BRINGING DISCOVERY FARMS® TO KING CONSERVATION DISTRICT TO EVALUATE THE EFFECTIVENESS OF RIPARIAN BUFFERS ON AGRICULTURAL LANDS

King Conservation District

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What is the Discovery Farms® Program?

The Discovery Farms® (DF) program is a research and outreach model developed by the University of Wisconsin to better understand the impact of on-farm practices on water quality through applied, field-level research, and outreach. The primary purpose of DF is to evaluate the impact of different agricultural practices on water quality. Discovery Farms research is conducted on private farm, known as a Discovery Farm, in cooperation with farmers, and farmers are involved in the planning and implementation of the DF studies. Thus, DF is a farmer-led on-farm result oriented research program. The mission of the program is understanding the economic and environmental effects of different agricultural practices through on farm and related research and communicate the results with producers, consumers, researchers and policymakers and to implement effective environmental management practices that are compatible with profitable agriculture.

The goal of the Discovery Farms programs is to:

- Increase understanding of agricultural impacts on water quality and work toward reducing adverse impacts though a collaborative approach;
- Integrate outreach and research programs with environmental management and regulatory efforts;
- Provide research-based information on agricultural production and natural resource management to public policymakers;
- Promote the economic viability of agriculture across diverse livestock and cropping systems.

The Discovery Farms program has three fundamental principles:[1]

Farmer leadership

The DF program is governed by a farmer led Steering Committee or Leadership Team and supported by a larger Advisory Committee and Research Team. This farmer-led committee is involved in identifying program priorities and research questions, selection of research locations/farms, and data interpretation and sharing via outreach.

[1] http://www.uwdiscoveryfarms.org/about/other-discovery-farms

Research/Demonstration

The Discovery Farms program conducts field studies following rigorous quality assurance protocols allowing data comparison between sites and regions. Projects are focused on surface water quality, but can be expanded to other media based on the interests of the Steering Committee and available funding.

Communicating the results

An important principle of the DF program is a strong outreach and education component that provides information to a wide variety of audiences including the agricultural community, consumers, researchers, agencies, and policymakers. Websites, tours, field days, seminars and publications are some of the means used to broadcast the study results and lessons learned.

Why Discovery Farms

Millions of dollars are spent on conservation practices to protect natural resources and the environment. However, the effectiveness of many of these practices is rarely monitored. Therefore, recent attention has been brought to the need for on-farm, system-oriented research approaches to address this gap. The success of the University of Wisconsin DF model has inspired more states to adopt the DF approach to study the impact of agriculture on water quality. The DF program offers real-life data that is crucial for making sound recommendations about agriculture and the environment. On-farm, producer-led research creates a conducive environment to work directly with farmers, facilitate peer-to-peer learning and test solutions locally under real-world conditions.

Using identical procedures and tools across DF programs sites ensures consistency and confidence and allows for data comparisons between different sites, counties, states or regions to one another. This comparison helps to see the bigger picture and provides an opportunity to develop models that predict results for various conditions.

On-farm research provides locally appropriate technical solutions while allowing farmers to see research results first hand. As a result, farmers may be more open to making changes to their practices to conserve natural resources and the environment. On-farm research can also increase the understanding and communication between nearby farmers. This shared learning experience can ultimately facilitate the adoption of improved conservation practices.

What is a Discovery Farm?

A Discovery Farm is an operating farm cooperatively participating in an on-farm systems research/evaluation/demonstration project. A farm that volunteers and/or is selected to be a Discovery Farm agrees to certain set of parameters including working collaboratively with the Research Team on project installation, operation, data sharing, and outreach.

History of Discovery Farms

Origins of Discovery Farms

The DF approach has its roots in the Netherlands. Personnel from University of Wisconsin visited farm-research facilities in the Netherlands. These facilities are used to investigate the impact of farming practices on environmental issues such as water quality. Following this visit, University of Wisconsin personnel, State agricultural leaders, and producers met to organize various agricultural groups and designed DF program to examine water quality issues that affects Wisconsin agriculture.

Discovery Farms in Wisconsin[2]

Wisconsin has been the pioneer state in using the DF program approach in the US. Discovery Farms Wisconsin started around 2000 with the intention of creating a farmer engaged research and outreach program that would enroll farmers as the messengers of water quality results. Currently, Wisconsin DF is working with 40 farmers across the state on edge of field water quality monitoring and nitrogen use efficiency. The Wisconsin DF program is part of the University of Wisconsin Extension, with local organizations, partners, and farmers supporting the program.

Edge of Field (EoF) monitoring has been the selected and refined method used by Wisconsin to help farmers improve and verify the effectiveness of land management practices. This method, developed in collaboration with USGS, has become the standard for surface runoff monitoring by DF in agricultural settings. The edge of field equipment, installed on the Discovery Farm, measures the quantity and quality of water drained from a known area such as a production farm field. Using the results of the DF research, conservation managers and farmers can work together to modify land management practices to more effectively enhance water quality while still maintaining agricultural productivity. One of such example is

[2] http://www.uwdiscoveryfarms.org/

the manure spreading timing study. Nutrient loss and water contamination is a major concern associated with manure spreading. To address this concern, DF Wisconsin looked at the benefits and impacts of manure application timing and showed that early winter manure application is beneficial to the farm and reduces nutrient loss as compared to later applications (Discovery Farms Wisconsin, 2017).

The other DF project initiative in Wisconsin is focused on monitoring tile drainage system to better understand the timing and mechanisms of soil and nutrient loss. Soil health and soil carbon analysis is also conducted in these fields to investigate the relationship between these parameters and nutrient loss from the tile system.

