Earth System Science

A. Mission

The mission of the Earth System Science group is to address significant societal needs by offering innovative and relevant teaching, research, and outreach programs in the soil, hydrologic, atmospheric, earth observation, and environmental sciences, in collaboration with public and private partners.

B. Where we are now

1. Overview of the program

The Earth System Science group within the Department of Agronomy has changed significantly since the last departmental review in 2002. For the 2002 review document we titled our section *Soil and Environmental Sciences*, but referred to ourselves as the *Soils Group*. We consisted of 23 faculty members, five of whom held adjunct appointments and four administrative/professionals (Table 3.10). Five of the faculty members listed in Table 3.10 have retired or left the department since the last review. Hiring their replacements provided the unique opportunity to be transformed from a classical soils faculty into one that combines elements of traditional areas of soil science with greatly expanded capabilities in other disciplines, including hydrology, weather and climatology, remote sensing, geospatial technologies, and biogeochemistry. We have tentatively adopted *Earth System Science* as a title that better reflects the composition of the current group and the focus of our research and academic program.

2. Actions taken in response to the 2002 CSREES review

In 2002, the Soils Group considered itself to have the following areas of activity: (1) Environmental Fate and Transport Processes of Chemicals, (2) Soil-Plant Interactions, and (3) Land Use and Landscape Processes. Thirty eight graduate students were enrolled in the soils program in 2002. Of the 176 undergraduates in Agronomy in 2002, 11% were enrolled in environmental soil science and 10% in soil and crop science. It was noted that more than 75 students were enrolled in the College of Agriculture's undergraduate interdisciplinary Natural Resources and Environmental Science (NRES) Program, of which the majority of designate land resources and water as their focus areas.

The Soils Group at the Cross Road. In 2002 we began considering our research, teaching, and extension programs in terms of the spatial scale at which our programs were focused (Figure 3.13). Most of our capability was at the kilometer scale (landscapes and small watersheds) and smaller. With the impending retirement of both Chris Johannsen in remote sensing and earth observation, and Don Franzmeier in soil genesis, classification, and survey (pedology), we were losing the capability to address problems at state, regional, and global scales. We recognized that we would either need to terminate these programs, or put a much stronger emphasis on hiring individuals with skills at larger scales. We chose the latter because problems like climate change or nutrient transport from agricultural areas that leads to hypoxia in the Gulf of Mexico are regional and global in their scope.

For the 2002 review, we identified four focus areas for the upcoming decade (2002-2012): (1) develop intellectual resources to address major ecological and environmental concerns, (2) obtain state-of-the-art equipment and technologies for conducting progressive research, (3) enhance linkages within the department and across campus, and (4) enhance soils education and outreach. Our accomplishments in each area are summarized briefly below.

Develop intellectual resources to address major ecological and environmental concerns. Five areas were identified in which we needed to hire faculty to develop our intellectual capital in strategic areas. With the university just entering a major growth phase, we had the good fortune to hire individuals for each of these positions (Table 3.11). We were also able to address a long-standing need for a full-time state climatologist. Four of the seven individuals who were hired have joint appointments in other departments. As described in more detail below, these hires brought new expertise in modeling at coarser scales and earth observation using new sensing technologies.

Obtain state-of-the-art equipment and technologies for conducting progressive research. Table 3.12 lists major equipment purchases and facility investments since the 2002 review. This equipment has allowed us to maintain and enhance our research programs in soil and environmental chemistry, while adding new capability for air quality monitoring and satellite-based earth observation. Funding for equipment purchases was often compiled on a case-by-case basis, including extramural grant funds submitted by individual investigators and internal College or University support. Unfortunately, funding required for maintenance and upkeep of routine equipment is a critical challenge.

