Natural Resources Engineering – Its time has come

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1. Abstract

The reduction in numbers of students with farm background, the increase of female participation, the increase in students computer literacy and intellectual capacity along with the increasing rigor required in supporting courses of chemistry and biology requires that we reevaluate our approach to teaching soil and water conservation. Taking the typical soil and water conservation topic outline to a more theoretically rigorous level, inclusion of problems and labs relating to problems at the rural-urban fringe, including some additional topics relevant to the rural-urban fringe and moving from an implied farm scale to a more explicit problem scale that lies between the bench and the region is the essence of the transformation from "Soil and Water" to "Natural Resources Engineering" advocated herein. A more rigorous approach and viewing problems from a perspective of scale instead of production agriculture is a valid foundation for an engineering discipline which will command respect and be genuinely relevant for years to come.

2. Introduction

With the demographic change in the "Agricultural engineering" student population that has occurred, the traditional "Soil and Water engineering" area should be replaced with "Natural Resources engineering". This change of demographics requires that we re-evaluate how we as instructors relate to students that are not from the farm. Further, we must evaluate how we prepare students for employment in future job opportunities.

An underlying assumption in this presentation is that unique expertise of the classical agricultural engineer can and should be applicable to problems common at the rural-urban interface. This demands that air as a resource needs to be considered along with soil and water. Further, one should broaden the classical view of soil and water area to be more inviting to students from a non-farm background.

The goals of this paper are to present a definition of "Natural Resources Engineering," justify from a Georgia demographic perspective why the paradigm is relevant, and suggest how one may move toward adoption of the paradigm.

3. Selected Demographics and Trends

Demographic data in Georgia are presented to exemplify shifts that have been occurring not only in Georgia but in many places across our nation. The past decade has witnessed the continuation of several ongoing demographic shifts in Georgia and around the nation. The population in

Georgia has doubled in the last 50 years, with most of the increase occurring near the standard metropolitan statistical areas (SMSAs) in north Georgia (see Figure 1). Numbers of farms of all economic classes have gradually declined over the last decade (Snipes, 1997). Cropped acres have remained nearly the same over the past decade; however, farms with cattle, hogs and dairy animals have decreased (Snipes, 1997). Poultry production has increased steadily (Figure 2) in Georgia, with significant increases in North Georgia in the first part of the decade and increases in south Georgia in the last few years. Poultry production is concentrated in the indicated counties in Figure 3. Similar trends are true with other animal enterprises in other states.

Georgia and the nation have continued the development of an information-based society via the continued infusion of computers into homes and schools. Since 1994 the Georgia lottery corporation spending for education in Georgia ranged from $163 M to $484 M in 1997. About 6% of these funds (based on 1997 results) were and continue to be dedicated to equipping elementary and secondary schools with computers (Boatright and Bachtel, 1998).

Demographic shifts in the state at large have, not surprisingly, caused some demographic shifts in student enrollment in the University of Georgia College of Agricultural and Environmental Sciences, home of the Biological and Agricultural Engineering (BAE) Department. The College enrollment has generally declined over the past decade (Figure 4). More than 50% of the student body of the college has come from the SMSAs in the state over the entire decade, with the percentage approaching 60% as the decade comes to a close. Counties surrounding the Atlanta-Athens-Chattanooga SMSAs were found to provide about 10% of the students over the past decade, with a slight decline over the decade. Students from the non SMSA and non border counties are considered as predominately rural students who form about 30% to 40% of the college student body. Female percentages since 1993 have increased in the College from 32% to 43% now.

Percentage of students from rural areas appears to have declined from a high near 40% in 1992 to a low of about 30% currently. The introduction of the HOPE scholarship program in 1993 has caused fewer excellent students to go out of state, thereby increasing pressure at the university level to restrict admissions. This student pool typically does not select agricultural majors. An ongoing goal of the BAE department is to increase the visibility of the BSAE and BSBE programs to these students as they select majors.

The SAT scores of the students have trended upward over the past decade (Figure 5). The total College SAT score has consistently exceeded the university average over the past decade (not shown). These trends follow through to the BAE department level. Increasingly selective admissions explain the increase in SAT scores.

