Environment and Natural Resources Trust Fund
2016 Request for Proposals (RFP)

Project Title: **ENRTF ID: 069-B**

Impacts of Invasive Earthworms on Water Quality in Minnesota

Category: B. Water Resources

Total Project Budget: $ 406,110

Proposed Project Time Period for the Funding Requested: 3 years, July 2016 to June 2019

Summary:

This study determine how invasive earthworms affect movements of sediment, pollutants, and nutrients from land to wetlands or other water bodies. The scientific findings will inform water resource managers.

Name: Kyungsoo Yoo

Sponsoring Organization: U of MN

Address: Department of Soil, Water, and Climate 439 Borlaug

St. Paul MN 55108

Telephone Number: (612) 624-7784

Email kyoo@umn.edu

Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Hypotheses and goals: exotic earthworms negatively impact water resources in MN

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: *Impacts of Invasive Earthworms on Water Quality in Minnesota*

I. PROJECT STATEMENT

In Minnesota, native earthworm species were eradicated when the most recent glaciers disturbed preexisting soils and deposited earthworm-free till. Earthworms in contemporary Minnesota forests are largely exotic Asian or European species that have spread with agriculture, fishing, and logging activities. A number of studies show that invasive earthworms fundamentally and negatively affect natural vegetation, nutrient availability, and the carbon cycle in forests. It is widely accepted that this invasive species seriously threatens the sustainability of MN forests, but we perceive an unacknowledged threat to water resources.

Our goal is to determine how invasive earthworms affect the movement of sediment, pollutants, and nutrients from land to nearby wetlands or other water bodies. These scientific discoveries inform resource managers and educate the public through outreach. This goal is particularly relevant for natural resource management in MN where connections between lands and waters are exceptional. We intend to answer the following questions: (1) Do invasive earthworms significantly increase the levels of critical nutrients and aquatic pollutants (nitrogen (N) and phosphorous (P)) in soil water, groundwater, and runoff water?, (2) Do invasive earthworms significantly reduce water infiltration through soils, which would in turn increases overland flow? and (3) Does runoff carry significantly higher amounts of eroded soils in forests with exotic earthworms?

We will use an extensively studied site in the Chippewa National Forest in central Minnesota where significant vegetation changes and losses of soil carbon (C), N, and P have been documented as a function of the timing and intensity of earthworm infestations.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Analyzing and interpreting soil chemistry data that have been collected along an earthworm invasion gradient.* **Budget: $111,521**

In 2009, we installed 21 soil water samplers along an earthworm invasion gradient in a deciduous forest. Soil waters were collected biweekly during 2010 and 2011 except in the winter, and the water samples have been analyzed for the most common nutrients, metals, and ions. USDA (expired in 2011) and the PI's start up (no longer available) funds were used to collect and archive these data, but limits on those funds prevented full analysis of the data despite another body of research findings that were recently published. These data are needed to understand soil, groundwater, and surface water interactions in the increasingly earthworm-infested forests of MN. Analysis and publication of these data by a graduate student does not involve new field or analytical costs

Outcome	Completion Date
1. Data sets analyzed	*May. 2017*
2. Data sets interpreted and published	*Aug. 2018*

Activity 2: *Collecting, analyzing and interpreting water infiltration rate data.* **Budget: $118,061**

Regarding the hydrological roles of earthworms, virtually all textbooks are based on knowledge from agricultural examples that are not reflective of forest soils. Though earthworms create large pores in soils compacted by agricultural machinery and thus facilitate water infiltration, this paradigm does not fit what we have routinely observed in MN forests. We know that water infiltration is consistently and dramatically reduced in heavily earthworm infested forest soils, but our many observations are qualitative, not quantitative. To better close this knowledge gap and provide new, quantitatively meaningful data that are relevant to forest management and scientific communication, we will measure infiltration rates along earthworm invasion gradients. Results from this study will improve estimates of soil water budgets, and knowledge about forest soil erosion, while providing a fundamental update to basic principles of hydrology and watershed management.

Outcome	Completion Date

1. Field work to conduct infiltration experiment	*Aug. 2017*
2. Data sets interpreted and published	*Aug. 2018*

Activity 3: *Collecting, analyzing and interpreting runoff chemistry and sediment data.* **Budget: $176,527**
We collected fallout ^{137}Cs activities as a tracer of mixing and erosional processes along the earthworm invasion gradient in 2011-2012. Our preliminary analysis of the data strongly suggests earthworm-infested areas have suffered significantly greater soil erosion loss. This loss is consistent with our hypothesis that earthworm invasion reduces water infiltration, resulting in greater overland-flow. At the site in the Chippewa National Forest, the ground surface is undulating with seasonal depression wetlands that store runoff water and collect sediments. We will (1) analyze existing tracer data, (2) measure ^{210}Pb activities, as a tracer of erosion and deposition, in cores that will be newly collected from the soils and seasonal wetlands, and (3) collect and analyze the water in seasonal wetlands.