Enhance linkages within the department and across campus. Our group has made major strides in enhancing linkages over the past five years through the new hires and collaborative research projects. Recent faculty hires with joint appointments in other departments across campus include Melba Crawford, joint with Civil Engineering; Laura Bowling, courtesy appointment in Agricultural and Biological Engineering; and Dev Niyogi, Qianlai Zhuang, and Kevin Gurney, all joint with Earth and Atmospheric Sciences. The Center for the Environment, of which Linda Lee is Associate Director, has 23 faculty affiliates from the Agronomy Department, while the Purdue Climate Change Research Center has eight affiliate members from Agronomy. Faculty members from the Earth System Group collaborate with colleagues across campus, across the U.S., and around the globe on various projects. These collaborations enhance the reach of the Purdue Agronomy Department, bring in new ideas and perspectives, and allow the Department to be better integrated into campus-wide initiatives, including large interdisciplinary proposals such as those for strategic training centers and the NSF critical zone observatories. One of our goals is to be more competitive for such “big science” initiatives.

Enhance soils education and outreach. This focus area is described in detail in the undergraduate and graduate education documents elsewhere in this document.

3. Program focus

As noted previously, the Soils Group in 2002 (Table 3.10) was still fairly traditional in the sense that the entire faculty had received graduate or postdoctoral training in soil science programs. Many of the new hires since 2002 received their training in other disciplines. For example, Laura Bowling’s training in civil engineering brings us new expertise in watershed hydrology and modeling. Melba Crawford’s broad-based background in engineering brings new expertise in earth observation that ranges from satellite sensor and algorithm development to sensing of crop residue and soil moisture. Dev Niyogi, Kevin Gurney, and Qianlai Zhuang have backgrounds in biogeochemistry and atmospheric sciences, which brings new expertise in climatology and atmospheric modeling, and an emphasis on understanding the global causes and impacts of climate change. All bring new and exciting skills and perspectives.

The disciplinary diversity of the current faculty provides new opportunities to develop programs and conduct research for which the group name of “soil science” no longer fits. After much discussion, we have initially selected *Earth System Science* as an overall designation that describes the teaching and research of our current group reasonably well. Earth System Science has the additional advantage that it encompasses faculty members whose major focus is in atmospheric science, hydrology, and earth observation.

In the past, we have described ourselves by listing individuals under only one or two areas of specialization. Many of us, however, felt that this approach does not capture the breadth and diversity of who we are today. As a result, we have chosen to describe ourselves using three different tables of data. Each member self-selected the discipline areas, scales, and programmatic themes that they felt best described “who they are and what they are doing” today. The option to choose primary and secondary focuses provides additional detail. These summary tables are an attempt to capture both the complexity of our individual programs, and to summarize our strengths as a group.

a. ***Disciplinary areas represented in the Earth System Science Group:*** With 19 disciplinary areas listed, Table 3.13a shows clearly the breadth of disciplinary areas represented within the Earth System Science group*[1]. Many of us work in more than one disciplinary area, and many disciplinary areas are considered a primary focus by three, four, or more individuals. This is important, as it demonstrates that despite the new breadth of the Earth System Group, there is still sufficient overlap in expertise and interest to provide disciplinary depth and to more efficiently share equipment and other resources. For example, the SEAL Analytical Autoanalyzer (Table 3.12) was identified as a critical need by several faculty members with interests in water quality, and a joint effort was made to replace older equipment that had belonged to a single researcher. Table 3.13b summarizes the data to represent the relative distribution of faculty within the areas. Soil chemistry and soil fertility emerge as strong primary disciplinary areas, followed by biogeochemistry, mineralogy, and pedology. Hydrology, soil physics, and geospatial science (GIS and remote sensing) are very clear secondary strength areas.

b. ***Scales of measurement that characterize the work of the Earth System Science Group:*** In Table 3.14a, each of us indicated the length scales that we feel characterize our research work, while Table 3.14b is again a summary. Collectively, our work spans all scales of terrestrial measurement, from the nanometer scale of interactions of atoms and molecules, to the scale of thousands of kilometers that characterizes our remote sensing and modeling work. By comparing Figure 3.13 to Table 3.14b, it is particularly clear that we have new strengths at the global, regional, and state-wide scale. This was addressed by hiring individuals who model global or regional processes, as well as a shift by a number of other faculty members to work that incorporates GIS as a tool to visualize and understand processes at coarser landscape scales.

