Soil Fertility—Phenomenon and Concept[§]

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Accepted 10 November 1999

Summary – Zusammenfassung

This paper is based on an extensive review of soil fertility in the literature of soil science, agronomy and ethnic studies. The spectrum of scientific opinions on soil fertility was visualized in mind-maps, definition types were analyzed, and problems within the conceptual approach towards soil fertility were shown.

Differently oriented concepts were divided between the terms of soil fertility and soil quality. Soil fertility is not applicable as a technical term in natural sciences as it describes a definite, but dispositional (concealed), soil feature; therefore, it is not fully operationalizable for the natural sciences.

Soil quality denotes undefined and interchangeable sets of appreciated soil attributes and functionalities, which are assigned by value judgments. It is a tool that integrates different soil state variables and functions in order to evaluate the capacity of a soil to do what it is expected (i.e. function) or to assess the sustainability of current land-use practices.

The phenomenon of soil fertility appears to the consciousness as an autonomous counter-instance with its own mental and material qualities, referred to in traditional cultic cultivation. The main features of cultic cultivation of soil fertility are the uniting of the four elements, the *religio* towards the spiritual side of nature, the sacrificial, and the *eros*.

A reevaluation of the soil fertility phenomenon in modern terms would be an innovative and forward-looking research program. Practical and scientific work on soil fertility should rediscover and revive the feeling for, and apperception of, the phenomenon of soil fertility in its mental and material aspects.

Key words: soil fertility / yield giving capacity / soil quality / soil culture

Bodenfruchtbarkeit – Phänomen und Begriff

Auf Grund einer breit angelegten Auswertung der Literatur über Bodenfruchtbarkeit aus den Gebieten der Bodenkunde, der Agronomie und der Ethnologie wird die Vielfalt von Definitionen und Umschreibungen der Bodenfruchtbarkeit grafisch in Form „mentaler Landkarten“ dargestellt. Eine Typologie der Bodenfruchtbarkeitsdefinitionen wird erstellt, und Probleme bei der konzeptuellen Annäherung an die Bodenfruchtbarkeit werden erörtert. Darauf aufbauend werden unterschiedlich ausgerichtete Konzepte den Begriffen „Bodenfruchtbarkeit“ und „Bodenqualität“ zugeordnet. „Bodenfruchtbarkeit“ lasst sich nicht als naturwissenschaftlicher Fachbegriff fassen. Der Begriff beschreibt zwar eine bestimmte Bodeneigenschaft, aber weil diese dispositional (verborgen) ist, kann sie wissenschaftlich nicht vollständig operationalisiert werden.

„Bodenqualität“ dagegen umfasst unbestimmte Mengen austauschbarer Bodenmerkmale und Bodenfunktionen, die dem Begriff durch Werturteile zugewiesen werden.

Das Phänomen der Bodenfruchtbarkeit erscheint dem Bewusstsein als autonomes Gegenüber, das nicht nur eigenständige materielle sondern auch geistige Qualitäten besitzt. Wesentliche Strukturelemente der auf das Phänomen bezogenen traditionell religiösrituellen Bodenkultur sind: das Zusammenbringen der vier Elemente, die *religio* angesichts des Geistigen der Natur, der Eros und das Opfer.

Wir brauchen heute einen neuen, zeitgerechten Zugang zum Phänomen der Bodenfruchtbarkeit. Ein solcher Zugang konnte in ein innovatives und zukunftsweisendes Forschungsprogramm münden. Wissenschaft und Praxis sollten die Gefühlsbeziehung zum Phänomen Bodenfruchtbarkeit und die bewusste Wahrnehmung seiner geistigen und stofflichen Aspekte neu entdecken und weiter entwickeln.

1 Introduction

In soil science and agronomy, the concept of soil fertility has an almost infinite number of definitions, and viewpoints vary widely with regard to its meaning and importance. Some researchers have suggested abandoning the concept while others suggest that attention should be shifted towards another concept, namely that of soil quality.

In this paper we review literature on soil fertility, and structure, visualize and analyze its terminology and underlying scientific approaches. We include literature discussing traditional cultic cultivation of soil fertility into the analysis to show its main features. Potential relationships between soil fertility and soil quality, a concept that is being used to assess how a soil is functioning for a specific use or to evaluate the sustainability of current land-use practices, are discussed and theses on the relation of the concepts of soil fertility and soil quality and on the phenomenon of soil fertility are presented.

2 Conceptual approach to soil fertility: Searching for scientific definitions

A scientific foundation for the concept of soil fertility emerged when—on the background of a new way of observing nature—the basic principles of chemistry were

[§] The paper is based on the diploma work of the first author at the Department of Environmental Sciences (ETH Zurich).

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  1436-8730/00/0204-0129 $17.50+.50/0

applied to natural systems approximately one hundred and fifty years ago. Liebig pioneered this development *(Liebig,* 1840, 1876)[1]. Even earlier the perception of the soil as an economically important production factor that needed labor to produce a useful outcome had emerged *(Thaer[2],* 1809; *Wulffen,* 1847). The scientific notion of soil fertility, stimulated first by agronomy and later by the emerging discipline of soil science, formed a foundation for ideas containing different traditional ways for both describing and conceptualizing fertility.

To understand how current concepts of "soil fertility" („Bodenfruchtbarkeit" in German-language literature) evolved, we began our investigation by conducting a thorough literature review to identify different definitions and descriptions that have been given to soil fertility and closely related terms. This was followed by a form and content analysis of those definitions. Yield-giving capacity („Ertragsfähigkeit") was also reviewed because, as a closely-related term in the word-field of soil fertility, it is equated with soil fertility by some authors, discerned from it by others. We reviewed numerous definitions and circumlocutions (roundabout expressions) in scientific papers to illustrate the broad spectrum of viewpoints published with regard to soil fertility. The more recent concept "soil quality" („Bodenqualität"), discussed especially in the English-language literature, was also reviewed to determine how, if at all, it was related to various concepts of soil fertility.

Our purpose for this review was that until recently, the existence of different languages often resulted in quite separate research communities with different *linguae francae.* Within these communities, different notions of a term and conceptual differences could easily arise because of different linguistics, literature background, and the momentum of research focus and scientific discussion. This historical fact has to be taken into account with regard to the terms *soil fertility (Bodenfruchtbarkeit)*[3] and *soil quality (Bodenqualitat),* respectively.

[1] "Die Pflanze lebt von Kohlensäure, Ammoniak (Salpetersäure), Wasser, Phosphorsäure, Schwefelsäure, Kieselsäure, Kalk, Bittererde, Kali (Natron), Eisen, manche bedürfen Kochsalz" (p.9). "The plant feeds on carbonic acid, ammonia (nitric acid), water, phosphoric acid, sulfuric acid, silica, lime, magnesia, potash (bicarbonate of sodium), iron; some require sodium chloride" (transl. by the authors).

[2] "Ohne Arbeit trägt der Boden nichts." "Die Arbeit ist es, wodurch der Mensch alles gewinnt oder gewonnen hat, was er genießt. ... Jedoch erfordert jede Arbeit ein Material, an dem sie ausgeübt wird. Dies Material gibt die Natur der Ackerarbeit im Grund und Boden, und aus dem durch die Arbeit aus dem Grund und Boden hervorgebrachten Produkte wird das Material fur die Verwendung jeder anderen Arbeit geliefert" (Vol. 1:99). "Without manpower, the soil bears nothing." "It is the work, by which means men and woman obtain or have obtained everything they enjoy. Every work, however, needs a material, on which it is done. This material, given by nature for agriculture, is the land. And the products, that are brought forth from the lands by manpower, are the basic materials for every other kind of work" (transl. by the authors).

