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Isee - Integrating spatial educational experiences into soil, crop, and environmental sciences

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Abstract
Many of the concepts that our students must master in soil, crop, and environmental science courses are inherently spatial, but our ability to make these spatial patterns clear to our students has been limited. Students, however, need more geospatial skills to understand and address the increasingly complex societal problems that will confront them throughout their careers. We are developing a web-based geographic information system based on Google Earth that will allow students to access a large variety of soil and other maps for any area of the state of Indiana, USA, and we are integrating this new spatial educational experience into our curricula. We have two goals: (1) to develop the ability of our students to use geospatial information to understand how and why soils and landscapes vary spatially at scales ranging from individual fields to a region as large as Indiana, and (2) to develop our students' understanding as to how the spatial distribution of soils and landscapes impacts the distributions of crops, cropping systems, land use, and environmental and natural resource issues. This paper introduces the Isee web site (http://gis.lib.purdue.edu/isee/) and describes our first experiences using it in the classroom.

Key Words
Soil survey, visualization, spatial technologies, Google Earth.

Introduction
Many of the concepts that students learn in soil, crop, and environmental science courses are inherently spatial. Soils vary across landscapes in predictable, repeating patterns. Certain soils and landscapes are better for particular crops than others. An environmental problem may impact a whole watershed, not just the point at which a contaminant is introduced. Patterns of land uses, whether for crop production, forestry, wildlife habitat, or urban development, vary spatially in response to soils, topography, geology, human infrastructure, and many other factors.

Although we implicitly acknowledge the existence of spatial patterns in our soil, crop, and environmental sciences courses, our ability to explicitly observe these spatial patterns visually and make them clear to our students has been limited. Geographic Information Systems (GIS) allow us to visualize and analyze such complex geospatial information. It is well known that an active, visually rich learning environment, like that which GIS offers, significantly increases comprehension and retention relative to a more passive, auditory environment (Bransford *et al.* 2000). We have only begun to take advantage of the powerful, learner-centered instructional tools that GIS has to offer.

In the fall of 2005, we began using a "teaching with GIS" approach in our *Soil Classification, Genesis, and Survey* course using 3 tablet PCs and a minimal GIS dataset. We now routinely take our class on weekly, 3-hour field labs, and on two, all-day field trips using 14 tablet PCs and a GIS dataset that has grown to encompass the entire state of Indiana (92,895 km^2) (ArcNews Online 2008). Our focus is to teach students how soils and landscapes vary spatially over many different scales, and how the soil geomorphic concepts illustrated with diagrams in the classroom correspond to actual features observed in the field. This approach has significantly altered how we teach field soil science, what we teach (we have learned many new things ourselves), and has significantly impacted student learning.

In this paper we describe our progress in moving our GIS content to a web-based platform to make it available to a larger population of students, and ultimately to the general public.

Methods

Data Layers

We have developed an approach for structuring our GIS data so that it functions as an effective teaching tool. We rely heavily on two data sets, namely, detailed soil survey data that covers the area of interest, and a Digital Elevation Model (DEM) of the same area. Each data set alone is informative, but in combination, the information conveyed is vastly greater.

DEM data is available for Indiana at 1.5 meter pixel resolution (ISDP 2009). We resampled this to 5 meter resolution without compromising the ability to display subtle geomorphic features, but with a substantial reduction in file size. A hillshade was calculated from the DEM data. The hillshade is one of the most useful layers because of how it graphically illustrates the topography. It is used extensively as a base layer for other data, particularly soils data.

Our most important layers are derived from the Soil Survey Geographic (SSURGO) Database available from the United States Department of Agriculture, Natural Resources Conservation Service's Soil Data Mart (Soil Survey Staff 2009). The SSURGO database consists of the detailed order 2 soil survey data covering the entire state. We create maps of some of the information available in SSURGO as is, but we have also created additional maps based on our own interpretations of the soil survey data and how it relates to the surficial geology of Indiana.

Most of Indiana was glaciated during the Pleistocene, and there is a very close correspondence between the various glacial deposits and the properties of the soils which formed in and on them. Thus, we rely heavily on a soil geomorphological approach in teaching soil science in Indiana. A *dominant soil parent material* map that we developed from our own interpretation of the SSURGO data is the single most useful map in our GIS dataset. Since many soils in Indiana developed in two and sometimes even three different parent materials, we define the dominant soil parent material as that material with the greatest influence on other soil properties, or a material that highlights a particular distinguishing feature. Usually, the dominant soil parent material is the lowest one in the profile, but it may be at the surface, such as in soils which contain organic soil material. By grouping soil map units with similar soil parent materials, we are able to visualize the soil landscape in new ways. Outwash plains, flood plains, dune fields, and other geomorphic features stand out in stark contrast to the surrounding till plains when a transparent dominant soil parent material layer is draped over the DEM.

A separate loess depth map provides information on the wind-blown silt that covers large areas of the state. Maps of natural soil drainage class, presettlement vegetation, soil orders, and others provide information on other soil and landscape properties.

Web Interface

Our web interface is based on the Google Earth API (Application Programming Interface, http://code.google.com/apis/earth/) and is designed to allow a user to quickly and fluidly zoom and pan to any part of the map, and to quickly switch the visible layer. As of October, 2009, only a few layers are active, but we intent to add additional layers by mid-2010. A screen shot of the web interface is shown in Figure 1. The site is accessible at http://gis.lib.purdue.edu/isee/.

Results

We are just beginning to incorporate the Isee web site into our soils courses, so a full assessment of its effectiveness as a teaching tool is not yet available. The initial student responses, however, have been very positive.

In a class of 44 freshman and sophomore college students in a *Crop Production* class during the fall semester of 2009, 41 (93%) indicated that they had previously used Google Earth, validating the choice of Google Earth as an interface that is already familiar. The students were asked to respond to a number of questions on a scale of 1 to 5, with one being "strongly disagree" and 5 being "strongly agree." The average response for the question, "I learned something new today," was 4.2; for the question, "I feel Isee is a valuable tool for expanding my knowledge," the average response was 4.3; and for the question, "If given the option, I would further explore the Isee web site," the average response was 4.0. The response to the latter question is particularly noteworthy because one of our goals is to create a site that students will want to explore on their own.

In a *Soil Classification, Genesis, and Survey* class consisting of 9 graduate students and 1 senior undergraduate, we asked groups of 2 students each to use Isee to develop a diagram or a written set of rules that explained how natural soil drainage class is related to soil parent materials and topography in central Indiana. The goal was to see if we could use Isee to lead students to the type of mental models that field soil scientists develop as they are mapping soils in the field. This exercise required students over a 2 hour laboratory period to compare two different map layers at 4 different places chosen by the instructor to be representative of particular “end member” situations. Of the 5 groups, only one developed a diagram that explained the situation clearly, 3 created reasonable, but not particularly clear diagram or rules, while one group struggled to create even a simple diagram. As experts, it is easy to forget how difficult and time consuming it can be for the novice to conceptualize soil landscape models that explain how soils occur in a particular area. Thus, in the future we plan to pace the exercise differently, particularly to allow students more time and with more feedback from the instructors along the way.

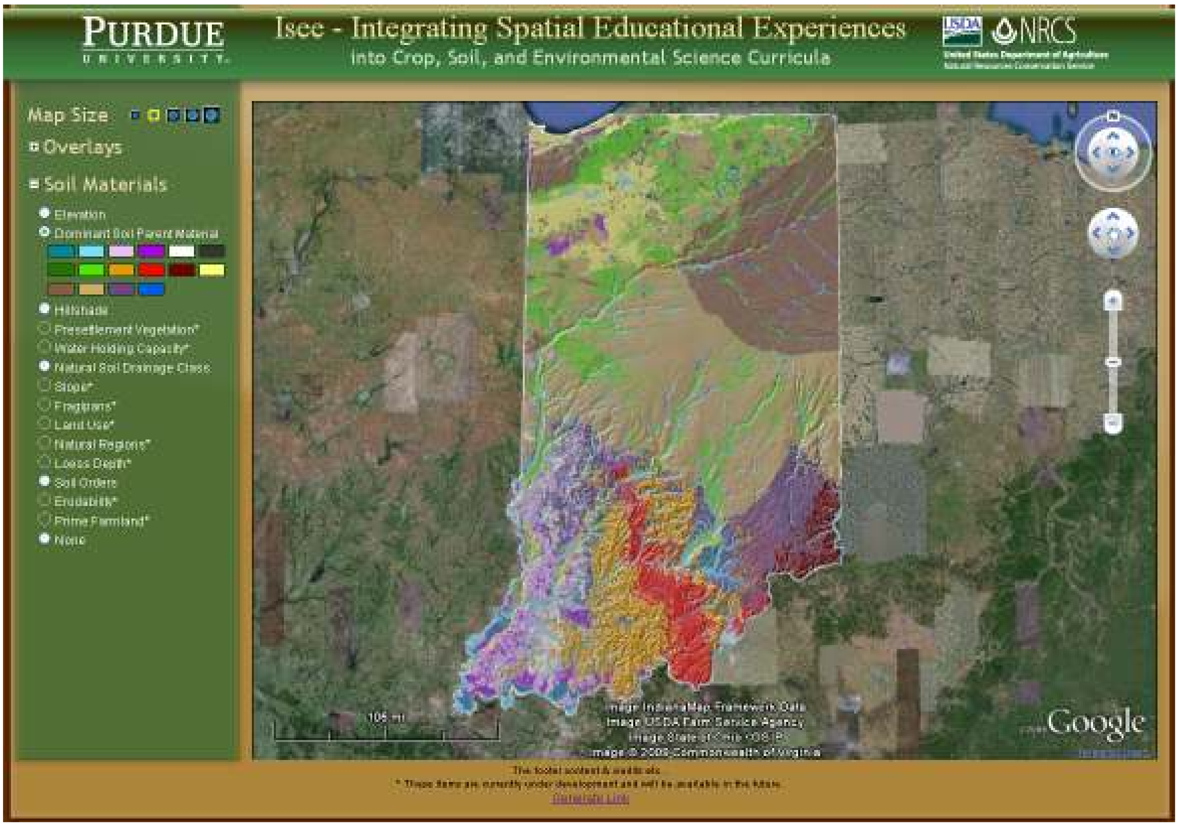

Figure 1. A screen capture from the Isee web site with the Dominant Soil Parent Material map of Indiana being displayed. The normal Google Earth controls are used to navigate the map. When the user moves the cursor over the color swatches in the left panel, the legends appear in popup boxes. If needed, the user clicks on a swatch to open a panel on the right side of the screen that provides additional explanation.

