2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Meeting Presentation

Paper Number: 1008943

Land-Based Measures of BMP Performance

Gene Yagow, Brian Benham, and Erin James Ling

Virginia Tech, Biological Systems Engineering Department

Written for presentation at the
2010 ASABE Annual International Meeting
Sponsored by ASABE
David L. Lawrence Convention Center
Pittsburgh, Pennsylvania
June 20 – June 23, 2010

Extracted from the Draft form of a White Paper presented to the National Fish and Wildlife Foundation; April 20, 2010; Washington, DC.

Abstract. *Typically, the effectiveness of agricultural and forestry BMPs is evaluated based on in-stream measurements of nutrients and sediment. However, as can be seen from the wide range of reduction efficiencies attributed to any BMP from published research, a large number of climatic, fate, and transport variables often obscure cause and effect relationships and the exact mechanisms responsible for load reduction. In-stream pollutant reductions from BMP implementation are also typically not immediate, but gradually accrue over time as vegetative BMPs mature, or while BMPs reduce nutrient build-up in the soil or bacteria attached to channel sediments. Because of these uncontrolled variables and time lags between BMP implementation and pollutant reduction, BMP performance efficiencies are difficult to evaluate.*

This paper summarizes the results of a white paper to quantify BMP performance based on land-based, rather than in-stream, measures in an attempt to identify interim measures of BMP performance that could assist in better evaluating project progress for short-term (1-2 years) projects that do not include funding support for monitoring and lab analysis of water quality samples. Three categories of metrics were identified for 15 BMPs: site selection, performance over time, and maintenance, with the emphasis in this paper on the performance metrics. The intent is to eventually relate these interim measures with in-stream water quality measures, so that they can serve as useful surrogates to guide implementation and to ensure long-term sustainability of implemented BMPs, even after practice life or project periods end.

Keywords. Metrics, BMPs, performance.

Introduction

This paper is based on a white paper funded by the National Fish and Wildlife Foundation (NFWF) through the Chesapeake Bay Stewardship Fund (CBSF) for addressing agricultural and forestry projects (Yagow et al., 2010). The types of programs administered though CBSF include the Chesapeake Bay Small Watershed Grants (SWG), the Innovative Sediment and Nutrient Reduction Grants (ISNR), the Targeted Watershed Grants (TWG), and the Conservation Innovation Grants (CIG).

The purpose of the white paper was to identify metrics and protocols that can be used by small watershed groups for relatively short-term (e.g. 1-2 year) projects funded through NFWF. These metrics and protocols are intended to provide feedback to small watershed group grantees for assessing progress towards attaining project goals and to improve the assessment of NFWF grantee accountability by NFWF managers. These interim, land-based metrics are important, since many small watershed grants do not have a field-based monitoring component, are not of a length that would allow measurement of significant changes in in-stream pollutant reductions or habitat enhancements, and may not have in-house technical expertise to conduct field-based monitoring.

The metrics identified in the white paper include site selection, the quality of the control measure installation, the proper care and maintenance during maturation of an in-field installed control measure, and land-based performance measures that can also be used to evaluate post-project performance. Site selection metrics are tailored more toward NFWF project managers, to help evaluate and select projects with characteristics that are more likely to be most effective and have a greater chance of successful outcomes. Site selection metrics can also be useful to prospective grant applicants in making sure their projects have been sited appropriately. The performance metrics should be equally beneficial to small watershed groups and NFWF project managers in assessing control measure performance, so that mid-project corrections can be made in a timely fashion to ensure the success of each project. The performance metrics, which are the focus of this paper, are intended to be measured at intervals to evaluate progress and to detect change over time throughout each project period, as well as for post-project evaluation. Some of these metrics can also be used with specific thresholds that may indicate desirable or non-desirable levels.