The demographics of the Biological and Agricultural Engineering (BAE) Department reflects to some extent the College of Agriculture and Environmental Sciences. Figure 6 shows the BSAE and BSBE student enrollment over the past decade along with the percent of the total in the College. The initiation of the BSBE degree program in 1994 has grown steadily without adversely impacting the BSAE program. The BSBE degree was initiated in response to projected development of biotechnology-based processing and environmental needs. The percentage of college enrollment in the BAE department has increased steadily throughout the decade. The UGA BAE department has chosen to restrict enrollment due to resource constraints over the past year. Figure 7 shows the percent female participation in the BSAE and BSBE degrees. Female participation in the BSBE program is in the 40% to 50% range, similar to the college (Figure 4). The BSBE availability may have somewhat reduced female participation in the BSAE program. The natural resources option area is the largest option area in the BSAE program and the environmental engineering option area is by far the largest option area in the BSBE program.

The percentage of nontraditional students may be increasing, although the trend is hard to document. We define nontraditional students as those pursuing degrees while pursuing near full-time work. Most of these students are somewhat older than the traditional 18-23 year-old student. Many problems in student performance relate to difficulties in time management, not to an inability to comprehend the material with appropriate effort.

Based on an informal survey, BAE student ownership of computers has changed from near zero 3 years ago to nearly half now. The department currently does not require student ownership of computers. The department will likely require ownership in the next year. The computer as a resource is fully as important as the calculator.

Students in engineering at UGA continue to improve in SAT scores and increase in computer literacy. Female participation is increasing. Diversity of race remains a problem. The percentage of students from the farm has been less than 50% for the entire decade and is continuing to decrease. Although the area in crops did not change, the numbers of farms have declined and the inventory of livestock declined, suggesting that the trends in student demographics will not likely reverse. Extensive, as opposed to intensive, agriculture will provide fewer and fewer jobs in the future. Intensive approaches to agricultural production which emphasize biotechnology-based approaches will provide more and more jobs. The poultry industry in Georgia is an example of an intensive agricultural enterprise that continues to develop near and within the state's largest SMSAs.

Predominant job opportunities of graduates of the BAE department have, for many years, not been associated with production agriculture. General engineering positions associated with diverse industries have traditionally provided the overwhelming majority of jobs for our BSAE graduates. This trend seems to be developing for the BSBE graduates. Increasing needs in the environmental area across all industries will likely perpetuate this trend.

Georgia is unique in that Biological and Agricultural engineering at the University of Georgia has survived and thrived in the absence of other engineering disciplines in close proximity. The "how to remain viable in the face of related strong disciplines question" has been and is being faced by other schools with which the author is familiar. It is well known that disciplines such as Civil, Mechanical, Electrical and Chemical engineering compete well in the arena for urban students. The decline of farm numbers and decline of rural population affects the numbers of Agricultural engineers in these programs, with urban students being more naturally attracted to the related disciplines. The introduction of the Biological engineering options and/or degrees (or name change) has attracted more of the urban clientele to those programs. The concept of

Natural Resources Engineering on the field, as opposed to the region and as opposed to the lab, has merit in this context also.

4. Moving from The Soil and Water paradigm to the Natural Resources Engineering paradigm

The typical Agricultural Engineering instructor likely graduated with class mates that were from a farm and was attracted to the profession because they had aptitudes for science and math. They related well to the noble endeavor of mechanizing many labor intensive tasks found on the farm and/or to the reduction of soil loss associated with the tillage practices of the day. Agricultural engineering classes were typically homogenous in student gender and background. Instructors of these classes were typically of the same gender and background. Taking engineering science classes with students of other engineering disciplines did offer exposure to non-farm background engineers but did not typically increase diversity concerning gender or race.

The introductory soil and water conservation class in the Midwest or southeast US typically covered (Schwab et al., 1993):

- Conservation and the environment of production agriculture
- Precipitation
- Infiltration, Evaporation and Transpiration
- Water erosion and control
- Wind erosion and control
- Vegetated waterways
- Surface drainage
- Terracing
- Open channels
- Subsurface drainage
- Pumps and pumping
- Water supply and quality
- Conservation structures
- Earth embankments and ponds
- Irrigation practices
- Surface irrigation
- Sprinkler irrigation
- Micro irrigation

Backgrounds of students in introductory Natural Resources engineering classes are typically 5% to 20% female and 75% to 95% non farm. Typically half these students are in the BSBE degree program. These students typically respond when one includes urbanization impacts along with agricultural impacts on the environment.