Conclusion

Soils information based on detailed soil survey data combined with digital elevation models and delivered via fast Web 2.0 technologies provides exciting new possibilities for learning about soils and landscapes at various scales. We have only begun to exploit the potential of this approach for soils teaching and research, both for students in our classes, as well as for educating the general public.

Acknowledgement

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New horizons for profiling soil science in schools

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Abstract
A key objective of this soil science education initiative is to enable teaching and learning experiences related to soil science to become embedded in school curricula. This initiative is composed of a targeted curriculum resource (SPICE Soil Science) and the Monitoring Soil Science Project. The program includes a teaching resource that directly relates to science curricula using the context of soil, supporting procedural material for teachers, allocation of soil scientists as school mentors, a dedicated website and a reference suite of soil analyses for each school. The keys to the sustainability of the project are the soil-related science curricula, support for teachers, and the website. The project provides an opportunity for school children, their teachers and parents to engage in activities that raise awareness of soil, first as a habitat for small animals and microbes and later as a significant global resource. It opens windows to the public about the importance of soil and creates a novel learning environment that is relevant to chemistry, physics, biology, geography and the earth sciences. It creates an awareness of 'dirt'.

Key Words
Education, soil plot, mentoring, soil analysis, soil fauna, science communication.

Introduction
The SPICE program is developing a soil science teaching resource. It specifically targets science curricula outcomes using soil fauna to illustrate the concepts - *interdependence of living things* and *sustainability of life and wise resource use*. The Monitoring Soil Science Project complements this teaching resource and seeks to establish innovative student-scientist partnerships through ongoing soil-based research. Students are trained in scientific methodologies, including sampling strategies, which they will use to collect a series of biological, chemical and physical soil science data. They upload their results onto a shared online database. The project introduces students to the importance of soils in the environment and to topical issues such as the climate change debate and environmental monitoring, in addition to developing scientific research skills including data collection and analysis.

The project seeks to engage and connect students and teachers in ongoing research in soil science. Student-scientist partnerships enable students to participate in genuine and realistic science activities. Monitoring soil fauna provides an engaging introductory step into soil science awareness as well as a springboard to discuss broader issues, such as the diversity of landscapes and climate change. Students follow scientific protocols to collect valid and reliable data, distinguish between the physical, chemical and biological aspects of the soil ecosystem, and interpret patterns and trends in these data. They can also compare their results with those of students from other schools, and develop their own soil science research project. In addition, students involved in programs of actual scientific value are possibly more likely to continue studying science-based courses in their later school years, and onwards (Woolnough 2000; van Eijck and Roth 2009). With this in mind, a pilot project was established in 2009 to trial and evaluate the Monitoring Soil Science Project in collaboration with SPICE Soil Science materials with six high schools in Western Australia (WA).

Embedding soil science teaching into the school curriculum
The SPICE program creates learning resources for teachers in collaboration with the Department of Education, Western Australia and The University of Western Australia; it supports teachers in providing innovative science experiences for students. Experiences with a wide range of curriculum development projects have shown that for a new initiative to become sustainable, strong links have to be forged to the core curriculum within schools. A SPICE learning sequence is being developed that uses a soil science context to support Years 8, 9 and 10 syllabus content related to: (i) *Investigating*: the planning, conducting, processing and evaluating of data, (ii) *Earth and Beyond*: the sustainability of life, and wise resource use, and (iii) *Life and Living*: the interdependence of living things, within Western Australia. Through the provision of engaging, challenging and innovative learning materials that initially focus upon soil fauna, all students are encouraged to become involved in soil science. The Monitoring Soil Science Project further enables students

to participate in a student-scientist partnership that enhances and extends their learning.Much of the subject matter associated with the Monitoring Soil Science Project is novel and new to science teachers and so a key strategy of the project has been to develop a structure that builds confidence through practical support. This has ranged from detailed professional learning, through comprehensive background and procedural documents to the provision of a mentor with soil science expertise.

Additional benefits of the project include a realistic context for students to study the interdependence of living things coupled with the opportunity to demonstrate scientific investigation skills driven by their own research aims, thereby enabling them to achieve essential learning outcomes. This process empowers students by encouraging them to take responsibility for their learning and allows them to develop scientific knowledge within a context that has been influenced by their own decisions.

A set of soil tests provided by a scientific laboratory for each school will be used as a baseline for ongoing investigation related to soil and land, and establishes potential links to other areas of science and technology. The permanent ‘soil plot’ underpins investigations above and below ground, and the accumulation of data creates additional avenues for investigation by students, including sharing of knowledge among students as they progress from year to year. The interactive website gives students a global window to soil science with support of their local soil science mentors.

Pilot for the monitoring soil science project in 2009

During the 2009 trial period, six schools tested the suitability of the written materials and practical equipment prepared for them to start the Monitoring Soil Science Project. Two accessible areas of land (plots 4m x 4m) were selected at each school as permanent sites for monitoring. A soil scientist was allocated to participating schools by the WA Branch of the Australian Society of Soil Science Inc. (ASSSI) as a mentor for the project.

Initially, each school monitored their soil plots for the abundance of mites and springtails and several soil tests such as soil pH and electrical conductivity, bulk density, soil moisture content and organic matter content. The project included an initial discussion among the students about how and where the soil samples should be taken. The location of the soil plots depend on the characteristics of the site and a discussion of options is an important first step in the process. Students can log-in and upload their data onto the Monitoring Soil Science Project website which automatically presents their information in a graphical form within their log-in area. The cumulative data for all accredited schools are visible on the internet without a log-in requirement.

Students are encouraged to pursue their own investigations alongside the project, and this is expected to expand as the project develops. The desired project outcomes are that students will be able to (i) participate in science activities that are not artificial, (ii) follow scientific protocols to collect valid and reliable data, (iii) distinguish between the physical, chemical and biological aspects of the soil ecosystem, (iv) interpret patterns and trends in these data, and compare their results with students at other schools who will have different soil types and land management practices, and (v) develop their own soil science project.

The pilot schools included extremely remote, rural and city schools with a range of science facilities. This gave a breadth of experience from which to evaluate the resources provided. Based on the evaluation of the pilot project in 2009, changes are being made for wider implementation. The next phase includes more schools from a wider geographical area, supported by their local soil science mentor. Accredited schools can participate via the online access section of the website and upload their data.

Getting the monitoring soil science project started

As a preliminary step in developing the instructions for teachers, the methodology for sampling soil was investigated by a group of senior high school students who were participating in a workshop at The University of Western Australia as part of the Primary Industry Centre for Science Education (PISCE) program. The PICSE program was established at the University of Tasmania and seeks to establish a national model of collaboration among universities, their regional communities and local primary industries to attract students into tertiary science and increase the number of skilled professionals in science-based primary industries and research institutions.

The students at the PICSE workshop were assigned the task of determining how they would sample soil for mites and springtails within a defined area of the university campus. Limited instructions were given to the students; they worked in groups to problem solve the task of defining the 'soil plot' location and sampling methodology. It was interesting to watch how the four groups tackled the concept of the 'soil plot' in different ways. This open-ended investigation proved to be a useful starting point for the Monitoring Soil Science Project, before the students were supplied with the standard instruction protocol required for consistent data collection. The students concluded that it was essential to have a specific explanation of (i) data quality, (ii) data variability, (iii) sampling strategies and (iv) statistical analysis, in the resource package for teachers. Background information was also requested about soil physics, soil chemistry, soil biology, pedology, soil mineralogy, use of geographical information systems technology and soil management.

After trialling the concept of establishing and sampling the 'soil plot', the students concluded that:

1. Clear instructions needed to be given to teachers about the potential variability of sites with a recommendation that the first activity could deal primarily with sampling strategies and assessing site variability.
2. Instead of selecting one large plot (as first intended), smaller plots should be selected to include different soil environments within the study area.
3. Details of the kit for soil sampling, soil animal extraction and analysis methodology should be simple and easily obtained.
4. Very clear information about the sampling implements and method of sampling need to be included (e.g. sampling depth and suggestions about what to do with leaf litter or mulch).
5. Additional notes about the site should be made including presence of plants and soil quality.
6. Clear instructions about the volume of samples are necessary and a standardized volume should be used because of differences in bulk density (which could be measured as well).
7. Sampling high traffic areas (e.g. walkways) should be avoided.
8. Contrasting sites should be selected to maximize the chance of differences in soil fauna, and correlate differences with soil factors (e.g. soil carbon).

Soil science resources for teachers

A detailed concept design for the soil science teacher resources was developed in relation to the project outcomes. Background theoretical and factual information was researched, reviewed and amended following teacher feedback. Procedure sheets, worksheets and results sheets were drafted for the pilot project and reviewed by teachers during the pilot project. Amendments were made following teacher feedback. A soil science equipment kit was prepared for each school with the support of members of the Western Australian Branch of ASSSI. A set of soil science text books which included information relevant to Western Australia was provided to each school by ASSSI. A professional learning day for the teachers was held by the SPICE program prior to the commencement of the pilot project in schools.

The Monitoring Soil Science Project website is being developed with two levels of access: one for schools which have been accredited and granted log-in approval, and one for the general public, including schools which are not yet accredited. Accreditation of schools to participate in the project involves establishment of a formal agreement between a local soil scientist and the school, and approval via the website. Accreditation will enable schools to upload data collected by students and a defined set of reference soil analyses provided by an approved local soil-testing laboratory, with oversight by the soil science mentor. A variety of resources will be available to all schools via the website so that accreditation is not essential, but it will be encouraged so that soil scientists are formally linked with a school in a mentoring role within an international network. The schools are located on the website via Google Earth. The general access to the website will enable anyone to follow the instructions and explore their own soil in a global context.

