ENGAGING PRE-SERVICE TEACHERS AND ELEMENTARY SCHOOL STUDENTS IN THE FORESTRY RECLAMATION APPROACH THROUGH EARTHWORM INOCULATION[1]

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Abstract: In the spring of 2009, a partnership was formed between the Appalachian Regional Reforestation Initiative (ARRI) and the Appalachian Coal Country Watershed Team (ACCWT) for the purpose of restoring forests on post-bond release mine sites in Appalachia. ARRI is a broad-based citizen/industry/government program working to promote and encourage the planting of productive trees on Title IV (abandoned coal mine land) and Title V (active coal mine land) sites under the Surface Mining Control and Reclamation Act (SMCRA). The ACCWT, an innovative partnership between the Office of Surface Mining (OSM) and AmeriCorps*VISTA was founded in response to requests from small, community volunteer-based watershed groups throughout coal country to target problems associated with the legacy of pre-regulatory coal mining in Appalachian watersheds. As a result of the partnership between ACCWT and ARRI, 27,000 trees were planted on 36 acres of previously reclaimed mined land by 520 volunteers in five Appalachian coal states in the spring of 2009. In addition, because the value of earthworms in improving soil quality and thus, improving plant survival is well documented, elementary education students from Indiana University of Pennsylvania (IUP) had the opportunity to develop vermiculture protocols and earthworm lesson plans for use by teachers participating in these reforestation efforts, as part of a service learning project in their life science content class. The protocols were distributed to classroom teachers in areas served by the ARRI/ACCWT reclamation project to assist them in raising earthworms and promoting earthworm-related learning experiences with their students. Earthworms were then released by elementary and middle school students while trees were being planted on old mine sites in an effort to improve soil quality and increase tree survival. A discussion of this vermiculture project, which included the inoculation of earthworms into mine soils of pre- and post-SMCRA mine sites near Haysi, Virginia, and Carcassonne, Kentucky are described in this paper.

Additional Key Words: Earthworm Inoculation, Mine Reclamation, Reforestation, Service Learning, Pre-service Teachers, Earthworm Lessons

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Introduction

Successful reclamation of post-bond mining sites requires the cooperation and support of many agencies, community groups, and individuals, especially in the face of current economic and environmental considerations. In the spring of 2009, a partnership was formed between the Appalachian Regional Reforestation Initiative (ARRI) and the Appalachian Coal Country Watershed Team (ACCWT) for the purpose of restoring forests on post-bond release mine sites in Appalachia. ARRI is a broad-based citizen/industry/government program working to promote and encourage the planting of high-value hardwood trees on Title IV (abandoned coal mine) and Title V (active coal mine) land under the Surface Mining Control and Reclamation Act (SMCRA) using the Forestry Reclamation Approach (FRA) (Burger et al., 2005). This method consists of five steps, which include creating suitable soil conditions for root growth and creating non-compacted soils, both areas in which earthworms can play an important role. The ACCWT, an innovative partnership between the Office of Surface Mining (OSM) and AmeriCorps*VISTA was founded in response to requests from small, community volunteer-based watershed groups throughout coal country to target problems associated with the legacy of pre-regulatory coal mining in Appalachian watersheds. As a result of the partnership between ACCWT and ARRI, 520 volunteers in five Appalachian coal states planted 27,000 trees on 36 acres of previously reclaimed mined land through the spring of 2009. In two of these sites, elementary school students used vermiculture protocols developed by Indiana University of Pennsylvania (IUP) elementary pre-service teachers to raise earthworms for release during the planting process to help increase the chance of seedling survival.

In an effort to expand awareness and involvement in reclamation and reforestation, college students from IUP majoring in elementary education were invited to develop classroom-friendly procedures for raising earthworms and to create inquiry-based earthworm lesson plans for use by teachers participating in these endeavors. This was part of a service learning project in their life science content class, Fundamentals of Environmental Biology for Elementary Educators. Service learning is defined as graded class assignments or activities that involve community improvement and participation (Billig and Weah, 2008). Not only did this give these pre-service teachers the opportunity to practice lesson plan development and address state education standards; it also offered them the chance to be involved with a significant project to improve the environment. This provided additional benefits for these students, based on the value of service

learning activities which have been found to have a positive effect on personal development and satisfaction, and incorporated authentic assessments to assess content understanding (Astin and Sax, 1998; Davies and Wavering, 1999). The protocols were distributed to classroom teachers in areas served by the ARRI/ACCWT reclamation project to assist them in raising earthworms and promoting earthworm-related learning experiences with their students. These earthworms were raised and then released by elementary and middle school students while trees were being planted on old mine sites, in an effort to improve soil quality and increase tree survival.

