Driftless Area Land Cover and Land Use

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1. Settlement of the Driftless Area by Europeans between 1850 and 1935 altered the landscape through intensive agriculture and removal of forest cover, which resulted in significant sediment delivery to streams.
2. Replacement of forest and vegetative cover with row crops or continuously grazed pastures altered flow regimes in streams because of reduced ability of the catchment to absorb precipitation.
3. Beginning in 1935, after instituting the first watershed-scale soil and water conservation demonstration project in the United States in the Coon Creek watershed, cropping systems and land management changed in the Driftless Area, which led to reduced sediment losses from the landscape.

Land Cover and Use | Agriculture | Water Quality | Stream Habitat | Biotic Integrity

Stream quality, stream habitats, and fish communities respond to land use at catchment and riparian scales in the Driftless Area. The relationship between land use/land cover and instream characteristics and aquatic organisms is complex and is affected by catchment size, soil, geology, slope, vegetative cover, and other abiotic characteristics (1–5). Sediment and chemical input and discharge are primarily governed by hydrology, geology, soils, and vegetation at a watershed scale (6). However, land use, primarily agriculture, can substantially influence the quality and quantity of sediment, nutrient inputs, and discharge in streams (7–9).

Land Use and Aquatic Systems

Agriculture, urbanization, timber harvest, and other human modification of the landscape has altered and degraded stream ecosystems in multiple ways that reduce water quality, and which in turn affect fish spawning and rearing habitat related to siltation and erosion, and nutrient and chemical pollution from subsurface and overland flow (7, 10, 11). In areas of high topographic relief, such as the Driftless Area of southwest Wisconsin and southeastern Minnesota, historical replacement of forest and vegetative cover with row crops or continuously grazed pastures substantially altered flow regimes by reducing the ability of the catchment to absorb precipitation, which has contributed to more frequent and severe flooding and destabilization of streambanks and stream channels (see Potter, page 15, and Melchior, page 20). Flooding physically alters stream habitat and has been shown to reduce recruitment of young-of-year (YOY) trout in southeast Minnesota (12, 13).

Trimble (14), summarizing a number of earlier authors, described the pre-European settlement land cover in the Driftless Area as prairie where the landscape was level to rolling uplands and hillsides tended to be forests, whereas valleys had varied vegetation. Prairies had less than one tree per acre (0.4 per ha). Prairie soils were deep, fertile, and high in organic carbon and nutrients with high infiltration rates. Prairie plants were sometimes taller than a person on horseback. Prairies were maintained by fires caused by lightning during dry conditions and by Native Americans, likely to perpetuate bison and other large animals, e.g. elk *Cervus canadensis*. Forests were northern deciduous hardwoods. Forests on north-facing slopes were sugar maple *Acer saccharum*, beech *Fagus spp.*, and basswood *Tilia americana*, whereas bur oaks *Quercus macrocarpa* were found on sunny slopes. Many steep southern and western slopes were treeless. Vegetation on floodplains and terraces were varied with trees in some areas and grasslands in other areas. Trees were maples *A. spp.*, birch *Populus spp.*, and elm *Ulmus spp.*. Streambanks could often be lined with trees, even when the adjacent areas were grassland. However, sketches by early visitors indicate no more than 20% of the streambanks were lined with trees. Floodplains were characterized as having a dark well-developed non-stratified soil with little vertical accretion. Streams were clear with little lateral migration and channel bottoms were usually sand or gravel.

Settlement by Europeans began as early as the 1820s in Wisconsin south of the Wisconsin River and around 1850 in southeast Minnesota (15). Trimble (14) provides an overview of agriculture and land use practices, which led to significant alteration of the landscape and the extensive erosion and sediment delivery to streams that followed. Early settlers were miners attracted by lead deposits in southern Wisconsin. Mining resulted in spoil piles, which were subject to erosion. As the population increased, other activities contributed to erosion, such as road building and forestry, but agricultural practices, circa 1850, led to significant erosion. Between 1850 and 1935, many savannas and prairies in southern Wisconsin were converted to cropland and pasture (16). Following the arrival of Europeans, extensive land use transformation took place. Agriculture lead to deforestation and overgrazing of bluffland hillsides, and poor soil management led to massive sedimentation, flooding, channel alteration, and severely degraded streams. A major contributor to erosion was a result of the United States rectilinear land survey where land was laid out in rectangles. This system encouraged farmers to lay out their fields along straight lines and led to a practice of

Statement of Interest

Brook Trout *Salvelinus fontinalis*, the only trout species in streams in the Driftless Area prior to settlement, were described to be very abundant. However, following settlement with the advent of mining, forestry, and agriculture, sediment delivery to streams and alterations to stream channels Brook Trout were nearly extirpated. Brook Trout were successfully reintroduced to many streams following the improvements in stream channels bought about by the conservation efforts that began in 1935.