Making sure the monitoring soil science project is viable and ongoing

Embedding access to knowledge of soil science in school curricula and supporting teachers in using information about soil in their science teaching is an ongoing goal of the Monitoring Soil Science Project. Sustainability of the project requires: (i) establishing a reference plot of land at the school (every school has some land!), (ii) providing an entry point for students to attract their attention (living organisms – soil fauna), (iii) instructions that are easy to follow and do not require complex materials or equipment, (iv) support for teachers and students from a nominated soil science mentor, (v) web access for data uploading and visualization, (vi) involvement of local soil-testing laboratories through provision of a set of reference soil analyses for each school, (vii) availability of suggestions for further activities, and (viii) connection with other schools via the website. Accreditation of schools which participate is an important part of the project, and this involves a connection with soil scientists and soil science societies. The project is affiliated with the International Union of Soil Sciences (Division 4).

Responses to the monitoring soil science project

Science teacher: *"The year 9 students felt really privileged and excited to be a part of a pilot project like this one. Most of them did not realise and were amazed at the number of organisms that were living in such a small sample of soil. They had an opportunity to carry out scientific procedures and also to use technical equipment which they had not used before. Soil is no longer 'boring'! Teaching the project was easy as all the procedures were provided and easy to follow."*

Science teacher: *"Initially the students were unsure of what they would find. Once they had experienced seeing the mites and springtails their interest was generated. All sorts of ideas of how we should proceed in our investigation were suggested. We pursued one particular avenue: a comparison between managed and unmanaged land. There was lots of discussion of possible further work. It was an excellent opportunity to conduct open-ended investigative work, which helps students understand the nature of science and the scientific method."*

Student participant: *'Sir, soils aren't soils anymore ..... it's a proper ecosystem"*

Soil science mentor: *"I worked with high-achieving students who had a passionate, committed and highly skilled teacher. The students were very engaged with the activities in the project and seemed to have a good background knowledge. Guided by their teacher, the project gave students a great opportunity for hands-on learning, and it was great to see many of them experience moments of personal discovery."*

Photo 1. Collecting soil samples.

Photo 2. Examining the soil fauna.

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Professor Lyn Beasley, Chief Scientist of Western Australia and Anthony Meczes initiated, encouraged and created the 'seed' for this project. PICSE staff enabled the participation of students in the development of the soil sampling protocols. IUSS Outreach and Division 4 provided financial assistance. ASSSI (WA Branch) initiated the mentoring component. Lee Goodyear created the website and Dr Peter McCafferty of the ChemCentre in Western Australia, enabled a reference set of soil analyses to be provided to schools in the pilot project. Associate Professor Adrianne Kinnear contributed inspiration and her extensive of knowledge of soil fauna. Deborah Lin made a significant contribution by reviewing the information on the website, including the support packages for teachers and soil science mentors.

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Soil Quality indicators for Australian cropping systems.

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Abstract
To date, the Western Australian soil quality programme has benchmarked soil status at over 1300 sites across WA's agricultural regions, with a similar campaign currently underway in eastern Australia offering more national coverage. Analyses cover a range of biological, chemical and physical indicators, providing a 'snapshot' of soil quality from which change can be monitored through time. The programme focuses on landholder involvement and extension, with 19 grower groups engaged for soil collection, each receiving two workshops. Development of www.soilquality.org.au continues to provide a unique means of presenting a large soil analysis database in a variety of ways depending on the needs of the user. The use of this website to engage landholders, resource managers and the wider community is a simple and effective link between actual data and information on soil management strategies. The development of a 'traffic light' system is a simple diagrammatic method of sourcing information relevant to critical soil quality indicators, and a range of simple calculators present a means of assessing the economics of changing farm management, comparing lime sources or investigating soil organic matter change.

Key Words
Soil quality, indicator, health, extension, monitor, benchmark

Introduction
The significant interest in soil quality (also termed soil health) is largely related to agricultural production systems and the identification of soil constraints to production so that farming enterprises are sustainable into the future. Compared to other world production systems, Western Australia's grain production sector is relatively young, with the majority of cropped land cleared within the last 100 years. Additionally, the majority of agricultural soil is deeply weathered, infertile and coarsely textured (Moore 1998), presenting a range of difficulties for landholders. The long term impact of agricultural production on these soils is largely unknown, necessitating the need to know current soil status and monitor change through time.
The development of the Western Australian component of the soil quality monitoring programme addressed a number of these issues, through the development of a biological, chemical and physical indicator package. This measure of soil quality had two aims: (1) Provide a benchmark of soil quality for that site allowing for comparison into the future and (2) Determine current possible constraints to production at that site, based on yield potential (French and Schultz 1984).
In addition to actual measurement of soil parameters, the project had a particularly strong focus on community engagement through extension of results and information. All results and soil quality information are housed on the specially developed website www.soilquality.org.au, allowing growers, catchment co-ordinators, and regional development bodies to view individual or aggregated datasets for sites measured in their local area or region. Growers involved with the project are given unique WebID's enabling access to their specific soil analysis results and comparisons with other local producers. Aggregated data in the form of bar-charts identifies critical soil quality issues on a regional and sub-regional basis, and allows for development of strategic management plans for production constraints.

Methods
Grower Engagement
Selection of sites for the project concentrated on engaging active landholder groups focussed on continual improvement of management strategies for long term sustainability of farms. In this way, the soil quality programme conducted initial workshops with each grower group to outline and discuss project aims, but also important soil related issues facing land-holders in that specific area. Identification of key soil types of the area allowed each group to choose initial sample sites based on satellite imagery.

Soil collection
Soil was collected over a four year period from 2005-09 from 1362 sites from a range of cropping and pasture regions across the Western Australian agricultural zone. All sites where used predominantly for grain

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production, however some sites included mixed cropping and beef/dairy enterprises. At each site a composite of between ten and fifteen separate sample points where collected at three depths; 0–10 cm, 10–20 cm and 20–30 cm. Further sampling at 30-60 cm and 60-90cm was carried out with two groups to investigate deeper soil constraints in the form of boron toxicity and salinity. Sample collection occurred during summer months to avoid within-crop fluctuations in soil biology related to crop stage and rainfall events. This also enabled chemical data from soils to be used as part of fertiliser decision support systems.

Soil Analysis and Measurement

The 0-10 cm layer from each site was subject to a range of biological, chemical and physical analyses (Table 1) with some chemical analyses also conducted in sub-soil layers. A major focus of the project was to introduce agricultural communities to biological functioning of the soil, and how various management practices impact upon these processes. For ease of understanding, labile carbon, microbial biomass carbon, microbial respiration and potentially mineralisable nitrogen was measured on each sample. Further biological measurements involved "Predicta-B®" DNA analysis for range of pests and diseases of crops. Standard chemical analysis by a commercial laboratory matched typical soil testing carried out by growers on an annual basis. Particle size analysis, gravel content and water holding capacity represented the physical status at each site. Samples taken below 10 cm were analysed for pH ($CaCl_2$) and electrical conductivity only, except where further boron analysis was required.

Table 1. List of all soil quality indicators measured during the soil quality project.

Biological	Chemical	Physical
Microbial biomass	pH ($CaCl_2$, H_20)	Particle Size Analysis
Labile carbon	Electrical conductivity	Gravel Content
Microbial respiration	Water repellency (MED)	Water holding capacity
Potential mineralisable N	Total organic carbon	
Take-All disease	Nutrients (N, P, K, S, B)	
Rhizoctonia		
Root lesion nematode		
Cereal cyst nematode		

Figure 1. Home page of www.soilquality.org.au.

Presentation and Extension

A significant portion of the project was devoted making soil quality data accessible and useful for members of the agricultural community. Key to this aim was using indicators that are easily interpretable to landholders and the wider community, with direct connections to management strategies. The soil quality indicator package was developed to educate growers of potential constraints to grain production and methods of management improvement. In some cases issues outside the standard analyses where identified by the individual grower group as significant soil constraints in their area. In particular, two grower groups funded further sampling to 90 cm to investigate boron toxicity common to local soils. All data developed through the project was delivered back to individual growers in the form of a group workshop, results booklet and through WebID access to www.soilquality.org.au. This website (Figure 1), was developed to provide public access to otherwise unseen scientific data presented diagrammatically and linked to information about soil quality and the economics of associated management practices.

Expert Panels
Three self-auditing sessions were held during the project that encouraged criticism of the choice of soil quality indicators and importantly, the functionality of the website. Two separate sessions invited experts in their respective topics to discuss (a) soil biological indicators, and (b) soil physical and chemical indicators. A third session invited key extension officers to scrutinize www.soilquality.org.au. The outcome of these sessions was a list of critical values for a range of relevant indicators, and ultimately, an improved website.

Results
Data Presentation
The data housed on www.soilquality.org.au is presented in a number of different ways. At the simplest the data from a grower group or region is presented in the form of a bar chart indicating the relative range of values for each indicator, giving a general overview that is useful for catchment co-ordinators, agronomists and natural resource management officers. As a grower, it is possible to compare individual soil test data against other local farms. This is presented in the form of basic box plots split into upper and lower 25% of sites, and middle 50% of sites (Figure 2). While not necessarily providing an indication on absolute status it provides the user with an indication of where they are operating in local community. Finally, a relationship graphing function provides an extension tool used to improve understanding of inherent soil properties and how they impact upon soil biological functioning. Using actual data it is possible to follow each biological indicator and how each one influences others.

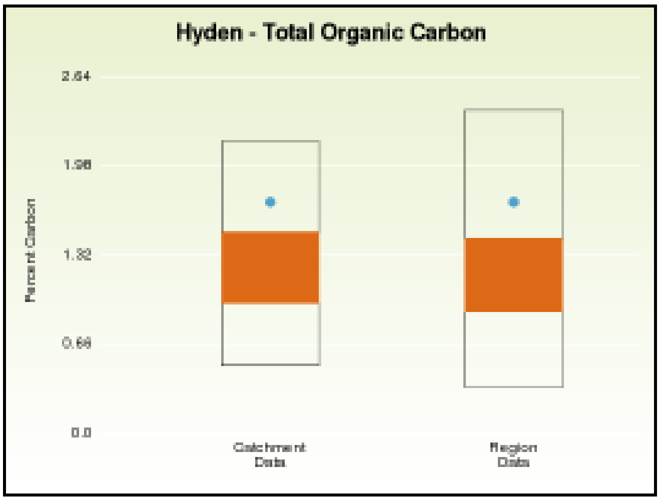

Figure 2. Simple box plots represent the spread of total organic carbon values locally at a catchment level and for the larger regional dataset. The blue dots indicate the individual landholders' value.