Discovery Farms Wisconsin also works on special short-term projects specific to regional environmental concerns. These projects include a nitrogen use efficiency (NUE) study and a feed storage leachate study. The NUE study is conducted by tracking nitrogen from all sources as it cycles from soil to plants. The efficiency is measured as the field's productivity compared to its N input. The feed storage leachate study is being used to better understand the quantity and timing of nutrient loss from bunker soils.

Discovery Farms in Minnesota[3]

The Discovery Farms Minnesota program focuses on assessing the movement of sediments and nutrients such as nitrogen and phosphorus over the soil surface and through subsurface drainage tiles. These studies result in a better understanding of the relationship between agricultural management and water quality. Discovery Farms in Minnesota have two key features: core farms and special projects. Core farms represent a farming system representative of the state's farming enterprise that needs to be evaluated. Core farm studies are long-term studies that begin with two to three years of baseline water quality monitoring. Special projects are shorter term, two to three-year projects, that focus on specific environmental concerns.

Joint work by Minnesota and Wisconsin

Discovery farms in Wisconsin and Minnesota started to work collaboratively several years ago to protect and enhance water quality. The studies in these two states complement each other in that DF in Wisconsin mainly focuses on forage systems with manure as the main nutrient source, while DF research in

[3] https://discoveryfarmsmn.org/

Minnesota has primarily focused on grain cropping systems with a mix of manure and fertilizer as a nutrient source.

Discovery Farms in Arkansas[4]

Arkansas DF currently has nine private farms representing livestock (broiler poultry and pasture grazed beef and sheep) and row crop agriculture (corn, cotton, rice, soybean, and wheat) where water quality monitoring is being conducted as a function of conservation management. The conservation practices being evaluated at each site are informed by the preferences of the farmers and typically coincide with regional soil or water quality concerns.

Discovery Farms in North Dakota[5]

North Dakota DF also has surface runoff and tile drainage water quality monitoring studies like the other states. Discovery Farms was adopted to North Dakota because of a concern that environmental regulations were inconsistent with economic viability of farms. The goal of the program is to help decision-makers balance the priorities of agricultural profitability and environmental protection.

Discovery Farms in Washington[6]

The Washington Discovery Farms program, started in 2016, functions under the same principles and goals as the other States to monitor and improve the effectiveness of conservation practices and reducing impacts to natural resources while maintaining the economic viability of and improving farming. The Washington DF program is led by Conservation Districts with input from state and local partners, local research teams, and farmers. The program is largely focused on evaluating the effectiveness of land conservation practices and their potential impact to surface waters using edge of field monitoring. However, other media and research options have been proposed for new sites. At this time there are four EoF sites currently in Whatcom County and more under development across the State. The sites in Whatcom County are largely funding through NRCS' Environmental Quality Incentive Program- National Water Quality Initiative Edge of Field project funds. Other funding sources are being pursued for future sites.

[4] https://aaes.uark.edu/discovery-farms/about.aspx
[5] https://www.ag.ndsu.edu/df
[6] http://www.wadiscoveryfarms.org/

Discovery Farms Partners

Discovery Farms works in partnership with producer groups such as different Co-ops, crop and livestock associations and agencies such as Department of Agriculture, Department of Natural Resources, Natural Resources Conservation Service, Environmental Protection Agency, Farm Bureau, and organizations such as Universities, United States Geological Survey, and different regional and local environmental groups. Cooperation between government organizations, producer associations and environmental groups and researchers has been key to the past and future success of DF. Discovery Farms in each state has its own funding, data collection and sharing agreements with its partners.

Bringing DF to King Conservation District (KCD)

King Conservation District has been investing and installing riparian buffers with farmers for over two decades. Over that period, riparian buffer recommendations have been evolving to address multiple natural resource goals. In fall 2017, KCD began scoping for a Discovery Farms program focused on better understanding the effectiveness of agricultural buffers. KCD's first step was to conduct numerous interviews with regional riparian buffer experts to identify key research needs. In addition to evaluating the latest research on riparian buffers, these experts pointed to the need for additional evaluation of the effectiveness of the existing riparian buffer on agricultural lands.

To date, DF programs in other areas have mainly focused on assessing the impact of agriculture on water quality and working towards better agricultural practices that can improve water quality while maintaining agricultural productivity. For this new DF Project, KCD is proposing to use the Discovery Farms model to study the effectiveness of riparian buffers on agricultural land sticking with the three fundamental principles of DF model: farmers' leadership, scientific research, and strong educational and outreach.

Using Discovery Farms, the goals of KCD are:

- To provide scientific evidence to policymakers.
- To empower natural resource conservation managers with better knowledge.
- To increase farmer's knowledge about environmental impacts of farm practices.
- To enhance adoption of best management practices.

Organizational structure

Steering/ leadership committee chaired by farmers

The central steering committee will be composed of farmers and industry representatives who provide input on research needs, identify projects potentials, prioritize projects for funding, and identify research locations.

Stakeholder group

The stakeholder group will provide guidance and feedback on the research project as needed. This group is composed of agencies such as Department of Ecology, King County, and organizations such as American Farmland Trust, Citizen's Alliance for Property Rights, and other interested groups and individuals.

Research team

This group, chaired by farmers, includes neighboring farmers, ranchers, consultants, extension staff, conservation districts, NRCS, and other local agencies that will conduct the research, evaluate progress, gather and analyze data, report and distribute results.

