Decreasing student numbers—along with related causes and concerns—is a common topic of discussion in the international soil science community. Such discussion is seldom quantitative. Here we present long-term student numbers (in undergraduate courses as well as MS and PhD graduates) of soil science departments in North America, Europe, and Oceania. A previous study by P. Baveye and co-workers had shown that in the United States and Canada student numbers fell by 40% in more than 80% of the universities between 1992 and 2004. The United States and Canada experienced an increase in female students in soil science between 1992 and 2004. Meanwhile, the number of foreign students has decreased. Student numbers have also decreased in New Zealand. Numbers at Dutch universities decreased in the early 1990s but have since stabilized. Two of three Australian universities had increasing numbers of students for undergraduate courses as well as MS and PhD graduates. Currently in the Netherlands almost half of all MS soil science graduates are female, while in the 1970s and up to the mid-1980s 80% or more of soil science graduates were male. It seems that teaching is becoming more general (more introductory courses to a range of other disciplines), while soil science research is experiencing an opposite trend: specialization.

INTERNATIONAL SURVEY
A questionnaire was sent to 43 colleagues at universities in Europe, North America, South America, Africa, and Oceania. We requested long-term data (>25 years) on student numbers between 1980 and 2005. Twelve responses were received.

One of the aims of this research was to quantify trends in student numbers, and it is therefore unfortunate that we were not able to get data from several countries in which soil science is highly important or had made major contributions. For example, no response was obtained from the United Kingdom, where only a few soil science departments have remained; others have closed, have been re-labelled, or have been merged with other departments.

It is a tedious job to extract the type of information requested; this may have contributed to the low response rate. In addition, some of those who received the survey might have felt uncomfortable with the results and were not keen to have them published even though we tried to make it as anonymous as possible. Baveye et al. (2006), who surveyed 61 universities in the United States and Canada, found that some universities could not respond because their legal counsel found it unethical and inappropriate to release information about graduate students. That could be another reason for the limited response in our study.

As only 12 universities responded, the results presented here may not be representative of the whole globe. Here we discuss the main trends and speculate on their possible causes, followed by some discussion on the future of soil science education and student numbers.

STUDENTS IN SOIL SCIENCE
North America
Baveye et al. (2006) surveyed 61 soil science departments in the United States and Canada in 1992 and in again in 2004. The total number of soil science gradu-
ates (MS and PhD) in 1992 and 2004 is depicted in Figure 1. The number of PhD students decreased (~63%), of the 36 institutions that responded, 5 universities had increased enrollment, 1 university had constant enrollment, and 30 had decreased enrollment.

A major trend was the increase in the number of female students for both MS and PhD graduates (Figure 2). The number of foreigners decreased (Figure 3). In 1992, it was found that female students were almost exclusively interested in environmental applications, while male students and students from rural areas were more interested in agricultural issues.

We also received 25 years of student data from a university in the Midwestern United States. Figure 4 presents the number of students in three different courses. The "Soils" course is made up of about 10% majors in agronomy, so 90% of the students are outside agronomy and soils. The "Soil Fertility" course is made up of majors in agronomy or turf science, and the agronomy major includes those with specific interest in soil science. The "Environmental Quality" course is a general education course; it is within the list of courses that students select to broaden their perspective and to get exposed to environmental issues related to soil. Undergraduate students come from production, business, consulting, plant breeding, and soil and environmental sciences. Some of the production, consulting, and business students may be soil science oriented.

Europe

In the Netherlands, serious soil investigations were started by W.C.H. Staring in the mid-1800s, followed by J. Van Baren in Wageningen, and D.J. Hisink in Groningen in the early 1900s. Soil science rapidly expanded in the mid-1900s with university courses in Amsterdam, Groningen, Utrecht, and Wageningen and the establishment of research institutes (Bouma and Hartemink 2002). After World War II, the number of soil scientists was very large and the knowledge base of Dutch soil science grew enormously. In 1998, there were 23 soil scientists per 100,000 ha (247,000 ac) agricultural land in the Netherlands compared with 3 in France and Denmark and 6 in the United Kingdom (van Baren et al. 2000).
Currently, soil science is taught at five Dutch universities, although not all have majors in the subject. Enrollment of first year earth science students is depicted in figure 5; these first year students include those who will study geology or petrology. The general trend is that numbers declined from the early 1990s but more or less stabilized since the late 1990s. The number of master's level graduates with a soil science major at Wageningen University is given in figure 6. The number of Dutch master's level students (Ingenieurs [Ir] is the Dutch equivalent of MS) peaked in the mid-1990s, decreased, but then had another peak in 2004. The number of foreign MS soil science graduates was around 10 for most of the 1990s.