[3] In the following the English expressions *soil fertility* and *soil quality* are used exclusively.

Recognizing the fact that these scientific communities are now meeting with English as the global *lingua franca,* supported by electronic media, striving for clarity and consistent terminology among agricultural and scientific communities throughout the world is becoming more and more important.

2.1 Materials and methods

Our goal was to identify citations associated with either "soil fertility" or "yield giving capacity" research in the German-language literature and with the relatively recent "soil quality" concept in the Anglo-Saxon literature. Electronic databases, maintained by libraries and private services, were searched to identify key publications associated with each research theme. The electronic searches were supplemented by manually following citation lines through the various reference lists.

The citations were analyzed and categorized using a qualitative content analysis *(Mayring,* 1993). This approach uses a systematic text analysis to identify a reasonable number of categories based on literature content. The content analysis requires five steps: (i) abstracting and summarizing; (ii) paraphrasing and condensing, (iii) developing first-order groups, (iv) consolidating into more general second-order groups, and (v) selecting a letter code to enhance clarity of each classification theme. The process results in a table that can be transformed into a picture or mindmap *(Buzan,* 1997) that provides a visual overview of all the relevant literature. These mental pictures also provide a weak hierarchical classification system for the various concepts. The system is considered "weak" because any one element (citation) can be placed at several places, if its properties warrant such classification. Another advantage of weak hierarchies is that they are less susceptible to methodological bias than strong hierarchical systems *(Bandelt* et al., 1991). Finally, the grouping of statements and arrangement of branches within the hierarchies are designed to represent relationships between citations in each category.

2.2 Concepts and soil fertility

The numerous concepts associated with soil fertility in the German-language literature are illustrated in Fig. 1. The short statements that name each branch or node are not quotations but simply labels indicating how one or more of the authors conceptualized soil fertility. The three main branches have an additional "category name" ("provides yield, is the sum or resultant of something, or is an ecological or life process") that is intended to help the reader quickly grasp the predominant themes associated with citations listed along those branches. For cases where a citation appears in multiple categories, this simply illustrates (1) the multi-dimensionality of the weak hierarchical classification, (2) the ambiguity in definition or circumscription of the term soil fertility in the citation, or (3) the occurrence of multiple, non-corresponding statements within the same paper.

The main feature of the term "soil fertility" **(Branch #1)** in the German-language literature is *"provides yield".* This concept is dominant in 30 (Branch 1, nodes a to e) to 40 (Branch 1, nodes a to g) percent of the publications. The largest node on the diagram (la) identifies literature where actual yield is identical with or fully representative of the soil fertility concept *(Brinkmann,* 1922; *Köhnlein,* 1957b; *Scheffer,* 1959; *Rosenkranz,* 1963; *Deutsche Akademie für*

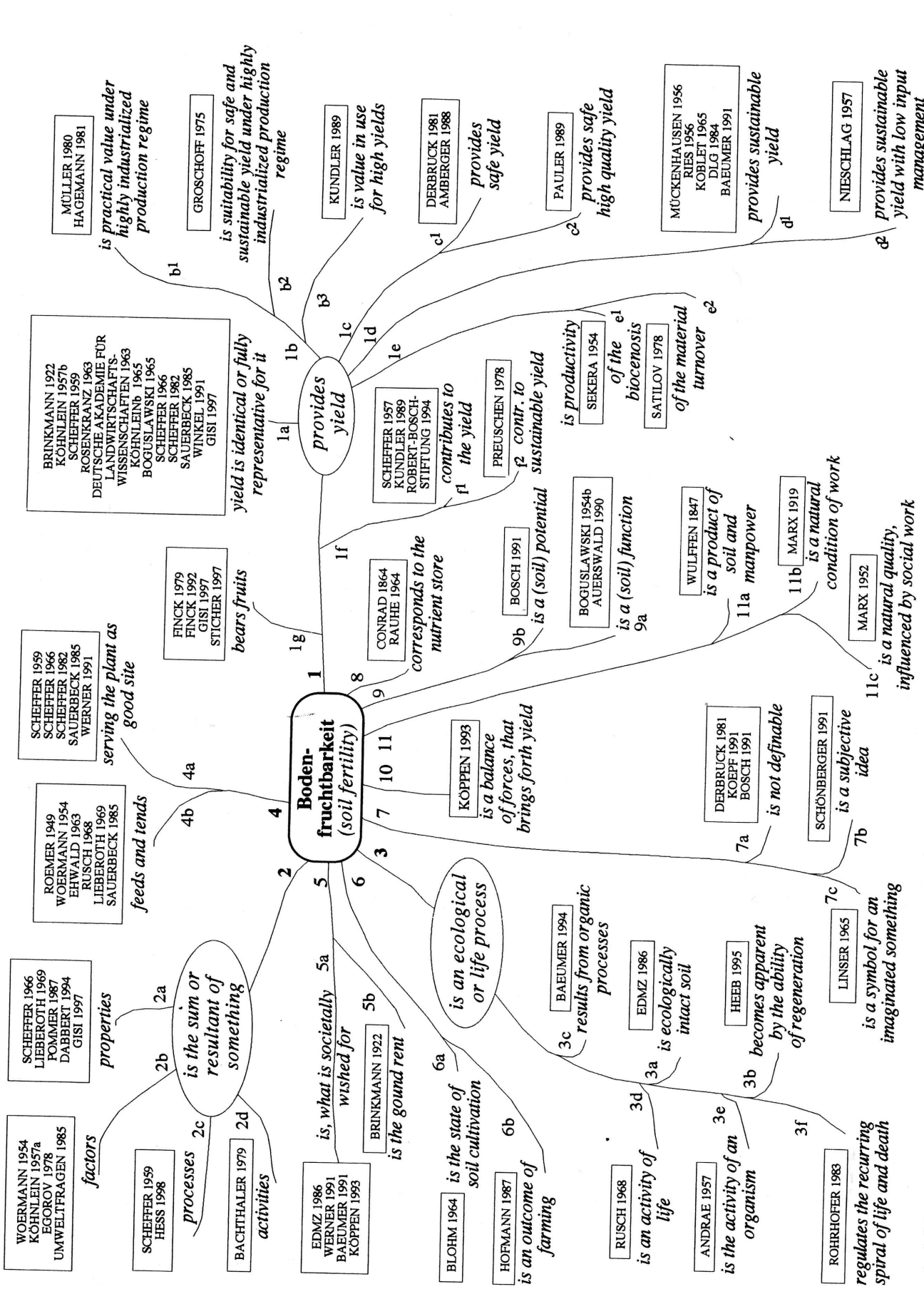

Figure 1: Soil fertility in the German-language literature. The picture represents a weak hierarchical system of the contents of the papers, befitting their similarities. Some publications occur several times. The short statements in italics show what is stated in the paper. The main branches are labeled with their common statement. The number labels and the references are mentioned again in the text.