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Fig. 1. Massive gully and erosion in the Driftless Area. Credit: USDA-NRCS

plowing up and down or across steep slopes, which resulted in eroded hillsides and formation of gullies that contributed significant sediment delivery to streams (Figs. 1, 2). Initially, wheat was the major crop with little crop rotation. Wheat production was replaced with corn and oats as agriculture shifted to dairy and grazing, but grazing was often practiced on steep hillsides or in riparian areas, which also resulted in significant erosion. The loss of upland vegetative cover led to frequent and severe flash flooding in downstream communities. For example, the town of Beaver in the Whitewater watershed in southeast Minnesota was buried under 9-ft (3-m) of sediment (17). Altering natural land cover for agricultural land use altered stream channel cross sections related to increased flooding (18).

Agriculture, Floods, and Sediment

Floods and increased sedimentation were correlated with agricultural practices (e.g., tillage and grazing) and timber harvest in riparian areas and upland habitats in the past two centuries (19). Low flows and average flows in agricultural watersheds increased in Wisconsin between 1915 and 2008 (20). However, Juckem, et al. (21) noted an abrupt increase in baseflow around 1970, which coincided with increased precipitation and changes in agricultural land management. Conversion of natural land cover to agriculture in the Platte watershed of southwestern Wisconsin lead to an increase in the magnitude of floods (18). Increased flooding has resulted in streambank erosion and loss of aquatic habitat. Past land use, particularly agriculture, has resulted in long-term effects on aquatic diversity regardless of reforestation of riparian zones (22). Natural resource policymakers acknowledge that the legacies of land-use activities may influence ecosystems decades or centuries after activities have ceased (23). These activities have included plowing, overgrazing, channel diversions and alteration, reductions in and wider extremes of instream flow, riparian habitat loss and degradation, point and non-point source pollution, and streambank erosion (17) (Fig. 3). As a result of these land use practices native Brook Trout *Salvelinus fontinalis* were virtually eliminated by degraded instream habitat and overfishing by 1900 in the Driftless Area (15).

Conservation Practices

Interventions to address these issues on the broader landscape began with the formation of the Soil Erosion Service in 1933, which became the Soil Conservation Service in 1935 (now named the Natural Resources Conservation Service) (15, 24). Coon Creek, Wisconsin, located in the Driftless Area, was the first watershed-scale soil and water conservation demonstration project in the United States (21). Widespread adoption of soil conservation practices led to a decrease in flood peaks and in winter/spring flood volumes in streams, such as the East Branch of the Pecatonica River in Wisconsin (25). Trimble and Lund (26) found significant reductions after 1935 in erosion and sedimentation in the Coon Creek basin following improvements in land management and changes in land use. Although the crops grown did not change improved crop rotations and contour plowing began to be implemented, which decreased erosion (14). Trimble and Lund (26) reported that between 1934 and 1975 several land management practices which included contour plowing, contour stripcropping, long rotations, crop residue management, cover crops, and controlled grazing were instituted (Fig. 2). The rate of alluvial sediment accretion in the agricultural Coon Creek Basin decreased dramatically compared to the 1930s, but the changes were variable across the basin (27).

Public Law (PL) 566 in the 1950s and 1960s reduced flooding, erosion, and sedimentation and increased infiltration and base flow in streams in southeast Minnesota (15). PL566 provided support to landowners working with federal agencies to build small dams, stabilize gullies, and protect eroding streambanks (14, 28). Base flow in watersheds in southern Wisconsin increased from 13% from 1981 to 2010, to 18% from 1950 to 1980 (29), but part of the increase may have been related to an increase in precipitation after 1970 (21). Agricultural land use practices, such as no-till and conservation tillage, were also developed and supported by the Natural Resources Conservation Service. Concurrent with the environmental movement in the late 1960s and 70s, state fisheries managers and conservation groups, such as Trout Unlimited, employed site-level management strategies to increase fish populations in streams. The advent of "stream restoration" led to the recognition that improving stream quality and fish populations required site-based restoration and management strategies and landscape-scale interventions, such as making stream channels narrower and deeper to increase water velocity and maintain cool stream temperatures during the summer and sloping stream banks to dissipate flood energy into the floodplain rather than eroding streambanks. These restorations and interventions require expertise found within multiple disciplines (e.g., engineering, geomorphology, ecology).