The most remarkable shift has been in the ratio between male and female soil science graduates (figure 7). Up to the mid-1980s, 80% or more of soil science graduates were men; from then on, the women-to-men ratio increased and has been around 50% to 55% in the past six years (with the exception of 2002). A similar trend, although starting later, happened with the foreign MS students; 70% of soil science graduates in 2005 were female (figure 8). The MS program used to be a two-year program, so there were no graduates every other year from the start of the foreign MS program at Wageningen University in 1972 until it changed to an 18-month program in the 1980s (hence, the gaps in the graph).

The ratio of foreign versus national MS/Ir soil science students is plotted in figure 9. In the 1970s and 1980s, about
40% to 50% of all soil science graduates were foreigners; thereafter, the share of foreigners decreased (except for the year 2000). In the past five years, foreign MS students were less than 40% of all soil science graduates at Wageningen University.

Oceania

Survey responses were received from three universities in Australia and one in New Zealand.

Soil science is taught in 16 universities in Australia. For our study, information on soil science courses and undergraduate, MS, and PhD theses was received from three universities (in Adelaide, Brisbane, and Sydney).

The University of Adelaide has trained soil scientists since the Waite Agricultural Institute opened in 1924. Since World War II, the university has produced on average at least one graduate in soil science per year at BS honors, MS, and PhD levels.

The number of BS honors and PhD graduates has increased since 1995 to about 4 to 5 per year. The number of soil science theses for BS honors, MS, and PhD levels is presented in figure 10.

The number of students attending the “Introductory Soils” and “Soil-Plant Relationships” courses more than halved between 2000 and 2006 at the University of Queensland, Brisbane (figure 11). The trend is comparable to the data from the United States (figure 4), but these are
short-term data; longer term data have shown that interannual fluctuation is considerable.

At the University of Sydney, the second year course is an introductory one on soil properties and processes. The third year course is an applied course focusing on soil mapping, soil geography, and environmental issues. The fourth year consists of a large research project and three separate more advanced courses on soil chemistry, soil physics, and pedology. The number of BS students in second and third year soil science courses increased between the early 1990s and 2005. Student numbers in the fourth year is steady. The number of MS and PhD graduates has fluctuated considerably in the past two decades, but the number of PhD students is larger now than in the late 1980s and early 1990s (figure 12).

In New Zealand, soil science is taught at six universities. Figure 13 presents data from one university on student enrollment in soil science courses at the second, third, and fourth year. There is a general increase from the early 1980s to a peak in the mid-1990s, after which the numbers in the second and third years decreased to the level of the early 1980s. The large numbers in mid-1990s probably reflect baby boom echo—that is, an overall surge in young people heading to university. The soil science enrollment decline from early 2000s mirrors a decline in enrollment at the whole university.

**SOIL SCIENCE TRENDS**

The main trends include decreasing numbers of soil science students in several parts of the world, a shift in MS/PhD, male/female, and foreigner/national student ratios, and increased teaching to other disciplines.

**Numbers of Soil Science Students**

The number of soil science students declined in some but not in all universities, and some differences exist between countries. In the United States and Canada, the number of students decreased by 40% in about 80% of the universities, while in Australia two out of three showed a steady increase in student numbers attending soil science courses and the number of graduates. In a university in New Zealand, the number of soil science students has decreased recently, while in the Netherlands that decrease happened 10 years earlier and student numbers are steady now. Kenya and Tanzania have experienced decreasing numbers as well, despite the importance of agriculture for 80% of the population (Ngugi et al. 2002). Considerable variation was found in the annual number of students attending courses or graduating. The fluctuation in student numbers is partly due to overall university enrollment and number of high school graduates.