Outcome	**Completion Date**
1. Field sampling	*Aug. 2018*
2. Data set compiled, analyzed, and published	*Aug. 2019*

Activity 4: *Public education: exotic earthworms and their impacts on soil water resources.* **Budget: $0**
Few expect that earthworms in MN are invasive species, and many are surprised by their profound but negative impacts on MN forests. Issues related to exotic earthworms therefore provide an effective gateway to share the state's soils and sustainability issues with the public. In the coming years, there will be Soil Kitchen Events in the Twin Cities (led by Prof. Nic Jelisnki at UMN), wherein members of the public are invited to bring their backyard soil samples for pollutant testing and in turn receive soup, which fosters discussions between scientists and citizens. The PI will participate in the event to share the results from this study. No fund is requested for this outreach, which will be based on the results from this proposed study.

Outcome	**Completion Date**
1. Public presentations on invasive earthworms at Soil Kitchen Events	*Once a year in the year 2 and 3*

III. PROJECT STRATEGY

A. Project Team/Partners

The PI will work closely with Stephen Sebestyen, Ph.D. a research hydrologist at the Forest Service, Northern Research Station, MN. This collaboration is essential to couple water and soil, and the fates of eroded soil materials. Sebestyen and Yoo collaboratively published two peer-reviewed publications from the study conducted on the proposed earthworm invasion gradient site. Water chemistry analyses are budgeted at $50 per sample at the Forestry Sciences Chemistry Lab, but no salary is requested for Sebestyen's participation in the project.

B. Project Impact and Long-Term Strategy

Exotic earthworms' negative impacts on soil nutrients and vegetation have been well studied. These publications were essential in shaping the MN Department of Natural Resources invasive earthworm policy. Little has been studied, however, about how and to what degree invasive earthworms affect water quality and soil erosion. This proposal builds on extensive previous studies and existing instrumentation that were established by our team . Much of the data have been already collected at the cost of roughly $350,000. Thus this study is exceedingly cost effective relative to key insights that will be newly gained to further develop natural resources policy. Currently the PI has no other funds that support this study, and this is the only pending proposal for this work.

C. Timeline Requirements

This study will require 36 months to complete. During this period, three MS students will complete their thesis research on the proposed works. All project goals will be achieved during the proposed timeline.

2016 Detailed Project Budget

Project Title: Impacts of Invasive Earthworms on Water Quality in Minnesota

INSTRUCTIONS AND TEMPLATE (1 PAGE LIMIT)

IV. TOTAL ENRTF REQUEST BUDGET *[Insert # of years for project]* **years**

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Personnel: In the 2015 academic year, a full time graduate student costs the stipend of $22,079 and the fringe (tuition+health care) of $18,300 per year. Here we expect the student finish his/her MS program in 2 years and 1 extra summer. We also include 2.5% increase in salary and fring per year.	
One MS level full time graduate student: this student will analyze, interpret, and publish the soil water quality data that has been collected from the earthworm invasion gradient in the Chippewa National Forest.	$ 90,632
One MS level full time graduate student: this student will collect, analyze, interpret, and publish the soil infiltration rate data along the earthworm invasion gradient in the Chippewa National Forest.	$ 90,632
One MS level full time graduate student: this student will collect sediment cores from seasonal depositional wetlands along the earthworm invasion transect and analyze them for 210Pb based soil erosion rate and publish the results.	$ 92,898
1.5 month summer salay for the PI. The PI will advise the three MS students and supervise the entire step of the research from data collection to data interpretation and publication. His 2015 academic year 9 month salary is $96,569 over 19.5 pay perids. Per pay period salary is $4,952.3. Therefore we are requesting three pay periods salary ($14,856.8 in 2015 academic year) for three years. Fringe rate is 33.8%. The amount requested reflects annual 2.5% increase in salary.	$ 62,667
Professional/Technical/Service Contracts:	
We cotract Dr. Stephen Sebestyen for analyzing runoff water samples for total N, nitrate and nitrite, cations and anions, and dissoloved organic carbon. We will collect approximately 300 water samples (50 samples per wetland. 3 wetlands that are heavily influenced by earthworms vs. 3 wetlands with relatively rare presence of earthworms). Analytic cost per sample is $50.	$ 15,000
Equipment/Tools/Supplies:	
We will determined 210Pb activities using alpha spectrometer. This method is significantly cheaper than other available method of gamma specstroscopy but has higher throughput. The PI has experience wit the instrument. $43,000 will cover purchasing a main console with four connected detectors. Additional $3,000 will be for purchasing standard isotopes and sample preparation procedure. This instrument will outlive the project but will continue to be used for soil erosion research in MN.	$ 46,000
Double Ring Infiltrometer. Each costs $2,400. We will purchase two of them for multiple replications.	$ 4,800
Travel:	
Sampling trips to the Chippewa National Forest. Two field trips are scheduled in the year 2017 and 2018. Each trip costs $690 which includes car rental for three days ($150), three day lodging ($210), and diem ($100 per day for three for three days = $300).	$ 1,380
Additional Budget Items: Laboratory and field supplies. This includes day to day needs of laboratory items such as kimwipes, reagents, beakers, containers, etc. Here we request $700 per year.	$ 2,100
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 406,110

