**Institution:** University of Edinburgh and SRUC, Scotland's Rural College

**Unit of Assessment:** 6

**Title of case study:** Visual evaluation of soil structure reliably assesses soil quality and has been adopted world-wide to enable soil improvement for enhanced crop yield.

**1. Summary of the impact** (indicative maximum 100 words)

**Impact:** Policy, Economic: Improved soil fertility and crop yield, reduced erosion and flood and reduced greenhouse gas (GHG) emissions from waterlogged and compacted soils.

**Significance:** A decrease in soil structural quality as a result of compaction or erosion decreases grain yield substantially. Novel indicators that assess visual structure and biological quality allow soil samples to be easily assessed for possible improvements in quality.

**Beneficiaries:** Farmers, agronomists, environmental bodies e.g. Scottish Environment Protection Agency (SEPA), water companies and waterway authorities, local government, policy makers and the general public.

**Attribution**: Dr. Ball and Prof. Watson (SRUC)

**Reach:** The visual structure index uses a simple colour guide that has been widely distributed and promoted in nine countries overseas and three continents.

**2. Underpinning research** (indicative maximum 500 words)

Research on soil structural quality and management (1996-onwards) by Dr. Ball (Senior Researcher, employed 1978-onwards), concluded that soil structural quality in Scotland was particularly vulnerable to compaction, which in turn reduced grass and grain yields [3.1]. In 1998, Prof. Watson (Team Leader, employed 1990-onwards) showed that soil structure and biological activity are particularly important in managing productivity within organic crop rotations because crops depend more on soil of good quality when common fertilisers and pesticides are eliminated [3.2]. Soil quality or soil fertility is measured by indicators of physical, chemical and biological activity. Soil underpins the hugely important agri-food supply chain that contributes £96 billion to the UK economy. The Foresight Projection on Global Food and Farming Futures emphasised the importance of improving soil structure and organic matter levels to achieve successful integrated soil management.

Research on organic farming in 2000-2002 by Ball in North-East Scotland produced a simple test to assess soil structural quality [3.3]. The test, comprising three visual scoring keys, proved useful in quantifying properties of the soil surface, structure and rooting conditions that related to differences in fertility between the cropping phases within rotations. In 2004-7, the Visual Evaluation of Soil Structure (VESS) was refined in collaboration with colleagues from the University of Aberdeen and the University of Aarhus, Denmark. The VESS is a simple test in which the aggregation, porosity and root growth of a spadeful of soil are integrated into a single score - a structural indicator [3.4]. The indicator is assessed from a key containing photographs and traffic-light grading of quality on a laminated field chart that allows users to score their soil quickly.

VESS was used to measure physical condition and crop growth under different tillage systems in Denmark and differences in fertility within Scottish organic rotations [3.4]. In a trial on establishment of organic cereals, VESS showed that the soil was of good quality but was also susceptible to compaction damage that reduced grain yield [3.5]. Research with Lincoln University in New Zealand demonstrated the value of VESS for assessing structure and porosity in different topsoil layers under dairy pasture, particularly near the surface where the powerful greenhouse gas nitrous oxide is produced [3.6] or in stony soils where the use of destructive sampling techniques are not possible.

**3. References to the research** (indicative maximum of six references)


3.1) Ball, B. C., Campbell, D. J., Douglas, J. T., Henshall, J. K. and O'Sullivan, M. F. (1997). Soil structural quality, compaction and land management. European Journal of Soil Science. 48: 593-601. http://dx.doi.org/10.1111/j.1365-2389.1997.tb00559.x

3.2) Watson, C. A., Atkinson, D., Gosling, P., Jackson, L. R. and Rayns, F. W. (2002). Managing soil fertility in organic farming systems. Soil Use and Management. 18: 239-247. http://dx.doi.org/10.1111/j.1475-2743.2002.tb00265.x

3.3) Ball, B. C. and Douglas, J. T. (2003). A simple procedure for assessing soil structural, rooting and surface conditions. Soil Use and Management. 19: 50-56. http://dx.doi.org/10.1111/j.1475-2743.2003.tb00279.x

3.4) Ball, B. C., Batey, T. and Munkholm, L. J. (2007). Field assessment of soil structural quality – a development of the Peerlkamp test. Soil Use and Management. 23: 329-337. http://dx.doi.org/10.1111/j.1475-2743.2007.00102.x

3.5) Ball, B. C., Watson, C. A. and Baddeley, J. A. (2007). Soil physical fertility, soil structure and rooting conditions after ploughing organically managed grass/clover swards. Soil Use and Management. 23: 20-27. http://dx.doi.org/10.1111/j.1475-2743.2006.00059.x

3.6) Ball, B. C., Cameron, K. C., Di, H. J. and Moore, S. (2012). Effects of trampling of a wet dairy pasture on soil porosity and on mitigation of nitrous oxide emissions by a nitrification inhibitor, dicyandiamide. Soil Use and Management. 28: 194-201. http://dx.doi.org/10.1111/j.1475-2743.2012.00389.x


**4. Details of the impact** (indicative maximum 750 words)

**Impact on Policy**

The research was incorporated into practice guidelines for the Scottish Government document *The Farm Soils Plan* (used to help compliance with the EU requirement for Good Agricultural and Environmental Condition) and contributed to the report *The State of Scotland's Soil (SoS)* [5.1]. The Farm Soils Plan was distributed to 10,000 farmers within the UK and is on the Scottish Government web site. The SoS report has been used as evidence to support further thinking on soils, which has in turn influenced UK policy. The main impacts of SoS are tied in with other drivers such as Scottish Soil Framework, Land Use Strategy and Rural Diffuse Pollution Plan for Scotland.

