Qualitative Analysis in Science, Consultance and Training in Soil Conservation

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Introduction

The increase of inundations develops more and more into a threat of life quality in Europe. However, what unfortunately finds little entrance in the media discussion is the fact that not only the sealing for settlement and traffic areas or possible climate changes are responsible for increasing flood events but – in a large extent - also the reduced water infiltration, storage and filter capability of our soils suffering more and more strongly compaction through an intensive agriculture and forestry. The increasing susceptibility of soils in Europe for compaction and erosion shows syndromes of soil degradation which cause enormous macroeconomic costs and must be termed as a serious threat for the maintenance of life quality (UNEP 1990, WBGU 1994, HURNI 1996, BLUME et al. 1998, FLEIGE 1999, EC 2002, WBB 2002, BESTE 2002, 2005). Many statements in science and in policy summarise the urgent necessity of research to step further in combating soil degradation.

Protecting soil functions

Soils fulfil five substantial functions for production, landscape balance and social life quality. These according to WBGU (1994), GLOESS (1997) and UBA (1998), are defined as follows:

1. Habitat and Living Space
2. Production and Utilisation
3. Ecological Regulation
4. Spatial function
5. Cultural function

According to De KIMPE and WARKENTIN (1998) soils degrade, if the balance between the natural soil functions (1. – 3.) is disturbed. Therefore, different forms of land use must be able to ensure maintenance of these soil functions on a long-term basis, in order to be sustainable. Agricultural soil use has influences on the largest areas. For an ecologically and economically long-term balanced productivity and maintenance of soil functions for agricultural productivity and social and ecological life quality, the *living space* and *regulation* function of soils must be taken strongly more into account. To document the effects of soil and land management systems on ecological soil functions, sensitive indicators and economic suitable scientific methods have to be defined respectively developed, which are able to show the influence of management systems on soil vitality. These indicators and the methods, which serve the examination, must react sufficient sensitively to changes of management practice, in order to point out changes in soil quality as early as possible (UBA 1998, BESTE 2003).
About that a statement of the International Soil Conservation Organization (ISCO1996 pp. 325) to this requirement has been also:
“Not only sophisticated methods but also quick methods that can be applied by non-researchers should be developed. Although there is a dominant interest in quantitative data, qualitative data often is more relevant and revealing”.

Reference and target values

The specification of limiting-, task-, or reference-values for soil conservation presupposes that these also can be checked by a corresponding measuring. The costs of the administration and control effort are a general problem at the fixing of limiting values (WETTERICH 2004). Especially at the problem of soil compaction and structure degradation, till now, usable measuring techniques with real evidence about structure conditions aren't applied for general data collection (EC 2002, EC 2004).
With regard to the on-site and off-site symptoms of soil degradation in Europe as there are: erosion, compaction, increasing fertilizer and plant protective substance effort, decreasing plant health, decreasing soil fertility, floods and endangerment of soil water recharge and quality - chief attention has to be given to the condition of soil structure because of its close connections to water circulation, soil life activity, transformation capacity and aggregate stability. If the structure of our soils is in good con-

dition, the symptoms described above - which threaten production and life-quality - are reduced decidedly and high costs can be saved. The good suitability of a structure examination for the judgement of management measures has been documented and confirmed repeatedly by soil experts and farmers (MÜCKENHAUSEN 1947, GÖRBING/SEKERA 1947, DIEZ 1991, AID 1992, HASINGER 1993, HAMPL 1995 ab, 1996, HARRACH 1998, BESTE 1998 ab, 1999 abc, 2000 ab, NSRI 2001, USDA 2001, BESTE 2001, 2002, RAJALA 2002, BESTE 2003, 2004 b, 2005).
The difficulty till now was, that there have been no uniformly standardized task values for the assessment of soil structure condition due to the variety of the soil types and structure expressions. It cannot be defined generally how many pores or earthworms a soil must have in 1 m^3, which Kf-value has to be measured, how high soil respiration has to be etc.. There are scientific based positive and negative areas *in tendency* for all these indicators for different soil types. But this makes soil assessment and decision making complicate and expensive for practice and policy - and in consequence little is done. For a uniform assessment of the soil condition and an orientation for future measures, task values are decisive. They on the one hand give clear specifications for the condition which is aimed at and with that for the action level. On the other hand a *judging* assessment of the actual state isn't possible without a definition of a task or reference value. TURIAN (1993) demands both, target and load/overuse values to be able to carry out a safe judgement.