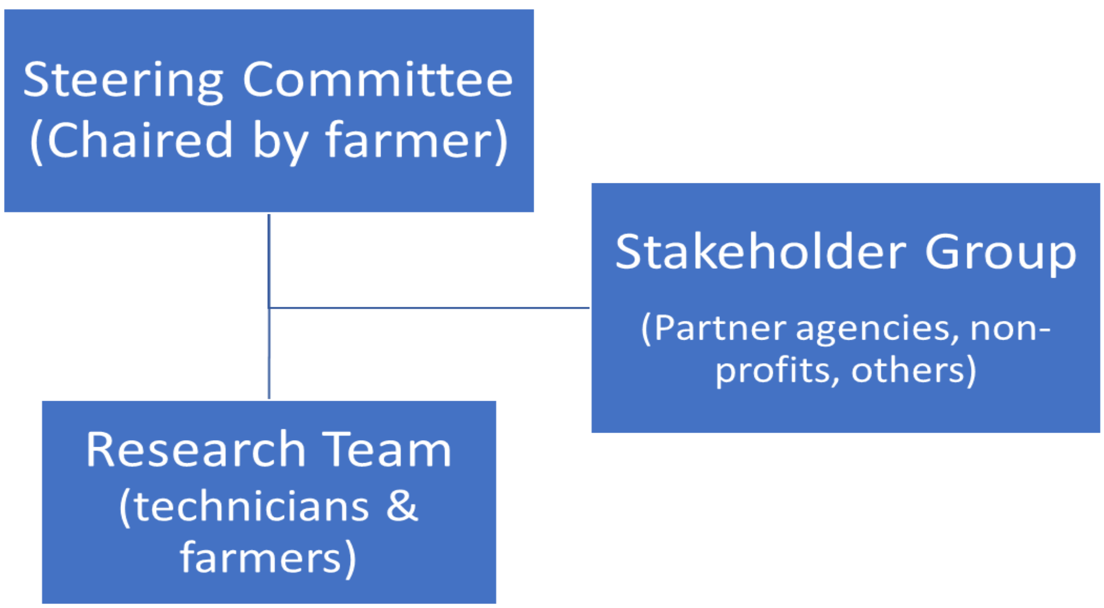

Figure 1. Structural organization of KCD Discovery Farms

Bringing DF to KCD

- KCD's method for introducing the DF model into King County to study riparian buffer effectiveness on agricultural lands, involved first reaching out many local governmental and non-governmental organizations and individuals who might have interest in buffer research. All parties contacted provided general and specific comments on buffer research and what aspects they are interested in exploring further. One thing learned from all interested parties is that there is a shared concern for the lack of available science on the effectiveness of riparian buffers on agricultural lands.
- Several meetings were conducted with Nichole Embertson, a de facto coordinator of Washington State's Discovery Farms program, to ensure statewide consistency in the project development.
- The third step of the process is this white paper. This white paper is prepared to provide a background on the DF program and the motivation for studying riparian buffer effectiveness on agricultural land.
- The next step will be a stakeholder meeting with all the parties mentioned above (farmers, tribes, other government agencies and non-governmental organizations who might have interest in buffer research.
- Post meeting, the steering and advisory committees will be formed.
- Staff from the Washington State Department of Ecology will prepare a quality assurance plan/protocol for the riparian buffer effectiveness study.
- A specific research plan will be developed.
- Site selection and field trials will be conducted.
- Data will be collected, analyzed and interpreted.
- The results will then be disseminated through reports, peer-reviewed journal articles, presentations, fact sheets, posters, workshops, field tours, blogs, etc.

Table 1. Current KCD Discovery Farms project time line

Sept – Oct, 2017	Contacting potential stakeholders
Sept, 2017 – Jan, 2018	Establishing partnership with Whatcom CD DF
Sept – Nov, 2017	Literature review
Nov, 2017 – Jan, 2018	White paper preparation
Feb, 2018	Stakeholder meeting
March, 2018	Steering, stakeholder committee forming
Jan – April, 2018	QAPP preparation
May, 2018	Site selection
Starts June, 2018	Field trial
Result will be disseminated periodically as needed	Result

Riparian buffers on agricultural land

Benefits of riparian buffers

Table 2 summarizes different benefits of vegetated riparian buffers on agricultural land. It indicates that benefits from buffers are not limited to salmonids. Farmers can also benefit from shade for their livestock. The shade can also suppress the growth of invasive species (Tu, 2004). Vegetated riparian buffers can also create pollinator habitat or habitat for biological control (insects that eat crop pests) which enhances agricultural productivity (Maria, 2013). Buffers can act as windbreaks which can increase crop productivity by improving the microclimate, retaining humidity, and reducing crop loss due to high winds. Buffers are also important for the environment by helping in carbon sequestration, creating and enhancing terrestrial and aquatic habitat and food, improving soil and water quality, increasing biodiversity as well as the many other benefits displayed in Table 1.

Table 2. Benefits of riparian buffer on agricultural land

Buffer function	Benefits for farmland/ livestock	Benefits for salmon habitat	Other environmental benefits	Source
Temperature control /shade	✓	✓	✓	Gumbert et al., undated
Windbreak	✓			Chow et al., 1999
Filtering sediments		✓	✓	Sweeney and Newbald, 2014
Stream channel and bank stabilization	✓	✓	✓	Yuan et al., 2009
Water quality improvement (nutrient and pollutant reduction, algal growth)		✓	✓	Hawes and Smith, 2005
Pollinator habitat	✓		✓	Whitaker et al., 2000
Habitat for biological control	✓			Landis & Wratten, 2002
Habitat for prey		✓	✓	Whitaker et al., 2000
Habitat for wildlife			✓	Wenger, 1999
Large woody debris and leaf litter		✓		Murphy and Koski, 1989
Runoff reduction	✓	✓	✓	Sullivan et al., 2004
Prevent erosion	✓	✓	✓	Hawes and Smith 2005
Increase biodiversity			✓	Mosley et al., 2006
Reduce wind-related evaporation	✓		✓	Burt et al. 2005
aesthetic value	✓			Sullivan et al., 2004
Economic value	✓			Breslow, 2001

Challenges of buffer practice implementation

Farmer perception

Although vegetated riparian buffers have widely recognized benefits for farm productivity, fish habitat, and the environment, some farmers are not aware of the natural resource concerns associated with smaller streams. Planting buffers can also cause some challenges for different land uses. The challenges are especially significant for small scale farmers. Many of these farmers resist buffer planting because of concerns about taking land out of production. Some farmers argue that assigning land for buffer planting

can threaten the economic viability of the farm that could escalate to loss of livelihood (Breslow, 2001). For some farmers, wider buffer planting can restrict access to road due to the shape and size of their land and the associated streams[7]. Farmers assert that there isn't enough scientific evidence behind the wider buffer recommendations (Breslow, 2014). Some farmers view buffer regulations as an intrusion in their property rights and feel it could result in a lack of control over their property (Breslow, 2001). Some farmers complain that buffers create mess and debris negatively impacting the visual aesthetics of their farm (Martin, 2009). Buffers are also thought to cause problems with drainage maintenance and can attract beavers and other nuisance wildlife that may damage crops (King County, 2016).