This breadth of scale is important because most, if not all, major societal problems have aspects that cover multiple scales of measurement. For example, to address a complex problem like hypoxia in the Gulf of Mexico, one must understand the molecular mechanisms of nitrogen transformations; how water and nutrients move over and through the soil to ground and surface water; whether water from different watersheds containing different soils, crops, and soil management practices varies in its nitrate load; and how all this

*[1] Note that three individuals, Brouder, Grant, and Niyogi, have research programs that fit into both the Earth System Group and the Crop Sciences Group. They are listed in the tables for both groups.

impacts the nitrogen load that ultimately enters the Gulf of Mexico at the mouth of the Mississippi River.

c. ***Programmatic themes of the Earth System Science Group:*** The programmatic themes under which people are currently working are listed in Table 3.15. Self-identified areas of research include a total of 40 different titles. Although many of the research areas are truly unique (e.g., Indian monsoon; digital soil mapping), at least 30 of the titles can be grouped into broader categories. These include: (1) anthropogenic contaminants, (2) greenhouse gases, (3) land use/sustainability, (4) nitrogen, phosphorus, or potassium in water and soils, (5) soil management, and (6) watershed hydrology. Effort across these categories is fairly well distributed. Notably, “N, P, or K in water and soils” is a category in which at least 13 faculty are working, reflecting the importance of the major plant nutrients from both agronomic and environmental perspectives.

Members of the Earth System Science group are also engaged in the department-wide initiative to identify and develop Grand Challenge areas for the immediate future. During the fall of 2008, the entire department drafted white papers and held extended discussions on six theme areas. The Earth System Science faculty helped define these themes based on their expertise, research interests, and understanding of societal needs. These white papers are included elsewhere in this document and are intended to articulate a strategic vision for moving forward with greater focus and presence into Grand Challenge areas that will be finalized over the upcoming months. Earth System Science faculty interest in the Grand Challenge areas is summarized in Tables 3.16a & 3.16b.

C. **Where we want to go/ How we will get there**

We are extremely fortunate to have both the depth and breadth to address almost any aspect of the soil-water-climate continuum, and together with our crop science group, the crop-soil-water-climate continuum. We have succeeded in transforming ourselves in terms of faculty composition, and are now addressing the challenge of developing a high level cohesive strategic vision. Preparing for this review has provided an opportunity to initiate this important process. Our initial discussions of the various Grand Challenge areas have provided a focus for these discussions. We have the following plan for moving forward.

1. Develop a new corporate identity for the Earth System Science Group

During our discussions in preparation for this review, *Earth System Science* seemed to encompass who we are as group today. Earth System Science as a paradigm has a distinctive appeal (http://serc.carleton.edu/introgeo/earthsystem/index.html), but we have not yet discussed the issues of adopting Earth System Science as an area "title" compared to other titles such as *Environmental Soils and Landscape Processes* used on our department Web site and in the department's current strategic plan. Resolving what we call ourselves is important for several reasons: (1) we need a corporate identity that we can all rally around, (2) we need to distinguish ourselves from other departments and groups on campus, the Earth and Atmospheric Science Department, for example, and (3) how we present ourselves to the outside world impacts our ability to attract the best and the brightest students.

2. **Develop a conceptual research framework for the Earth System Science Group**

Our current departmental Five-Year Strategic Plan (Appendix F) (http://www.agry.purdue.edu/pdf/StratPlan04-09.pdf) was written to encompass the 2004-2009 time period. A major goal under "Preeminence in Discovery" was to "Develop intellectual resources that integrate basic and applied sciences to address major agricultural, ecological, environmental, and other societal concerns." We have achieved this goal, as described previously by hiring new faculty. However, we articulated only a very general goal relative to our research program, namely, to "Enhance the impact of departmental research on science and society." Whether we have accomplished this awaits evaluation of the metrics identified in the 2004-2009 plan, but there is a sense among many of our group that we can do a better job of defining and articulating our overall research agenda.

We have made a very good start in this direction with the preparation of the Grand Challenge white papers. While that effort has helped to articulate future research objectives, it has largely been internal to the department and does not encompass a strategy to realize these goals. We should now consider expanding the effort to include input from our collaborators and key stakeholders.

