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Soil science and the *h* index

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Soil science is a relatively young and specialised field of science. This note discusses the use of the *h* index as a scientific output measure in soil science. We explore the governing factors of *h* index in soil science: the number of soil scientists, the number of papers published, the average number of citations, and the age of the scientist. We found the average relationship between *h* index and scientific age for soil science: $h = 0.7\ t$. The *h* index for soil science is smaller than other major science disciplines but norms for *h* need to be established

Introduction

The systematic study of soil science started somewhere in the middle of the nineteenth century. In the beginning most soil investigations were published through books and monographs but the first scientific journal solely dedicated to soil science was published in 1899 in Russia. It was named *Pochvovedenie*. Prior to the Second World War there were only a few scientific journals in which soil investigations were published. A considerable number of soil science journals was established directly after the war and another peak occurred in the early 1980s. Only two journals were established in the 1990s and both focus on soil biology. Currently, there are about 35

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journals with their main focus on soil science although there are an increasing number of soil publications in other journals (HARTEMINK, 2001).

Soil science journals have an impact factor between 0.5 and 2.5 as annually calculated by the Institute for Scientific Information (ISI) in Philadelphia USA. The impact factor of most soil science journals has gradually increased in the past two decades (HARTEMINK et al., 2001). In many university departments and research centres, individual soil scientists are evaluated using these impact factors whereby the number of publications is matched with journals in which the papers were published. Although it is generally favourable to publish in papers that are highly ranked and with a high impact factor such matching says little about individual papers and other methods are used and needed to evaluate a scientist's productivity and impact.

HIRSCH (2005) suggested the *h* (Hirsch) index as a measure of scientific 'output'. The index reflects both the number of publications, and their impact as measured by the number of citations. Although it has received some criticism (KELLY & JENNIONS, 2006), it has been used in various fields of science for evaluating progress and individual research records (BALL, 2005; GLÄNZEL, 2006). The *h* index can also be used for groups of scientists, for example, in university departments. BRAUN et al. (2005) calculated the *h* index for journals and suggested its use to complement the ISI impact factor. BANKS (2006) showed that it can be used as an index for research topics and chemical compounds and the *h* index can differentiate between new "hot" topics and "older" ones.

The typical *h* index depends on the discipline or field of science. The *h* index of an individual scientist is influenced by:

- the size or number of scientists in the field,
- the number of papers produced by the scientists in the field,
- the average number of citations in the field, and
- the age of the scientist (HIRSCH, 2005).

Here we explore some publication trends in soil science, the *h* index with its governing factors, and attempt to find a "standard" *h* index for soil science. We hypothesize that (i) the *h* index is related to the scientific age, (ii) the *h* index for soil science as a group is smaller than other major disciplines and natural resources topics, and (iii) the standard *h* index for soil scientist is smaller than major science disciplines.

Data and analysis

We used the ISI Web of Science database and the data were retrieved in November 2006. We counted the number of publications in the subject of natural resources with "soil", "air" and "water" in the title, keywords, or abstract from the year 1991 to 2005. We also counted papers that are published in soil science journals in the ISI database.

There are 29 journals categorized under the subject of "Agriculture, Soil Science" in ISI, with impact factors in 2005 ranging from 2.4 to 0.1.

For the calculation of the individual scientist's *h* index, we selected 228 soil scientists from all major subdisciplines. The soil scientists were selected from the editorial board of major soil science journals, the ISI highly cited researchers, and the database of International Union of Soil Sciences (IUSS).

Results

Number of soil scientists

The larger the number of scientists in a field, the larger number of citations, thus typical *h* values should be larger. On the other hand, HIRSCH (2005) argues that the larger the field, the larger the number of scientists to share a larger number of citations, so typical *h* values should not necessarily be larger. According to the IUSS database there are about 50,000 soil scientists in the world. Only a fraction of these are in research and actively publish in international refereed journals. The size of that fraction is hard to estimate but probably in the range of a few thousand very active soil scientists and less than 10,000 occasionally publishing soil scientists. The number of soil scientists in the world has decreased considerably in the past two decades as a result of reduced government funding and a range of other factors (IUSS, 2006; MERMUT & ESWARAN, 1997; TINKER, 1985). There has also been a considerable decrease in soil science students in the past decade (BAVEYE et al., 2006).

