1) Final Report for SAIF Category A: Developing a New Method to Determine Invasive Earthworm Impacts on Native Forest Communities

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2) Type of Project: Research project

3) Abstract: The funding for this project provided summer salary and a salary for one undergraduate research assistant, Jenna Zimmerman, to conduct exploratory analyses of changes in tree root anatomy associated with the environmental changes incurred following European earthworm invasion into previously earthworm-free hardwood forests in northern Wisconsin. Tree root sections were collected at 100 m intervals along a transect that crossed an active earthworm invasion front in the Chequamegon National Forest, northern Wisconsin. We were able to successfully thin-section 22 tree root cross sections. The samples were stained, mounted to slides, and scanned at 4800 dpi using an optical scanner. The digital images were analyzed using WinCELL software to measure the lumen area of individual xylem cells along one radii per sample. The lumen area data were then analyzed using regression and regime shift analysis to determine if any significant change in cell size occurred in each sample, and then these data were compared to the position along the transect to compare root anatomy in earthworm-invaded vs. earthworm-free conditions. The results were encouraging, though further research will be required to hone the field and laboratory analyses associated with this research. In some samples a distinct decrease in cell size occurred toward the outer rings of the roots, potentially indicating a slow exposure of the roots to the atmosphere due to the compaction of forest soils and loss of the organic horizon following earthworm invasion (Figure 1). Inconsistent results, however, indicate that to firmly establish the mechanism behind these changes additional samples need to be collected along the tree roots at increasing distance from the tree to determine if the changes were consistent within each root sampled. Funding to expand this research has been requested through an NSF CAREER proposal.

Figure 1. Scanned images of stained root thin sections. Vessels appear as black dots. Mean vessel lumen area is plotted across each sample. Both of these samples, collected at a recently invaded site, exhibit declining cell size, potentially caused by earthworm invasion.
4) **Intrinsic value of the project:**
   
   a. **To myself:** This project provided a critical boost for my research program investigating invasive earthworm impacts on hardwood forest ecosystems in the Great Lakes region. The potential to identify a mechanism that would enable the absolute determination of earthworm invasions would allow a range of questions pertaining to the long-term effects of earthworm invasion to be pursued. This research has never been attempted before, and in discussing the results of this project at invited lectures at the Laboratory of Tree-Ring Research at the University of Arizona, Willamette University, and the University of Wisconsin-Madison, I have received considerable praise and encouragement from leading researchers and scholars in my field. The research that grows from this project will help me establish myself as an innovative researcher in the field of dendrochronology and expand my area of expertise into wood anatomy, a new and growing field with widespread applications in geomorphic, biogeography, and ecological research.
   
   b. **To the Department of Social Sciences, the College of LAE, and the University:** This research has been presented in several talks and this project is now associated with the University of Wisconsin-Platteville. This research has provided hands-on research experiences to an undergraduate student from the Social Sciences Department. The publications that will result from this work will all be associated with UW-Platteville.

5) **Opportunities for external funding support:** The data developed from this project provided key proof-of-concept data for a 5-year, $870,000 proposal that I submitted to the National Science Foundation CAREER program, the most competitive funding program at the NSF. Funding for the project was declined, but the review panel strongly suggested revising and resubmitting the proposal. The following language was included in the review:

   "What a strikingly important phenomenon to address! These invasive worms appear to be incredibly strong interactors with the pedosphere and this work will obtain critically important information on not only characterizing what is going at worm invasion fronts but also developing a tree-ring based method for detecting the invasions in the past."

In light of the positive reviews, I will be revising and resubmitting this proposal for the next CAREER deadline in late July of 2014.

6) **Sharing results of the project with university colleagues and the university community:** The results from this work have been shared with the University Community through a poster presented on Research Poster Day, multiple lessons of my course GEOG 1040: Planet Earth, and will be featured in multiple exercises in my GEOG 3340: Biogeography course.

7) **Manuscripts, Case Studies, and Journal Articles:** Data from this project are included in a manuscript that I am submitting to the premier scientific journal *Nature*, over the 2013-14 holiday season. The manuscript is nearly complete but has been slow to be completed due to the involvement of six co-authors, several of which are international experts and at times difficult to communicate with.