**Impact on Stakeholders**

The VESS chart [5.2] and associated research results were communicated to the agricultural industry mainly through talks to farmers and consultants via the Scottish Agricultural College (now SRUC) and the Scottish Agricultural Organisation Society Monitor Farm schemes, Soil Association Climate Change Programme, England Catchment Sensitive Farming Delivery Initiative, HGCA-SAC Cereals Open Days and Knowledge Transfer days [5.3], supermarkets, schools, the Farming for a Better Climate Initiative and the Royal Highland Shows. Average attendances were between 10 and 50 per event. The VESS chart and training videos are freely available on the SRUC webpage (1500 views of the videos so far) and VESS is promoted by other organisations such as the Soil Association, Linking Environment and farming (LEAF) and the Duchy College Rural Business School. Feedback forms (between 7 and 40 per meeting) from farmers' meetings indicate that the research and associated advisory effort is increasing farmers' awareness of the risk of soil structural damage with stated intentions to improve affected soil and increase farm profitability. In overview, major stakeholder engagement activity based upon this research has contributed significantly to raising awareness of the importance of soil quality. It also highlighted the importance of using indicators of quality to guide improvements of soil fertility and to reduce the emission of nitrous oxide, the greenhouse gas dominating equivalent carbon budgets in UK.

**Economic Impact**

Reduction of soil structure has an immediate economic impact at farm level because a decrease in soil quality decreases crop yield. A decrease in structural quality as a result of compaction decreases grain yield by, typically, 16% [5.4]. If each of 1000 farms with substandard soil structure was improved by one VESS unit of soil structural quality then wheat yield would increase by 28

tonnes, a potential increase in revenue of £4,500 per farm, £4.5M annually overall (these figures are based on an average sized farm in the UK of 60 hectares with one third of the soil assumed to be in sub-standard physical condition and an average wheat yield of 7 t/ha. The structural improvement cost is estimated to be £50/h).

**International impact**

The VESS chart [5.2] has been adopted internationally and translated into several languages – including Spanish (Universidad Politécnica de Madrid, Spain), Portuguese (Universidade Estadual de Maringá, Brazil), French (INRA, Péronne, France) and Danish (Aarhus University, Denmark). The impact has been particularly noticeable in Brazil, where VESS is used as a rapid means of estimating soil quality in areas under no-tillage, and under sugar cane production (9.6 million ha in 2011). In the past three years, 300 agricultural students and 350 agronomists have been taught how to use the method in Paraná and Goias States. In 2009-2012, it was shown to be a useful indicator of soil quality relevant to grain yield in a large international study [5.8]. In response to invitations, Dr Ball travelled to demonstrate and develop the method locally in Brazil, Denmark, France and New Zealand.

**5. Sources to corroborate the impact** (indicative maximum of 10 references)


5.1) Dobbie KE, Bruneau PMC and Towers W (eds.) 2011. The state of Scotland's soil. Natural Scotland, http://tinyurl.com/q7fkxkc

5.2) Visual Evaluation of Soil Structure guidance http://tinyurl.com/nsd2r52

5.3) HGCA: soil2crop, knowledge transfer projects on soil management for profitable crop production (2002/2004) http://tinyurl.com/q2qpxz3

5.4) Knight S et al. 2012. Desk study to evaluate contributory causes of the current 'yield plateau' in wheat and oil-seed rape. HGCA Project Report 502, 226 pp. http://tinyurl.com/qap4l3b

5.5) EEA 2010. Mapping the impacts of natural hazards and technological accidents in Europe. An overview of the last decade. Technical Report No 13/2010, 145 pp. http://tinyurl.com/o9bhbp3

5.6) Jones A et al. 2012. The state of soils in Europe. EEA JRC Report EUR 25186, 80 pp http://tinyurl.com/pjjjukx

5.7) Letters and emails of personal corroboration were received from Dr Tim Chamen, Controlled Traffic Farming (CTF Europe) Ltd, Sam Adams, Soil Association, Prof. Cassio Tormena, University of Maringá, Brazil and Dr Audrey Litterick, Earthcare Technical Ltd. http://tinyurl.com/nwqhksz

5.8) Giarola NFB, da Silva, AP, Tormena, CA, Guimarães, RML and Ball, BC 2013. On the Visual Evaluation of Soil Structure: The Brazilian experience in Oxisols under no-tillage. Soil & Tillage Research 127: 60-64. http://dx.doi.org/10.1016/j.still.2012.03.004