Int. J. Engng Ed. Vol. 22, No. 1, pp. 93–101, 2006
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Challenges for Bioresources Engineering Education in South Africa

J. C. SMITHERS
School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg Campus, Private Bag X01, Scottsville 3209, South Africa. Email:smithers@ukzn.ac.za

The objective of this paper is to illustrate the scope, uniqueness and opportunities for Agricultural Engineering and to present an overview of Agricultural Engineering education in South Africa. The need for engineers in South Africa is assessed, and the output from the schooling system in South Africa to meet this need is illustrated. Thereafter, the performance of engineering students at the University of Natal is analysed and selected challenges and opportunities for agricultural engineers in South Africa are summarized. From the results of the study it is evident that the performance of students in their final year of school is a poor indication of their performance in their first year of engineering studies and the standard of the school education system presents challenges to tertiary engineering educational institutions that need to focus on the retention and throughput of students.

Keywords: agricultural engineering; bioresources engineering; agricultural degree accreditation; GPA

INTRODUCTION

Engineers identify peoples' needs and use innovation, ingenuity, science and technology to provide optimum solutions for these needs. Various definitions of 'Agricultural Engineering' exist. For example, according to [1] 'Agricultural, Food and Biological Engineers develop efficient and environmentally sensitive methods of producing food, fiber, timber, and renewable energy sources for an ever-increasing world population'. Another definition is 'Agricultural engineers connect the living world of plants, soil, water and animals with the technology of engineering, i.e. systems, structures and machines' [2]. Thus agricultural engineers have a unique field of work that is exclusive of other engineering disciplines.

In South Africa the discipline of agricultural engineering is small relative to other engineering disciplines. Up to the end of 2003, degrees in Agricultural Engineering were offered through the Universities of Natal (NU) and Pretoria (UP). From 2004 the UP no longer offered a degree in Agricultural Engineering and the University of Natal merged with the University of Durban-Westville to form the University of KwaZulu-Natal (UKZN). For the purposes of this paper the information and statistics presented are associated with the NU, under whose auspices the degree was awarded for the period under consideration (1993–2003).

As will be outlined in the paper, the terms 'agricultural' or 'bioresources' engineering are interchangeable, although the former is perceived to have less marketing appeal and a smaller scope than the latter term. For the purposes of this paper and for uniformity, the term 'agricultural engineering' (AE) will be used, even though 'bioresources engineering' has been used since 1999 in marketing the degree at NU, and in the name of the school (Bioresources Engineering and Environmental Hydrology) through which the degree was offered at NU and continues to be offered through the UKZN.

The objectives of this paper are to provide an overview of the training of agricultural engineers in South Africa. The need for engineers in South Africa is assessed, and the output from the schooling system in South Africa to meet this need is illustrated. Thereafter, the performance of engineering students at the NU is analysed before selected challenges and opportunities for agricultural engineers in South Africa are summarized.

AGRICULTURAL ENGINEERING EDUCATION IN SOUTH AFRICA

As shown in Fig. 1, the average annual total number of graduates from the agricultural engineering programmes at the UP and NU has declined from a peak of 22 engineers in 1996 to approximately 10 engineers per year from 1998 to 2003. It is also evident that the increase in undergraduate agricultural engineering students at NU coincided with the decrease in undergraduate numbers at UP. For postgraduate studies, UP offered BEng (Hons), MEng and PhD postgraduate degrees while the NU offered MScEng and PhD degrees. During the period 1990 to 2003, only two agricultural engineering PhD degrees were awarded, both from NU. As shown Fig. 1, the number of postgraduate agricultural engineers produced by the two programmes is variable from year to year, but approximately 38% of the graduates continue with their studies and are subsequently awarded postgraduate qualifications.

* Accepted 23 August 2005.

