Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

Reducing Agricultural Runoff to Combat Ocean Dead Zones

BE 230 - Spring 2021
Engr. Analysis of Biological Systems
Dr. Safferman

Allison Smith, Caylie Davis, Grant Gmitter, Marisa Porco, Marshall Humphrey

Introduction

Commonly known as “dead zones”, these massive hypoxic regions in our oceans have the capability to bring about devastating effects on sea life and coastal ecosystems. Hypoxia refers to a depletion of oxygen so low that it can result in the death of many organisms. Although natural fluctuations in dissolved oxygen levels occur, an increase in these hypoxic regions has resulted due to human activity and climate change [1].

The Gulf of Mexico hosts one of the largest coastal dead zones, caused by excess organic matter carried through the Mississippi River basin. As explained in Figure 1, a heavy inflow of nutrients, including nitrogen and phosphorus, often comes from runoff and causes eutrophication [1]. Reducing agricultural runoff could significantly minimize the negative effects of eutrophication. Multiple agricultural approaches like cover crops and nutrient management will aid in this process.

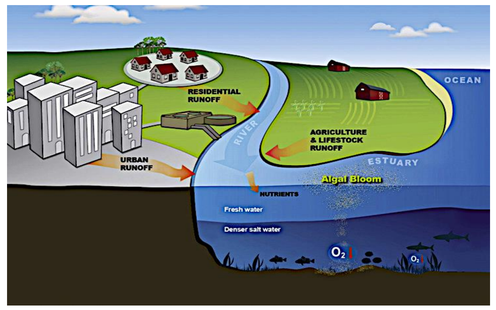

Figure 1: Process of eutrophication in oceans [1]

Process Description

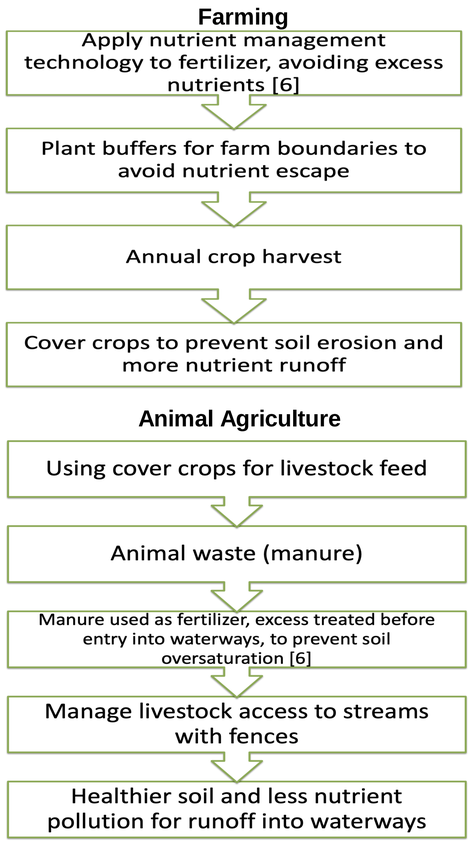

Figure 2: Process of reducing nutrient runoff into waterways for crop and animal agriculture

Impact on Ecosystem services

The United States is reliant on the current agriculture practices, that include fertilizers and pesticides, irrigation and water use, crop and livestock practices, and much more. Almost 45% of the U.S. designated to farmland, most of which, is located within the Mississippi river basin [7], as seen in Figure 3.

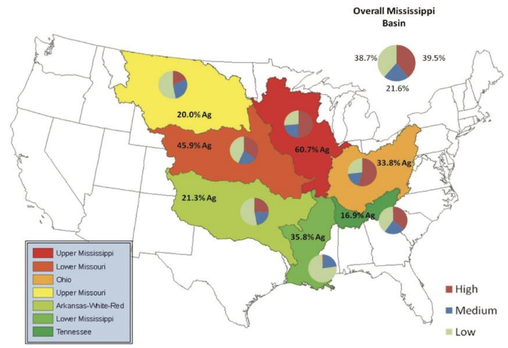

Figure 3: Percentages of land in the Mississippi River basin occupied by agriculture [7]

With most of the surrounding area occupied by farms, the Mississippi watershed receives enormous amounts of runoff, containing heavy levels of nitrogen and phosphorus (two main components of fertilizers). As a result, the neighboring streams experience an algae bloom and decomposition that leads to reduced dissolved oxygen levels [7]. Continuous contamination from runoff accumulates overtime, traveling from local regions to infect the entirety of the Mississippi River, and the coastal areas of the Gulf of Mexico. The result devasts the ecological communities and are outlined in the list below.

Ecosystem Impact

- Marine life death
- Sea life migration (and/or death)
- Minimized CO_2 Consumption

These impacts extend past ecosystem destruction, to disrupt the livelihood of families and communities. Local communities along the Gulf of Mexico rely on fishing practices as a significant part of their economics. Without this stability, families are forced to relocate or find other sources of income, furthering the economic pitfall. Underneath are some of the factors that relate to the community affect.