Number of soil science publications

Figure 1 shows the number of publications in the subject of natural resources with "soil", "air" and "water" in the title, keywords, or abstract from 1991 to 2005. The number of "soil" publications is lowest, and standing at about 30% of "water" publications and 80% of "air" publications. The number of soil publications is currently increasing at a rate of about 5% per year. Papers that are published in soil science journals are a small percentage of the total number of the "soil" papers, and declined from 22% in 1991, to 16% in 2005.

We calculated the *h* index for the topics in "soil", "air", and "water" which is an indicator of the relative impact for each discipline (Figure 2). The *h* index for "soil" is lower than "air" and "water" and papers published in soil science journals also have a lower *h* index compared to the others. The trend lines also suggests that natural resources subjects have a slow intake or the impact progresses slowly. The *h* index is shown to increase slowly from the year it was published to about 8–10 years where it starts to plateau.

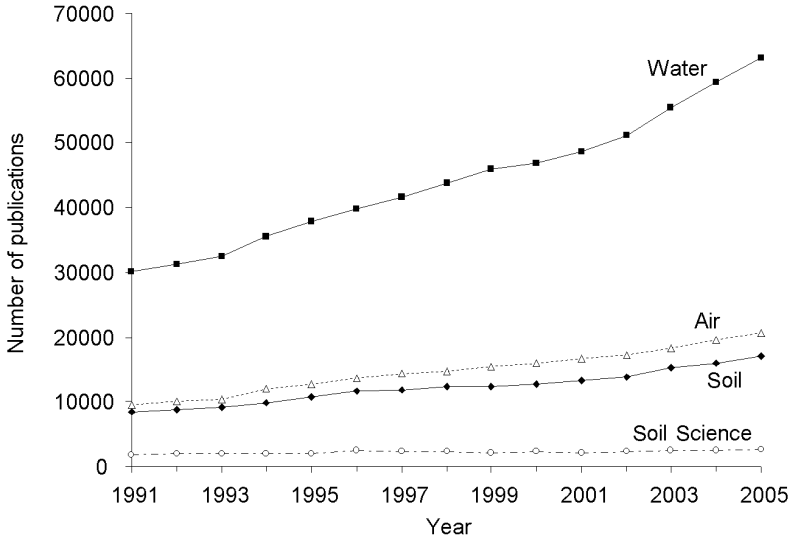

Figure 1. Trends in publication with topics "soil", "air", "water", and papers in primary soil science journals (data from ISI web of science). Papers were counted with "soil", "air" or "water" in keyword, title or abstract

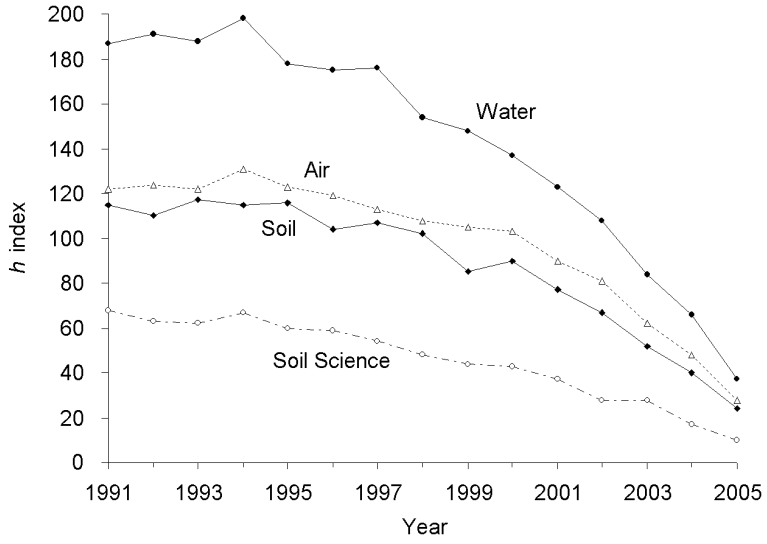

Figure 2. *h* index for papers under topic "soil", "air", and "water", and papers in primary soil science journals. The *h* index is calculated based on publications in Figure 1

