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Defining a new engineering course and emphasis for the 21st Century – Natural Resources Engineering

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Abstract

The goal of this paper is to evaluate the transition of the soil and water conservation agricultural engineer to the natural resource engineer considering questions of changing society, current student demographics, institutional priorities, current instructors and field of knowledge. Natural resources engineering is defined as the design of planned activities complimentary to or opposing natural or societal forces leading to modifications of the soil, water, biota and/or air environment. The problem space is on the farm, field or small watershed scale as opposed to the regional or large watershed scale. The purpose is resource development and/or environmental management. Thus, we in effect broaden the definition of natural resources from the usual oil/gas mining extraction activity to the more general crop production and urban development activities. Ancillary site development activities associated with bioremediation, bioconversion and resource extraction are included by the more general definition.

Natural resources engineers solve problems arising from nonagricultural rural population, concentration of animal production, outward advances of the "urban fringe," and waste/residue recycling to productive land. Natural resources engineers also address traditional agricultural production problems. Pressure for improving stream water quality to meet total mass daily loadings (TMDLs) continues. The engineers meeting these demands in the future are increasingly likely to be from a non-farm background. The natural resources engineer will address field scale problems. The civil engineer will address regional scale issues. There will be numerous opportunities for natural resource and civil engineers. The current institutional priorities, incoming students, society and support the transition from the traditional soil and water agricultural engineering to natural resource engineering, as does the expanding field of knowledge. Attention must be devoted to hiring appropriately trained instructors to actualize the transition.

Background

The main thrust of the presentation will be oriented towards presenting an analysis of the area following an accepted protocol for examining curriculum questions[1]. Specific problems that develop the above definition of the natural resources engineer will be presented in this context.

Links with the traditional civil/environmental engineer will be presented which highlight the differences and commonalities in the disciplines.

The agricultural engineering curriculum was developed in an era of extensive rural development of an agricultural based economy. There were courses on soil and water engineering, rural electrification, power and processing, agricultural structures and machine design. Agricultural engineers traditionally study all the common engineering science courses with colleagues in other disciplines, then focus on discipline specific coursework that extends engineering science and emphasizes design. The focus of this paper is the soil and water course and how it is being transformed into an emphasis area or curriculum for contemporary relevance. The traditional agricultural engineering student was male, white and from a farm background. He studied engineering hydrology including runoff, soil erosion and its control, introduction to channel design including vegetated waterways, irrigation and drainage. Though these were important in the development of agriculture in the 20th century, changes in societal needs, entering students, institutional priorities, the background of instructors and the field of knowledge[1] itself necessitates a comprehensive revision.

Societal Needs

The United States is now well developed, except for regions designated to remain in a natural state. Conservation tillage and reversion of agricultural lands to pasture/forest is rendering many erosion control terrace systems installed in the 60s obsolete. Irrigation acreage for crop production is not increasing because economically accessible water has been exploited. New drainage has been curtailed by the current drive to preserve wetlands. Thus, students cannot expect to find significant employment in traditional agricultural engineering venues.

Urban sprawl in many regions is pushing the city into the country, creating an "urban fringe." Wastes and odors associated with concentrated animal and poultry production quickly come to the forefront at the urban fringe. Traditional agricultural engineering ignored odor-related problems. There is an emphasis on various bioconversion approaches including composting for processing wastes in a more acceptable manner.

A major societal need related to the skills of the agricultural engineer is in the water quality preservation. Animal and poultry producers are now required to develop comprehensive nutrient management plans for their farms if there are 300 or more animal units on the land. Land application system permits are soon to be required for spray irrigation of wastes on these lands. Irrigation principles still apply, however scheduling must consider nutrient issues as well as hydraulic loading. Simply stating that waste handling facilities were designed and approved by the NRCS is no longer sufficient for EPA (or state equivalent) approval. Current societal needs for water quality expertise were clearly not met by the traditional course.

University of Georgia Priorities

The Biological and Agricultural Engineering (BAE) department has for years met the needs of the agricultural engineering community in the state. The BSBE degree has also developed a reputation with employers as an excellent General Engineering Degree, formally known as the Batchelor of Science in Agricultural Engineering (BSAE). The BAE department has had progressive leadership and has made changes in degree offerings to improve contemporary relevance. The Batchelor of Science of Biological Engineering (BSBE) degree, with an environmental option area, was added in 1993 in response to needs of contemporary relevance.