Indicators for sound soil conditions

At the intensive enquiry after a suitable indicator or aim value for sound soil structure in literature one meets the term "soil tilth" which has been developed in the agricultural practice. This term for a long time stood for the optimal structure condition of a productive soil and has been agricultural judgement scale. SEKERA (1984, pp. 15) defines “soil tilth” as "*crumbly structure, vitally built up by micro organisms*". For the preservation of this structure condition much has been searched within the first 50~60 years of the last century aiming at an augmentation of fertility and productivity. These early cognitions about sound and productive soil structure are predominantly up-to-date today (among others: MARTIN 1945, 1946, DAL 1958, HARRIS et al. 1966, SEKERA 1984).
What corresponds to the term "soil tilth" after today's knowledge?
In the literature different definitions for soil structure are found. In general it is described as the distribution of firm soil substance in the space. Visible soil structure is divided in three main groups (MÜCKENHAUSEN 1947, KUNTZE et al. 1994):

1. Single grain structure (sand),
2. Coherent structure (dense, matrix example: nougat) and
3. Aggregate structure (put together, matrix example: popcorn).

In general, cultivated soils show mixtures of these structure types.
A relatively fine, crumbly expression of a mixed soil structure with high share in aggregated particles represents the so-called "sponge structure". It is most similar to “soil tilth” and is termed as to be the "*ecologically optimal*" structure condition which should be striven for in agricultural soil management by the majority of soil and agro-scientists (a. o. KUNTZE et al. 1994, RBS 1994, SEKERA 1984, 1951, DAL 1958, SEKERA/BRUNNER 1943). The "sponge structure" is particularly beneficially for the balance of the ecological soil functions: habitat-, regulation- and production-function.
So how should the ideal soil structure look?
Surely, a crumbly condition of soil structure described as optimal turns out differently for the different soil types. Sandy soils build up another soil structure as loamy or clay soils. However, the interesting and decisive point is, that in case of good humus supply and high biological activity the structure always moves in the direction of an increasing aggregate formation with a sponge like expression both for sandy soils and for the loamy and clay soils. That means, the "sponge structure" represents an optimal target value which is usable for the predominant number of soils being under agricultural management (restrictions must be stated for stony soils and peat soils).
For example: Single grains of sandy soils stick better together in case of good humus supply and high biological activity (aggregate formation) and the initially very high infiltration and airing moves in favour of a better water storing, filtering and cleaning capacity as well as a better humid habitat condition for soil organisms.
For strong clay soils in case of high humus supply and biological activity the process of aggregate formation means segregation, a splitting of the soil matrix in smaller units. This moves the high water storage capacity in favour of a higher infiltration and airing and due to that an increase of soil organisms’ habitat potential (SCHINNER/SONNLEITNER 1996 b, BESTE 2005).
For almost all soils under agricultural use in temperate zones can be stated that nutrient exchange capacity, structure quality and aggregate stability increases at good humus supply and high biological activity.

Effort and evidence of some current soil structure analysis methods

Till now, the proximity or distance to the condition of the "sponge structure" could not have been quantified in its individual expressions. Simple physical methods for the structure judgement as measurements of bulk density, pore volume or penetrating resistance have in common that they concentrate on quantifying aspects like the sum of cavities or a rough graphic of compaction data principally. These parameters give clues for the ascertainment of harming compaction or plough soles. However, they can not at all show the difference between the existence of a sponge like aggregate structure with many biogenic middle pores and crumbles or a compacted structure with many secondary pores. Inner aggregate compaction is not discovered in any case.

Especially with the measurement of penetration resistance, as one of the most frequently applied methods for the examination of soil structure due to the easy applicability and clear curve presentation, some dangerous misinterpretations are possible: In case of humid loamy and clay soils the low resistance gives an impression of low compaction and can cover heavy compaction of soil structure, which can be shown by a profile pit or spade diagnosis. For the check of the porosity of soil structure in the crumb this methodology isn't suitable (BESTE 2005 pp. 85). More complex approaches for structure analysis as there are the pore size distribution (RICHARDS cit. in SCHLICHTING et al. 1995), digital image analysis (WILKENS 1992), radiograph morphological examinations (WERNER 1993), computer-tomographic examinations (ROGASIK et al. 1995) or thin-cut analysis (ALTEMÜLLER 1991) are very effortful and expensive in the execution, don't show the structure on-site in its actual condition and give no reference values for a judgement even. Soil biological examinations (e.g. counting out of earth-worms, measurement of total biomass, soil respiration or species composition) are also effortful and expensive and - till now - don't deliver any assessment scales and reference values either for structure quality or soil functions.

A useful tool for structure analysis: "Improved Spade Diagnosis"

Some years ago the field method „Spadediagnosis" has been rediscovered and further developed for scientific use in a recent study (BESTE 2003). In this research paper the proposal is made to use soil structure as indicator for sound soil functions because of its close connections to water circulation, soil life activity and transformation capacity. With the *Improved Spade Diagnosis* a methodology has been presented, which combines new structure evaluation schemes developed on current knowledge about sound soil structure conditions and their connection to soil functions and measurement of common soil structure parameters.