We envision developing a conceptual research framework that will not dictate what we as individuals must work on, but that can guide and focus new projects and serve to illustrate how our current projects fit into a larger whole. We envision first developing a draft among ourselves, seeking to capture both the breadth and depth of our current research and our goals for the future, as well as identifying possible strategic collaborators within and outside of Purdue. Next, we would approach our strategic collaborators and administrators within Purdue and refine and focus a second draft based on their inputs. Finally, we would seek input from key external stakeholders and collaborators. Once completed, we would publicize the plan and make it available to our collaborators, stakeholders, and the public through our Web site. More importantly, the plan would guide and focus our own work into the immediate future.

We recognize that development of a conceptual research framework is time consuming and often contentious, and that it may require external assistance from individuals with specialized skills. Developing such a framework, however, would sharpen our focus, increase our visibility, and may lead us into productive new research areas that we have not yet considered.

3. Enhance our undergraduate and graduate education program

An important part of our mission is to prepare the next generation of scientists to address pressing societal needs using state-of-the-art science. There are two initiatives currently under way that should help to broaden the Agronomy educational experience and increase visibility of the Earth System Science program within the University.

First, as discussed as part of the graduate education document, the department is in the process of modifying the Ph.D. degree requirement to make it competency-based, and to reduce the course credit hour requirement. As part of this initiative, we have defined a new disciplinary area for Earth System Science. Students choosing this disciplinary area will be evaluated for a selected set of competencies that will draw from the Soil Science and Cropping Systems areas, as well as incorporating spatial technologies and land-atmosphere interactions. We feel that the visibility of this disciplinary area will help to attract high quality graduate students to the research programs of some of our newest faculty members. In addition, it will provide an educational framework for a new generation of soil scientists who will have a greater focus on the interaction of soils with the atmosphere and biosphere, and who will be better equipped to tackle large scale questions of landscape management, climate change, and sustainable agricultural water resources. We hope that this new area will substantially broaden the graduate applicant pool and increase its numbers.

Secondly, as discussed in the Undergraduate Education portion of this document, we have begun discussions for a new undergraduate degree program, tentatively titled “Soil and Hydrologic Sciences,” that will emphasize courses in soil physical sciences, pedology, and water movement at landscape and watershed scales. This program may have substantial interaction with the Agricultural and Biological Engineering (ABE) Department, which has a growing program in hydrologic modeling and observation. This interaction will enhance our capacity for training in hydrologic field techniques.

4. Additional faculty expertise needed over the next five years

Although we have made great strides in developing our intellectual capital, we still have significant gaps in faculty expertise. Soil physics is one area where additional expertise is needed, particularly since John Cushman left the department leaving a gap in the area of environmental soil physics. Microwave remote sensing for soil moisture is one research area that could be addressed by a new hire in soil physics. Additional expertise in soil microbiology is also needed to address some of the many environmental issues facing Indiana, the Midwest, and the world today.

