USDA
United States Department of Agriculture

IN THIS ISSUE

- Developing a Riparian Planting Plan
- A National Conservation System
- Notices and Technical Tips
- Local Habitat Conditions can Safeguard Trout against Forest Harvest and Climate Change
- Development of Online Tools to Support GIS Watershed Analyses

The Technical Newsletter of the National Stream and Aquatic Ecology Center

Fort Collins, Colorado *August 2016*

Developing a Riparian Planting Plan

J. Chris Hoag
Riparian Plant Ecologist
Hoag Riparian and Wetland Restoration, LLC

Riparian vegetation is critical for the function, health, and natural processes of a riparian system, with vegetation plantings arguably being the single most important aspect of stream corridor restoration projects. Vegetation, both woody and herbaceous, provides roughness to reduce stream velocities, induce deposition, and stabilize the streambanks (Figure 1). After completing any construction within a stream corridor, vegetation has to be reestablished to provide stability, shade, improved water quality, and habitat. However, the choice of plant material, species, installation method, and planting locations can be daunting.

The first question that many practitioners often ask is: should we plant? Nature abhors a vacuum. Sometimes practitioners claim that there is no need to plant because vegetation will recolonize anyway. Succession decides what vegetation types will recolonize. Weeds and annuals naturally come in first. Shrubs come in next, then broadleaf trees, and then evergreen trees (this of course depends on site conditions and what they will support). It takes many years for a climax vegetation community to develop. Woody species can take a long time to recolonize and reach an age where they provide function to a stream.

Figure 1: Steep, rapidly-eroding streambank (left) on the Carson River, Nevada. A planting plan was developed and the area was planted using a variety of streambank bioengineering techniques. The photo on the right is the same site after 8 years.

StreamNotes is an aquatic and riparian systems publication with the objective of facilitating knowledge transfer from research & development and field-based success stories to on-the-ground application, through technical articles, case studies, and news articles. Stream related topics include hydrology, fluvial geomorphology, aquatic biology, riparian plant ecology, and climate change.

StreamNotes is produced quarterly as a service of the U.S. Forest Service National Stream and Aquatic Ecology Center (NSAEC). This technical center is a part of the Washington Office's Watershed, Fish, Wildlife, and Rare Plants program.

Editor: David Levinson

Technical Editors:
- Steven Yochum
- Brett Roper

Layout: Steven Yochum

To subscribe to email notifications, please visit the subscription link.

If you have ideas regarding specific topics or case studies, please email us at StreamNotes@fs.fed.us

Ideas and opinions expressed are not necessarily Forest Service policy. Citations, reviews, and use of trade names do not constitute endorsement by the USDA Forest Service. Click here for our nondescrimination policy.

Planting can accelerate vegetation growth and riparian function recovery. Rather than wait, plant the species you prefer in the community. However, do not plant climax species first; it takes time to develop the right site conditions for climax species to establish, grow, and spread. Planting vegetation will also improve post construction site aesthetics and it is usually required for regulatory compliance.

A good planting plan can help organize revegetation tasks and help develop a schedule. When developing a plan, keep in mind the guiding principles for stream channel stability. The first is that ground surfaces should rise in elevation away from the active channel to provide areas where water will concentrate during floods in the channel and floodplain. Second, roughness should increase away from the active channel. Flow resistance due to roughness increases as vegetation increases in extent and density. To help maintain high flow conveyance predominantly in the channel, increase plant density in the upper floodplain and transition zones (Figure 2). Plant density is usually increased by planting a variety of species (tall, short, wide, thick, etc.) and decreasing the spacing. Third, physical, and vegetative transitions should be gradual. Channel meanders should have the correct sinuosity and minimize channel constrictions. The most common channel width constrictions are bridges and culverts – these structures need to be carefully engineered so that the sizing is correct for the stream morphology.

A first task is to map out the various riparian planting zones in the project area (Hoag et al. 2001). Planting zones take advantage of the physical and hydraulic forces at work on different parts of the riparian corridor. They can help determine which woody and herbaceous riparian species can effectively be planted in the various zones based on plant life history strategies, stream velocities, common stressors, groundwater depth, ice and debris, freeze thaw cycles, and plant growth characteristics.

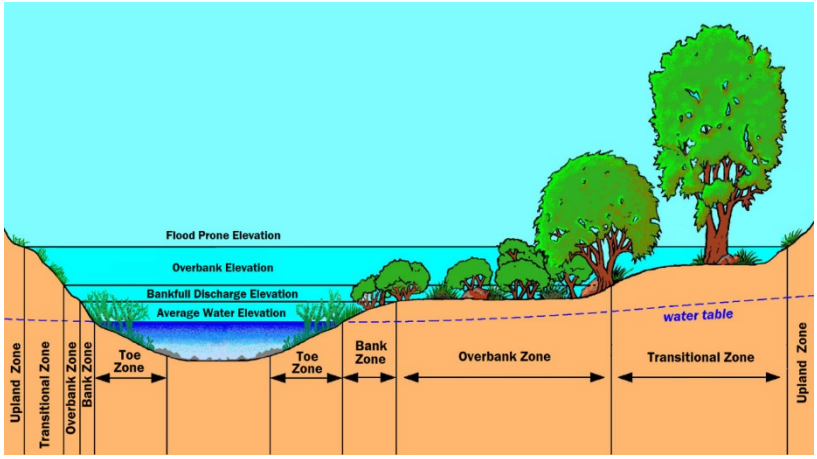


Figure 2: Riparian planting zones, with typical vegetation types of each zone.