One approach to enlarging the envelope to include interests of diverse students is to realize that the principles brought to bear in the above outline are actually much more general than the above outline might suggest. Taking the above outline to a more theoretically rigorous level is justified based on the increased sophistication of the students. Inclusion of farm-scale (or small watershed-scale) problems and labs relating to problems at the rural-urban fringe is useful since many students have been around developments where erosion has generated notoriety. Including some additional topics relevant to the rural-urban fringe such as odors and bioremediation is inviting to the biological engineer. This is the essence of the transformation from “Soil and Water” to “Natural Resources Engineering” paradigm advocated herein.

Problem size or scale definition is useful for delineating rough boundaries between the Natural Resources Engineer and the Civil Engineer and the Chemical Engineer. The classical Soil and Water paradigm always implied the farm or small watershed scale. The notion becomes more explicit in Natural Resources Engineering. "Scale" can delineate between regional scale efforts more appropriate to Civil engineers (e.g., river hydraulics) and the field scale appropriate to Natural Resources engineers. "Scale" also delineates between bench scale efforts more appropriate to Chemical engineers and the field scale appropriate to Natural Resources engineers.

Stream improvements and sediment control plans that have typically been left to civil engineers can in our view be more appropriately done by Natural Resources Engineers. Some extensive approaches such as constructed wetlands for environmental management and some bioremediation techniques are field scale in nature and thus appropriate to Natural Resources Engineers. This delineation is fuzzy. There will always be some overlap in the problem scales worked on by all engineering disciplines and everyone benefits with cooperation.

Now for a definition of Natural Resources Engineering. The author defines Natural Resources Engineering as the design of planned activities complementary to forces that modify the soil, water, biota and/or air environment within and around a problem space on the farm or field scale for purposes of resource development and/or environmental management. The author envisions Natural Resources Engineering to be everything that Soil and Water used to be (is) and then much more.

Discussions of evaporation and transpiration need to be more rooted in theory to appeal to the biological engineer who has or will study more deeply into transport phenomena. For example, assumptions and derivations of the combination equation merit exploration. Practical aspects of ET prediction should be retained by discussion of other approaches such as the Modified Blaney-Criddle, Jensen-Haise and the evaporation pan. In the discussion of infiltration a discussion of the Green and Ampt model is very useful for relating the theory of infiltration to soil physical properties. This introduction prepares students for more advanced course work in unsaturated zone hydrology. Structured labs and demonstrations are important to help visualize infiltration phenomena.

Watershed delineation and runoff peak and volume prediction continue to be important. Problems involving urbanizing watersheds are as relevant as those in agricultural watersheds for teaching the rational method and the NRCS TR55 approaches for peak flow. One may discuss water erosion in connection with construction site erosion and sedimentation control plan development. One may expand water quality to include general aspects of non-point source pollution and an introductory discussion of how to characterize non-point source pollution and an overview of best management practices to reduce non-point source pollution. Simple labs and structured demonstrations are helpful.

One may integrate discussions of vegetated waterways and terrace/diversion channels into a more comprehensive discussion of unlined channel design. Terrace design and layout topics are justifiably minimized because the prominence of terraces in erosion control schemes is greatly diminished with the coming of minimum tillage farming. The design of diversion channels is very relevant in urbanizing settings. Laboratory exercises where students go to field sites, estimate peak runoffs for existing conditions, survey existing channels to determine stage-discharge relationships and survey existing culvert structures to determine peak capacity are well received by students whatever their background.

Hydraulic structures, especially culverts, are worthy of increasing emphasis. We enlarge the design of ponds to include other small structures such as sediment basins and storage structures. Embankments are not so large as to trigger dam safety legislation considerations.

Irrigation and drainage are considered to be full courses in themselves. The introduction to Natural Resources engineering course may briefly touch upon these topics. One may say the same of wind erosion control especially focusing on the eastern half of the United States. One may generalize wind erosion to include dust control on construction sites.

A discussion of odor and air pollution is a needed new dimension. For example, comparing the primary poultry production areas in Georgia (see Figure 3) with the SMSAs in north Georgia gives graphic evidence of potentials for odor and air pollution, given the growth of population and the growth of the poultry industry (see Figure 2). In the past year large hog operations have proposed to move into regions between Columbus and Macon, raising the possibility of odors and water pollution (this region is an important aquifer recharge zone). An introduction to Natural Resources engineering should include an introduction to odor characterization and some meteorology associated with odor accumulation and transport.

