



# 2024 West Virginia Envirothon

## Special Environmental Topic

### Renewable Energy, Sustainable Bioenergy Production and the Challenge of Nitrate Runoff

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# 2024 WV Envirothon Special Environmental Topic: Renewable Energy, Sustainable Bioenergy Production and the Challenge of Nitrate Runoff

## Scenario

Your team operates a 250-acre farm in West Virginia. In recent years, profits from traditional crops have been declining. Your team will investigate how to utilize renewable energy to increase profits, protect local ecosystems, and incorporate renewable energy into operations. Your team also desires to incorporate social responsibility into the farm's operations, ensuring your farm contributes positively to the local community and society.

## Introduction

Your team's mission is to investigate a pressing environmental issue while simultaneously contributing to sustainable energy production. You are tasked with developing a proposal to enhance bioenergy crop management, specifically targeting the mitigation of nitrate runoff and improving water quality. Additionally, you will investigate other forms of renewable energy to include in your operation. Your proposal (presentation) will focus on (1) innovative approaches and strategies to minimize the environmental impact of bioenergy cultivation, ensuring its long-term viability, and (2) a companion renewable energy type that is suitable to your site and can work in tandem with bioenergy production.

## Objective

The primary objective of your research team is to create a proposal (presentation) that addresses the following key points. Please also read the **Background Information** section below, which supplies more context:

1. Crop Selection and Diversity: (Learn More: <https://aqwater.extension.wisc.edu/articles/cover-crop-selection-and-management-to-reduce-nitrate-leaching-risk/>)
  - Investigate the role of crop selection and diversity in reducing nitrate runoff.
  - Develop recommendations for selecting appropriate bioenergy crops.
  - Suggest strategies for crop diversification and rotation to optimize nutrient management.
2. Precision Agriculture Techniques: (Learn More: <https://www.ers.usda.gov/amber-waves/2016/december/precision-agriculture-technologies-and-factors-affecting-their-adoption/>)
  - Explore the significance of precision agriculture in nitrate runoff prevention.
  - Research and evaluate real-time monitoring, targeted nutrient application, and precision irrigation technologies.
  - Assess precision agriculture's feasibility and economic benefits for sustainable bioenergy crop management.
3. Sustainable Soil Management Practices: (Learn More: <https://extension.psu.edu/managing-soil-health-concepts-and-practices>)
  - Investigate the impact of sustainable soil management practices on nitrate leaching, including reduced tillage and cover cropping.
  - Develop guidelines for effective implementation of these practices across various agricultural settings.
  - Examine the long-term benefits and environmental impact of these practices.
4. Organic Matter Incorporation: (Learn More: <https://www.sare.org/publications/building-soils-for-better-crops/what-is-organic-matter-and-why-is-it-so-important/>)
  - Research the benefits of incorporating organic matter into soils in preventing nitrate migration.

- Provide guidance on types and quantities of organic matter that are most effective in improving soil fertility.
5. Innovative Irrigation Practices: (Learn More: <https://www.waterworld.com/home/article/14070345/smart-irrigation-reduces-nitrogen-leaching>)
    - Explore using innovative irrigation methods, such as drip irrigation and soil moisture sensors, to reduce nitrate leaching.
    - Assess the effectiveness of these technologies in different agricultural contexts and climates.
  6. Sustainable Sourcing of Biomass: (Learn More: <https://www.eesi.org/topics/bioenergy-biofuels-biomass/description>)
    - Investigate sustainable biomass sourcing for bioenergy production, including afforestation and reforestation initiatives.
    - Assess these practices' feasibility and environmental impact in offsetting biomass-related environmental harm.
  7. Policy and Incentives: (Learn More: <https://www.epa.gov/environmental-economics/economics-biofuels>)
    - Quantify responsible practices' economic and environmental benefits and their impact on the bioenergy industry.
    - Develop evidence-based recommendations for policies that promote responsible bioenergy production.
  8. Complementary Renewable Energy Production
    - Research other renewable energy types (solar, geothermal, wind, hydro) Resource: <https://www.energy.gov/clean-energy>.
    - Select at least one other renewable energy source to produce at your site.
    - Determine what characteristics would be beneficial at your site to support bioenergy crop production and your other selected energy type.
    - Explain why you chose this type of renewable energy and how it will benefit the farm operation, community, and society.