Successful establishment of vegetation in the riparian zone depends on several actions:

1. Understanding of your stream system
2. Accurate planning, without gross estimation
3. Reconnaissance and inventory
4. Selection of plant material and species
5. Plant material handling and on site storage
6. Plant installation and establishment
7. Monitoring and maintenance

Project success is dependent on the complete integration of these actions.

Keep in mind these steps when developing a planting plan:

- Objectives are essential and drive the entire planting plan. Spend significant time establishing clear and thorough objectives and be as specific as possible. Objectives are typically measureable project outcomes. You will know when you have done a good job on your objectives when any question that you ask about the project can be answered by the objectives.
- A thorough inventory conducted by qualified technical staff is important. An inventory characterizes existing conditions at the site. Inventory vegetation, stream flows, soils, and infrastructure, such as bridges, culverts, dams, diversions, wells, pumps, etc. Much of the inventory can be done in the office with GIS using high-resolution aerial photography, land ownership maps, soil surveys, and published vegetation surveys. However, a trip to the field to ground truth what you found is essential (Figure 3).
- Determine the system potential. The potential is the optimum condition for the system.
- Develop design options for the project. Once you have a good idea of the site conditions, develop alternatives for what can and should be done. Alternatives are different ways to achieve the potential. Remember that the "do nothing" alternative is always a consideration. The budget will often control alternative development and selection.
- Include monitoring and maintenance in your plan. Monitoring is used to measure

success and direct maintenance. Monitoring identifies failures or developing problems after planting and can be used to indicate a need for more regular maintenance or a need to change management practices. Most importantly, monitoring ensures that the planting plan objectives and targeted functions are addressed and developing according to plan.

- Common mistakes when developing monitoring and maintenance guidelines are that they are not taken into account during the initial planning process and their costs are not added into annual budgets and personnel work time allocations. The annual operations plan must have time allocated for monitoring and maintenance and responsible parties need to be specifically identified. Additionally, responsible parties must have time in their own annual work plan to complete the monitoring and maintenance.
- Keep in mind that the objectives drive each of these steps.

Understanding of the soils, climate, and water availability and seasonality at your site are additional factors used in developing a good planting plan. A typical planting plan based on riparian planting zones, the capillary fringe, and water table are illustrated in Figure 4. Soils provide key information about the planting site, such as texture, stratigraphy, chemical factors, and any major limiting growth factors. The USDA NRCS Web Soil Survey is a valuable resource for soils information. Climate information, including total annual precipitation, seasonal precipitation, hardiness zone, and temperature extremes, will affect plant selection and engineering designs. Water and temperature are extremely important considerations for engineering designs. Understanding the amount and seasonal availability of water, water table history, low water level, and timing of runoff are all necessary to determine what types of planting stock you will need and what species will work in the project location. Identify the locations of diversions, dams, culverts, bridges, stream crossings, water gaps for watering livestock, etc. that will affect how water moves through the project area. Estimate how much of the water volume will actually reach the project site.

Figure 3: On the ground reconnaissance of the project site is essential to understand what the problems are, what riparian plant species are present, and what major stream work might need to be done before planting.

Both current and historic land use should be considered when developing a planting plan. Current and future stream morphology, as well as flooding history, are intertwined with land use and should be considered. These factors help characterize the site and provide a better understanding of factors that will dictate what techniques and methods will be needed to establish riparian herbaceous and woody vegetation. For example, if a site is in a big game wintering range and establishing woody vegetation will be very difficult, fencing and plant protection may be required. Remember that changing the grazing management practices is often the cheapest and simplest means of restoring the stream.

A plant inventory that determines the composition of the wetland, herbaceous, and woody species found on the project site will help start the species list you will need for the planting plan. It will also help determine if adequate planting materials are available onsite to harvest and replant, or harvest and propagate. Be sure to record plant condition, density, and diversity.

Record any beaver activity that you see in the project area. If beaver are in the area, there may be a need for some control in the first growing season. The state wildlife management agencies can help with alternatives. There are many options. The best option may be to trap the beaver and move them to new areas. Typically, if the beaver are controlled for the first growing season, the plant materials will have

a much better chance for establishment. Once the material is established, the beaver will typically manage the woody plant material on their own.

