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Overview of relevant standards for the BonaRes-Program

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Abstract

Major task of the BonaRes Data Centre is to create a user-friendly data repository to upload, manage and provide soil and soil-related research data in findable, accessible, interoperable and reusable formats for continued use (see FAIR data principles). To meet these requirements, the application of accepted and widely used standards, regulations, conventions and guidelines for the different stages of research data life is necessary. Regarding the BonaRes project such standards concern e.g. the classification and description of soils, field and lab methods, agricultural technology, plant varieties, fertilizers, farming and agricultural business data, metadata, data quality control, transfer to data bases, data storage and archiving, exchange formats and languages, controlled vocabularies, and, not least, the provision of data via geo-data services and a web portal.

This document presents and discusses a variety of data standards for all data life stages from its acquisition to its provision. It aims to inform owner, provider and users of soil and agricultural data and to facilitate data integration and data use within the BonaRes data repository.

Keywords

BonaRes, standards, research data, data management, data provision, data interoperability, FAIR principles, soil science, agricultural science, agronomy

Overview of relevant standards for the BonaRes-Program

Contents

0 Introduction

In the scope of the German research initiative "BonaRes" (*Soil as a sustainable resource for the bio-economy*) the BonaRes Data Centre created a geo-database for soil and agricultural research data and accompanying metadata. Beside data from national research projects, the BonaRes Data Centre is open for other soil-related data, e.g. from long-term field experiments (LTFE). The BonaRes Data Centre provides DOI, easy access and long-term availability for all uploaded research data. According to the Berlin Declaration on Open Access (2003) and the initiative "Digitale Information" (Alliance of Science Organizations in Germany, 2013), metadata and research data will not be subject to any restrictions on reuse. Metadata are always available and, after a limited embargo-time, also research data are provided accessible for the international research community. Further information is given in the BonaRes Data Guideline (Svoboda and Heinrich, 2017).

The BonaRes Data Centre promotes the availability of soil and soil-related research data and generates the incentives for data-holders to join this endeavor. It sets-up the required infrastructure for providing soil research data in standardized form for users from scientific, regulatory and farming communities. Only premise for (meta-)data upload is that research data are connected with spatial information (geo-data).

The BonaRes data repository follows the FAIR data principles (Findable, Accessible, Interoperable, Reusable, see Wilkinson et al., 2016) and aims to be user-friendly, i.e. facilitate data upload and provide data citable formats for continued use. To meet these two important demands and enhance the research data reusability (FAIR Principle R 1.3), the use of standards, relevant community standards and data documentation during *data life* is necessary. Such standards concern, beside others, the classification and description of soils, field- and lab methods, agricultural technology, plant varieties, fertilizers, farming and agricultural business, data quality control, the transfer to data base, used formats, data storage and -archiving, and metadata management.

In 2017 the BonaRes Data Centre started to collect data from national soil and agricultural research projects, such as collaborative BonaRes projects on soil and agricultural research. The Data Centre may support the entire process of all data life stages, i.e. primary data generation, data storage, data management, data provision, data publication, and long-term archiving. Research data which were collected under standardized conditions, described with coherent metadata, proofed by quality tests, and stored in the BonaRes data repository, will be visible and accessible for any data re-use (e.g. modelling), exchange and further review.

In the long term it is planned to consolidate the BonaRes repository into international infrastructures for soil and agricultural research data. This requires data interoperability by internationally accepted and applied standards. Transformation tools may help to translate data from national to international valid systems and formats.

This document is grouped based on three major data life stages:

1. Data acquisition
2. Data management
3. Data provision

Tasks of this report are to describe, compare, review and recommend standards for the whole data life and to assist soil and agricultural scientists to integrate research data into the BonaRes frame-work. Missing and competitive national and international standards and potential conflicts are stated and, based on internal and external expert knowledge, outstanding standards for the BonaRes Data Centre are highlighted and summarized to recommendations:

★★	Favored	= highly recommended for application in BonaRes (not mandatory)
★	OK	= acceptable alternative but maybe requires later transformation

In the Appendix the highly recommended standards as well as many code lists, glossaries and web links are listed in tables.

1 Data Acquisition

The acquisition of soil-, crop-, agricultural machinery-, farming-, business, and other, soil- and agricultural related research data are regulated by numerous, sometimes inconsistent, standards, laws, guidelines and conventions. Many regulations are used only in national contexts and may require transformation to be interoperable in international contexts.

In this chapter, standards in soil science from field and lab work (e.g. soil mapping, -classification, and -quality), meteorology, agriculture (e.g., crops, tillage tools, field management, and fertilization), business, and personal data (e.g. farm size, attitudes of farmers, income, and property rights) are collected, described and evaluated.

1.1 Field Soil Description and Soil Classification

Overview of existing standards

German Soil Survey Guidelines ("*Bodenkundliche Kartieranleitung*"), 5th edition, Ad-hoc-AG Boden (2005, KA5), short: KA5 ★★

The first edition (1965) was a nation-wide accepted guideline in administration and research. Still in use in some federal states are also the editions (KA4, 1994 and KA3, 1982). The administrative soil surveys of the federal states (*Bundesländer*) often use adaptations and modifications of this guideline. A shortened and simplified version of the German Soil Survey Guidelines has been extracted from KA5 for soil conservation purposes (*Arbeitshilfe Boden*; short: AHB); the Federal Soil Protection and Contaminated Sites Ordinance in Germany refers nonetheless to KA4.

The major part is about describing site, soil profile, layers and horizons, naming horizons and soil's allocation in the German soil system ("*Bodensystematik"*) as well as a classification of the soil material (substrate classification; "*Substratsystematik"*). A large number of parameters, often with partly extensive code lists, and a formalized way to record auxiliary information (form, degree of expression, share, and size) are provided. It is thus one of the most detailed guidelines for soil description in the world. However, a strict data model is not included.

A new edition is awaited (possibly in 2019) with improvements in the soil system and substrate classification, horizon notation, code lists and in the mapping part. The simplification of soil description (AHB) shall be included in the new edition.

Besides, BonaRes focuses primarily on German soil data. Therefore, the current edition of the German Soil Survey Guidelines (KA5), as the most common national standard for soil description and classification, is strongly recommended. Foreign national standards without or with minor international aspects are less important for BonaRes.

World Reference Base for Soil Resources (IUSS Working Group WRB, 2014) ★★

The WRB was developed by a working group with the participation of IUSS, FAO, and ISRIC. It provides a standard taxonomic soil classification system which allows the accommodation of national systems. It is designed to serve as a common denominator for communication at the international level and as a correlation between existing classification systems. The WRB classification system contains two hierarchical levels: On the level of "Reference Soil Group" (RSG) 32 units are differentiated. On the second level the RSG is described more precisely by the use of "Qualifiers". For every RSG a list with corresponding principal and supplementary Qualifiers is defined. Classification is done by using both levels via diagnostic horizons, materials and features.

DIN 19682-1ff – Soil Quality - Field Investigation ★

The DIN 19682 series describes in 9 parts determination and measurement techniques for soil properties which are applicable in the field. Those parts that address description of soil properties (color (1), particle size distribution and soil type (2), soil moisture (5), soil structure (10) and decomposition level of peat soils (12)) are adopted from the German Soil Survey Guidelines. The other parts contain analytical methods for field-measurements of the following parameters: water infiltration rate (7), water and air permeability (8 & 9), carbonates, sulfides, pH-value and iron(II)-ions (13). This German standard is often used in international soil studies and can be a helpful supplement for general soil descriptions in the field by **ISO 25177:2008**.

Guidelines Soil Assessment („Arbeitsanleitung neues Feldschätzungsbuch: Bodenschätzung", Bundesministerium der Finanzen, 1996) ★

Soil assessment (*"Bodenschätzung"*) is the basis for the taxation of arable land in Germany. Soil mapping according to these guidelines is required by law and organized by the German fiscal authorities. Mapping is realized by the description of soil profiles with 1 m depth at intervals of 50 m, resulting in large scale soil information. The guidelines provide a soil taxation framework for field assessments ("*Bewertungsrahmen*") which combines soil type, soil condition/development and the parent material of which the soil is composed. Soil investigation which is following this standard, results in a soil value ("*Bodenwertzahl*"). It expresses the relative net income that, under normal and proper management, is determined only by the profitability of the soil. It is the basis for taxation of every plot used as crop- or grassland.

FAO Guidelines for Soil Description (FAO, 2006) ★

The FAO guidelines provide a complete procedure for soil description and for collecting field data necessary for classification according to second edition of the World Reference Base for Soil Resources (IUSS Working Group WRB, 2006). Notes for classification purposes are added to each chapter and explain the relevance of the described feature for classification according to the WRB.

ISO 25177:2008 Soil Quality – Field Soil Description ★

ISO 25177 traditionally was based on the FAO Guidelines, but was removed from it during the last editions. A current revision process aims at amalgamating the soil scientific soil description with the geotechnical soil description (**ISO 14688**).

This international standard provides rules for describing soil in the field and its environmental context at a given site. Sites may be natural, near natural, urban or industrial. Soil observations can be made on various levels (project site, plot, layer, horizon, specific soil constituents). ISO 25177 can also be used to describe non-soil layers, e.g. artificial material and coarse material. The standard addresses various research fields, e.g. soil science, geotechnical examinations, and investigation on soil contamination. Depending on the specific objective, ISO 25177 can be used in combination with other standards that provide guidelines or requirements for specific aspects of soil observation and measurements. Several parameters are mentioned that have to be observed for soil investigation and partially corresponding code lists are provided (Appendix, Table 10).

DIN 4220:2008-11 - Pedologic Site Assessment - Designation, Classification and Deduction of Soil Parameters ★

This German standard provides guidelines with several code lists, based on the German Soil Survey Guidelines, for pedologic site assessment in various fields, e.g. agriculture, forestry or water economy. It defines rules for procedures of soil survey in the field, classification and deduction of pedologic parameters.

DIN 19706, DIN 19707, and **DIN 19708 Soil erosion risk and nutrient supply**

National standards provide guidelines and determination keys to quantify the risk of soil erosion by water (DIN 19708:2017) and wind (DIN 19706:2013) and the nutrient supply of a soil site (DIN 19707:2004).

Conflicts and solutions (transformation and derivation tools)

National:

The Soil Survey Guidelines in its 5th edition (KA5) is currently the valid basis for soil description in Germany. However, some administrative soil surveys of the federal states use modifications of these guidelines. Even prior editions of 1994 (KA4) and 1982 (KA3) are still applied. Harmonization of data acquired according to different editions of KA can be realized by the use of a transformation tool developed by the Federal Institute for Geosciences and Natural Resources BGR (see Chapter 0).
DIN 4220 is based on KA5, but deviates in some detail and in particular regarding some site assessment parameters. DIN 4220 is often applied in the context of geotechnical investigation. KA5 has a more expanded scope of application and community of users than DIN 4220. Thus, DIN 4220 as a national standard for soil description in the field has less importance than the German Soil Survey Guidelines.

The substrate classification of soil assessment deviates clearly from that given in the German Soil Survey Guidelines. Mineral soil types are determined by the fractions of sand, loam and clay. Silt is not represented as a grain fraction, contrary to other established substrate classification systems, so that comparison with other soil data is difficult. However, soil assessment data are valuable for various soil scientific issues regarding their high spatial resolution (scale 1:5.000) and comprehensive availability for agricultural area (see Transformation tool for Soil Assessment data, Chapter 2.3).

The German version of ISO 25177 is not intended to compete with the German Soil Survey Guidelines or with its deducted standards (e.g. DIN 4220) nor to replace them. It rather should facilitate soil survey work abroad, especially in Europe. In principle, soil description is feasible according to ISO 25177 also for soils occurring in Germany. But for most national purposes the application of the German Soil Survey Guidelines is recommended or even mandatory, according to national law.

Table 1: Selected national standards in the field of soil description and classification

Standard	**Contents**
***Germany**: 2. bundesweite Bodenzustandserhebung Wald (BZE Wald II, Arbeitsanleitung), (Wellbrock, 2006)*	investigation of state and changes of forest soils, vegetation, treetops and forest nutrition at about 2000 sites
***Germany**: Forstliche Standortsaufnahme. (Arbeitskreis Standortkartierung, 2016)*	national standard in the field of forest site survey, suited for functional use in the field, mentions federal state-specific differences
USA*: USDA-NRCS Field Book for Describing and Sampling Soils and US Soil Taxonomy (Schoeneberger et al. 2012)*	summarizes the present science and type of describing and documenting soils and soilscapes in the USA. Intended to be used by professionals who describe soils for various purposes, includes key descriptors, conventions, and concepts from soil science and geomorphology, support for understanding soil descriptions and data of soil surveys and soil scientific research
***UK**: English and Welsh Soil Survey Field Handbook (Hodgson, 1997)*	technical guidelines for describing soil profiles
***France**: Guide pour la description des sols (Baize and Jabiol 1995)*	description of soils and their environment, one part deals with interpretation of soil observations in terms of e.g. pedogenesis and soil. The classic French soil classification system (Classification des sols, Commission de Pédologie et de Cartographie des Sols CPCS 1967) seems to be still in use, in particular in tropical and subtropical areas with French colonization history
***France**: Référentiel Pédologique. (Baize and Girard 2009)*	soil classification of the reference system type that is applicable world-wide. In contrast to WRB, the system is open, i.e. classes can be added if the user may them deem necessary
***Australia**: Soil and Land Survey Field Handbook. (National Committee for Soil and Terrain, 2009)*	follows a more landscape-oriented approach with extensive parts on landform, vegetation and land surface description. Includes short substrate classification, the soil description part resembles the English & Welsh handbook

International:

There are significant differences between WRB and German soil classification. Main criteria for the latter are type and vertical order of genetic horizons in soil profiles. In contrast the WRB system uses diagnostic horizons, features and materials that are described independently from each other. The WRB nomenclature of soil types is based on 32 Reference Soil Groups (RSG) with principal and supplementary qualifiers. A simple translation of the German soil name into the WRB name is not feasible for a wide range of soil types due to the deviant approaches. Moreover, WRB uses analytical parameters for classification, which are either not available for many soil profiles in Germany or are analyzed with different methods than those intended by WRB.

1.2 Soil Sampling

Overview of existing standards

GlobalSoilMap (Sampling depths) ★★

The GlobalSoilMap initiative of the Digital Soil Mapping Working Group, International Union of Soil Science (IUSS), supports generating and providing standardized soil data for the world. It sets-up an internationally accepted specification for six sampling and modelling depths: 0–5, 5–15, 15–30, 30–60, 60–100, and 100-200 cm.

ISO 18400-1ff series, Soil quality – Sampling ★★

Standardized soil sampling methods used to be described in the ISO 10381 series which has been technically and structurally revised and replaced by the **ISO 18400-1ff** series. ISO 18400 is currently in development and has, in contrast to its precursor, a modular structure. Examples are the framework for a sampling plan (ISO 18400-101:2015), safety aspects (ISO 18400-103:2015) and quality control/assurance (ISO 18400-106:2015).

ISO 15903:2000 - Soil quality - Format for recording soil and site information ★

This standard regulates the format and recording of soil information, including recommendations on sample design and -transport with the aim to "achieve a high degree of harmonization in reporting results".