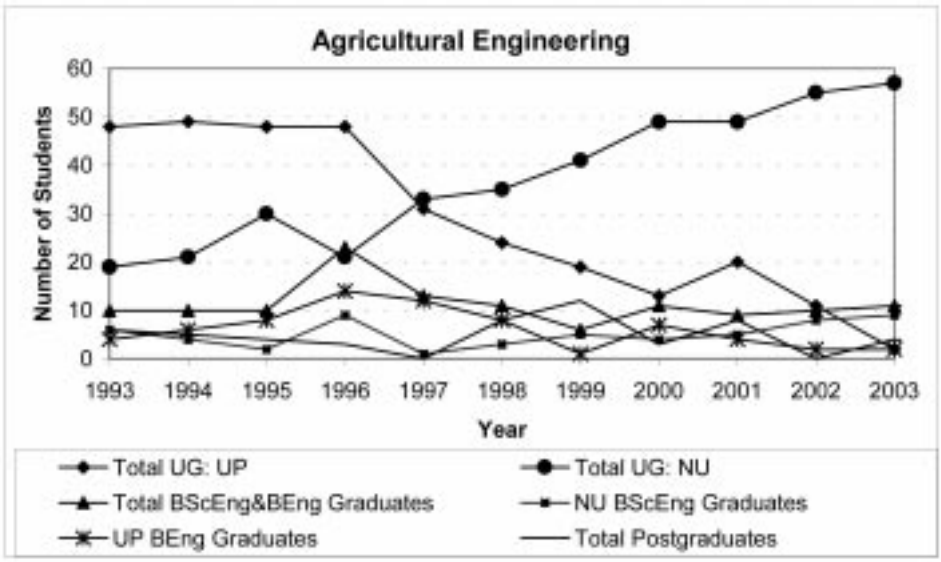

Fig. 1. Number of agricultural engineering undergraduate (UG) and postgraduate students in South Africa: 1993–2003.

PROGRAMME CONTENT

The purpose of the BSc Agricultural Engineering Programme at NU is to prepare engineers with appropriate and sustainable skills and knowledge, as well as with a professional, collaborative and innovative outlook, who are competent to address the needs of society in the field of engineering applied to the production, management and/or processing of biological resources. The programme is structured to be completed over a period of four years. Modules range from the fundamental and basic sciences, which are taught in the first year, to the application of the science in the second year, to the solving of engineering problems in the third year and finally to the solving of open ended engineering problems related to agricultural engineering in the fourth year of study. In addition to the specialist Agricultural Engineering modules, the programme uses modules offered by the Civil, Electrical and Mechanical Engineering and the Applied Environmental Sciences programmes.

Given the relatively small numbers of Agricultural Engineering staff and the broad scope of agricultural engineering, the NU programme traditionally focused on 'Power and Agricultural Machinery' and 'Soil and Water' as specialist agricultural engineering fields of study and, to a lesser extent, on other fields such as 'Agricultural Structures'. The current focus of the specialist Agricultural Engineering modules is, to a large extent, on first world, commercial agricultural applications. For example, diesel engine performance, tractor traction, combine harvesters and associated implements are some of the topics covered in lectures, while animal power and associated implements receive little attention. Similarly, irrigation design focuses on the design of irrigation systems, typically used by large commercial farmers or agricultural estates, with little emphasis on the requirements of subsistence, emerging and small-scale farmers.

Table 1. Outcomes required by ECSA

Number	Outcome
1	Engineering problem solving
2	Application of fundamental and specialist knowledge
3	Engineering design and synthesis
4	Investigations, experiments and data analysis
5	Engineering methods, skills, tools and information technology
6	Professional and general communication
7	Impact of engineering activity on society and the environment
8	Team and multidisciplinary working
9	Lifelong learning
10	Professional ethics and practice

PROFESSIONAL ACCREDITATION OF THE AE DEGREE

The Agricultural Engineering programme at NU is accredited by the Engineering Council of South Africa (ECSA) with on-site accreditation visits performed every four years. ECSA have identified ten generic outcomes, listed in Table 1, which university engineering programmes in South Africa have to meet as part of the accreditation requirement. In addition, and as contained in Table 2, ECSA specify a minimum distribution of content within prescribed knowledge areas that have to be covered by the engineering programmes. Included in Table 2 is the distribution of knowledge areas covered by the Agricultural Engineering programme offered at the NU. From Table 2 it is evident that agricultural engineers at NU receive a thorough grounding in mathematics and engineering sciences, with much of the permissible discretionary knowledge (25%)

falling into these two fields, but the NU Agricultural Engineering programme still meets the minimum ECSA requirements in all the other knowledge areas.

NEED FOR ENGINEERS IN SOUTH AFRICA

In order to sustain an economic growth of 3% to 5% in South Africa, it is estimated by the South Africa Association of Consulting Engineers that the number of consulting engineers will need to double over the next ten years or economic growth will be seriously affected [3]. The Human Sciences Research Council in South Africa identify engineers as playing a crucial role in industrial development, but believe that currently there is no shortage of engineering skills and that there is a shift towards employers recruiting engineers with postgraduate qualifications [4, 5]. However, the challenge to meet the growing demand for high quality black and female engineering graduates is made difficult by the legacy of poor quality mathematics and science education in historically black schools [5]. Woolard *et al.* [6] expect the 'demand for engineers to remain strong' as a result of new technologies in all spheres of life and forecast a 1.4% annual average increase in engineering positions for the period 2001 to 2006. This translates into a 3.4% annual shortage of engineers in order to meet new and replacement demands [7].

