Science of the Total Environment 601–602 (2017) 580–593

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

A review on effectiveness of best management practices in improving hydrology and water quality: Needs and opportunities

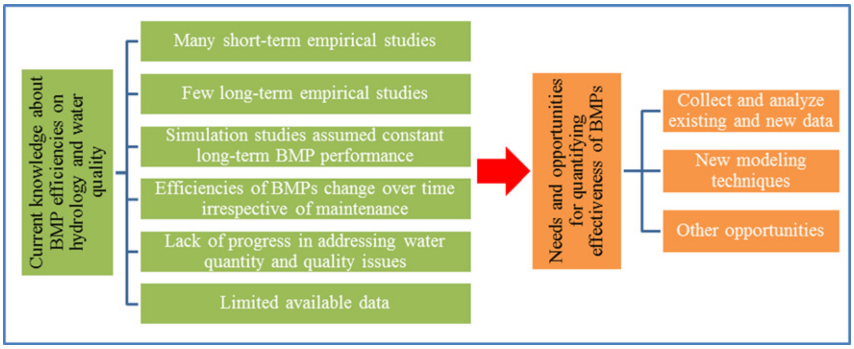
Yaoze Liu [a], Bernard A. Engel [a,*], Dennis C. Flanagan [a,b], Margaret W. Gitau [a],
Sara K. McMillan [a], Indrajeet Chaubey [a,c]

[a] Department of Agricultural and Biological Engineering, Purdue University, West Lafayette, IN 47907, USA
[b] USDA, Agricultural Research Service, 275 S. Russell Street, West Lafayette, IN 47907, USA
[c] Department of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette, IN 47907, USA

HIGHLIGHTS

- Few studies have documented long-term BMP efficiencies on water quantity and quality.
- Most simulation efforts have assumed constant long-term BMP performance.
- Efficiencies of BMPs likely change over time irrespective of maintenance.
- Limited empirical data have been collected to describe the performance of BMPs.
- Needs and opportunities for quantifying effectiveness of BMPs are provided.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 12 April 2017
Received in revised form 20 May 2017
Accepted 23 May 2017
Available online xxxx

Editor: Jay Gan

Keywords:
Low impact development (LID)
Green infrastructure (GI)
BMP
Nonpoint source
BMP effectiveness
Maintenance

ABSTRACT

Best management practices (BMPs) have been widely used to address hydrology and water quality issues in both agricultural and urban areas. Increasing numbers of BMPs have been studied in research projects and implemented in watershed management projects, but a gap remains in quantifying their effectiveness through time. In this paper, we review the current knowledge about BMP efficiencies, which indicates that most empirical studies have focused on short-term efficiencies, while few have explored long-term efficiencies. Most simulation efforts that consider BMPs assume constant performance irrespective of ages of the practices, generally based on anticipated maintenance activities or the expected performance over the life of the BMP(s). However, efficiencies of BMPs likely change over time irrespective of maintenance due to factors such as degradation of structures and accumulation of pollutants. Generally, the impacts of BMPs implemented in water quality protection programs at watershed levels have not been as rapid or large as expected, possibly due to overly high expectations for practice long-term efficiency, with BMPs even being sources of pollutants under some conditions and during some time periods. The review of available datasets reveals that current data are limited regarding both short-term and long-term BMP efficiency. Based on this review, this paper provides suggestions regarding needs and opportunities. Existing practice efficiency data need to be compiled. New data on BMP efficiencies that consider important factors, such as maintenance activities, also need to be collected. Then, the existing and new data need to be analyzed. Further research is needed to create a framework, as well as modeling approaches built on the framework, to simulate changes in BMP efficiencies with time. The research community needs to work together in

---

[*] Corresponding author at: Department of Agricultural and Biological Engineering, Purdue University, 225 South University Street, West Lafayette, IN 47907-2093, USA.
E-mail address: engelb@purdue.edu (B.A. Engel).

http://dx.doi.org/10.1016/j.scitotenv.2017.05.212

addressing these needs and opportunities, which will assist decision makers in formulating better decisions regarding BMP implementation in watershed management projects.

Contents

1. Introduction

Changes in land uses from natural land covers (such as forest or grass land) to agricultural and urban land uses often have adverse effects on water quantity and quality, such as increased runoff volume and rates, decreased runoff lag time, decreased groundwater recharge, and impaired water quality (Chen et al., 2017; Gitau et al., 2016; Grimmond, 2007; Liu et al., 2017; Scanlon et al., 2005; Wang et al., 2014; Wang and Kalin, 2011, 2017). Agricultural activities, such as mismanagement of fertilizer/pesticide application, can be significant reasons for nonpoint source pollution from agricultural areas (Arabi et al., 2008; Hashemi et al., 2016; Rong et al., 2016; Shen et al., 2014). Similarly, urban activities, such as lawn care, transportation, and construction, would be sources of nonpoint source pollution from urban areas (Ibekwe et al., 2016; Taebi and Droste, 2004; Xia et al., 2016).

Best management practices (BMPs), sometimes called low impact development (LID) practices or green infrastructure (GI) practices in urban areas, have been widely used to address hydrology and water quality issues in agricultural and urban areas (Ahiablame et al., 2012; Andrews et al., 2013; Gilroy and McCuen, 2009; Liu et al., 2015a, 2015b; Mwangi et al., 2015). Agricultural BMPs, such as contour farming, crop rotation, nutrient management, cover crops, no tillage, grassed waterways, constructed wetlands, grade stabilization structures, vegetated buffer strips, and blind (tile) inlets, are popular approaches used to improve water quality and reduce hydrologic impacts in agricultural areas. Urban BMPs, such as bioretention systems, porous pavements, permeable patios, rain barrels/cisterns, green roofs, wet ponds, and dry ponds, are common practices implemented in urban areas to treat stormwater runoff quantity and quality. Some of those practices, such as constructed wetlands and ponds are large-scale practices that are implemented at outlets of drainage areas to manage stormwater runoff; while other practices, such as buffer strips, bioretention systems, and green roofs, are small-scale practices that are distributed throughout the site at the source of pollution (Liu et al., 2015a, 2015b). For the purposes of managing water quantity and improving water quality, increasing numbers of BMPs have been studied in research projects and implemented in watershed management projects globally (Chen et al., 2015b; Stang et al., 2016; Wang et al., 2014; Wang and Kalin, 2011; Wright et al., 2016; Yuan et al., 2002; Zhuang et al., 2016).

In spite of wide spread BMP implementation, questions remain about efficiency and which combination of practices will best attain goals. Numerous empirical studies of individual practices have been conducted to quantify BMP efficiencies to assist selection and implementation of practices (e.g., Ahmed et al., 2015; Hunt et al., 2006; Lewellyn et al., 2016). For planning purposes, computer models are commonly used to predict the impacts of BMPs at the watershed level due to the expense of collecting empirical data (measured data), hydrometeorological variability and countless possible implementation scenarios (e.g., Ahiablame et al., 2013; Liu et al., 2016a, 2016b, 2016c; Weiss et al., 2007). Results from previous studies showed that both