Further definitions of field sampling methods can be found in the standard group "Geotechnical investigation and testing". Examples are **ISO 22475-1:2006** (Sampling of soil and ground water), **ISO 22476-2:2005** (Sampling by hydraulic hammer), and **ISO 17628:2015** (Determination of thermal conductivity). Besides soil sampling, the sampling of grains, cereals and cereals products is described in **ISO 24333:2009.** German standards for soil sampling are part of the Handbook of Soil Investigation (Handbuch der Bodenuntersuchung, Blume et al., 2016). Selection of sampling locations, sample preparation, treatment and transportation are described in this compilation (see also Chapter 0).

1.3 Laboratory Methods

Soil data users may require basic information, such as pH and bulk density according to well established standard methods in soil science. It is therefore recommended to collect these parameters for each soil sample. The BonaRes Data Centre uses acknowledged coding systems for field- and laboratory methods to enhance methods documentation, data comparability and interoperability.

Overview of existing standards

Soil sample pretreatment for laboratory analysis are defined by **ISO 11464:2006** ★★ and **DIN 19747:2009** ★ . The national standard **DIN 32645:2008-11**★ contains statistical approaches and calibration features for chemical analysis and describes limits of detection and determination under statistical replication conditions. Alternative methods on detection limits and calibration can be found within the international standard **DIN ISO 11843-1ff** series ★★ (see below). In Table 2 important standards for soil quality analysis are listed.

Methods of Soil Analysis (SSSA, 2017), Book Series 5 ★★

The book series is a standard work in the US and collects lab and field methods in soil science within five parts: Physical and Mineralogical Methods, Microbial and Biochemical Properties, Chemical Methods, Physical Methods, and Mineralogical Methods.

Handbook of Soil Investigation (Handbuch der Bodenuntersuchung, Blume et al., 2016) ★★

Loose-leaf collection with relevant standards (12,195 pages, 15 folders, in German) for soil description and investigation as well soil assessment. These standards cover the whole range of soil investigation: selection of sampling locations, sample preparation, treatment and transportation, extraction and fractionation techniques, analytical measurements, and evaluation methods. Many of these standards are enshrined in German legislation. More than 300 standards of the Handbook of Soil investigation are cited in the Federal Soil Protection and Contaminated Sites Ordinance.

Table 2: Recommended soil quality analysis as regulated by national or international standards ★★

Soil quality parameter	**Standard**
air permeability	DIN 19682-9:2011
Al-oxides/hydroxides extraction (oxalate acid)	ISO 12782-3:2012
ammonium	ISO/TS 14256-1:2003, -2:2005
carbon (TOC)	ISO 14235:1998, ISO 10694:1995, EN 15936:2012, DIN 18128:2002
carbonate	ISO 10693:1995, DIN 19682-13:2009
cation exchange capacity (CEC)	ISO 11260:1994
color	DIN 19682-1:2007
compression stress	ISO 17892-5:2014
DNA extraction	ISO 11063:2012
dry bulk density	ISO 11272:1998, ISO 17892-2:2015
dry matter fraction	EN 15934:2012
ecotoxicological characterization	ISO 15799:2003
electrical conductivity	ISO 11265:1994
(trace) element contents (total, dissolution)	ISO 14869-1:2001, -2:2002
(DTPA solution)	ISO 14870:2001
(Aqua Regia extraction)	ISO 11466:1995, ISO 11047:2003
(X-ray fluorescence)	ISO 13196:2013, DIN EN 15309:2007
(ICP-AES -spectroscopy)	ISO 22036:2008
(dilute nitric acid)	ISO 17586:2016
(ammonium nitrate)	ISO 19730:2008
exchangeable acidity	ISO 14254:2001
Fe-oxides/hydroxides extraction/ions	ISO 12782-1:2012, -2:2012, DIN 19682-13:2009
humic substances extraction	ISO 12782-4:2012, -5:2012
hydraulic conductivity	ISO 11275:2004, DIN 19682-8:2012
infiltration rate	DIN 19682-7:2015
microbial abundance and activity	ISO 17155:2012
biomass	ISO 14240-1:2011, -2:2011
diversity	ISO/TS 29843-1:2014, -2:2014
nitrate, nitrite	ISO/TS 14256-1:2003
nitrification (potential)	ISO 15685:2012
nitrogen (mineral, nitrate and ammonium)	DIN 19746:2005
(nitrate, ammonium, solute)	ISO 14255:1998
(total)	ISO 11261:1995, ISO 13878:1998, ISO 25663:1993
nutrient supply condition	DIN 19707:2004
pH	ISO 10390:2005, DIN 19682-13:2009, ASTM-E1910
particle density	ISO 17892-3:2015
Phosphorus	ISO 11263:1996
pore water pressure	ISO 11276:1995
sampling of soil invertebrates	ISO 23611 (1-6)

Table 2 - continued

Soil quality parameter	**Standard**
shear strength	ISO 17892-6:2014
soil structure	DIN 19682-10:2014
soil texture	ISO 11277:1998, ISO 17892-4:2014, DIN 18123:2011, DIN 19682-2:2014, DIN 66115:1983
soil water content/soil moisture	ISO 11461:2001, ISO 17892-1:2014, DIN 18121-2:2012, DIN 19682-5:2007, DIN 19745:2006
Sulfide	DIN 19682-13:2009
sulfur (total)	ISO 15178:2000
thermal conductivity	ISO 17628:2015
water retention	ISO 11274:1998

VDLUFA Method Book "The Investigation of Soils" (Methodenbuch "Die Untersuchung von Böden", VDLUFA, 2016) ★★

Loose-leaf collection with seven supplements (1991-2016) . One of the main issues of VDLUFA (Association of German Agricultural Analytic and Research Institutes) is to establish uniform methods and evaluation principles in agricultural research. The methods book treats analysis on soil quality for agricultural issues, including methods which are not (yet) described in international ISO standards. The methods include sampling, determination of total element contents, characterization of organic matter, and many other soil chemical and physical analyses and field methods (Table 3).

Laboratory Methods for Soil Testing ("Labormethoden-Dokumentation", Utermann et al., 2001) ★

It contains preferred analytical procedures for investigation of the most important soil parameters. This selection was discussed and agreed with the Geological Surveys of the Federal States in Germany. It was designed as a method database containing descriptions of analytical procedures, references to existing standards and method codes that link methods with analytical results in the laboratory database of the Federal Institute for Geosciences and Natural Resources (BGR). Information about the application range of analytical methods, plausibility of analytical results, restrictions, and common sources of errors are given in this documentation of laboratory methods.

Table 3: Recommended soil quality analysis as regulated by the VDLUFA Method Book (VDLUFA, 2016) ★★

Parameter	**Chapter**
Chemical analyses (Section A)	
Ammonium	A 6.1.2, 8.2
boron (plant available)	A 7.1
carbonate (total, demand)	A 5.3, 5.2
CEC (potential)	A 9.1
copper (plant available)	A 7.3
heavy metals, Aqua Regia	A 2.4.3.1
humic substances, extraction, fractionation	A 4.4.2
magnesium (plant available)	A 6.2.4.1
manganese (plant available)	A 7.2
Mercury	A 2.5.1
molybdenum (plant available)	A 7.4
Nickel	A 3.4.1
nitrogen (total), Kjehldahl	A 2.2.1
nitrogen (plant available) nitrate, mineral-bound	A 6.1.1, 6.1.4.1
pH	A 5.1.1
phosphorus (total)	A 2.4.2.1,
phosphorus (plant available)	A 6.2.1.1, 6.2.1.2, 6.2.3.1
potassium (total)	A 8.1
potassium (plant available)	A 6.2.1.2, 6.2.1.7
radio nuclides	A 12.2
Salinity	A 10.1.1
sodium (plant available)	A 6.2.5
soil organic matter (total)	A 4.1
strontium (^{90}Sr)	A 12.1
sulfur (plant available)	A 6.3.1
zinc (plant available)	A 7.5
Physical analyses (Section C)	
bulk density	C 1.3
compression stress	C 7.3
load capacity	C 7.4
permeability air/water	C 6.1 / 5.11
pore size distribution	C 4.3
sediment density	C 1.2
soil texture	C 2.2
soil water content	C 1.1

Handbook of Forestal Analytics (Handbuch Forstliche Analytik, HFA), GAFA (2005, suppl.1–5, 2014)

Loose-leaf collection with 5 supplements containing harmonized analytical methods for the resources soil/humus, plant and water in forest context, starting from sample preparation up to determination of physical and chemical parameters. Moreover the handbook provides a customized method coding system that was developed in order to enable complex documentation of analytical methods in a database and to make them evaluable and interoperable. Analytical methods and method codification are applied for the National Forest Soil Inventory in Germany and for Environmental monitoring in Europe. Several methods are based on accepted national and international standards (DIN, EN, ISO), which is tagged in the handbook. If there are deviations from certain standards, these are marked as well.

Conflicts and solutions

Soil analytical methods which are described within VDLUFA Method Book are considered to be national standards. In Germany the VDLUFA Method Books for soil analyses are established as standard field and lab methods for soil quality analyses on national scale and compete with existing other national standards and ISO standards. Numerous soil analytical laboratories in Germany use these methods for a long time to ensure comparability of national data. However national standards may complicate data transfer to international data bases and reduce comparability of data sets in international contexts.

The future challenge will be to develop transfer procedures for soil quality methods and results within different countries. The establishment of an international IT-infrastructure on soil and agricultural data could be an important step on this process.

The BonaRes Data Centre gives support to find and use derivation tools (if any exist) to transfer data that was acquired according to national standards into international standards (see Chapter 2.3).

1.4 Soil Management

The regulation of soil management is less ruled by ISO standards but more by laws, policies, commitments, and recommendations. However, most soil management practices strongly depend on local soil characteristics and changing biological and physico-chemical conditions as well as variable meteorological phases. In this context, flexible management activities by farmers including a frame for open regulations are provided by lawmakers and agricultural agencies.

Overview of existing standards

Association for Technologies and Structures in Agriculture (KTBL), Germany

The handbook „Operation Planning Agriculture 2014/15“★★ (KTBL, 2014) provides methodical information on soil management questions. For soil management sequences, key parameters for economic success and costs per unit agricultural products are listed. The Pocket Book Agriculture (KTBL, 2015) provides, beside others, information on agricultural machines, prices for services and machines, and fertilizers, in numerous tables. Soil tillage tools and cropping systems in national contexts are provided. For example, no-till and non-turning cultivation are described in the “Definition of Soil Tillage and Management Systems”.

Good Agricultural Practice (GAP) ★★

GAP for soil management are national and international commitments and principles to reduce soil erosion and prevent soil functions such as soil fertility as a contribution to assure food security (FAO, 2003). GAP was implemented in numerous national and international agricultural policies and laws.

ICASA Data Standards for Agricultural Field Experiments and Production (Version 2.0, 2013) ★

Published by the International Consortium for Agricultural System Applications (ICASA), it was set-up for documenting agricultural field experiments and modeling crop growth and development. It is used in the tool of the Decision Support System for Agrotechnology Transfer (DSSAT). The format of the data standard is XML and was assessed by the FAO (White et al., 2013).

NRSC (Natural Resources Conservation Service) ★

This service provides numerous technical guidelines and conservation practice standards for soil and water conservation in agriculture. Examples are Terraces (Code 600), Grassed Waterways (Code 412), and No-Till

Common Agricultural Policy (CAP)

This EU-Policy was established in 1992 and revised in 2013. Today the key objectives of the CAP are an enhanced competiveness, an improved sustainability and greater effectiveness of the agricultural sector in Europe. Since 2015 crop diversification rules, the maintenance of permanent grassland and areas set apart for ecological purposes are integrated in the first pillar of the agricultural policy as obligatory measures.

Federal Soil Protection Act (BBodSchG, 1998) and the Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV, 1999), Germany

This law and regulation set general legal requirements for agriculture and soil management to tackle degradation threats to soil, e.g. for weather- and site adapted tillage operations. Both, the BBodSchG and BBodSchV do not go into detail but are frameworks for more detailed policies.

WOCAT (World Overview of Conservation Approaches and Technologies)

WOCAT is a global network. It supports decision-making processes for best management practices and sustainable land management and aims to unite the efforts in knowledge management and decision support for up-scaling sustainable land management among the different stakeholders.

Soil Protection Review, UK

The review was introduced in 2010 as part of the Good Agricultural and Environmental Conditions (GAEC 2010). The rule aims to maintain soil structure and organic matter and to prevent soil erosion and compaction.

Further regulations

Numerous laws and standards are defined by organizations and can be found in national and international records, e.g. for the US standard ASAE ASABE S578 provide rules for yield monitoring. Responsible for agricultural standards are e.g. the United States Department of Agriculture-National Agricultural Library (USDA-NAL), and in international contexts the FAO (AIMS, Agricultural Information Management Standards).

Conflicts and solutions

Some LTFE in Germany were set-up within the former German Democratic Republic (GDR). In the GDR, so called *"TGL standards"* were applied for agricultural field experiments such as plant production (TGL 21168/12), experiment design (TGL 21168/02) and physical soil analysis (TGL 31222/01). Although TGL standards have expired in 1990, most legacy data from LTFE in the former GDR were acquired by these standards. Even though these standards have expired, their former applications must be documented as metadata.

1.5 Agricultural Tools and Machineries

Standards for tractors and machineries in agriculture are developed by the ISO/TC 23. Numerous tillage tools for sowing preparation and soil loosening equipment are defined in rulebooks and standards.

Overview of existing standards

In Table 4 the most important national and international standards on agricultural tools and machineries are compiled.

Table 4: Recommended standards for tillage tools and agricultural machines★★

Content	**Standard**
Tools and Equipment	
Cultivator Blades (fixing dimensions)	ISO 8945:1989
Cultivator Tines and Shovels (fixing dimensions)	ISO 5680:1979
Disks	ISO 5679:1979
Harvester	DIN 11389:1988
Hoe blades	ISO 4197:1989
Pesticides and herbicides (granulated, equipment) *(spraying)*	ISO 8524:1984 ISO 5682-1:1996
Plough	ISO 8910:1993
S-tines	ISO 8947:1993 ISO 5678:1993
Seed drills	ISO 7256 (1-2)
Shallow tillage (dimensions, attachment points)	ISO 6880:1983
Sowing and planting (equipment)	ISO 17962:2015 ISO 4002 (1-2)
Sprayers	ISO 10627-2:1996
Turf and seeding	DIN 18917:2002

Table 4 - continued

Content	**Standard**
Machines	
Machines, self-propelled - assessment of stability	ISO 16231:2013 (1-2)
Machines, safety (-6 sprayer, -9 seed drills, -10 rotary tedders, -12 rotary disc)	ISO 4254 (1-12)
Machines operations	VDI 6101:2014
Tractors, mounted rotary cultivators, motor hoes drive wheel	EN 709:1997
Tractors, rear-mounted power take-off types	ISO 500:2014-1
Tractors, remote control hydr. cylinders for trailed implements	ISO 2057:1981
Tractors, connection via three-point linkage	ISO 2332:2009 ISO 730:2009
Tractors, operators manual	ISO 3600:2015
Tractors, safety	ISO 26322-1:2008
Tractor-mounted sensor interface – specifications	ISO 11786:1995
Tractors, track widths	ISO 4004:1983
Tyres (general): definition of terms	ISO 4223-1:2017
Tyres (agricultural): dimensions (-1) load ratings (-2) *dimensions and designation* *dimensions, load ratings and reference speeds*	ISO/DIS 4251:2013 ISO 7867-1:2005 ISO/DIS 8664:2017(E)
Wheels and tyres, radial construction *measuring conditions*	DIN 7807:1995 DIN 70020-5:1986
Wheels and castors, test methods	EN 12527:1998
Weigh-in-Motion of road vehicles	DIN 8113:2009
Working width (sawing, planting, fertilizing)	ISO 6720:1989

1.6 Field Crops, Fertilization and Plant Protection

Field crops and agricultural activities, such as pest management and fertilization, are often regulated in directives and method books, rather than in ISO standards. Specific code lists are given in the Appendix (Chapter 4.1).