You (the Team) should plan to work collaboratively to develop a comprehensive proposal that addresses the need to enhance bioenergy crop management, with a specific focus on mitigating nitrate runoff and improving water quality. Further, your team will investigate at least one renewable energy source (geothermal, hydro, solar, wind) to incorporate into your proposal. Use the eight key points above to guide your research and inform your presentation. By investigating these key areas, conducting research, and considering practical solutions, you will contribute to a more sustainable and environmentally responsible energy future.

### **Background Information**

The global energy landscape is at a crossroads. As humans confront the pressing issues of climate change, environmental degradation, and socio-economic disparities, decisions made regarding energy sources are critical. Embracing new and developing renewable energy technologies for production will be vital as societies address these challenges. Wind, solar, hydropower, biomass, and geothermal present opportunities to diversify energy production and reduce climate impacts.

One avenue that holds promise in addressing these challenges is the cultivation of bioenergy crops. Bioenergy, derived from organic matter such as plants, offers an eco-friendly and renewable alternative to fossil fuels. However, this promising energy source is not without its environmental concerns, particularly related to nitrate runoff and water quality issues. The following text includes a presentation of bioenergy production's significance in slowing climate change, examining its environmental, economic, and social implications, and delving into various forms of renewable energy, focusing on biomass.

### *Bioenergy and Climate Change Mitigation*

The cultivation of bioenergy crops represents a promising avenue for sustainable energy production and a vital tool in the fight against climate change. Climate change is driven by the excessive release of greenhouse gases into the atmosphere, primarily carbon dioxide from burning fossil fuels. Bioenergy offers an alternative energy source that can significantly reduce greenhouse gas emissions. Unlike fossil fuels, bioenergy is considered carbon-neutral because the carbon dioxide released during its combustion is offset by the carbon dioxide absorbed by the plants during their growth. This closed carbon cycle makes bioenergy a valuable asset in mitigating climate change.

However, the environmental impact of bioenergy crops is not limited to carbon emissions alone. Nitrate runoff, which arises from excessive fertilization and inadequate nutrient management in bioenergy fields, poses a significant challenge. Nitrate runoff contributes to water quality problems, which can ultimately compromise the health of aquatic ecosystems and drinking water sources. Thus, while bioenergy production can help combat climate change, its environmental consequences must be carefully managed to ensure the long-term viability of this renewable energy source.

### *Environmental Considerations and Bioenergy Crop Management*

The environmental impact of bioenergy crops, particularly nitrate runoff, necessitates a comprehensive reassessment and improvement of management practices. The primary environmental concern is the leaching of nitrates into freshwater bodies, leading to eutrophication, impaired aquatic ecosystems, and compromised drinking water quality. Adopting an integrated approach that includes agronomic, soil health, and water management strategies is imperative to address these challenges.

#### 1. Crop Selection and Diversity

Effective management of bioenergy crops begins with crop selection. Choosing the right crops and incorporating diversity and rotation into the cropping system is pivotal in mitigating nitrate runoff. Diverse cropping systems help reduce the risk of nutrient imbalances and enhance soil nutrient retention. By varying the types of crops grown and their planting sequences, farmers can promote soil health and minimize nitrate leaching. This practice has additional benefits, such as pest control and improved soil structure.

#### 2. Precision Agriculture

Precision agriculture techniques are essential for preventing over-fertilization and curbing nitrate leaching. By using advanced technologies like targeted nutrient application and real-time monitoring, farmers can optimize their use of fertilizers. This reduces the environmental impact and enhances economic efficiency by minimizing input costs.

#### 3. Sustainable Soil Management

Sustainable soil management practices play a crucial role in mitigating nitrate runoff. Reduced tillage and cover cropping, for example, enhance soil structure, increase water infiltration, and reduce surface runoff. These practices mitigate nitrate leaching and contribute to soil health and resilience, ensuring the long-term viability of bioenergy cultivation.

#### 4. Organic Matter Incorporation

Incorporating organic matter into soils can further aid in reducing nitrate leaching. Organic matter, such as compost and crop residues, improves soil fertility and acts as a natural buffer, binding nitrates and

preventing their migration into water bodies. This practice safeguards water quality and promotes soil health and sustainable farming practices.