The University of Georgia is unique as a land grant institution in that the only engineering entity on campus is the biological and agricultural engineering (BAE) department. Georgia has historically not produced adequate numbers of engineers for its growing economy. The university strategic plan calls for further development of engineering at the university over the coming decade. The BAE department is one of the foci for this growth. The department has made a strategic decision to build growth along the strengths of the university. Life science, ecology and marine science are areas of strength relevant to this paper. The addition of engineering in the strategic plan bodes well for a continuation of the transformation of engineering within the current department.

Students

Students entering the university via the BAE department have SAT scores near 1200, up significantly over the past 10 years. The University of Georgia currently has an enrollment cap of about 32,000 students. Many potential applicants from rural agricultural regions do not meet admission standards. Thus, classes now have few students from farm backgrounds. Over 50% of the students are now from metropolitan regions. Nearly 50% of the enrollment is female. There is an emphasis on minority recruitment. These shifts due in substantial measure to the addition of the BSBE degree and its environmental option area. Enrollment has held steady in the agricultural engineering degree, perhaps due to the possibilities opened by a degree in general engineering.

The diversity resulting from the shift to metropolitan area students from the white, rural males of farm background necessitates some emphasis on ethics. Preservation of natural areas and associated preservation of endangered species creates some interesting ethical issues. Introducing ethics into a course or curriculum is a challenge for the student and the teacher.

Computer literacy of incoming students is phenomenal. Sophisticated software is available for solving many engineering problems. Is the teaching of engineering computational methods relevant in the 21st century? The author presumes that computational methods must be taught. The tendency to over value outputs of engineering software is real. Due diligence in developing inputs and associated alternatives must be learned. Students who have experience in calculations are able to recognize “garbage” occurring with commercially available design program input errors. Students will make increasing use of spreadsheets and equation processing software, just as their teachers have jettisoned the slide rule. Those who can make fast, reasoned judgments of engineering alternatives are in high demand.

Instructor background

Whereas in the past instructors were white, male and from a farm, now newly hired faculty may be female and from outside the USA. They may have a civil engineering background or may have had extensive research experience in a civil engineering area. New instructors with diverse engineering backgrounds are now in place for the biological and agricultural engineering degree programs. They are well versed in both agricultural and urban issues and concerns. In addition to the historically good macro biology background of traditional soil and water conservation, ecology and microbiology are emphasized in evaluating the academic preparedness of instructors. Comprehensive nutrient planning for concentrated production operations has arrived. The new storm water discharge quality regulations are likewise anticipated. Students must now be prepared for comprehensive watershed analyses including point and non-point pollution from a variety of agricultural and urban sources.

Field of knowledge

Solutions for many traditional agricultural engineering problems are closely related to solution to many environmental problems of the urban fringe. Many of those who will be helping clients solve these problems are in fact from the urban fringe. Herein lies the root of much motivation to maintain contemporary relevance from the programmatic and student interest viewpoints.

Sophisticated software is now available for solving many traditional agricultural engineering soil and water problems. One strategy for developing a course (or series of courses) is to evaluate the prerequisites for understanding the output of the identified program. For example, there are several excellent surface hydrology programs on the market (e.g., SEDCAD©, Haestad Methods PondPack©). These programs may apply a design storm, evaluate erosion and runoff, enable channel design and facilitate sedimentation basin design. Software packages are also available for irrigation and drainage. Software frequently enables choosing many best management practices (BMP) alternatives. Considerable engineering knowledge is required for making appropriate inputs and evaluating outputs for various alternatives. Alternatives must, of course, be intelligently identified.

Without declaring that models are the justification for the course, the 3 hour, 15 week Introduction to Natural Resources Engineering semester course proceeds as shown in Figure 1, beginning with rainfall.