It is often difficult to find enough native willows, dogwoods, or cottonwoods on the project site to provide the appropriate quantity of plant materials. It may be necessary to look in numerous areas of a project watershed to identify locations with sufficient quantities of donor plants. In some cases where there has been major changes in riparian areas or large scale removal of riparian species within the project watershed, it may be necessary to look in adjacent watersheds. Elevation can play an important role in identifying plant materials collection locations. Generally, plant materials collected from a higher elevation than the project area can be established successfully; however plant materials collected from lower elevations may not be as successful. Collecting plant material from a higher elevation and planting at a lower elevation can extend the planting season by several weeks. When the willows, dogwoods, or cottonwoods have already broken bud on the project site, the same species higher up will not have broken bud. Furthermore, plant material collected at lower elevations will often have difficulty adapting to higher elevations due to a shorter growing season where the physiological cycle is different (i.e., emergence from dormancy and bud break, flowering times etc.). The amount of elevation difference that can cause problems varies with the site, but usually a difference in 800 to 1000 feet is significant. Check for whether the timing of break bud is different at different elevations when conducting reconnaissance for planting plan development.

Once all the information for the project site has been collected and analyzed, a potential species planting list can be created and different plant stock types determined. Various planting methods should be evaluated to identify which would be the most appropriate for the soils and water regime in the different zones and don't forget they need to be cost effective. Once you are on site, identify and delineate the riparian planting zones with marking paint or flags. This will help your planting crews know where to plant species or where planting methods will change. Use different color paint or flags to differentiate the location of the different species. The more effort you put into organizing and laying out the planting site, the better the results will be.

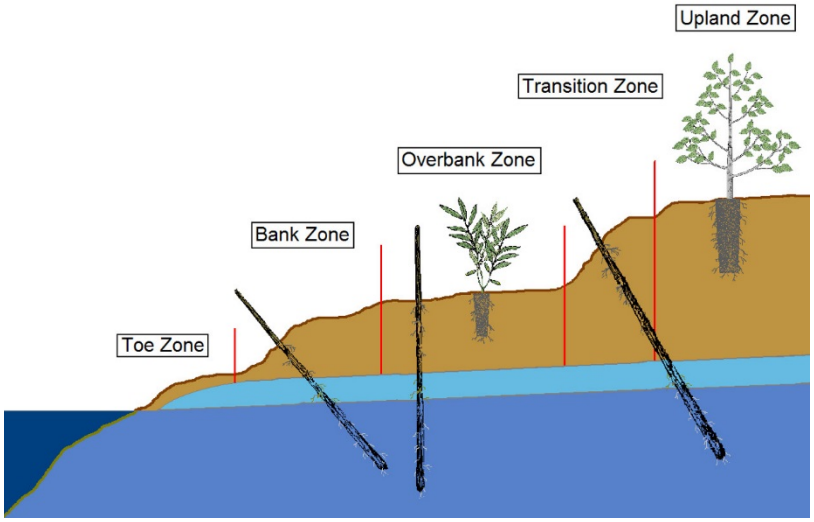


Figure 4: Typical planting plan based on riparian planting zones, the capillary fringe, and water table. Plant material includes unrooted cuttings and containerized stock.

Management Implications

- Developing a planting plan prior to starting work will make the project go smoother and with fewer mistakes. It also reduces the amount of time, effort, and money involved in completing the riparian restoration project.
- The vegetation component of a restoration project is rarely allocated enough money in the planning process to make the system function as a true riparian system and yet the riparian vegetation is one of the most important components.
- Completing as much work as possible in the office with all the resources that are available there prior to going to the field will make the plan much more complete. Remember that there is no replacement for going to the field and verifying on the ground conditions.
- One of the biggest mistakes often made while working on a planting plan is not identifying a knowledgeable grower and getting the containerized plants ordered and growing sufficiently ahead of time. It can take 2 years or more to grow woody stock for planting within a riparian corridor.
- A riparian planting plan needs to include not only the streambank, but also the riparian buffer zone on top of the bank. The buffer zone is critical for the stream to improve water quality, reduce sedimentation, and improve wildlife and fish habitat.

Additional Information

For more detailed information on developing a riparian planting plan and its implementation, see Hoag 1997. Additional guidance for the planning and design of riparian

plantings for restoration is provided in numerous other publications. The National Stream and Aquatic Ecology Center technical note Guidance for Stream Restoration and Rehabilitation (Yochum 2016) provides links to these references.

Acknowledgements

I appreciate the assistance of John H. Bair and Jon Fripp in developing and reviewing the information in this article. David Merritt is also appreciated for his review.

References

Hoag, J.C. 1997. Selection and Acquisition of Woody and Herbaceous Plant Species and Materials for Riparian Corridor, Shoreline, and Wetland Restoration and Enhancement. USDA NRCS Plant Materials Centers, Riparian/Wetland Project Information Series No. 2.

Hoag, J.C., Berg, F.E., Wyman, S.K., Sampson, R.W. 2001. Riparian Planting Zones in the Intermountain West. USDA NRCS Plant Materials Centers, Riparian/Wetland Project Information Series No. 16, March, 2001 (revised).