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: *Indicate any additional non-state cash dollars secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	N/A	*Indicate: Secured or Pending*
Other State $ To Be Applied To Project During Project Period: *Indicate any additional state cash dollars (e.g., bonding, other grants) secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	N/A	*Indicate: Secured or Pending*
In-kind Services To Be Applied To Project During Project Period: *Indicate any additional in-kind service(s) secured or applied for to be spent on the project during the funding period. For each type of service, list type of service(s), estimated value, and indicate whether it is secured or pending. In-kind services listed must be specific to the project.*	N/A	*Indicate: Secured or Pending*
Funding History: *Indicate funding secured but to be expended prior to July 1, 2016, for activities directly relevant to this specific funding request, including past and current ENRTF funds. State specific source(s) of fund and dollar amount.*	N/A	
Remaining $ From Current ENRTF Appropriation: *Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Indicate the status of the funds.*	N/A	*Indicate: Unspent? Legally Obligated?*

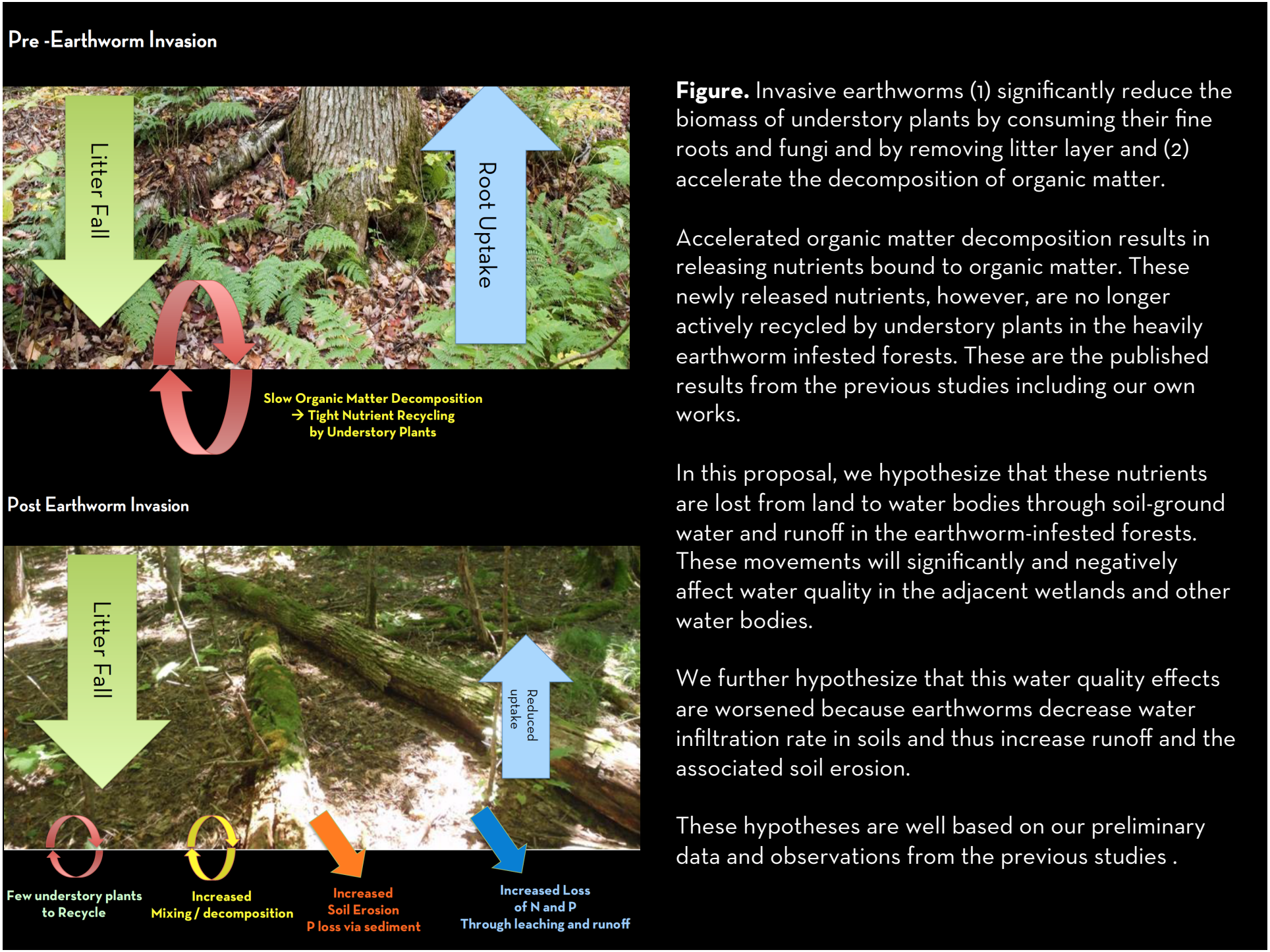

Figure. Invasive earthworms (1) significantly reduce the biomass of understory plants by consuming their fine roots and fungi and by removing litter layer and (2) accelerate the decomposition of organic matter.

Accelerated organic matter decomposition results in releasing nutrients bound to organic matter. These newly released nutrients, however, are no longer actively recycled by understory plants in the heavily earthworm infested forests. These are the published results from the previous studies including our own works.

In this proposal, we hypothesize that these nutrients are lost from land to water bodies through soil-ground water and runoff in the earthworm-infested forests. These movements will significantly and negatively affect water quality in the adjacent wetlands and other water bodies.

We further hypothesize that this water quality effects are worsened because earthworms decrease water infiltration rate in soils and thus increase runoff and the associated soil erosion.

These hypotheses are well based on our preliminary data and observations from the previous studies .

Project Manager Qualifications & Organization Description:

The PI, Associate Professor Kyungsoo Yoo, is well qualified to conduct this research. He has published the following four publications on earthworm invasion at the study site. The first authors (*marked) are the MS graduate students Yoo advised.