The total number of registered professional engineers for all disciplines has declined in South Africa from a peak of 15530 in 1998 to 14861 in 2003 [8]. Similarly, the total number of candidate engineers has generally declined for the period shown [8]. Emigration of engineers is an important factor in South Africa [4] and may partially explain the decrease in the population of registered engineers in South Africa. Woolard *et al.* [6] report that it is unclear if the declining employment of engineers is due to a decline in demand or a decrease in supply, while Kraak [7] reported that that the decline mirrors the general decline in engineering graduates in South Africa since the mid-1990s. There has also been a shift in the age distribution of engineers. Steyn and Daniel [4] report a reduction in the number of engineers in the 21–30 year age group with this group making up 37% of the engineers in 1995 and decreasing to 27% in 2001, with the 31–40 age group increasing correspondingly.

It is thus possible that the decline in the total population of professional and candidate engineers in South Africa could retard economic growth and, with engineers being in short supply, should lead to an increased demand for engineers. This demand will need to be met by universities recruiting and producing more engineering graduates. The relative decrease in the contribution of the agricultural and mining sectors to the gross domestic product (GDP) in South Africa has resulted in a reduction in demand for engineers with expertise in these sectors, with a related increase in demand for engineers in the manufacturing and service related technologies [4]. However, a preliminary study [9] indicates that at least 19 positions for agricultural engineers are currently available in the Provincial Departments of Agriculture (PDA) alone. Moreover, at least 16 additional positions have been advertised for agricultural engineers, ranging from graduate to more experienced levels, in one national Sunday newspaper during the period January to June 2004. The need for agricultural engineers and the shortage of supply has been recognized both by the National Department of Agriculture (NDA), which advertised 25 bursaries for Agricultural Engineering students in 2004, as well as by at least three PDAs, which currently offer bursaries for Agricultural Engineering students. The ability to recruit suitable school pupils with the necessary academic background and interest in Agricultural Engineering is largely dependent on the marketing of Agricultural Engineering as a career and on the school education system.

Table 2. ECSA prescribed minimum knowledge areas

Knowledge area	ECSA minimum (%)	NU: 2003 (%)
Mathematics	10.0	17.7
Basic sciences	10.0	10.9
Engineering sciences	30.0	41.3
Design and synthesis	12.0	14.3
Computing and IT	3.0	3.9
Complementary studies	10.0	11.9
Discretionary	25.0	
Total	100.0	100.0

MARKETING OF AGRICULTURAL ENGINEERING IN SOUTH AFRICA

In 1999 the Department of Agricultural Engineering at NU was renamed the School of Bioresources Engineering and Environmental Hydrology (BEEH). Hydrology was included in the name of the School as BEEH also offers a BSc degree in hydrology through the Faculty of Science and Agriculture. The term 'bioresources' was adopted as it incorporated the many opportunities for agricultural engineers that exist beyond the farm gate and where many of the graduates from NU currently find employment. From a marketing point of view, the name 'Bioresources Engineering' has generated much more interest from both the general public and school pupils than the traditional 'Agricultural Engineering' name. It is postulated that the growing undergraduate student numbers at NU, illustrated in Fig. 1, may be partially attributed to the name change.

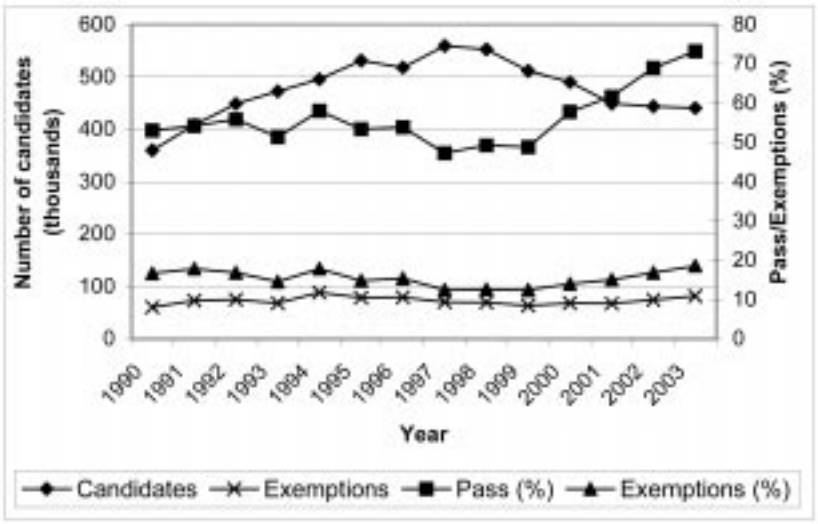

Fig. 2. Number and pass rates of school pupils writing Senior Certificate Examinations in South Africa [10].

