**MICROBIOME MANAGEMENT FOR IMPROVED NUTRIENT-USE EFFICIENCY AND WATER QUALITY**
**Project Implementation Plan Summary**

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**Summary**
The conventional agricultural system in North Dakota (ND) is a success story in many ways, with ND leading the nation in yields of spring wheat, beans, canola as well as many other agricultural and livestock products. While a steadily increasing production capacity is well-supported by a dynamic agriculture sector, poor nutrient-use-efficiency (NUE) remains a major challenge. In particular, *nutrient losses via leaching of water (i.e., nitrogen and phosphorus) from agroecosystems* caused by low NUE has resulted in undesirable effects on the environment. As much as *57% and 69% of the ND rivers and streams were found in 'poor' conditions due to excess nitrogen and phosphorus, respectively*. *Runoff, drainage and leachate from croplands and animal feeding operations were identified as major contributors to the excess nutrients*, highlighting the lack of effective nutrient management strategies and an urgent need for sustainable practices in ND agricultural systems. In addition to hydrological and soil chemical factors, nutrient losses can also be determined by nutrient-use efficiency and soil biological parameters. *However, the importance of soil biological activities for managing intensive agricultural systems has received little recognition until now*. Sustainable intensification of agroecosystems aims to alleviate environmental footprints through targeted utilization of soil biological traits. Microbiomes are an indispensable component of agroecosystem functioning and thus can be an important tool to achieve agricultural sustainability. The proposed study aims to use a long-term field trial at the Carrington Research and Extension Center and strategic sampling of several farmlands in the region to understand how the timing and rates of nutrient applications can influence plant- and soil microbiomes and vice versa. Our study aims to reveal how key microbial players can be manipulated to enhance nitrogen- and phosphorus-use-efficiency, decrease their losses to water bodies, and improve the water quality in ND. The overall goal of this project is to enhance water quality by optimizing microbial contributions and alleviating nutrient losses from ND agroecosystems. The project will monitor changes in water quality in response to various timing and rates of fertilizer applications across cropping systems. It will identify the cropping practices that are optimal in enhancing soil biological contributions for efficient nutrient uptake in various soil conditions. Specifically, we will be addressing the following objectives: a) exploring the relationships among microbial communities, nutrient-use efficiency and water quality under various agricultural management practices, hydrological and soil conditions; and b) disseminating results and findings to producers and landowners in ND, and to promote awareness about the importance of microbiomes for nutrient-use efficiency and water quality. Knowledge generated will be disseminated to ND farmers and stakeholders using existing outlets and networks at NDSU to enhance awareness regarding the microbial roles in reducing nutrient losses from agricultural systems. We will also formulate recommendations for various soil types and agronomic practices.

## 3.0 PROJECT DESCRIPTION

### *3.1 Project Goals*

The overall goal of this project is to enhance water quality by optimizing microbial contributions and alleviating nutrient losses from ND agroecosystems. The project will monitor changes in water quality in response to various timing and rates of fertilizer applications across cropping systems. It will identify the cropping practices that are optimal in enhancing soil biological contributions for efficient nutrient uptake in various soil conditions. It aims to harness key players in the plant and soil microbiomes through management practices to mitigate future water quality impairment in ND. By incorporating seasonal patterns, the project aims to develop models linking pedological and agronomical data to microbial characteristics. Knowledge generated will be disseminated to ND farmers and stakeholders using existing outlets and networks at NDSU to enhance awareness regarding the microbial roles in reducing nutrient losses from agricultural systems. We will formulate recommendations for various soil types and agronomic practices. Such tailored recommendations will facilitate producers to understand nutrient loss patterns in their farmlands and make informed decisions. This will potentially enable them to readjust fertilizer inputs, reduce the cost of related agricultural practices, and reduce externalities that have consequences to water resources. Furthermore, the linkage between agricultural microbiomes and water quality is a key watershed management priority and yet an underexplored area. The project aims to fill this informational void. In particular, it will create opportunities to disseminate outcomes at regional and national meetings on watershed and natural resource management.

