trees. If you can come in with controlled burns after that, removing at least half of the shrubs and the ground fuel, all that together gives you a forest that can produce much more runoff.

But the forest regrows back with time. We've analyzed dozens or maybe a few 100 disturbances, either medium severity wildfire or equivalent management actions across the Sierra Nevada. Of course, the forest grows back. Using LANDSAT data from 1985 to the present, we can track that within between 15 to 20 years, the water use is often back to what it was before the treatment or the disturbance. The biomass may take a little bit longer to get there, and there's a lot of scatter in the data. But, at this point, I would encourage any land manager to be tracking evapotranspiration and biomass on an annual level because the data are available now to do that.

Laurie Wayburn: There's a relationship between what you're talking about of annual data and then how that accumulates. One of the things that I hear from all of you is that these younger, faster-growing forests need more water. And the older forests, which may have in total more biomass, normally do have more biomass, but it's just in fewer larger trees that are spaced, are going to be able to release more water in the summer than the younger plantation forests are.

QUESTION: You've been given the magic wand, and you can make any recommendation that would be followed to restore and maintain watershed function to provide that more reliable, clean, cool water throughout the year. What would you do?

Dr. Jerry Franklin: I would develop a very aggressive program of restoration in both the dry and the moist forests to restore more diverse and structurally complex systems. It's particularly important to do this in the dry or frequent fire landscapes where you have an opportunity to treat a green forest before it turns black.



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A view of the South Fork American River in the El Dorado National Forest in California's Sierra Nevada on January 15, 2016. Photo by Kelly M. Grow / DWR

Dr. Roger Bales: I would put the water benefits into a regional partnership. I would encourage and incentivize regional partnerships that can bring the multi-benefit perspective and, thus, develop creative financing to manage our forests for multiple benefits, and water will follow. Water will be an important part of that. I don't see us optimizing the forest for snow retention, but removing a lot of the small trees gets rid of a lot of the heat that melts the snowpack and causes tree well, so it will benefit, as long as we don't open it up completely so that we get the sun on the forest floor. So the multi-benefit perspective, people will come up with the resources. I think it's been shown people will come up with the resources and creative multi-benefit approach, which will give us the water benefits.

Dr. Julia Jones: I think we have a societal need to change our relationship with disturbance. We have had catastrophic wildfires in much of western Oregon in September of 2020. The uniform reaction was that we have to cut down on all the burned trees, which still retained something like 98% of the carbon on that site; we have to replace those areas and rapidly get them into even-aged young plantation forest again. And that response is probably not what we need either for carbon sequestration or water yield.

It's this fairly fundamental human response that a disturbance, such as a windthrow or when snow knocks over the canopy or fire, we have to go in and fix it somehow. Whereas, if those processes were allowed to proceed uninterrupted, those processes may very well produce more sustained, high-quality water yield and eventually a more diverse forest.

Ms. Wayburn: One of the questions we posed was, if we aren't managing for watershed benefits, why not? And I think all of you are implicitly answering the question, which is that financial return from forests comes from timber and other fiber-type product harvest. And it is also why we harvest to capture value after fires or other disturbances.

QUESTION: Roger pointed out that when we involve the water contractors and water agencies in the equation differently, there may be revenues to help pay forest landowners and other forest managers in the public system to do that. One question we have refers to money precisely that way, flagging that there are literally billions of dollars in the federal budget to work in forest restoration over the next years. You've given some indications of how you think that money would be best spent. But the question is, how optimistic or pessimistic or worried might you be that the money will be well spent for those watershed functions?

Dr. Jerry Franklin: I think it will be a mixed bag. It almost always is when you have those kinds of resources. But, of course, the agencies are also burdened by the fact that they don't have a sufficient workforce anymore to very quickly increase their workforce so they can optimally use all of that money. So I am of the opinion that some of it will be used very effectively, and some of it will be used to do the more traditional forestry responses, as opposed to ecologically focused responses. The tradition of foresters and forestry agencies is it's all about wood, and it's not all about wood anymore. It's all about water. And that is not going to be fully reflected in the restoration activities that go on.

Dr. Roger Bales: A several-university team worked with the Forest Service a few years ago in California, helping them put in place a better adaptive management (https://mavensnotebook.com/glossary/adaptive-management/) framework that involves the public. I think that's the right approach. We're in an adaptive management situation. There are real capacity issues; people just don't have the time or resources to bring in the best science. We have better science now than we did a decade ago, even to help inform ecologically-based forest management. But we have to build the capacity to use that.

(https://i0.wp.com/mavensnotebook.com/wp-content/uploads/2022/04/Instruments-in-the-forest-USFS.jpg?ssl=1)**Dr. Julia Jones:** I will simply echo that the multiple benefits of forests extend over very long spatial and temporal scales. We studied 60 years of change in streamflow into and out of 25 major reservoirs in the Columbia River Basin, which is a huge area. And over that 60-year period, there has been declining incoming water in the summer, which may in part be due to intensification of forest management in some of that area as well as climate change.

The interesting thing is that when we presented those results to the Army Corps of Engineers and the Bureau of Reclamation, and other reservoir managers, we showed that they had been compensating for those long term changes in reductions, but they didn't know they were, because it wasn't part of their mission.