This project was designed to meet three goals. First, the release of earthworms in recently replanted mine sites will increase soil quality and nutrient availability, thus improving the survival of tree seedlings. Second, the involvement of the education students from IUP will give them experience in designing lesson plans to meet state science standards and will offer them the benefits inherent in service learning activities. Third, local elementary and middle school students from the mined regions will be actively involved in reclamation through raising and releasing the earthworms, giving them the opportunity to participate first-hand in environmental stewardship. As a result of the partnerships between government agencies, local watershed groups, college students, elementary and middle school students, and public school teachers, hundreds of individuals worked together to improve the environment in the Appalachian Coal Region.

Earthworms and Soil Quality

In areas where soil has been adversely affected by mining, logging, agriculture, development, and other human activities, problems can include pollutants, erosion, leaching of nutrients and minerals, and compaction. Some or all of these issues can be found in old sites, such as those currently being reforested in the Appalachian Coal Region through the efforts of ARRI.

The benefits of earthworm activity have been researched repeatedly in areas where human activities have had an undesirable effect on soil. It has been noted that earthworms might be the most important macroanimals found in soils, primarily because of the way they affect its physical properties. Their burrows improve aeration and drainage, their wastes improve soil stability, and their feeding habits increase the availability of nutrients for uptake by plants (Brady and Weil, 2002; Edwards and Lofty, 1980). Earthworms help develop a stone-free layer at the soil surface and actively mix particles of organic matter with mineral fragments they have

ingested. They are especially important in the growth and success of hardwood and mixed woodland forests (White, 1987). In their research on two mine sites in Ohio, Vimmerstedt and Finney (1972) noted that earthworm introduction in post-mining soils improves soil quality and available nutrients for tree seedlings and leads to improved growth. Under SMCRA, mining operations are required to establish permanent vegetative cover that matches pre-mining conditions. Virtually all of the land in Appalachia was once forested. In the past, many areas have been mined and reclaimed to pastureland but are no longer being utilized for such a purpose. These reclaimed sites were acceptable for bond-release under SMCRA, but forest once stood, this land is now in a state of arrested natural succession and the potential to return to a productive forest is minimal. Today, surface mines in Appalachia are commonly reclaimed using the FRA. Earthworm inoculation in these areas where trees are being planted can increase the chance of seedling survival by improving the physical characteristics and quality of surrounding soil.

In their research with earthworm inoculation and cereal grain root growth, Edwards and Lofty (1980) observed that natural earthworm burrows were significantly better than simulated burrows due to the increase in available nutrients from waste lining the natural burrows. The presence of earthworms in various combinations of soil and toxic Pb/Zn mine tailings from Chinese mines increased the available phosphorus available for plant use by up to 10%, leading to an increase in plant yields by as much as 30% (Ma et al., 2003). Butt (1999) also noted the value of earthworms for reclaiming soil degraded by a variety of human activities, including landfill sites, mines, and steelworks. Because they have a beneficial effect on soil structure, earthworms of appropriate species for the location and conditions should be utilized for soil remediation when possible. A more recent study examining the effect of various soil microorganisms and macrofauna on leaf litter decomposition in brown-coal mining tailings also supports the value of introducing earthworms as part of a soil remediation project (Frouz et al., 2007). Researchers compared the effects of microorganisms alone; microorganisms and mesofauna; microorganisms and macro-arthropods such as millipedes; and microorganisms with earthworms on both reclaimed and unreclaimed soil samples. Unreclaimed soil samples showed significant decomposition of organic matter only in the presence of earthworms, clearly indicating the value of earthworm inoculation as part of a comprehensive remediation project.

Earthworms contribute to improved soil structure and increased availability of nutrients for plant growth. Because of the research demonstrating their positive effects, introducing earthworms during tree planting efforts on mine sites in the Appalachian region may help meet the ARRI goal of increasing survival rates and growth rates of planted trees.