Overview of existing standards

Crop varieties (Bundessortenamt 2015) ★★

The Federal Plant Variety Office (BSA) provides descriptive variety lists e.g. for cereals, maize, oil and fiber plants (Bundessortenamt, 2015). The BSA frequently sends variety names and codes to the International Union for the Protection of New Varieties of Plants (UPOV).

Directive for agricultural value analyses and variety trials (Bundessortenamt, 2000) ★★

In Germany several professional, rating methods ("*Boniturmethoden*") exist. Beside rating ("*Bonitur*") different field crops it additionally provides recommendations on sowing dates, amounts and periods and densities, plant maintenance, fertilization, and soil and plant sampling for lab analyses. The State Offices of Germany regularly published recommendations for numerous agricultural products, e.g. maize, pasture grass and soy beans.

EU Regulation No. 2003/2003 (European Parliament and of the Council relating to fertilizers) ★★

The regulation treats all issues which are connected with fertilizers. In Annex IV numerous methods of samplings and laboratory analysis of fertilizers are given.

European Plant Protection Organization (EPPO) ★★

The EPPO provides numerous free available code lists and standards and guidelines on pest risk, plant protection products, risk assessment and diagnostic.

VDLUFA Method Books, manure and fertilizing regulations ★★

Similar to soil management, crops, crop protection and fertilizing are predominantly regulated by national directives. While the legal fertilizing regulation in Germany (DüV, Bundesministerium der Justiz und für Verbraucherschutz, 2006) only treats nitrogen and phosphorus, VDLUFA Method Books volumes II.1 and II.2 (VDLUFA, 2016) deal with all other relevant soil nutrients.

Cross-compliance (Council of the European Union, 2009)

Cross-compliance mechanisms link payments to farmers with requirements on plant, animal and soil protection.

Water Framework Directive (Council of the European Union, 2000)

The directive addresses, beside others, the water pollution by nitrates from agriculture, and is thus a legal framework for agricultural activities on crop protection and fertilization.

Plant Protection Act, Germany

It regulates the protection of field crops and agricultural products against harmful organisms and the prevention of health damages for plants, animals, natural systems and humans from the agriculture (Bundesministeriums der Justiz und für Verbraucherschutz, 2012).

Further standards★★

- For the investigation of the yield structure the determination of the mass of 1000 grains is a common approach, which is defined in **EN ISO 520:2010**.
- The determination mass per hectoliter (bulk density or "*Schüttdichte*") of grain is described in **ISO 7971-1ff series**.
- The determination of components of grain which does not belong to the good cultivated grain (="*Besatz*") is regulated in **DIN EN 15587:2014**.
- **DIN 18916:2016-06** regulates activities on agricultural plant and soil works including mulch (which inhibits evapotranspiration) and measures against wildlife.
- **VDI 3957-1:2014** describes biomonitoring as a method to determine and assess air pollutants effects on plants.
- Seed saving, reproduction and certification ("*Saatgut Nachbau und Zertifizierung*").

1.7 Accompanying Disciplines

Beside soil and agricultural data, accompanying data from different research fields concern the BonaRes Program.

Overview of existing standards

Land use classification

- The **CORINE Land Cover** ★★ provides an EU-wide unique and comparable data set of land cover with 44 land use classes, out of which 37 classes are relevant for Germany. Mapping of the land cover and land use was performed on the basis of satellite remote sensing images on a scale of 1:100.000.
- The German land survey authorities provide topographic data and maps. Their contents are reported in the feature type catalogue of the Official Topographical Cartographic Information System (**ATKIS**)★★ , where topographical appearances are classified in categories with land use information. ATKIS data are available in different scales (from 1:1.000.000 up to 1:25.000). Because of the higher spatial resolution, compared to e.g. CORINE Land Cover, the feature type's catalogue comprises more land use classes (around 130 feature types).

Meteorology

Meteorological raw-data are often available in time series with different temporal distributions. The conversion into convertible data and the supply for further processing is challenging.

- The German **DIN 1319-1:1995-01ff** ★★ series defines basics in meteorological measurement techniques e.g. terms of measuring equipment (Parts 1 and 2) and measurement uncertainties (3 and 4).
- On international scale the **EN ISO 20988:2007** ★★ provides a detailed guideline to estimate measurement uncertainties for meteorological data. It includes statistical operations on systematic data deviations, calibration, ring trials, drift controls, and evaluation on variances. In particular the standard helps to evaluate and validate air quality data.
- **ISO 9169:2006** ★★ defines the performance characteristics of an automatic meteorological system.
- Meteorological measurements are described in guidelines **VDI 3786ff** including an extensive glossary and instructions on data aggregation for archiving (1) and air temperature (3).

Vegetation

- Phenology stages can be described by the BBCH★★ scale (Meier et al., 2009). The coding system was first published in 1992 by different expert groups and was than extended to all common crop types.
- The Minimum Information standard MIAPPE★★ is open and community driven. It defines a list of necessary attributes to describe and to harmonize data from plant phenotyping experiments.
- The Braun-Blanquet-Scale ★★ , as part of the Relevé Method, defines approaches of vegetation survey.

1.8 Business and Personal Data

There are different types of data describing characteristics of farming businesses and actors involved in agricultural activities (e.g. farmers and other land users, planners of land use, representatives of interest groups, politicians in the agricultural sector, and consumers of agricultural products). These types of data include surveys, official and other statistics, interviews, workshops with experts' judgements, focus groups, and other. They can be provided in different forms such as text, numbers, audios, or videos. The data can be distinguished between different statuses, i.e., raw data, result data, and syntax data. Thus, standards vary over different data types and statuses.

This chapter focus on standards for raw data from surveys, statistical analysis and interviews as the most common data collected, evaluated and delivered in the BonaRes project.

Overview of existing standards

Certification and labels for organic farming (Council of the European Union, 2007)

In the European Union the Council Regulation No 824/2007 on organic production aims to ensure an "effective functioning of the internal market, guaranteeing fair competition", and "protecting consumer interests". It lists rules e.g. for livestock production, fertility management and soil protection.

Demographic Standards 2010

This is a collection of Quality Reports about methods, definitions and standards for statistical information, including anonymization, table design, classification of professions, demographic standards, and macro and micro data statistics.

Joint recommendation by ADM and the German Federal Statistical Office provide survey versions. GESIS provides the **ZIS Version 14.00**, 2010, which is a collection of social science items and scales.

Education, status and prestige

- ISCED-International Standard Classification of Education by the UNESCO (1997/2011):
- SIOPS/ISEI/EGP Occupational Status (Ganzeboom and Treiman, 2003)
- ESeC – European socio-economic classification (User Guide)
- KldB – Classification of occupational status in Germany (Federal Labor Office 2010)

More information about statistical data, DESTATIS, in German

- Classification of professions, thesaurus (LINK)
- Statistical reporting, macro and micro data (LINK)
- Table design (LINK)
- Anonymization (LINK 1, LINK 2)

Guidelines for focus groups:

- Guideline for conducting a focus group (2005)
- AIMRO (Association of Irish Market Research Organizations, 2009)
- Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups (Tong et al. 2007)

Table 5: Standards and guidelines for methodological approaches ★★

Content	**Standard**
Bio-based products - Life cycle assessment	EN 16760:2015
Environmental labels and declarations - Self-declared environmental claims (Type II environmental labelling)	EN ISO 14021:2016
Environmental management - Eco-efficiency assessment of product systems- Principles, requirements and guidelines	EN ISO 14045:2012
Environmental management - Environmental communication- Guidelines & Examples	EN ISO 14063:2006
Environmental management - Environmental performance evaluation - Guidelines	EN ISO 14031:2013
Environmental management - Life cycle assessment- Illustrative examples on how to apply EN ISO 14044 to impact assessment situations	ISO/TR 14047:2012
Environmental management - Life cycle assessment- Requirements & Guidelines (refers to the environmental aspects and potential environmental impacts e.g. resource use and impact of emissions over the product life cycle from raw material acquisition through production, use, waste treatment, recycling to final disposal)	EN ISO 14044:2006
Environmental management - Life cycle assessment- Principles & Framework	EN ISO 14040:2006
Evaluation of sustainability	VDI 4605:2016-02
Guidance on social responsibility	ISO 26000:2010
Resource efficiency - Methodical principles and strategies and - Raw Materials	VDI 4800-1:2016 VDI 4800-2:2016
Stakeholder Engagement - Guidelines for decision making processes dealing with climate change (REGKLAM project)	DIN SPEC 35810:2014
Sustainable management in small and medium-sized enterprises - Guidance notes for sustainable management	VDI 4070-1:2016
Sustainability criteria for bioenergy	ISO 13065:2015

Further Guidelines

- ecoinvent provides high quality environmental assessment, life cycle assessment and product chains in database
- Guideline Foresight (JRC)
- Sustainability Reporting Guidelines: GRI (Global Reporting Initiative)
- EC 2015: Better Regulations Guidelines e.g. on impact assessment

2 Data Management

The topic *data management* includes methodical standards to structure and quality assure research data as recorded by standardized methods. Quality by supervised or unsupervised procedures e.g. data completeness, normal distribution, integrity, and removal of outliers, is prerequisite for well-maintained data storage, -exchange, -processing and -evaluation. Descriptive data should be checked on misspellings, synonyms and inconsistencies to enable clear data allocation and combination of different data sets.

When research data are collected, tested, described, and maybe pre-processed (e.g. pedotransfer-functions, biological models, upscaling) data must be technically prepared to be transferred into the data base. At this point internal data base management becomes relevant. Data (base) management includes e.g. rules on the data structure, languages and formats used. These need to meet the requirements on later data applications such as archiving, evaluation, re-use, and publishing. An example for national agricultural data management is the PIAF system (**P**lanning, **I**nformation and **A**nalysis for **F**ield trials). Internationally accepted Data Management Plans (DMP) may help to plan, manage and publish research data. Tools and guidelines are provided by open access platforms such as ReDBox (Australia) and OpenAIRE (EU - Funding Program Horizon 2020). The CGIAR provides different tools to capturing data and managing experiment and agricultural data e.g. via Field Book Registry.

This chapter provides an overview of standards with general requirements on data quality, -structure and -formats, and -types, as well as geographic reference systems, units and dimensions.

2.1 General Conventions

Overview of existing standards

In Table 6 (following page) an overview lists recommended standards with general and geographic data conventions and requirements e.g. on geographic reference systems, units and dimensions.

EN ISO 19156:2013

This standard defines a conceptual schema for observations and features involved in sampling. It is used in INSPIRE and provides models for the exchange of information describing observation acts and their results, both within and between different scientific and technical communities. A common set of sampling feature types is defined that is classified primarily by topological dimension, as well as samples for ex-situ observations. The schema includes relationships between sampling features (sub-sampling, derived samples).

Table 6: Recommended data conventions (Standard for general and geographic data) ★★

Content	Standard
Data General	
Alphabet (Latin) -8-bit single-byte coded graphic character set	ISO/IEC 8859-1:1998
ASCII (American Standard Code for Information Interchange), 7-bit	ISO/IEC 646:1991
Country codes, Region codes	ISO 3166-1:2013 and ISO 3166-2:2013
Dates and times representation (interchange formats)	ISO 8601:2004
Languages	E DIN 2335:2014
Meteorological parameter e.g. air pressure (kPa), relative humidity (%) and wind velocity (m/s)	ISO 4226:2007
SI-units, Unit names, Unit symbols	EN ISO 80000-1:2013 DIN 1301-1:2010 DIN 1313:1998
Territorial units	NUTS (EUROSTAT statistics)
Universal coded character set	ISO/IEC 10646:2014
Geographic Data	
Application schema (rules)	ISO/DIS 19109:2013
Conformance	EN ISO 19105:2005
Coverage standards	EN ISO 19123:2007
Data product specifications	EN ISO 19131:2008
Encoding	EN ISO 19118:2011
Feature cataloguing	ISO/DIS 19110:2013
Filter encoding	EN ISO 19143:2012
Imagery and Gridded data	ISO/TR 19121:2000
Item Registration	EN ISO 19135:2015
Observation and measurements	EN ISO 19156:2013
Point location by coordinates	EN ISO 6709:2009
Positioning service	EN ISO 19116:2006
Profiles	EN ISO 19106:2006
Reference Model and System	EN ISO 19101-1:2014 DIN 18709-6:2016
Simple Feature Access	EN ISO 19125-2:2006
Spatial referencing by coordinates (geodetic reference systems) (ISO 19111)	WGS84 ETRS89 GRS80
Spatial referencing by geographic identifier	EN ISO 19112:2005
Spatial schema	EN ISO 19107:2005
Temporal schema	EN ISO 19108:2005

2.2 Data Quality and Statistics

In this chapter quality assurance is provided by standardized methods of data acquisition, e.g. in laboratories, processing, and management. Data bases with scientific data should provide statements on data quality features. Data base clients, in particular modeler, need to get information on the quality level of a data set and information on completeness and consistency. Therefore, quality checks should be carried out when research data are uploaded to the data base.

Helpful features of data quality analysis are (automated) validation and statistical data checks. Workflows including statistical test algorithms, accuracy of estimation, number of replication, outlier test, Gaussian normal distribution, and peakedness (single or multiple), data gaps, systematic errors, syntactical checks, data integrity, and data plausibility are relevant for data quality evaluation and systematic data error identification. Data assessment needs also additional information on the quality criteria of the data set.

Overview of existing standards

EN ISO 19157:2013 - Data quality ★★

Information about the quality of available geo-data is vital to the process of selecting a data set because the value of data is directly related to its quality. ISO 19157 provides:

- a classification schema for data quality and data errors, which are categorized into different elements, depending on their nature,
- principles how geo-data can be described and guidance on assessing the quality of actual datasets, and
- a framework of procedures for determining and evaluating data quality that is applicable to digital geographic datasets.

Core Trust Seal ★★

Best practices for high data quality and interoperability for data repositories are given by the “Core trustworthy data repository requirements”. A checklist with mandatory repository requirements helps to proof the data repository if it fulfills all the necessary quality standards. Repository operator can apply for the Core Trust Seal via an Application Management Tool (AMT).

DIN ISO 11843-1:2004ff series - Capability of detection ★★

This norm has five parts including terms (1), linear calibration of data (2), determination of the critical value for the response variable (3), comparing the minimum detectable value with a given value (4) and linear and non-linear calibration cases (5).