Community Impact

- Decreased food availability
- Polluted water supplies
- Poor fishing economy

A possible method of reducing nutrient runoff is the implementation of cover crops. This way, it would require the farmers to make space on owned land to grow the plants, attempting to stop the issue at the source. Additionally, by the cover crops being on the farmer's own land, the direct benefits of the plant are received. Some direct benefits of this crop are seen listed below.

Cover Crop Impact

- Reduces runoff velocity
- Increase soil quality
- Increases water quality

Sensitive Unit

Cover crop farming, shown below in Figure 4, is known for recycling excess nutrients, which reduces agricultural runoff. There is potential risk associated with cover crop farming that can be difficult to manage. Some variables that determine good cover crop establishment include temperature, rainfall, and good seed-to-soil contact [5]. However, the most sensitive unit of cover crop farming is the type of cover crop used, which determines the amount of nutrients a cash crop can receive. Below is a list of some of the outcomes of grass and legume cover crops.

Figure 4: Soybeans no-tilled into a cover crop [5]

- Nitrogen release depends on the type of cover crop used. Legumes and grasses that are killed too soon tend to have a lower C:N ratio. Crop yields will decrease if nitrogen is not released. This happens when cover crops temporarily immobilize nitrogen as they decompose [5].
- Grass cover crops are useful for scavenging nutrients from previous crops, suppressing weed growth, and have extensive root systems that reduce erosion [6].
- If grass cover crops are grown to maturity, the amount of nitrogen left for the next cash crop is reduced [6].
- Legume cover crops have a high ability to fix nitrogen from the atmosphere and add it to the soil, attract beneficial insects, and reduce erosion [6].
- Some legumes, such as crimson clover, may supply over 100 lbs of nitrogen to the next crop, while other legumes, such as field peas and red clover, may supply 30-80 lbs of nitrogen [6].

Table 1: The advantages and disadvantages of legume cover crops.

Legume Cover Crops	
Advantages	**Disadvantages**
• Best at fixing nitrogen	• Require specific inoculation
• Some withstand severe winters	• Could decrease nitrogen
• Attract beneficial insects	• Could immobilize nutrients

Table 2: The advantages and disadvantages of grass cover crops.

Grass Cover Crops	
Advantages	**Disadvantages**
• Best at scavenging nutrients	• Could decrease nitrogen for crop
• Extensive root system	• Could immobilize nutrients
• Produce large amount of residue	• May become a problem weed

There are several species of legume cover crops and grass cover crops, and different types will have varying success in reducing nutrient runoff.

Research

To understand how different types of cover crops affect nutrient run off, research can be done to compare legume and grass cover crops, such as ryegrass shown in Figure 5. If one type is more effective at preventing high nitrogen and phosphate levels in a watershed, then it is the optimal type to use.

Objectives:

- Determine whether legumes or grasses are best for cover crops for a certain area.
- Increase cover crop usage.
- Determine if there are significant differences in nitrogen and phosphate levels in watersheds with different cover crops.

Tasks:

- Find two similar watersheds that can be compared.
- Take water samples throughout each area to measure initial nitrogen and phosphate levels.
- Increase the area that each of the types of cover crops are grown.
- Take water samples four times a year.

Data analysis:

- Compare initial nitrogen and phosphate levels to measurements over time.
- Perform a P-test to determine if the values are significantly different statically over time.
- Compare nitrogen and phosphate levels the two different areas where legumes and grasses are the cover crops.
- Perform a P-test to determine if the difference in nutrient levels is statistically high between the two areas.
- If there is not a difference in the nutrient levels in the water, then nutrient absorption effectiveness does not need to be a factor when determining the type of cover crop that is grown.

Figure 5: Annual ryegrass used as a cover crop [8]

References

1. A. H. Altieri and R. J. Diaz, “Dead Zones: Oxygen Depletion in Coastal Ecosystems,” *World Seas: an Environmental Evaluation*, pp. 453–473, 2019.
2. S. Joyce (2000). “The dead zones: oxygen-starved coastal waters.,” *Environmental Health Perspectives*, vol. 108, no. 3, pp. 120–125.
3. Downing JA, et al (1999). Gulf of Mexico hypoxia: land and sea interactions. Task force report no. 134. Ames, IA:Council for Agricultural Science and Technology.
4. J. Hoorman, "Using Cover Crops to Improve Soil and Water Quality," Ohio State University Extension, Lima, OH, 2009
5. "Types of Cover Crops," *SARE*, 2020
6. J. Martinez, P. Dabert, S. Barrington, and C. Burton, “Livestock waste treatment systems for environmental quality, food safety, and sustainability,” *Bioresource Technology*, vol. 100, no. 22, pp. 5527–5536, 2009.
7. National Geographic Society, “dead zone,” National Geographic Society, 09-Oct-2012.
8. “Annual Ryegrass,” *Cover Crops in Wisconsin*. [Online]. Available: https://fyi.extension.wisc.edu/covercrop/annual-ryegrass/.