The majority of CBSF-funded agricultural projects have conservation endpoints and center around implementation of conservation measures and BMPs for the reduction of sediment and nutrients entering into surface waters and eventually making their way into the Chesapeake Bay. Since the state offices of the U.S. Department of Agriculture’s Natural Resources Conservation Service (USDA-NRCS) in all Bay states already have established agricultural nonpoint source cost-share programs in addition to some state programs, BMPs are, for the most part, well-defined with established standards and procedures for implementation. Since these cost-share programs are supported at the local level through Soil and Water Conservation Districts, technical expertise is available for assisting grant recipients with planning and implementing individual BMPs. Forestry projects funded through the CBSF grants typically have a combination of conservation and restoration endpoints and center around planting trees on private landowners’ land using established state standards and procedures for implementation, and are supported with technical assistance by state foresters.

In-stream monitored reductions of sediment and nutrient concentrations and loads are the typical measures used to relate on-the-ground installed conservation measures with in-stream water quality. Because of the short-term (1-2 year) nature of most NFWF grants, the typical time lag between implementation of control measures on the land and reduction of in-stream pollutants, and the confounding influence of distance between where control measures are implemented on the land and where in-stream measurements are taken, in-stream monitoring during the project period would be unlikely to show the water quality outcomes expected from these projects. In the past, project progress has been typically charted solely using structural metrics, such as the number of farmers participating, or the number of acres installed and benefitted, and gross estimates of sediment and nitrogen load reduction using simplified algorithms, with few or no in-the-field measures of progress related to functional water quality or habitat benefits. The purpose of this research was to identify indicator measures of on-site BMP performance, “interim” measures, if you will, that over the longer term can be linked with the more desirable functional goals of in-stream load reductions. These land-based measures are intended to give both grantees and project funders a better gauge, during the project period, of the likelihood of meeting their downstream functional goals (e.g., in-stream pollutant reductions).

Methods

The BMPs included in this study were identified from past NFWF-funded projects, as well as the primary BMPs being promoted by the EPA Chesapeake Bay Program, and became the starting point for the metrics identified during this research and review, as shown in Table 1.

Table 1. Agricultural and Forestry BMPs used as a basis for the Performance Metrics.

BMP	BMP Description
Livestock Exclusion	Implementation of a structural and/or management practice that enhances or protects vegetative cover to reduce runoff of nutrients and sediment from existing pastureland and therefore reduces non-point source (NPS) pollution associated with livestock grazing. Stream exclusion fencing is a required component of this BMP.
Grass Riparian Buffers	Planting of vegetative buffers located along the banks of water courses to filter runoff, anchor soil particles, and protect banks against scour and erosion.
Nutrient Management	Development and annual revision of nutrient management plans to minimize the adverse environmental impact of nutrients used in crop and hay production.
Critical Area Stabilization	Stabilization of a source of sediment, such as grading, shaping, and filling. The practice involves the establishment of grasses (including filter strips), trees or shrubs, and similar measures to stabilize critically eroding areas.
Cover Crops	Establishment of vegetative cover on cropland between harvesting and the next planting to protect the ground surface from erosion, to reduce the amount of nitrogen in the active root zone, and to minimize leaching to groundwater.
Pasture Management	Development of management, operations, and maintenance plans to address pasture management issues, including water sources, environmental impact of winter-feeding pad location, soil fertility maintenance, access lanes, fencing needs, carrying capacity of the land, and rotational schedules.