Other barriers

Sometimes the challenge comes from a different direction. In King County, some farmers would like to plant buffers in the less productive parts of their land but are not able to because their enrollment in the Farmland Preservation Program (FPP)[8]. The King County FPP limits vegetated riparian buffer widths to 25 feet on agricultural land enrolled in the program, as the program considers vegetated riparian buffers as 'untillable area'[9]. Local site conditions can be a barrier as well, sites that are inundated for too long into the growing season or too rocky or droughty are challenging for tree and shrub survival and establishment.[10]. Another barrier is infrastructure, such as roads and buildings. Roads are common in floodplains. Their location often limits the width of riparian buffers. Flexibility in buffer width is important to be able to provide benefit in these areas.

Buffer regulations

King County government has been engaged in assessing and attempting to limit negative effects of land use on the environment since the 1980s. Targeted salmon habitat recovery planning also started in late 1990 following the Endangered Species Act (ESA) listing of Puget Sound Chinook salmon (King County, 2012). Increased environmental pressures led to new regulations put into place to protect natural resources and to promote salmon habitat recovery. The Critical Areas Ordinance (CAO) is a set of

[7] Personal communication: Jacobus Saperstein staff at KCD.
[8] Personal communication: Emmett Wild, staff at KCD
[9] To learn more about FPP - http://www.kingcounty.gov/depts/dnrp/wlr/sections-programs/rural-regional-services-section/agriculture-program/farmland-preservation-program.aspx
[10] Personal communication: Debbie Meisinger, staff at KCD

regulations that address the protection of designated critical areas. The King County CAO regulates aquatic areas and associated buffers and dictates required buffer widths and setbacks for development activities. It requires 25 – 165 feet buffer setbacks from streams depending on classification and 25 – 300 feet buffer setbacks for wetlands depending on the category/ type of the wetland[11]. These regulations were derived from peer reviewed best available science using contemporary science on ecology, biology and land use conditions (King County, 2012).

The King County Livestock Management Ordinance (LMO) is another set of regulations enacted to protect designated critical areas. The LMO pertains specifically to livestock owners and is designed to minimize adverse impacts of livestock on water quality and salmon habitat. Regarding buffers, the LMO requires a 50-foot minimum vegetated buffer from designated critical areas for livestock. There are certain exceptions to this 50-foot buffer/setback, for instance, a livestock owner may be eligible for a variance to the 50-foot buffer if a Farm Management Plan, provided by the King Conservation District, is developed to minimize non-point source pollution from agricultural activities. In this circumstance, a 25-foot vegetated buffer is the minimum required. A variance may also be given if an existing fence was installed prior to 1994 placed according to the 1990 Sensitive Areas Ordinance that preceded the current LMO.

Buffer Conservation Practices

The County's Agricultural Drainage Assistant Program (ADAP), while not requiring a specific buffer width, does require 1-3 rows of trees and/or shrubs spaced at 3 feet on center, to be planted following dredging activities on artificial and modified waterways. The number of rows required is dependent upon on the classification of the waterway and determined suitability for fish use.[12]

The USDA Natural Resources Conservation Service (NRCS)[13] has conservation practice standards for buffer plantings. According to the NRCS Field Office Technical Guide (eFOTG), the minimum width of a riparian forest buffer for specified conservation purposes is 35 feet. If planning a riparian forest buffer for fish habitat, the minimum buffer width is 50 feet. In addition to the riparian forest buffer specification, NRCS also has a hedgerow specification that applies to aquatic area buffers. This hedgerow practice standard

[11] To learn more about the King County CAO http://www.kingcounty.gov/depts/permitting-environmental-review/info/SiteSpecific/CriticalAreas.aspx
[12] For more information on ADAP http://www.kingcounty.gov/services/environment/water-and-land/stormwater/agricultural-drainage-assistance.aspx
[13] To learn more about NRCS conservation practices https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849

specifies that a 15 feet wide hedgerow planting can be applied to natural channels with bankfull widths of 5 feet or less or modified agricultural channels with bank-full width of 15 feet or less. In Washington State, any buffer planting projects using NRCS funding must abide by these vetted practice standards. Conservation District funded projects, in most cases, also abide by these NRCS practice standards.