ISO 3534-1/-2:2006 Statistics and terms ★★

Define statistical terms and terms used in probability. They provide also rules on probability calculations, random sampling, correlations, and estimation functions.

National standards on data quality and statistics

DIN 66270:1998 - Software document evaluation, Quality characteristics ★★

The German standard defines requirements of documents according to its identification, content (completeness, adequacy, correctness, and consistency), and representation (comprehensibility and clarity).

Table 7: National standards on statistic evaluation and tests ★

Content	**Standard**
Methods for the examination of water, waste water and sludge (describes statistical data evaluation and treatments)	DIN 38402-1:2011-09
Stochastics, probability theory, concepts, signs, terms, symbols, formula	DIN 13303-1:1982, -2:1982
Chemical analysis – Decision limit, detection limit and determination limit under repeatability conditions – Terms, methods, evaluation	DIN 32645:2008-11
Limit of detection and limit of determination (quantitation) as processing parameters. Estimation in an interlaboratory test under reproducibility conditions; Terms, meaning, proceeding (are used for statistical evaluation of chemical analysis. Define e.g. detection limits under repeatability conditions)	DIN 32646:2003
Statistical evaluation (provides continuous features e.g. frequency distributions, random sample, frequency distribution, tests on normal distribution, and outlier)	DIN 53804-1:2002-04

Quality management system and Measurement management systems

The quality management system (QMS) is closely coupled to **ISO 9000ff** and **ISO 10000ff** series (e.g. EN ISO 9000:2015, 9001:2015, 9004:2009, ISO 10005:2005, 10006:2003) and **DIN 55350-100:2017** which are mainly focusing on the management aspect to achieve costumer's satisfaction. The **DIN 55350** series describes concepts and definitions in quality and statistics. Examples are:

EN ISO 9001:2015 contains the general requirements for the competence to carry out tests and / or calibrations, including sampling. It refers to tests and calibrations that are based on specified in normative documents methods of methods that are not defined in normative documents, and those that were developed in the laboratory (ISO/IEC 17025:2005). ISO 9001 specifies requirements for a QMS.

EN ISO 9004:2009 gives guidance on a wider range of objectives of a QMS, for long-term success and improved performance. These standards can be applied to support organizations to develop a coherent quality management system. Guidelines for technical subjects in support of QMS are provided by e.g. ISO 10005, 10006, 10007, 10014, and 19011.

EN ISO 10012:2003 defines measurement processes and emphasizes the requirement of suitable equipment for an effective measurement management system. It aims to control risks of wrong data and results. Other management systems are given in the EN ISO 14001ff (Environmental management systems) and EN ISO 50001 (Energy management system).

2.3 Data Transformation

A data transformation is the process of reorganizing or restructuring data from the source format into destination data format in order to enhance data usability. When data are obtained by national standard methods or classified by national systems they may need to be transferred into international classification systems. Gaps in data-sets could preclude the direct use within models and thus require gap-filling methods.

Overview of existing standards and tools

Transformation tool for the 5th edition of the German Soil Survey Guidelines (KA5) ★★

The revision of the German Soil Survey Guidelines resulted in a modified data encoding and classification of soils. For the transformation of soil data from a previous towards the following edition of the German Soil Survey Guidelines a software tool has been developed by the Federal Institute for Geosciences and Natural Resources (BGR) in cooperation with the Geological Surveys of the German federal states. It enables the translation of horizon symbols and derivation of soil systematic units based on the horizon data, as well as translation of substrate types and substrate systematic units. This software tool is available for the transformation of data recorded according to the 3rd edition of the German Soil Survey Guideline (KA3) towards its 4th edition (KA4) and KA4 towards KA5. The function for derivation of soil systematic units according to the German soil classification is only implemented in the last-mentioned version (KA4/KA5). A free download for both versions is provided on the homepage of BGR.

Conformity key for KA5 ★★

BGR developed a quality assurance tool for soil data according to the KA5. With this database application users can check their soil data for conformity according to the rules of the KA5. Complex algorithms test soil and substrate types as well as horizon symbols. The enumeration of horizons and depth information is tested for validity, and missing profile or horizon datasets are identified. Correction of errors can be performed by the user and KA5-compliant data can be exported. This application helps to improve data quality of either newly acquired data or already existing databases.

Derivation tool - KA5 (2005) to WRB (2007) ★★

The BGR devised a software tool to derivate international common soil notations (WRB 2006, update 2007) from soil data, which were acquired according to the German Soil Survey Guidelines. However, criteria for the determination of distinct diagnostic and naming elements of the WRB classification system are very complex. For each of these elements a graphic algorithm has been developed that refers directly to parameters of the KA5-nomenclature and selective laboratory values. Feasible input data (arrays of KA5- and laboratory parameters) are interrogated in order of decreasing reliability. If less appropriate arrays have to be used for derivation of WRB-names, this is documented in a report for the user in order to prove the results' quality. The application is currently in further development: The next edition is aimed to derive soil notation according to WRB 2014, update 2015.

Transformation tool for Soil Assessment data

A software tool for the transformation of Soil Assessment data ("*Bodenschaetzungsdaten*") into the nomenclature of the German Soil Survey Guidelines (4th edition) has been developed by the Geological Survey of Lower Saxony (LBEG). It is also used by some other federal states. This software tool enables transformation of certain soil features (substrate type, soil color, humus content) into KA4-nomenclature. Horizon symbols and soil types are derived on basis of the transformed features. For further information see Bartsch et al. (2003), Engel and Mithöfer (2003) and (Hangen and Förster, 2013).

Other transfer functions

- a taxotransfer scheme allows to estimate missing soil properties based on taxon information (Batjes, 2016). Such a tool was developed for the SOTER database and is used to fill gaps by a defined procedure (Batjes, 2003).
- numerous pedotransfer functions (PTFs) using basic soil properties such as pH, texture and/or bulk density to model non-measured soil properties or soil functions. Van Looy et al. (2017) evaluate PTFs and outline perspectives for their development and applications

2.4 Data Exchange and Formats

Overview of existing standards

OGC standards ★★

The Open Geospatial Consortium (OGC) develops open standards for different stages of geo-data management within a consensus process. All OGC standards are based on XML language.

- **GML** (Geography Markup Language, EN ISO 19136:2009) is a XML grammar developed to express geographic features. GML is not only an open exchange format for geographic transactions on the internet, it also serves as a modeling language for geographic systems. The conceptual modelling framework of GML includes spatial and non-spatial properties of geographic features. A GML document is described using a GML schema. This enables the user to describe generic geographic data sets. Specialized extensions of GML are developed to provide community-specific application schemas in order to facilitate data exchange in a certain subject. The current version GML 3.3 was published in 2012 and extends the previous version with additional schema components and requirements.
- **KML** (Key Markup Language) is a XML grammar developed to express geo-objects in vector or raster graphics. Today it is often used to visualize geo-data in Google Earth.
- **Observations and Measurements – XML Implementation** This standard specifies an XML implementation for the OGC and ISO Observations and Measurements conceptual model. The XML schemas defined in this standard are specified for observations and for features involved in sampling when making observations. Aim is to enable exchange of information describing observation activities and their results within and between scientific and technical communities.
- **WaterML** is a standard information model for representation and exchange of hydrological observation data. It aims to serve as an interoperable exchange format for transport of data sets across information systems. The current version WaterML2.0 is implemented as an application schema of GML 3.2.1 by the use if the OGC Observation & Measurement standards.
- **Sensor Observation Service (SOS)** defines a web service interface to query sensor data including time series, sensor descriptions and encoding format

XMI (XML Metadata Interchange, OMG) ★★

XMI enables the metadata information exchange between software development tools. Based on XML-format, data can easily be produced, processed, stored and exchanged via internet.

GeoSciML ★★

Data transfer standard for geological data. GeoSciML is XML based and provides solution for the exchange of geoscientific information, e.g. features from geological maps.

AgroXML and **ISO-XML** ★★

Communication and data transmission between sensors and tools are indispensable in modern agricultural sector. On international level, the **ISO 11783-1:2007ff** series provides an uniform communication language between agricultural machinery, e.g. operating supplies like fertilizers and pesticides, and office software. Applications and hardware (e.g. standardized plugs) that operate with ISO 11783ff are referred to as "ISOBUS". It focuses on the exchange of mobile and spatial data between both systems. Within this standard the language ISO-XML is defined.

While ISO-XML mainly addresses communication between farm machineries and -orders, the data exchange language AgroXML has also an interface via farm management information systems to external partners. AgroXML was developed by a German consortium of agricultural software providers and industry under the leadership of the KTBL.

To enable consistent frameworks for data standards and the integration of spatial data into web services, both languages be bound for integration into GML specification (Toth and Kucas, 2016).

UML (Unified Modeling Language, ISO/IEC 19501:2005) ★★

UML is the dominant graphical language for object-oriented modeling with a semantic specification, geographic notation, interchange format, and a repository query interface.

ISO 28258:2013 Soil quality - Digital Exchange of soil-related data (SoilML) ★

This standard provides a generic, conceptual schema for soil-related data and the structural framework for the interoperable exchange of individually defined data. It contains a data model (following the rules of Unified Modeling Language UML) with (feature-) types that are generally applicable types with the aim of covering most of the individual, country or data provider specific types. Essential feature types included in the model are, e.g. Plot, Profile, Horizon or Layer. These feature types are defined in a feature catalogue, which is non-extensible. Provider-specific feature types are only allowed to be used, if a taxonomic subtype relationship to at least one of the generic feature types defined in the catalogue is explicitly stated. ISO 28258 encodes soil data using eXtended Markup Language (XML) that is encoded according to the structure given in an XML schema definition file (XSD). The XSD file for SoilML data files is called "*soilml.xsd"*.

Currently ISO 28258 is in revision. An amendment with editorial and conceptual modifications, such as renaming of feature types and improvement of the UML-data model, will be published in 2018.

INSPIRE Data Specification on Soil (INSPIRE Thematic Working Group Soil, 2013)

Providing data according to INSPIRE is a legal obligation to public administration in the European Union. Due to this obligation no explicit recommendation is provided in this report.

INSPIRE is not only about data interoperability, but aims at data harmonization. In the INSPIRE data model real soil objects were designed as feature types, and not features created to represent real objects. Thus soil maps were not introduced in the model (handled as metadata, see following section). The INSPIRE model can be extended regarding the parameters for describing features. Extensible parameter lists and code lists are kept in registries.

The INSPIRE data model differentiates between observed and derived soil profiles. An observed profile is directly linked to a soil plot, whereas a derived soil profile describes a soil body without a connection to a certain plot. Soil-related information can be provided as vector data by using the *SoilDerivedObject* feature type, information structured as raster data is supplied by using the *SoilThemeCoverage*.

SoTerML (Soil and Terrain Markup Language) ★

For the exchange of soil and terrain data between various sources an XML schema was developed within the European FP7 project 'e-SOTER'. It comprises the existing SOTER database conceptual modelling, the WRB and FAO soil data structures and classifications. In SOTER major soil and terrain databases as the European Soil Database (ESD) are covered. The principles of SoTerML are generic, so that they should be applicable to other geo-scientific domains and not only to soil data (Pourabdollah et al., 2012).

GlobalSoilMap

The GlobalSoilMap Specification provides an internationally agreed set of attributes and terminologies for soil data. It is the basis for the generic soil information model GSMML. Global soil map data is published as GSMML compliant data service (Wilson et al., 2014).

Other data formats of accompanying disciplines

Beside soil- and agricultural data, other common data formats are widely used such as:

- The query language *SPARQL* was developed by the RDF Data Access Working Group of W3C. It is compatible to RDF data model and used as a data access protocol for the Semantic Web.
- *GRIB* (GRIdded Binary) format for meteorological data as well as historical and forecast weather data (WMO)
- *JSON, GeoJSON* and *Esri-JSON* are JavaScript notations to represent Simple-Feature-Access-Specifications e.g. for data exchange. It is used to transform and safe structured data.
- *netCDF* is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.
- *GeoRSS* (Geographically Encoded Objects for RSS feeds) is a geotagged RSS feed which describes the locations of a web feed, blog or any news. It is available in XML or GML format and provides meta information of a web content like authors, date, title, narrative description, hypertext link and, at least, one location per feed.

Table 8: Further standards on data exchange and languages

Content	Standard
Bibliographic data (sharing, access)	MARCXML
Conceptual schema language	ISO 19103:2015
Data interchange between information systems in agriculture	BS ISO 11788 (1-3)
Format for information exchange (bibliographic information)	ISO 2709:2008
Functional standards	ISO/TR 19120:2001
Language to transform XML documents into other formats	XSLT
Query language, developed by W3C	XPath
Shapefile	ESRI (quasi-standard)
Statistical data and metadata exchange (SDMX)	ISO 17369:2013

Conflicts and solutions

ISO 28258 vs. INSPIRE DS Soil

The most significant difference between both models for soil-related data is, that the INSPIRE model provides two subtypes for the soil profile feature type (observed and derived soil profile), which are missing in the ISO model. There is only one type of soil profile in the ISO model that can be used in both ways, in so far as a connection between soil profile and plot information is provided or the soil profile is directly linked to a soil mapping unit representing geometry in a soil map. Furthermore the INSPIRE model allows to specify from which observed soil profiles a derived soil profile was made what is not feasible in ISO. Feature types for providing soil information as raster data are not included in the ISO model. On the other hand ISO provides feature types for project information and soil samples that are missing in INSPIRE.

These differences are due to the diverging approaches. INSPIRE focuses on data products and their use, as well as the delivery of data to the users. ISO aims to data exchange in a wide range, even for scientific use. Both models need extension by the data provider regarding definition of parameters, which is rather simple with ISO, whereas there are more formal procedures in INSPIRE.

Relation between OGC and ISO standards

In the field of data exchange formats OGC and ISO developed standards in cooperation. As a result, these standards are double branded or divided into different parts with regard to contents. These standards do not compete with each other and have a broad acceptance.

- The XML encoding of the OGC standard GML is consistent with **EN ISO 19118:2011** and, more specifically, with **EN ISO 19136:2009** in terms of transport and storage of geographic information. The basic concepts used by GML to model geographic information are drawn from the **EN ISO 19101ff** series and the OpenGIS Abstract Specification. Current version GML 3.3 is backwards compatible with the previous version 3.2, which is identical to EN ISO 19136:2009.
- Observations and Measurements Implementation Standard is published in two parts: the conceptual model (in UML) is published as **EN ISO 19156:2013**, the XML implementation as an independent document by OGC.

2.5 Data Archiving

Research data which are replaced by new data and no longer actively used need to be stored permanently on separate storage devices with long durability. To enable long-term search and access to archived data standard digital archival systems should be used.

Overview of existing standards

DIN 31644:2012-04 - Digital Archives ★★

This standard describes criteria for trustworthy digital archives in general and pre-conditions for the establishment and operation of digital archives. The German standard contains information on archival packages, data identification (e.g. DOI), and descriptive, technical and structural metadata. Users of this standard are encouraged to work through the task list within its takeover project. For practical assistance, a control list is annexed.

The project **nestor** (=Network of Expertise in Long-Term Storage of Digital Resources) provides an archiving seal based on DIN 31644.

ISO 14721:2012 - Open archival information system, OAIS ★

Originally developed by NASA and other space companies, OAIS provides frameworks for archival concepts, long-term digital information preservation, terminologies and concepts for describing and comparing archive architectures.