BMP	BMP Description
Cropland Conversion to Forest	Planting trees (hardwoods and/or conifers) on land currently used as cropland or pastureland to permanently convert land to forest.
Residue Management; No-Till	Implementation of continuous no-till or reduced till system and nutrient management planning technologies to increase biomass/soil quality and to reduce the movement of nitrogen, phosphorus, sediments and runoff to surface waters.
Manure Management System	Provision of facilities for the storage and handling of livestock and poultry waste and the control of surface runoff water to permit the recycling of animal waste onto the land.
Precision Feed Management	Control of livestock dietary phosphorus, such as through the use of phytase additives to livestock feed. The use of phytase additives in livestock feed reduces the amount of phosphorus excreted by livestock.
Forested Riparian Buffers	Establishment of a wooded buffer zone along streams for protection and filtering action from surrounding land, and requires establishing a temporary grass cover to protect the site from erosion until trees are established.
Reforestation	Planting of pine seedlings on cutover timberland after careful planning prior to timber harvesting and, after harvesting, the site preparation for planting.
Streambank Stabilization	Provision of vegetative stabilization on stream channel banks or improvement of management techniques to more effectively control soil erosion, sedimentation and nutrient loss from surface runoff to improve water quality.
Revegetation	Implementation of soil stabilization practices on forested land where soil is exposed and is likely to erode to adjacent streams. Stabilization through revegetation is recommended on all bare soil areas that exceed 5% slope or on highly erodible soils.

The literature was reviewed both for explicit metrics reported in the literature and for any identifiable on-site measures implied from lessons learned and other descriptions of reported progress. A Microsoft ACCESS™ database was created to store information collected from the literature review and was used to manage the relationships between BMPs, metrics, protocols, and supporting evidence.

A number of different types of metrics or guidelines were identified as being important to the overall efficiency of each BMP. Metric types included those used for “site selection”, for evaluation of “performance”, and for periodic “maintenance” of the selected BMP(s). Also, since calculations to estimate expected sediment and nutrient reductions are requested on each NFWF grant application, standardized sources of formulas and coefficients were proposed as a common reference to be used by NFWF project managers for comparison between proposals, although additional methods and formulas could be incorporated with appropriate justification. While descriptions of each of the metric types are defined below, this paper focuses on the performance metrics.

Site selection metrics can be used to prioritize locations or site-specific characteristics associated with successful conservation projects, or which have served as the basis for some state or federal prioritization related to Bay restoration and preservation. Some of these are already included in state BMP specifications, while others were gleaned from the literature. At present, no recommendations have been made as to which site selection metrics are most important, or how many of these metrics should be used, as the number and importance are expected to vary from state-to-state, by BMP, and by local jurisdiction. The important point to remember is that matching a site-specific problem with the most appropriate type of solution is the first step in achieving the greatest potential pollutant reduction and water quality benefit. An example of a site selection metric is a prioritized ranking analysis for water quality protection such as the Trust for Public Land's assessment of restoration priority in their Source Water Stewardship Program (DEPRM, 2007).

Performance metrics are, for the most part, measurements that should be taken periodically throughout the life of a project to evaluate proper BMP establishment and maturation, and to serve as a means of engaging grantees in an on-going interaction with each BMP, so that the BMP is not just implemented and then abandoned. Examples of performance metrics are tree density or percent vegetative cover.

Maintenance items are not metrics, per se, but rather checklist items of conditions that the grantee either wants to achieve or to guard against, as the BMP matures. Performance and maintenance metrics are intended to provide feedback and guidance not only during the initial grant period, but also to serve as a means of ensuring longer-term sustainability of the BMP once the grant has been completed. Examples of maintenance metrics are "maintaining 30% surface residue" or "maintaining rotational grazing patterns". Emphasis will also be placed on closer monitoring of conditions in runoff-related BMPs after each major rainfall event to prevent formation of concentrated flow paths and/or unintended flows onto or by-passing the BMP.

The performance metrics that we identified as having potential for measuring on-site performance of one or more of the BMPs included:

- **Percent canopy cover**: The percentage of a horizontal plane that does not receive direct solar radiation due to shading, (%).
- **Percent invasives**: The percentage of one or more identified invasive species of concern, as a percent of total area sampled, calculated from a representative sample of the treated area, (%).
- **Percent vegetative cover**: The fraction of sampled treatment area covered by ground vegetation as opposed to bare soil, expressed as a percentage, (%).
- **Soil test P**: The phosphorus (P) content that corresponds with the fertility rating typically given in lab soil test results, (ppm P).
- **Plant species composition**: The percent distribution of the major plant categories within the sampled treatment area, i.e. coniferous, deciduous, shrubs, grass, or major specific species, i.e. oak, maple, loblolly pine, (%, by species). MD-DNR and USDA-FS, 2002.
- **Tree survival rate**: For tree planting projects, this is the number of remaining trees at any given point in time divided by the number of trees originally planted times 100%, (%). MD-DNR and USDA-FS, 2002.
- **Tree density**: Within a given project plot, this is the number of live trees divided by the plot area, (trees/ac). MD-DNR and USDA-FS, 2002.