### 3.2 Objectives

The project will use a combination of exploratory field surveys and experimental manipulations at farmlands and a long-term field trial, respectively, to achieve the integrated objectives outlined below. Note that these objectives are integral to the project goal and are not intended to be interpreted as independent components. A long-term agricultural field trial at the Carrington Research Extension Center (CREC) of NDSU will be the primary site. Additionally, several farmlands will be selected across soil types and management practices for monitoring the linkage observed at the long-term experimental site. The synergistic use of these sites under different soil types and weather conditions will be a unique strength of this study. Furthermore, a range of physical, chemical and molecular techniques will be used to assess hydrological, edaphic, agronomic, and biological properties. Such comprehensive measurement will also be a strength of this project. All information and data will be summarized and disseminated to landowners, agricultural producers, state and county extension agents, and the ND Department of Environmental Quality personnel for educational events to the general public and stakeholders.

**Objective 1:** *To explore the relationships among microbial communities, nutrient-use efficiency and water quality under various agricultural management practices, hydrological and soil conditions.*

**Task 1:** This task will explore the link between microbial communities and hydrological properties across several farms and in a long-term soil management and crop rotation field trial at the Carrington Research Extension Center (CREC) of NDSU.
**Task 2:** This task will monitor the seasonal patterns of hydrological and edaphic properties across a management intensity gradient.

**Objective 2:**
*To disseminate results and findings to producers and landowners in ND, and to promote awareness about the importance of microbiomes for nutrient-use efficiency and water quality.*
**Task 3:** As part of this task, we will make educational materials on the overall importance of agricultural microbiomes for soil nutrient cycling processes with subsequent implications for water quality.

**6.0 MILESTONE TABLE**

| **Milestone Table for Microbiome Management for Improved Nutrient-Use-Efficiency and Water Quality** | | | | |
|---|---|---|---|---|
| | | | | |
| **Objectives and Tasks** | **Product/Output** | **2021** | **2022** | **2023** |
| **Objective 1:** *To explore the relationships among microbial communities, nutrient-use efficiency and water quality under various agricultural management practices, hydrological and soil conditions.* | A) Assessment of soil nutrient efficiency and water quality; B) Annual project reports with an updated summary; C) Final project report with complete project summaries, data analyses, and recommendations for government agency personnel, landowners, and other stakeholders; D) Extension circulars, factsheets, and videos; E) Interviews in farmers' radio stations; F) Presentations of findings at local and regional stakeholder events; G) Presentations in regional, national and international scientific meetings by graduate students and PIs; H) International peer-reviewed journal articles | X | X | |
| **Task 1:** This task will explore the link between microbial communities and hydrological properties across several farms and in a long-term field trial. | | | | |
| **Task 2:** This task will monitor seasonal patterns of hydrological and edaphic parameters across a management intensity gradient. A series of tillage (conventional, minimum and no-tillage), fertilizer (high, moderate and low), crop rotation gradient (high and low), types of cover crops will be included in this task. | A) Assessment of crop nutrient-use efficiency and water quality; B) Statistical Models linking hydrological, microbiological and agronomic properties | X | X | |

| | | | | |
|---|---|---|---|---|
| ***Objective 2:*** *To disseminate results and findings to educate producers and landowners in ND, and to promote awareness about the importance of microbiomes for nutrient-use efficiency and water quality.* | A) A website on microbiomes and water quality; B) Statistical Models linking key microbial groups to nutrient-use efficiency and water quality; C) Tailored recommendations for individual cooperating farms and anonymous comparison to other farmlands; D) Presentations at existing NDSU Extension programs and events. | | X | X |
| **Task 3:** As part of this task, we will make educational materials on the overall importance of agricultural microbiomes for soil nutrient cycling processes with subsequent implications for water quality. | | | | |