Abbildung 1: Bodenfruchtbarkeit in der deutschsprachigen Literatur. Die Literaturverweise wurden gemäß der Ähnlichkeit ihrer Aussagen in Form einer schwachen Hierarchie grafisch dargestellt. Einige Publikationen werden zugleich an mehreren Stellen eingeordnet. Die kursiven Texte bezeichnen den Inhalt der entsprechenden Publikation; die „Hauptäste" wurden mit Gruppennamen benannt. Die Ordnungsnummern finden sich ebenso wie die Literaturverweise im Text wieder.

Landwirtschaftswissenschaften, 1963; *Köhnlein,* 1965; *Boguslawski,* 1965; *Scheffer* and *Schachtschabel,* 1966; *Scheffer* and *Schachtschabel,* 1982; *Sauerbeck,* 1985; Winkel, 1991; Gisi et al., 1997). Within this group there is the full range from defining the notion of "providing yield" as a potential yield capacity to yield as an actual result or measurement.

All of the nodes on the right side of Figure 1 (lb-Id) illustrate subtle differences associated with the "yield-centristic" point of view *(Muller,* 1980; *Hagemann* and *Schnee,* 1981; *Groschoff* etal., 1975; *Kundler,* 1989; *Derbruck,* 1981; *Amberger,* 1988; *Pauler* and *Neumann,* 1989; *Muckenhausen,* 1956; *Ries,* 1956; *Koblet,* 1965; *DLG,* 1984; *Baeumer,* 1991; *Baeumer* and *Keller,* 1991; *Nieschlag,* 1957). The main difference within these citations is that they range from highly mechanized and chemical-dependent agriculture on the one side (lb) to low external input management on the other side (Id). The secondary nodes (i.e. lb^1 to lb^3 or Id^1 to Id^2) help differentiate these publications according to the timeframe (current or actual yield to long-term yield sustainability) that the citation appears to be considering.

The fertility-yield-equation is emphasized in viewpoints expressed in citations listed along Branch If, where soil fertility is conceptualized primarily as a contributor to crop yield *(Scheffer* and *Lieberoth,* 1957; *Kundler,* 1989; *Robert-Bosch-Stiftung,* 1994; *Preuschen,* 1978). Citations expressing an ecocentric viewpoint, but still predominantly yield-orientated, are listed along Branch le, and generally conceptualize soil fertility as either productivity of the biocenosis *(Sekera,* 1954) or material turnover *(Satilov,* 1978).

Conceptualizing soil fertility being able *"to bear fruit"* (Branch lg) is very close to the yield-centrism concept *(Finck,* 1979; *Finck,* 1992; *Gisi* et al., 1997; *Sticher,* 1997), although subtle differences in the connotations of this expression should be acknowledged. It is a step away from the purely utilitarian purpose ascribed to soil. "Bearing fruit" is etymologically close to the German word „Bodenfruchtbarkeit" which means to hold or bring something forth.

The second primary Branch (**#2**) conceptualizes the term soil fertility as the "sum or resultant of something". This visualization or mind-map is encountered in one-seventh (14%) of the citations. The driving forces for this concept are "properties" in Branch 2a *(Scheffer* and *Schachtschabel,* 1966; *Lieberoth,* 1969; *Pommer,* 1987; *Dabbert,* 1994; *Gisi* etal., 1997), "factors" in Branch 2b *(Woermann,* 1954; *Köhnlein,* 1957a; *Egorov,* 1978; *Rat von Sachverst. f. Umweltfragen,* 1985), "processes" in 2c *(Scheffer,* 1959; *Hess,* 1998) or "activities" in 2d *(Bachthaler,* 1979). Each of these categories forms an open or closed set of attributes or properties that determine or describe soil fertility, In each case, "soil fertility" is defined through its function as a generic term that encompasses all sorts of relevant pedologic parameters.

A third primary definition, or circumscription of the concept soil fertility in German-language literature (Branch **#3)** refers to the concept as an indicator of "ecological or life process". In biologically orientated papers (node 3a and 3b) soil fertility is depicted as an "ecologically intact soil" *(EDMZ,* 1986) or as soil that has an intact regeneration ability *(Heeb* and *Wetter,* 1995). In some publications, soil fertility is pictured as a "vital activity" (nodes 3c-3e). These references have a broad range of emphasis extending from "organic processes" *(Baeumer,* 1994) to "an organism" *(Andrae,* 1957) or more generally simply to "life" *(Rusch,* 1968) within the soil. From a rather metaphysical viewpoint (node 3f), soil fertility is conceptualized as "regulating the recurring spiral of life and death" *(Rohrhofer,* 1983).

The fourth main Branch (**#4**) of our conceptual soil fertility map defines the term as being able to "serve the plants". This is also encountered in one-seventh (14%) of the citations. This function is addressed indirectly as "serving as a good site" in 4a *(Scheffer,* 1959; *Scheffer* and *Schachtschabel,* 1966, 1982; *Sauerbeck,* 1985; *Werner,* 1991), or directly as "feeding and tending" the plant in 4b *(Roemer* and *Scheffer,* 1949; *Woermann,* 1954; *Ehwald,* 1963; *Rusch,* 1968; *Lieberoth,* 1969; *Sauerbeck,* 1985).

In addition to the four main themes categorizing, defining, or circumscribing soil fertility, we identified at least eight other conceptualizations. One definition (node **5a**) describes soil fertility as all that is societally wished for *(EDMZ,* 1986; *Werner,* 1991; *Baeumer* and *Keller,* 1991; *Baeumer,* 1991; *Köppen,* 1993) and is a trend that currently appears capable of becoming the new mainstream for soil fertility research. This trend seems to be influenced by the Anglo-Saxon term "soil quality", which emerged in the 1980s in the USA. A simple predecessor for this view of soil fertility (node **5b**) is an equation published in the 1920s with regard to "ground rent" *(Brinkmann,* 1922). The decisive role of the farmer with regard to soil fertility is emphasized along Branch **#6** where the term is defined as "the state of soil cultivation" *(Blohm,* 1964) or simply "the output of farming" *(Hofman,* 1987).

Although some have implied that soil fertility and soil quality are interchangeable terms, this was not the intent of the authors asked by the Soil Science Society of America to define soil quality, examine its rationale and justification, and identify the soil and plant attributes that would be useful for describing and evaluating soil quality *(Karlen,* et al. 1997). Several German-language authors including *Derbruck* (1981), *Koepf* (1991) and *Bosch* (1991) consider soil quality too complex to even be definable (node 7a). Other authors, such as *Schönberger* and *Wiese* (1991) and *Linser* (1965), consider soil quality to be undefined because of the abundance of subjective ideas included in the concept (nodes 7b and 7c).