- **Tree height**: Average tree height from a sampled population, (feet). MD-DNR and USDA-FS, 2002.
- **Livestock excluded from stream**: A measure of the impact of livestock, excluded, or removed from the riparian grazing area, so that they no longer have access to the stream, (AU-days/yr). EPA, 1997.
- **Soil test nitrate**: A field measurement of plant available nitrate using commercial test strips, (ppm NO3-N). Stewart and Janovicek, 2006.
- **Forest ecosystem integrity index**: The index is a weighted index composed of mean patch area, the mean patch fractal dimension index, the Clumpy index, the mean Core Area Index, and the area-weighted mean Shape Index. Pfister, 2004.
- **Percent soil organic carbon content**: The amount of organic carbon in a specified layer of soil, divided by the total amount of soil in a sample, expressed as a percentage, (%). Wills et al., 2007.
- **Percent crop residue**: The fraction of cropped land that is protected from direct raindrop impact, after harvest, due to the presence of corn stalks, soybean stubble, or other crop residue, (%).
- **Above ground woody biomass**: The total vegetative mass on a given area, (metric tons/ha). Kasischke et al., 1997.

Part of the purpose of the literature review was also to look for supporting evidence that might link the selected metrics to the quality of the BMP installation. However, very little information was available in the literature that dealt with on-site measures of BMP quality. Literature related to “evidence” of effectiveness, dealt more with effectiveness of the BMPs, and very few articles referred to the appropriateness of the various metrics by which effectiveness could be gauged. Those references with evidence of BMP effectiveness often referred to in-stream reductions of nutrients and sediments. While the review for the white paper was not intended specifically to repeat previous reviews and summaries of BMP effectiveness for in-stream nutrient and sediment reduction, some of the evidence included is of this nature. The evidence that was found in the literature was categorized by performance metric and applicable BMP.

Results and Discussion

The BMP, metric, and protocol information from the literature review was assembled in a Microsoft ACCESS™ database and then organized into BMP Fact Sheets, which constitute the results of this study. These BMP Fact Sheets are intended for use by grant applicants and grantees. Each Fact Sheet includes: a description of the BMP; a list of relevant design standards and typical units of implementation; a standardized procedure for relevant sediment and/or nutrient reduction calculations; lists of site selection, performance, and maintenance metrics or checklist items and related protocols that describe how the site selection and performance metrics can be measured; and, finally, relevant references and evidentiary citations. While some material will be repeated from one Fact Sheet to the next, this format was intended to provide all of the information about each BMP in a separate Fact Sheet for ease of use. These Fact Sheets can be generated from the Microsoft ACCESS™ database, making updates and revisions relatively simple. The intention is for NFWF grant applicants and grantees to use these fact sheets to improve their proposals and progress reporting. An example of one of these BMP Fact Sheets is shown at the end of this paper.

Technical assistance with agricultural and forestry BMP installation is available through NRCS, local Soil and Water Conservation Districts (SWCDs), and state forestry departments and will be required, if these practices are implemented in conjunction with state or federal cost-sharing programs. Therefore, although it is not necessary for the NFWF grantee to have this expertise, details of the possible BMP components and links to their technical descriptions are provided on the Fact Sheets should they desire more information about the installation of each BMP.