Yochum, S.E. 2016. Guidance for Stream Restoration and Rehabilitation. U.S. Forest Service, National Stream and Aquatic Ecology Center, Tech Note 102.2.

A National Habitat Conservation System

D.A. Boyce

National Wildlife Ecologist
Washington Office WFWARP

The National Forest Management Act requires the Forest Service to maintain biodiversity, but despite our laws, rules, and regulations biodiversity is being lost nationally on both public and private lands, as are ecosystem functions and services. The recent article in Bioscience *Completing the System: Opportunities and Challenges for a National Habitat Conservation System* looks at several international efforts as models for success (Arycrigg et al. 2016). The authors propose that a national conservation vision and producing a system that protects ecological integrity at multiple scales with enhanced connectivity is "the single most important action we can take as a nation to conserve our natural heritage."

Collaboration across multiple agencies and organizations is needed, along with a cohesive strategy to connect the admittedly ad-hoc conservation approach of the past with the enduring conservation needs of our natural resources into the future. With just 13.3% of the total land base in the United States in a conserved status (Figure 5), our current effort falls short of the recommended international conservation goal. As such, many conservation areas are too small or isolated to provide for long-term persistence. Conserving ecosystems of sufficient size, redundancy, and connectivity are needed to increase ecosystem resiliency and persistence into the future.

The recent Bioscience article highlights three successful conservation models: (1) the North American Bird Conservation Initiative, (2) Natura 2000 of the European Union, and (3) the National Reserve System of Australia. The first is successful partnership development while the second and third are establishing new conservation areas for biodiversity. In the article the authors propose four key actions: 1) develop a common vision for conservation, 2) assess our current state of the conservation of our natural heritage as it relates to the vision, 3) set standards to measure progress toward the vision, and 4) implement strategies to complete the habitat conservation system for the nation. As stated by the authors "The lack of a comprehensive vision and strategy to integrate these efforts for achieving national as well as local conservation goals is a major impediment to ensuring our individual efforts add up in the most effective manner to conserving our nation's natural heritage."

Reference

Aycrigg, J.L., Groves, C., Hilty, J.A., Scott, J.M., Beier, P., Boyce, D.A., Figg, D., Hamilton, H., Machlis, G., Muller, K., Rosenberg, K.V., Sauvajot, R.M., Shaffer, M., Wentworth, R. 2016. Completing the System: Opportunities and Challenges for a National Habitat Conservation System. BioScience Forum: 1–11.

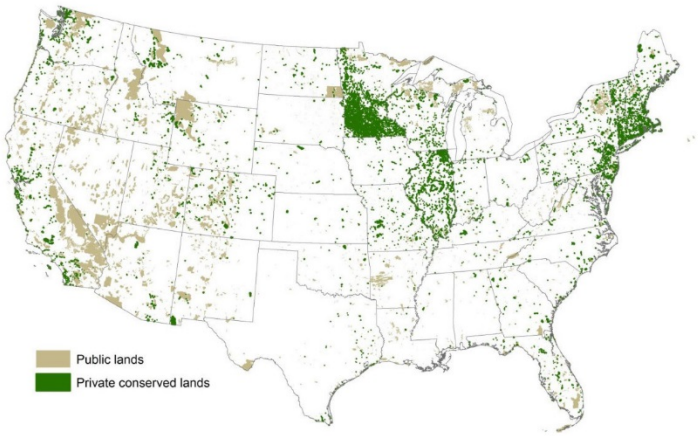
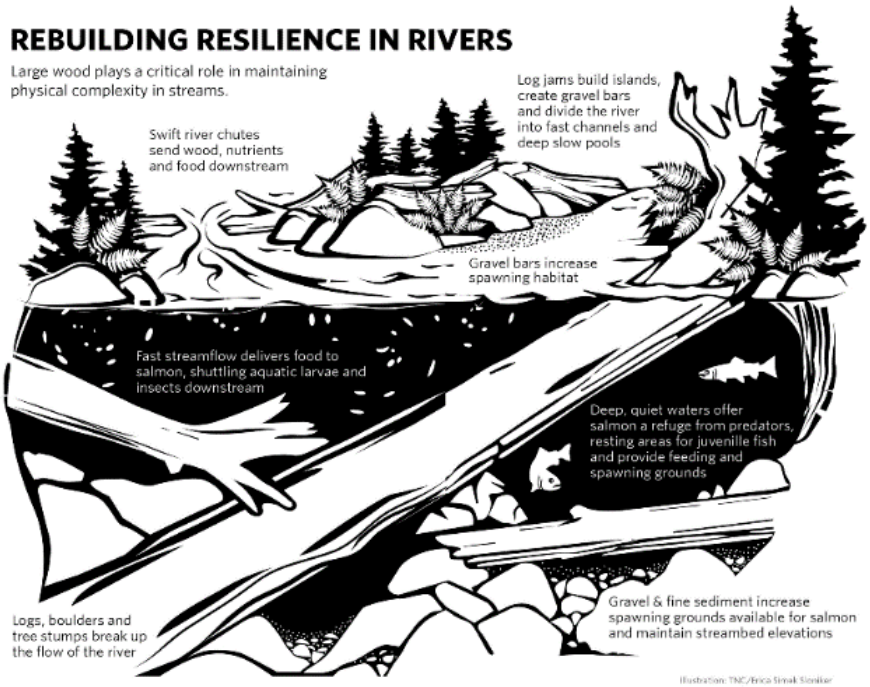


Figure 5: Conservation areas of the Continental U.S. (Arycrigg et al. 2016).