THE SCHOOL EDUCATION SYSTEM

With the advent of democracy in South Africa in 1994, the school education system has undergone significant changes in an attempt to redress the inequalities of the past. This has included the phased implementation of an outcomes-based education approach and the writing of common final Senior Certificate Examinations (SCE), which were previously set independently by the Provincial Departments of Education. The number and performance of pupils writing the SCE are shown in Fig. 2 [10]. The number of pupils writing SCE has decreased since 1996 and the pass rate has increased substantially since 1999, while the number of pupils receiving exemptions, which allow them to pursue university education, has also increased but to a lesser extent. The net result is a small increase in the number of pupils obtaining exemptions for their SCE. Hence, there should be a larger pool of potential students who are suitably qualified to study engineering. The performance of these pupils in the Engineering Faculty at NU is examined in the following section.

PERFORMANCE OF STUDENTS IN THE NU FACULTY OF ENGINEERING

The average number of first year engineering students registered in the Faculty of Engineering at NU was 360 and the annual variation for the period 1990 to 2003 ranged from 301 to 423 students. For the period 1990 to 1998, the number of engineering graduates per year ranged from 151 to 192, with an average of 174.

Table 3. Allocation of points for grades achieved in SCE

Symbol achieved in Senior Certificate subject	Number of points allocated	
	Higher grade	Standard grade
A	8	5
B	7	4
C	6	3
D	5	2
E	4	1
F	1	0

All students entering the faculty are generally required to meet the minimum requirements set by the Engineering Faculty which stipulates a minimum mark of 60% in Senior Certificate Mathematics and Physical Science, both at the higher grade, and a points score of at least 36 points, which is calculated using the points allocation shown in Table 3. A frequency analysis of the number of points obtained by first year engineering students entering the faculty is contained in Fig. 3, which indicates a sharp increase since 2001, over the entire distribution, in the number of points per student. An analysis of the credit weighted Grade Point Average (GPA) obtained by first year engineers is shown in Fig. 4 and indicates that significant numbers achieved a GPA of less than 50%, but there was some improvement since 1998 in the GPAs achieved by the poorer performing students. Similar trends are evident when the pass rate of first year modules are considered, as shown in Fig. 5. However, the trends in Fig. 5 also show that since 1994 a larger proportion of first year engineers are not passing all their first year modules in their first year of study. The number of years taken to complete the four-year engineering degree is shown in Fig. 6, which indicates a consistent decline since 1992 in the number of students completing the degree in the minimum prescribed time. The proportion of students taking more than 4 years has remained relatively consistent over the time period considered. However, the percentage of students who registered for engineering and who were either excluded, or who voluntarily de-registered, shows an increasing trend from 1990 to 1996. The apparent increase in the retention of students in the faculty after 1996 is influenced by

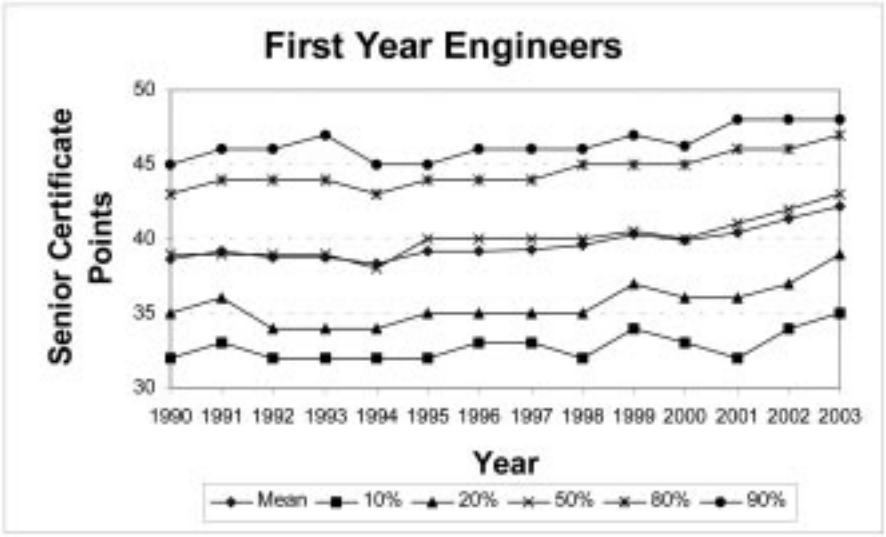

Fig. 3. Frequency distribution of Senior Certificate points of first year engineering students at NU: 1990–2003.

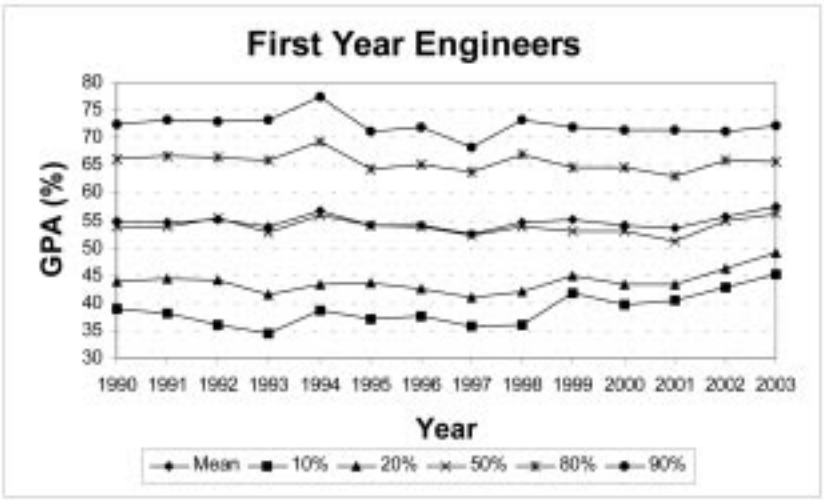

Fig. 4. Grade point average for engineering students at first year level: 1990–2003.