A "How-To Use the BMP Fact Sheets" guide will be developed illustrating suggested uses for grant applicants and grantees. Some possible uses of the BMP Fact Sheets include project planning, grant application, project implementation, and post-project planning, with suggested applications listed below:

- Project Planning
    - If your project is designed around a specific site, you can browse the various Fact Sheets to determine appropriate BMPs to address the defined problems, in conjunction with your local NRCS, SWCD, or state forestry contact.
    - If your project is targeted to a specific watershed, the site selection metrics can be used to identify smaller priority areas most in need of conservation and restoration.
    - If your project is based on the promotion of a specific BMP, the site selection metrics on the relevant fact sheet can once again help in targeting those areas most likely to provide the most "bang for the buck".
- Grant Application
    - Load reduction calculation: Formulas are provided to allow for somewhat standardized calculations of the requirement in most CBSF grant applications to estimate long-term reductions in sediment and nutrient loads.
    - Performance metrics: While you will include typical measures of how many people participated and how many acres have been treated by a given BMP, the suggested performance metrics can also help you to assess the quality of the BMP, even if direct water quality impacts are not monitored.
- Project Implementation
    - Performance metrics and protocols: The protocols detail the procedures needed to measure the performance metrics, which should be applied periodically throughout the project in order to measure change over time.
    - Maintenance tasks: Most BMPs mature over time and require more than just BMP installation at a specific location. These maintenance tasks are reminders of some of the major tasks that are associated with each BMP. Complete lists of all maintenance items can be found in the NRCS BMP Component Standards.
- Post-Project Planning
    - Long-term sustainability
        - Performance metrics: Benefits typically continue to accrue from BMPs long after the grant period ends. Plan to continue to monitor these benefits within your organization in order to capture these long-term benefits.
        - Maintenance tasks: Once again, to ensure that the BMPs maintain their effectiveness and to extend their useful life, periodic maintenance is required. Plan to perform these tasks, even after the grant period ends.
    - Replicability

- Site selection metrics: Use these metrics to identify other watersheds or locations where you can apply what you learned in this project to other similar areas.

Summary

The next stage in this project will be to select a number of active projects on which to test the metrics and a number of older projects on which to conduct a post-audit evaluation of their usefulness. This field testing will be performed to fine tune procedures for use with new CBSF grant applications and projects beginning in summer 2010.

While these on-site measures may not always give direct evidence of the eventual goals of sediment and nutrient reduction or habitat restoration, they may help ensure that installed BMPs are maturing and performing as expected, and ensure that the funded projects are performing to the limits of their capabilities. The hope is that these metrics can be incorporated into longer-term, larger-scale watershed projects with explicit in-stream monitoring components, such as the proposed small watershed accelerated implementation projects planned by USDA-NRCS under the Chesapeake Bay Watershed Initiative funding in the 2008 Farm Bill. The goal is to develop empirical relationships between the land-based “interim” measures presented in this paper and the overall Chesapeake Bay functional goals, so that these land-based measures can eventually be expressed in terms of water quality benefits.

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Appendix: Example BMP Fact Sheet

BMP Fact Sheet #2: Livestock Exclusion

Description: This is a structural and/or management practice that will enhance or protect vegetative cover to reduce runoff of nutrients and some sediment from existing pastureland and therefore reduces NPS pollution associated with grazing livestock. Stream exclusion fencing is a required component of this practice. This practice may also include providing alternative livestock watering systems and fencing that will improve water quality by eliminating direct access to surface waters and by improving pasture management by establishing rotational grazing to control erosion.