Traffic Lights
The traffic light system is a simple and easy interpretive tool that provides a visual 'snap shot' of the status of a group data set. It quickly and easily presents an idea of the potential soil constraints facing a particular group. Development of these diagrams on www.soilquality.org.au provides "point and click" access to management implications and strategies for specific indicators when the user hovers over the diagram. For example, pH throughout the soil profile is an obvious issue in the Hyden area (Figure 3). Hovering over the red portion of the diagram informs the user there is an acidity issue in the area. Clicking this leads to fact sheets on soil acidity and information regarding amelioration strategies.

Calculators
In addition to providing data and information relating to range of soil quality indicators, www.soilquality.org.au houses a number of calculators aimed at providing basic agronomic/economic data for a range of management options. A most useful example relating to management of soil acidity is the

"lime comparison calculator", allowing users to compare the relative neutralising value of different lime sources as well as accounting for the cost of transport and spreading the product.
With the current interest in the ability of soils to store increasing amounts of organic matter, a calculator was developed to indicate the relative amounts of organic matter required for a targeted change in soil organic carbon (%). Other calculators cover issues surrounding stubble retention, green manuring and controlled traffic farming.

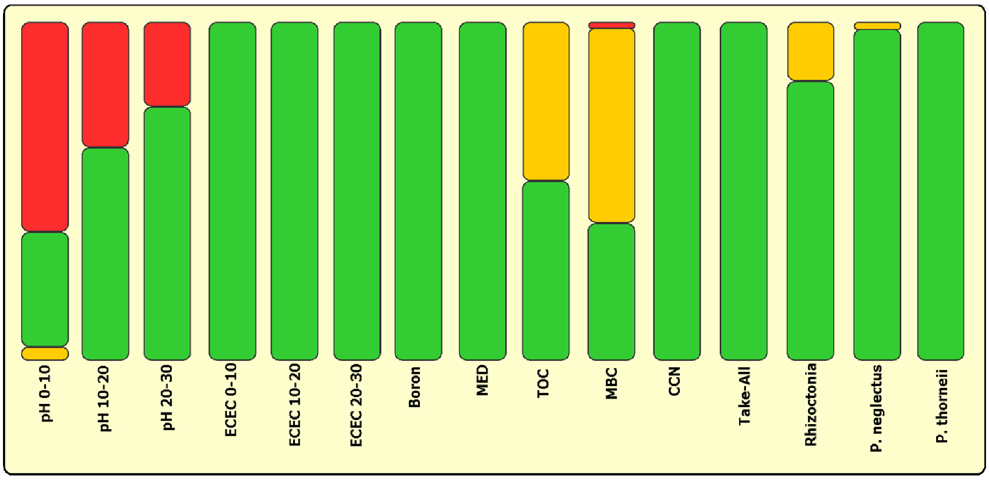

Figure 3. An example of a traffic light diagram from growers sampled in the Hyden area of Western Australia. Red indicates negative production impacts and the need for immediate action, amber indicates probable production penalties and the need to consider management change, while green represents no impact on production but ongoing monitoring is suggested.

Conclusion

The soil quality monitoring programme has produced www.soilquality.org.au as an easily accessible tool for the introduction of soil related issues to the wider community. It is a useful resource of general information on a wide range of soil related topics, while also providing specific data and management tools for growers, agronomists, natural resource management officers and regional development personnel. Experience with landholders suggests a preference for diagrammatic representation of analytical data that must be easy to interpret and linked to management strategies. Current pressures of profit driven primary production limit landholders' ability to research and obtain reliable information on soil related issues.
The soilquality website allows every interested research and/or grower group to take ownership of their own datasets and soil issues pertinent to local production systems. As such, it is currently undergoing national expansion to include monitoring and education from other Australian states.
The 1362 sample sites throughout Western Australia provide a benchmark for soil quality, from which future sampling and analysis can provide indications of change in WA's agricultural soil resource. This is recommended to occur on a 5-year time frame so repeat analysis of sites can occur prior to assessment of 2020 targets for soil properties such as pH. It also introduces a range of soil biological properties relating to crop production and provides a range of tools and information to understand the relevance of each one. While biological indicators of soil quality are not necessarily linked directly to crop production, the agricultural community recognises the important roles organic matter plays in production systems and a greater awareness of soil biology is actively sought by the agricultural sector.
The ongoing development of www.soilquality.org.au provides the wider community with a significant database of soil analytical data with which to investigate and interpret. It allows landholder groups to identify local soil related production issues, access relevant information, and formulate strategies to manage or overcome these constraints. Improved knowledge of a wide range of soil quality issues limits degradation of productive soils, has positive impacts on food and fibre production and ultimately provides for sustainable soil systems.

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Soils ARE dirt

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Abstract
'Soils ain't dirt' is a common mantra of soil scientists trying to educate people about the importance of soils, but the reality is that soils ARE dirt, for soil fertility depends on the excrement of living things to nourish it. Human excrement is an important component of soil fertility, and we need to overcome our intuitive disgust to find ways to return our excreta to the soil as valuable fertiliser and soil conditioner. There are many innovative techniques available to do this, but soil scientists still have important roles to play because they can educate people about this issue and reduce community fear, participate in excreta nutrition trials, and catalyse governments and institutions to take action.

Key Word
Soil, dirt, human excreta, urine, faeces, nutrients.

Introduction
The word 'soil' comes from the Latin *solium* meaning seat, or *solum*, meaning ground, and the word 'dirt' comes from the Old Norse *drit,* meaning excrement, the material expelled from living bodies, and a known source of contamination and disease. 'Soils ain't dirt' is a common mantra of soil scientists trying to educate people about the importance of soils, but the reality is that soils ARE dirt, for soil fertility depends on the excrement of living things to nourish it. 'Soils ain't dirt' exacerbates a perceptual dichotomy between soils and dirt at a time when we need urgently to reconnect the two.

Excreting urine and faeces (from the Latin *fæx* meaning 'dregs') is an unavoidable human activity, but when we gather in groups, our combined excretions overwhelm the decomposing capacity of soil organisms. Instead of building our soil fertility, our excreta become a source of odour and contamination, and their disposal is a necessity for the health of the community. Common diseases caused by contact with excreta include salmonella, cholera, dysentery and hepatitis (Santamaria & Toranzos 2003). All cultures have evolved sanitation systems to deal with excreta. Chinese records indicate their use as agricultural fertiliser 3000 years ago, particularly once fallow rotations changed to crop-crop rotations. Mixes of excreta and other organic materials such as human hair were used until the introduction of synthetic fertilisers in the 1980s (Shiming 2002). Until the mid-19th century, the contents of English cesspools had a market as agricultural fertiliser, but this market collapsed with the discovery of the fertiliser value of guano, so unwanted excreta literally flowed in streets and into streams. The appalling stench from the Thames River in 1858 was the catalyst for sewering the city and inspiring a revolution in public health (Black & Fawcett 2008b).

Many countries are now in a similar position to 19th century London. Population growth has outstripped infrastructure development; currently 2.6 billion people have no toilets at all and their untreated faeces and urine create huge health hazards for their communities (George 2009). In Western cultures sewerage systems enable us to flush and forget about our excreta, but these water-based systems are becoming unsustainable. Clean water is an increasingly rare resource and sewerage infrastructure is expensive to build and maintain. Disposal of faeces and urine pollutes waterways and represents an enormous loss of organic matter and plant nutrients that should have been returned to the soil. While recovery of dewatered biosolids for land use is becoming increasingly sophisticated, there are still contamination issues dealing with biosolids extracted from sewerage systems that contain both human and industrial waste.

There is growing interest in returning human excreta directly to the soil, an interest driven by water scarcity and stress, degradation of freshwater resources, increasing population, the resource value of excreta and its nutrients, and delivery of the United Nations Millennium Development Goals, particularly environ-mental sustainability and eliminating poverty and hunger (World Health Organisation (WHO) 2006). In 2008 two popular books, 'The big necessity' (George 2009) and 'The last taboo' (Black & Fawcett 2008b) looked at the appalling state of global sanitation and the social and ecological results of our refusal to deal with it.

Nutrient value of human excreta
The nutrient content of excreta is substantial. One estimate is that on average each person excretes 500kg urine and 50kg faeces (10kg dry matter) a year, with a nutrient content of 5.7kg nitrogen, 0.6kg phosphorus and 1.2kg of potassium. Most of the nutrients are in the urine which contains 90% of the nitrogen, 50-65% of the phosphorus and 50-80% of the potassium. These figures vary from person to person according to bodyweight, climate, water intake, and diet characteristics, especially protein content. Urine has much higher fertiliser value than faeces, which are more useful as organic matter for soil organisms to break down and improve the condition of the soil (Heinonen-Tanski and van Wifk-Sijbesma 2005).

The phosphorus value of human excreta is of particular importance given the dwindling resources of non-renewable rock phosphate currently used to produce agriculture fertiliser. Currently 148 million tonnes of rock phosphate are mined each year for fertiliser, and at this rate the supply will be exhausted within 100 years, sooner if demand for food production increases as populations increase (Cordell *et al*. 2009). Globally, humans consume around 3 million tonnes of phosphorus each year and excrete almost all of this in urine and faeces, but only around 10% of this valuable resource is recirculated back to agricultural soils and aquaculture ponds. Most of the phosphorus excreted by urban humans ends up in waterways where it is a pollutant, or in sewage sludge buried in landfills.

Cultural responses to management of human excreta
We face a dilemma with our excreta. It is a valuable resource, but also a potential source of illness, disease and untimely death, if not handled correctly, and human cultures reflect this dilemma. Some are faecophobic, with strong taboos against handling and talking about human faeces; while faecophilic cultures have no taboos, and are happy to use faeces and urine to build the fertility of their soils. These attitudes are largely determined by existing tradition and religious beliefs or practices (Avvannavar and Mani 2008).