Stream Habitat Management

Investigations of streams usually focus on the local or riparian scales, and much progress has been made in instream and site-level habitat management, such as stream restoration. However, land use at catchment scales may confound or constrain influences on the structure of aquatic communities (6). Processes at larger scales may account for many of the observed habitat losses that are often poorly addressed (30). Removal of riparian vegetation, whether for agriculture or timber harvest affects streams in a number of ways. Stream water temperature can increase, as much as 4.5°F (2.5°C), along streams when vegetation is removed because of reduced shade on the water surface (31). Trimble (32) reported that four reaches in Coon Creek streams bordered by grassed streambanks were narrower and stored more sediment than reaches with forested streambanks. Interestingly, Wang, et al. (5) reported habitat quality and index of biotic integrity (IBI; a way to use fish or insect assemblage information to assess stream health) scores were positively correlated with the amount of forested land and negatively correlated with the amount of agricultural land in watersheds in 103 streams in Wisconsin, and IBI scores decreased when agricultural land use exceeded 50% (Fig. 4). Coldwater IBI scores increased over time in streams in high Conservation Reserve Program (CRP) areas relative to streams in low-CRP areas (33).

Catchment and Riparian Land Use

A discussion of the relative importance of managing riparian areas versus modifying land use at a catchment scale to protect streams is important to consider. This discussion is important because most stream restoration efforts are focused primarily on modifying stream channels and altering streambanks and riparian areas to improve stream habitat and fish, usually trout, abundance. Importantly, riparian areas with forest or grass cover removes minimal land from agricultural production. Riparian zone management plays essential roles in restoration of aquatic systems (34). Riparian vegetation has been found to reduce overland water flow, sediment, and nutrients entering streams. Riparian areas affect water chemistry by trapping nutrients, sediment, and other nonpoint source pollutants in agricultural settings (35–38). Riparian areas can influence instream water temperature, habitat structure, hydraulic complexity, channel morphology, and nutrient inputs (7, 27, 31, 39–42). Riparian areas can influence fish productivity and other aquatic biota (4, 43, 44). For example, fish assemblages were more related to reach-scale habitat rather than to watershed agricultural land cover (45, 46). Nerbonne and Vondracek (47) found the percent of fine sediment and embeddedness in stream channels in the Whitewater River, Minnesota decreased with riparian buffer width. In addition, Nerbonne and Vondracek (47) found fine sediment, embeddedness, and exposed streambank soil were lower along stream reaches with grass buffers compared with grazed or wooded buffers. Riparian vegetation can slow the timing and amount of peak discharge from rainfall events and snowmelt, which can be important in the Driftless Area in light of winter snowfall and increased precipitation since 1970.

Grazing. Grazing and dairy operations, although declining in the Driftless Area, are still an important land use. Continuous grazing, whether for beef cattle or dairy, in riparian zones can result in significant streambank erosion and nutrient input to streams (48, 49). An alternative, often labelled rotational grazing, can affect stream channel stability and significantly reduce streambank erosion and nutrient input, which can lead to increased abundance of fish and aquatic invertebrates (3, 50–52).

Urbanization. Although there are few large urban areas in the Driftless Area, Wang, et al. (5) and Wang, et al. (53) indicate that low levels of urban development can affect coldwater stream systems (Fig. 5), specifically, land cover within the riparian area (30-m, or 100-ft) explained more variance in fish assemblages than land cover beyond 30-m. Wang, et al. (53) suggested that minimizing imperviousness may limit damage to stream systems. Low levels of urban development can affect coldwater streams, primarily due to increased impervious surfaces, which can increase water temperature and alter base flow (53). Allan, et al. (6) found higher levels of total nitrogen and phosphorus adjacent to urban land than for agricultural or forested land cover.