## 7.0 BUDGET TABLES

**Budget Table for Microbiome Management for Improved Nutrient-Use-Efficiency and Water Quality**

| Part 1: Funding Sources | 2021 | 2022 | 2023 | TOTAL |
|---|---|---|---|---|
| FY21 Section 319 Funding | 119,990 | 109,660 | 65,350 | 295,000 |
| NDSU Non-federal Match** | 64,654 | 65,302 | 66,711 | 196,667 |
| Total | 184,644 | 174,962 | 132,061 | 491,667 |

**Microbiome Management for Improved Nutrient-Use-Efficiency and Water Quality**

**Part 2: Section 319/Non-Federal Budget**

| Fiscal Year | 2021 | 2022 | 2023 | Total 319 Funds | Total NDSU Non-federal Match | Total |
|---|---|---|---|---|---|---|
| **A. PERSONNEL (Salaries and Wages)** | | | | | | |
| 1. PI's and Key Personnel | $0.00 | $0.00 | $0.00 | 0.00 | 123,711.00 | 123,711 |
| 2. 1 MS GRA @ $18,000 | $18,000.00 | $18,540.00 | $0.00 | 36,540 | | 36,540 |
| 3. 2 Research Specialist @ $9,000 each | $18,000.00 | $18,540.00 | $19,097.00 | 55,637 | | 55,637 |
| 5. 1 CREC Research Specialist @33% time | $9,000.00 | $9,270.00 | $9,548.00 | 27,818 | | 27,818 |
| **TOTAL PERSONNEL** | **$45,000.00** | **$46,350.00** | **$28,645.00** | | | |
| **B. PERSONNEL FRINGE BENEFITS** | | | | | | |
| 1. PI's and Key Personnel | $0.00 | $0.00 | $0.00 | 0.00 | 53,285 | 53,285 |
| 2. Fringe benefits on GRA salaries @ 3% | $540.00 | $557.00 | $0.00 | 1,097 | | 1,097 |
| 3. Fringe benefits on Research Specialist salaries @ 45% | $8,100.00 | $8,343.00 | $8,594.00 | 25,037 | | 25,037 |
| 5. Fringe benefits on CREC Research Specialist salary @ 45% | $4,050.00 | $4,172.00 | $4,297.00 | 12,519 | | 12,519 |
| **TOTAL FRINGE Benefits** | **$12,690.00** | **$13,072.00** | **$12,891.00** | | | |
| **TOTAL PERSONNEL AND BENEFITS** | **$57,690.00** | **$59,422.00** | **$41,536.00** | | | |
| **C. EXPENDABLE MATERIALS AND SUPPLIES** | | | | | | |
| 1. Sampling equipment (vials, caps, bags, flags, batteries, cleaning agents) | $1,667.00 | $1,718.00 | $1,770.00 | 5,155 | | 5,155 |