Standards

NRCS Code	BMP or Component Name	Units	Citation
472	Access Control	Ac.	USDA-NRCS, online
575	Animal Trails and Walkways	Ft.	USDA-NRCS, online
342	Critical Area Planting	Ac.	USDA-NRCS, online
362	Diversion	Ft.	USDA-NRCS, online
382	Fence	Ft.	USDA-NRCS, online
393	Filter Strip	Ac.	USDA-NRCS, online
412	Grassed Waterway	Ac.	USDA-NRCS, online
561	Heavy Use Area Protection	Ac.	USDA-NRCS, online
590	Nutrient Management	Ac.	USDA-NRCS, online
512	Pasture and Hay Planting	Ac.	USDA-NRCS, online
378	Pond	No.	USDA-NRCS, online
528	Prescribed Grazing	Ac.	USDA-NRCS, online
391	Riparian Forest Buffer	Ac.	USDA-NRCS, online
390	Riparian Herbaceous Cover	Ac.	USDA-NRCS, online
574	Spring Development	No.	USDA-NRCS, online
580	Streambank and Shoreline Protection	Ft.	USDA-NRCS, online
578	Stream Crossing	No.	USDA-NRCS, online
612	Tree/Shrub Establishment	Ac.	USDA-NRCS, online
642	Water Well	No.	USDA-NRCS, online
614	Watering Facility	No.	USDA-NRCS, online

Load Reduction Calculation

Pollutant reduction in-stream: For livestock exclusion, calculate "instream load/yr" for each grazing animal type as no. of livestock excluded (AU-days/yr) x nutrient or bacteria content in manure (lbs or cfu/lb of manure) x manure production rate (lbs/AU-day). See metric 14 for calculation of AU-days/yr. (EPA, 2002).

Pollutant reduction in-stream: For BMP enhancements and land conversion eligible for trading credits, use Appendix A in this reference for the appropriate Basin and BMP to calculate load reduction (lbs/yr) by multiplying the delivered pounds of N and P per acre per year (lbs/ac-yr) x the number of acres treated by the BMP. (DEQ, 2008).

Site Selection Metrics and Protocols

Metric Name: Adjacency to streams with "fair to poor" channel stability

Protocol Description

A suite of 10 different types of measurements are given for assessing channel condition. Perhaps the most easily measured metric for small watershed groups is a stability rating based on bank height ratio (see Table 1 in the reference). (Rosgen, 2001)

The "fair to poor" channel condition can be assessed with the bank stability metric from the Habitat Assessment in EPA's Rapid Bioassessment Protocols. (Barbour et al., 1999)

Metric Name: Adjacency to streams with "fair to poor" habitat conditions

Protocol Description

Use the habitat assessment protocol, Section 5.2, in EPA's Rapid Bioassessment Protocols. (Barbour et al., 1999)

Metric Name: Locate buffers in headwater reaches or below completely buffered upstream reaches.

Metric Name: Exclude all livestock from upstream tributaries.

Metric Name: High ecological integrity rating

Protocol Description

The Virginia Natural Landscape Assessment (VaNLA) is a landscape-scale geospatial analysis for identifying, prioritizing, and linking natural lands in Virginia. Using land cover data derived from satellite imagery, the VaNLA identifies large patches of natural land with at least one hundred acres of interior cover. This interior cover, known as core area, begins one hundred meters from patch edges. Small patches with ten to ninety-nine acres of interior cover are included as habitat fragments that support landscape corridors and that may be important in localities with few large patches of natural land. Core areas and habitat fragments are referred to collectively as ecological cores. Although the VaNLA is predominantly an analysis of forests, ecological cores include marshes, dunes, and beaches where these covers are abundant and exceed minimum size requirements. Ecological cores were mapped for the entire study area, which included the commonwealth of Virginia and a 20-mile buffer around the state. Over fifty attributes were assigned to the ecological cores providing information about rare species and habitats, environmental diversity, species diversity, patch characteristics, patch context, and water quality benefits. These attributes can be used by planners to select ecological cores that have the characteristics and provide the benefits of greatest interest to them. To assist in identifying highly significant ecological cores, VNHP selected nine ecological attributes and used them in a principal components analysis to develop a prioritization by ecological integrity.
All ecological cores in the two highest categories of ecological integrity (i.e. C1 and C2) were connected by landscape corridors and nodes to create a statewide network of natural lands. This was done by developing a model that represented impedances to wildlife movement through the landscape and then selecting the easiest routes between each high priority ecological core and its neighboring cohorts. These routes, known as least cost paths, were each expanded to a width of three hundred meters to create the landscape corridors. This width was chosen to maintain one hundred meters of interior cover along the entire length and one hundred meters of buffer on each side. The corridors were guided as much as possible through natural lands and lower-ranked ecological cores (i.e. C3, C4 or C5), the latter automatically becoming parts of the statewide network of natural lands as corridor nodes. The products of the VaNLA include GIS data, hardcopy and digital maps, and a report that summarizes the methodology and results and discusses potential uses of the GIS data. Three GIS layers comprise the statewide network of natural lands: ecological cores, landscape corridors and nodes, and natural landscape blocks. (DCR, 2008)