The h index, number of citations, and scientific age

HIRSCH (2005) suggested the relation between h and the number of total citations $N_{c,tot}$ is given by:

$$N_{c,tot} = ah^2 \tag{1}$$

According to Hirsch a is between 3 and 5. The value of a is related to the average number of papers published per year, and the number of citations earned by each paper. Evidently h is related to the age of the researchers, a relation with age is proposed by HIRSCH (2005):

$$h \approx m\,t \tag{2}$$

where t is the "age" of the researcher. We can approximate t by the number of years after the first published paper which usually takes place towards the end of the PhD degree (approximately 25–30 years of age). Thus, m can reflect the productivity of a researcher or field of research. The value of m can be calculated for individual researchers $m_i = h/t$. For physicists, HIRSCH (2005) found $m \approx 1$ characterising a successful scientist, and $m \approx 2$ for outstanding scientists.

We calculated the h index for soil scientists using the ISI Web of Science database. These data represent a range of soil scientists from early researchers with scientific age of 1 year, to mature scientists with 56 years of publications. The median is 24.5 years, the mean is 25, and the standard deviation 11.8 years. The h index has a mean of 18, a standard deviation of 10.6, median of 17, minimum of 1, and maximum of 51. The median of the average number of citations per paper is 15, minimum 1 and maximum 103. Individual scientist's m_i has a median of 0.69, minimum of 0.17, and maximum of 2.62.

Rather than analyzing individual researchers we calculated the relationship for equations (1) and (2) for the whole dataset as a representation of the soil science community. Figure 3 shows a strong relationship between h and $N_{c,tot}$ with $a = 3.5 \pm 0.05$. For soil scientists we have the following relationship between h and t (Figure 4):

$$h = (0.7 \pm 0.02)\,t \tag{3}$$

Only 21% are above the $m = t$ line (successful scientists according to Hirsch), and 1% are above $m = 2\,t$ (outstanding scientists).

We found that the number of publications with time can be approximated by a linear relationship:

$$N_p = p\,t \tag{4}$$

$p = 2.9 \pm 0.11$, which means that soil scientists have an average of three papers per year.

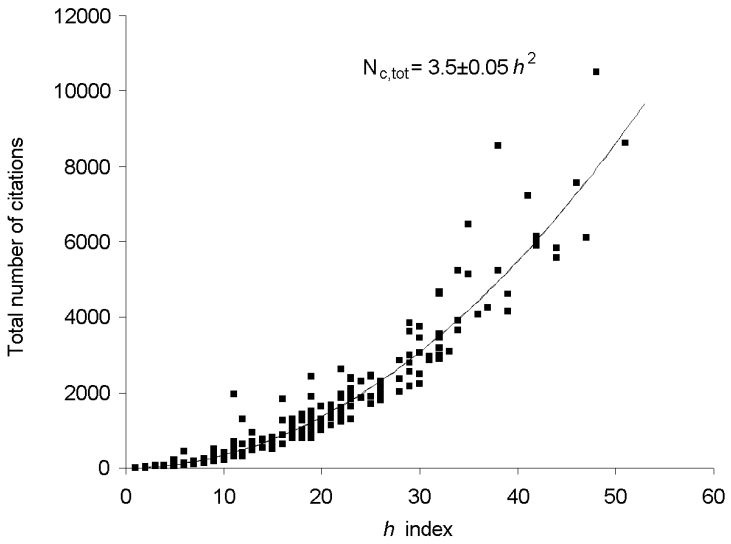

Figure 3. Relationship between *h* index and total number of citations for 228 individual soil scientists