Faecophobic cultures are disgusted by faeces. The emotion of disgust is universally recognised around the world, and is thought to be an evolutionary mechanism to defend the body from pathogens and parasites (Curtis and Biran 2001). It is reinforced by child rearing practices and by some religions which mandate strict hygiene practices. Levels of disgust vary. Decomposed faeces such as those in septic tanks evoke less disgust than fresh faeces; faeces of babies and family members are more acceptable than those of strangers (Curtis and Biran 2001). People used to defecating in the open find the idea of indoor toilets disgusting, while people with indoor toilets find outdoor defecating disgusting. Nomad cultures are faecophobic because they have no need of latrines or agricultural fertiliser. These differences indicate that while disgust is a universal primal emotion, it is context-dependent, according to culture, tradition and familiarity (Avvennavar & Mani 2008).

Faecophilic cultures tend to be agricultural, where there is a strong understanding of soil fertility and the need for nutrients. Human excreta are regarded as part of the natural cycle, and burial in soil proved to be a safe method of decomposition. Originally people would have defecated in fields away from their homes to return excreta to the soil, and this habit became tradition. Faecophilic cultures are not common, but include China and Vietnam where there is a long history of excreta use as fertiliser (Winblad and Simpson-Hebert 2004). Interestingly, all cultures are more relaxed about urine than about faeces; urine has many uses, including therapeutic drink, antiseptic, insecticide, and production of gunpowder, detergent, dye and fertiliser (Drangert 2004). In some areas of Sweden urine is collected from residential areas and used on agricultural land for its fertiliser value (Johansson *et al*. 2009).

The range of cultural attitudes and practices to management of human excreta means that any attempts to introduce new sanitation practices are fraught with difficulty. The literature is littered with examples of failed projects where innovative installations were ignored or shunned because the designers did not take into account people's attitudes and beliefs concerning sanitation (Avvannavar and Mani 2008).

Innovative sanitation
Given the current issues we face in managing our excreta, including disease, water scarcity, dwindling phosphorus, and increased demand for food production, the ideal sanitation system is waterless, odourless, and returns our nutrient-rich excreta to the soil with minimum danger to us. These are among the goals of the ecological sanitation movement (http://www.ecosan.org/) which has worked with communities around the world for the past decade to develop sanitation systems that safely return excreta to the soil (Schonning

and Stenstrom 2004). Design options include arborloos where trees are planted in filled pits, dry toilets where excreta are collected and composted elsewhere, urine diversion toilets which enable separate collection, waterless urinals, double alternating composting pits, composting toilets, constructed wetlands, and windrow composting. There are many informative, well illustrated publications that detail construction methods, and benefits and costs, of the different systems, including *Ecological sanitation* (Winblad and Simpson-Hebert 2004), *Smart sanitation solutions* (Netherlands Water Partnership 2006), *Toilets that make compost* (Morgan 2007) *Compendium of sanitation systems and technologies* (Tilley *et al*. 2008), all available on the web.

Many ecological sanitation systems separate urine and faeces, because mixing the two creates odours and disease problems that we associate with excreta (Winblad and Simpson-Hebert 2004). Separating the two means the urine can be used as a fertiliser relatively safely, as it is by and large sterile and contains the NPK needed for plant growth in soil (von Munch and Winker 2009). Without the urine, faeces dry more quickly, which reduces their pathogen load, and makes them compost more easily into a valuable soil conditioner. Both EcoSanRes (Jonsson *et al.* 2004) and the WHO (2006) have published guidelines for the safe use of human excreta in food production.

Composting toilets that do combine urine and faeces are being installed in many buildings around the world, including Australia (Davison and Walker 2003). US practitioner Joseph Jenkins describes them as ‘humanure’ systems that require both faeces and urine to ensure there is enough moisture and nitrogen required for thermophilic composting. They also require substantial amounts of primary carbon cover material such as sawdust, peat moss, rice hulls, grain chaff or paper products for the toilet, and secondary cover materials for the pile such as woodchips. The high dependency on carbon sources means it is not an option in areas where there is little spare organic matter available (Jenkins 2009).

Another option gaining in popularity is biogas where human excreta are fermented anaerobically to produce gas that can be used for cooking, lighting, and heating. The solid effluent can be safely used on soils. Household biogas systems using animal and human excreta are an important part of China’s sustainable energy program (Chen *et al.* 2010); in India, the humanitarian organisation Sulabh has built 200 plants fuelled by excreta from public toilets (Patak 2009).

Roles for soil science

According to Esrey (2002) it is not a question of whether ecological sanitation will be adopted; but when, if resources are to be managed for a sustainable future. If this is the case, what roles can soil scientists play in assisting with this process? Soil scientists are already important players in recycling human excreta through their expertise in agricultural use of sewage effluent and biosolids, and septic tank management. As depletion of our resources makes re-use of human excreta a nutritional imperative, we need to be able to talk about our faeces and urine without embarrassment. Soil scientists can desensitise the topic by helping people understand the nutrient value of our faeces and urine, the importance of organic matter for soil fertility and structure, the sanitising role of compost, and the many structures and designs available to help people ‘close the nutrient loop’ and build our soil fertility. Such conversations will overcome what Black & Fawcett (2008a) described as ‘the unwillingness in societies everywhere to talk about excreta disposal and behave as if it was a matter of public importance instead of private embarrassment and shame’.

Research is still needed into the use of faeces and urine applied to agricultural soils. Several speakers at the 3rd International Dry Toilet Conference held in Finland in August 2009 (http://www.drytoilet.org/dt2009/), indicated that work is needed to better manage pathogen loads, transport urine easily, and reduce pharmaceutical residues. Soil scientists also have a key role in optimising excreta’s crop fertiliser value, as it is likely that nutrient supplements will be needed (Mnkeni and Austin 2009).

Soil science organisations can also help overcome institutional ‘urine blindness’ by promoting the importance of nutrient recycling in principle. According to Cordell *et al.* (2009), urine recycling to recover phosphorus is hampered by the lack of an institutional or organisational home in Australia because our flush and forget systems make recycling a peripheral concern to policymakers. Esrey (2002) says the future of ecological sanitation requires ‘dialogues with other sectors and professionals, such as those involved in agriculture, planning and architecture’ to ensure that ecological sanitation is perceived as an important part of sustainable development, not just as an alternative toilet design.

Conclusion
Declining phosphorus supplies and freshwater resources are rapidly raising the value of human excreta as important soil fertiliser that provides nutrients, improves soil structure, holds soil moisture and produces more food. But our intuitive disgust in handling our excreta due to its contaminant potential means that closing the 'nutrient loop' requires conversation, education, changes in cultural attitudes, technological innovation and still more conversation. Soil scientists have a role in all of these areas, starting with conversation today on why soils ARE dirt.

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State regulations, organic lawn management, and nutrient accumulation in soils

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Abstract

State statutes and regulations concerning land use decisions are often created with no consultation with soil scientists. The state of Connecticut passed a statute banning pesticide applications on athletic fields at Kindergarten through eighth grade schools. The expectation was that organic practices would be used to manage the turfgrass. The state Department of Environmental Protection started a program of education for school officials about organic turfgrass management with an advocacy group promoting organic practices. Much of the education recommended application of amendments to the soil to improve the soil-food-web with the expectation of improved turfgrass growth, and disease and insect resistance. Many of the recommended amendments were expensive. School officials requested university soil scientists be part of the educational committee. Soil scientists informed the committee that many of the recommended practices had no scientific data to validate their efficacy, and some practices would saturate the soil with phosphorus. Implementation of the statute has been delayed while a suitable, scientific-based solution is developed. The process used by the soil scientists to educate school officials, environmental advocacy groups, and regulatory personal will be described and publications used to educate about what is known and not known about the soil-food-web will be shown.

Key Words

Soil-food-web, soil phosphorus, organic practices, turfgrass, state statutes, soil scientists.

Introduction

Soil scientists can provide much needed information to legislators, government regulatory agencies and organizations involved in making decisions about the use of land. Land use decisions are complex and require input from many different perspectives. Historically land use decisions have been made primarily by using the advice of engineers, biologists, and economists. Many decisions, however, could be improved by the inclusion of the expertise of soil scientists. One relatively new and popular topic for making land use decisions is a requirement for organic land care management. Organic land care management uses the ideas of Sir Albert Howard (Howard 1943) and J.I. Rodale (Rodale 1942) to manage turfgrass and landscape plants (NOFA CT 2009). Organic land care management is often thought of primarily as a method to eliminate the use of conventional pesticides, which are considered by many people, including those promoting organic practices, to be toxic and unnecessarily harmful to the environment and to humans. A concern about the application of pesticides to turfgrass on athletic fields at schools in Connecticut prompted the passage of a law banning all pesticide use on school grounds, including athletic fields, at kindergarten through eighth grade schools (State of Connecticut, HB 5234 2007).

No soil scientists were consulted during the discussion and debate about the new state statute probably because the discussion and debate were about the effects of pesticide use on children and the environment. The discussion about the new statute included an expectation that organic lawn care would be substituted for conventional lawn care. Organic lawn care is based on the premise that if the soil is managed properly the need for pesticides will be eliminated (Heckman 2007). The biologists, environmentalists, toxicologists and others who testified about the benefits and need for the ban on pesticides had no knowledge about the effect of good soil management on the need for pesticides on turf. Information about the management of nutrients, especially phosphorus, to avoid accumulation of nutrients and subsequent loss of environmentally harmful concentrations of nutrients from the soil was absent from the discussion.

This paper is a case study about how the legislative and regulatory process to improve land use decisions can be improved by including soil scientists in the process. We also provide a summary of recommended organic lawn care practices, many that are meant to improve the soil-food-web, and a summary of the scientific data about how modification of the soil-food-web can enhance the growth of turf.

Methods

We completed a literature search of information about the practices and amendments recommended by practitioners of organic lawn care. Information about how recommended organic lawn care practices can enhance the soil-food-web, and how the enhancement may or may not protect turf from insects and disease were searched for and compiled.

