Engineering Solution Proposal: Vegetative Plant Buffer for Nutrient Runoff

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Abstract:

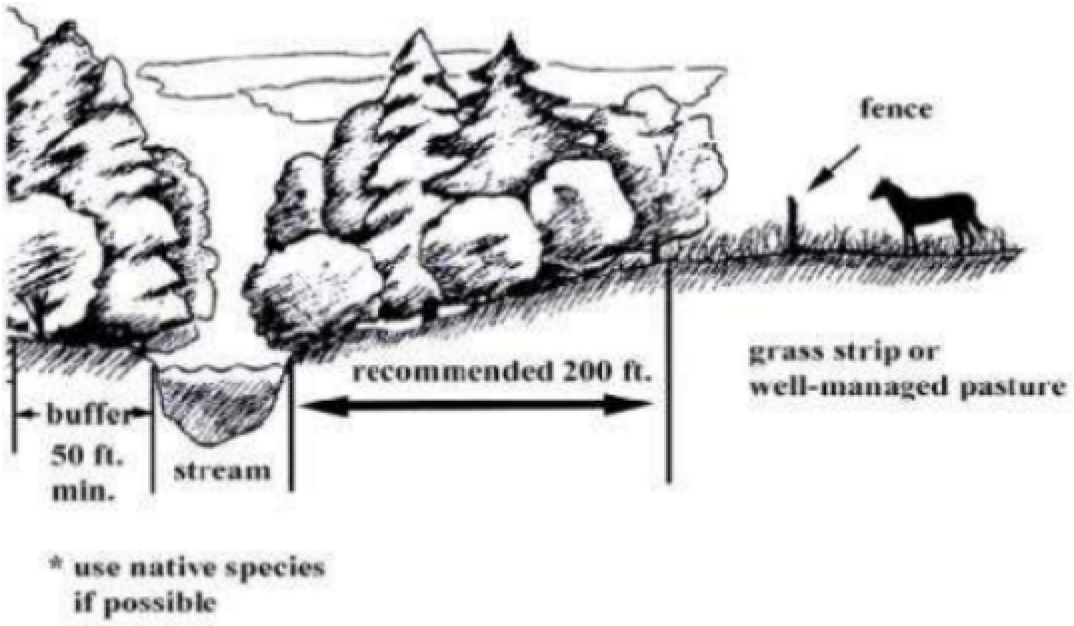
As different forms of agricultural refinement start to emerge, the usage of nitrogen-based fertilizer increases to optimize crop yield and quicken growth time. Over 100 million tons are applied to the Earth's surface annually (Cary 2015), both helping and harming the natural environment. This "N-fertilizer" is at risk of over-saturating soil and running off into near water bodies, causing an excess spurt in growth of algae, which combines with cyanobacteria such as microcystin and further grows to be toxic to living organisms in the near habitat as well as deems the water as inconsumable. The objective of this paper is to propose an adaptation solution to counter the exacerbating issue of nitrogen runoff by establishing a buffer strip that is able to absorb the excess runoff that the already saturated soil is unable to absorb. This would provide a feasible option for the termination of chemical runoff changing the equilibrium state of aquatic ecosystems.

Introduction:

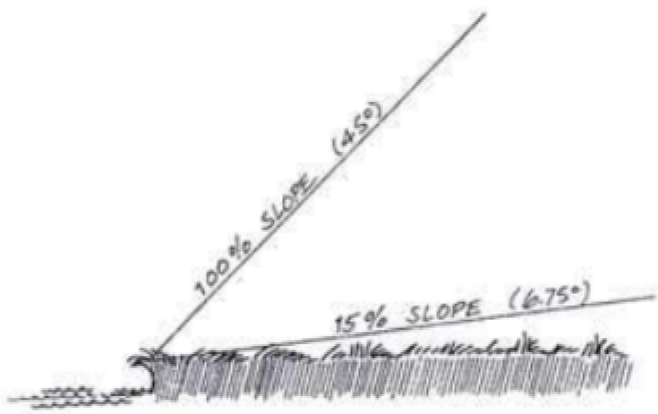
In the past two decades, the growth of nitrogen and phosphorus usage in the field of agriculture has immensely increased, subsequently causing excess chemical runoff from croplands. These excess chemicals fall into near water bodies, causing a spurt in growth of algal blooms. Algae requires 10-40 times more nitrogen than phosphorus (Pelley 2016), so absorbing nitrogen from croplands is a continuous cycle. Overgrowth of algae not only produces cyanobacteria overgrowth, but also is at risk of causing dead zones - where oxygen levels are so low that life is unable to be sustained in those areas. (Rutledge, et al. 2022).