Agriculture. Several researchers suggested that land use at a watershed scale governs nutrient, sediment, and water yield, regardless of the extent of buffers (6, 54–56). Land use at broader scales can affect trout habitat by physically and chemically altering stream channel structure and water quality. Increased flooding and increased stream discharge lead to streambank erosion. Agricultural practices continue to affect water quality and channel structure and function related to increased nutrient and sediment delivery to streams. Richards, et al. (57) found surficial geology at a catchment scale influenced channel morphology and hydrologic patterns, which influenced macroinvertebrate assemblages in 58 catchments, but macroinvertebrate species traits (feeding habits, etc) were

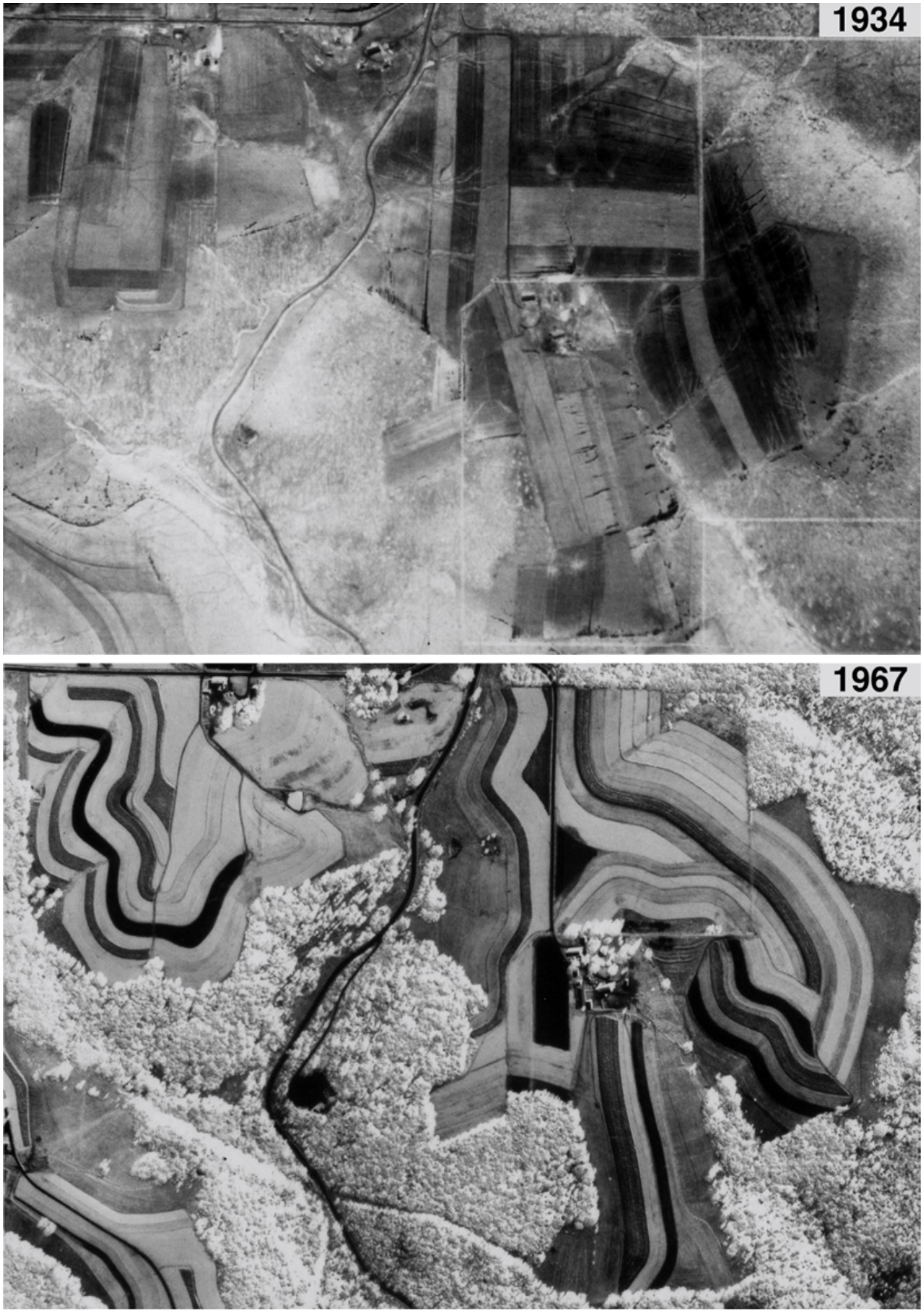

Fig. 2. Air photos of Coon Creek landscape, 1934 and 1967, just north of Coon Valley (SE1/4,T15N, R5W, Vernon Co.). 1967: Note contoured and strip cropped fields with no rills or gullies. From Trimble (14).

Fig. 3. Streambank erosion due to lack of buffer between farm fields and streams. Credit: J. Hastings.

related to local environmental conditions. Agricultural land at a catchment scale across 103 sites in Wisconsin negatively affected habitat quality and the IBI when agricultural land use exceeded 50% and relationships were generally stronger for the entire watershed than for the buffer (5) (Fig. 4).

