

In this article, we would like to introduce a bibliometric measure called the *Degree of Separation*. We can define the Degree of separation (dS) between two articles as the number of papers that need to be sought for the two articles to “meet”.

For example: We searched for the linkage between published work on on-the-go soil strength measurement. As we showed in the previous issue of *Pedometron* (No. 23), the first work is from Haines and Keen (1925). After this paper there seemed to be no paper on this subject for a while until Stafford and Hendrick (1985, 1988) and with the advent of site-specific soil and crop management. We searched for some key papers on the on-the-go soil strength measurement and

tabulated them in Table 1. We calculated the degree of separation dS between the papers. For example, the dS between articles Alihamsjah et al. (1990) and Chung et al. (2001) is 1, as Alihamsjah et al. (1990) was cited by Chung et al. (2001). This is shown as row H, column M of Table 1 below. Another example is for Adamchuk & Christenson (2007) and Stafford and Hendrick (1988) is 2. In Adamchuk & Christenson (2007), no reference is given to Stafford and Hendrick (1988), but it gives reference to Adamchuk et al. (2001). In Adamchuk et al. (2001) there is a reference to Stafford and Hendrick (1988). Therefore there are 2 degrees of separation between the two articles (shown as row E, column O of Table 1 below).

The degrees of separation of the main papers on this topic are shown in a matrix in Table 1. The

Table 1 Degrees of separation between papers on on-the-go soil strength measurement

	D	F	G	H	I	J	K	L	M	N	O
A	∞*	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
B	1	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
C	1	∞	∞	∞	∞	∞	∞	∞	∞	1	∞
D	0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
E	∞	1	1	∞	∞	2	3	2	3	∞	2
F		0	∞	∞	∞	1	2	2	2	∞	2
G			0	∞	∞	∞	∞	1	2	∞	1
H				0	∞	1	1	2	1	∞	2
I					0	∞	∞	2	1	∞	2
J						0	1	1	1	∞	1
K							0	∞	1	∞	2
L								0	∞	∞	2
M									0	∞	1
N										0	∞
O											0

*∞ as we possibly have not found all intervening papers this might be better expressed as >5

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|---------------------------------|-----------------------------------|
| A Keen & Haines (1925) | I Van Bergeijk et al. (1996/2001) |
| B Haines & Keen (1925a) | J Adamchuk et al. (2001) |
| C Haines & Keen (1925b) | K Hall & Raper (2005) |
| D Haines & Keen (1928) | L Mouazen & Ramon (2006) |
| E Stafford & Hendrick (1985/88) | M Chung et al. (2006) |
| F Owen et al. (1987) | N Watts et al. (2006) |
| G Glancey et al. (1989) | O Adamchuk & Christenson (2007) |

rows and columns are in chronological order and the lower half of the matrix is blank because we assume earlier papers cannot refer to later ones. There appears to be a literature developing but there is also a relatively high degree of non citation - many of the cells show infinite separation*. The most remarkable finding is that none of the early work of Haines and Keen appears to have been referenced in the scientific literature (see rows A, B, C, D) until the Broadbalk measurements were repeated recently (Watts et al., 2006), and Watt et al.'s work seems to be separated in the citation sense from the main body of contemporary soil strength sensing work (see column N)

Haines and Keen's work was lost or seen as irrelevant until the new impetus given by precision agriculture in the 1990's when similar, but independent, work evolved again.

The 'degree of separation' analysis can be used to identify and help towards the development of ideas in a discipline.

References

- Adamchuk, V.I., Morgan, M.T., Sumali, H., 2001. Application of a strain gauge array to estimate soil mechanical impedance on-the-go. *Transactions of the ASAE* 44, 1377-1383.
- Adamchuk VI, Christenson PT., Development of an instrumented blade system for mapping soil mechanical resistance represented as a second-order polynomial. *Soil and Tillage Research* 95, 76-83.
- Alihamsyah, T., Humphries, E.G., Bowers Jr., C.G., 1990. A technique for horizontal measurement of soil mechanical impedance. *Transactions of the ASAE* 33, 73-77.
- Chung, S.O., Sudduth, K.A., Hummel, J.W. 2006 Design and validation of an on-the-go soil strength profile sensor *Transactions of the ASABE* 49, 5-14
- Glancey, J.L., Upadahyaya, S.K., Chancellor, W.J., Rumsey, J.W., 1989. An instrumented chisel for the study of soil-tillage dynamics. *Soil and Tillage Research* 14, 1-24.
- Haines, W.B. and Keen, B.A. 1925a. Studies in soil cultivation. II. Test of soil uniformity by means of dynamometer and plough. *Journal of Agricultural Science (Cambridge)*, 15: 387-394.
- Haines, W.B. and Keen, B.A. (1925b) Studies in soil cultivation. III. Measurements on the Rothamsted classical plots by means of dynamometer and plough. *Journal of Agricultural Science (Cambridge)*, 15: 395-406.
- Haines, W.B. and Keen, B.A. (1928) Studies in soil cultivation. IV. A new form of traction dynamometer. *Journal of Agricultural Science (Cambridge)*, 18: 724-732.
- Hall, H.E., Raper, R.L., 2005. Development and concept evaluation of an on-the-go soil strength measurement system. *Transactions of the ASAE* 48, 469-477.
- Keen, B.A. and Haines, W.B. (1925) Studies in soil cultivation. I. The evolution of a reliable dynamometer technique for use in soil cultivation experiments. *Journal of Agricultural Science (Cambridge)*, 15: 375-386.
- Mouazen AM, Ramon H., 2006. Development of on-line measurement system of bulk density based on on-line measured draught, depth and soil moisture content. *Soil and Tillage Research* 86, 218-229.
- Owen, G.T., Drummond, H., Cobb, L. and Godwin, R.J., 1987. An instrumentation system for deep tillage research. *Transactions of the ASAE* 30, 1578-1582.
- Stafford, J.V., Hendrick, J.G. 1985. Dynamic control of pan rupturing tines. *ASAE Paper No. 85-1547*.
- Stafford, J.V., Hendrick, J.G., 1988. Dynamic sensing of soil pans. *Transactions of the ASAE* 31, 9-13.
- Van Bergeijk, J., Goense, D., 1996. Soil tillage resistance as tool to map soil type differences. In: Robert, P.C., Rust, R.H., Larson, W.E. (Eds.), *Proceedings of the Third International Conference on Precision Agriculture, ASA-CSSA-SSSA, Madison, Wisconsin*, pp. 605-616.
- Van Bergeijk, J., Goense, D., Speelman, L., 2001. Soil tillage resistance as a tool to map soil type differences. *Journal of Agricultural Engineering Research* 79, 371-387.
- Watts, C.W., Clark, L.J., Poulton, P.R., Powlson, D.S. and Whitmore, A.P., 2006. The role of clay, organic carbon and long-term management on mouldboard plough draught measured on the Broadbalk wheat experiment at Rothamsted. *Soil Use & Management*, 22: 334-341.

Soil Science on D-Day

Murray has written an article on "Science on the Normandy Beaches: J.D. Bernal and the Prediction of Soil Trafficability for Operation Overlord" for *Soil Survey Horizons* 49:12-15 (Spring, 2008). This is following his "From the Chair" editorial in Issue No. 21 of *Pedometron*. You can access the article for a limited time at:

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