Service Learning

A significant feature of this project for the pre-service elementary teachers at IUP was participation in an environmental project where the lesson plans they created would be used in real classrooms and in real mine reclamation sites by real teachers and real public school students. This is one important element of service learning, a method of teaching and learning that incorporates service to the community with classroom academics. Key aspects of true service learning experiences include clear connection to the curriculum, student participation in designing and evaluating the projects, reflection about the experience, partnerships with community organizations, meeting authentic community needs, and assessment of the project as a part of the course grade (Billig and Weah, 2008).

Connection to the Curriculum

Each of the requirements for quality service learning was met as pre-service teachers worked through this project during the semester. By developing lesson plans related to soil quality and mine remediation efforts, they were applying content discussed in class. Authentic assessments turn lifeless rote learning into dynamic, functional information requiring students to apply their learning in life-based situations (Davies & Wavering, 1999). By encouraging real-life applications of content, authentic assessments help students understand the value and applicability of the course material. They were also designing their lessons to meet one or more of the Pennsylvania State Standards for Environment and Ecology, which they will be addressing in their own classrooms once they graduate. Finally, pre-service teachers used the 5-E format developed by Trowbridge and Bybee (1990) to ensure that the lesson plans were inquiry-based and incorporated critical thinking skills, important features for meeting current education requirements.

Student Participation

Pre-service teachers were introduced to the project by working in groups to research methods of raising earthworms. These were then written up in a format of their choice for preliminary

distribution to teachers in the Appalachian region. An example of a vermiculture protocol designed by the pre-service teachers is shown in Table 1. As the semester progressed, they designed individual 5-E lesson plans about any aspect of earthworms they found interesting. These included lessons about anatomy, harvesting, and habitat requirements. Examples of these lesson plans can be seen in Table 2 and Table 3. By giving pre-service teachers the opportunity to choose the topics for their individual lessons, they could follow their own interests while meeting the assignment requirements. Once they had a first draft of their lesson plans, lessons were exchanged with classmates, who made comments and suggestions. Pre-service teachers then had the chance to make changes based on the peer evaluations and comments from the instructor.

Reflection about the Experience

At the end of the earthworm project, pre-service teachers completed an evaluation asking them to reflect on their participation, taking into consideration their experiences in lesson plan design, their role in reclaiming mine sites in the Appalachian region, and the value of their involvement in this activity. These college students also had the opportunity to read newspaper articles about the elementary students who raised and released earthworms during a tree planting event in Haysi, VA. The class in Haysi, VA, and another class in Letcher County, KY, used the protocols developed in the initial portion of the project to assist in raising the earthworms that were released. Reflections on the project included comments such as "I feel like I really made a difference," "This was more than just a classroom activity. Real classes will use these," and "This is something I can use when I'm teaching." Pre-service teachers felt as though they were part of something that mattered, rather than just going through the motions artificially.

Community Partnerships

Community partnerships with ARRI and ACCWT were clearly identified from the start of the project, so the pre-service teachers understood that would be a part of something authentic. Pre-service teachers received brochures that explained the goals of ARRI before they started on the lessons and were given individual letters to keep in their portfolios at the completion of the semester. As noted in their reflections, the pre-service teachers realized that they were having an impact on an environmental problem that affects their own region, while polishing skills they will need as teachers in the future.

Table 1. A protocol for raising earthworms designed by a pre-service elementary education teacher.

Raising Earthworms
Raising earthworms is generally easy as long as they are provided with the things they need to survive. Worms require five things for survival: moisture, warmth, food, darkness and oxygen.
Habitat: The first thing to do is to get a supply of worms. Either dig them out of the soil yourself or buy them at a bait shop. Next, the worms need a place to live. A container that has a place for drainage or flower pots are great. Y ou also need to cover the container. This helps keep the moisture and warmth in. The soil, air and water are what provide the worms with oxygen, which worms breathe in through their skin.
Soil: After the container is set up, soil will be added. Soil from your backyard or plain potting soil work fine and will be suitable for worms to live in. The soil should be moist enough that the worms do not dry out and die, but be careful not to make the soil too wet as you don't want the worms to drown. It should be damp enough that the soil isn't soggy and the water doesn't pool on top.
Temperature and Oxygen: Keeping the worms warm is also important. The perfect temperature for worms is between 60^{o} and 70^{o} F. Be careful not to overheat your worms and to make sure that the soil is always moist and doesn't dry out. Do not refrigerate the worms. Worms need a dark environment to survive. Keeping worms in a dark place out of direct sunlight will also help to keep the soil moist. Having a covered container is the easiest way to accomplish this, but if you use a tub with a lid, be sure to poke holes in the lid to allow oxygen flow.
Food: Worms also need some kind of a food source. Animal manure is a good food source. Dead leaves and grass are good food sources; along with table scraps and vegetable matter. Before the worms are added to the tub or bin, make sure that the food source is already placed inside. This gives the food source time to start decomposing. Feed the worms about once a week. Moisten the soil when feeding the worms. Don't forget to cover the container to keep the moisture in and the light out.
Resources: http://www.ehow.com/how_2083672_raise-earthworms.html http://www.redwormcomposting.com/raising-earth-worms/ http://aqualandpetsplus.com/Live%20Food,%20Earthworms.htm http://www.howtodothings.com/hobbies/how-to-raise-earthworms

