Agricultural Best Management Practices

INTERVENTION CATEGORY: MANAGEMENT

DESCRIPTION

Agricultural Best Management Practices (BMPs) are strategic interventions in agricultural systems that are designed to reduce environmental impacts. They can entail a range of different practices, which typically are most effective when combined. Agricultural systems that rehabilitate or conserve ecosystem services can be as productive as intensive, high-input systems, but with significantly reduced harm to the agro-ecosystem both at the field and watershed levels.[1] Categories of agricultural BMPs that are particularly capable of addressing Water Security Challenges are:

- **Conservation Agriculture** (CA) has three basic approaches: minimum soil disturbance through reduced or zero tillage, permanent soil cover by growing cover crops in otherwise fallow periods, and crop rotation. These practices can enhance biodiversity and natural biological processes above and below the ground surface, contributing to increased water and nutrient use efficiency and to improved and sustained crop production.[2]
- Incorporating **trees into croplands** is done by, for example, practicing alley cropping or creating windbreaks. Agroforestry practices can increase ground cover, provide shade, diversify farm income, improve soil structure and infiltration, decrease erosion by water and wind, and enhance biodiversity.[2]
- **Vegetative strips** (trees and/or grasses) at edges of fields reduce amount of sediment, organic matter, nutrients and pesticides before runoff enters a surface water body.[1]
- **Nutrient management** practices for managing application of organic manures and composts intended to improve soil fertility. These practices simultaneously enhance soil structure, water infiltration and percolation, while avoiding excessive fertilizer use.[2]

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WATER SECURITY CHALLENGES (WSCs) ADDRESSED

TYPE		IMPACT	MAGNITUTE	DEPTH OF EVIDENCE BASE
Water availability	Groundwater recharge	Increased mean annual groundwater recharge	★★☆	★★☆
	Dry season flows	Maintained dry season flows	★☆☆	★☆☆
Disaster risk	Flood risk	Reduced peak discharge	★★☆	★☆☆
Water quality	Erosion and sedimentation	Reduced on-site erosion and sediment yields	★★★	★★★
	Nutrients and pollutants	Reduced in-stream nutrient and pollutant concentrations	★★★	★★★

Factors such as the location, climate, crop type, type and amount of fertilizer applied, local cropping practices, type of irrigation systems (if any), and institutional constraints are a few of the drivers that determine the overall impact of agricultural BMPs. Available literature on WSC impacts of agricultural BMPs is largely focused on water quality benefits.

Enhanced infiltration and percolation under BMPs affect the partitioning between surface runoff and groundwater recharge, where the latter is typically enhanced. This can also positively affect baseflows, although a counterbalancing effect of increased annual evapotranspiration from cover crops can lead to an overall negative annual water yield.[3] The reduction of surface runoff also leads to decreased flood risk under extreme rainfall.[4]

With regards to water quality, less nutrients and pollutants are transported to water bodies due to more efficient fertilizer use and in-field measures to enhance sediment deposition. A comprehensive review of impacts involving (different combinations of) agricultural BMPs found 3–85% reductions in total nitrogen, up to 79% reductions in total phosphorus, and up to 90% reductions in total suspended solids.[5] The variability of achieved impacts is large, and depends on the factors outlined above.

OTHER BENEFITS

WHAT?	HOW?
Enhanced biodiversity (terrestrial)[6]	Agroforestry provides habitat for species and supports connectivity.
Enhanced biodiversity (aquatic)[7]	Increased fish species richness and abundance.
Improved air quality	Management of soil nutrients can reduce ammonia and nitric oxide emissions.8 Tree planting helps capture airborne particles and pollutant gases.[9]
Increased opportunities for recreation, and health benefits[8]	These are potential additional benefits of improved water quality downstream.

LINKAGES TO CLIMATE CHANGE

Mitigation: Presence of trees and cover crops enhance biomass volumes, increasing carbon sequestration in the vegetation as well in the underlying soil.[2]

Adaptation: Agroforestry practices provide shade and reduce local temperature due to enhanced transpiration. Agricultural BMPs reduce surface runoff during (heavy) rainfall events, regulating both water quantity and quality on the watershed scale.[10] The potential of agricultural BMPs to increase soil water holding capacity can also be viewed as an adaptation benefit in contexts where more erratic rainfall is projected, although this may be offset to a certain extent by increased evapotranspiration.