Table 3. summary of the different buffer regulations

Regulation	Buffer width	Condition
CAO	25-165 ft	Depending on stream type
CAO	25 – 300 ft	Depending on wetland type
LMO	50 ft	If no farm plan or existing diverse vegetation buffer
LMO	25 ft	If it has farm plan or existing diverse vegetation buffer
ADAP	1-3 rows	Depending on waterway type and suitability for fish use
NRCS	35 ft	Other conservation purposes (not fish)
NRCS	50 ft	If the waterway is potential for fish use
NRCS	15 ft	5 feet or less natural channels
NRCS	15 ft	15 feet or less wide modified agricultural channel

Voluntary buffer financial assistance programs

The United States Department of Agriculture Farm Service Agency oversees several voluntary natural resource conservation programs, one of which is the Conservation Reserve Program (CRP), a nationwide program that works with farmers and landowners to mitigate environmental problems. In Washington State, CRP includes Conservation Reserve Enhancement Program (CREP), a joint Federal and state funded program carried out by NRCS and Conservation District staff. The mission of CREP is to protect and restore salmon habitat by subsidizing farmers to plant riparian buffers. CREP requires a minimum width of 50 feet of riparian forest buffer (or in some cases a 15-foot-wide hedgerow) and a maximum width of 180 feet. The program pays 100% of installation costs (at set rates) and pays farmers with an annual cash rental payment for enrolling in the program with a 10 or15 year contract. There is also a onetime sign up bonus and the option for re-enrolling after the initial contract expires. CREP also provides funds to maintain the buffers for at least five years.

The King Conservation District has its own buffer financing program. Unlike CREP, it does not pay a signup bonus or rental payment for buffer planting. However, it does have a cost-share program that provides financial assistance, project planning, implementation and maintenance services for cooperators who volunteer to install, enhance or expand riparian buffers on their farm. As stated earlier, this program follows the NRCS standards for minimum width determination. This program has a much simpler enrollment process and planning requirements and experiences wider participation among small farm land managers than the CREP program. Unlike CREP, available financing for this program is capped to limit per landowner buffer plantings to 1 acre or less while CREP is funded to cover much larger acreage projects.

Other organizations such as Stewardship Partners[14] also encourage farmers to plant buffers by helping with planting and maintenance costs. As these organizations are nonprofits they are able to be more flexible in their minimum width requirements and have fewer technical requirements, making them more popular. However, since they rely on grant funding they are not always able to meet the demand.

In eastern Washington, Spokane County Conservation District (SCCD) in collaboration with Department of Ecology started a unique "Commodity buffer" program last year[15]. This program compensates farmers just as much as they would earn if they plant crops instead of buffers[16]. The buffer width is determined depending on stream type and Soil Tillage Intensity Rating (STIR). The program was successful as a lot of farmers signed up. However, it faces budget uncertainty this year.

[14] http://www.stewardshippartners.org/tag/king-county/
[15] http://www.sccd.org/wp-content/uploads/2017/08/Commodity-buffer-Outreach-Fact-Sheet-2017.pdf
[16] http://www.capitalpress.com/Water/20160323/commodity-buffers-pay-farmers-same-as-crops

Table 4. Summary of the voluntary buffer practices

	Buffer width	Pro	Con
CREP	50 – 180 ft	Signup bonus Rental income Installation cost Maintenance cost	Lengthy enrollment process Too wide for many farmers
King Conservation District	NRCS standard	Cost share for installation and maintenance Easy enrollment	Limited to 1 or less acre per farmer No rental income
ADAP	1 -3 rows	Installation cost share	Limited to farmers enrolled in ADAP
Stewardship Partners	Flexible	Easy enrollment Installation financial assistance Flexible width	Limited capacity No rental income

Existing conditions

Despite the challenges discussed above, farmers are willing to set aside some land for habitat restoration (King County, 2016). Although historical farmland loss is mainly due to development, farmers have a great concern about the amount of land taken out of farming in the name of habitat restoration (Martin, 2009). The major contention is around the required buffer widths (Breslow, 2001). Some agencies are requiring a wider minimum buffer width, up to 100 feet in some cases, for eligibility into voluntary incentive programs (Smith, 2013). However,even programs with lesser buffer widths requirements such as the NRCS's 35 feet wide buffer for riparian forest buffers can be too much for some farmers. Even with the financial incentives provided by CREP, in Washington State, only 8% of the CREP eligible streamside is currently enrolled by CREP (Smith, 2013).

Buffer effectiveness

Worldwide, a riparian buffer between human land use and waterways is considered beneficial (Roni et al., 2008). In Washington, ecologically significant fish habitat areas are intertwined with major agricultural production areas and strongly intersect in riparian areas (Dittbrenner et al., 2015). Therefore, many groups are seeking ways to conserve salmon habitat without compromising agricultural productivity. Efforts to balance these competing goals raises questions of riparian buffer effectiveness. Riparian buffer effectiveness is measured by studying the rate of functions a buffer provides per unit of width. In most studies, buffer effectiveness is expressed as percent reduction of sediment, nutrient, or pollutant reaching the waterway, rate of temperature maintenance, index of terrestrial and aquatic biodiversity (Lee et al., 2001).

May and Horner, (2000) suggest that riparian buffers should be judged according to width, quality (vegetation density, height, and species composition) and length. However, riparian buffer width is mostly the only criteria by which riparian corridor management is defined. As discussed above, in Washington state, riparian buffers are planted in prescribed width through regulations and voluntary programs following standard practices defined by Natural Resources Conservation Service (NRCS). However, many farmers, as well as professionals, believe that there is not enough scientific evidence to back these recommendations[17]. Moreover, the effectiveness of these practices is rarely monitored. As a result, riparian buffers on agricultural land have become a source of persistent tension between advocates of salmon recovery and advocates of farm land preservation (King County, 2016).

Appropriate buffer width depends on several factors such as: desired function, site condition, economic feasibility and political acceptability (USDA-NRCS, 2000). For instance, significant shade or erosion control can be provided by narrow buffers, but these same narrow buffers may not be sufficient for other aspects of water quality or for salmon and wild life habitat, such as large wood debris. Regulation of fixed width buffers is easy to enforce and cheaper to administer as compliance inspection staff do not need special skill (Johnson and Ryba, 1992). However, such buffers might not be wide enough in very susceptible areas and can be unnecessarily big in another area (Castelle et al., 1994). Fixed width buffers also reduce the flexibility needed to install buffers in challenging areas.