A very simplistic approach (Branch **#8**) is the proposed identity of soil fertility as the soil's nutrient store *(Conrad,* 1864; *Rauhe* and *Lehne,* 1964). Another attempt to achieve both simplicity and scientific accuracy is to define soil fertility a mathematical formula (node **9a**) such as in equation 1:

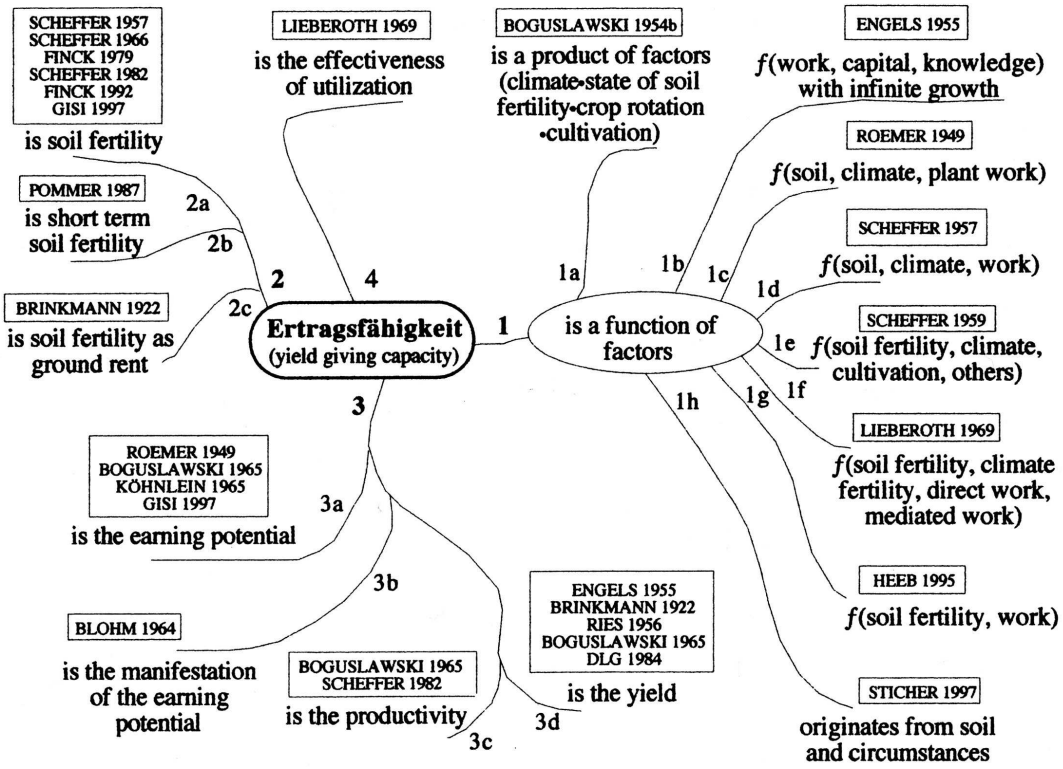

Figure 2: Yield giving capacity in the German-language literature. The references are presented graphically following the same principles as used for Fig. 1. The number labels and the references are mentioned again in the text.
Abbildung 2: Ertragsfähigkeit in der deutschsprachigen Literatur. Die Literaturverweise wurden nach den selben Prinzipien wie bei Abb. 1 grafisch dargestellt. Die Ordnungsnummern finden sich ebenso wie die Literaturverweise im Text wieder.

$$sf = f(y,t,cl,cr,cu), \qquad \text{Equation [1]}$$

where sf = soil fertility, y = yield, t = time, cl = climate, cr = crop rotation and cu = cultivation (adapted from *Boguslawski*, 1954). *Auerswald* and *Schwertmann* (1990) generally speak of soil fertility as soil potential, while *Bosch* (1991) concludes that soil fertility is simply a function (node 9b). Branch #10 shows that *Köppen* (1993) designates soil fertility as a balance of forces that brings forth yield, while *Wulffen* (1847) and *Marx* (1919, 1952) define it as an outcome resulting from a combination of nature and culture.

2.3 The concept of "yield giving capacity" (Ertragsfähigkeit)

Branch **#1** along Fig. 2, identifies literature suggesting that one way to conceptualize *yield giving capacity* (Ertragsfähigkeit) is to define it as a "function" (although not strictly mathematical) of location factors. Although the factor sets vary with authors, they have in common a conceptual closeness to economic thinking in several categories related to crop production.

Except for the case of *Friedrich Engels* (1955)[4], who excluded any natural factor of the yield giving capacity (node lb), soil or soil fertility is always a member of the factor set that determines the yield giving capacity. Climate and cultivation are the other two generic factors. The papers of *Roemer* and *Scheffer* (1949), *Scheffer* and *Lieberoth* (1957), *Scheffer* (1959) and *Lieberoth* (1969) form a traditional line of thinking (nodes lc-f). This viewpoint has seemingly been taken up by *Heeb* and *Wetter* (1995) whose paper (node lg) represents the official Swiss Administration position. *Sticher* (1997) holds a modified position (node lh) of the "factor-set-group" emphasizing that to bear fruits, the soil needs some "necessary circumstances". *Boguslawski's* (1954) texts are characterized by a remarkable fuzziness in semantics (node lb), but he seems to compensate this with the precision of formulas such as equation 2:

$$ygc = f(cl,sf,cr,cu), \qquad \text{Equation [2]}$$

where ygc = yield giving capacity, cl = climate, sf = state of soil fertility, cr = crop rotation, and cu = cultivation.

Besides defining it as a function, *Lieberoth* (1969) equates the yield giving capacity (Branch **#4**) with the effectiveness

[4] Engels wrote: "Die Ertragsfähigkeit des Bodens ist durch Anwendung von Kapital, Arbeit und Wissenschaft ins Unendliche zu steigern" (p.31). "The productivity of the soil is to be increased infinitely through the application of capital, work and science" (transl. by the authors).

[5] Lieberoth: "Ertragsfähigkeit = Effektivität der Bodennutzung. ... Ertragsfähigkeit bedeutet den höchstmöglichen Ertrag an wirtschaftlich vertretbaren Produkten, den eine bestimmte Fläche unter den gegebenen natürlichen Standortsbedingungen bei Anwendung optimaler Kulturmaßnahmen im Durchschnitt mehrerer Jahre hervorzubringen vermag." "Yield giving capacity = effectiveness of soil exploitation. ... Yield giving capacity means maximal revenue of products (which are acceptable from an economic point of view), which an acre is able to bring forth in the mean of several years, under the natural locational factors and optimal cultivation practice" (transl. by the authors).

of utilization. Assuming that he is equating "effectiveness" and "efficiency" this would mean optimizing the productivity factors.[5]

Scheffer and coworker's publications and textbooks support those who define soil fertility as the soil's ability to bear fruits and have the opinion that soil fertility and yield giving capacity are equal (node **2a**). *Pommer* (1987) emphasizes that the time scale distinguishes fertility and productivity (node **2b**). Fertility is considered a long-term condition, whereas productivity is a short-term response to the same phenomenon. Also part of this group is *Brinkmann* (1922) who defines both soil fertility and yield giving capacity as the ground rent (node 2c). There is a spectrum (Branch **#3**) of ideas that range from viewing "yield giving capacity" as earning potential to accepting it as the absolute yield. In the case of *Roemer* and *Scheffer* (1949), *Boguslawski* (1965), *Köhnlein* (1965) and *Gisi* et al. (1997), it's the earning potential (node 3a); while in *Blohm's* view (1964), it is the actual manifestation of the earning potential (node 3b). A proposed relationship between the equation of productivity (in the sense of the German word "Produktivität") to yield giving capacity (node 3c) is given by *Boguslawski* (1965) and *Scheffer* and *Schachtschabel* (1982). The opinion, that the yield giving capacity is identical to the yield itself (node 3d) is held by *Engels* (1955), *Brinkmann* (1922), *Ries* (1956), *Boguslawski* (1965) and *DLG* (1984).