In the United States and Canada, the number of soil science PhDs is decreasing relative to the number of MS graduates. In other parts of the world (e.g., the Netherlands and Australia), it is more or less the other way around: fewer students are graduating at the BS honors or MS levels, and the number of PhD graduates in soil science is increasing. In part this has to do with increased higher education in the developing world, while students are more likely to go on for doctoral education in Europe and Australia.

If we assume that total number of students has not decreased, then the decline in soil science students is absolute. However, at some universities the decline in soil science student numbers may mirror the decline in overall enrollments. All in all, students seem to prefer other studies (business, law, and medicine), and these are generally viewed as money-making degrees. The decline is not unique to soil science but has also occurred in geology, geography, weed science, chemistry (Baveye et al. 2006), and several other disciplines such as physics. In 2003, less than 500 US citizens earned physics PhDs, the lowest number since the early 1960s (Nature, December 1, 2005). Overall, there is a strong growth in information science, medicine, and computer science and little
student growth in engineering, mathematics, and physical sciences.

External factors include high school education systems, societal and university changes, and more internal factors such as links to agriculture, the re-labeling of the discipline, and “the failure to excite” factor. In many countries, soil science has maintained strong links with agriculture, while the interest in agriculture in the developed world has diminished. That has several causes, including there being enough food but also because there are far fewer farmers and many of them have higher degrees themselves (in the Netherlands, 20% of the farmers have a university or polytechnic degree). In other words, fewer academics are needed in agriculture—so they think.

Other problems start at high school. In the Netherlands, for example, the high school curriculum was rearranged 10 years ago into different profiles. These profiles (e.g., nature and technology, culture and society) contain six to eight fixed subjects and replaced the classic model in which high school students chose their own set of subjects. Now it appears that with certain profiles it is not possible to study soil science. High school students with an interest in physical geography cannot take the profile that contains geography as that profile lacks the subjects necessary to be admitted to a soil science course at a university. A combination of essential science subjects with geography is not possible. So there is a mismatch between what high schools deliver and what universities require, at least for some university soil science courses. Another problem is that many geography teachers at high school are social geographers with little interest or encouragement in physical geography.

National/Foreigner Student Ratios

The share of foreign students is decreasing in the United States and Canada, which is related to the increased difficulties for foreigners to enter the United States (Baveye et al. 2006). In 2001, 200,000 visas were authorized for highly skilled workers, but that had shrunk to 65,000 by 2004. At the American consulate in Chennai, India, the wait to just get a visa interview is more than five months. The United States has always attracted a large number of foreign students and greatly benefited from the import of highly skilled people. According to The Economist (May 6, 2006), 3,000 of the technology firms created in Silicon Valley since the 1980s (that is more than 30% of the total) were founded by entrepreneurs with Indian or Chinese roots. We are not for certain how much the visa restriction and the perceived aggressions affect student mobility and choices, but the Australians, Canadians, and Swiss—countries that are not known to have the same level of obstacles as the United States—have been successful in attracting foreign talent.

Male/Female Student Ratios

Soil science courses and graduations have become increasingly dominated by female students. Clearly, our science is emancipating, and it appears that the encouragement for females to take the science subjects (maths, physics, chemistry) at high schools is starting to pay off. There may also be deeper rooted problems with males at high schools. Several people in the Netherlands suspect that enrollment of males into university is decreasing as they are more likely to fail either at high school or first year at university; females may be better organized, harder working, and stronger in language and non-technical skills. Another cause could be that soil science is now much more attractive to young women than it was 10 or 20 years ago. In any case, the next generation of soil scientists will be more dominated by women, but that is currently not reflected in leading positions. For example, less than 10% of all International Union of Soil Sciences officers (65 people) in 2006 were women. Articles have been recently published on the achievements of women in soil science in the United States (Levin 2005) and Russia (Prikhod’ko 2006), but little attention has been given to the emerging trends in female students. That will likely change.