[17] Personal communications with different parties interested in buffer research

Also, an unintended consequence of requiring wide buffers that discourage landowners from implementing, is a loss of length of buffers along streams. Science has shown that while wider buffers provide additional benefits, that benefits are not linear across widths. Benefits are greater near the stream. If wider buffers discourage implementation, then we lose the most significant benefits of buffers that could be narrower, but important for ecological function, especially when looking at the cumulative benefit over a watershed (Smith, 2013). Barton et al., (1985) Showed that length of a buffer is just as important as the width of a buffer in reducing maximum summer weekly temperatures. The advantage of continuous narrow buffers over scattered patches of wide buffers in moderating stream temperature and reducing nonpoint source pollution, is also reported by Fischer and Fischenich (2000).

The decline of salmon is one of the major drive for riparian vegetation management in the Pacific Northwest. Salmon need clean, cool water and other organic input for food and shelter. In this review, we looked at different buffer width recommendations for five major buffer functions which might be beneficial not only for healthy water and salmonids but also for farmers and the environment.

Streambank stabilization and sediment reduction

Streambank instability and associated sedimentation have a deleterious effect on agricultural land, infrastructure, and the ecological health of waterways thus they are major environmental issues (Pollen and Simon, 2005). Streambank stability is affected by many factors such as soil type, hydrology, overland flow, and soil compaction due to wildlife, livestock or vehicle movement (GEI, 2002). The primary pollutant (by concentration) in US waterways is sediment (Sweeney and Newbald, 2014). Effective buffer width required for sediment removal is higher in other land uses than in agricultural land (GEI, 2002). Wenger (1999) reviewed multiple peer-reviewed findings on the sediment filtering function of riparian buffers and concluded that 30 m wide buffer traps sediment under most circumstances. In the short-term buffers as narrow as 4.6 m can trap sufficient sediment but in the longer-term buffers as wide as 30 m are more efficient (Wenger, 1999). A review of sediment trapping capacity of buffers on agricultural land by Yuan et al., (2009) found that sediment trapping efficiency is site-specific, and there is no significant difference between grass buffer and forest buffer. More importantly, the review indicated that a small buffer as narrow as 3m could remove a significant amount of sediment and maximum removal can be achieved by a 6m buffer. Another review by Hawes and Smith (2005) recommended 9m to 30m buffer for erosion control depending on erodibility of the soil. Hawes and Smith’s recommendation is based on forest land use. The commodity buffer program started at SCCD associates buffer width with tillage

efficiency to reduce sedimentation[18]. Farms with a Soil Tillage Intensity Rating (STIR) score of 30 or less require little to no buffer depending on the stream type.

Water pollutant reduction

Water quality maintenance is one of the most important functions of riparian buffers (Hawes and Smith, 2005). The effectiveness of riparian vegetation on pollutant reduction depends on many factors such as soil type, geomorphology, hydrology, biological processes (i.e., microbial activity), vegetation type, height and angle, annual rainfall, level of pollution loading, types of pollutants, adjacent land uses and buffer width (Kerwin, 2001).

There has been a significant effort to quantify pollutant trapping efficiency of different buffer widths at the edge of the field. However, recommendations on minimum width required for pollutant reduction are contradictory. According to Corley et al., (1999) a 10m riparian buffer removed 84% nitrate and 79% of Phosphate Phosphorus, regardless of vegetation height. A study by Mendez and Mostaghimi (1999) found that 8.5m buffer removed 90% of sediment, 77% of nitrate, 85% of dissolved ammonium, and 82% of total Kjeldahl nitrogen. They also reported no significant difference in pollutant removal between 8.5m and 4.3m buffer widths. Research conducted by Webster and Shaw (1996) compared pesticide trapping efficiency of 4m and 2m wide buffers composed of tall fescue (*Festuca arundinacea Schreb*) and concluded that pesticide trapping efficiency is not affected by buffer width. Others also reported a narrow buffer of 3-5m could reduce 50 to 80% of pollutants (Dillaha et al., 1989; Simmons et al., 1992). Another study on cropland in Italy by Borin et al., (2005) showed that a 6m buffer strip could effectively trap pollutants.

In cases of concentrated runoff such as from feedlot effluent, wider buffers of 90m -300m removed less than 70% of nitrate and total solids (Dickey and Vanderholm, 1981). Therefore, in case of concentrated flow, other actions (with or without riparian buffer) must be taken to prevent pollutants from entering waterways. Hawes and Smith, (2005) provided a very wide range of buffer width for water quality based on their literature review; 5m -50m for nitrogen and phosphorous removal, 15m to 100m for pesticide removal and at least 9m for bio-contaminants such as fecal coliform removal. A more recent literature review by Sweeney and Newbold (2014), suggests that the minimum buffer width for nitrogen removal should be at least 30m. However, the authors noted that buffer width explains only a small proportion of nitrogen removal efficiency. They also noted that narrow buffers can efficiently remove nitrogen in areas

[18] http://www.sccd.org/wp-content/uploads/2017/08/Commodity-buffer-Outreach-Fact-Sheet-2017.pdf

where subsurface water flux is low. Since buffer width explained only around 23% of nitrogen removing efficiency, studying and controlling the major factors that contribute to higher nitrogen removal efficiency might be a wiser approach than recommending higher buffer widths of >30m to achieve higher nitrogen removal. There is a lack of research on the effectiveness of narrow buffers of less than 9m at the local scale (Kallestad, 2009).

