Evaluation of Agroforestry for Protecting Coldwater Fish Habitat

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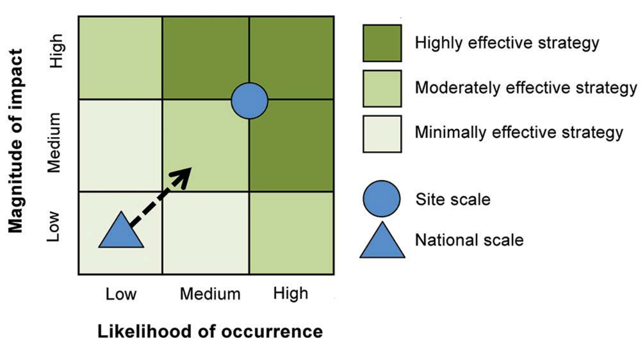
The implementation of agroforestry practices on U.S. agricultural lands can offset predicted increases in stream temperatures due to climate change, thereby protecting coldwater habitat for salmon, trout, and related fishes. Riparian forest buffers can moderate the rise in stream temperatures in watersheds where they are implemented, but the magnitude of impact on the aerial extent of favorable fish habitat, at both local and national levels, will be low if landowners are reluctant to implement agroforestry on their farms (fig. B.4).

Figure B.4. The likelihood of occurrence and impact of agroforestry implementation on stream temperatures in agricultural areas. The implementation of agroforestry practices can offset predicted increases in stream temperatures due to climate change, thereby protecting coldwater habitat for salmon, trout, and related fishes. Riparian forest buffers can moderate the rise in stream temperatures in watersheds where they are implemented thoroughly (circle). At a national scale, however, the impact will be low, because many landowners are currently reluctant to implement agroforestry on their farms (triangle). National-scale effectiveness would be higher (arrow) if market conditions and program incentives, among other factors that affect landowners' decisions, become more favorable for the adoption of agroforestry and the aerial extent of implementation increases.



Salmon, trout, char, grayling, and whitefish (collectively called salmonids) are a significant ecological, commercial, recreational, and cultural resource in the United States. A number of these species are listed under the Federal Endangered Species Act and face increasing pressures under climate change (Mantua et al. 2010). Water temperature is a key factor in determining habitat suitability for salmonids, and excessively high water temperature can act as a limiting factor for the distribution, migration, health, and performance of salmonids (McCullough 1999). As temperatures rise, salmon become more susceptible to disease, and prolonged exposure to stream temperatures across a threshold can be lethal for juveniles and adults (McCullough 1999). Climate change is predicted to increase air temperatures and the frequency and magnitude of droughts, all of which, in turn, lead to higher water temperatures in streams and rivers (Melillo et al. 2014, Mohseni et al. 1999). Water temperatures have been increasing in many streams and rivers throughout the United States during the past several decades (Kaushal et al. 2010).

Riparian forest buffers can reduce the effect of climate change on stream temperature and salmonids. Solar radiation received by a stream is one of the most influential factors affecting stream temperatures (Brown and Krygier 1970, Caissie 2006). Riparian forest buffers provide shade, reducing solar radiation received by a stream, leading to lower summer water temperatures and a reduction in stream temperature fluctuations (Barton et al. 1985, Bowler et al. 2012, Brown and Krygier 1970). The implementation of riparian forest buffers along salmonid-bearing streams that currently lack shade can help offset increases in stream temperatures due to climate change.

Preferred temperatures for salmonids vary by species and life history stage; however, temperatures above maximum weekly temperature thresholds indicate habitat loss and increased mortality. For most salmonids in the United States, the maximum weekly temperature thresholds range between 21 and 24 °C (Eaton et al. 1995).