Notices and Technical Tips

- **Direct technical assistance from applied scientists at the National Stream and Aquatic Ecology Center** is available to help Forest Service field practitioners with managing and restoring streams and riparian corridors. The technical expertise of the Center includes hydrology, fluvial geomorphology, riparian plant ecology, aquatic ecology, climatology, and engineering. If you would like to discuss a specific stream-related resource problem and arrange a field visit, please contact a scientist at the Center or David Levinson, the NSAEC program manager.
- A partnership between the Hopi Tribe and Kaibab National Forest performed two **spring restoration projects** on the Kaibab. Through this partnership effort, Hopi tribal elders had the opportunity to share traditional ecological knowledge for integration into Forest Service management plans while also providing youth training. A video was developed to document the ongoing projects; it is available at this link.



- A June 30th blog article by Emily Howe, of The Nature Conservancy, provides an informative summary of the **value of large wood to stream ecosystems**: Fish of the Forest: Large Wood Benefits Salmon Recovery "As a global society, we have spent the last 100 years intentionally removing wood from stream and river channels in order to improve navigation, water conveyance, and the transportation of goods. Wood removal was once even thought to promote fish passage. As a result, the amount of large wood in streams is far below natural levels. Historically, coastal river travel required navigating – on average – one downed tree every 6 feet. Today, you'd be lucky to find one tree every quarter mile. The cumulative effect of large wood removal projects over the past century has been to severely simplify river systems. If complexity promotes ecological resilience, then river simplification can only hinder it."
- A **Fish Habitat Decision Support Tool** has been developed and is available for use by land managers and the general public. The tool provides "access to data, models, and prioritization tools for use with multiple fish habitat assessments performed for specific regions across the United States. Three main analytical tools (visualization, ranking, and futuring) are combined with intuitive basemaps and mapping features to allow users to explore the details of the assessments and perform subsequent analyses. This tool was developed with funding from the U.S. Fish and Wildlife Service and the Midwest Fish Habitat Partnerships. Additional data and models were developed through funding and coordination by the North Atlantic LCC, the Atlantic Coastal Fish Habitat Partnership, and The Nature Conservancy."

Local Habitat Conditions can Safeguard Trout against Forest Harvest and Climate Change

Brooke Penaluna

Research Fish Biologist; Pacific Northwest Research Station

Local variability in environmental conditions may play a key role for understanding emerging responses of populations to land use and climate change, but this mechanism has been previously overlooked. Effects of climate change at the regional and global scale may not provide realistic assessments of factors affecting populations. Some local habitat conditions can be managed and, hence, managers have the potential to safeguard the local persistence of populations by helping them resist broad-scale change. Our findings, published in PloS ONE, highlight the importance of local variability among streams, like water depth and available habitat that mediate the effects of forest harvest and climate change on Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*). Changes in stream temperature by climate change affects trout by triggering early emergence, reducing numbers of older trout, and increasing numbers of younger trout. In contrast, forest harvest produces fewer and less consistent responses across trout populations and, even, in some cases, reduces or counters the effects of climate change alone through increased summer streamflow. The net effects for most simulated trout responses are different from or less than the sum of their separate scenarios. The most visible and consistent response is a phenology response (earlier fry emergence; Figure 6), whereas demographic responses of survival, growth, or biomass were not detectable and inconsistent across scenarios and streams. Ultimately, it is important to identify the array of key features at the local scale that will allow trout to resist broad-scale change and swim on in their streams in the future.