The importance of good laboratories and demonstrations cannot be over emphasized. As classes have fewer and fewer students from the farm where much hands-on experience was the norm, the hands-on lab is increasingly more important. Responses to an email survey polling the community on adequacy of instructional material for environmental instruction and on use of software packages in instruction suggest an ongoing debate about how to properly incorporate software into a course. One must balance employer needs and expectation with the very real requirement to avoid the “garbage in -- garbage out” syndrome. We suggest a middle of the road approach. Packages such as TK® which have a reasonably good front end while requiring the student to become involved with the equations may be reasonable compromise. The disadvantage is that students must learn yet another package that may or may not be further used in other courses and would likely not be of use after graduation. Another approach is to stress the more theoretical aspects in one course of a two-course sequence and then introduce good design software in the second course where realistic design projects may be the major expectation. The increasing advantage to students of software experience as they approach the job interview and the long term value of understanding the underlying theory will continue to stimulate this debate.

Increasing SAT scores coupled with increasing chemistry and biology emphasis suggests that more theoretical approaches which unify the somewhat scattered way similar topics were presented in the classical agricultural engineering model are needed. The increase of females and non-farm background students in conservation courses requires that instructors continue to look for ways of reaching the diverse student body. Examples and problems beyond the realm of production agriculture are important for enabling non-farm students to relate to the material. The demands of the job market appear to be going in the direction of increased use of computer software packages, which demands that students understand strengths and limitations of models to avoid the “garbage in-garbage out” syndrome. The current emphasis on odors with intensive animal production and bioconversion operations suggests that an introduction to odor detection and transport should be introduced.

5. Summary and Conclusion

Natural Resources engineering is defined as the design of planned activities complementary to forces that modify the soil, water, biota and/or air environment within and around a problem space on the farm or field scale for purposes of resource development and/or environmental management. Taking the typical soil and water conservation topic outline to a more theoretically rigorous level, inclusion of problems and labs relating to problems at the rural-urban fringe, including some additional topics relevant to the rural-urban fringe and moving from an implied farm scale to a more explicit problem scale that lies between the lab and the region is the essence of the transformation from “Soil and Water” to “Natural Resources Engineering” advocated herein.

In conclusion, the evolution of Soil and Water Conservation to Natural Resources Engineering is consistent with demographic shifts and the meeting of future employer needs. Fundamental soil, water and air transport processes and management have not changed. Our presentation of these issues must change with the times. Urban and female participation is increasing, implying that prior experience of classes as a whole with soil, water and air issues are somewhat different and that the perceived relevance of these issues to daily life is somewhat different. Student computer literacy and intellectual capacity is increasing based on SAT scores. Student exposure to more rigorous chemistry and biology requires that we approach soil, water and air related problems from a more rigorous perspective. A more rigorous approach and viewing problems from a perspective of scale instead of production agriculture is a valid foundation for an engineering discipline which will command respect and be genuinely relevant for years to come.

6. References

Boatright, S.R. and D.C. Bachtel. 1998. *The Georgia county guide* (17th edition). Center for Agribusiness and economic development, University of Georgia College of Agricultural and Environmental Sciences, Athens, GA.

Snipes, L.E. 1997. *Georgia Agricultural statistics*. Georgia Dept. of Agriculture, Athens, GA .

Schwab, G.O., D. D. Fangmeier, W.J. Elliot and R.K. Frevert. 1993. *Soil and water conservation engineering* (4th ed.). John Wiley & Sons, New York, NY.

Figure 1. Standard metropolitan statistical areas in Georgia based on the 1990 Census (from Boatright and Bachtel, 1998).

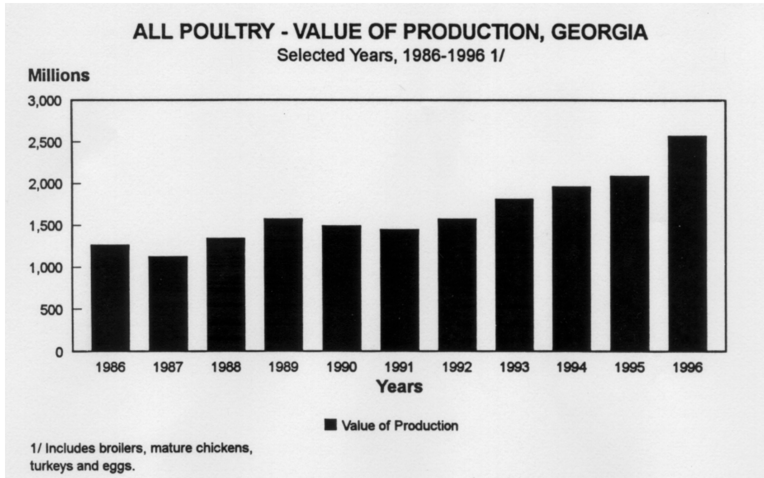

Figure 2. Poultry production in Georgia over the past decade (from Snipes, 1997).