Shade provision and temperature regulation

High stream temperature is one of the key contributors to Salmonid habitat degradation in the Pacific Northwest (Richter and Kolmes 2005). Climate projections point to increased overall and seasonal temperatures in streams that will put higher stress on salmonids in the future (Vano et al., 2010; Battin et al., 2006; Nelson and Palmer, 2007). Annual maximum stream temperature depends on a lot of factors including: proportion of the stream that is shaded, elevation, hydrologic inputs, geomorphology, tile drain presence, distance to the ocean, air temperature, regional topography and solar radiation (Chang and Psaris, 2013; Mayer et al., 2005; Johnson, 2004; Tague at al., 2007; Zwieniecki and Newton, 1999; Rex et al., 2012). Solar radiation is the single most significant influencer of stream water temperature (Johnson, 2003). Riparian buffers can directly influence stream temperature by blocking solar radiation (Mayer, 2012).

The amount of shade a buffer can provide depends on: buffer width, latitude, stream aspect, leaf area index or vegetation density, composition, and height (DeWalle, 2010; Sridhar et al., 2004). The temperature regulating potential of the buffer also depends on the angle of the sun, the degree of cloud cover, canopy angle, season, stream volume, the volume of subsurface flow, width and depth of the stream (IMST, 2002).

Wenger (1999) concluded that a 10m wide forested buffer that is continuous along the stream channel could maintain the stream temperature from increasing due to forest harvest. Another review by Broadmeadow and Nisbet (2004) noted that the required buffer width for temperature moderation ranges from 15 m to 70 m. A comparison between 5m and 30m wide buffer retained after forest cut showed a temperature reduction of 3.25 and 3.42 °C respectively as compared to land that had been clear-cut (Meleason & Quinn 2004). This indicates that narrow buffers may be enough to maintain stream water temperature from rising due to forest cutting. A study by Bowler et al. (2012) showed that riparian buffer effectiveness in maintaining stream temperature is not affected by buffer width. Another research study conducted by Benedict and Shaw (2012) showed that narrow buffers of 1.5m and 4.5m could be as

effective as wide buffers of 10.6m and 55m in minimizing summer air temperature. However, the channel width of the waterways used in this study increased with buffer length which might have had a confounding effect on the result.

The location of shade along the stream is also very important. Knutson and Naef (1997) explained that the best predictor of instream temperature at any given location is the input temperature immediately upstream of that location. Riparian vegetation around small streams (1-3 order in stream classification) exerts profound influence on downstream water temperature (Hansen et al., 2010). Within a stream at the local scale, longitudinal change in water temperature is mainly due to shade over the stream (Chang and Psaris, 2013). Knutson and Naef (1997) suggested that many thermal problems in agricultural basins can be partially attributed to hydrological change in upland basins due to logging. Small streams can heat and cool quickly due to their surface to volume ratio and have a very high impact on the temperature downstream. Therefore, shading may be more effective on small streams than bigger streams.

Shading, in addition to cooling, can provide other benefits. A study by Burrell et al., (2014) indicated that shading could reduce stream eutrophication. Shading can also suppress the growth of invasive species which could cause big problems, especially in drainage ditches.

Large Wood Debris and other organic input

Large woody debris (LWD) is comprised of stems, branches, and roots greater than 10cm in diameter and is a crucial structural component that influences the behavior and morphology of small forested waterways (Lisle, 1986). LWD is known to enhance both quality and quantity of fish habitat (Lisle, 1986; Harvey et al., 1999; Reid and Hilton, 1998).

Width recommendation for LWD from various studies is as follows 8m – 30m (Murphy and Koski, 1989), 20m (Castelle and Johnson, 2000), 50m -60m (Reid and Hilton, 1998) at least 30m (Hansen et al., 2010, Sweeney and Newbald, 2014) 30 to 60m Cederholm (1994). Van Sickle and Gregory (1990) reported that the relationship between LWD input and buffer width is affected by channel width as wider channels have less concentration of LWD. As channel width increases, its ability to transport LWD downstream also increases (Harmon et al., 1986). Thus, large streams tend to have less resident LWD. The type of vegetation also has an impact on the quantity and quality of LWD. Bisson et al. (1987) showed that LWD from coniferous forests is more durable than from deciduous forests.

There has been very limited study regarding LWD and riparian buffers around agricultural land (GEI, 2002). Knutson and Naef (1997) suggested that 50% of LWD in agricultural areas was obtained from upland forests. There is a need to study the role and needs of LWD in lowland streams particularly in agricultural land use areas (GEI, 2002). LWD in many low gradient agricultural channels is not popular with most farmers due to concerns about drainage and maintenance impacts[19].

Instream functions

A diverse population of primary and secondary producers and consumers such as algae, benthic macroinvertebrates, and fish are an indication of properly functioning streams (GEI, 2002). A study by Quinn et al., (2004) found that a range of buffer widths from 8-27m supported stream invertebrate communities just as effectively as a native established forest. A literature review by Hawes and Smith (2005) showed that the minimum width of riparian vegetative buffer required for aquatic wildlife, including trout and invertebrates ranges from 10m to 50m in forestry land use. Sweeny and Newbald, (2014) reviewed the impact of riparian buffers on fish communities in forest, agricultural and urban land uses and concluded that minimum of 30m wide buffer is required to maintain natural level macroinvertebrates including fish in all land uses. However, the studies by Lee et al., (2001) and Fischer et al., (2010) which were reviewed by Sweeny and Newbald (2014) representing agricultural land use, do not have a buffer width recommendation. Both studies compared buffer versus no buffer and had contrasting results. Lee et al., (2001) concluded that riparian buffer (30m) wide improved Fish and other species richness level as compared to unbuffered reaches. Whereas Fischer et al. (2010) concluded that there was little to no relationship between buffer and fish assemblage structure and instream habitat characteristics. The buffer studied by Fischer et al. (2010) was mostly grass (about 80%) and likely did not provide enough shade to promote salmon habitat.