Is the current male dominance in soil science (for as long as it takes) an exception? Overall, science is male dominated. In the United Kingdom, for example, less than 4% of tenured physics professors are women (Institute of Physics 2006). Most science department heads are male.

Table 1

<table>
<thead>
<tr>
<th>Department/course name</th>
<th>Approximately corresponding period</th>
</tr>
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<tbody>
<tr>
<td>Agronomy</td>
<td>1950</td>
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<tr>
<td>Pedology</td>
<td>1910</td>
</tr>
<tr>
<td>Soils and Soil Investigations</td>
<td>1980</td>
</tr>
<tr>
<td>Soil Fertility</td>
<td>1990</td>
</tr>
<tr>
<td>Agrology</td>
<td></td>
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<tr>
<td>Agricultural Chemistry</td>
<td></td>
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<tr>
<td>Soil Chemistry and Bacteriology</td>
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<tr>
<td>Soil Technology</td>
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<tr>
<td>Agricultural Biochemistry</td>
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<tr>
<td>Soil and Plant Nutrition</td>
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<td>Soil Inventurisation</td>
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<tr>
<td>Soil Science</td>
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<tr>
<td>Soil Pollution and Ecotoxicology</td>
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<tr>
<td>Soil, Crop &amp; Atmospheric Sciences</td>
<td></td>
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<tr>
<td>Soil and Water</td>
<td></td>
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<tr>
<td>Land, Air and Water</td>
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<tr>
<td>Soil Quality</td>
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<td>Nutrient Cycling</td>
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<tr>
<td>Earth System Science</td>
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<td>Biogeochemistry</td>
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<td>Hydrology</td>
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<td>Vadose Zone</td>
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<td>Soil and Land Systems</td>
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<tr>
<td>Critical Zone</td>
<td>2005</td>
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<tr>
<td>Land Sciences</td>
<td></td>
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<tr>
<td>Soil Art</td>
<td>2010?</td>
</tr>
</tbody>
</table>

Soils Research Specialization

Highly active university departments routinely attract students as there is an exciting field of research, sufficient funds, and a good research infrastructure for nurturing and educating students and the next generation of scientists. Funding research is a political issue that differs widely between countries (Brumfiel 2006). Globally, three regions take the lead when it comes to funding: United States, Japan, and Western Europe. The United States dominates research funding in the sciences globally, spending almost $145 billion (€100 billion) on research and development in 2006, more than any other country or region. About 60% of that is defense related. The 25 countries of the European Union spend more than $85 billion (€59 billion) per year on research. Yet science budgets in the United States, Germany,
Figure 14
Soil Science Society of America (left) number of members age distribution and (right) percentage of members gender distribution (2006 data).

France, and Japan have been stagnant in recent years. In contrast, scientific research budgets in China have increased by 16% in 2004, in South Korea by 10% in 2005, and in India by 25% recently. The collective research budgets of China, South Korea, and India are less than one-quarter that of the United States, but that will change (Brumfiel 2006). Funding patterns affect scientific disciplines and education; changes in funding amounts and priorities have an impact on everything from the content of university courses offered to the types of employment opportunities that are available for graduates.

In many countries, government funding for soil research has decreased since the 1980s (Hartemink 2002; Mermut and Eswaran 1997; Tinker 1985). In part, this was due to the economic policies of the Thatcher government in the United Kingdom, resulting in privatization and the rule-of-market forces affecting many facets of society including the sciences (Tinker 1985). In part, it was due to the strong link between soil science and agriculture (Baeye et al. 2006). As the interest in agriculture was reduced in much of the developed world (there was ample food, agriculture was perceived to be harmful for the environment), so fell the interest in soil science. The decline in soil science was also due to its inability to cope with the new challenges. Some in the soil science community were split internally about the definition of the kandic or ferralic horizon, and there was a lack of answers for real-world problems or hard data useful for other disciplines. These trends have been observed in many countries, though with some exceptions (Bouna and Hartemink 2002).