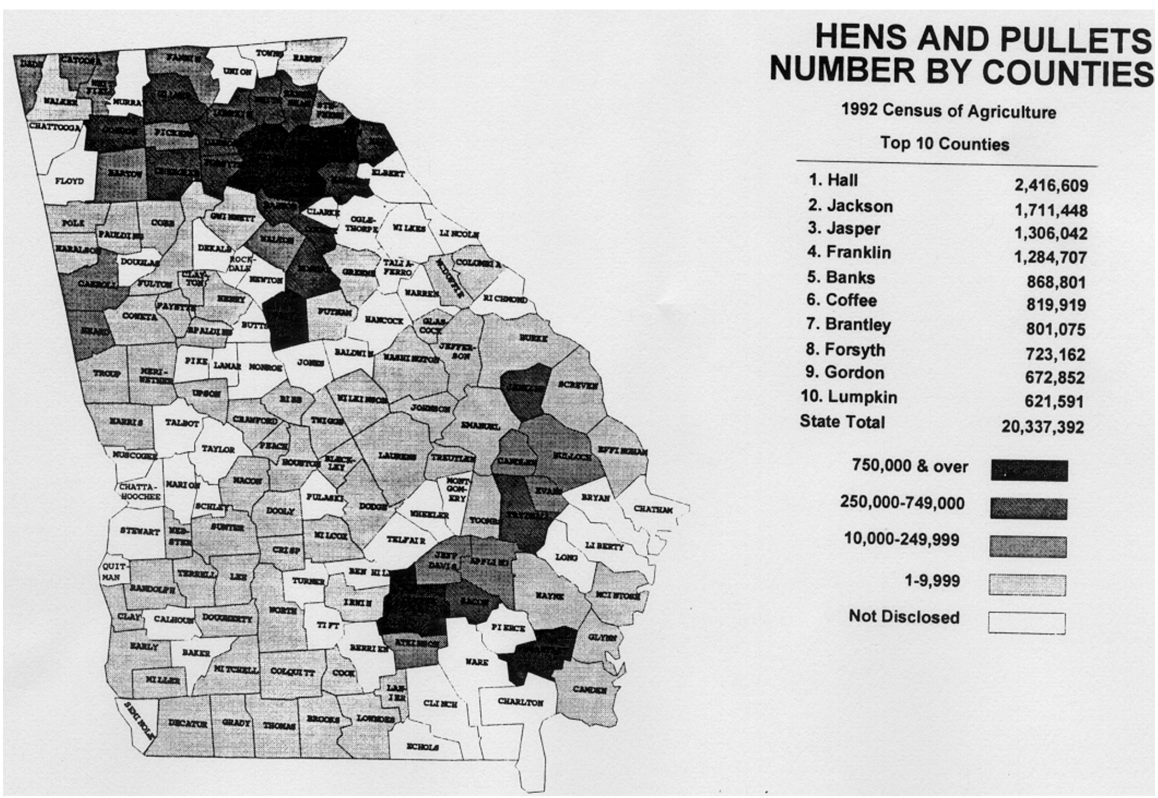

Figure 3. Hens and pullet production in Georgia. Broiler production is generally concentrated in these counties as well (from Snipes, 1997).