Performance Metrics and Protocols

Metric Name: Percent invasives

Protocol Description

The Multiple Species Inventory and Monitoring (MSIM) species composition monitoring protocol is given in the reference. The species composition tabulation results in a percent distribution of specified plant categories using a quadrat, sub-plots, and transect sampling design. "Percent invasives" is one component of this distribution. (Manley et al., 2006)

The Species Dominance Worksheet can be used to track and record the most common species, weeds, and invasives; and to rank the most common species by life form, e.g. annual grasses, perennial grasses, forbs, shrubs and trees, succulents, and biological crust, p. 75. (Pellant et al., 2000)

Metric Name: Percent vegetative cover

Protocol Description

Herbaceous percent cover measurements are recorded at 20 or 25-foot intervals on the right side of a transect tape (the right side is determined by standing at 0 feet and facing the line of travel/transect azimuth). The monitor should walk on the left side of the transect line to reduce sample disturbance. A square 0.1m2 micro-plot grid is used in grasslands to estimate percent cover of herbaceous vegetation while a rectangular 0.5m2 grid is generally used in shrublands (the 0.5m2 grid may also be used in grasslands if desired). The rectangle grids are placed with the near right corner on the sampling interval and the long axis perpendicular to the tape. An example of micro-plot grid placement is shown in Figure 1 in the reference. Approximately 20% of the micro plot is covered by vegetation in the example. Grid samples are considered independent samples for statistical purposes. (Ashley, 2006)

The Cover Worksheet can be used to track and record multiple canopy cover classes and different types of ground cover, p. 71. (Pellant et al., 2000)

Metric Name: Livestock excluded from stream

Protocol Description

Calculated as the reduced amount of time that livestock spend in-stream, as calculated previously in equation (4) and repeated as follows: Reduction of time livestock spend in-stream (AU-days/yr) = no. of ivestock (AU) x average daily time spent in-stream (hrs/day) / (24 hrs/day) x no. of days with stream access (days/yr).

MaintenanceTasks

Keep livestock off of buffered areas.

Protect filter strips from damage by livestock.

Performance Metric Supportive Evidence

Metric Name: Percent vegetative cover

Supportive Evidence

Studies have shown that forest riparian areas, ranging in width from 16 to 285m, reduce nitrate-N concentration in groundwater by 80-99%, and in surface water from 60-95%. It was estimated that riparian forest buffers can remove 21 pounds of nitrogen and 4 pounds of phosphorus per year each year. (EPA, 2005)

Studies have shown that vegetated filter strips, ranging from 13-1500 feet in width, can reduce TSS by 50-95%, N by 0-92%, P by 27-89%, and nitrate-N by 54-73% across the U.S. (EPA, 2005)

Metric Name: Livestock excluded from stream

Supportive Evidence

Cows are important agents of geomorphological change. On the uplands, heavy grazing compacts the soil, reduces infiltration, increases runoff, and increases erosion and sediment yield. However, light and moderate grazing have effects that are much less significant. In riparian zones, grazing decreases erosional resistance by reducing vegetation and exposing more vulnerable substrate. Trampling directly erodes banks, thus increasing turbulence and consequent erosion. (Trimble and Mendel, 1996)

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