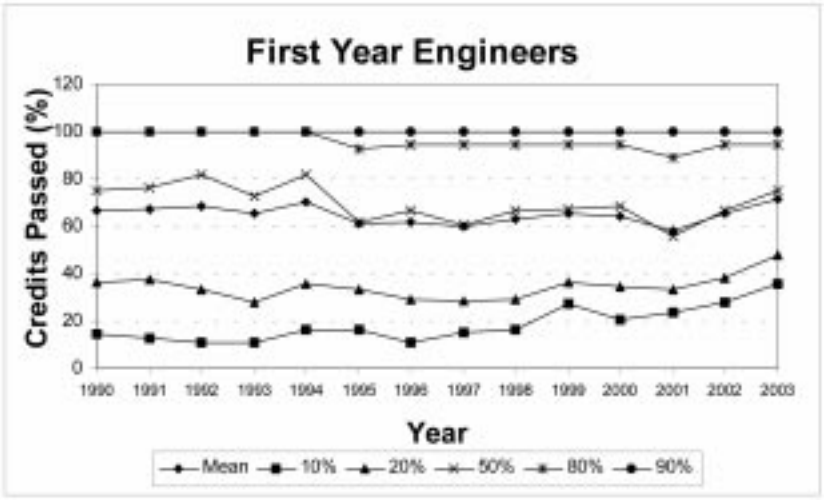

Fig. 5. Percentage of credits passed by first year engineers: 1990–2003.

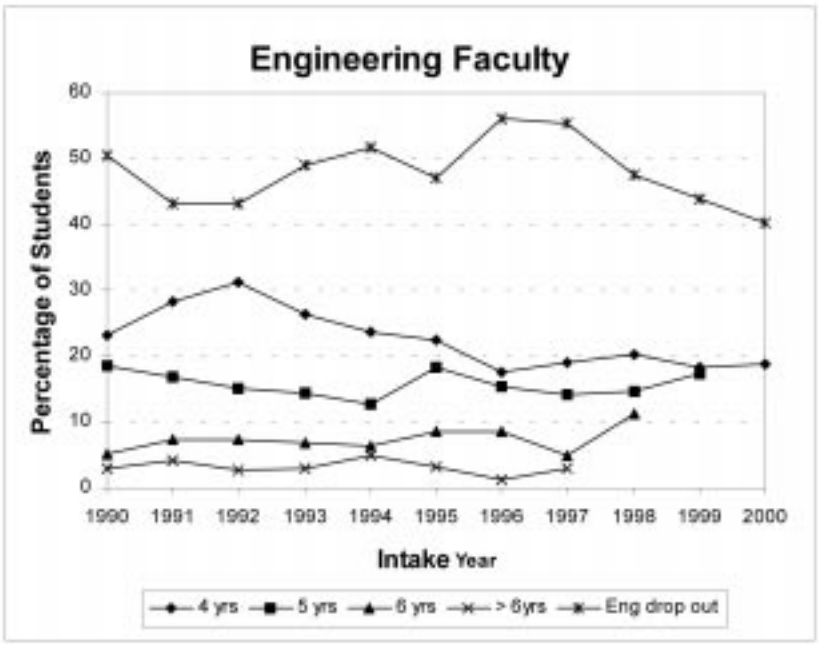

Fig. 6. Number of years taken to complete a BSc Eng degree at NU: 1990–2000.