Results

The state of Connecticut's Department of Environmental Protection (DEP) obtained a grant with a non-profit organization in the state, the Northeast Organic Farmers Association, who promotes organic land care practices (NOFA 2009). The grant provided money for the non-profit to develop education programs for town employees who manage athletic fields at Kindergarten through eighth grade schools, and to perform demonstration trials on athletic fields of two towns who volunteered to work with the DEP and NOFA. The demonstration trials compared conventional management of turf using soluble fertilizers and conventional pesticides with organic management of turf without using soluble fertilizers and conventional pesticides. The demonstrations consisted of two athletic fields in one town having half of each field treated with conventional practices and the other half treated with organic practices. Two professors of turf from the University of Connecticut were asked to evaluate the performance of the fields without knowing which treatment was used on which half of the fields. The other town had a similar trial with one athletic field having half the field managed with conventional practices and the other half with organic practices. There was no unbiased evaluation of the practices at the second town.

The demonstration trials were only partly successful. The town with two fields in the demonstration did not implement the most important organic practice, topdressing with compost, to only the organic fields, but also applied the compost to the conventionally managed fields. The town with only one field in the demonstration reported that there was little difference in the condition of the fields after two seasons of differential management. There were two main problems with the implementation of organic turf management on the athletic fields. The expense of buying and applying the recommended organic amendments was substantially greater than the expense of conventional practices, and the demonstration trials were not conducted in a manner that allowed a valid comparison. Part of the problem with the organic practices was that organic practitioners mistakenly asked for the wrong analysis for the compost the towns used for topdressing the fields. The analysis requested was for a soil sample and not for a compost sample. The procedures used to analyse soil samples provide extractable nutrient concentrations while the procedures used for compost provide total nutrient content. The total nutrient content is always much greater than the extractable concentration of a compost sample. This mistake caused much confusion because the rates of application were to be based on the analysis of the compost. The rates applied were instead based on the typical application of compost recommended by organic practitioners, which is 2 to 4 mm applied in the spring and in the fall. Applying this much compost annually to turf often will increase the soil phosphorus content to levels that are environmentally harmful. One of the demonstration fields already had an excessive amount of phosphorus in the soil from previous applications of phosphorus and no compost should have been applied to the field.

Many town employees in the state were informed of the high cost of the recommended organic practices by their colleagues at the two towns hosting the demonstration trials. Some of the employees called Tom Morris and another soil scientist at the University of Connecticut to discuss the recommended organic turf practices. The senior author obtained a copy of the recommended organic practices. A review of the literature was performed to obtain scientific literature about the effectiveness of the recommended organic practices. The senior author contacted the DEP and asked to be included on the advisory committee for the educational program and for the demonstration trials. The advisory committee had scientists on the committee, but none were soil scientists. This lack of knowledge about soils and soil fertility was a severe limitation of the program. This limitation was causing some of the town employees, especially those with formal training in soils and turf management, to think that the DEP was no longer basing their programs on science. The DEP agreed to include the senior author on the committee. We had a meeting to discuss how to ensure that the educational program and the recommendations from NOFA were based on science and not on the opinion of the organic practitioners. The DEP and NOFA agreed the program should be based on science and that we should develop a joint educational program with the participation of DEP, NOFA and University of Connecticut.

The advisory committee developed three new educational workshops with the turf management section of the University of Connecticut's Department of Plant Science and Landscape Architecture. The workshops were a mix of practical advice from the organic practitioners and science-based advice from the university. This change was much appreciated by the town employees who would be required to manage turf without pesticides. Two of the most important ideas that developed from the discussions of the advisory committee after soil scientists were added to the committee were that a review of the literature was needed to evaluate the recommended organic practices and that the law only required elimination of pesticides and not the elimination of soluble fertilizers. The total reliance by DEP in the beginning of the education program on NOFA, which is an organization that believes that soluble fertilizers are detrimental to soil microbiological life, gave the impression to town employees that fertilizers were also banned.

The review of the literature showed that there was scant scientific information about the effectiveness of organic turf practices. Unfortunately, there is little to no scientific information published in referred journal articles that provide unbiased information about the effectiveness of most practices recommended by the organic practitioners. Most of the practices were recommended by a private laboratory that specializes in providing recommendations for organic turf management. The laboratory is the Soil Food Web at: http://www.soilfoodweb.com/. We could not find information in the scientific literature about the practices recommended by the Soil Food Web laboratory. We especially looked for the field trials comparing the recommended products or practices with either conventional amendments or practices, or to a no treatment control. Only a few scientific papers could be found that made comparisons of this type for the practices recommended by the Soil Food Web. Most of the recommendations seemed to be based on the owner of the laboratory's opinion that was based in ecosystem theory of soil ecosystems (Ingham *et al.* 1985) or on general studies showing differences in soil microbial populations between different ecosystems, such as grassland (Hunt *et al.* 1987) and forest soils (Ingham *et al.* 1986). Scant scientific information about the effectiveness of practices promoted by practitioners of organic land care indicates that this area should be targeted for funding.

Conclusion

The process to create and pass the state statute banning pesticides on athletic fields of Kindergarten through eighth grade schools was flawed because it was based on the assumption that organic management of turf would be sufficient to maintain the quality of turf needed for safe participation in athletic competition by children. The scientific evidence is scant about whether this assumption is true or not. There is anecdotal evidence that turf can be maintained using organic methods for a few years, but there is no scientific or anecdotal evidence about whether turf can be maintained for the long-term at sufficient quality for safe athletic competition by children. The process to create an education and demonstration program about organic turf management did not include soil scientists. This oversight resulted in the presentation of misinformation in the education program and incorrect methods in the demonstration program. Soil scientists should be included in decisions about most land use decisions. Even when soil scientists are included on committees about organic land care, however, there are few scientific publications available to provide a scientific basis for recommendations made by organic practitioners. Including a soil scientist on committees involving implementation of organic land care practices will at least allow the delineation of what is known and not known about the scientific basis for organic land care.

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Understanding your soils – working with land managers

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Abstract
Training workshops delivered in Victoria, Australia, through the Department of Primary Industries 'Healthy Soils' project has increased the understanding of soils by land managers. This has been clearly demonstrated through evaluation of workshop participants. Land managers and advisers were invited to attend training workshops comprising presentations, hands-on activities and in-field soil assessment to improve their knowledge of soils. Workshops of regionally specific information on subjects such as soil type, soil structure, soil chemical testing, soil biology, and organic matter were held at community centres across Western Victoria initially, expanding into other regions of Victoria over time. Average workshop attendance was 20 participants, with a total of approximately 1060 participants attending 49 workshops to June 2009. Evaluation has demonstrated the usefulness and relevance of these workshops, and learning outcomes were achieved by greater than 80 % of participants. Many participants planned to make better management decisions and change management practices on farm as an outcome of the workshops. The workshops are an example of a successful program to educate land managers of the importance of soils in production systems, providing them with a greater skill set to understand and assess their soils and improve their land management practices.

Key Words
Education, training, evaluation

Introduction
Understanding and managing soil is the key to a productive and sustainable land management strategy. In 2006 the Department of Primary Industries (DPI) Victoria embarked on a four year 'Healthy Soils' project to improve land managers understanding of soils. The project was funded as part of the State Government of Victoria's *Environmental Sustainability Action Statement* (2006-2010) and by the Federal Government of Australia's *Healthy Soils for Sustainable Farms* programme (2006-2008). The project's major focus has been on the grains industry in Western Victoria.

Improving land managers understanding of their soils involved education and training with support from regional farmer groups including Southern Farming Systems, Birchip Cropping Group and Mallee Sustainable Farming. Training workshops of typically 3-6 hours were used to increase land managers awareness of the importance of soils in production systems. Each workshop was regionally specific with the goal to provide land managers with an improved awareness and understanding of their soils, and some skills with which to assess and adapt their land management practices. Workshop topics included 'Understanding soil structure and soil types', 'Understanding soil biology', 'Managing soil organic matter' and 'Managing subsoil constraints', 'Understanding soil tests – chemical'.

Methods

Presentations using Powerpoint

Powerpoint presentations combining text, photographs, tables and schematic diagrams were used during workshops to educate the land mangers about their soils. Each workshop participant was also provided with a folder of workshop materials, including supporting Technical Notes and Quick Reference Guides.

Hands-on activities

Hands-on activities such as soil texture, aggregate stability, and a potassium permanganate test for labile carbon were conducted outside (weather permitting), and were used at recess during the Powerpoint presentation component of the workshop.

In-field assessment

A soil pit was used, where suitable, to support the presentation and hands-on components of the 'Understanding soil structure and soil types' workshop. Participants (in groups) used information that they had learnt from the in-house session to characterise a soil profile (assessing soil horizons, colour, structure, aggregate stability, biology, pH, and evidence of compaction and crusting).

Online support

Each participant was provided with access to a password protected *Soil Health Project Forum* website after the workshop. All Powerpoint and written materials were available to download, providing participants with access to resources and contact details for further information.

The Victorian Resources Online (Department of Primary Industries Victoria 2009) website now contains specific information on soil health and provides online support and details of further information for workshop participants. This website also provides access to written references and other online sources.

Evaluation

Each workshop participant was asked to provide feedback using evaluation question sheets. Workshop evaluation is presented graphically (reported here) and typically requested participants to agree or disagree with statements regarding learning outcomes. The evaluation was designed to gather evidence from participants as to whether their understanding of soils was improved as a result of attending the workshop.

Results

At the time of preparing this paper, approximately 475 participants from 49 workshops across Victoria had provided evaluation feedback on the training workshops held in their region (approximately 1060 participants have attended these events to June 2009). Evaluation of workshop participants will continue until June 2010 when the project is completed.

Table 1. Occupation of training workshop participants

Occupation	Percentage (%)
Farmer	64
Consultant	11
DPI extension officer	10
DPI researcher	1
Student	1
Other*	13

* Other occupations identified included hobby farmers, Landcare coordinators, teachers (including university and secondary educators), farmer group coordinators, and local Government employees.

The results presented below have been extracted from extensive evaluation reporting and provide evidence on how the training workshops improved participants understanding of their soils.

Figure 1 shows that over 80 % of participants found the training workshops to be useful, relevant, an efficient use of their time, provided useful resource material, and of high to very high quality.