This *Improved Spade Diagnosis* (ISD) contains new developed structure evaluation schemes and a new developed simple test of aggregate stability. Both can be combined with the measurement of bulk density and shearing or penetration resistance if necessary. Experimentation and improvement of ISD has been implemented 1996-2003 by BESTE as Ph.D.-thesis in agro sciences (Institute of Crop-Management, Department of Organic Agriculture, University of Gießen, Germany) within the Research- and Demonstration-Project Ecological Soil Management (PÖB). The survey was based on the investigation of soil conditions depending on different crops and different tillage systems (BESTE 1999a, 1999d, 2003, LPP 2002, SÖL 2005). With results of ISD and a differentiated analysis of the meso-morphology and stability of 44000 soil aggregates in this study the experience could be confirmed that green fallow and intercrops combined with conservation tillage contribute heavily to soil regeneration (BESTE 2003). New experience about factors which contribute to aggregate building and different aggregate morphology were gained. For the new developed aggregate stability test and the new developed structure evaluation, adapted assessment schemes for different soils (loamy, clay and sandy soils) and a new rooting evaluation scheme have been developed. The comprehensive impression and evidence of qualitative structure analysis has been proved to be very helpful for the judgement of management practice (manure management, crop-rotations, tillage-systems etc.) by agricultural advisors and farmers (who can introduce this methodology on their own after a short training). The study showed that the methodology is applicable as well for scientific analysis. A comparable view on the actual state of health of a soil can not be delivered as immediate, non distort and complex by isolated samples or data from laboratory tests. One of the great advantages of the combined methods of ISD is also that compaction caused aggregate stability can be differentiated from biogen aggregate stability out of porous structure conditions:

Both polyeder and crumbles are stabilised by clay or lime content. Biological stabilising factors have as well effects on all aggregate types (the part of biological stabilization factors is stated to increase with aggregate size and porosity TISDALL/OADES 1982, OADES 1984, ANDERSON 1991). Thus it is to emphasize that isolated test of aggregate stability can lead to incorrect evaluations about functional structure conditions and wrong conclusions since compaction or a high clay or lime content can even

cause high aggregate stability in soils with low biological activity (CZERATZKI 1957, LIEBEROTH 1969, MULLA et al. 1992, ROTH 1996, BESTE 2003, 2005). All current methodologies of water stability tests cannot clear up, if the aggregate stability is caused by biological stabilization (which is important for the soil functions) or by physical compaction (which has stated to be a sign of functional degradation). For all these methods it has to be emphasised that they deliver data about water stability but no evident results about good or bad status of soil structure quality. Only in combination with a qualitative structure analysis it can be cleared, whether a high aggregate stability is caused by an inner compaction or by biological stabilization. So a high aggregate stability of soil aggregates can be judged as functional positive in case of a middle till high structure mark based on the structure evaluation scheme referring BESTE (2003) (which puts the main emphasis on a soil morphology appearance, which stands for high biological activity and a sound production and regulation function). There is no need for action here. In case of low structure marks in structure analysis (which are given for compacted structure even at the single aggregate scale) a high aggregate stability is probably caused by compaction or liming. In this case intercropping (loosening and stimulation of the biological activity by rooting) or an increased application of organic stable manure or compost is to be recommended. It is also necessary that in case of a good structure judgement (high structure marks >3) the aggregate stability is checked since a loose porous structure can be very susceptible against compaction as well if it is not stable. Only with test of aggregate stability the dynamic aspect of the soil condition and its susceptibility for silting (and due to that compaction) can be checked. With the great evidence of the results from the combination of these simple soil analysis methodologies decision making is strongly facilitated.
2001 the independent Institute for Soil Conservation and Sustainable Agriculture, was founded at Mainz, Germany, - offering analysis, consultance and training in soil evaluation and management by means of Improved Spade Diagnosis. Much of practical experience with ISD has been gained since 1996 with analysis, consultance and training work for the Food Industry, Universities, Advisory Services, Development Projects etc.. In the context of the EU-SCAPE project (Soil Conservation and Protection for Europe) guidelines for the recommendation of soil examination methods (Guidelines for soil assessment) are in preparation which shall standardize and facilitate the collection of soil data. A guideline for qualitative soil assessment by means of Improved Spade Diagnosis as a simple, practical and economic method has been worked out by the Institute of Soil Conservation and Sustainable Agriculture in commission of EU-SCAPE-Project and will be available in 2006 (information under: www.gesunde-erde.net).

Links

Links with information, literature and downloads about simple soil structure analysis

Institute for Soil Conservation and Sustainable Agriculture, Germany
http://www.gesunde-erde.net

Soil Conservation and Protection for Europe, Netherlands
http://www.scape.org

European Land and Soil Alliance, ELSA e.V., Germany
http://www.bodenbuendnis.org

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