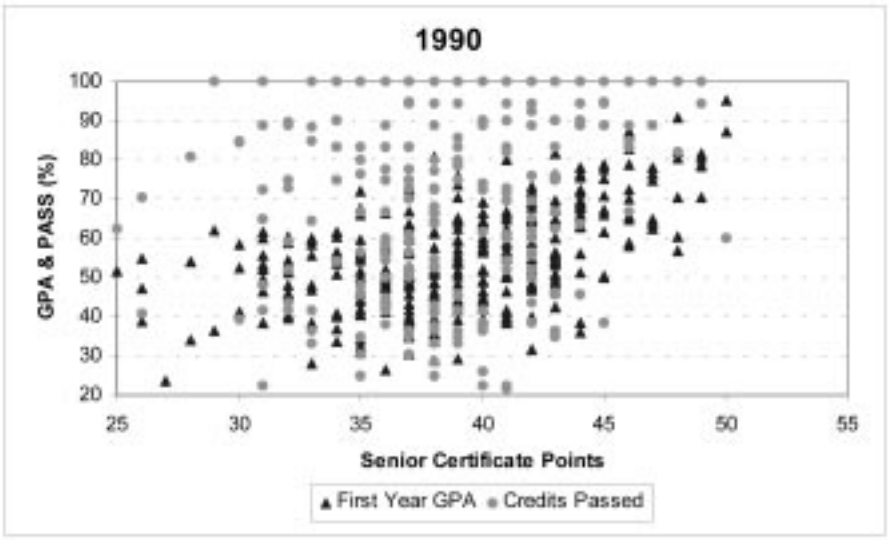

Fig. 7. Performance of first year engineers at NU: 1990.

the students who were still registered in the faculty and had not yet 'dropped out'. From the above analysis it is concluded that the throughput and retention rates in the Engineering Faculty are major areas of concern.

The distribution of first year GPAs and percentage of credits passed vs. points obtained in the SCE are shown for the years 1990 and 2003 in Figs 7 and 8 respectively. Clearly, the distribution of SCE points and the performances of the students are different between these two years. The Kendall correlation coefficient (t) is summarized for the period considered in Fig. 9 and, although the correlation between GPA and points is significant at the 1% level for all the years considered, the degree of correlation has generally decreased over the time period considered, indicating a weaker correlation between SCE points and performance of first year of engineering students at NU.

CHALLENGES AND OPPORTUNITIES FOR BIORESOURCES ENGINEERS

Some of the challenges facing South Africa where agricultural engineers can make valuable technological inputs include:

- sustaining our environment for current and future generations,
- ensuring sufficient and adequate supply of water,

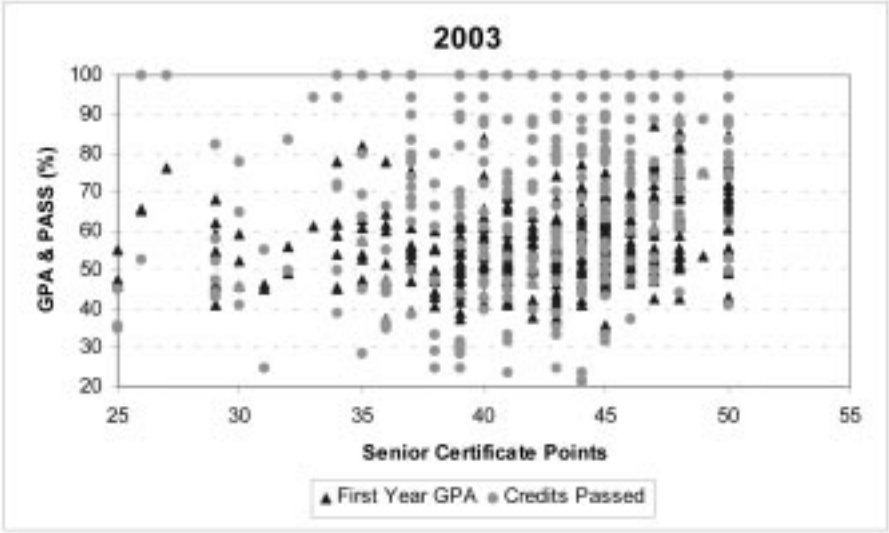

Fig. 8. Performance of first year engineering students at NU: 2003.

- ensuring sufficient food to feed the population,
- coping with climate variability and climate change, and
- poverty alleviation and socio-economic upliftment.

As in many countries of the world, South Africans have high levels of environmental awareness and recognize the need for sustainable environmental management and food production. For example, the LandCare project, which is a community based and government supported approach to the sustainable management and use of natural resources, is identified as a key programme by the National Department of Agriculture [11].

As shown by Schulze [12], South Africa is a semi-arid country with both a highly variable climate and distribution of water resources. The implementation of the relatively new and far-reaching National Water Act [13] has introduced new paradigms and significant challenges in the management of water resources in South Africa. These include the provision of reserves to meet human and ecological requirements as primary priorities, the devolution of the responsibility for the management of water from a national to a regional level and the requirement that stakeholders participate in the management of water resources. It is estimated that in 1990 irrigation used more than 50% of the surface water in South Africa and this percentage is expected to decline to 45.9% in 2010 [14]. With the increasing demand for water in South Africa, increasing pressure will be on irrigators to use less water and to use water more efficiently. In all these activities, which have catchment management as a focus, agricultural engineers have an important role to play.