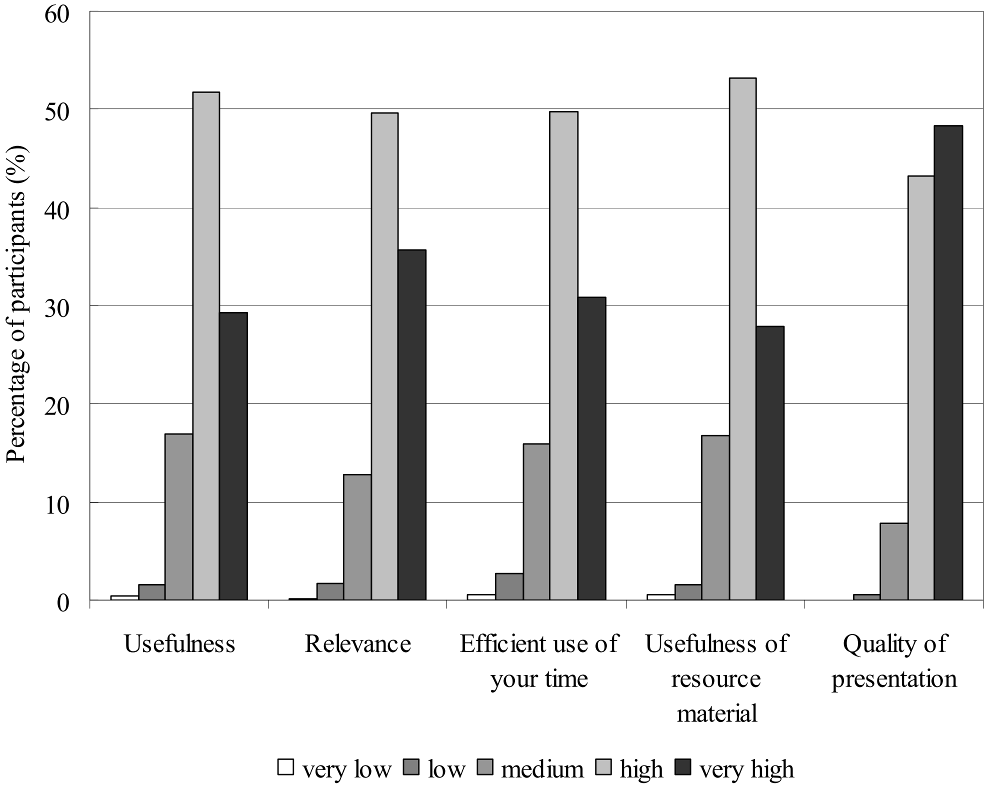

Figure 1. Participants ranked each training workshop from very low to very high regarding usefulness, relevance, efficient use of their time, usefulness of resource material, and quality of the presentation.

Figure 2 shows that, for each of the four learning outcomes, 82 % to 95 % of participants agreed or strongly agreed that the training workshop improved their understanding of soil biology.

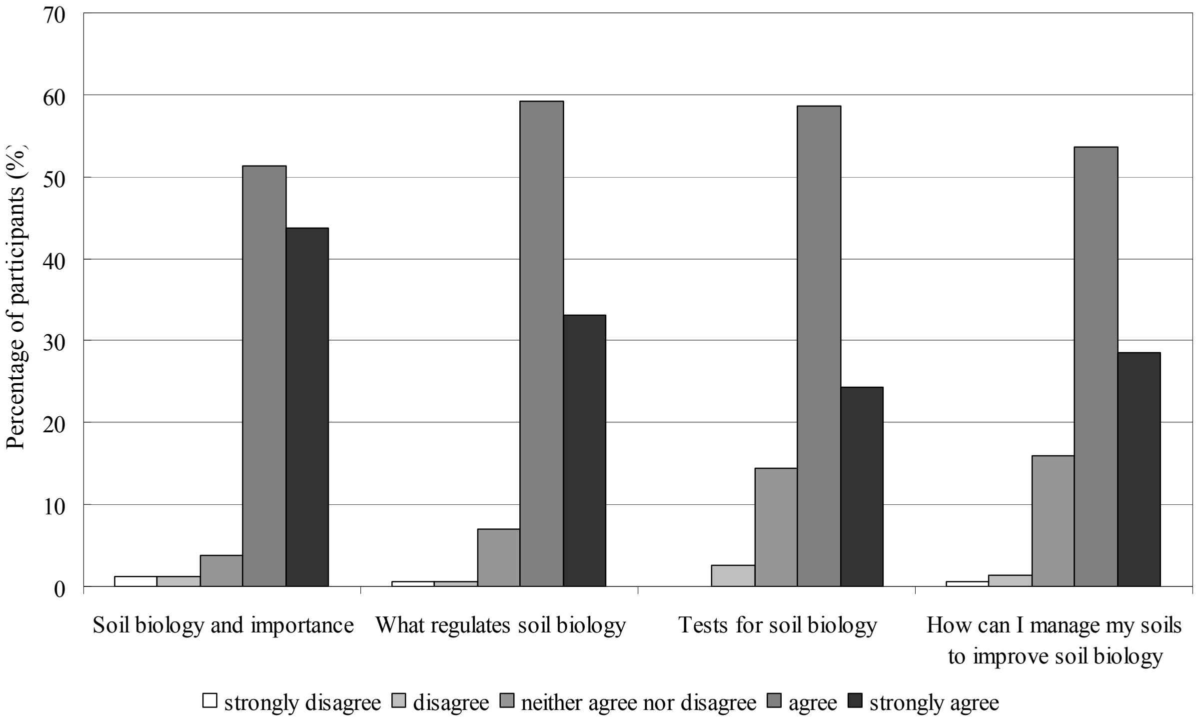

Figure 2. Evaluation data for the question "The 'Understanding Soil Biology' training workshop improved my understanding of…".

Participants were strongly encouraged throughout the training workshops to apply their new-found knowledge to their own soils by looking at the soil profile, assessing aggregate stability, looking for earthworms and other biological activity, testing for nutrients, and looking for evidence of compaction, crusting and erosion. For many participants the workshop exposed them to the complexity of their soils, and how management (for example traffic and cultivation) significantly influenced their soil condition. Participants were asked "How will what you learnt today help you to do your job better?" To detail just a few responses: "Careful planning with rotations, herbicide use, stubble management, etc"; "Adopt practices that will increase biological activity"; "I will now go and look at [the] structure of the soil and make management decisions"; and "Be more viable as a farmer into the future".

Figure 3 displays the responses of 296 participants to the evaluation question "How will what you learnt today help you to do your job better?" Responses were categorised by key words such as "understanding", "decisions", "awareness", "communicate", and "confidence". Key messages were also used to categorise responses (e.g. "I need to refine my stubble retention practices e.g. less tillage to get same result" categorised as 'change practices').

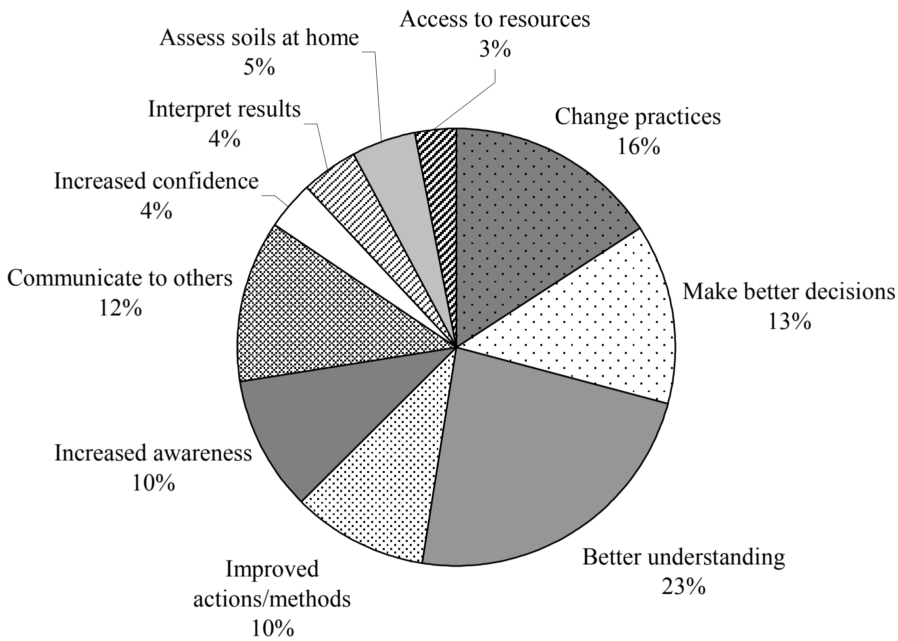

Figure 3. Responses to evaluation question "How will what you learnt today help you to do your job better?" categorised by key word/key message.

Conclusion

The training workshops clearly resulted in an increased understanding of soil, and the intention of workshop participants to apply their knowledge to their soils. The workshops were successful at increasing awareness of the importance of soil to the farming community of Victoria, and how soils can be managed to contribute to improved farm productivity. The benefit of these workshops to individuals, groups and farming communities is evident in the evaluation data collated and represented here. It is anticipated that the workshops will encourage significant changes in farming practices across Victoria in the future, and will be integrated with a 'Soil Health Management Plan' as part of other 'Healthy Soils' project work. The training workshops will continue to be conducted throughout Victoria and the information disseminated via the Victorian Resources Online website (Department of Primary Industries Victoria 2009).

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Value-added futures: education, the environment and the economy

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Abstract
The proportion of students choosing to study the quantitative sciences has been decreasing for over 15 years, coinciding with the advent of the Y-generation and educational reforms. The aim of the reforms, which occurred in many developed countries, was to prepare students to be successful in a global world – to have confidence, analyse and interpret based on sensibilities rather than memorised facts, to challenge ideas, and to express opinion. At the same time, the value of time and money was impressed upon them, and working 'smarter not harder' became the rule. The unintended consequence is that those disciplines where memory and accuracy are important have become less popular than the creative disciplines associated with talent. Of equal importance is that laboratory-based subjects are more time-consuming than non-laboratory based subjects. Where the intended career is in a profession perceived to have high kudos and financial reward (e.g. medicine and veterinary studies), students are still attracted into the sciences, prepared to put up with strictures and effort on the basis of future gain. For careers based on soil science, however, the rewards are not at present apparent to the young. This paper discusses the origin of the problem and suggests a path for change.