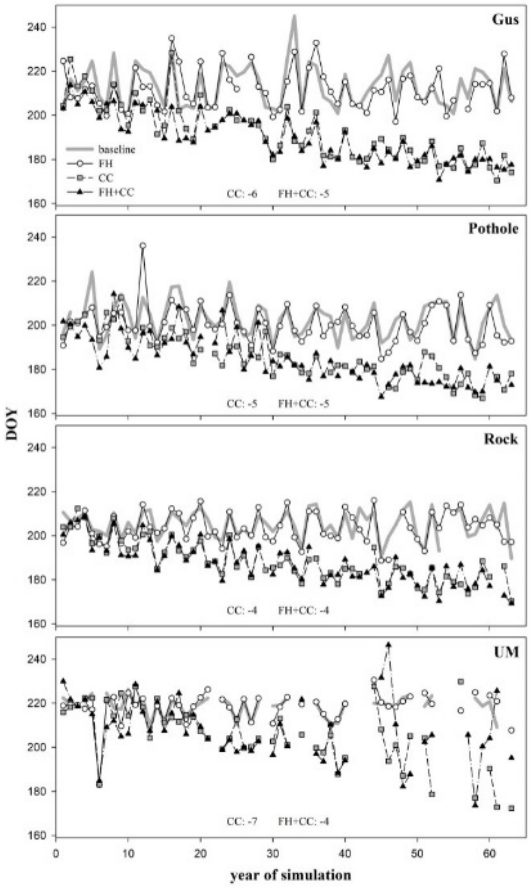


Figure 6: Day of year (DOY) from five replicate simulations when median number of modeled fry had emerged over time in Gus Creek, Pothole Creek, Rock Creek, and Upper Mainstem (UM), Trask River Watershed, OR. Scenarios include manipulations of stream temperature and regimes. Only significant trends ($P < 0.05$) over time are listed and include the slope of the trend (days per decade). Negative values represent early fry emergence. Gaps in data are due to years with no fry emergence because model thresholds for spawning, egg development, or emergence were not met.

Management Implications

- Habitat variability is the key to protecting trout into the future because habitat diversity decouples the effect of land use and climate change on trout. Management plans may encourage a mix of conditions changing through time to diversify population responses.
- The lack of coherence among responses of demography of trout have practical consequences because biological responses commonly quantified in field studies (survival, growth, and biomass) may not be able to detect or predict the effects of land use and climate change very well.
- Seasonal low flow represents a biological crunch time-period for trout. Increasing pool habitat in streams will improve their biomass by both increasing their survival and body size.
- Consideration of any stressor without climate change is erroneous because climate change is occurring now and net effects for most trout responses were different from or less than the sum of their separate scenarios. Hence, climate change warrants consideration by managers and policymakers aiming to conserve trout and aquatic ecosystems.

Development of Online Tools to Support GIS Watershed Analyses

William J. Elliot

Research Engineer, Rocky Mountain Research Station

In 1996 there was a meeting in Tucson of hydrologists from every Forest Service region, as well as Forest Service research scientists engaged in watershed-related activities. This meeting was organized by the Stream Team (which has since been enveloped by the National Stream and Aquatic Ecology Center). The focus of the meeting was to identify tools that needed to be developed to support watershed management. One of the suggested tools was a GIS-based application that could run on the internet. At that time, federal websites were in their infancy, and the development of GIS tools for watershed analysis was only just beginning. Scientists at the Forest Service Rocky Mountain Research Station (RMRS) took this challenge to heart. In 1999, with support from the San Dimas Technology and Development Center, they introduced the first ever online interface to the Water Erosion Prediction Project (WEPP) model to predict soil erosion for forest road segments and forest hillslopes disturbed by wildfire (Figure 7), as well as for forest management (Elliot 2004). These interfaces were quickly adapted by the Forest Service and other land management agencies.

Figure 7: Wildfire-impacted hillslope, from the 2012 High Park Fire (photo credit: Steven Yochum).

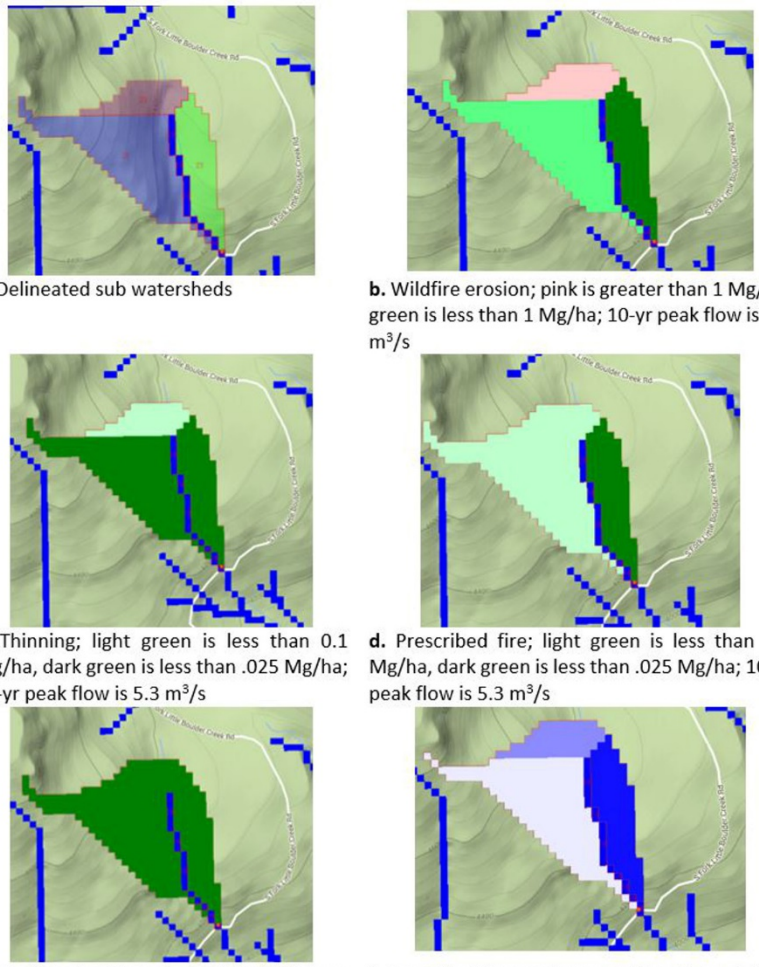
In the late 1990s, a GIS interface was developed by the USDA Agricultural Research Service (ARS) National Soil Erosion Research Laboratory for the WEPP Watershed Version (Cochrane and Flanagan 1999). The interface ran in ArcView, and shortly after introducing it a GIS wizard was developed to aid in applying GIS tools to predict erosion from hillslope polygons delineated by the wizard using the WEPP model (Renschler 2003). Two grants were received from the Joint Fire Science Program to further enhance this tool, known as GeoWEPP, for forest conditions. It was upgraded to run in ArcMap 8.x and continues to be upgraded for current versions of ArcMap by the State University of New York, Buffalo. When field personnel tried to apply this tool, however, many found that they did not have the time to develop the level of GIS skills required to use GeoWEPP. In the early 2000s, the ARS also developed a proof of concept online GIS watershed tool that was not intended for widespread application (Flanagan and others 2004).