Rural development, poverty alleviation and socio-economic upliftment are focus areas of the current government in South Africa, and agriculture has a

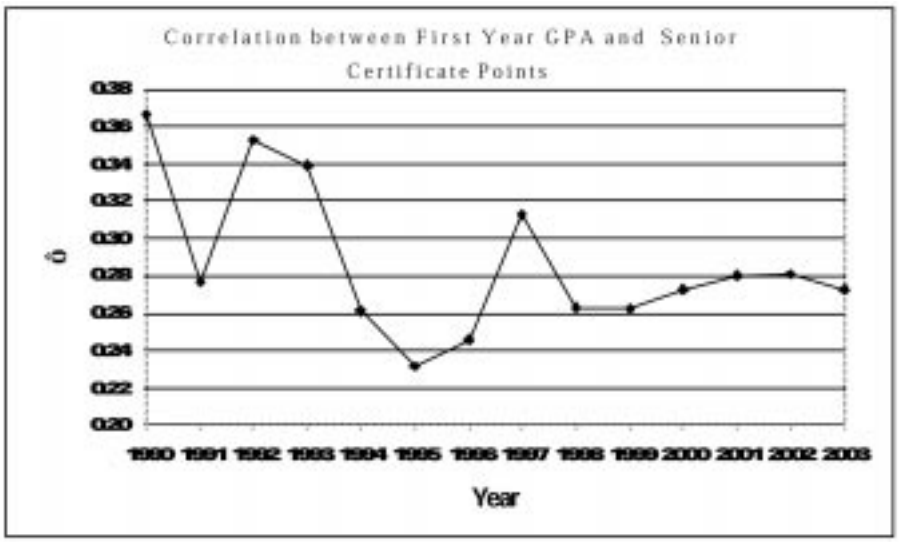

Fig. 9. Kendall correlation coefficient (t) between first year engineering GPA and SCE points at NU: 1990–2003.

large role to play in this respect. It is postulated that appropriate technology, developed and adapted for local conditions by agricultural engineers, can aid both subsistence and emerging farmers to be more efficient and productive.

Other potential growth areas for agricultural engineers in South Africa are in the fields of forest engineering, food process engineering and machinery management. Significant forest activities take place in South Africa and it is perceived that agricultural engineers could play a larger role in this field. Initiatives to add value to agricultural products on farms will benefit from input by agricultural engineers. With diminishing profit margins for farmers and the capital-intensive nature of commercial farmers, the efficient and effective use of expensive machinery is vital to the success of commercial agricultural operations.

Steyn and R. C. Daniel [4] believe that the number of school leavers with the required academic qualifications and the perceived unattractiveness of the engineering profession, limit the number of school leavers entering the engineering profession. These issues have been addressed by many tertiary institutions, including NU, by bridging programmes to develop underprepared students from an inadequate schooling system and by marketing the different engineering disciplines.

Engineers with entrepreneurial skills are increasingly required [4]. In order to compete in the global economy, high quality, high value export-orientated manufacturing and services are required that can be attained with high levels of general education and the development of multi-functional skill capabilities, which will enable workers to be able to rapidly adapt to changing market needs [7]. It is postulated that the broad-based education that agricultural engineers receive make them strong candidates to compete and succeed in the global economy.

DISCUSSION AND CONCLUSIONS

Engineers are needed to sustain economic growth in South Africa and the decline in both registered professional engineers and engineering graduates is of concern. School leavers with the appropriate academic potential need to be convinced that engineering is an appealing career. This requires the marketing of engineering as a career and high exit standards from the schooling system.

Although the number of pupils writing the SCE has declined in recent years, the number of pupils obtaining university exemptions has increased. The results presented in this paper clearly indicate an increase in the number of points obtained for the SCE by students entering the Engineering Faculty at NU. While this seems to have improved the first year GPA results for the distribution of students who were not doing well, it has had little effect on the distribution of the students who were doing well. It is also evident that only half the first year students have a first year GPA above 55%, with a large proportion falling below the 50% level.

Even though the correlation between the points obtained in the SCE and the students' performance in the Engineering Faculty is statistically significant for all the years considered in this study, the correlation is growing weaker. This is also evident in the smaller percentage of students completing the degree in the minimum prescribed period and the larger percentage of students either being excluded or not completing their studies in the faculty. Hence, it is concluded from the results presented in this paper that the performance of school pupils in the SCE is a poor indication of their performance during their first year engineering studies.

Student retention and throughput are issues that need to be addressed and these will adversely affect the Engineering Faculty by new government funding policies which target both these issues. Given the weakening correlation between the SCE points and student performance, it is essential that strong consideration be given to the introduction of independent faculty entry examinations. One option to address the throughput rate is to admit fewer students with good potential.