2.4 Conceptual categories and structure of soil fertility definitions

To understand subtle differences among the various concepts of soil fertility, it is important to not only examine *what* is said, but also *how* it is said. In natural sciences, quotations are seldom used because it is normally sufficient to cite the meaning of a scientific result. For this review, we take a closer look at original texts, because in defining soil fertility, it's often not clear what meaning was intended and if the chosen wording is arbitrary or essential. For this purpose we developed a rough classification of different semantics and definition types and applied them to the definitions and circumscriptions of the investigated terms.

Different ways of defining soil fertility

Three categories or dimensions for defining soil fertility were identified, each having two distinctly contrasting perspectives. These dimensions and their various combinations are basic knowledge in the philosophical disciplines associated with logic and philosophy of language. As such, these literary concepts are not new, but they have rarely been applied to natural science literature and never before to the various scientific concepts of soil fertility. The utility of these three dimensions is that they help formulate the shape of each definition or what each author presumably intends. The opposite perspectives associated with each dimension provide valid criteria for classifying each definition.

The first dimension examines whether a publication claims to have the power to define a term or not. The two contrasting perspectives consider whether the definition is *stipulated*, or if it is *reported.* Stipulative definition claims that the reader *should* use the term in the proposed manner, basically pleading that the author's definition is correct. An example of a stipulative definition would be the sentence: "soil fertility should not only be understood as representing yield opportunities, but also as the integral of various pedologic and socio-economic quality indicators." The *reporting* approach is the opposite of the stipulative. In this case, the author reports what has been observed in the literature as a common definition. An example would be: "Soil fertility is generally understood as the potential of the soil to bring forth yield." This approach is essentially referring the reader to a scientific "common sense".

The second dimension is formed by the opposites of *extensional* or *intensional* definition. Some scholars prefer to define soil fertility through the conceptual content („Begriffsinhalt") assigned to the term, while others define it by the extension of terms or observations covered by the definition („Begriffsumfang").

The *extensional* type of definition fits well with the scientific practice because it allows the definition of the term to be given as a set of measurable features. It also allows mathematical formalization. One way of developing an extensional definition is by enumerating individual concepts („Individualbegriffe") that are often properties. For example: "soil fertility enfolds the texture, the content of organic matter, the microbial activity, the pH and others ..." A more general extensional definition could refer to some broad property classes, such as: "soil fertility is the sum of all physical, chemical and biological soil properties." An extensional definition is useful if one wants to make a scientific statement without making a commitment.

An *intensional* definition is equally widespread in scientific literature as the extensional type. This type of definition aims to declare the significance („Sinnbedeutung") of the term, which is often the author's purpose for defining a term. For example, the defining purpose of soil fertility is to fulfill one or several functions. Therefore, the common definition "a fertile soil brings forth yield" is an intensional definition; the purpose is the yield. This definition type is also very handy for an "interdisciplinary" or "integrated" approach that tries to incorporate many different but desired qualities. An example of an intensional definition would be: "A fertile soil has a high biodiversity, a high productivity, a good structure and a high ability to neutralize toxic agents."

The third dimension within which various definitions of soil fertility are found concerns the extension of the significance that is claimed. The two extremes associated with this dimension claim to be either essentialistic or of operational significance. The former is considered to be the *real definition* (Realdefinition), which says something about how things really *are* in their *essence,* whereas the later case is considered to be a *nominal definition* (Nominaldefinition)

or a term that is intended only to be helpful for communication.

Explicit *real definitions* are quite rare in scientific literature, because other authors often contest their scientificity. Generally, it is not clear if an author intends to give a real definition or not. An example would be: "In its essence, soil fertility regulates spiritual powers driving the recurring spiral of life and death." In contrast, a *nominal definition* is a generic statement found in scientific literature. An example with respect to soil fertility would be the sentence: "The term 'soil fertility' assigns the productivity of the agro-ecosystem."

In addition to the three dimensions that were described above and used to differentiate the various soil fertility definitions, it can be observed that the entire spectrum of explicitness or implicitness and of possible grammatical expression have been used by the various authors. This means that there is no common convention or consensus within the scientific community with regard to how the term "soil fertility" should be addressed when trying to define or circumscribe it.

The most common grammatical approach is the nominal sentence construction beginning "soil fertility *is* ..." Subsequently, the end of each sentence is either an equated nominative term such as "production power" or "a potentiality" or a complex explanation. Most often, the equated nominatives are soil "properties" "processes", "capabilities" or "functions". Another approach is to say soil fertility "comprehends" or "includes" or "covers" something. This "something" may be an open or closed list of attributes or simply "everything important".

Rather implicit are definitions that describe soil fertility by what it is "measured", "indicated", "characterized" or "mirrored". Similarly, but with rather active connotations are implicit definitions, which claim that soil fertility "unhides" or "expresses" itself by something, or is described by the effects that it "causes". Another indirect approach for defining soil fertility is to promote or evoke efficient causes for it. An example of this approach would be to state that fertility is "due on" something (e.g. clay complexes) or is "determined by" something (e.g. soil life).

2.5 Problems of the conceptual approaches to soil fertility

Problems associated with using a conceptual approach towards soil fertility can be grouped into four theses. The first states that: *The term "soil fertility" is not apt to be shaped as a technical term of natural sciences.* This type of problem occurs because with regard to soil fertility, disciplinary terminology and lifeworld (spoken everyday) language often do not agree. When this occurs it is often impossible to uncouple scientific definitions from the real-world language without losing a lot of the term's significance. The rich and different human perceptions lead to a striking variety of meanings associated with terms like soil fertility. The nearly inescapable conclusion, especially for natural science standards, is that any attempt to specifically define soil fertility leads either to an undue ambiguity or to objectionable restrictions. For these reasons, theoretical claims for conceptual clarity and rigor in most conceptual definitions are generally not fulfilled in practice.

The second thesis is that: *Extensional definitions of "soil fertility" tend to be poor in real substance.* When trying to define soil fertility in this way, it doesn't explain anything. It only enumerates something. In the generic case, in extensional definitions, the term "soil fertility" serves only as a label for the sum of the terms it represents, i.e., almost no further substance is assigned to it. Therefore, such definitions become rather superfluous labels without explanatory capability and generally with poor normative power. Consequently, we are not keen to claim that this way of dealing with the term "soil fertility" should be extensively followed.

A third thesis suggests that: *Intensional definitions of "soil fertility" are particularly connected to scientific and societal Zeitgeist.* This also applies to definitions that are completely embedded in the scientific discourse. Intensional definitions are - as extensional ones - in most cases open to extension with further elements. This type of definition usually results from a negotiation process in either the scientific or public arena. It is therefore particularly useful for incorporating socially expressed features, but when used, such definitions should be conscious decisions and fully declare their context. We qualify this thesis by the assumption that the suggested flexibility doesn't affect the core intension of soil fertility that is "To bring forth what nourishes". This intension certainly appears to be a cultural constant.

The fourth thesis is that: *"Soil fertility" is a qualitative dispositional term that is not completely operationalizable in natural sciences.* Its actual state is not measurable because of its nature to be a partial and indirectly perceivable state of the soil, capable of bringing forth something under certain conditions. This feature contributes to the observable mess of implicit, indirect and either over-stretched or over-restricted definitions of soil fertility.