In 2009, the Army Corps of Engineers, Chicago Office, approached RMRS to develop an online sediment delivery tool that could be applied to forested watersheds in the Great Lakes Basin. RMRS, in collaboration with the ARS and Washington State University, began the development of a user friendly online GIS tool to support forest watershed management. The team built on the Flanagan and others (2004) prototype, and upgraded it with a Google Map interface to zoom into sites. A comprehensive forest soil and management database similar to the FSWEPP database (Elliot, 2004) was added. The interface accessed digital elevation data from a USGS server and an 800-m climate database from the Natural Resource Conservation Service (NRCS; Frankenburger and others 2011). The interface also accesses the USGS land cover database and NRCS Soil Survey Geographic Database (SSURGO) Soils Database. For a single run, the watershed area is limited to about 400 ha (1,000 acres). On larger watersheds, spatial variability of weather becomes important, with higher elevations of the watershed receiving more precipitation, and much of that as snow. Work is ongoing to incorporate climate variability into the model and increase the area that can be modeled.

The skill level necessary to use the model is similar to that required to use other online mapping tools with advanced features, such as Google Earth. An online set of instructions can be downloaded to guide the use through the steps necessary to carry out a post-wildfire run, or a set of fuel management runs. Figure 8 summarizes the four recommended scenarios for a fuel management analysis (low-severity wildfire; thinning, prescribed fire, forested). This example is from the East Deer Creek watershed in the Colville National Forest, a watershed that provides municipal water to a nearby town. To use this tool, the user first zooms to a site of interest, builds a channel network, and selects an outlet point for the sub watershed of interest (Figure 8a). This sub watershed is then run for the four scenarios. The results of each run can be saved as maps and tables, and allow the user to compare the potential sediment delivery from forest management to that from an undisturbed forest and a wildfire. Figure 8 shows some of the results from the four runs.

Figure 8f shows the distribution of predicted surface runoff plus lateral flow following a prescribed burn. Note that not all hillslopes respond the same way to a prescribed burn. The maps shown in Figure 8b – e are useful in helping managers decide which hillslopes may be at risk to the greatest erosion, and prioritize those hillslopes for treatment. The example analysis shows that the hillslope at the top of the watershed has the greatest erosion risk, so managers may consider practices other than prescribed fire to treat this slope, like thinning followed by mastication, or doing a prescribed burn in early summer when conditions are damp, and the loss of duff will be minimal when burning slash or understory.

Users can export the results of each run for importing into ArcMap, where the results from several runs can be displayed in a single map. A recommended approach for summarizing the model outputs is outlined in Table 1 (Elliot 2013). With this approach, the sediment delivery associated with the disturbance is divided by the frequency of the disturbance to determine an average annual sediment delivery due to the disturbance. In the example in Table 1, the sediment deliveries averaged out over the time between every disturbance are less than the annual sediment delivery from an undisturbed forest, suggesting that in the long term, sediment delivery on this watershed is not impacted by these disturbances. Table 1 also shows the estimated sediment delivery the year of the disturbance, which may be of interest to downstream water users in that year. The interface can also predict return period values for daily sediment delivery, a number that can be considered a reasonable estimate for a Total Maximum Daily Load. Figure 8b – e also shows the predicted peak flow rates at the outlet of this watershed, which is at a road-stream crossing. Note that the estimated post wildfire peak flow is nearly 20 times greater than



a. Delineated sub watersheds

b. Wildfire erosion; pink is greater than 1 Mg/ha, green is less than 1 Mg/ha; 10-yr peak flow is 8.8 m^3/s

c. Thinning; light green is less than 0.1 Mg/ha, dark green is less than .025 Mg/ha; 10-yr peak flow is 5.3 m^3/s

d. Prescribed fire; light green is less than 0.1 Mg/ha, dark green is less than .025 Mg/ha; 10-yr peak flow is 5.3 m^3/s

e. Undisturbed forest; predicted hillslope erosion is 0; 10-yr peak flow is 0.47 m^3/s

f. Prescribed fire: surface runoff and lateral flow; dark polygon is 150 mm/yr, lighter polygon is 120 mm/yr, and lightest polygon is 105 mm/yr