Key Words
Discipline, science subjects, students, Y-generation

Introduction

Soils feed us, clothe us and filter our drinking water.
Soils, plants, lakes and rivers form the landscape in which we live.
Soil Science helps us to understand the landscape and to balance the needs of production and conservation.
Professor I.S. Cornforth, Why Soil Science? 1993

Given the importance of soils to human existence, and therefore the underpinning disciplines of biology, physics, chemistry and mathematics, the decline in popularity of these subjects is something of a conundrum. It is, however, a global phenomenon – at the very time when pressures on the globe are escalating, and the need for scientists, technologist, engineers and mathematicians (STEM) has never been greater. In addition to environmental and food production concerns is the drive for economic development and improved productivity, which is linked to tertiary education in science and technology (Wolff and Gittleman 1993). Of equal importance is the ability to create wealth from innovation, which is closely and significantly related to the relative number of scientists and engineers in the workforce (Porter and Stern 2001).

Investment is being and has been made made in various countries (e.g. Canada, UK and USA) in an attempt to ensure a strong supply of skilled STEM workers. Analysis has suggested (Westgate 2007) that factors behind the decrease in STEM students include shortage of specialised STEM teachers, (2) image of science and scientists (not trendy), (3) perception of science as a harder subject and (4) lack of knowledge about what STEM careers entail. All of these factors are true, but school children still take the sciences if they want to be doctors or veterinarians (Hipkins *et al*. 2006). The challenge, then, is to make STEM careers as attractive as the medical professions by showing the students that the rewards are high. At present, however, a considerable portion of the value that soil scientists experience is intrinsic (discovery) rather than extrinsic (money and kudos). Career decisions are made at school before many of the children have the maturity to understand the difference between intrinsic and extrinsic rewards. Well-meaning suggestions that specialisation can be avoided by doing 'general subjects' actually limit future options.

This paper considers the changes that have resulted in the current trends and discusses the potential for a different future to ensure that soils are not treated like dirt.

The generational change

People are affected by the world in which they grow up. While having individual experiences as part of a family, they have collective experiences as part of a school, region, and country. War, depression and affluence are experienced collectively, and buffered individually. Baby Boomers, born between approximately 1946 and 1964, were brought up post-war by conservative parents influenced by the depression as well as the war itself. Education was a privilege (only approximately 3% of school leavers actually went to university), discipline was expected, and science and technology were regarded as the way of the future. To be accepted into a science career spoke well of intelligence, and the future of the world was associated with having good people making discoveries. Salaries were not startling, but the kudos and security were innate.

By 1965, the contraceptive pill meant that babies were (increasingly) the product of choice about family size, and the birth rate dropped. By the mid-60s, electrical convenience was becoming commonplace and the world was ‘globalising’. In order to cope with the coming trends, including education for a greater disparity of people, educational reforms were ongoing.

In the late 70s, the birth rate began increasing, reflecting the fact that Baby Boomers had started families. The group born between approximately 1978 and 1994 (but sometimes considered to be 1982-2000) is the first in history to have been born during a period of affluence (plus two income families), with no direct experience of war. The minor depression of the late 80s did not factor into their experience. The Y-generation is being followed by the Zappers, or Z-generation, currently still at school. It is expected that the Z-generation will be similar to the Y-generation in terms of attitude because the factors in positive parenting and schooling have not changed. Their world view, however, and consequently their attitudes towards environmentalism and employment security, is being influenced by climate change and the current economic downturn.

Members of these new generations have been brought up as the focus of the family. Parents have tried to give better parenting than they received from their own parents, and have typically brought their children up with more affection and involvement than previous generations. These parents have articulated the ‘I don’t mind what they do, I just want them to be happy’ mantra (Cooper and Keitel 2008). In a deliberate move to give them the confidence to be able to compete successfully in the global workplace, and in marked contrast to the ‘children should be seen and not heard’ attitude of previous generations, they have frequently treated the children as equals. The benefit to the parent is that their children regard their parents as friends, but in adopting the role of friend and equal, parents are finding it difficult to provide guidelines and assume the role of authority (Poulter 2008). Positive parenting in an era of high tolerance has resulted in huge confidence and an awareness of self-value: in 2006 two thirds of the 16,475 American college students evaluated nation-wide in the Narcissistic Personality Inventory recorded above-average scores – a 30% increase since 1982 (Twenge 2006). At the same time, however, underperformance has increased and ‘anxiety’ has reached record levels (Twenge 2001). The sad irony is that in encouraging children to be happy and ‘all that they can be’, the result has been the opposite.

Education

Reforms in the education system towards the end of last century were focussed on ensuring that every child completed a qualification with a sense of achievement. Subject liberalisation was intended to make education more relevant for a greater proportion of the population, and choice increased. At the same time, the need for a scientifically-literate society able to understand the benefits and risks of new developments was recognised and the approach to teaching traditional subjects was changed. This involved a move away from the ‘old’ system where knowledge and abstract facts were considered to be important and exams were final, to a child-centred approach with greater emphasis on course work, open-ended tasks, context dependent knowledge, analytical skills and verbal reasoning (Warrington and Younger 1999).

The unintended consequence has been that as the Y-generation members have a high awareness of work-life balance and expect rewards without having to ‘bust a gut to achieve them’ (Sheahan 2005), children have tended to opt for the subjects which they perceive to be enjoyable and where acceptable achievement can be obtained for minimum effort. Research from the Centre of Evaluation and Monitoring, Durham University (Coe *et al.* 2008), has revealed that it is more difficult to achieve high grades for subjects where accuracy and memory are required (physics, chemistry, biology, maths, French, German) than in the creative subjects (drama, design, photography).

The future

Students are interested in science and do see it as having value for the future (National Education Monitoring Project 2007). Furthermore, they are concerned about the environment. The links to employment choices then depend on making the science careers attractive. Having a variety of assignments in work, and contributing to society, were important career goals for approximately one third of the 7,500 students from Durham University participating in the Universum Graduate Survey in the UK (Van Mosselvelde 2007). The

proportion for contributing to society was similar in the US, but somewhat smaller in Europe and China. Work life balance rated more highly in all countries – it was the most important career goal for over 50% of respondents. At the same time, salary expectations are high. Research by Robert Half International (2008) indicates that members of the Y-generation want salary, benefits, career growth, location, good leadership, respected brand and job title. They believe that having gained a degree, their job should reflect the effort and years spent at university.
Knowing the background and goals, it should be possible to create an attractive proposition for employment.

Dollars and status
Salary should never be discounted: it is ranked (Robert Half International 2008) as the top reason for changing jobs. In New Zealand salary packages currently offered to final year degree students with science, particularly soil science, in their degrees are so attractive that postgraduate education is being eschewed – the opportunity cost of further study is too great and the graduates are 'sick of study and want to have some fun' – for which they need money.

Beyond money, part of the attraction in becoming a doctor or veterinarian reflects the fact that there is status and kudos in being accepted into these professions – there is a respected brand and job title. Substantial education and training are required, the nature of which is determined by members of the profession, who also influence entry to the profession. This implies accreditation of, for example, university courses that are judged to meet these standards to facilitate entry, a code of conduct to regulate how members behave in their professional lives, and mechanisms for disseminating knowledge of good practice to members.
Attempts at establishing accreditation schemes such as CPAg and CPSS have not received universal acclaim, because there is no regulatory body operating in the same manner for agriculture and soil science as there is for the medical, veterinary and engineering professions. Regulation also implies litigation, however, hence reluctance to embrace the model.

Satisfaction
Job satisfaction is difficult to explain to the young who tend to concentrate more on the lifestyle that the salary can afford (hence the work-life balance) than the satisfaction innate in the work. However, with a third of students indicating 'society' as important, emphasis in recruitment into the sciences can be placed on this aspect, but might take some adjustment in the employer to achieve, in this era of accoutability.
Autonomy (the ability to take responsibility and to be treated as if those responsibilities will be exercised) is associated with job satisfaction and engagement (Deci *et al*. 1989), as are usefulness and social interaction (Borooah 2009). An engaged workforce is productive and creative – making progress is the single biggest motivator for employees (Amabile and Kramer 2009); workers are most creative the day following a happy day (Amabile *et al*. 2005).

Job opportunities
The economic recession has brought job security back into the concerns of undergraduates and senior school children. Although unemployment has increased globally, increases in job opportunities in science-based careers are apparent. Statistics New Zealand has reported (Laugesen 2009) an almost 11% increase in the year to June in the 'life science and health professionals' category (which includes doctors, dentists, veterinarians, pharmacists, nurses, midwives, biologists, agricultural scientists and botanists). Physical, mathematical and engineering sciences experienced a 9% increase.

Job variety
Perhaps of most importance given the desire for variety in work, plus the prediction that they will have 22 different 'careers' (Sheahan 2005) is the fact that from the sciences most things are possible – that the reward for 'sticking with the hard stuff' is flexibility. In addition to the obvious science-based careers, a study by Cornell University in 1995 reported that 90% of 500 Chief Executive Officers thought people with higher degrees in physics, chemistry, maths and computer science would be the next generation of managers, and over 66% agreed that the competitiveness of the company would be increased if more senior managers had a technical background (Motluk 1996). Education also requires science people – the need for great science teachers to inspire students to excel in mathematics and science has been highlighted by President Obama since before his election. Similarly, the media employers are increasingly interested in reporters with knowledge – particularly in the science and technology areas which form an important part of news.

Actions
Peter Sheehan and other Y-generation gurus have said repeatedly that the Y-generation place culture and

leadership at the top of their consideration (once money has been addressed). They also want their jobs to have purpose and meaning, entail responsibility, give promotional opportunities, challenges and experiences, fair remuneration, increased employability, and allow creativity and individuality (Sheahan 2005). Science should allow all these things. Of note in some minds might be ‘creativity’ – but science is a creative activity as it creates new knowledge. Florida (2003) lists (in order) creative types as: scientists and engineers, university professors, poets and novelists, artists, entertainers and actors, designers and architects.

Conclusion
Members of the younger generations are still focussed on salary and lifestyle, but are increasingly concerned about the environment and food production. The economic recession has refocussed thinking on to what matters in the world, and the auguries are right for a resurgence in science as food security becomes paramount for the global population. The world needs more scientists to manage the environment and produce food sustainably as well as to create economic development, and they will become the gold-collar workers of the future. Everything that the younger generations need, want and desire can be managed from a science-based education… as long as it is clear that society values their efforts and the soil appropriately.

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