ISO 16363:2012 - Audit and certification of trustworthy digital repositories

The ISO sets out comprehensive metrics for what an archive can be used based on OAIS. Primary Trustworthy Digital Repository Authorization Body (ISO-PTAB).

ISO 16919:2014 Space data and information transfer systems

This standard specifies the requirements for bodies providing audit and certification of candidate trustworthy digital repositories.

3 Data Provision

Structured research data, reasonably described by standardized metadata facilitates its provision and increase its visibility. Open metadata, free and widely accepted geo-data protocols and accepted licenses facilitate data queries and access for user.

This chapter provides an overview of metadata standards, possibilities for data publication, accepted licenses and thesauri and ontologies as applied in soil and agricultural science.

3.1 Metadata

A key precondition to store and share data and to fulfil the FAIR data principles (see Introduction) is the proper description of research data by metadata. When set-up an own interoperable metadata schema for a data repository it is very important to use assignable elements of widespread and open metadata standards.

Overview of existing standards

Standards only dealing with metadata for diverse purposes and are published by ISO. Metadata for geographic information are regulated in **ISO 19115-1ff** series (Geographic information - Metadata). ISO 19115-1:2014 and -2:2009 contain many code lists on identification information, geometry types and other relevant topics.

Requirements for metadata related to geographic information services are defined in **EN ISO 19119:2016**. A technical guideline for encoding of metadata using a XML-schema is provided by **ISO/TS 19139:2007** (XML schema implementation). Regulations for metadata are also part of other standards that relate to soil data, for example **INSPIRE DS Soil** or **ISO 28258:2013**.

The German Infrastructure for Spatial Information (GDI-DE) requires the application of ISO 19115, 19119 and 19139 in the context of INSPIRE for acquisition and support of metadata. For such purposes the Drafting Team Metadata and European Commission Joint Research Centre published a technical guideline with INSPIRE implementing rules for metadata (JRC, 2007).

The Digital Curation Centre (DCC) provides a list of common metadata standards.

The BonaRes Metadata Schema has been created by combining elements of the two schemes INSPIRE (EU) and DataCite (DOI) since few relevant elements within these two standards have been found.

INSPIRE (European Union) ★★

The INSPIRE directive contains metadata elements on dataset-level that should be applied for documenting metadata for an entire dataset or a dataset series. Metadata can also be stored on object-level. This means that metadata can be described for each individual spatial object. Due to the product-oriented approach of INSPIRE, metadata provide not only information on data quality and validity, but also on conditions for accessibility, use of data, access restriction (including reasons) and charges.

DataCite ★★

The DataCite was developed to provide easy access to scientific data over internet. It provides domain agnostic services which belongs to the concept of a long term or *persistent* identifier. DataCite is using *Digital Object Identifiers* (DOIs) to register a resource associated with metadata. The objective of DataCite is to increase the acceptance of research data as legitimate, citable contributions to the scientific record and to archive data for future study. Besides a wide range of metadata elements, DataCite provides the opportunity to acknowledge contributions of disciplinary work. To enable an accurate and consistent identification of a resource (e.g. for citation) the metadata scheme offers a list of essential metadata properties. The da|ra is the DOI registration agency for social and economic research data. The recent Metadata Scheme is 4.0 (DataCite, 2016).

Dublin Core Metadata Element Set (Version 1.1) ★

This set is a vocabulary of fifteen properties to describe a resource. It is maintained by the Dublin Core Metadata Initiative (DCMI). The Dublin Core metadata elements formally endorsed in **ISO 15836: 2009**, **ANSI/NISO Z39.85-2012** and **RFC 5013** (Kunze and Baker, 2007).

Schema.org ★

Is a collaborative activity founded by technology companies as Google and Microsoft. It provides a standardized schema for structured data on the internet and defines entities and relationships to be used to describe e.g. data sets or web pages. It is used e.g. to structure data in the research data search tool “Google Dataset Search”.

METS (Metadata Encoding & Transmission Standard)

This is a standard for coding and management of metadata from digital or analogue sources of different formats (picture, text, audio, video…). Precondition are beside others sections for the presentation of the internal structure of a digital object, group related files, technical metadata, and information about the source. METS documents can link and integrate different metadata (e.g. from PREMIS, Dublin CORE or MARC).

PREMIS (PREservation Metadata: Implementation Strategies)

Initiative for the development and maintenance of internationally recognized long-term archiving metadata standards. PREMIS aims to develop recommendations, suggestions and best practices for implementing preservation metadata, further development of the standards, as well as the connection to other standards.

DDI (Data Documentation Initiative)

Open standard (metadata model) to describe social and economic research data and survey data. Basic concept is the description of the complete Data Life Cycle with XML.

GESIS (Leibniz-Institute for the Social Sciences)

In line with DDI, presentation of detailed metadata and standards for surveys and interviews, e.g. in the following technical reports: Zenk-Möltgen and Habbel 2012, Jensen and Schweers 2014.

Business Association ADM (Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute e.V.)

Represents the interests of private-sector market and social research agencies in Germany and provides guidelines, quality standards and the ICC/ESOMAR Codex e.g. about telephone, online and personal surveys, about focus group discussion, qualitative interviews and ethical standards in data collection.

Quali-Service (University of Bremen)

Emerging data service center for qualitative primary data (focus on interviews) and provision of reports about metadata standards, e.g. Betancort Cabrera and Haake 2013.

Conflicts and solutions

INSPIRE vs. ISO Metadata

The problematic issue of metadata and data is that almost any piece of data can be metadata in a more specific context. In the application schema of ISO 28258 any piece of information that can be handled as data should at least be handled as data, but can additionally be handled as metadata. According to ISO 28258 information e.g. on projects or soil maps can be described as data (in the form of features) or metadata. In line with INSPIRE this information is metadata of a dataset.

After reviewing INSPIRE metadata schema for dataset and services, GDI-DE, DataCite and Dublin Core metadata standards, a new metadata schema was created (Gärtner et al., 2017, DOI: 10.20387/BonaRes-5PGG-8YRP). In the schema all mandatory elements of INSPIRE and DataCite 4.0 elements are blended.

3.2 Geo-Data Services

Geo-data service provides access to a geo-database by local area network (LAN) or the internet using ArcGIS server or open source GIS servers, i.e., geo server to view, search and queries into database. Open Geospatial Consortium (OGC) regulates rules and standards for geo-data services. So called "OGC services" are listed in this chapter. They are widely accepted and applied by geo-data providers and users. Requirements, types and structure of services are defined in **EN ISOS 19119:2016** and **ISO 19133:2007** (data types, operations and implementation).

Overview of existing standards

All OGC standards on web services (OWS) and supporting documents are available to the public at no cost, e.g.:

WMS (Web Map Service) ★★

WMS offer geo-registered map images in different format (e.g. JPEG, PNG) from distributed geo-database system through GIS servers. It is basically a HTTP/HTTPS link, which provides different request types, two of which are required by any WMS server: GetCapabilities and GetMap, defines a certain geographic location and layer(s) to be managed. Request types that WMS optionally support include: *GetFeatureInfo*, *DescribeLayer* and *GetLegendGraphic* (OpenGeoSpatial). Rules and applications of WMS are provided by **EN ISO 19128:2008**.

WFS (Web Feature Service) ★★

WFS allow any usage that might work with web services to get geographic features from one or more distributed spatial information system or a map itself. Similar to WMS (mapping output as an image), WFS deal with create, update, delete and query functions of feature instances from regarding database. WFS serve eight general operations: *Capabilities, DescribeFeatureType, DescribeFilterModel, Feature, FeatureWithLock, Property, LockFeature* and *Transaction*. Rules and applications of WFS are provided by **EN ISO 19142:2010**.

WCAS (Web Catalogue Service, also known as **CSW,** Catalogue Services for the Web) ★★

CSW service provides options to publish and searching capabilities of metadata about geospatial data, services, and related information objects. Request types that CSW services offers include: *GetCapabilities, DescribeByRecord, GetRecords, GetRecordById, GetDomain, Harvest*, and *Transaction*. Requests can encode the parameters in three different ways: GET with URL parameters, POST with form-encoded payload and POST with XML payload.

WCS (Web Coverage Service) ★★

WCS returns the original data with its descriptions along with actual semantics. This service allows access into coverage data for client-side rendering. WCS also offers clients to get information of a certain portions based on constraints and certain criteria, similar to WFS and WMS service (OGC Networks).

WMTS (Web Map Tile Service) ★★

WMTS makes detailed rendering of a raster data or a large volume of vector data in tiles which supports Key-Value-Pair (KV, process oriented) encoding interfaces, REST (Representational state transfer) encoding and SOAP encoding.

TJS (Table Joining Service) ★★

The TJS standard joins attribute data with its associated geospatial framework. Attribute data can be stored in one network and mapped with geographic data into another network which contains geometries for the attribute data. TJS provides simple web-based services for searching, accessing and using attribute data from different sources which can generate database, perform analysis and populate maps.

WMC (Web Map Context) ★★

The OGC XML file standard WMC describes meta-information of a WMS (e.g. the URL, different layers within the service, bounding box rectangle, coordinate system) in XML file, stores and loads XML schema which belongs to it.

WPS (Web Processing Service) ★★

WPS service defines how to implement a geoprocessing service, geographic calculations or models as a service. It offers simple web-based standardized method of finding, accessing and using of geoprocessing services, at the same time also direct requests and responses of those services. WPS uses HTTP GET, HTTP POST, SOAP and XML as a mechanism for describing the data and for interoperability.

3.3 Data Publication

The publication of research is a central issue in science. Beside traditional scientific papers, data publication became more important in the past years. Research data are stored and published by data journals, central (thematic) data repositories or in open data bases (e.g. University). To provide proper findability, reusability and citeability of these data, (persistent) identifiers are necessary, e.g. to assign data sets or authors to research. Most significant is the:

DataCite, DOI ★★

The BonaRes Data Centre is partner of the TIB and thus qualified for DOI registration. The DOI system became the standard for information and documentation **(ISO 26324:2012)** . In the DOI system the object is identified unambiguously to its institution (prefix). There is no limit of the length of either suffix or prefix and all DOI, provided by BonaRes, have the prefix: *10.20387*. Metadata can be associated with the object.

Persistent identifier (PI)

Persistent individual digital identifiers for authors and researchers can be used as name lists for creator and contributor names e.g. in DataCite. Examples are:

ORCID (Open Researcher and Contributor ID), **Scopus** (Elsevier), **ResearcherID** (Clarivate Analytics, Thomas Reuters), **LinkedIN**, **ResearchGate**, **ISNI** (ISO 27729:2012 International Standard Name Identifier) and the **Handle** system. The last was implemented into the digital object identifier (DOI), specified by the US-standard **ANSI/NISO Z39.84-2005** and managed by the DOI Foundation. Further PIs are Persistent URL (**PURL**), Uniform Resource Name (**URN**), Archival Resource Keys (**ARK**), and Extensible Resource Identifier (**XRI**). More information is given by Juha Hakala, 2010.

Taxonomies for author contributions to science

CRediT (Contributor Roles Taxonomy)

This taxonomy aims to provide transparency to the contributions of researchers to published work, to enable discoverability and to improve attribution, credit, and accountability. There are 14 categories defined for author's contribution.

IGSN (International Geo Sample Number)

Alphanumeric code to provide transparency to the contributions of researchers to scholarly published work, to enable discoverability and to improve attribution, credit, and accountability.

Data journals (selected overview):

A review of efficient and enhanced publishing, dissemination, sharing and re-use of bio-diversity data are given by Chavan and Penev (2011). Data publication in data journals are classified as "**p**ure" publish data papers only and journals classified as "**m**ixed" publish both. TRAC integrated SCM & Project Management provides a list of Data Journals.

Biodiversity Data Journal (Pensoft)

This journal is community peer-reviewed and Open-Access. It is in accordance with the Data Publishing Policies and Guidelines of Pensoft Publishers. Important standards for this Journal: related data must have DOI or other persistent identifier, XML.

CODATA Data Science Journal (Ubiquity Press)

This open access and peer-reviewed data journal is open for papers on data management, (re)use and databases across all research domains, technology and arts.

Earth System Science Data (Copernicus Publications)

International, interdisciplinary journal for the publication of articles on original research data (sets). Important standards for this Journal: Dataset with persistent identifier; OAI-PMH; Metadata in Dublin Core format (oai-dc), full-text XML.

Ecological Archives / Data Papers: (Ecologigal Society of America, ESA)

Provides and hosts supplemental material to ESA articles. Data is registered in official Data Registry of the ESA. Data are fully peer reviewed, technical review of data and metadata. Data ingest as text format. Important standards for this Journal: Metadata following (Michener et al., 1997).

F1000 Research (F1000 Research Ltd, Science Navigation Group)

Data articles are citable and authors are credited when data are reused. Important standards for this Journal: CC0, no explicit standards but guidelines for different datasets, metadata of date linked to the journal should be, when possible, in standardized machine readable formats (DataCite).

Mostly DataCite as well as DOI were important standards used in these Journals. The most important Persistent Identifier (PI) used is the DOI.

Geoscience Data Journal (Wiley)

Open Access with scientific peer-review. Important standards for this Journal: Linked data must be stored in an approved repository and assigned with DOI.

GigaScience / BioMed Central

Is an open access, open-data and open peer-review journal concerning research from life and bio-medical science.

Hindawi publishing (Hindawi Publishing Corporation)

Was a peer-reviewed and open access journal with dataset papers in all areas of geoscience. The journal ceased new publications in 2017. Important standards for this journal: Content is archived in Portico, LOCKSS.

Journal of Open Research Software (JORS, Software Sustainability Institute)

Publish peer-reviewed (meta-)papers describing research software.

Journal of Physical and Chemical Research Data / AIP Publishing LLC

Published by the American Institute of Physics (AIP) for the National Institute of Standards and Technology (NIST); reviews of measurement techniques, critical data evaluation. Important standards for this Journal: Standard Reference Data Act (Public Law 90-396); Article and supplemented material with DOI.

Data repositories (selected overview)

An overview and recommendations of over 2,000 repositories available are published by re3data.org (full scale resource of registered repositories across subject areas).

Dryad Digital Repository

Dryad is a nonprofit membership organization which governs this data repository. It is a curated open resource for data underlying scientific publications.

PANGAEA (Data publisher for earth & environmental science)

Is an open access library, data publisher and archive for geo-data in earth- and life sciences. Data are easy accessible, citable and are managed free of charge for data provider and data user.

Scholix (Scholary Link eXchange)

This initiative links and connects data and metadata. It aims to establish an interoperability framework information exchange between literature and data and to set-up an open information framework to describe and understand what data underpins literature and what literature references data.

Conflicts and solutions

While the expression of DOI as URN is possible, conversions from DOI into other systems, such as XRI or ARK, are difficult or impossible, respectively. In contrast to URN, DOI goes beyond identifying an electronic manifestation of a resource. The DOI-prefix also identifies the location of access.

3.4 Licenses

License information for research data and metadata is important because it informs users what they allowed to do with data and metadata. Without an explicit license, reuse is restricted. Licenses should not be created individually but existing licenses should be used.