Figure 8: Example of a set of runs on the online interface. The watershed area was limited to only 32 ha (80 a) for this example, located in the Colville National Forest. The interfaces determined that the watershed was 96 percent forest. The erosion rates shown are for estimated hillslope erosion.

Table 1: Summary of a fuel management analysis. Column 3 is the average predicted sediment delivery for the year following the disturbance; Column 4 is the average annual sediment delivery following the disturbance divided by the frequency of the disturbance. In this watershed, erosion rates from wildfire, prescribed fire, and thinning are all sufficiently low that when averaged over the frequency of the disturbance, they are unlikely to change the long term average sediment yield. This analysis assumes all hillslopes are treated the same, and that the fire return interval is increased from 40 to 60 years if fuel management practices are applied.

Unmanaged				**Managed**			
Land Use	Disturbance Frequency (yr)	Disturbed Erosion (Mg ha^{-1})	Avg Annual Erosion (Mg ha^{-1} yr^{-1})	Land Use	Disturbance Frequency (yr)	Disturbed Erosion (Mg ha^{-1})	Avg Annual Erosion (Mg ha^{-1} yr^{-1})
Forest	1	0.1	0.1	Forest	1	0.1	0.1
Wildfire	40	0.8	<0.1	Wildfire	60	0.8	<0.1
				Thinning	20	0.4	<0.1
				Rx Fire	20	0.5	<0.1
Weighted Average			0.1	Weighted Average			0.1

the peak flow for an undisturbed forest. The online documentation shows how to carry out an analysis where not all hillslopes are treated the same in a given year

An online interface to be used after wildfire is under development. It can currently predict the erosion following a wildfire, and work is ongoing to allow users to compare this to pre-fire conditions and to evaluate the benefits of mulching. Another interface is under development for the Lake Tahoe Basin that is incorporating enhanced output analyses to predict delivery of phosphorus and fine sediment (silt- and clay-size particles and aggregates). Once complete, it can be applied nationwide. A prototype interface is also under development for predicting sediment delivery from roads within a watershed. Because the national road database is so large, further resources will be needed to develop a consistent road database to support it. The road interface has been used once to support an analysis in a sensitive area within the Colville National Forest. A similar interface was also developed for post mining conditions where a user could upload a post mining digital elevation model, but the interface is not currently online. It includes advanced features to aid users in evaluating the effectiveness of sediment basins. If there is sufficient interest, the post mining interface can be reactivated.

Management Implications

With the use of online tools for GIS watershed analyses, key advantages are that:

- The time required to assemble the necessary database for a GIS watershed analysis is eliminated; specialists can focus on modeling and not GIS data acquisition and formatting.
- There is no need to rewrite watershed management software every time a new version of proprietary GIS software is released.
- Training time on how to apply GIS tools to watershed analyses is reduced.
- Online NRCS soil and climate databases can be readily accessed to support other planning activities.

References

Cochrane, T.C.; Flanagan, D.C. 1999. Assessing water erosion in small watersheds using WEPP with GIS and digital elevation models. Journal of Soil and Water Conservation. 54, 678-685.

Elliot, W.J. 2004. WEPP internet interfaces for forest erosion prediction, Jour. of the American Water Resources Assoc. 40(2): 299-309.

Elliot, W.J. 2013. Erosion processes and prediction with WEPP technology in forests in the Northwestern U.S. Trans ASABE. 56(2): 563-579.

Flanagan, D.C.; Frankenberger, J.R.; Engel, B.A. 2004. Web-based GIS application of the WEPP model. Paper No. 042024. Presented at the Annual International Meeting of the ASAE, 1-4 August, 2004, Ottawa, Canada. St. Joseph, MI: ASAE. 12 p.

Frankenberger, J.R.; Dun, S.; Flanagan, D.C.; Wu, J.Q.; Elliot, W.J. 2011. Development of a GIS interface for WEPP model application to Great Lakes forested watersheds, Paper No. 11139. Presented at the International Symposium on Erosion and Landscape Evolution, 18-21 September, 2011, Anchorage, AL. St. Joseph, MI: Am. Soc. Ag & Bio Engrs. 9 p

Renschler, C.S. 2003. Designing geo-spatial interfaces to scale process models: The GeoWEPP approach. Hydrological Processes 17: 1005-1017.