To summarize, we can say that definitions of soil fertility are limited (i) by its constitutive aspect to be a disposition (which is never present at hand) and (ii) by the fact that it comprises a striking plurality of significant aspects transgressing the realm of natural sciences. That's why in the observed literature, the concept often either dissipates in a multitude of enumerated measurable quantities or is inflated by the societal wish list. Without reservation, the definition - in the sense of "degree of distinctness" - of soil fertility can't escape the trade-off relationship with regard to its degree of completeness.

2.6 Distinctions between soil fertility and soil quality

The problems associated with a conceptual approach to soil fertility result in substantial confusion and sometimes

an explicit laziness to seriously define the term in scientific work and publishing. Therefore, to relieve some of the strain on having only a single term and solve some of the observed conceptual problems, we propose to distribute the multiple conceptual concepts associated with "soil fertility" to the two terms: "soil fertility" and "soil quality". This does not imply that we are simply replacing one term with another, as some have concluded with regard to U.S. literature on soil quality, but to use the two terms for concepts that have a distinctly different focus. To clarify our recommendation, we suggest that the following distinctions be made between the two terms.

Soil fertility denotes a definite feature of the soil, but it is a dispositional ("concealed") one. This feature cannot be substituted for or supplemented by additional attributes without changing (replacing) the term. Its conception is swayed by value judgments and the specific features will vary among soil resources.

Soil quality encompasses an indefinite (open) set of tangible or dispositional attributes of the soil. These attributes may be substituted for or supplemented by other attributes without needing to change the term. Therefore, it is a vessel to contain what is assigned to it. The attributes assigned to the term will differ among soils and the various demands, because the term is influenced by value judgments.

Our rationale for recommending two distinct terms is that if soil scientists and others do not try to include everything that would be actually desirable from an ideal soil in the definition of "soil fertility", the established term would not suffer from a complete shift of meaning or a conceptual expansion to the point where there is complete dissipation of any true meaning for the term. Based on this reasoning, most of the observed broadened intentional definitions (containing more than one element) of soil fertility should be assigned to the term soil quality. This indefinite term (i.e. soil quality) is more suitable to encompass all of the attributes that are valued as being important for measuring a soil against a given standard and to mark its capacity to do what it is expected to do. The more definite term "soil fertility" is the right one to keep in focus the concealed phenomenon of "bearing new life and bringing forth what nourishes".

We also suggest that adopting these two distinct terms for the German literature will help reduce confusion associated with these terms. For example, in the United States of America, the concept of soil quality[6] arose partially in reaction to an emphasis in soil fertility research and practice that was shown to be environmentally harmful and was considered too one-sided from societal, ecological and pedological *{Revelle,* 1984)[7] perspectives. A policy change towards sustainable agronomy was called for *{Paul,* 1989; *American Societey of Agronomy,* 1989[8]; *Brklacich* et al., 1991[9]). The first proposed definitions of soil quality were very similar to those associated with sustainable agronomy *{Parr* et al., 1992[10]; *Committee on Long-Range Soil and Water Conservation, National Research Council,* 1993[11]). A characteristic of the definitions proposed for understanding soil quality was an attitude that it "should" encompass a more diverse set of physical, chemical and biological properties and processes than previously being considered *{Doran* et al., 1994[12]) and that goals for soil quality need to be "set" *{Cox,* 1995[13]). Some authors acknowledge the relativity of the soil quality definitions *{Hortensius* and *Welling,* 1996[14]; *Doran* and *Parkin,* 1996[15]; *USDA,* 1996[16]) that leads to the assumption of changeability *{Steinhardt,*

[6] The most common present definition is: "Soil quality is the fitness of a specific kind of soil to function within its surroundings, support plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation." See for example USDA (1996).

[7] "In the past, soils have been utilized as a source for production of nitrogen and other plant nutrients, hence the concepts of soil fertility, i.e., the availability in the soil of nutrients for plant growth. With the advent of the modern technology of use of chemical fertilizers, soil fertility in this sense has ceased to be important. But the physical properties of soils - their capacity to retain water that can be extracted by plant roots to provide calcium and other cations through base exchange in clays and to maintain fertilizer in available form for the plants - are of vital importance." (p. 471)

[8] "A sustainable agriculture is one that, over long term, enhances environmental quality and the resource base on which agriculture depends; provides for the basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society as a whole."

[9] "A sustainable food production system (SFPS) is defined here as an agrifood sector that over the long term can simultaneously (1) maintain or enhance environmental quality, (2) provide adequate economic and social rewards to all individuals and firms in the production system, and (3) produce a sufficient and accessible food supply." (p. 10)

[10] They define soil quality as "the capability of a soil to produce safe and nutritious crops in a sustained manner over a long period, and to enhance human and animal health, without impairing the natural resource base or harming the environment." Further they stress the function of soil as environmental filter affecting air and water quality.

[11] "Soil quality is best defined in relation to the functions that soils perform in natural and agroecosystems." The authors say that the term soil quality has been long time closely related or even synonymous to the term soil productivity, but now "there is growing recognition that the functions soil carry out in natural and agroecosystems go well beyond promoting plant growth. Soil quality can be defined, as the ability of a soil to perform its three primary functions: to function as a primary input to crop production, to partition and regulate water flow, and to act as an environmental filter." (p. 20If.)

[12] "Soil quality should not be limited to soil productivity, but should encompass environmental quality, human and animal health, and food safety and quality."

[13] "We need to set national goals for soil quality".

[14] "It is recognized that quality is a relative concept; when soil measurements are considered of good quality for one purpose, they may be of very poor quality when considered from another perspective."

[15] "Perceptions of what constitutes a good soil vary depending on individual priorities for soil function and intended land use; however, to manage and maintain our soils in an acceptable state for future generations, soil quality *must be defined,* and the definition must be broad enough, to encompass the many functions of soil."

[16] "The types of indicators that are the most useful depend on the function of soil for which soil quality is being evaluated."

[17] "The concept [of soil quality] is not rigidly fixed and will evolve and change with time."

[18] The definition of soil quality and health is "functional" and "interchangeable".

1995[17]) and even "interchangeability" *(Harris* et al., 1996[18]) with some soil fertility definitions. Soil quality is thus defined by value judgments concerning various attributes and is therefore in agreement with our proposal for using the term as a vessel for *this* aspect of dealing with the soil.

Developing a more distinct relationship between soil fertility and soil quality will result in a clarification of the concepts and improve communication regarding their role in both scientific and societal discourse. This "allocation of tasks" between the two terms may also help avoid some of the problems of dealing both scientifically and culturally with the soil. It may especially help avoid mingling of concepts focusing on the phenomenon of soil fertility versus the value judgments associated with soil quality.

Adopting the distinctions recommended above would free soil fertility from the numerous attributes that are more appropriately assigned to soil quality. This would enable scientists and others to focus on the concealed phenomenon, but it doesn't answer the question: how can we describe and deal with "soil fertility"? From the literature review we learned that soil fertility cannot be grasped by a technical term, that it's not actually measurable, that extensional definitions are rather evasive actions and that intensional definitions are particularly connected to culture and Zeitgeist. Therefore, we will return to some papers to examine the persistent closeness of the term "soil fertility" to lifeworldly (lebensweltlich) perceptions and how these perceptions have, for natural scientists, resulted in the sometimes annoying variety of definitions that are associated with the term.