#### 5. Innovative Irrigation Practices

Innovative irrigation practices are another avenue for reducing nitrate leaching. Efficient irrigation methods like drip irrigation can significantly reduce water usage and nitrate runoff. Soil moisture sensors provide real-time data, enabling precise water application control and further minimizing excess water usage and nitrate leaching.

#### 6. Biomass as a Promising Bioenergy Source

Biomass, which includes organic materials such as wood, crop residues, and dedicated energy crops, represents a significant portion of bioenergy production. Among the various forms of renewable energy, biomass has garnered considerable attention due to its potential for sustainable energy production. The cultivation and utilization of biomass have a unique set of challenges and opportunities that warrant exploration.

Biomass can be a versatile renewable energy source that can replace fossil fuels in various sectors, including electricity generation, heating, and transportation. It offers numerous advantages, such as carbon neutrality, job creation, and rural economic development, making it an appealing option in transitioning to a more sustainable energy mix. However, as with any energy source, it comes with environmental, economic, and social considerations.

#### 7. Environmental Considerations

As discussed earlier, one of the primary environmental concerns associated with biomass production is the risk of nitrate runoff. Efficient management practices, such as crop selection, precision agriculture, and sustainable soil management, are essential in mitigating these environmental challenges. Additionally, it is important to consider the sustainability of biomass sourcing, ensuring that it does not lead to deforestation or converting valuable ecosystems into monoculture plantations. Sustainable sourcing practices, including afforestation and reforestation, can help offset the environmental impact of biomass production.

#### 8. Economic Implications

From an economic perspective, biomass has the potential to stimulate rural economies by providing new revenue streams for farmers and landowners. It can create jobs in the bioenergy supply chain, including farming, transportation, and processing. However, the economic viability of biomass production is closely tied to government policies, subsidies, and market demand. A stable policy framework that supports bioenergy production and incentives for sustainable practices is essential for fostering a thriving bioenergy industry.

#### 9. Social Considerations

The social aspects of biomass production are multifaceted. On one hand, it offers opportunities for rural development and increased income for local communities. On the other hand, concerns arise regarding land use competition, mainly when dedicated energy crops displace food crops. Striking a balance between food security and bioenergy production is essential. Additionally, bioenergy projects should engage with local communities, ensuring that their perspectives and needs are considered and that potential adverse social impacts are mitigated.

### *Renewable Energy on Biomass Sites*

The surge in renewable energy across the United States presents significant economic prospects for rural areas, agriculture, and forestry. Integrated agriculture and wind energy systems alone generate more than \$200 million annually for rural landowners, while the solar photovoltaic (PV) industry has expanded by 800-fold since 2008, providing lease payments to landowners hosting large-scale systems. Smaller PV systems are aiding businesses and households nationwide to reduce their power bills. With corn ethanol production now at 16 billion gallons annually, constituting nearly 40 percent of domestic corn production, and U.S. biodiesel production standing at 1.7 billion gallons annually, renewable (clean) energy markets are creating direct economic benefits for these sectors and their associated feedstocks. Beyond economic gains, renewable energy enhances energy independence, bolsters security, mitigates wildfire risks through forest management and significantly reduces greenhouse gas emissions.

Nevertheless, the expansion of bioenergy feedstock production might adversely affect soil and water quality due to land conversion. Additionally, while renewable energy technologies offer environmental benefits compared to conventional energy sources, challenges such as increased wildlife mortality from wind turbines, water consumption in biomass power generation, and changes in land use for utility-scale PV systems need consideration. Despite these challenges, mitigation strategies exist. Various regions specialize in renewable energy markets: the Midwest leads in ethanol, biodiesel, and wind electricity, the Southeast excels in wood pellet and biomass electricity production, and the Northeast and Southwest dominate the solar electricity market. Given the rapid growth and diversity of renewable energy, the availability of a comprehensive, credible information source is crucial.

### **Conclusion**

The cultivation of bioenergy crops holds significant promise in addressing the global energy challenges we face today, particularly in the context of slowing climate change. Bioenergy represents a renewable energy source that, when managed sustainably, can reduce greenhouse gas emissions and contribute to a more environmentally responsible energy mix. However, the environmental impact of bioenergy crops, specifically the issue of nitrate runoff and water quality problems, requires careful consideration. An integrated approach encompassing agronomic, soil health, and water management strategies is essential to address these challenges. By selecting the right crops, adopting precision nutrient management, enhancing soil health, and implementing innovative irrigation practices, nitrate leaching can be mitigated, thereby protecting critical water resources and aquatic ecosystems.