Table 2. 5-E Lesson Plan – Introduction to Earthworms (2^{nd}-3^{rd} grade level)

	Description	Example from a lesson designed by a pre-service elementary teacher
Engage	A brief activity or question that whets the students' appetite and gets their attention focused on the topic.	The students will be introduced to the book Wiggling Worms at Work. They will be asked to tell what they think the book will be about. After being allowed to respond, the students will be told that they will be learning how an earthworm moves.
Explore	An activity in which the students develop questions and attempt to answer them to encourage the students to think in depth about the topic.	The students will split up into groups to observe an earthworm. They will write predictions and observations on how an earthworm moves in their science journals. The students will be given time to discuss their answer within their group and respond in their journals.
Explain	Groups share their results, whether they have done an experiment or worked through a question. The teacher can also clear up misconceptions and misinformation at this point	After being given time to discuss their answers as a group and respond in their journals, each group will share their answers with the entire class. After this, the students will go to the reading center of the class and move like a worm on the large carpet.
Elaborate	Groups might do further laboratory work, do research, give presentations or simply discuss more complex questions within their groups, allowing them to build a deeper understanding.	Each lab group will pick another feature of the earthworm to observe, such as what it eats, its color, what end is the front and/or back, where mouth is located, etc. Once they have finished observing their earthworm and answered the question they chose on the note card, they will present the information they have gathered to the class.
Evaluate	Evaluation can take numerous forms, including standard quizzes or tests, written assignments, oral presentations, student self-evaluations or observation of student participation in group activities.	The evaluation for this lesson will consist of the students being given participation points for their group work and moving like a worm. Also, the student will be writing a descriptive story about their earthworm. They will describe the life of an earthworm and how it moves around. These stories will be collected and an individual grade will be given.

Table 3. 5-E Lesson Plan – Researching Earthworm Habitats (4^{th}-5^{th} grade level)

	Description	Example from a lesson designed by a pre-service elementary teacher
Engage	A brief activity or question that whets the students' appetite and gets their attention focused on the topic.	Students will be asked if they would prefer to eat carrots, a radish, lettuce, a moldy apple, moldy bread, or leaves. Most of the students will probably laugh or make a disgusting face. This will grab their attention and interest.
Explore	An activity in which the students develop questions and attempt to answer them to encourage the students to think in depth about the topic.	The students will split up into groups to create 3 earthworm habitats using plastic water or pop bottles, keeping all conditions except one identical. They will determine the variable condition for each habitat (food source, light, temperature, moisture, etc.) and will make predictions about which will be best for earthworm survival.
Explain	Groups share their results, whether they have done an experiment or worked through a question. The teacher can also clear up misconceptions and misinformation at this point	Each group will design a poster explaining their hypothesis and the variable they chose for their experiment. Groups will present their posters to the class, explaining their experiement, and will answer questions about their research design.
Elaborate	Groups might do further laboratory work, do research, give presentations or simply discuss more complex questions within their groups, allowing them to build a deeper understanding.	Students will check their habitats daily and will record observations. At the end of two weeks, students will examine their data and determine whether their hypothesis was correct. Groups will create a table or graph showing the results of their experiement and will present this to the class.
Evaluate	Evaluation can take numerous forms, including standard quizzes or tests, written assignments, oral presentations, student self-evaluations or observation of student participation in group activities.	Students will write individual reports discussing their hypothesis, experimental design, data collection, and results. They should draw conclusions, note possible sources of error and changes they would make if they did the experiment again.