Scheffer and *Lieberoth* (1957) suggest that the term's closeness to folksy intuitions resulted because of its "origin from *anschauungen* of natural philosophy". *Schönberger* and *Wiese* (1991) identified the term's "mythological origin" as separating it from scientific terminology. *Linser* (1965) states that soil fertility is a "symbol" for something that we suppose exists as an efficient cause. Following Linser, the naming of this symbol can be different; it may be a fertility Goddess of primitive people, or the scientifically conceived term "soil fertility". *Rohrhofer* (1983) evokes consciously mythological connotations of a "recurring spiral of life and death" as a chief feature in his soil fertility definition. To further illustrate the multiple aspects of the soil fertility phenomenon, the next section focuses on the relationship of cult and cultivation.

3 The cultic cultivation of soil fertility[19]

Based on ethnic studies performed by *Mannhardt* (1875—77), *Dieterich* (1913), *Frazer* (1928), *Bächthold-Stäubli* (1927-1942), *Weber-Kellermann* (1965) and *Winiwarter* (1999), we sketch some features of a conception of soil fertility, which addressed the spiritual side of nature. We focus on fertility cults and rites mostly observed in European practices until the last century. These cults and rites covered the full range from hidden underground culture to official high-cultural events.

The concern with the four elements - water, fire, air and earth - and the attempt to unite them in the correct way, were assumed to form an underlying pattern of many rites.

Concerning the antagonism of water and fire, one reported belief was that if a fire-wheel rolling down the hill in spring ends up in the river (so that fire and water could unite), there would be a good juice of the vine at the end of the year. Both of these elements had to enter the soil, and the one that was under-represented was brought into it.

In other instances, the plough was sprayed with water to bring moisture to the earth (because water symbolized fertilization) or dipped in water or a river, and was then accompanied with burning candles to counterbalance the abundant water. Sometimes the reapers and the harvest were also sprayed with water when returning from the fields.

Fire, either through burning torches or by a plough that had been pulled through a fire, was brought onto the fields in spring to "awaken the corn". The fire and the ashes were also employed for protection against destructive influences such as evil spirits or plant diseases.

Soil was often seen as a feminine element that bears and protects vital processes. The soil was invoked in rituals concerning conception, birth and strengthening of children. Also for the relief of illness and to ease the dying, except in cases where the concerned person had insulted the soil. In the context of soil fertility, the earth was seen as the site where the other elements should be fixed in and united in a way that new life may be born.

Wind and air were seen as manifestations of a spirit reviving and inhabiting woods and crops, living in the breath of the wind. In response, people left corn ears and fruit "for the sake of the wind and his child", or threw flour into the wind to feed it and as protection against its destructive aspects. There were stories that the corn of the farmer who forgot the wind became barren.

The four elements can be looked at as primary opposites in the inner and outer realm of human experience. In their uniting, a spirit played a crucial role. The vegetational spirit was seen in the wind or in actual personifications. There were tales of women and animals inhabiting the vegetation as spirits and sometimes appearing to humans. The spirit was represented by the last ears of corn in a field, by figures made of grain, or by men and women dressed in special costumes made of tissues or plants. It was seen as both the creative and created. The spirit appeared as old and moribund or as renewed, resurrected, or newborn. The vegetational spirit had aspects of both sexes, in analogy to mythical mother-son pairs. Its female aspect was often called "corn mother" because she "bears children, many thousands". She gave birth to grains and was also involved in human marriage and fertility, as expressed by many rituals, especially of women.

The adjective "cultic" and the noun "cultivation" both originate from the Latin root "cult-" what means "inhabited, cultivated, worshipped".

Two behavioral elements are important factors for the cultic cultivation of soil fertility - sacrifice and offering on the one side and eros on the other.

Whereas real human sacrifice for soil fertility lies far back in history (e.g., ancient Athens), or at a great distance (India), the offering of produce is still present in Europe and America, most prominent in Thanksgiving.

Similar to the "feeding of the wind", there were rituals for "feeding the four elements". Flour or bread was divided into four portions and was exposed to the wind, thrown into a river or well, burnt in a fire and buried in the earth. Different forms of eros were cultivated to bring oneself, the soil, and the community into a mode of belonging together. One form was the direct, physical and emotional getting in touch and joining together with the soil and the four elements. Close to that behavior were attempts to participate in special events among natural forces, such as a thunderstorm in a "marriage of the elements".

Another aspect of the eros was the *hieros gamos*[20] of men and women on the field, in sympathy with the uniting of elements within the soil. Bridal pairs played the role of "maypairs" partaking with the spiritual wedding of opposites or symbolizing it for the sake of the whole community. This was a symbolic move that supported the recurring process of renewal. On the community level, there were rituals of circumambulating the arable land, often accompanied by prayers, liturgy and fine food, so that all were made to feel content both with those present and within the greater coherence.

In summary, (i) the feeding and uniting of the four elements, (ii) the relation to the spirit, (iii) the sacrifice and (iv) the eros were essential features of the cultic cultivation of soil fertility. The common linkage among those features is the *eros* or principle of making relation.

4 Concept and phenomenon of soil fertility

Our literature-based investigation of soil fertility produced two main results. First, it would be very desirable to recognize both soil quality and soil fertility as distinct terms. By incorporating both terms into scientific and non-technical literature it becomes more feasible to describe different concepts and their different frames of reference without using the same term. Adopting soil quality still leaves several different definition types[21] associated with the concepts of soil fertility. Our second conclusion is that we must also distinguish between concept and phenomenon of soil fertility. This means taking into account the qualified status of the conceptual approach and thoroughly examining alternative perceptions of soil fertility and methods of relating to it both mentally and physically.

[20] *hieros gamos* means "holy wedding" or "sacred unification"

[21] For the various *definition contents* and their frequency ranks see sections 2.2 and 2.3.

Conceptual approach

Within the conceptual approach towards soil features and functions, we firstly wish to highlight the differences between soil fertility and soil quality. The first contains conceptions about the definite, but dispositional (concealed), soil feature named fertility; the second relates to concepts dealing with undefined and interchangeable sets of appreciated soil attributes, named soil quality. The diverse soil attributes and various direct or indirect soil functions are assigned by value judgments to be part of soil quality, which are reached through finding social consensus. Such a conceptualization of soil quality allows the recognition of diverse soil physical, chemical, and biological parameters that must be considered when striving to use soil resources appropriately to simultaneously meet the numerous societal goals imposed upon that resource. That may mean to lay the focus on valuating material soil parameters in the light of societal goals which are indicated by measurable soil properties, or it may mean to include non-pedologic and non-agricultural parameters explicitly into the soil quality indicator sets.

The conceptualization of soil fertility is, on the other hand, a practical approach for handling the phenomenon of soil fertility and an approach for quantifying it or gaining an apperception of it. Conceiving soil fertility as a concept is therefore one possible approach toward recognizing or understanding the phenomenon of soil fertility.