Different departments have coped differently with rapid changes in society, and many have relabeled their activities to break away from agriculture or have merged with other departments into schools of natural resources or food production. Just like departments of agronomy have been renamed departments of plant or crop and soil sciences (Raun et al. 1998), so have many departments of soil science been renamed in the past century. Table 1 attempts to list some common names of soil science departments in the English-speaking world and how they changed over time. This timeline reflects relabelling but also expansion of the discipline. It is hard to say what is fashionable, but the “Department of Soil and Crop Sciences” is certainly not a popular name at the moment. All in all, it seems that soil is not a too favorable word in the naming of departments; in many cases, it has been replaced by land, earth, or environment.

Despite the fact that there are far fewer active soil scientists than two decades ago and that there are fewer soil scientists trained in several parts of the world, the number of soil science publications still increases (Hartemink 2001). Between 1994 and 2006, the number of soil science publications in peer-reviewed journals doubled. No doubt there is some recycling of ideas and dilution of research results over several papers, but the quantity of soil-related publications is an indication that much soil research goes on and there are many global and local issues, now and in the future, to which soil science can contribute (Minsay et al. 2007).

The Aging of Soil Science
Not only are soil science departmental names retiring, so are its people. The aging of the workforce is a common problem in much of the developed world (Lutz and Qiang 2002). The aging of the workforce is noticeable in many departments and soil research centers. Asked what he thought of the 18th World Congress of Soil Science, an Elsevier salesman responded, “Lots of old people, perhaps not a sign of vigorousness” (Philadelphia, July 2006).

We have data on age distribution in the soil science community from the United States, the Netherlands, and Denmark.

In the United States, 44% of the members of the Soil Science Society of America are over 50 years of age and male (figure 14). The older generation is male dominated, while most of the younger members are female.

In 2002, a questionnaire was sent to the 466 members of the Dutch Society of Soil Science. In total 152 people responded
(32%). The average age was 52 years and more than 16% of the respondents were above 65 years of age. Only 2% of respondents were younger than 25 years, and 9% reported being between 26 and 35 years old. Student members equalled only 1% (Boshoven and Hartemink 2003).

In Denmark, 50% of Danish Soil Science Society members (70 in total) are over 50 years old, and about one-fifth is between 25 and 40 years of age (O. Borggaard, personal communication, 2007).

The increasing age of soil science society members may be due to (1) the lack of influx from a younger generation, which would indicate a lack of soil science graduates, and/or (2) younger soil scientists not joining learned societies in the same proportions as the previous generation. In any case, the decline in soil science graduates has been a matter of concern and is discussed at soil science meetings and conferences.

CONCLUSIONS
Funding, politics, and the vigor of a scientific discipline all affect student numbers. Choices differ greatly between individuals, universities, and nations, but some general principles apply: students are attracted by the vigor and chirpiness of a subject (some may call it sexiness) and the possibility of getting a position (perhaps even well paid) after a university degree has been obtained.

The number of publications with hard data on student numbers is limited (it is not good publicity), but there has been some attention to soil science education, particularly in the United States (Baveye et al. 1994), but also in Australia (Smiles et al. 2000), India (Rao et al. 2000), and Africa (Ngugi et al. 2002; Temu et al. 2004). As far as we know, the first paper showing trends in the number soil science students was by Taskey (1994), who showed a severe decline in student enrollment from about 170 students in the late 1970s to around 45 in the late 1980s at a university in California. The faculty responded by establishing three new concentrations under the soil science degree program: land resources, environmental management, and environmental science and technology. As a result, soil science enrollment nearly tripled within two years (Taskey 1994).

While our research is specializing with advances in several subdisciplines, our teaching is generalizing: more and more soil science is being taught as part of other science curricula (e.g., ecology). We also see that soil science is being taught by other departments and that soil research is conducted by other disciplines (e.g., geology).

The soil science community should be worried by the declining numbers of soil science students (McBratney 2006).

It is our impression that current soil science graduates have no problems finding employment, and there is a shift from the public to the private sector in job opportunities. But will these trends continue? What expertise is needed in the near and further future and does our soil science teaching yield capable graduates?

The most difficult task ahead is to convince policy makers and land users on the need for adequate and up-to-date soil information but to make sure that there are enough young soil scientists equipped with the latest techniques and insights to address future issues. Convincing students that soil science is a valuable study is an important part of that.

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