DESIGN-ENABLING CONDITIONS AND TYPICAL CONSTRAINTS

- The effectiveness of BMPs to address WSC depends on several factors: proper implementation and maintenance, local environmental factors such as geology, soil type and properties (especially erodibility), precipitation regime, depth to groundwater, slope of the land, farming practices (including the crop types), and the spatial and temporal extent of irrigation, rotation, and fertilizer use.[5]
- Effects of hydrogeology and climate on timing and magnitude of downstream water quality impacts can be summarized as follows:[11]
  - The hydrological pathway for delivering the effect. Often the measure is not implemented directly adjacent to the water resource, and therefore the outcome is impacted by overland flow (particulate pollutants), a combination of overland and subsurface flow (dissolved pollutants), infiltration to groundwater and groundwater flow (e.g., nitrate).
  - The path travel rate: fast (e.g., ditches and artificial drainage outlets to surface waters), moderate (e.g., overland and subsurface flow in porous soils), slow (e.g., infiltration in absence of macropores and groundwater flow), very slow (e.g., transport in a regional aquifer).
  - Precipitation regime: wet periods generally increase volume and rate of transport, dry periods generally decrease volume and rate of transport.
- BMPs require maintenance to continue providing the expected level of efficiency. For example, trees must be maintained to ensure they survive past seedlings and young trees, more trees may be needed over time, harvesting may be necessary, and invasive species and weeds must be monitored and managed. Cover crops must be planted and maintained on a regular basis to ensure continued effectiveness.[5, 12]

RELATION TO GREY INFRASTRUCTURE

INFRASTRUCTURE?	SERVICE PROVIDED BY GREY SOLUTIONS	TYPE OF RELATION
Controlled drainage structures[12]	Short-term water retention	Alternative
Grade stabilization structures[12]	Reduced erosion from hillslopes	Alternative
Efficient irrigation systems, e.g., drip irrigation	Reduced water demand (only effective if "freed up" water is not abstracted)	Complementary

COMMON RISKS AND TRADE-OFFS

- Depending on species and management, alley cropping practices may be prone to weeds, potentially impacting crop productivity.[13]
- Other factors (off-farm) on the watershed scale may impact services delivered by the BMPs, such as changes to upland and/or upstream land uses, dams, stormwater, and non-point and point source pollution.[5]
- If not properly managed, BMP impacts can be affected by invasive species.[14]
- In particular cases, low and no-till agricultural practices have resulted in significant increases in pesticide usage, negatively affecting water quality and freshwater biodiversity.[15]
- In some cases, there is a potential of decreased crop yield compared to intensive farming systems.

MONITORING OPPORTUNITIES

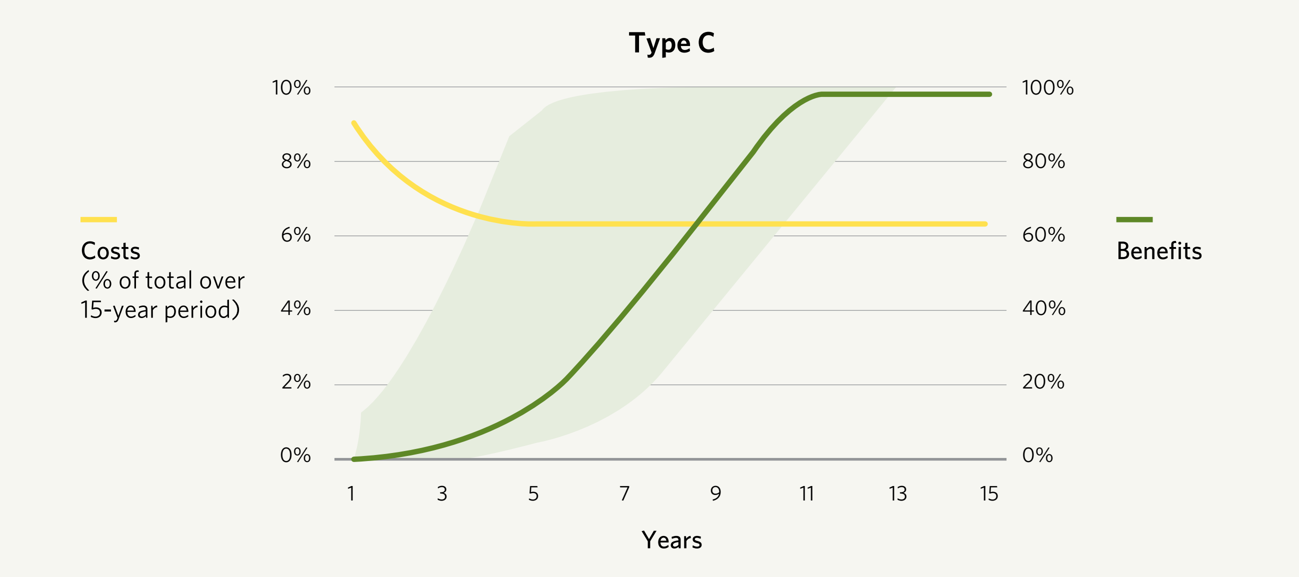
- For analyzing vegetation across larger agroforestry projects, satellite remote sensing or UAV's can be used for assessing vegetation health, tree cover, or species identification.[16, 17]
- The spatiotemporal dynamics of impacts of agricultural BMPs, driven e.g. by climate and watershed characteristics, pose a challenge to proper monitoring. An integration of edge of field monitoring with more regional approaches (GIS and /or modelling) is required. For evaluating water quality effects, long-term regional-scale measurements, statistical analyses techniques and spatial modelling are often used.[18]
- In-stream flow and water quality can be monitored with field equipment to evaluate impacts of agricultural BMPs.
- Water-related monitoring should be combined with agricultural metrics, such as yield per hectare from crop cuts, to relate WSC aspects to agricultural productivity.