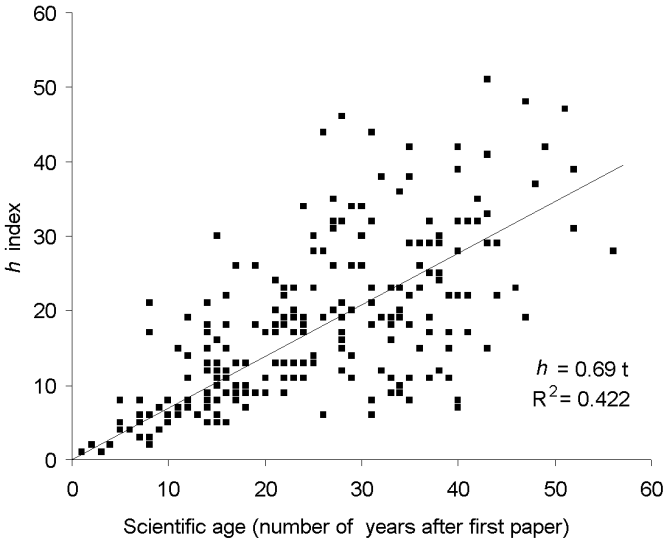

Figure 4. Relationship between scientific age of 228 individual soil scientists and *h* index. The scientific age is defined as the number of years after the first publication in an international journal

Using relationships between h, $N_{c,tot}$, N_p and t we can derive the average or expected relationships between number of citations and scientific age and number of papers. From Equations (1) and (2) we have the relationship between time and total number of citations:

$$N_{c,tot} = a\, m^2\, t^2 \tag{5}$$

HIRSCH (2005) also defined c as the average number of citations per paper per year with the following relationship:

$$N_{c,tot} \approx \frac{(1+c/p)^2}{2c/p} h^2 \tag{6}$$

With the average number of papers per year p = 2.9, the possible values of c satisfying equation (6) are 0.6 and 14. According to HIRSCH (2005) realistically $c > p$, where most contributions to $N_{c,tot}$ is from the highly cited papers (the h papers that have the number of citations > h). However, from our data, we find that the slope between the average number of citations per paper ($N_{c,tot}/N_p$) and scientific age t is 0.69. Thus c is more likely to be 0.6 for soil science publications, which means that sparsely cited papers (the $N_p - h$ papers) give the largest contribution to the total number of citations. This assumes that the contribution to the citations of each paper is equal, which is not true. Only the top papers (the h papers) are frequently cited, others (the $N_p - h$ papers) are seldom cited and some are never cited. Moreover the citation of a paper follows the popularity of a topic, it will reach its maximum at some time after the subject becomes popular, and then the citation rate will start to drop.

Discussion

The number of soil publications is about 17,000 in 2005, of which only 16% are published in primary soil science journals. The number of publications is increasing at a rate of 5% per year, which is much lower than other natural resources subjects such as "water" or "biodiversity" (HARTEMINK, 2001). The average number of publications by soil scientists is 3 papers per year, and on average the number of citations per paper is 0.6 per year.

The h index for soil science as a group is smaller than other natural resources topics. The h indices for soil scientists are smaller than major disciplines; the median of h index is 17 with an inter quartile range between 10 and 24. The maximum h index we found was 51 whereas in biology and physics it is over 100 (HIRSCH, 2005).

We found the average relationship between h index and scientific age for soil scientists to be: $h = 0.7\, t$. Since the h index is closely related to the total number of citations, we also found that it varies within sub-disciplines of soil science. For example

pedology (the study of soil formation and distribution) has the lowest value of m (= 0.5) and soil biology has the largest value of m (= 1.0). We did not find m to vary significantly between countries.

Soil science papers have a small audience, a smaller number of citations and lower impact than other major disciplines such as physics and chemistry. The number of citations of papers in soil science journals is also much smaller for example in physics (REDNER, 2005).

In conclusion, the h index appears as a useful measure of the effectiveness of scientific output for individual scientists. For soil science h depends largely on the 'scientific age' and the square root of the total number of citations. The impact of soil science paper progresses slowly and the h index does not measure or take into account the 'sleeping beauty' or 'single-hit wonder' papers. Since it is governed by the nature of the publications in the field, norms for h need to be established for scientific disciplines.

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