Table 3.10. Faculty and staff listing for the Soils Group in 2002

Personnel	**Specialization**	**Budgeted FTE**		
		R	**E**	**T**
C. Beyrouty	Soils in the Rhizosphere (Dept. Head)	0.33	0.34	0.33
S. Brouder	Plant Nutrition, Cropping Systems	0.30	0.60	0.10
J. Cushman*[1]	Environmental Soil Physics	0.80	0.00	0.20
D. Franzmeier*[2]	Pedology	0.40	0.10	0.50
J. Graveel	Soils Teaching, Microbiology (0.5 NRES)	0.15	0.00	0.35
C. Huang	Soil Physics (*Adjunct*)		USDA/ARS	
B. Joern	Soil Chemistry, Plant Nutrition	0.30	0.50	0.20
C. Johannsen*[2]	Land Information System	0.20	0.60	0.20
C. Johnston	Soil Physical Chemistry	0.80	0.00	0.20
E. Kladivko	Soil Physics	0.65	0.10	0.25
B. Lee*[1]	Land Resources	0.35	0.50	0.15
L. Lee	Environmental Chemistry	0.80	0.00	0.20
W. McFee*[2]	Soils Teaching, Forest Soils	0.33	0.33	0.34
C. Nakatsu	Environmental Microbial Genetics	0.80	0.00	0.20
M. Nearing	Soil Conservation, Erosion (*Adjunct*)		USDA/ARS	
D. Norton	Soil Erosion, Pedology (*Adjunct*)		USDA/ARS	
P.S.C. Rao	Soil Physics (0.75 FTE Civil Eng.)	0.25	0.00	0.00
D. Schulze	Soil Mineralogy, Chemistry, Pedology	0.85	0.00	0.15
P. Schwab	Soil Chemistry	0.70	0.00	0.30
G. Steinhardt	Soil Management, Tillage Systems	0.15	0.60	0.25
D. Stott	Soil Biochem., Structure, Erosion (*Adjunct)*		USDA/ARS	
R. Turco	Soil Microbiology, Xenobiotic Degradation	0.10	0.00	0.15
G. Van Scoyoc	Soils Teaching, Chemistry, and Fertility	0.20	0.00	0.80
Administrative/Professionals				
M. Bischoff	Environmental Microbiology	1.00	0.00	0.00
J. Lindell	Microbial Molecular Genetics	1.00	0.00	0.00
G. Premachandra	Laboratory Technician	1.00	0.00	0.00
S. Sassman	Analytical Chemist	1.00	0.00	0.00

*[1] left the department

*[2] now retired

Table 3.11. New faculty positions identified in the 2002 review, the individuals hired in these positions and their departmental appointments

Discipline Area	Individual	Appointment
Evolutionary Geomorphology (Pedology)	Phillip Owens	Agronomy 100%
Earth Observation and Landscape Characterization	Melba Crawford	Agronomy 75%, Engineering 25%
Soil Nutrient Management and Soil-Crop Modeling	James Camberato	Agronomy 100%
Watershed Hydrology	Laura Bowling	Agronomy 100%
Biogeochemistry	Qianlai Zhuang	Earth & Atmospheric Sciences 75%, Agronomy 25%
Biogeochemistry	Kevin Gurney	Earth & Atmospheric Sciences 75%, Agronomy 25%
Climatology	Dev Niyogi	Agronomy 75%, Earth & Atmospheric Sciences 25%

Table 3.12. Major equipment and facilities obtained since the 2002 review, including the year in which they were purchased and their approximate cost, if provided

Equipment or Facility	Year	Cost
PANalytical X'Pert Pro MPD Powder X-ray Diffractometer	2004	$160,000
ICP Mass Spectrometer	2007	140,000
Liquid Chromatography Mass Spectrometer	2004	400,000
SEAL Analytical Autoanalyzer	2006	60,000
CN Analyzer (co-purchased with Animal Sciences)		
Mettler-Toledo Thermogravimetric Analyzer	2008	30,000
Mettler-Toledo Differential Scanning Calorimeter	2007	40,000
CO_2 Eddy Covariance Equipment	2006	25,000
GC/MS QP-20010 EI/PCI	2007	66,000
SeaSpace TeraScan 3.7m L-Band GEO receiving station	2005	
SeaSpace TeraScan 10 node Cluster Data Processing Server	2005	
SeaSpace TeraScan AXYOM 4.5m X/L-Band LEO receiving station with 5.5m radome on 9m tower	2005	
6 Tuneable Diode Laser Spectrometer systems	2007	400,000
Photoacoustic Spectrometer	2007	46,000
3 Instrumented Trailers for gas exchange measurements	2007	240,000
Water Quality Field Station repairs and upgrades	ongoing	120,000