Authentic Community Need

Most pre-service teachers in the class live in Pennsylvania and are familiar with coal mining and its impact on the environment. Many also have family members involved in aspects of coal mining. Even those from other areas have lived in western Pennsylvania while attending school and have seen mining operations. Consequently, they are familiar with the need for reclamation and remediation of mining sites. In addition, by sharing the news articles about elementary and middle school students using their protocols, pre-service teachers could see the value and significance of their contributions.

Assessment

Assessments that were part of the course grade for the pre-service teachers occurred throughout the project. Groups were assessed on their initial vermiculture protocols and throughout the development of lesson plans. Pre-service teachers were also assessed on their peer evaluations of classmates' lessons, notably on the accuracy of their comments and observations and the value of suggestions to improve the learning experiences in the lesson plans.

By participating in this project and developing a variety of activities for use by educators and their students in locations involved in ARRI reforestation efforts, the college students at IUP felt that they had a positive impact on the environment. They also had the opportunity to develop high-quality, inquiry-based lesson plans that will impact the education of students in other regions.

Community Involvement

Several government agencies, community organizations, education entities, and individuals have been involved in this endeavor. ARRI was formed to bring all these groups together for successful reclamation of mined land in the Appalachian region. Made up of representatives from the US Office of Surface Mining (OSM), the US Forest Service (USFS), the US Department of Energy (DOE), the coal mining states in the region (KY, MD, OH, PA, TN, VA, and WV), the coal industry, environmental organizations, land companies, and academia, ARRI members have committed to returning previously and currently mined land to productive hardwood forest. In collaboration with the ACCWT, ARRI has sponsored numerous tree

planting events with the goal of re-establishing native hardwood forests and creating future economic opportunity.

Community groups have gotten involved in this project to prepare land and plant trees in areas all over the Appalachian region. Participants have included local watershed organizations, primary and secondary schools, environmental groups, church groups, AmeriCorps volunteers, and scout troops. In two locations, Haysi, VA and Carcassone, KY, students also released earthworms during the tree planting, completing the final step in the cycle by implementing the protocols designed by college students in Pennsylvania.

Haysi, VA Tree Planting Event

In April 2009, students from 3 area schools visited an ARRI site in Dickenson County, VA recently planted with 1900 hardwood seedlings in an event coordinated by ARRI personnel; ACCWT; members of the Friends of the Russell Fork; and the landowner, The Forestland Group, LLC. Tree varieties planted at the 2-acre site in March 2009 included several oak species, green ash, redbud, persimmon, silky dogwood, river birch, and American chestnut. Planting was done by area middle school students, working with representatives of the VA Department of Forestry and the VA Department of Mines, Minerals, and Energy (VADMME). The visit by these students completed the initial phase of the project, as they inoculated the new seedlings with earthworms they had raised in their classrooms using protocols prepared by the IUP pre-service teachers (Fig. 1). Additional volunteers from VADMME, The American Chestnut Foundation (TACF), and Dr. Patrick Angel (OSM) gave talks on geology and forestry, and a professor from the University of Virginia's College at Wise talked about ecology and amphibians to the students after the earthworms were released (Fig. 2). It is clear that numerous government, community, academic, and environmental groups worked together to plan, coordinate, and carry out this project. A late summer visit indicated that the seedlings appeared to be doing well, making it likely that this area will once again become a healthy, sustainable hardwood forest.

Figure 1. Students prepare to inoculate a tree seedling with earthworms they raised in their classrooms. (Photo by Chris Eberly OSM/VISTA)

Figure 2. Dr. Patrick Angel, Soil Scientist for OSM and ARRI Coordinator teaches local school students in Haysi, VA about the ARRI project, the Forest Reclamation Approach, and the benefits of earthworm inoculation. (Photo by Jessica Vierling/ACCWT)

Carcassonne, KY Tree Planting Event

Carcassonne, located in Letcher County, KY, is found in the Eastern Coal Field regional of the state. The tree planting site near Carcassonne was mountaintop removal mine site that was reclaimed for a pasture and cropland but was not used as such by the landowner. Due to the excessive mine soil compaction and aggressive grass cover, the site was in a state of arrested natural succession and was likely to remain as such for an extended period of time. The watershed improvement group, Headwaters, Inc., organized volunteers from the Bluegrass (KY) Chapter of the Sierra Club, a local mining company, the local community, and students from the Letcher County school system to reforest the site. The mine soil compaction was mitigated by deep tillage (ripping with a D-9 dozer) and high-value, native, hardwood trees were planted in the loosened soil. Letcher County elementary school students participated by cultivating earthworms in the classroom and releasing them on the planted mine site. At the completion of the project, a representative from the United Nations Environmental Program presented students and local teachers with letters of appreciation for their contribution to the reforestation of the site.