Greenwood et al., (2012) showed the positive impact of a riparian buffer on invertebrate communities on agricultural land. They studied 64 agricultural waterways in New Zealand to see whether riparian management (tree planting and exclusion of stock) had an impact on the aquatic invertebrate community. The result showed that riparian management in agricultural land was associated with increases in pollution-sensitive invertebrate communities compared to agricultural lands with no riparian

[19] Personal communication: Joshua Monaghan: a staff at KCD

management. There is no study quantifying the relative effect of different sizes of a riparian buffer on the salmonid community around agricultural land use.

Factors affecting effectiveness of buffer

Many site conditions affect effectiveness of the buffer.

Stream size

Independent multidisciplinary Science Team (IMST, 1999) stated that stream functions are different in various size streams thus buffer width recommendation should consider stream size. Small order streams usually account the greatest miles of a watercourse in a basin and are therefore the greatest sources of sedimentation and pollution coming from headwater streams (Hawes and Smith, 2005). A review of buffers by the US Army noted that very good riparian vegetation around higher order streams could not effectively restore already degraded water coming from headwater streams (Fischer and Fischenich, 2000). Ryan et al. (2013) concluded that riparian vegetation does have a cooling effect on stream temperature at a small spatial scale and the degree of its cooling effect depends on stream size and weather conditions.

Soil type

Runoff water Infiltration rate is determined, in part, by soil type. Clay-dominant soils are less permeable, and thus, could be more susceptible to runoff. On the other hand, sandy soils allow for more rapid infiltration, but may not allow time for roots to absorb nutrients and/or pollutants. Moist, acidic soils are good at denitrification which is the release of nitrogen from soil to the atmosphere (Hawes and Smith, 2005). Thus, lands with such soil type may need smaller buffer. Johnson and Ryba (1992) reviewed three studies of buffer effectiveness in reducing sediments in runoff from agricultural lands and found buffer width recommendations ranging from 3 m for sandy soils up to 122 m for clay soils.

Vegetation type

A diverse riparian cover composed of trees, shrubs, and grasses is more effective at trapping a wide range of pollutants than a tree or grass-only buffer (Dillaha et al., 1989; Lowrance et al., 2000; Novak et al., 2002;

Lee et al., 2003). Density, height, and type of the vegetation also affect the amount of shade the buffer provides. Dense, tall trees with high canopy cover provide more shade than short, sparse trees.

Slope

Steep slope facilitates speed of water flow which reduces infiltration rate. In steeper slopes, buffers should be wider to give time for the soil to absorb pollutants and sediments.

Knowledge gap and research needs

- The effectiveness of most of the buffer function is site-specific (Collins et al., 2009; Gomi et al. 2006, Moore et al. 2005, Wilkerson et al. 2006). Local research is vital to quantify the effectiveness of buffers.
- Most buffer effectiveness studies are conducted in logging areas than agricultural lands. And most literature reviewers combined studies from both agriculture and logging and provided generalized recommendations. Clearing or thinning of a forest is completely different than planting a tree on a riparian zone on a bare agricultural field. Thus, riparian buffers on agricultural land need to be studied independently.
- Although there are findings that quantify the impact of a riparian buffer on pollutant reduction from agricultural land, there not much research on the impact of a riparian buffer on quantity and diversity of salmonid community adjacent to agricultural land. The relationship between the salmonid community and different sizes of riparian buffers on an agricultural land needs to be studied.
- Most of the research conducted so far is focused on very wide buffers, the efficacy of smaller buffers needs to be studied for agricultural lands. Narrower buffers could be appealing for farmers to get engaged in conservation practices.
- which is more beneficial to water quality: a stream buffered with fewer wide buffers or a similar stream buffered with many narrower buffers?
- Research showed that buffer effectiveness is affected by stream size. Therefore, buffer effectiveness study should take stream size into account.

- Identifying and quantifying other benefits of buffers such as improvement of crop yield through biological pest control, creating wind break and increasing humidity can also increase farmers interest in buffer planting.
- There is a need to develop an understanding and find solutions to the undesirable attributes of buffers on agricultural land such as drainage and beaver problem.
- Adding monetary value to the buffer plants can increase farmers interest. This calls for research on working buffers. Working buffers are buffer plants that have economic value in addition to resource conservation.
    - Just as the threatened Salmonids, there are pollinator species which are on the verge of extinction. Meadow type buffers could create pollinator habitat and help conserve native pollinators in addition to water quality.
    - Incorporating trees that can provide fruit, nuts, medicinal material, timber and/or ornamental produce can add value to the buffer while still conserving the environment.
    - Alley Cropping, Forest Farming, Silvopasture, and Short Rotation Biomass are some of the types working buffers (Dittbrenner et al., 2015).
    - Economic feasibility, conservation efficacy and site adaptability of all the above working buffer options need research.

Conclusion

Literature findings regarding buffer width are contradictory. There seems enough support for both wider and smaller buffers for most buffer functions. Many of the buffer studies focus on grass versus forest buffer or compare buffer with no buffer or a couple of buffer widths. There are not many studies that compare several widths in one study. Many of the literature reviews covered above compared studies from various locations and times to give buffer width recommendation. Since buffer effectiveness is affected by several site conditions, it is hard to make sound conclusion from experiments conducted in various locations and times. Some authors noted that length of a buffer is as important as width of a buffer. However, there are not many studies conducted comparing buffer lengths. To address these knowledge gaps, there is a need for well-designed buffer effectiveness study at the local scale.

King Conservation District have been investing a lot on riparian buffer practices for over two decades. This new program will give KCD the opportunity to assess riparian buffer effectiveness, and to better

understand the impact of these ongoing investments. Part of the goal of this work is to build a shared understanding of riparian buffer effectiveness with both natural resource agencies and farmer groups. KCD's close collaboration with both regulatory agencies and with farmers, makes it well positioned entity to take on this work.

The Discovery Farms program offers a proven approach for this effort. Discovery Farms' three key characters: farmers ownership, scientific research and strong outreach, are a good match for this project and to KCD's commitment to community based natural resource stewardship.

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