While biomass stands out as a promising form of bioenergy, it comes with environmental, economic, and social considerations. Efficient management practices, sustainable sourcing, and supportive policies are crucial to ensure that biomass contributes to a more sustainable and equitable energy future. Ultimately, the cultivation of bioenergy crops offers a valuable pathway toward sustainable energy production, but it demands responsible management and a holistic approach to address its environmental impact. By striking a balance between environmental stewardship, economic development, and social responsibility, we can harness the potential of bioenergy while safeguarding the planet for future generations.

## Key Components

As a research team embarking on the mission to develop a proposal for enhancing bioenergy crop management to ameliorate nitrate runoff and improve water quality, there are key outcomes, skills, and new awareness that you should demonstrate throughout your work:

### 1. Knowledge of Bioenergy Crop Management:

- Outcome: An understanding of bioenergy crop management, including the environmental challenges, sustainable practices, and their significance in renewable energy production.
- Skills Developed: Understanding of the principles and techniques related to bioenergy crop selection, precision agriculture, sustainable soil management, organic matter incorporation, innovative irrigation, and biomass sourcing.

### 2. Interdisciplinary Collaboration:

- Outcome: Enhanced ability to work effectively as an interdisciplinary team, integrating information from fields such as agronomy, environmental science, engineering, and policy development.
- Skills Developed: Improved communication, collaboration, and coordination among team members.

### 3. Problem-Solving and Research Skills:

- Outcome: Improved problem-solving skills and research abilities to identify, analyze, and address the complex environmental challenges of bioenergy crop management.
- Skills Developed: Proficiency in data collection, analysis, and interpretation, as well as the ability to propose innovative solutions based on findings.

### 4. Policy and Advocacy Awareness:

- Outcome: Increased awareness of sustainable energy production's policy and advocacy aspects and its role in influencing government decisions and industry practices.
- Skills Developed: Communicating research findings effectively and advocating for supportive policies that encourage responsible bioenergy production.

### 5. Environmental Stewardship:

- Outcome: A heightened sense of environmental stewardship, focusing on minimizing the ecological footprint of bioenergy production and promoting sustainable practices.
- Skills Developed: Considering standards and best practices prioritizing environmental preservation.

### 6. Knowledge Transfer and Public Engagement:

- Outcome: Ability to transfer knowledge to ensure that research findings and sustainable practices are disseminated to relevant stakeholders.
- Skills Developed: Effective science communication and ability to engage with diverse stakeholders.

### 7. Ethical Considerations:

- Outcome: An understanding of the ethical considerations and responsibilities associated with bioenergy crop management, including issues related to land use, food security, and ecosystem preservation.
- Skills Developed: The ability to critically consider complex ethical dilemmas and make informed decisions prioritizing energy sustainability and environmental ethics.

### 8. Long-Term Viability Perspective:

- Outcome: A forward-looking perspective that prioritizes the long-term viability of bioenergy initiatives, safeguarding critical water resources, and preserving aquatic ecosystems.
- Skills Developed: Thinking strategically and proposing solutions that balance short-term energy needs with long-term environmental goals.

By actively seeking these outcomes and skills, your research team will develop a comprehensive proposal (presentation) and contribute to the broader mission of addressing environmental challenges in the context of sustainable bioenergy production.

**Resources (web links also provided in-text):**

1. <https://agwater.extension.wisc.edu/articles/cover-crop-selection-and-management-to-reduce-nitrate-leaching-risk/>
2. <https://www.ers.usda.gov/amber-waves/2016/december/precision-agriculture-technologies-and-factors-affecting-their-adoption/>
3. <https://extension.psu.edu/managing-soil-health-concepts-and-practices>
4. <https://www.sare.org/publications/building-soils-for-better-crops/what-is-organic-matter-and-why-is-it-so-important/>
5. <https://www.waterworld.com/home/article/14070345/smart-irrigation-reduces-nitrogen-leaching>
6. <https://www.eesi.org/topics/bioenergy-biofuels-biomass/description>
7. <https://www.epa.gov/environmental-economics/economics-biofuels>
8. <https://www.energy.gov/clean-energy>
9. <https://www.usda.gov/sites/default/files/documents/renewable-energy-trends-2020>