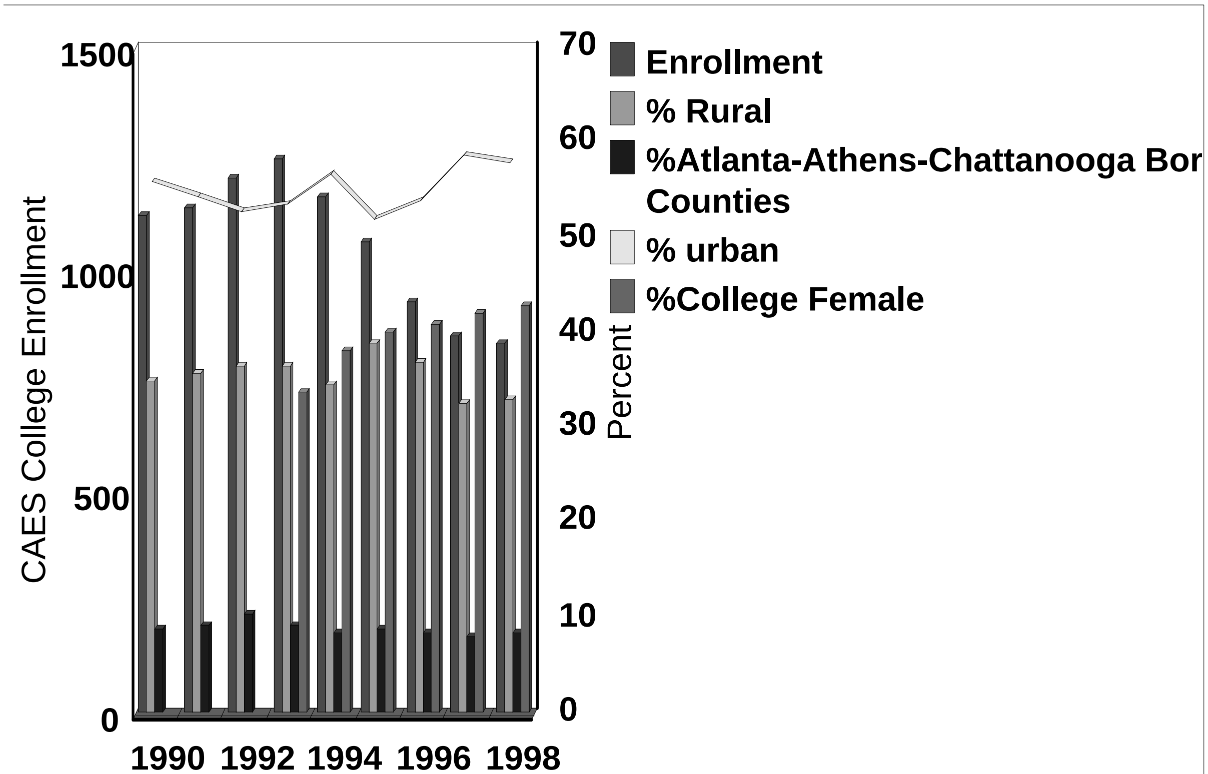

Figure 4. Enrollment and breakdown of percentages of students from Georgia SMSAs (urban), Atlanta-Athens-Chattanooga SMSA border counties, rural counties and percent female of CAES enrollment (data courtesy of Dr. Joe Broder, assistant director of academic affairs, UGA College of Agr. and Env. Sciences).

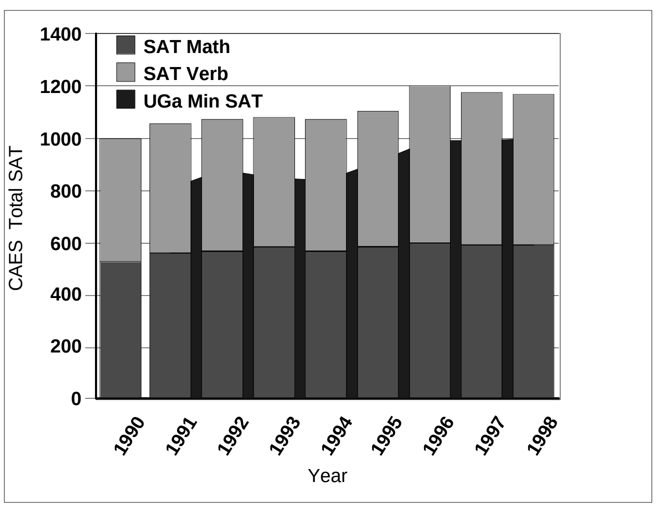

Figure 5. Math and verbal SAT scores of entering freshmen in the CAES over the past decade, with the UGA minimum total SAT score for admission shown in the background. The UGA minimum data is approximate for last 3 years due to change in admissions formula (data courtesy of Dr. Joe Broder, assistant director of academic affairs, UGA College of Agr. and Env. Sciences and Ms JoAnn Lowe, UGA Office of Institutional Research).