Overview of existing standards

Creative Commons (CC) ★★

Creative Commons is a global nonprofit organization that enables sharing and reuse of creativity and knowledge through the provision of free legal tools. Current version is 4.0. The BonaRes Centre strongly recommends the Creative Commons (CC) for licensing each data (research- and metadata) to be stored. Metadata is always unrestricted. The standard license for all research data stored in the BonaRes Data Centre is CC-BY that facilitates maximum distribution and usage of data.

Datenlizenz Deutschland (Data License Germany) ★

Was created by federal and state governments in Germany during the work at the Open Data Portal and has been specially developed for administrative data. Current version is 2.0.

GeoLizenz ★

This license was developed by the German GeoBusiness Commission (GIW-Kommission), which was founded by the Federal Ministry for Economic Affairs and Energy. The license is intended for geo-data, metadata and geo-data services.

GNU General Public License ★

GNU is intended to guarantee freedom to share and change all versions of a program and to make sure it remains free software for all its users.

Open Data Commons (ODC) ★

Open Data Commons is a project of the Open Knowledge Foundation with the aim to provide legal solutions for open data: Open Database License (ODbL) and Attribution License.

Open Software License (OSL-3.0) ★

OSL applies to any original work of authorship whose owner has placed the following licensing notice adjacent to the copyright notice for the Original Work: “Licensed under the Open Software License version 3.0”.

3.5 Thesauri and Ontologies

The use of thesauri, ontologies and glossaries with standardized, generally accepted and clearly assigned vocabularies, definitions and relations are necessary for smooth data integration and to allow an accurate exchange, query and reproduction of information. Not least, semantic data annotation by controlled vocabularies is precondition to provide interoperability of data repositories. Standardizes ontologies enable integration of data and information to the Semantic Web.

To link data and ensure its reusability it is important that thesauri are published online, using an open license and endowed with an URI (W3C, Best Practices for Publish Linked Data, 2014).

General information for development and operate thesauri are described in **ISO 25964 - Information and documentation – Thesauri & interoperability with other vocabularies** ★★ , that is published in two parts:

-1:2011 Thesauri for information retrieval

This is part one of an international standard for thesauri, that is published in two parts. It provides recommendations for the development and maintenance of thesauri intended for information retrieval applications. It is applicable to vocabularies about all types of information resources including knowledge bases and portals, bibliographic databases, text, etc. It provides a data model and recommended format for the import and export of thesaurus data and can be applied for monolingual and multilingual thesauri. Based on the data model it includes also an XML schema for data exchange.

-2:2013 Interoperability with other vocabularies

Provides guidelines for high quality information retrieval across networked resources that have been indexed with different vocabularies or Knowledge Organization Systems (KOS). It helps to set up mappings between different concepts (classification schema, taxonomies, subject heading schemas, ontologies, name authority lists, terminologies and synonym rings).

Overview of controlled vocabularies in agricultural and environmental science

AGROVOC ★★

Is a multilingual vocabulary developed by the FAO. It defines and relates some 36,000 concepts in 29 languages. The thesaurus is updated on a monthly basis. It is published as an RDF/SKOWS-XL concept schema and as Linked Data via SPARQL endpoint and is aligned with 16 vocabularies as related to agriculture. Editing is possible for registered users through VocBench 3.0, a web-based editing tool. AGROVOC thesaurus is released under CC Attribution 3.0 IGO license and published by the web-based SKOS browser “Skosmos”. The JAVA Command Line application “AgroTagger” ★ assigns and index semantic terms to textual content and as a keyword extractor from a set of web URLs. It allows to index web documents identifying main topics and creating RDF triples that link a Web URL to AGROVOC URIs.

GEMET ★★ (General Multilingual Environmental Thesaurus)

This thesaurus was developed by the European Environmental Information and Observation Network (EIONET). It summarizes different structured vocabularies and aims to define a common terminology for environmental terms in the European context. It is available in more than 27 languages and consists of more than 6000 records.

CAB ★

CAB is an Open Access, multi-lingual thesaurus with almost 3 million terms in world's science and technical fields. It includes some 250,000 plant, animal and microorganism names.

Crop Ontology ★

This ontology includes a large database with ontologies of crops and crop-related terms, structured in the categories phenotype, breeding, germplasm and trait. Terms are defined by a unique combination of trait, method used and scale. It is open access and open to improve by the crop community.

EUROVOC ★

This multilingual thesaurus maintained by the Publications Office of the European Union for indexing of documents of European institutions. It is available in 24 languages.

GCMD (Global Change Master Directory) ★

This directory was developed by NASA and can be implemented as thesaurus into a data base. Keywords are provided in different scientific disciplines such as agriculture, atmosphere and hydrology.

GACS ★

The GACS project developed this semantic concept scheme which integrates three important agricultural thesauri: AGROVOC, CAB and NAL thesauri. GACS is planned to be a hub for all concepts and shared value lists related to agriculture.

ISO 11074:2015 - Soil quality, Vocabulary ★

This standard summarizes all relevant terms of soil science in a glossary and is available in a trilingual edition. It defines a list of terms used in the preparation of other standards in the field of soil quality. The terms are classified under the following main headings: general terms, description of soil, sampling and assessment of soils, remediation, and soil ecotoxicology.

NAL (National Agricultural Library)

The United States Department of Agriculture (USDA) produced this agricultural vocabulary. It contains more than 135,000 terms, is updated annually, bilingual (English, Spanish), and available as Linked Open Data. Provided download formats are XML, RDF-OLS. It is mainly used for indexing and for improving retrieval of agricultural information.

OM (Ontology of Units of Measure and Related Concepts), Version 2.0

This ontology models concepts and relations for units, quantities, measurements and dimensions including conversion factors. It was developed by the Wageningen University and modelled in OWL 2.

QUDT (Quantities, Units, Dimensions and Data Types Ontologies)

This ontology is under development by the NASA and provides first unified model of quantities, dimensions, units, and conversion factors. Each unit has its own URI, and can thus be used as unique unit-identifier for data-sets.

EngMath

This ontology was developed for mathematical modeling and is mostly used by engineers.

EPPO Plant Protection Thesaurus

This European thesaurus includes pest-specific information, names (multi-lingual) and codes for plants, animals and microorganisms.

LandVoc

This vocabulary was created by Land Portal organization and includes a set of 270 concept about land governance. LandVoc is mainly derived from AGROVOC but links together other vocabularies.

PROV-O

This W3C ontology provides a set of classes, properties, and restrictions that can be used to represent and interchange provenance information generated in different systems and under different contexts. It can also be specialized to create new classes and properties to model provenance information for different applications and domains.

Semantic Sensor Network Ontology

This ontology was developed by the W3C Semantic Sensor Networks Incubator Group and describes sensors, observations, and related concepts (W3C Semantic Sensor Network Incubator Group, 2009). It provides numerous suggestions on the management of sensor data including metadata of sensor description (e.g. accuracy, detection limit).

Overview of vocabulary portals, look-up services, visualization, and gazetteers

AgroPortal ★★

The web portal provides access to agricultural ontologies and thesauri. Via a search field terms can be entered and concepts of more than 100 agricultural vocabularies. Registered user can provide new ontologies to this web service.

GODAN Agrisemantics Map of Data Standards ★★

This portal provides a global overview of existing vocabularies for the exchange of agricultural data. It is grouped in 14 main categories, such as “Natural Resources, Earth and Environment”.

GeoNames

This geographical database contains more than 11 million names of places.

Ontology Lookup Service

Is a web service interface which allows queries to more than 200 ontologies. The lookup service includes more than 5 million terms. Results link to single ontologies, concepts and output formats.

Open Tree of Life

Was funded by the NSF, describes and visualizes the biological taxonomic classification system and can be used to allocate taxonomic species names and classes.

Planteome

The project provides a platform to search and browse plant species, plant traits, phenotypes and gene expressions from different information systems.

Overview of tools, specifications, data models and ontology languages

SKOS – Simple Knowledge Organization System ★★

SKOS is a W3C recommendation for the representation of thesauri, classification etc. or any other controlled vocabulary. It gives guidelines to facilitate publication and use of vocabularies as Linked Data. SKOS is part of the Semantic Web standards built upon RDF and RDFS. SKOS was formal released in 2009 by W3C as a new standard that connects different KOS and the linked data community. It defines classes and properties to present common features of a standard thesaurus.

RDF – Resource Description Framework ★★

RDF is a family of W3C specifications that is applied as a general method for conceptual description or modeling of information that is implemented in web resources. Via an Application Programming Interface (e.g. RDF API) a standardized interface can be implemented e.g. in within web-based data portals.

ISO/IEC 13250-2:2006 - Information technology – Topic Maps ★★

This standard regulates the representation and interchange of knowledge, especially for information retrieval. Topics Maps enable the linkage of multiple indexes from different sources. The standard defines the abstract structure and interpretation of Topic Maps, rules for merging them and a set of fundamental subject identifiers. The purpose of the data model is to define the interpretation of the Topic Maps interchange syntax, and to serve as a foundation for the definition of supporting standards for canonicalization, querying, constraints, etc.

OWL (Web Ontology Language) ★★

Ontology language developed (and updated to OWL 2) by the W3C. It meets the requirements of the Semantic Web. Ontologies which were written in OWL 2 (e.g. OM) can be used and exchanged as RDF documents. Relations between agricultural terms, a set of 179 custom relations is provided by e.g. **Agrontology** (as used in AGROVOC).

VocBench ★★

Is an open source, web-based multilingual vocabulary editing and workflow tool. It was originally developed and released by the FAO and the Artificial Intelligence Research Group of the University of Rome Tor Vergata to manage AGROVOC, but now hosts a still expanding set of vocabularies.

Data Catalog Vocabulary (DCAT) ★

This RDF specification was designed by W3C to facilitate the interoperability between and search across different data catalogues. DCAT does not make any assumptions about the format of the datasets described in a catalogue. It incorporates terms from other vocabularies with stable term with appropriate meanings (e.g., foaf:homepage or dct:title).

RDFS – Resource Description Framework Schema ★

This RDF schema can be used for sematic data models and was published by the W3C (1998). It includes several classes with certain properties using the RDF extensible representation data model, providing basic elements for the description of ontologies.

Use cases for applied thesauri in databases

AGRIS (International System for Agricultural Science and Technology)

Is a global public domain database published by the FAO with more than 8 million records on agricultural science and technology. The AGRIS Search system allows scientists, researchers and students to perform sophisticated searches using keywords from the AGROVOC thesaurus, specific journal titles or names of countries, institutions, and authors. The AGRIS is a RDF-aware system and AGRIS database is exposed as RDF.

Conflicts and solutions

The AGROVOC thesaurus is widely accepted and appreciated within the agricultural science community. However, it was found that terms in soil science are often inadequately described or lacking as assigned for the objectives of the BonaRes Program. Terms and concepts can be edited and improved by the web editor tool VocBench3.

4 Appendix

4.1 Recommended standards

*Table 9: Overview of the highly recommended standards** for the BonaRes program (alphabetic order)*

Topic	Standard
Agricultural activities (Fertilization, Manure)	***EU Regulation 2003/2003***
	VDLUFA Method Books
Agricultural activities (Plant protection)	***European Plant Protection Organization (EPPO)***
Agricultural activities (Rating)	***Boniturmethoden, Bundessortenamt (2000)***
Agricultural activities (Soil management)	***DIN 18916:2016***
	GAP
	Operation Planning Agriculture (KTBL, 2014)
Agricultural activities (Sustainable management)	***detailed list for different aspects see Table 5***
Agricultural tools and machineries	***detailed list for specific tools see Table 4***
Crops (Varieties)	***Bundessortenamt (2015)***
Crops (Mass, Components)	***EN ISO 520:2010***
	ISO 7971-1ff series
	DIN EN 15587:2014
Data conventions (General)	***detailed list for divers data conventions see Table 6***
Data exchange (Agricultural data)	***AgroXML***
	ISO-XML (ISO 11783-1:2007ff)
Data exchange (Geo-data)	***OGC standards (GML, KML, WaterML, SOS,…)***
	GeoSciML
Data exchange (Metadata)	***XMI***
Data publication	***DataCite, DOI***
Data quality	***EN ISO 19157:2013***
Data quality (Repository, Seal)	***Core Trust Seal***
Data quality (Statistics)	***DIN ISO 11843-1ff series***
	ISO 3534-1/-2
	DIN 66270:1998
Digital archives	***DIN 31644:2012-04***
Geo-data services	***all OGC standards on web services (WMS, WFS, CSW, WCS, …)***
Land use classification	***CORINE Land Cover***
	ATKIS
Licenses	***Creative Commons (CC)***
Metadata	***INSPIRE (EU)***
	DataCite

Table 9 - continued

Topic	Standard
Meteorology	***DIN 1319-1ff series***
	EN ISO 20988:2007
	ISO 9169:2006
Ontology (Tools and Languages)	***SKOS***
	RDF
	ISO/IEC 13250-2:2006
	OWL
	VocBench
Soil analysis (Laboratory)	***ISO 11464:2006***
	DIN ISO 11843-1ff
	Methods of Soil Analysis (SSSA 2017)
	Handbook of Soil Investigations (Blume et al. 2016)
	VDLUFA Method Book (2016)
	detailed list for specific soil parameters see Tables 2 and 3
Soil description and classification	***KA5, German Soil Survey Guidelines***
	IUSS WRB
Soil description and classification (Conformity check)	***Conformity key for KA5 (BGR)***
Soil description and classification (Transformation)	***Transformation and derivation tools (BGR)***
Soil sampling	***ISO 18400-1ff series***
Soil sampling depths	***GlobalSoilMap***
Thesauri	***ISO 25964-1:2011***
	AGROVOC
	GEMET
Vegetation (Minimum information)	***MIAPPE***
Vegetation (Phenology stages)	***BBCH scale***
Vegetation (Survey)	***Braun-Blanquet-Scale***
Vocabularies (Portal)	***AgroPortal***

4.2 Code Lists

Code lists are useful tools for expressing longer lists of potential values and help to organize and harmonize data bases. Whenever a universal accepted code exists for a certain parameter, it is recommended extend the data base with a code column.

Soil survey

In the Tables 11-16 the most important code lists for field soil survey, description and classification, as parts of national and international standards, are listed:

Table 10: Overview of code lists on soil data survey

Standard	**Code list**
German Soil Survey Guideline (KA5)	*see Table 11*
DIN 4220:2008-11	*see Table 12*
Guideline Soil assessment	*see Table 13*
FAO Guidelines for Soil description	*see Table 14*
ISO 25177:2008	*see Table 15*
INSPIRE Code List, e.g. WRB for Reference Soil Groups, Qualifiers and Specifiers	*see Table 16*

For the German Soil Survey Guideline all parameters for field soil description provided with code lists are given in Table 11. The number of the field in the official form for soil scientific profile description, where a certain soil parameter has to be documented is also listed in the table. The accessibility of code lists is given by the corresponding page number in the guideline, number and title of code list. Code lists for deduction of soil parameters are not mentioned in this overview, because they are not relevant for field soil description.

Table 12 gives an overview of parameters in the German standard **DIN 4220** for soil feature designation and classification as provided by code lists. Code lists used for deduction of soil parameters are not listed, as they are not required for field soil description.