Summary

Several aspects of this project make it uniquely situated for long-term application. The careful use of scientific research to develop and plan planting and management protocols, the involvement of numerous community groups and individuals at multiple levels, and the support of government, industry, and private landowners all bode well for the continued success of ARRI. ARRI partnerships, such as the IUP project that engaged pre-service elementary education teachers and local school students in mine land reforestation, can generate many beneficial results for teachers, students, and the environment. Participation in community activities has been shown to have a favorable effect on individuals of all ages, increasing their sense of civic responsibility and awareness of local issues (Barber et al., 1997). By engaging a wide variety of groups and individuals in the reclamation and reforestation of the Appalachian region and encouraging the participation of younger individuals in the form of school students, there is a greater likelihood of continued support. As one student participant noted, “It would be such a great thing to show grandkids and know that we helped with it, helped bring it back.”

References

Astin, A. W., and Sax, L. J. 1998. How undergraduates are affected by service participation. *Journal of College Student Development,* 39(3), 251-263.

Barber, B. R., Higgins, R. R., Smith, J K., Ballou, J. K., Dedrick, J., and Downing, K. 1997. *Democratic Theory and Civic Measurement: A Report on the Measuring Citizenship Project.* Paper presented at the Campus Compact, Denver.

Billig, S.H and W. Weah, 2008. K-12 service learning standards for quality practice. National Youth Leadership Council. Retrieved from www.nylc.org December 27, 2009.

Brady, N.C. and R.R. Weil, 2002.The Nature and Properties of Soils (13th ed.). Prentice Hall, Upper Saddle River, NJ.

Burger, J., D. Graves, P. Angel, V. Davis, and C. Zipper. 2005. The Forestry Reclamation Approach. Forest Reclamation Advisory No. 2. Retrieved from http://arri.osmre.gov/Publications.shtm

Butt, K.R., 1999. Inoculation of earthworms into reclaimed soils: The UK experience. Land Degradation and Development 10/6: 565-575. http://dx.doi.org/10.1002/(SICI)1099-145X(199911/12)10:6<565::AID-LDR356>3.0.CO;2-K.

Davies, M. A., and Wavering, M. (1999). Alternative assessment: New directions in teaching and learning. *Contemporary Education, 71*(1).

Edwards, C.A. and J.R. Lofty, 1980. Effects of earthworm inoculation upon the root growth of direct drilled cereals. Journal of Applied Ecology, 17: 533-543. http://dx.doi.org/10.2307/2402635.

Frouz, J., D. Elhottova, V. Pizl, K. Tajousky, M. Sourkova, T. Picek, and S. Maly, 2007. The effect of litter quality and soil faunal composition on organic matter dynamics in post-mining soil: A laboratory study. Applied Soil Ecology, 37(1-2): 72-80. http://dx.doi.org/10.1016/j.apsoil.2007.04.001.

Ma, Y., N.M. Dickinson, and M.H. Wong, 2003. Interactions between earthworms, trees, soil nutrition and metal mobility in amended Pb/Zn mine tailings from Guangdong, China. Soil

Biology and Biochemistry, 35/10: 1369-1379. http://dx.doi.org/10.1016/S0038-0717(03)00216-5.

Trowbridge, L. & Bybee, R. 1990. *Becoming a secondary school science teacher* (5th ed.). Englewood Cliffs, NJ: Merrill.

Vimmerstedt, J.P. and J.H. Finney. 1973. Impact of earthworm introduction on litter burial and nutrient distribution in Ohio strip-mine spoil banks. p.388-391. Soil Sci. Soc. Amer. Proc. (Detroit, MI, Nov. 1969). 37/3. Ohio Agricultural Research and Development Center,

White, R.E., 1987. Introduction to the Principles and Practice of Soil Science (2nd ed.) Blackwell Scientific Publications, Oxford.