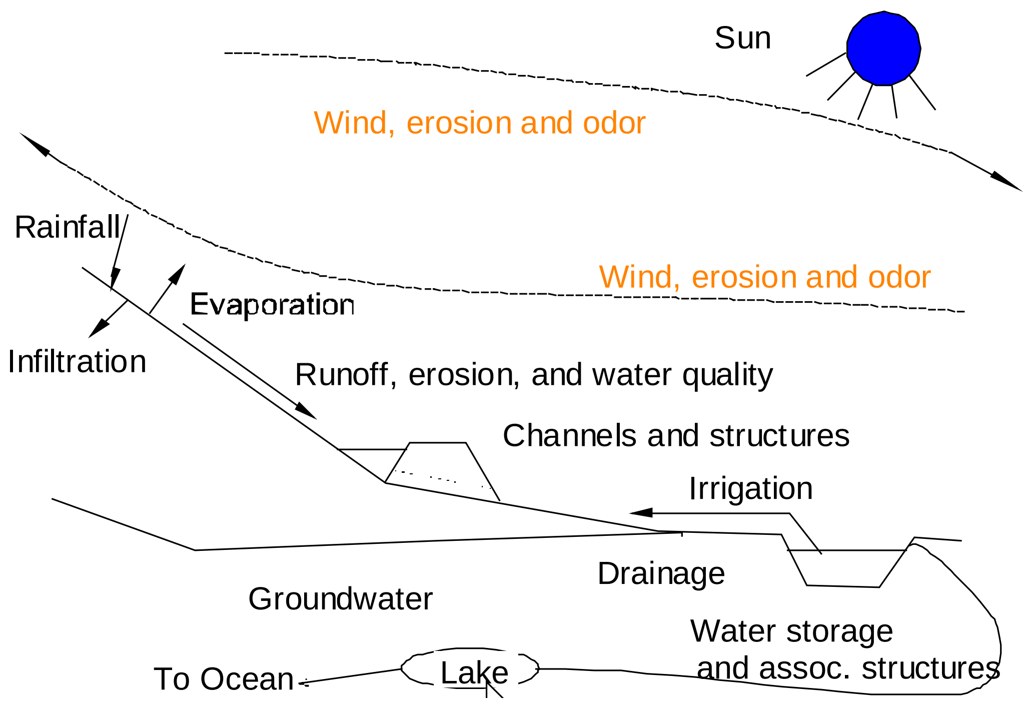

Figure 1. Schematic of the hydrologic cycle superimposed on natural resources engineering scope and processes.

Coverage is rigorous, fully engaging the students. Efforts are made to derive equations from basic principles, where possible. Topics, shown below in Table 1 are elaborated in the 15 week, 3 hour course. Commonalities with the topics as treated in the civil and agricultural disciplines are noted, based on the authors experience.

Table 1. Natural Resource Engineering Course Topics.

Precipitation	background on basic precipitation types and mechanisms; Computation of design storms (Weiss method, NRCS method), intensity-frequency duration curves. Both disciplines emphasize these topics.
Infiltration	overview, Horton, Holtan models, Head calculations, Green & Ampt model, pollution transport. Lab demo. Soil physicists developed many of these concepts. Students in both engineering disciplines who study hydrology are exposed to these topics.
Evaporation	Aerodynamic and energy methods, Penman-Monteith, Blaney-Criddle, pan, crop coefficients. Traditional agricultural engineering.
Runoff	NRCS curve number for runoff volume, rational and TR55 methods for peak flow determination; hydrograph development. Both disciplines.
Water Erosion	RUSLE equation and several concepts for sediment delivery ratio determination. Historically agricultural engineering.
Water Quality and Upland Nonpoint Pollution	Overview tests for water quality, discuss issues in management of uplands as they affect water quality, BMP selection. New to both disciplines.
Open Channel Hydraulics	Continuity, energy and momentum equations, design of transitions, channel design with lined channel, design of unlined channels, design of optimal channels. Well known in civil engineering, though many civil undergrads do not get extensive training in channel design.
Vegetated Waterways	Classical design of vegetated waterways. Largely unique to agricultural engineers.
Terraces and Diversions	Design of terraces and diversions, emphasis on diversions. Diversions are well known in civil engineering.
Hydraulics of Water Management Structures	weirs, orifices, culverts, spillways; routing flows through these structures. These topics are common in civil engineering, with increasing emphasis in biological and agricultural engineering.