Returning to the logic and philosophy of language, three formal dimensions or categories can be described or observed by applying different pairs of polar definitions to the terms soil fertility and soil quality. These include (i) *stipulated* and *reported* definitions which are equally common although sometimes a "report" is actually a hidden stipulation; (ii) *nominal* definitions which are generic and *real* ones which are rare, although an unreflected identification of nominal definition and real phenomenon is not uncommon, and (iii) *extensional* or *intensional* definitions which are again equally common.

We propose that the heterogeneous, intensional definitions of soil fertility [i.e. those containing several elements and strongly dependent upon scientific and social Zeitgeist and values] be assigned to soil quality. Other intensional definitions that focus on yield as the central material aspect of the phenomenon of soil fertility are often rather undifferentiated, but since they generally focus on bringing forth a product (Ertragsfähigkeit), we suggest they be associated with the term "soil fertility".

Extensional definitions tend to have little real substance because in many cases they only enumerate or list characteristics or some other process or property in an open or general format. Although the approach is defensible, the status and reason for various assumptions and added value of conceptual labels are often unclarified. As a result, extension type definitions are frequently used to make a scientific statement without making a commitment. Unfortunately this approach often gives an impression of

"not seeing the forest for the trees" or focusing so hard on the details that one has lost sight of the ultimate goal or unifying features of the phenomenon. These extensional definitions are also problematic because of characteristics of the phenomenon itself, as shown in the following two statements. *Firstly,* the term "soil fertility" cannot be shaped as a technical term of natural sciences. This occurs because it is impossible to uncouple its scientific definition from the striking variety of life-worldly meanings, which arise from the phenomenon of soil fertility and mythically related phenomena such as human fertility. As a result, the theoretical claim for conceptual clarity and rigor cannot be fulfilled without requiring an undue limiting of the term, robbing it of meaning. Detail-focused extensional definitions are an attempt to bypass this problem.

Secondly, the term "soil fertility" is considered to be a qualitative dispositional term, which is not completely operationalizable in natural sciences, as its actual value can never be verified. Soil fertility is not measurable in its actual state even if the concept is restricted to its material aspect. This is due to its being a partial and indirect perception of the soil as being able to bring forth something (i.e. crop yield) under certain conditions. That characteristic facilitates the creation of the observable mess of definitions.

The phenomenon of soil fertility Unlike concepts of soil fertility, which are products of conscious thought and decision-making, the phenomenon of soil fertility is something that appears to the consciousness as an autonomous counter-instance with its own mental and material qualities. Our underlying understanding of "phenomenon"[22] follows Goethe, Heidegger and Jung. A phenomenon is something that shows and tells itself *{Heidegger,* 1993)[23]. Following *Goethe* (1827), one can distinguish empirical phenomena and archetypal phenomena ("Urphänomene"). The latter are not principles that can be deduced from the multitude of appearances, but are archetypal appearances, which may lead to an understanding of the multitude of single phenomena.[24] Archetypal phenomena have both material and mental apparitions and significations *(Jung,* 1995). If we agree that soil fertility is such a phenomenon, it helps in dealing with the observed problems of conceptualization and opens up an understanding toward the meaning of the observed cultic cultivation of soil fertility. That is—besides trying to make a concept of it—another possible reaction to the phenomenon. Thus, we suggest regarding soil fertility as an archetypal phenomenon with mental and material aspects.

As shown above, different behavioral patterns towards the phenomenon of soil fertility are possible. The conceptual approach produced mostly constructions of soil fertility that in general refer—in an explaining and defining way—to the material side of the soil fertility phenomenon. The described features of the cultic cultivation of soil fertility by certain rites and connected beliefs show human reactions to and representations of that phenomenon, which were generic in former times among many cultures. They represent something like a primordial nonintellectual understanding and apperception of it, which joins together the mental or spiritual and the material side of this archetypal phenomenon of life. These expressions may no longer be fully satisfactory from our present viewpoint, but it is a point of departure to a body of evidence that should no longer be disregarded. As *Goethe* (1821) said: "In science, it is most commendable to find again the imperfect truth, which the ancients still possessed, and to lead it on."[25]

Based on our evaluation, we come to the conclusion that soil scientists, and not only these, need to re-evaluate the soil fertility phenomenon. This could provide an up-to-date understanding of the relationships among the mental and spiritual perspectives to which the former cultic cultivation referred, and for which it has effects even if we don't want to believe in them. This evaluation would result in a really innovative and forward-looking soil fertility research program. When approaching the task, one should not hurry to adopt a specific theory but first familiarize oneself with the findings and then try to envision the entire picture and its multitude of features. That is, joining together the four elements to bear new life as a fifth, the *religio* toward the spiritual side of nature, the sacrifice and the *eros.*

Making concepts of the phenomenon of soil fertility or alternatively, pursuing an almost unconscious worship *toward* it, are not the only options. It may be feasible to establish a conceptual vessel *for* the phenomenon including both a symbolic understanding and conscious apperception. However, due to the nature of the phenomenon, this will not be feasible using only dry intellect. Emotional commitments and relations are also necessary.

Having concepts, one is tempted to assume that we can control or have dominion regarding both soil fertility and soil quality. Conversely, the autonomous counter-instance of the phenomenon makes rather shy. It makes one feel that

The term "phenomenon" (gr. φαινομενον, [lat. apparentia, apparens] = "showing itself, coming to light") was introduced in philosophic terminology *(Ritter* and *Gründer,* 1989) by *Anaxagoras* (1986) with the sentence: "The sight of the concealed is the phenomenon" <οφις γαρ των αδηλων τα φαινομενα> *Maansfeld* (1986): fragment no. 76 [DK 59 B21a]). From Plato and Aristotle up to present philosophy, this term was interpreted filling the spectrum from mere appearance to real apparition, from the manifoldness of findings to the archetypal (basic) actualities, and from sense-data to self-evident inner experiences. All these interpretations are remaining in effect as connotations of the term.

A phenomenon is the "showing-itself-in/with-itself' ("Sich-an-ihm-selbst-Zeigende"), including a referential relation ("Verweisungsbezug") on itself (das "Meldende"); the act is called the "telling [or announcing] itself ("Sich-*melden").*

"Ferner ist das Urphänomen nicht einem "Grundsatz" gleichzuachten, *aus* dem sich mannichfaltige Folgen ergeben, sondern anzusehen als eine *Grunderscheinung, innerhalb* deren das Mannichfaltige anzuschauen ist" (*Goethe,* 1827).

In den Wissenschaften ist es höchst verdienstlich, das unzulängliche Wahre, was die Alten schon besessen, aufzusuchen und weiter zu führen".

there is a creative (and may also be destructive) ability, which is too strong and unfathomable to be simply "grasped" or "managed". In summary, we have examined a vast amount of literature, proposed differentiating the concepts of soil quality and soil fertility, and explored the phenomenon of soil fertility. Based on our review, we conclude that: (i) the concepts of soil fertility should be freed from topics leading away from the focus on the phenomenon itself; (ii) the term soil quality should consequently be used as a tool or vessel to encompass the diverse but appreciated soil properties and the various desired direct or indirect soil functions; and (iii) the practical and scientific work should rediscover, revive and lead on the feeling for and apperception of the phenomenon of soil fertility in its mental and material aspects.

Acknowledgments

We thank *Annette Johnson* for proofreading the manuscript, *Michael Esfeld* for verifying the philosophical background and *Theodor Abt* for some references on cultic cultivation.

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