IMPLEMENTATION COSTS AND TIMING OF BENEFITS

Cost patterns of agricultural BMPs vary. For example, costs for cover crops usually include seed, planting (labor), fuel, and any herbicide or spraying. Except for seed and any site preparation costs, these are mostly recurring costs. Overall installation costs in Minnesota, U.S., are estimated between 80–100 USD/acre.[12] Similarly, for nutrient management, operation and maintenance expenses such as fuel for management activities, repairs, and periodic soil and site sampling, make up a relatively large part of total costs.

Somewhat higher capital costs are incurred for agricultural BMPs that involve the installation of tree cover or grasses. Costs for installing vegetated buffers, strips or channels mostly pertain to the seed, cuttings, plugs, or transplants chosen for the site. Additional site preparation and maintenance expenses will also be necessary, such as weed control and invasive species removal.[12]

Timing of benefits from BMPs varies significantly per activity. For example, once excessive manure application is avoided, this results in a direct reduction of in-stream fecal bacteria loads. However, measures relying on establishment of plant communities can take up to ten years before the desired benefit is achieved.[11]



Alley cropping (source: USDA National Agroforestry Center).

EXAMPLES

Documentation of agricultural BMPs implementation, including quantitative information on costs and benefits, mostly focuses on farm-level analyses rather than considering the full watershed scale. Studies and reports that do incorporate downstream WSC impacts primarily focus on water quality aspects such as reduced nutrient loads and sediment yield. Some examples are provided below:

Illangama watershed, Ecuador[19]

Brief description: Over a period of 4 years, the impact of several agricultural BMPs (surface water deviation ditches, reduced tillage, residue retention, efficient application of N, improved crop rotation) on crop productivity and economic returns was analyzed.

Lessons learnt:

- For the potato-pasture systems on these Andean high-altitude soils, conservation agriculture increased yields and saved on production costs due to less tillage. Net economic benefits increased by 24% following adoption of agricultural BMPs.
- Off-farm benefits were generated in the form of reduced erosion and reduced impacts from erosion on water quality downstream, but these were not incorporated in the assessment of economic returns.

Maumee River Basin, Indiana, United States[20]

Brief description: A comprehensive modelling study was performed involving a range of BMPs, including cover crops, filter strips, grade stabilizations, no-till, and nutrient management. The impact on downstream total phosphorus load of different BMP arrangements was evaluated both biophysically and economically.

Lessons learnt:

- Yearly costs per kg of reduced total phosphorus were estimated at USD19, USD135, and USD77 for filter strips, cover crops, and nutrient management, respectively.
- It is important to consider the effectiveness of BMPs also on seasonal timescale, due to dynamics of climate and vegetation growth.
- Pollutant reductions for multiple BMPs in series cannot simply be estimated from individual reductions added together.

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