Table 1. (continued)	
Impoundments and Embankments	pond and embankment design with emphasis on small structures for ponds, aquaculture and sedimentation basins. Both disciplines, with civil predominating for larger structures teach these topics.
After covering these topics the 15 week semester 3 hour course comes to a close. The students are encouraged to keep the text for reference use. Based on experience with senior design related needs, the following topics are included.	
Shallow Ground Water Management with Drains and Wells	Surface drainage design, Dupuit-Forchheimer assumptions and their use, ellipse drainage equation, nonsteady drainage. Both disciplines teach these topics.
Irrigation	the soil water reservoir, design of moveable sprinkler lateral, center pivot, drip system. Both disciplines with agricultural engineering predominating. Associated plant biology may be stressed more by biological and agricultural engineering.
Steamflow Processes and Lake Dynamics	stream morphology, velocity distributions, introduction to aquatic ecology, chemical processes in streams and lakes. Many disciplines.

The above topics came from a newly developed text[2]. The topics were developed with the goal of extending the capabilities and horizons of students to problems similar to many in traditional agricultural engineering but relevant to other clients operating at the farm and field scale. The problem scale is the key bridge between the civil and agricultural disciplines, with civil engineers tackling the larger scale problems and agricultural engineers working with the farm-field scale. Natural resource engineers may work at the farm and field scale, integrating to the regional scale via appropriate watershed modeling software that requires farm and field scale inputs.

The course includes two field trips to the USDA-ARS station at Watkinsville, GA. This facility has state-of-the-art instrumented watersheds. Students analyze runoff expected from an instrumented watershed. Students analyze the passage of the flow through a culvert and channel, which they characterize. Students also measure the Manning n for two different channel linings in a laboratory flume. Tours of water quality laboratories are also included. The course also includes a tour to a bioconversion center with a pond catchment and land application system.

The introductory course is rigorous. Indeed, student sometimes complain about the work load. Numerous students completing the course over the past 6 years are currently working as consulting engineers in civil engineering offices in addition to the traditional agricultural (e.g., NRCS or other USDA, state agency) opportunities.

A separate "Maymester" course consisting of a 2 week tour of facilities around the state has been developed to provide further hands-on learning opportunities. A separate course covering drainage and irrigation topics has been included, as has a soil mechanics course. These courses plus other option area courses (selected from offerings in the College of Agriculture and Environmental Sciences, and the School of Forestry) complete the natural resource engineering emphasis area.

Conclusions

Changing society, current student demographics, institutional priorities and field of knowledge each warrant revising the traditional soil and water conservation agricultural engineering course and emphasis area. In response, a course and option area was defined that broadened the scope of the traditional agricultural engineer to one capable of solving problems of similar scale (e.g., the farm/field scale as opposed to the regional scale). Due diligence must be paid to securing instructors who will actualize the transition.

As metropolitan students come to school from the urban fringe, graduate to helping clients with urban fringe related problems, the segments of agricultural engineering addressing the environment and civil engineering addressing the environment are becoming somewhat blended, though they remain distinct and complimentary. The problem scale concept serves as a bridge from the traditional agricultural engineering domain to the natural resources engineering domain. Likewise, the problem scale is a lucid distinction between the natural resources engineer and the civil environmental engineer. The natural resources engineer will address field scale problems mainly, though regional scale problems may be addressed by appropriately integrating farm and field scale solutions to the regional level. The civil engineer will address regional scale issues from a regional perspective. There will be numerous opportunities for natural resources and civil engineers working jointly and separately.

Bibliography

1. Diamond, R.M. Designing and assessing courses and curricula. Jossey-Bass Publishers, San Francisco, CA (1998).

2. Tollner, E. W. Introduction to natural resources engineering, Iowa State University Press, Ames, IO (Under contract).

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Ernest Tollner has been employed by the University of Georgia for 20 years in research and teaching. He received his BSAE and MSAE degrees at the University of Kentucky, where he developed a description of flow hydraulics through grass filter strips that is contained within the SEDCAD© hydrological analyses program. He obtained his doctorate at Auburn University, where he research the use of organic byproducts for sealing waste lagoons. Research at the University of Georgia has focused on the measurement of soil properties using nondestructive testing methods. He is currently the graduate coordinator and teaches the soil and water conservation related courses.