- Resner, K.*, **K. Yoo**, S. Sebestyen, A.K. Aufdenkampe, C. Hale, A. Lyttle, A. Blum. (*2014).* Invasive earthworms deplete key soil inorganic nutrients (Ca, Mg, K, and P) in a northern hardwood forest. *Ecosystems.* October. doi:10.1007/s10021-014-981-0.

- Lyttle, A.*, **K. Yoo**, Cindy Hale, Anthony Aufdenkampe, Stephen D. Sebestyen, Kathryn Resner, and Alex Blum. (2014). Impact of Exotic Earthworms on Organic Carbon Sorption on Mineral Surfaces and Soil Carbon Inventories in a Northern Hardwood Forest. *Ecosystems.* September. doi:10.1007/s10021-014-9809-x.

- Lyttle A.*, **Yoo K.,** Hale C., Aufdenkampe A.K., Sebestyen S., (2011), Carbonmineral interactions along an earthworm invasion gradient at a sugar maple forest in Northern Minnesota. *Appl. Geochem*. Doi:10.1016/j.apgeochem.2011.03.037

- Resner K.*, A., **Yoo K**., Hale C., Aufdenkampe A.K., Sebestyen S., (2011), Elemental and mineralogical changes in soils due to bioturbation along an earthworm invasion chronosequence in Northern Minnesota. *Appl. Geochem*. Doi:10.1016/j.apgeochem.2011.03.047

Yoo's former research at the study site was funded by USDA NRI grant. Two MS students completed their theses on the impacts of invasive earthworms on inorganic nutrient losses from soils and on the soil carbon cycle.

He is currently the recipient of the CAREER award – which is considered as the most prestigious grant from National Science Foundation to young faculties in the US. He is also one of the leading PIs of the NSF- supported Christina River Basin Critical Zone Observatory ($4,3 million over 4 years). Yoo also recently completed a NSF-funded study, "coevolution of hillslope morphology and soils: responses to channel incision". In the fall 201, the Institute for Advanced Study (IAS) at UMN will host Yoo as a resident fellow. At IAS, Yoo will be waivered from teaching and focus on developing a large international and interdisciplinary proposal about the historical role of human migration and agricultural expansion in creating earthworm-engineered forests in the Glaciated N. Europe.

Below is the mission description of the Dept. of Soil, Water, and Climate at the University of Minnesota where Yoo is a tenured faculty.

The mission of the Department of Soil, Water, and Climate is to advance the understanding of Earth system processes and the interaction among land, atmosphere, and water. Through research, teaching, and extension we seek to:

- improve and protect the quality of soil, air, and water resources in natural and managed ecosystems;
- enhance agricultural and forest productivity and sustainability;
- predict and mitigate impacts of environmental and climate change on ecosystems and society; and provide science based knowledge for improved decision making and a better informed citizenry.