The majority of Earth's dead zones are along the U.S. East Coast and coastlines of Japan and the Korean Peninsula. The Gulf of Mexico has a seasonal hypoxic (little oxygen) zone that forms annually around late summer. (EARTH.ORG 2022). Cyanobacteria is present naturally in all types of water, but exponentially grow after feeding on dead algae (CDC n. d.). Algae consume oxygen, and once the algae die they are food for harmful bacteria (microcystin: large cyclic peptide ring with 7 amino acids) that can cause fatal diseases if ingested. More than 100,000 moles of rivers and streams, close to 2.5 million acres of lakes, reservoirs, and ponds, and more than 800 square miles of bays and estuaries in the U.S. have poor water quality because of nitrogen and phosphorus pollution. (EARTH.ORG 2022).

Numerous documents and papers have been written on this topic, concluding with similar thoughts as this paper. The solution of vegetated buffer strips has been a considered solution for some time, as shown in a recent paper written by the Massachusetts Department of Environmental Protection. In this paper, solutions are similarly stated, for example, "Establishing vegetated buffer strips along lakes and streams is a simple and inexpensive way to protect and improve water quality on your property and in your community." (Harper n.d.). This solution is expanded on and multiple diagrams have been pictured to gain a better understanding of the proposed solution, as seen below:



The proportion of width of the buffer strip to land slope was also discussed in this article, with a table and diagram to help visualization:



Slope of Land (%)	Minimum Width of Buffer Strip (Feet)
0	50
5	70
10	90
15	110
20	130
25	150

Although this paper does not discuss land slope and buffer width, a quick visualization of the relation from other articles is essential to understanding the logic and thought behind the primary solution. A second article to be reviewed, further discusses limitations and future study ideas of the buffer strip. For example, "In addition, there are questions about the maintenance required to maximize the performance of the buffer." and "Another area that may be in need of future studies is to quantify what percent of shallow groundwater moving to a particular stream interacts with the buffer zone." (Helmers, et al. 2005). The maintenance of the buffer strip has been considered in this paper, but the amount of shallow groundwater interaction with the buffer strip is not mentioned in this paper. Fundamentally, these two articles allow the solution of vegetative buffer strips to be further researched with the abundance of ample information.

Criteria and Constraints:

Criteria of this solution include safety of the strips when interacting with organisms of aquatic and terrestrial ecosystems, reliability of its function, and relative aesthetics when being placed in a highly commercial area. Constraints include costs- they must not be exorbitant, time, and resource and/or space availability.

Procedure:

For these buffer strips to be placed effectively and functional, a clear space near the body of water is required. Ridding the premises of excess trees and botanic growth is necessary. Once this is achieved, short, shrub-like plants can be planted along the banks of the water body, as pictured:

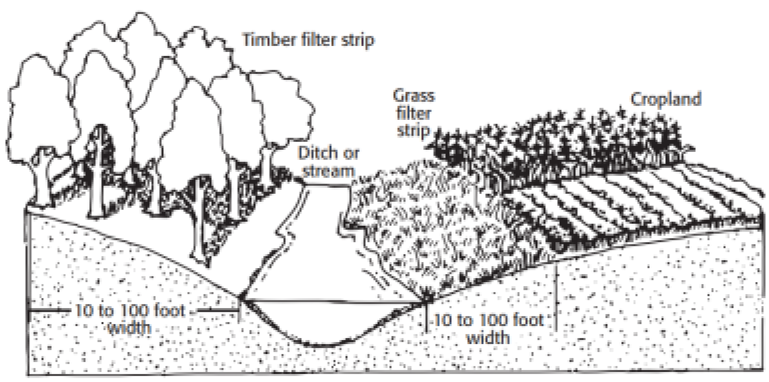


Figure 2: Filter strip design. Source: The Ohio State University Extension Service

Desired plants that have proven to have exceptional nitrogen absorption include the Ipomoea Aquatica, the Salvinia Natans, and the Hippuris Vulgaris. These plants are semi-aquatic themselves, so interaction with groundwater and coastal water would not "drown" these plants. They are also perennials, meaning they are able to live for longer than 2 years. Maintenance includes making sure plants stay in shape and are healthy throughout their lifetime. The buffer should be 10 to 100 feet wide, providing an ample filter from the cropland, as pictured in the model above.

Refinement:

In the occasion that refinement is needed, different plants could potentially be used to experiment with absorbancy rate and lifespan. If plants are inaccessible, a sponge-like buffer "wall" could be implanted, although research has not been done on this solution. Theoretically, this wall would be able to specifically absorb excess nitrogen and phosphorus without needing the care and maintenance that a typical plant would require.

Conclusion:

Hence, the addition of a vegetative filter strip to combat the uprising issue of harmful algal bloom formation due to excess nitrogen runoff would serve as a sufficient panacea. The process of eutrophication releases small amounts of nitrous oxide, which mixes into the stratosphere and destroys the ozone layer. Additionally, it also contributes to the greenhouse effect along with gasses like carbon dioxide and methane. Although making one-third of global food production possible, nitrogen fertilizers have proven to not only harm aquatic ecosystems by changing their equilibrium state, but also contribute to the detrimental growth in greenhouse gasses harming the ozone layer.

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