Maximum weekly stream temperatures are projected to increase from 1 to 3 °C across the continental United States, based on a climate scenario in which the atmospheric concentration of carbon dioxide is doubled from 330 to 660 parts per million (ppm) (Mohseni et al. 1999). It is estimated that the 660 ppm level could be reached by the end of this century (Karl et al. 2009). In response, maximum weekly stream temperatures are predicted to be 18 to 24 °C in the Rocky Mountains and on the West Coast, 22 to 26 °C in the upper Mississippi River basin and on the East Coast, and 26 to 30 °C in the lower Mississippi

River basin and portions of the South (Mohseni et al. 1999). Under this climate scenario, the number of U.S. Geological Survey stream-gauging stations nationwide indicating suitable thermal habitat for coldwater fishes is projected to decrease 36 percent (Mohseni et al. 2003).

Riparian forest buffers can maintain lower maximum summer stream temperatures by 3.3 °C compared with streams without buffers and lower summer mean stream temperatures by 0.6 °C based on a meta-analysis of 10 studies (Bowler et al. 2012). On this basis, implementing riparian forest buffers may be capable of offsetting the projected increases in maximum summer stream temperatures and maintaining those temperatures below critical thresholds in most regions currently containing salmonids.

In one geographically specific case, Wisconsin is recognized for its abundance of coldwater streams, which include more than 10,000 miles of classified trout streams that provide fisheries for brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) (WDNR 2002). Three future climate scenarios for Wisconsin predict (1) a "best case" scenario in which summer air temperature increases by 1.0 °C and water temperature by 0.8 °C, (2) a "moderate case" in which summer air temperature increases by 3.0 °C and water temperature by 2.4 °C, and (3) a "worst case" in which summer air temperature increases by 5.0 °C and water temperature by 4.0 °C (Lyons et al. 2010). Under the worst-case climate scenario, fish habitat suitability models predict brook trout to be eliminated from all Wisconsin streams and brown trout habitat, based on stream length, to decrease by 88 percent (Lyons et al. 2010). Even under the moderate scenario, brook trout habitat is expected to decrease by 94 percent; the best case scenario predicts a 44-percent loss of habitat (Lyons et al. 2010).

Increasing riparian shade on Wisconsin streams can substantially reduce stream temperatures. Based on a heat-transfer model, Cross et al. (2013) predicted maximum weekly temperature would decrease by 4.8 °C as stream shading increased from 0 to 75 percent and Gaffield et al. (2005) predicted temperature would decrease by 4.5 °C as stream shading increased from 0 to 80 percent. These predictions indicate that the establishment of riparian forest buffers may be capable of offsetting the projected increases in water temperatures in Wisconsin streams due to future climate change. Agriculture occupies 43 percent of the land area in Wisconsin. Riparian areas are frequently embedded in watersheds where agriculture is the primary activity (Wang et al. 1997), suggesting a high potential exists for implementing riparian forest buffers to protect trout from rising stream temperatures.

If mean summer water temperatures are already at or above critical temperature thresholds before projected climate change, the implementation of riparian forest buffers may not be enough to bring these temperatures below critical thresholds under a future warmer climate. A useful implementation strategy will be one that targets areas identified as those where riparian forest buffers can have the most impact (Cross et al. 2013).

Stream thermal regimes are quite complex and are influenced by many factors, including stream discharge, streambed conduction, air temperature, wind speed, channel morphology, groundwater inputs, and surrounding land use, in addition to solar radiation (Caissie 2006). In some cases, riparian forest buffers may increase stream widening, leading to shallower flows and increased solar exposure on the water surface, which could potentially offset the temperature reductions from riparian shade (Allmendinger et al. 2005, McBride et al. 2008). This complexity raises the uncertainty of the overall impact of riparian forest buffers on stream temperatures.

The likelihood of impact will be greatly influenced by the likelihood that landowners will adopt riparian forest buffers. Farmers and ranchers generally dislike riparian forest buffers because they view them as taking land out of production (Gillespie et al. 2007, Luloff et al. 2012). Piecemeal implementation of riparian forest buffers may diminish the magnitude of impact at a national scale or even at watershed scales. Programs offering financial incentive and technical assistance have had some success in increasing the adoption of riparian forest buffers. Nontimber forest products (e.g., nuts, fruits, medicinal plants, decorative materials) can be produced from riparian forest buffers, generating income for landowners willing to harvest and sell the products. It is unclear, however, how many landowners might be interested in this enterprise option.

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