Table 11: Parameters for field soil description provided with code lists in German Soil Survey Guideline (Bodenkundliche Kartieranleitung KA5, 5th edition, 2005)

Parameter (EN)	**Parameter (D)**	**field**	**p.**	**Cl-No.**	**Code list name**
sampling type	Beprobung Entnahmeart	-	40	Tab. 2	Entnahmeart und Definition der Probenahme
exploration type	Aufschlussart	9	56	List 2	Aufschlussart/Aufnahmeintensität/Probenahme
acquisition intensity	Aufnahmeintensität	9	56	List 2	
slope gradient class	Hangneigungsstufe	11	58	Tab. 6	Einstufung der Hangneigung
exposition	Exposition	12	59	Abb. 5	Windrose zur Kennzeichnung der Exposition
curvature	Wölbung	13	60	Tab. 7	Einstufung der Wölbungsstärke
relief type (simple)	einfacher Reliefformtyp	14	63 64 65 65	List 3 List 4 List 5 List 6	Reliefformtypen Untergliederung des Kulminationsbereichs Untergliederung des Tiefenbereichs Untergliederung des Hanges
relief type (complex)	komplexer Reliefformtyp	14	66 66 67	List 7 List 8 List 9	Komplexe Reliefformtypen Erhebung Geschlossene Hohlform
micro relief	Mikrorelief	16	69	List 10	Rauhigkeit R der Reliefoberfläche
position in relief	Lage im Relief	17	69	List 11	Lage im Relief
denudation/ accumulation processes	Abtrags/Auftragsvorgänge	18	70	List 12	Abtrags-/Auftragsvorgänge und deren Erscheinungen
denudation/accumulation phenomena	Abtrags/Auftragserscheinungen	18	70	List 12	
land use/ surface sealing	Nutzung/ Versiegelung	19	72	List 13	Nutzungsart/Versiegelung
vegetation	Vegetation	20	73	List 14	Vegetation
weather conditions	Witterung	21	74	Tab. 9	Kennzeichnung der Witterungsverhältnisse
anthropogenic changes	anthropogene Veränderungen	22	75	List 15	Anthropogene Veränderungen
lumbricids lifeform type	Lumbricidae Lebensformtyp	23	77 77	Tab. 10 Tab. 11	Lebensformtypen und Abundanzklassen der Lumbriciden
remarks (acquisition conditions)	Bemerkungen (zur Aufnahmesituation)	24	79	List 16	Flächen mit Sonderbestimmungen
lower horizon boundary form	Horizontuntergrenze Form	26	80	Abb. 11a	Form (Gestalt) der Horizontgrenze
lower horizon boundary orientation	Horizontuntergrenze Lage	26	81	Abb. 11b	Lage (Neigung) der Horizontgrenze zur Oberfläche
lower horizon boundary sharpness	Horizontuntergrenze Schärfe	26	81	List 17	Schärfe (Deutlichkeit) der Horizontgrenzen
horizon symbols	Horizontsymbole	27	86ff	Tab. 12	Vorgesehene Kombinationen von Haupt- und Zusatzsymbolen
color (without colorcharts)	Farbe (ohne Fabtafeln)	28	110	List 18	Farbbezeichnungen

Table 11 - continued

Parameter (EN)	Parameter (D)	field	p.	Cl-No.	Code list name
humus content	Humusgehalt	29	112	Tab. 15	Einstufung des Humusgehaltes (organische Substanz) von Böden
hydromorphology oxidative	Hydromorphie oxidativ	30	113	Tab. 16	Erscheinungsarten horizont-differenzierender Fe- und Mn-Verbindungen in hydromorphen Böden
hydromorphology reductive	Hydromorphie reduktiv	31	113	Tab. 16	
soil moisture	Bodenfeuchte	32	115	Tab. 17	
consistency	Konsistenz	33	115	Tab. 17	Konsistenz bindiger Böden, Konsistenz-grenzen und zugehörige Bodenfeuchte
other pedogenic features	sonstige pedogene Merkmale	34	114	-	Organische Merkmale, Mineralische Merkmale
soil structure type	Gefügeform	35	117 118 118 119	List 19 List 20 List 21 List 22	Grundgefüge Makrogrobgefüge Makrofeingefüge Gefügefragmente
compactness	Lagerungsart	36	121	List 23	Lagerungsart
porosity	Porenanteil	38	124	Abb. 13	Bestimmung des Makroporenanteils
tubes, channels	Röhren, Gänge	39	123	List 24	Röhren, Gänge
bulk density	Lagerungsdichte	40	125	Tab. 20	Bestimmungsschlüssel für die Ansprache der effektiven Lagerungsdichte
substance vol. (for peaty soil)	*Substanzvolumen* (bei Moorböden)	40	127	Tab. 22	Ansprache des Substanzvolumens SV bei Moorböden
degree of peat decomposition	Zersetzungsstufe (bei Torf)	40	128	Tab. 23	Bestimmung der Zersetzungsstufen und des Zersetzungsgrades von Torfen
root density	Durchwurzelungsintensität	41	129	Tab. 24	Einstufung der Durchwurzelungsintensität
fine root density	Feinwurzeldichte	41a	129	Tab. 24	
coarse root density	Grobwurzeldichte	41b	129	Tab. 24	
rootable depth class	Durchwurzelbarkeit	41	130	Tab. 25	Einstufung der Durchwurzelungbarkeit (physiologische Gründigkeit)
substrate genesis	Substratgenese	43	137	Tab. 137	Gliederung der Substratgenese auf den verschiedenen Niveaus
soil type	Bodenart	44a	144	Tab. 30	Definition der Feinbodenarten nach Fraktionen, Schlüssel zur Bestimmung der Bodenart im Gelände (Fingerprobe)
sand soil type	Sandbodenart	44a	148	Tab. 31	Kornfraktionen Bodenart „reiner Sand“ Ss
coarse soil fraction	Grobbodenfraktion	44b	150 150	Tab. 32 Tab. 33	Untergliederung + Kornfraktionen des Grobbodens Einstufung des Grobbodens
peat type	Torfart	44a	161	Tab. 36	Botanische Gliederung verbreiteter Torfe und ihre Zuordnung zu den bodenkundlichen Torfartengruppen
mud type	Muddenart	44a	164	List 25	Mudden
carbon content (substrate)	Kohlenstoffgehalt (Substrat)	45	166	Tab. 38	Einteilung des Kohlenstoffgehaltes bei der Substratartenansprache im Feld 42

Table 11 - continued

Parameter (EN)	**Parameter (D)**	**field**	**p.**	**Cl-No.**	**Code list name**
carbonate content	Carbonatgehalt	46	169	Tab. 40	Kennzeichnung des Carbonatgehaltes des Feinbodens und bei der Substratartenansprache im Feld 42
parent rock	Bodenausgangs-gestein	47a	174	Tab. 43	Bodenausgangsgesteine
periglacial cover beds	Periglaziäre Lagen	47b	181	List 26	Periglaziäre Lagen
coarse soil components	Grobboden-komponenten	47c	174	Tab. 43	Bodenausgangsgesteine
substantial inhomogeneities	Substanzielle Inhomogenitäten	47d	183	List 27	Substanzielle Inhomogenitäten
structural inhomogeneities	Strukturelle Inhomogenitäten	47e	184	List 28	Strukturelle Inhomogenitäten (sofern nicht substanziell differenzierbar)
stratigraphy	Stratigrafie	48	187	List 29	Stratigrafische Einheiten
remarks (horizon)	Bemerkungen (zum Horizont)	49	190	List 30	Geruch
soil type	Bodentyp	50	199	List 31	Bodensystematische Abteilungen, Klassen und Typen mit Horizontfolgen
humus form	Humusform	50	264	Tab. 46	Kriterien und diagnostische Horizontmerkmale der Varietäten
ground water level	Grundwasserstufe	53a	311	Tab. 59	Einstufung der Grundwasserstände
soil wetness class	Vernässungsgrad	54	315	Tab. 61	Ermittlung des Vernässungsgrades für Grund-, Stau- und Haftnässeböden
degree of erosion	Erosionsgrad	55	316	Tab. 62	Erosionsgrad und bodensystematische Ansprache

Table 12: Parameters for field soil description provided with code lists in DIN 4220:2008-11

Parameter (EN)	**Parameter (D)**	**p.**	**Table**	**Code list name**
soil and site characteristics	Boden- und Standorteigenschaften	10	1	Einstufung von Boden- und Standorteigenschaften
size and scale of features	Größen und Skalenbereich von Erscheinungsformen	11	2	Einstufung von Größen, Einteilung in Mikro-, Meso-, Makroskala
area percentage of features	Flächenanteil von Erscheinungsformen	11	3	Flächenanteil von Erscheinungsformen in Böden
soil texture class (fine soil)	Bodenart (Feinboden)	12	4	Kornfraktionen des Feinbodens
coarse fragments	Bodenart (Grobboden)	12	5	Kornfraktionen des Grobbodens (Bodenskelett)
soil texture main group, soil texture group	Bodenarten-Hauptgruppe, Bodenarten-Gruppe	13	6	Bodenarten (Gruppierung, Benen-nung, Kurzzeichen, Kornfraktionen)
sand texture classes	Sandbodenart	14	7	Unterteilung der Bodenart reiner Sand (0-5% Ton, 0-10% Schluff)
coarse soil shares	Grobboden Beimengungen	15	8	Einteilung Gemengeanteile Grobboden
humus content	Humusgehalt	16	9	Einstufung Humusgehaltes (organische Substanz) von Böden
rootable depth class	Durchwurzelbarkeit	17	10	Einstufung Durchwurzelbarkeit (physiologische Gründigkeit)
root density	Durchwurzelungsintensität	17	11	Einstufung Durchwurzelungsintensität
dry bulk density	Trockenrohdichte	18	12	Einstufung Trockenrohdichte
ground water level	Grundwasserstufe	18	13	Grundwasserstufen in Abhängigkeit mittl. Grundwasserflurabständen
capillary space	Kapillarraum	19	14	Einstufung geschlossener Kapillarraum
field capacity	Feldkapazität	20	16	Einstufung Feldkapazität
plant available water	nutzbare Feldkapazität	20	17	Einstufung nutzbare Feldkapazität
soil porosity	Luftkapazität	21	18	Einstufung der Luftkapazität
water content at wilting point	Totwasser	21	19	Einstufung des Totwassers
total pore volume	Gesamtporenvolumen	21	20	Einstufung Gesamtporenvolumens und Porenziffer
water permeability	Wasserdurchlässigkeit	22	21	Einstufung Wasserdurchlässigkeit
air permeability	Luftdurchlässigkeit	22	22	Einstufung Luftdurchlässigkeit
soil reaction	Bodenreaktion (pH-Wert)	23	23	Einstufung Bodenreaktion
redox potential	Redoxspotenzial	23	24	Einstufung Redoxbedingung
CEC	KAK	24	25	Einstufung potentieller KAK
base saturation	Basensättigung	24	26	Einstufung Basensättigung und Zuordnung von pH-Wert-Bereichen
peat type	Torfart	25	27	Botanische Gliederung von Torfen
substance volume	Substanzvolumen	26	28	Einstufung Substanzanteils von Moorböden
slope gradient level	Hangneigungsstufe	27	29	Einstufung Hangneigung

The *Guidelines for Soil Assessment* (*Bundesministerium der Finanzen 1996*) includes code lists for several soil parameters (Table 13). Symbols and class definitions of these code lists deviate conspicuously from other national standards (KA5 or DIN 4220) with the exception of the code lists for horizon symbols, which is taken from the German Soil Survey Guideline, 4th edition (KA4).

Table 13: Parameters for field soil description provided with code lists in the Guidelines for Soil Assessment

Parameter (EN)	**Parameter (D)**	**page**	**section**	**Code list name**
soil moisture	Bodenfeuchtigkeit	8	1.4	Feuchtigkeitszustand des Bodens
position in relief	Lage im Relief	9	2.1	Lage des Grablochs
exposition	Exposition	9	2.2	Hangrichtung des Grablochs
special cultivation type, characteristic water conditions	Sonderkulturarten und Besonderheiten der Wasserverhältnisse	10	2.8	Erläuterungen zum Kataster
cultivation type	Kulturart	11	2.9	Kulturart
soil texture	Bodenart	11	2.10.1	Bodenarten nach dem Schätzungsrahmen, Misch- und Übergangsbodenarten bei Acker- und Grünland, Schichtbodenarten bei Mineralboden, Schichtwechsel Mineral-/Moorboden bei Acker- und Grünland
geo- genesis	Geologische Entstehung	12	2.10.3	Entstehungsart
particularities	Besonderheiten	13	2.12	Besonderheiten, Abrechnungen (%)
remarks	Bemerkungen	15	2.16	Bemerkungen
humus content	Humusgehalt	18	3.2.1	Humus
carbonate content	Kalkgehalt	18	3.2.2	Kalk
soil color	Bodenfarbe	18	3.2.3	Farbe
iron compounds	Eisenverbindungen	19	3.2.4	Eisen
soil moisture	Bodenfeuchte	20	3.2.5	Feuchte
further soil features	sonstige Bodeneigenschaften	20	3.2.6	Sonstiges
main soil texture - fine soil	Hauptbodenarten - Feinboden	21	3.2.7	Hauptbodenarten - Feinboden
coarse fragments	Hauptbodenarten - Grobboden			Hauptbodenarten - Grobboden (Bodenskelett)
soil type - weathering soil	Bodenart - Verwitterungsböden			Verwitterungsböden
special soil textures	besondere Bodenarten			besondere Bodenarten
subordinate soil textures - fine soil	Nebenbodenarten - Feinboden			Nebenbodenarten - Feinboden
subordinate - coarse fragments	Nebenbodenarten - Grobboden			Nebenbodenarten - Grobboden

Table 13 - continued

Parameter (EN)	Parameter (D)	page	section	Code list name
additional information on soil texture	Ergänzende Angaben zur Boden-art			Ergänzende Angaben zur Bodenart
soil systematic unit - terrestrial soils	Bodensystematische Einheit - terrestrische Böden	26	4.1.1	Abteilung der terrestrischen Böden
soil systematic unit – semi-terrestrial soils	Bodensystematische Einheit - semiterrestrische Böden	29	4.1.2	Abteilung der semiterrestrischen Böden
soil systematic unit – bogs and fens	Bodensystematische Einheit - Moore	31	4.1.4	Abteilung der Moore
horizon symbols - organic horizons	Horizontsymbole - organische Horizonte	33	4.2.1	Organische Horizonte
horizon symbols - mineral horizons	Horizontsymbole - mineralische Horizonte	34	4.2.2	Mineralische Horizonte

The FAO Guidelines for soil description contain a huge number of code lists for numerous soil parameters (Table 14). In many cases several code lists are given for a distinct parameter describing different aspects of the parameter.

