



Opinion

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# Do Conventional Comparative Cost Efficiency Analyses Adequately Value Nitrogen Loss Reduction Best Management Practices?



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## Abstract

Increasing public awareness of nitrogen (N) loading to surface waters has resulted in increasing pressure for the adoption of Nitrogen Loss Reduction Best Management Practices (NLR BMPs). These practices are commonly evaluated by a comparative cost efficiency (CCE) that determines the ratio of implementation costs to N load reduction. This conventional methodology is essential for comparison of practices from a policy perspective. However, the CCE method does not consider potential short-term, on-farm benefits of in-field NLR BMPs. Therefore, it is the opinion of the authors that there is a need to advance the economic analysis of current NLR BMPs to better relate to the economics of adopting producers. In this paper we will discuss CCEs for several common NLR BMPs, argue that inclusion of cost-benefit analyses in CCE estimations of cover crops (CC) may alleviate producer financial concerns and increase practice adoption, and assert that there is a need for further research examining the economics of combinations of best management practices on field, watershed, and regional scales.

**Keywords:** Best management practices; Cover crops; Comparative cost efficiency; Conservation; Economics

**Abbreviations:** BMP: Best Management Practice; N: Nitrogen; CC: Cover Cropping; NLR: Nitrogen Loss Reduction; BMPs: Best Management Practices; CCE: Comparative Cost Efficiency; EOF: Edge of Field; IF: In Field; CEEC: Conservation Economic Efficiency Cost; USA: United States of America

## Introduction

Growing awareness of nutrient contamination from row crop agriculture and its link to surface water contamination, such as the Gulf of Mexico Hypoxic Zone, has increased public pressure on agriculture to reduce our environmental footprint [1-3]. In agriculturally dominated watersheds, producers are implementing best management practices (BMPs) to prevent excessive nutrient losses, which contribute to public safety and environmental issues, through voluntary adoption or governmental cost share initiatives. The authors recognize that many nutrients can potentially pose an environmental concern. However, this paper will focus specifically on nitrogen (N) contamination of surface waters and agriculture BMPs designed to reduce N loading. Cover cropping (CC), one of the most widely recommend N Loss Reduction BMPs (NLR BMPs), has been shown to reduce N leaching and loss from agriculture fields [4-7]. Additionally, CC potentially provides multiple soil health benefits, beyond reducing surface water N contamination, that are not included in traditional comparative cost efficiency (CCE) calculations, the ratio of implementation costs to nitrogen load reduction. However, these demonstrated environmental and soil health benefits have not translated into producer adoption, thus

only 2% of cropland acreage in the U.S. has adopted CC and only 4% of U.S. farmers have used cover crops [8].

This is evidence that there is a disconnect between cover crop research and producer adoption; which is exacerbated by the dearth of information that allows producers to understand the short-term value of CC. It has been established that BMPs are effective at reducing N loads; however, to drive voluntary adoption by producers, we must advance our understanding of how to determine the CCE of individual and systems of NLR BMPs. With this in mind, we intend to discuss CCEs for several common NLR BMPs, argue that inclusion of cost-benefit analyses in CCE estimations of CC may help producers value the short-term benefits of cc, and assert that there is a need for further research examining the economics of combinations of best management practices on field, watershed, and regional scales.

## Fundamental Differences in Edge of Field and In-Field NLR BMPs

NLR BMPs can be categorized into two groups Edge-of-Field (EOF) or In-Field (IF) practices. Constructed wetlands, denitrifying bioreactors, two-stage ditches, and controlled

drainage are examples of EOF practices. In general, these practices reduce N loading by slowing water flow, creating anaerobic conditions, and facilitating denitrification. In contrast, IF BMPs are adaptive management strategies that reduce the actual losses of N from agriculture fields before it reaches the tile drainage system. Some examples of IF BMPs are cover cropping (CC) and 4R N management (right rate, right time, right source, and right place). In the literature, economic assessments of NLR BMPs have been conducted using CCE methodologies; estimates for several common BMPs are reported here (Table 1). In policy discussions, CCE values allow for the ranking of N load reduction efficiencies across multiple BMPs. Examples of this can be found in the Nutrient Loss Reduction Strategies of multiple Midwestern states [9,10].

**Table 1:** Comparative cost efficiency values for nitrogen loss reduction best management practices commonly found in the Midwestern USA.