The UKZN is currently the only university to offer a degree in agricultural engineering in South Africa. It is postulated that the current situation and environmental issues in South Africa will result in an increased demand for agricultural engineers, both in the short and medium term. Studies have indicated a growing demand for engineers with postgraduate qualifications. There is thus a need to produce more agricultural engineers and to continue to increase the number of postgraduate students in Agricultural Engineering at the UKZN. However, in order for this happen, pupils with the necessary academic background and interest in agricultural engineering have to be available. From a university academic's perspective there is little that can be done to influence the school education system in South Africa. University initiated bridging programmes are in place and are being extended in an attempt to prepare students from disadvantaged backgrounds for university education. The marketing of 'Bioresources Engineering' as a career is actively pursued by BEEH and, to some extent, by the South African Institute of Agricultural Engineers. The recent availability of bursaries by the National and some Provincial Departments of Agriculture is an indication of the increasing awareness of the need for agricultural engineers. However, with the limited pool of suitable candidates and the severely limited financial resources available from the families of potential students, bursaries are often accepted by students irrespective of their interest in pursuing a career in agricultural engineering, which may limit the performance of the student.

It is necessary to prepare engineers who can

excel not only nationally, but also internationally, with appropriate and sustainable skills and knowledge, and with a professional, collaborative and innovative outlook, to competently address the needs of society in the field of bioresources engineering. Without distracting from the academic excellence this requires, it is important to ensure that the contents of the agricultural engineering programme at UKZN are relevant for the local context and to the environment in which many of the engineers will find employment. Thus, the programme needs to be broadened from the current focus on commercial, large scale agricultural applications to expose the students to issues related to small-scale, subsistence and emerging farmers. Thus, using the same principles an irrigation system may be designed for an emerging, small-scale or subsistence farmer as are used in the design of a large-scale commercial irrigation system. It is important that graduates are aware of, and sensitive to, both contexts.

Acknowledgements—Dr Charlotte Mbali of the Centre for Higher Education Studies, UKZN, is gratefully acknowledged and thanked for making available student records and scripts for SPSS that aided in the analyses presented in this paper.

REFERENCES

1. ASAE, 2004. Available from http://www.asae.org/about.html [Accessed on 9 June 2004].
2. BEEH, 2004. School of Bioresources Engineering and Environmental Hydrology. Available from http://www.beeh.unp.ac.za/ [Accessed on 9 June 2004].
3. C. Clarke, Meet the 2004 President—Craig Clarke, *Inside Track*, (March 2004), SAACE, Johannesburg, South Africa, 2004.
4. G. Steyn and R. C. Daniel, Chapter 24: Engineers and Technicians, *Human Resources Development Review 2003: Education, Employment and Skills in South Africa*, A. H. Kraak and H. Perold (eds), HSRC Press, Cape Town, South Africa (2003).
5. HSRC, 2004. Available from http://www.hsrc.ac.za/media/2004/2/HRDFactSheet8.pdf [Accessed on 9 June 2004].
6. I. Woolard, P. Kneebone and D. Lee, Chapter 20: Forecasting the demand for scarce skills: 2001–2006, *Human Resources Development Review 2003: Education, Employment and Skills in South Africa*, A. H. Kraak and H. Perold (eds), HSRC Press, Cape Town, South Africa, (2003).
7. A. H. Kraak, Chapter 28: HRD and the skills crises, *Human Resources Development Review 2003: Education, Employment and Skills in South Africa*, A. H. Kraak and H. Perold (eds), HSRC Press, Cape Town, South Africa (2003).
8. ECSA, Register of Engineers, Engineering Council of South Africa, Johannesburg, South Africa (2004).
9. A. van Niekerk, Personal communication. AvN Consulting, Hilton, South Africa (9 June 2004).
10. P. Lolwana, Judging the standards of the Senior Certificate Results, *AMALUSI News: March 2004*, UMALUSI, Pretoria, South Africa (2004).
11. NDA, 2004. National Department of Agriculture. Available from http://www.nda.agric.za [Accessed on 9 June 2004].
12. R. E. Schulze, South African Atlas of Agrohydrology and -Climatology, Water Research Commission, Pretoria, RSA (1997), p. 276.
13. NWA, National Water Act (Act No. 36 of 1998), Government Printers, Pretoria, South Africa, 1998.
14. DWA, Chapter 2.1: Estimation of water demand, *Management of the water resources of the Republic of South Africa*, The Department of Water Affairs, Pretoria, South Africa (1986).

Jeff Smithers is Professor of Agricultural Engineering at the University of KwaZulu-Natal in South Africa and is currently head of the School of Bioresources Engineering and Environmental Hydrology. His research interests include engineering hydrology and hydrological modelling. He is a Fellow of the South African Institute of Agricultural Engineers and a member of the American Society of Agricultural Engineers. He is a registered professional engineer with the Engineering Council of South Africa and is currently vice-president of the South African Institute of Agricultural Engineers. He received his PhD, MSc Engineering and BSc Engineering (Agric) degrees from the University of Natal in South Africa.