Table 3.13a. Discipline areas represented in the Earth System Science faculty

● = primary focus • = secondary focus	Beyrouty	Bowling	Brouder*	Camberato	Crawford	Grant*	Gravel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi*	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang
Soil Chemistry	●										●	●		•				●			•		●	●	●				●	•
Soil Biogeochemistry												●			•						•				●		●			●
Environmental Chemistry															●															
Soil Mineralogy											•	●		●				•					●						●	
Soil Microbiology							●									●											•	●		
Soil Physics									●	•			●	•				•		•	•									•
Pedology														●				•	●				●			●			•	
Soil Fertility	●		●	●							●							•							●				●	
Soil Remediation / Environmental							●																	•						
Soil Erosion							•			●								●		●										
Soil and Water Conservation							•			•										●										
Soil Management / Conservation			●				•						●													●				
Hydrology		●			•				•				•				•	•		•	●				●					•
Land Surface Modeling								•									●													
Remote Sensing		•			●	●			•								•					●				•				•
Geographic Information Systems		•			•				•		•			•			•					●	•							
Climatology		●			•	•		•									●													
Atmospheric Biogeochemistry			•			●		●																						
Nanotechnology												•																		

* Individuals who are also listed in the Crop Sciences document.

Table 3.13b. Summary of discipline areas represented in the Earth System Science faculty

Discipline Area	Total Responses
Soil Chemistry	●●●●●●●●•••
Soil Biogeochemistry	●●●●••
Environmental Chemistry	●
Soil Mineralogy	●●●●••
Soil Microbiology	●●●•
Soil Physics	●●••••••
Pedology	●●●●••
Soil Fertility	●●●●●●•
Soil Remediation / Environmental	●•
Soil Erosion	●●●•
Soil and Water Conservation	●••
Soil Management / Conservation	●●●•
Hydrology	●●●•••••••
Land Surface Modeling	●•
Remote Sensing	●●●•••••
GIS	●•••••••
Climatology	●●•••
Atmospheric Biogeochemistry	●●•
Nanotechnology	•

Table 3.14a. Scales of measurement that characterize the work of the Earth System Science faculty

● = major focus **• = secondary focus**	Beyrouty	Bowling	Brouder*	Camberato	Crawford	Grant*	Graveel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi*	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang
1,000 km global, regions, states		●			●			●	•	•	•						●		•		●	●	•		•					●
kilometers landscapes, watersheds		●	●	●	●	●		•	●	●	●	•	•	•	•		•	●	●	●	•	•	•		●		●		●	•
meters pedons, field plots	●	•	●	•	•	●			•	●	●	●	●	●	●			•	●	•	•		●	●	●	●	●		●	•
millimeters sand grains, roots	●		●				•				•	●		●	•			•	•	•				•	•		•			
micrometers clay particles, microbes						•	●				●	●		●	●	●		•	•				●		•		•	●	●	
nanometers atoms, molecules												●			•	•		•					•				•	●		

* Individuals who re also listed in the Crop Sciences document.

Table 3.14b. Summary of scales of measurement that characterize the work of the Earth System Science faculty

Scale	Total Responses
1,000 km global, regions, states	●●●●●●●••••••
kilometers landscapes, watersheds	●●●●●●●●●●●●●●••••••••••
meters pedons, field plots	●●●●●●●●●●●●●●●●••••••••
millimeters sand grains, roots	●●●●•••••••••
micrometers clay particles, microbes	●●●●●●●●●•••••
nanometers atoms, molecules	●●•••••

Table 3.15. Programmatic themes currently being addressed by the Earth System Science faculty

● = primary focus • = secondary focus	Beyrouty	Bowling	Brouder*	Camberato	Crawford	Grant*	Graveel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi*	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang	Total Responses
Anthropogenic Contaminants																															
Fate and transport of environmental contaminants (soil)			●									●																	●		●●●
Fate and transport of environmental contaminants (air)																	•														•
Fate of emerging organic contaminants of concern															●																●
Hormones from manure land-application															●																●
Impact of anthropogenic molecules on natural resources							●																					●			●●
Persistent organic pollutants												●																			●
Remediation/reclamation of disturbed/contaminated soils	•						•																	●		●					●●••
Greenhouse Gases																															
Agriculture - climate interactions			•					•									•														•••
Green House Gasses (GHG) and nitrogen atmospheric emissions, transformation, and depositions			•			●		●																							●●•
Impacts of GHGs on climate and society								●																						●	●●
Management impacts on GHG emissions			•		•			•				•					•								•		●			•	●•••••••