Vaché, et al. (8) used the Soil Water Assessment Tool to compare historical and then current agricultural land use practices with scenarios of potential land use. Interestingly, incorporating no-till cultivation (a practice currently in wide use) only slightly decreased mean sediment delivery to streams. A scenario that included riparian buffers 30-m (100-ft) on both sides of perennial streams and 15-m (50-ft) on both sides of ephemeral streams, as well as no-till, further decreased sediment delivery. A scenario that doubled the width of buffers, but also reduced monocultures of corn and soybean rotations and incorporating a strip of native perennials in fields of corn and soybeans reduced loadings of sediment by 37 to 67% and nutrients by 54 to 75%. A similar modeling effort was conducted by Zimmerman, et al. (9) that examined the relationship between water quality and fish communities within two agricultural areas using the Agricultural Drainage and Pesticide Transport (ADAPT) model. One of the streams was Wells Creek in southeastern Minnesota. A scenario in Wells Creek that included conservation tillage with recommended fertilizer application rates and 30-m (100-ft) riparian buffers along all waterbodies reduced sediment loading by approximately 30%. Land use changes that included maintenance of year-round permanent cover on agricultural land conversion to managed intensive rotational grazing and prairie and wetland restoration and 90-m (300-ft) riparian buffers led to reductions in sediment loading of up to 84% in Wells Creek; the reduction in sediment loading was directly related to a reduction in runoff by about 35%. These two modeling efforts found reductions in sediment loading can be achieved by no-till cultivation or conversation tillage (practices in current use), but including 30-m (100-ft) buffer areas along streams further reduced sediment delivery to streams. Although the Natural Resources Conservation Service currently supports installing buffer strips (see September 2016 NRCS filter strip Code 393), current agricultural practices, and importantly,

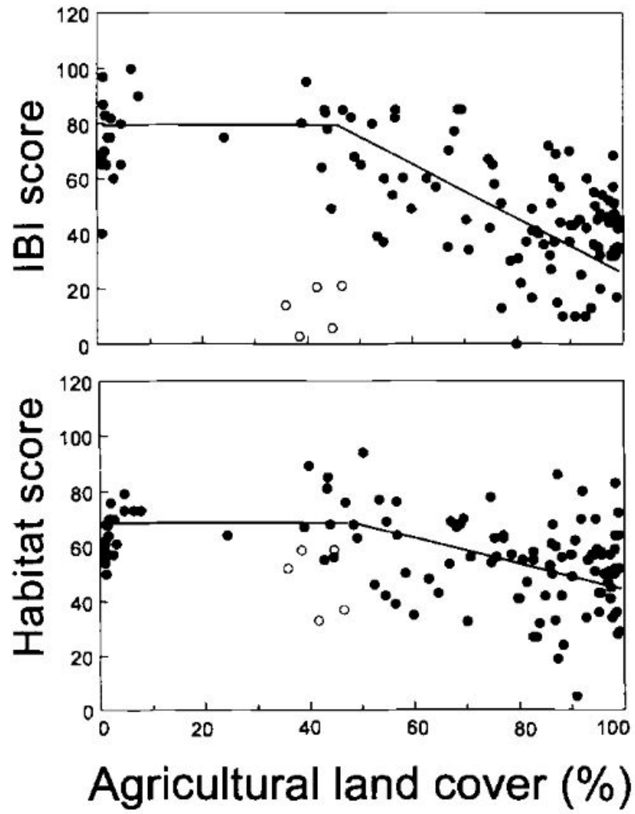

Fig. 4. Relationships between watershed agricultural land use and habitat and IBI scores. The open circles represent sites considered as outliers from the forest land use-IBI relationship. Lines were fitted by eye. From Wang, et al. (5)

national farm policy may offer limited ability to affect land use at broad scales because contaminants flowing off of farm fields - non-point source pollution - are exempt from regulations.

Stream Buffers. Recognizing the potential for buffers to improve stream water quality the Governor of Minnesota developed a Water Quality Buffer Initiative. A 'buffer bill' was passed in 2015 by the state legislature that required that buffer strips be placed along streams and ditches in Minnesota. The state of Wisconsin also instituted a buffer initiative that predated the Minnesota law. The University of Wisconsin, College of Agricultural and Life Sciences (UW-CALS) was asked by the Wisconsin Department of Natural Resources (DNR) in March of 2002 to provide an overview of the science behind riparian buffers (58). The UW-CALS ad hoc committee, presented a report that included a 700-item bibliography to the DNR in early May 2002 (UW-CALS website). The report emphasized an adaptive management approach with an ultimate recommendation to take a broad, systems approach to implementing agricultural conservation practices to improve water quality. The DNR Natural Resources Board, in consultation with key legislators, passed a resolution supporting the ad hoc committee's recommendations.