Comparative Cost Efficiency, \$kgN <sup>-1</sup>				
NLR BMP*	Minimum	Maximum	Mean	References
Constructed Wetland	2.9	8.93	4.91	Roley, et al. [12], Christianson [16], Hyberg [19]
Denitrifying Bioreactor	2.1	4.87	3.49	Illinois Nutrient Loss Reduction Strategy [9], Christianson [16]
Two-Stage Ditch			11.63	Roley, et al. [12]
Controlled Drainage	2	2.71	2.36	Christianson [16], Jaynes [17]
N Application Timing	-14	6.99	-3.51	Illinois Nutrient Loss Reduction Strategy [9], Christianson [16]
N Application Rate	-9.37	-1.6	-5.49	Illinois Nutrient Loss Reduction Strategy [9], Christianson [16]
Cover Crops	2.22	11.06	6.64	Illinois Nutrient Loss Reduction Strategy [9], Kladvik [11], Roley, et al. [12], Roth [13], Saleh [18]

These CCE analyses only examine implementation costs to producers but do not consider any potential benefits. This is appropriate for most EOF practices that do not provide on-farm benefits beyond N loss reduction. However, an essential feature of IF practices are their potential to provide short-term benefits to producers such as erosion control, improved nutrient cycling, and potentially increased N utilization by cash crops. Therefore, it is the authors' opinion that the conventional CCE calculations underestimate the efficacy of CC and do not relate well to the economics of a producer.

### Inclusion of Cost-Benefit Analysis in Comparison Cost Efficiencies

As indicated above, CC CCE analysis focuses only on the ratio of implementation costs (establishment, termination, and yield effects) to the N load reduction, regardless of potential on-farm benefits. In the literature, CCE values of US\$2.22kgN<sup>-1</sup> year<sup>-1</sup> [11], US\$6.24/kgN/year [13], US\$7.08 kgN<sup>-1</sup> year<sup>-1</sup> [9], US\$7.95 kgN<sup>-1</sup> year<sup>-1</sup> [12], and [18] have been reported that represent an average CCE of US\$6.64 kgN<sup>-1</sup> year<sup>-1</sup>. The lack of methodology to include short-term, on-farm benefits in conventional CCE analyses result in less relevancy to producers because they do not reflect the impact of adoption on producers' profitability.

To address this concern, the literature has suggested a method for CCE that uses corrected implementation costs by performing cost-benefit analyses that include short-term, on-farm benefits (erosion control and improved N cycling); termed the Conservation Economic Efficiency Cost (CEEC) [13]. In comparison to the CCE values, they reported an average CC CEEC of US\$1.09 kgN<sup>-1</sup>ha<sup>-1</sup> [13]. This model allows for a more accurate estimate of the cost of CC as an NLR BMP; which may alleviate producer financial concerns that are a barrier to BMP adoption. While this model is an initial step in improving our analysis of CC cost efficiency, more research is needed to provide valuation methods for other short-term benefits of CC across different regions and management systems.

### Systematic Best Management Practice Approach to N Reduction Goals on Field, Watershed, and Regional Scales

In addition to improving our economic analysis of individual NLR BMPs, there is a need to understand how to use CEECs to assess a system of conservation practices (multiple NLR BMPs over a field, watershed, or regional scale). This has not been investigated in the literature. However, we do know from the literature that there is potential for combined BMPs to provide increased environmental benefits. For example, individual N load reductions of 11.8% and 35.6% have been observed for cover crops and controlled drainage, respectively. In comparison, the combination of these two practices resulted in an N load reduction of 47.5%, which was greater than either of the individual treatments alone [14].

The systematic coupling of cover cropping and 4R management (N application timing) has been investigated across a two-year corn-soybean rotation. Researchers reported an average N load increase of 17% by adjusting N application timing from fall to spring; a 3.7% decrease and 41.7% increase in the corn and soybean years, respectively [7]. Spring N application resulting in increased N load in the soybean year has been reported elsewhere in the literature [15-20]. However, when N application timing and CC are coupled, a 15.1% decrease in the corn year and 32.8% reduction in the soybean year was observed

in drainage system N loading [7]. A similar trend was observed where cover crops resulted in an average reduction in N load of 53.3% across both phases of a corn/soybean rotation [20]. These studies demonstrate that the combination of multiple BMPs has the potential to increase N load reductions across field, watershed, and regional scales.

However, there is a dearth of knowledge regarding how to value these conservation systems in a way that economically producers. Therefore, there is further need for research that examines the economics of conservation systems that include multiple BMPs.

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