Table 3.15. continued

● = primary focus • = secondary focus	Beyrouty	Bowling	Brouder*	Camberato	Crawford	Grant*	Graveel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi*	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang	Total Responses
Quantification of CO_2, CH_4 and N_2O emissions								●																						●	●●
Land Use / Sustainability																															
Environmental sustainability			●																			●							•		●●•
Quantifying impact of land use/land cover change in agriculture					●														●							●			•		●●●•
Suburban and rural development														●												●					●●
Sustainable development																						●							•		●•
N, P, or K in Water and Soils																															
Ammonium, potassium and phosphorus interactions in soils and soil minerals	●			●							●	•						•					●		●				●	•	●●●●●●•••
Drainage water quality		•	●		•																								•		●•••
Evaluation of effects of seasonal saturation on fate and transport of nutrients			•															●													●•
Nitrogen transformation modeling in soils and landscapes		•	●	●	•						●	•						•							●						●●●●••••
Quantifying and modeling phosphorus movement in soils and landscapes											●							•	•						●						●●••
Soil Management																															
Best management practices for biofuel feedstock			●																								•				●•

Table 3.15. continued

● = primary focus **• = secondary focus**	Beyrouty	Bowling	Brouder*	Camberato	Crawford	Grant*	Graveel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi*	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang	Total Responses
Cover crops for soil and water quality													•																		•
Soil erosion processes and control at field and landscape scales										●								●		●											●●●
Soil quality within watersheds														●					•		•			•			●				●●•••
Use of soil amendments to improve water entry and control erosion																		●													●
Watershed Hydrology																															
Agricultural drainage and water quality			●										●																●		●●●
Assessing conservation effects at the watershed scale									•	●								•		●											●●••
Quantifying anthropogenic impact to water systems		●			●														•										•		●●••
Quantifying the impact of agri-cultural conservation practices on soil, air and water quality			●						●																●	●			•		●●●●•
Transport of carbon from watersheds (runoff, sediments)		•	●		•							•									•						•	•			●••••••
Ungrouped																															
Bacterial pathogens in water and soil																												•			•
Chemistry of carbon in soils			●									●							•												●●•
Disaster early warning & mitigation																	•					●									●•

Table 3.15. continued

● = primary focus • = secondary focus	Beyrouty	Bowling	Brouder*	Camberato	Crawford	Grant*	Gravel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi*	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang	Total Responses
Digital soil mapping																			●												●
Indian monsoon																	•														•
International ag. - Plant-soil interactions at low pH												•											●						●		●●•
Kinetics of soil enzymes	●																										•				●•
Land use land cover change impacts on weather and climate								●									●														●●
Public Health Impacts																						●									●
Visualizing the soil geomorphology of Indiana					•													•	●				●			●			●		●●●●••

* Individuals who are also listed in the Crop Sciences document.

Table 3.16a. Identification of Grand Challenge topics as major or secondary interest by Earth System faculty

● = major interest or focus • = secondary interest or focus	Beyrouty	Bowling	Brouder*	Camberato	Crawford	Grant*	Gravel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi*	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang
Landscape Mgmt. & Systems	●	●	●	●	●	•	•	•	●	●	●	●	●	●	•		•	•	●	•	●	●	●	•	●	●	●	•	●	●
International Agriculture	•		•		•			•			•	●		•			●	•					●						•	
Chemicals in the Environment	•	•	•			●	●		•	•	●	●	•	●	●	•	•	●		●	•		•	●	•			●	●	
Bioenergy		•	●		•			•			•	●	•				•				•						•	●		●
Plant Breeding & Genetics																														
Climate Change		●	•		●	●		●	•			●	•				●		•		•	●			•		●			●

* Individuals who are also listed in the Crop Sciences document.