Field- and Farm-Based Conservation Practices

Carvin et al. (59) compared two 5,000 ha (12,360 ac) watersheds in the Driftless Area of south-central Wisconsin to examine the UW-CALS recommendation to take a systems

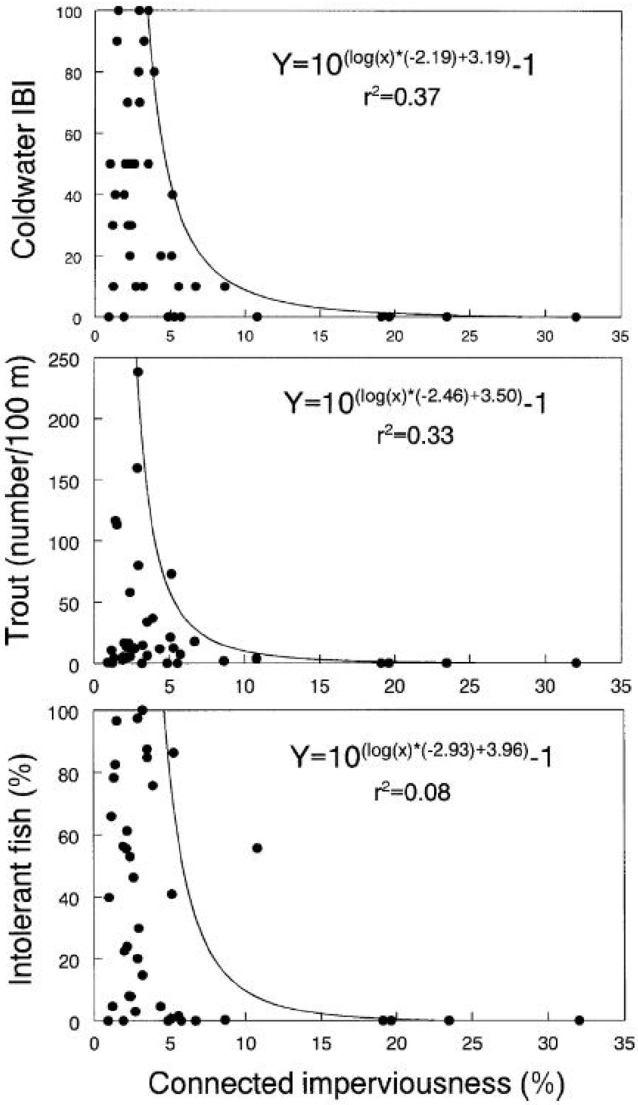

Fig. 5. Relations between percent watershed connected imperviousness and the coldwater index of biotic integrity (IBI), trout abundance, and percent intolerant fish in Minnesota and Wisconsin trout streams. From Wang, et al. (53).

approach to implement agricultural conservation practices. The design of the study was to implement baseline monitoring (2006 to 2009) followed (primarily in 2011 and 2012) by implementation of both field- and farm-based conservation practices. Both conservation practices were implemented in one watershed (treatment), whereas there were no out-of-the-ordinary conservation efforts in the second watershed (control). The watersheds were then monitored for four years (2013 through 2016). Storm-event suspended sediment loads in the treatment watershed was significantly reduced compared to the control watershed when the ground was not frozen. Year-round suspended sediment event loads appeared lower, but were not statistically significant. Total P loads were reduced for runoff events with a median reduction of 50%. Total P and total dissolved P concentrations during low-flow conditions were also significantly reduced in the treatment watershed.

Stream Restoration

Agencies and organizations, such as Trout Unlimited through the Driftless Area Restoration Effort, work diligently to restore habitat and water quality to restore habitat for fish and other non-game species and to provide recreational fishing access to restored areas. Stream restoration focuses on stream reaches with the intent to create narrower, deeper stream channels and stable streambanks. Thus, regardless of the broader debate about riparian versus larger land use scales, a focus on riparian areas can affect stream habitat quality. Restored stream channels may improve water quality and trout habitat, but they also help promote naturally reproducing, self-sustaining trout populations (see Dieterman and Mitro, page 29). However, streams prior to and after stream restoration are affected in a number of ways that are related to land use at riparian and larger scales and should be included in long-term planning and management.

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