| | | | | | |
|---|---|---|---|---|---|
| 2. Piezometers and suction cup lysimeters stations @ $3,650 each | $10,320.00 | $0.00 | $0.00 | 10,320 | 10,320 |
| 3. Chemicals and materials for soil extractions, digests, incubations | $1,667.00 | $0.00 | $0.00 | 1,667 | 1,667 |
| 4. DNA extraction kits (plant and soil) | $1,172.00 | $1,208.00 | $0.00 | 2,380 | 2,380 |
| 5. PCR and qPCR kits | $2,310.00 | $2,310.00 | $0.00 | 4,620 | 4,620 |
| 6. Molecular reagents (primers, adapters, gel electrophoresis etc.) | $500.00 | $515.00 | $0.00 | 1,015 | 1,015 |
| 7. Stable Isotope probing | $1,125.00 | $1,125.00 | $0.00 | 2,250 | 2,250 |
| 8. Chemicals for functional assays | $900.00 | $0.00 | $0.00 | 900 | 900 |
| 9. Microbiological media and reagents | $300.00 | $309.00 | $0.00 | 609 | 609 |
| 10. Lab supplies (PCR tubes, pipettes, tubes, gloves) | $500.00 | $515.00 | $0.00 | 1,015 | 1,015 |
| 12. CREC, Consumables for field site maintenance (fertilizers, chemicals, etc.) and Repairs on equipment used to impose, manage and maintain field trial treatments. | $1,800.00 | $1,854.00 | $1,910.00 | 5,564 | 5,564 |
| **TOTAL EXPENDABLES** | **$22,261.00** | **$9,554.00** | **$3,680.00** | | |
| **D. TRAVEL** | | | | | |
| 1. Travel to field sites (2-SUVs @ 2,000 miles in the 1st yr and 1000 miles in the 2nd yr @ $0.62/mile) | $1,240.00 | $1,240.00 | $0.00 | 2,480 | 2,480 |
| 2. Travel to present results at four local and regional events/yr (sedan @ 2,000 miles/yr @ $0.26/mile, lodging: $86.40/night x 4 nights, in-state meals per diem: $35) | $0.00 | $1,145.60 | $1,180.00 | 2,326 | 2,326 |
| **TOTAL TRAVEL** | **$1,240.00** | **$2,385.60** | **$1,180.00** | | |
| **F. OTHER DIRECT COSTS** | | | | | |
| 1. Soil fertility and salinity analyses fees | $10,260.00 | $10,568.00 | $10,886.00 | 31,714 | 31,714 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2. Plant nutrient fees | $1,440.00 | $1,484.00 | $1,529.00 | 4,453 | | 4,453 |
| 4. Land Leases | $6,000.00 | $6,180.00 | $0.00 | 12,180 | | 12,180 |
| 5. Amplicon sequencing ($30 per gene; 3 genes) | $6,000.00 | $6,000.00 | $0.00 | 12,000 | | 12,000 |
| 6. Metagenomic sequencing ($310/sample) | $3,100.00 | $3,100.00 | $0.00 | 6,200 | | 6,200 |
| **OTHER DIRECT COSTS** | **$26,800.00** | **$27,332.00** | **$12,415.00** | 66,547 | | 66,547 |
| **G. TOTAL DIRECT COST** | **$107,991.00** | **$98,693.60** | **$58,811.00** | 265,496 | 176,996 | 442,492 |
| **I. UNIVERSITY INDIRECT COSTS** | | | | | | |
| 1. University indirect costs (11.1111% of TDC) | **$11,998.00** | **$10,965.00** | **$6,534.00** | 29,497 | 19,666 | 49,163 |
| Subtotals | 119,989 | 109,659 | 65,345 | 294,993 | 196,662 | 491,655 |
| **Total 319/Non-Federal Budget** | 119,989 | 109,659 | 65,345 | 294,993 | 196,662 | 491,655 |

**Microbiome Management for Improved Nutrient-Use-Efficiency and Water Quality**

**Part 3: Value of Time and Services Provided by the Agricultural Experiment Station as non-Federal match**

| Fiscal Year | FTE | 2021 | 2022 | 2023 | Total |
|---|---|---|---|---|---|
| **Key Personnel/Support** | | | | | |
| Faculty (6) | 0.32 | 26,335 | 26,599 | 27,036 | 79,970 |
| Research Specialists (3) | 0.25 | 14,337 | 14,481 | 14,925 | 43,743 |
| **Fringe Benefits** | | 17,517 | 17,692 | 18,078 | 53,287 |
| Indirect costs match | | 6465 | 6530 | 6672 | 19,667 |
| **Total Non-Federal Match Budget*** ** | | 64,654 | 65,302 | 66,711 | 196,667 |

*** Matching funds are estimated at the beginning of the three-year period. Amounts are subject to change with changing staff and changing salaries. Total match will always meet agency requirements.