I recently read that Lake Powell is close to falling below the minimum pool that would allow it to produce hydroelectricity for a huge area of the Southwest. And so the question that is raised is, is water connected to all these other benefits? And what could be done to forests in the upper reaches of the Colorado River that could possibly help mitigate these long-term changes driven by much larger forces, including climate change and increasing demand for water and electricity by people? So it's a pretty big issue.

Ms. Wayburn: It is a big issue. The relationship of agencies that were established to fundamentally put water to productive use, which is what the Bureau of Reclamation has focused on, and other agencies that were charged. For example, the Forest Service was established to protect watershed benefits. But there's no linkage between the funding for the work of the Bureau and the work of the Forest Service; there is no formal linkage between water users and watershed managers. And closing the loop between those two things so that there is a direct payment system back into forest management on a consistent basis for water is really in the power and water beneficiaries' self-interest.

There is a law within the state of California to enable that. But it will take time to realize the optimism in terms of that, just given the politics of water. As the old saying goes, 'whiskey is for drinking and water is for fighting.'

QUESTION: Can you explain how larger trees impact water release in the summer? Why is it that older, larger trees release more water in the summer? Do they use less water than lots of little young trees?

Dr. Roger Bales: You want the engineer to talk about forestry? I can measure the phenomenon, but I can't explain it physiologically. What we saw during the drought is that as the water level drops in the root zone, some of the trees start to shut down. Some of them shut down completely during the drought, and that's when the bark beetles found a very good environment for further activity and killed the trees. So as a hydrologist, I would say it's because the roots can't access as much water.

(https://i0.wp.com/mavensnotebook.com/wp-content/uploads/2022/04/King-Fire-USFS.jpg?ssl=1)

King Fire photo shows some of the burn in the early stages of the fire when it was not as high intensity and thus the fire actually did some good ecological work. Photo by the USFS.

Dr. Jerry Franklin: It's fairly complex. But in summary, the old Douglas Fir trees are much more efficient in their water use. They not only access more water, but they do a better job of regulating their transpiration than the young trees do. So they're just much more efficient in their use of it, even though the older forests have more leaf area, which is very interesting.

Dr. Julia Jones: That has been corroborated by measurements of sap flow, which is the water going up to transpiration in young planted forests versus old forests. That the young planted forests, on a per tree or per leaf area basis, are taking up more water, especially during the summer season, when the older trees can take up less water.

There are a variety of reasons for that. It could have to do with the air flows and the vapor pressure deficits within the stands. It could be the properties of the needles; there's even some thinking about whether the fungal communities living within the needles of older trees have some capacity to assist in the uptake of dewfall or fog. So there are mechanisms that we don't understand that range from the microbial to the whole structure of the stand that I think all contribute to this. And that's why continued observation and learning from the old forest that we still have is so crucial.

QUESTION: Sometimes, the unseen can be very important. Are there things in terms of managing disturbance in the soil, such as the microbial communities, that impact the water regulation of forests?

Dr. Jerry Franklin: The most poorly known portion of the forest is the below-ground portion, yet it's the most dynamic uses. It uses a disproportionate amount of energy to sustain itself. It's very, very complex and rich in terms of interrelationships among biota. And, of course, we're very aware that the trees have important relationships with fungi that formed this mycorrhizal relationship. So there is a tremendous dynamic below ground, a tremendous amount of collaboration as well as competition below ground that we don't understand at this point. Could that be part of what's going on? Oh, yes.

Dr. Roger Bales: In our critical zone observatory, we had people who looked at that, but it was looked at as more of a long timescale process, not something that is acting year to year, that is affecting the functioning of the critical zone, which includes the soil and the soil formation and how water interacts with the critical zone.

In conclusion …

Ms. Wayburn: That's a wonderful note on which to end, which is that forests are very long-lived systems. And what we do in our management needs to be calibrated to those long cycles. Which is to say that just a one and you're done, 'we've thinned it and we're good; our forest will be better for water' or 'it was good this year, so it'll be good next year.' So that long-term perspective has to be front and foremost in what we're looking at.

I am also walking away from this with a clear consensus that more natural densities and structure and composition really impact forest watersheds. And so it's insufficient for us to look just at buffers or wet meadows and think that we've looked at watershed function."

FOR MORE INFORMATION …

- Save water by cutting trees? (https://ceoas.oregonstate.edu/feature-story/save-water-cutting-trees), article by Julia Jones, Oregon State University
- 3 Surprising Ways Water Depends on Healthy Forests (https://www.wri.org/insights/3-surprising-ways-water-depends-healthy-forests), short article at the World Resources Institute
- Managing the forest water nexus: Opportunities for climate change mitigation and adaptation (https://siwi.org/publications/managing-the-forest-water-nexus/), Policy brief from the Stockholm International Water Institute
- Water, Climate Change, and Forests: (https://www.fs.fed.us/pnw/pubs/pnw_gtr812.pdf)Watershed Stewardship for a Changing Climate, report from the US Forest Service
- Managing forests for both downstream and downwind water, (https://oregonstate.app.box.com/s/fdkkumd8uypff4iavzdtxxnzmt7opi0d) open access article from Frontiers in Forests and Global Change
- Pacific Forest Trust website (https://www.pacificforest.org/)

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