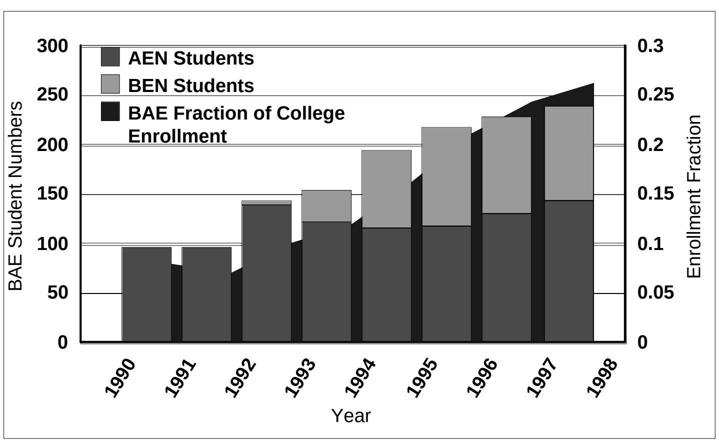

Figure 6. Total AEN and BEN students over the past decade, showing percentage of college enrollment represented by AEN and BEN students.

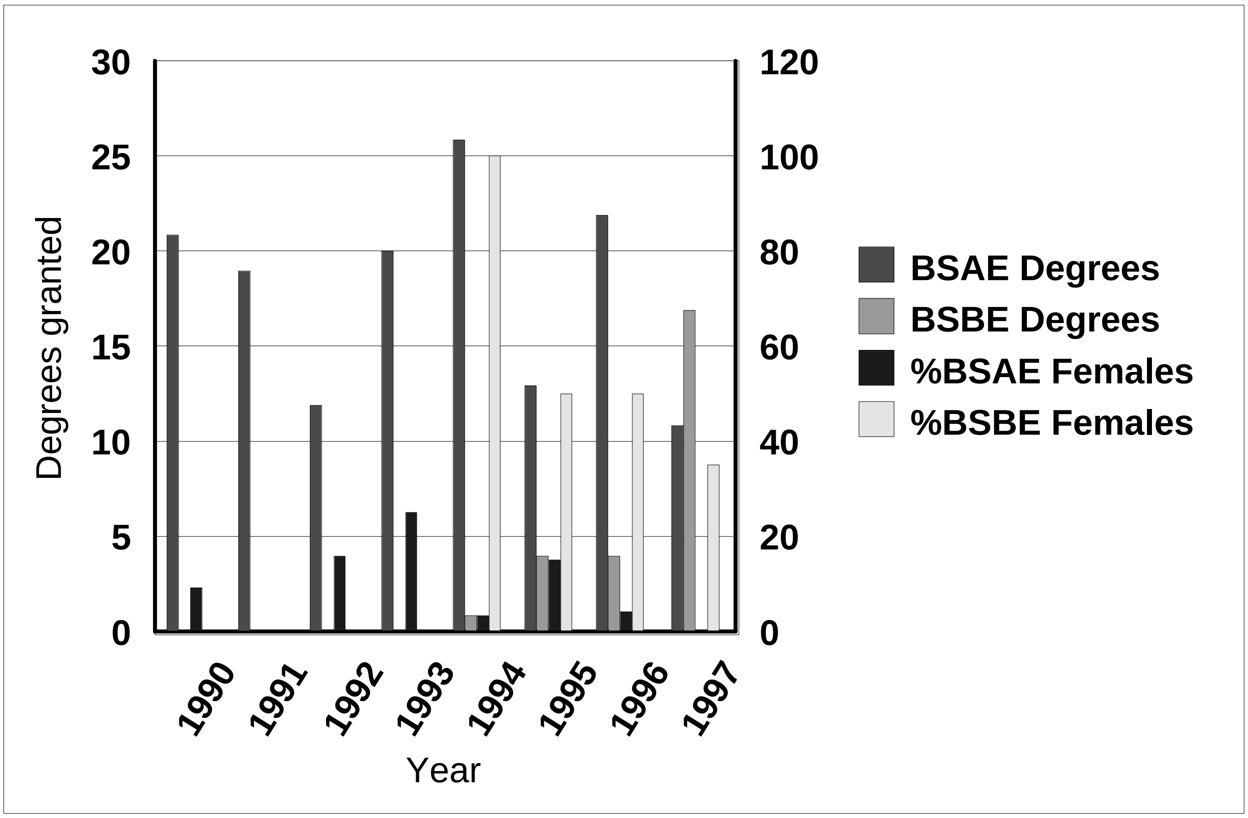

Figure 7. Total AEN and BEN degrees awarded over the past decade along with % females plotted for each degree by year.