Table 3.16b. Summary of Earth System Science faculty interest in specific Grand Challenges

Grand Challenge	Total Responses
Landscape Mgmt. & Systems	●●●●●●●●●●●●●●●●●●●●•••••••••
International Agriculture	●●●••••••••
Chemicals in the Environment	●●●●●●●●●●●•••••••••••
Bioenergy	●●●●••••••••
Plant Breeding & Genetics	
Climate Change	●●●●●●●●●••••••

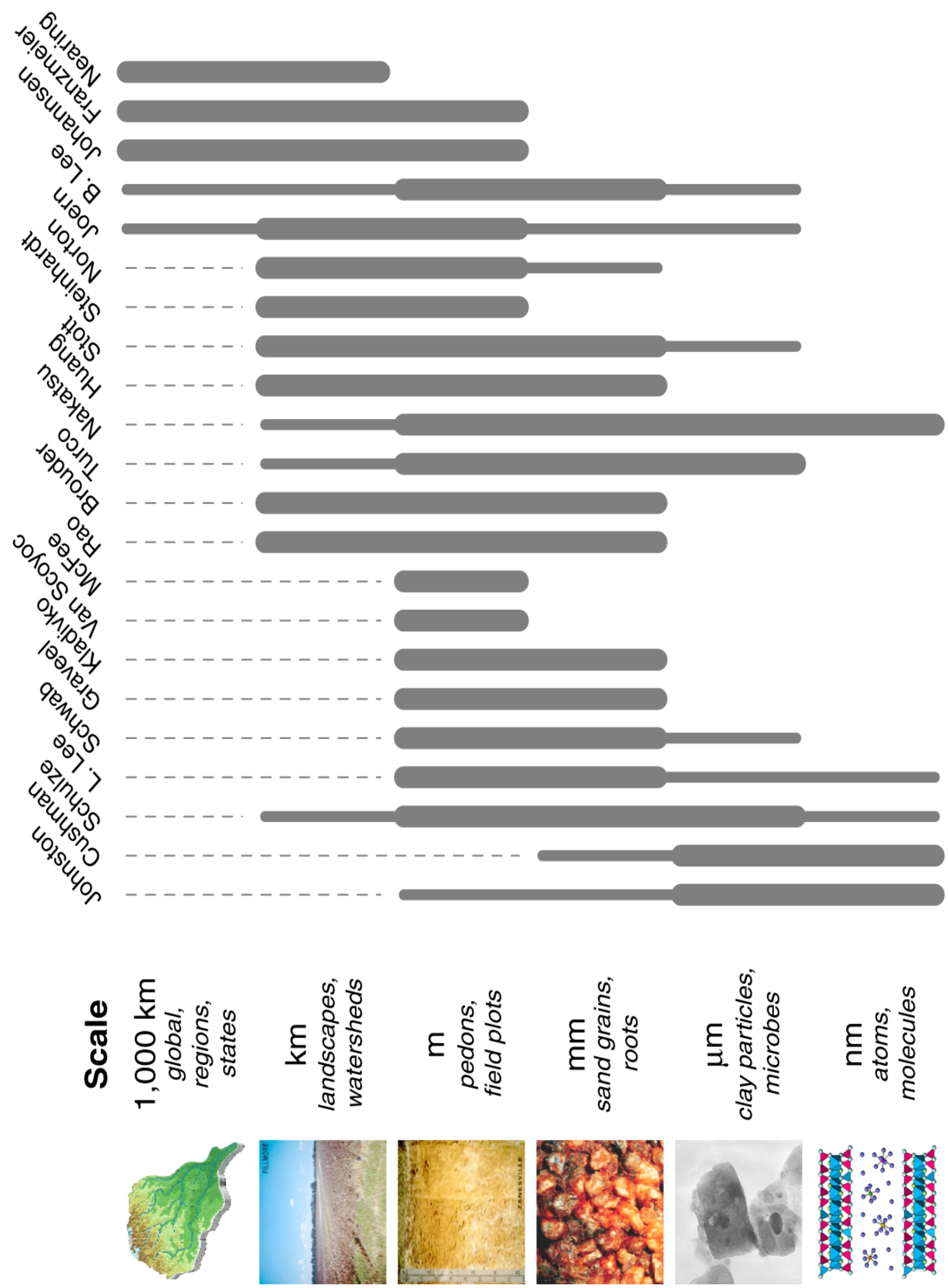

Figure 3.13. Length scales that characterized the Soils Group in 2002