Table 14: Parameters provided with code lists in FAO Guidelines for soil description (4th edition, 2006)

Parameter	page	Table	Code list name
weather	9	2	Codes for weather conditions (Schoeneberger et al., 2012)
	9	2	Former weather conditions (Ad-hoc-AG-Boden, 2005)
soil climate	10	3	Soil temperature and moisture regime codes
landform (relief)	11	4	Hierarchy of major landforms
	11	5	Subdivisions for complex landforms
slope form	12	6	Classification of slope forms
slope gradient	12	7	Slope gradient classes
land use	14	8	Land use classification
cultivation	15	9	Crop codes
anthropogenic influence	15	10	Recommended codes for human influence
vegetation	16	11	Vegetation classification
parent material	18	12	Hierarchy of lithology
age of land surface	19	13	Provisional coding for age of land surface
rock outcrops	21	14	Recommended classification of rock outcrops
coarse surface fragments	22	15	Classification of coarse surface fragments
erosion	22	16	Classification of erosion, by category
	22	17	Classification of total area affected by erosion /deposition
	22	18	Classification of erosion, by degree
	23	19	Classification of erosion, by activity

Table 14 - continued

Parameter	page	Table	Code list name
surface sealing	23	20	Classification of attributes of surface sealing
surface cracks	24	21	Classification of surface cracks
salt at surface	24	22	Classification of salt characteristics
bleached sand at surface	24	23	Classification of bleached sand characteristics
horizon boundary	25	24	Classification of horizon boundaries, by distinctness and topography
soil type (fine soils)	28	25	Key to the soil textural classes
coarse soil fraction and artefacts	29 30 31 31	26 27 28 29	Abundance of rock fragments and artefacts, by volume Classification of rock fragments and artefacts Classification of shape of rock fragments Classification of weathering of coarse fragments
nature of rock fragments	31	30	Codes for primary mineral fragments
degree of decomposition (peat)	32	31	Field estimation and coding of the degree of decomposition and humification of peat
mottles	35 35 36 36	32 33 34 35	Classification of the abundance of mottles Classification of the size of mottles Classification of the contrast of mottles Classification of boundary between mottle and matrix
soil redox potential	36	36	Redoximorphic soil characteristics and their relation to rH values and soil processes
reductimorphic properties	37	37	Reductimorphic color pattern and occurrence of Fe compounds
carbonate content	38 38	38 39	Classification of carbonate reaction in the soil matrix Classification of forms of secondary carbonates
gypsum content	39 39	40 41	Classification of gypsum content Classification of forms of secondary gypsum
salt content	40	42	Classification of salt content of soil
field soil pH value	41	44	Classification of pH value
soil odor	42	45	Classification of soil odor
organic matter content	43	46	Estimation of OM-content based on Munsell soil color
soil structure	45 46 46 47 47 47	47 48 49 50 51 52	Classification of structure of pedal soil materials Classification of types of soil structure Codes for types of soil structure Size classes for soil structure types Combined size classes for soil structure types Combinations of soil structures
consistence	48 49 49 49	53 54 55 56	Consistence of soil mass when dry Consistence of soil mass when moist Classification of soil stickiness Classification of soil plasticity
soil-water status	50	57	Classification of moisture status of soil
bulk density	51 52	58 59	Field estimation of bulk density for mineral soils Field estimation of volume of solids and bulk density of peat soils
porosity	52 53 53 53	60 61 62 63	Classification of porosity Classification of voids Classification of diameter of voids Classification of abundance of pores

Table 14 - continued

Parameter	page	Table	Code list name
coatings	55	64	Classification of abundance of coatings
	55	65	Classification of the contrast of coatings
	55	66	Classification of the nature of coatings
	56	67	Classification of the form of coatings
	56	68	Classification of the location of coatings, clay accumulation
cementation and compaction	56	69	Classification of the continuity of cementation/compaction
	56	70	Classification of the fabric of cemented/compacted layer
	57	71	Classification of the nature of cementation/compaction
	57	72	Classification of the degree of cementation/compaction
mineral concentrations	58	73	Classification of the abundance of mineral concentrations
	58	74	Classification of the kinds of mineral concentrations
	58	75	Classification of the size and shape of mineral conc.
	58	76	Classification of the hardness of mineral concentrations
	59	77	Examples of the nature of mineral concentrations
	59	78	Color names of mineral concentrations
root diameter	60	79	Classification of the diameter of roots
root density	60	80	Classification of the abundance of roots
biological activity	60	81	Classification of the abundance of biological activity
	60	82	Examples of biological features
artefacts	63	83	Classification of kinds of artefacts
anthropogenic deposits	64	84	Determination table and codes for human-made deposits
horizon symbols	72	85	Subordinate characteristics within master horizons

Table 15: Parameters provided with code lists in ISO 25177:2008, Soil description in the field

Parameter (EN)	**Parameter (D)**	**p.**	**Cl-Nr.**	**Code list name**
precipitation	Niederschlag	7	-	Vorangegangene Niederschlagsereignisse
land use	Flächennutzung	8	-	Flächennutzung (ausführliche Felduntersuchung) auf Plottebene
nature of the water	Grundwasserbeschaffenheit	11	-	Beschaffenheit des Wassers
percentage of rock outcrops or non-natural materials	Flächenanteil von Gesteinsaufschlüssen oder „nicht natürlichen“ Oberflächen	11	-	Prozentualer Anteil von Gesteinsaufschlüssen oder „nicht natürlichen“ Oberflächen
erosion and soil accumulation	Erosion und Bodenauftrag	12	-	Anzeichen von Erosion
abundance of mottles	Flächenanteil von Flecken	14	-	Häufigkeit von Flecken
organic matter content	Gehalt an org. Substanz	15	-	Geschätzter Gehalt org. Substanz
abundance of coarse elements	Grobbodenanteil	15	-	Grobboden, Auftreten (als Volumenanteil in Prozent)
maximum grain size of coarse elements	Maximale Korngröße Grobboden	16	-	Max. Korngröße häufig auftretender Bestandteile des Grobbodens
carbonate content	Carbonatgehalt	16	-	Intensität des Aufbrausens
carbonate distribution	Carbonatverteilung	17	-	Auftreten des Aufbrausens
soil structure	Bodengefüge	17	-	Hauptkategorien des Bodengefüges
		39	Fig. F.1	Bodengefügeformen
compactness	Festigkeit	18	-	Festigkeit
porosity	Porenanteil	18	-	Geschätzte Gesamtporosität
root diameter	Wurzeldurchmesser	18	-	Dicke (Durchmesser) der am häufigsten auftretenden Wurzeln
root density	Durchwurzelungsintensität	19	-	Häufigkeit von Wurzeln
density of worm channels	Wurmröhrendichte	19	-	Dichte von Wurmgängen
lower horizon boundary form	Horizontuntergrenze Form	19	-	Kontur der unteren Horizontbegrenzung
Reference Soil Groups	Referenzbodengruppen	21	Tab. B.1	Referenzbodengruppen der WRB (FAO, ISRIC und ISSS, 2006)
fine earth fractions	Feinbodenfraktionen	35	Tab. D.1	Richtwerte für die Einteilung mineralischer Böden mit Korngrößenbereichen

Table 16: INSPIRE Code List register for soil parameter (selected)

Content/Definition	Name
master horizon symbols	FAO Horizon Master Value
subordinate horizon symbol	FAO Horizon Subordinate Value
connotes the master horizon symbol of the lower of 2 or 3 (prime, double prime) horizons with identical Arabic-numeral prefixes & letter combinations	FAO Prime Value
values indicating the placement of the Qualifier with regard to the WRB reference soil group (RSG).	WRB Qualifier Place Value
possible qualifiers of the WRB for Soil Resources	WRB Qualifier Value
possible RSG (i.e. first level of classification of the WRB for Soil Resources). RSG are distinguished by the presence/ absence of specific diagnostic horizons, properties and/or materials	WRB Reference Soil Group Value
possible specifiers	WRB Specifier Value
gives an idea whether current non-pedogenic processes affect the soil or not	Layer Genesis Process State Value
layer classification	Layer Type Value
properties that can be observed to characterize the profile element	Profile Element Parameter Name Value
properties that can be derived from soil data	Soil Derived Object Parameter Name Value
status of contaminating activity	Contaminating Activity Presence Value
possible values indicating reasons for conducting a survey	Soil Investigation Purpose Value
terms specifying on what plot observation is made	Soil Plot Type Value
properties observations to characterize soil profiles	Soil Profile Parameter Name Value
properties observations to characterize soil sites	Soil Site Parameter Name Value
trigger to have site or future investigations	Investigation Trigger Value
status risk assessment	Risk Assessment Stage Value
entities exposed to pollutants at the site.	Risk Receptor Value
indicates restrictions on the site as a consequence of the current situation	Soil Contamination Specialized Zone Type Code

Important code lists for crops, breeding, agriculture, land use, and measures

- The **International Code Council** (ICC) develops affordable code lists for global markets, agriculture and science.
- Within its World Program for the Census of Agriculture 2010, the **FAO** published an "Alphabetic List of Crops with Botanical Names and Crop Codes" (FAO, 2005).
- The Indicative Crop Classification (**ICC-**FAO) lists crop codes. The 2-4 digits codes do not differ between varieties and sowing dates (e.g. winter wheat). In 2017 a new version 1.1 was published which is now closely based on the Central Product Classification (CPC)
- The Central Product Classification (CPC) Version 2.1 was published by the United Nations (2015) and classifies goods and services such as crop products.
- A code list for crops is provided by the **Clemson University** (2008).
- The Genetic Resources Information System (GRIS) provides breeding and variety information and codes for wheat and triticale (09:2018: 171,000 varieties)
- Codes for tractors and other agricultural machineries are provided by the Harmonized Commodity Description and Coding System (HS-Codes) which was developed by the World Customs Organization (WCO)
- In Germany crop types and varieties are registered, described and coded by the Federal Plant Variety Office (**BSA**, Bundessortenamt). It provides descriptive variety lists e.g. for cereals, maize, oil and fiber plants.
- Within the extended **BBCH-scale** phenological development stages are described and coded for all kinds of agricultural plants and products (Hack, 1992).
- Based on the EU-regulation 1305/2013 (in Germany "InVeKoS") code lists on different crop types and culture codes, 3 digits were established (Flächennutzungsnachweis, **FNN**).
- In the United States, fertilizers are listed in the **UFTRS Code List** (Uniform Fertilizer Tonnage Reporting System, 3 digits).
- The Federal Office of Consumer Protection and Food Security (**BVL**) provides code lists on land use (1 letter), plant protection (active substances, 4 digits), function (1 letter), authorization holders (3-4 characters), and type of formulation (2 letters).
- The **EPPO-Code** (European and Mediterranean Plant Protection Organization) contains plants, pests and pathogens in the frame of agriculture and crop protection.
- Land use classes are coded in the CORINE Land Cover (**CLC**) including a 3-level nomenclature. Agricultural areas start with number "2".
- The code system **UCUM** (Unified Code for Units of Measure) includes units of measures being contemporarily used in international science and engineering. UCUM is based on EN ISO 80000 and is used e.g. for electronical data interchange protocols.

Important code lists for data management and metadata

- There are 33 code lists in ISO 19115-1ff (including references to other ISO standards e.g. language code- ISO 639-2). Code lists of EN ISO 19115-1:2003, 19115-2:2010 and 19119:2016 are used in INSPIRE and GDI-DE metadata schema as data type for several metadata elements e.g. CI_RoleCode, MD_CharacterSetCode, MD_ClassificationCode, MD_keywordTypeCode, MD_RestrictionCode, and MD_TopicCategoryCode.

- While the standard EN ISO 19108:2005 deals with geographic information and a temporal schema, ISO 8601:2004 contains data elements and interchange formats and represents date and times. Both have been implemented for INSPIRE.

- RFC 4646: tags for identifying languages, RFC 3986, Uniform Resource Identifier, TGN (Getty Thesaurus of Geographic Names) for coverage and DCMI Type Vocabulary [DCIM-TYPE], to describe nature or genre of the resource have been used in Dublin Core.

- The INSPIRE Metadata Regulation 1205/2008/EC (JRC 2007) mandate the presence of at least one keyword. This can be associated with a controlled vocabulary which in ISO standard is referred to as “thesaurus”.

Further code lists and glossaries (summarized)

Table 17: Further BonaRes relevant code lists

Feature	Publisher/Standard
air quality, exchange of data	ISO 7168-1:1999
coordinate reference systems	EPSG-Codes
culture codes, crop types	InVeKoS-FNN (Flächen-und Nutzungsnachweis)
date and time	ISO 8601:2004
languages, language names	ISO 639-1:2002 and ISO 639-2:1998 DIN 2335:2014-07
SI units	EN ISO 80000-1ff series
soil data formats	ISO 28258:2013; INSPIRE DS Soil
sprayers	ISO 10627-2:1996
vegetation survey (homogeneity, species, abundance)	Braun-Blanquet-Scale (Relevé method)

Table 18: Glossaries and vocabularies

Feature	Publisher/Standard
access panels in market, opinion, social research	ISO 26362:2009
castors and wheels	EN 12526:1998
earth-moving machinery	ISO 6165:2012
equipment for crop protection	ISO/DIS 5681:2014
equipment of harvesting	ISO 6689-1:1997
forage harvester	ISO 8909-1:1994
grain species	ISO 5527:2015
market, opinion and social research	ISO 20252:2006
meteorology (data aggregation)	VDI 3786-1:2013
quality management	EN ISO 9000:2015
soil quality	ISO 11074:2015
soil tillage, ploughing	ISO 8910:1993
soil water	ISO 15709:2002
statistics (terms, symbols)	ISO 3534-1:2006
tractors and (self-propelled) machines	ISO 14269-1:1997
tractors - symbols for operators	ISO 3767-2:2008
water quality	ISO 6107-1:2004

4.3 Web Links

(checked: July 2018, www…)

ADM guidelines: adm-ev.de/index.php?id=richtlinien

ADM quality standards: adm-ev.de/qualitaetsstandards/?L=1%27

ADM ICC/ESOMAR Kodex: adm-ev.de/index.php?id=kodex

AGRIS: agris.fao.org/content/agris-your-link-world%E2%80%99s-agricultural-information

AgroPortal: agroportal.lirmm.fr/

AGROVOC: aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus

AIMRO: aimro.ie/sites/default/files/documents/basic-page/QUALITY%20STANDARDS.pdf

AIMS: aims.fao.org/

ASI: asi-ev.org/

Attribution License: opendatacommons.org/licenses/by/

Better Regulations Guidelines: ec.europa.eu/smart-regulation/guidelines/toc_guide_en.htm

BGR: bgr.bund.de/

BonaRes Data Guideline: doi.bonares.de/BonaRes-E1AZ-ETD7/BonaRes-E1AZ-ETD7.html

BVL: biosicherheit-bch.de/SharedDocs/Downloads/04_Pflanzenschutzmittel/psm_uebersichtsliste.pdf?__blob=publicationFile&v=33

CAP: ec.europa.eu/agriculture/cap-overview/index_en.htm

Copernicus Publications: earth-system-science-data.net/

CORINE Land Cover: eea.europa.eu/publications/COR0-landcover

Creative Commons: creativecommons.org/

Crop Ontology: cropontology.org

Data journals (TRAC list): proj.badc.rl.ac.uk/preparde/blog/DataJournalsList

Data License Germany: govdata.de/lizenzen

DDI Data Documentation Initiative: .ddialliance.org/alliance/structure

Decision Support System for Agrotechnology Transfer (DSSAT): dssat.net

DESTATIS: destatis.de/DE/Methoden/DemografischeRegionaleStandards/Standards.html

destatis.de/DE/Methoden/DemografischeRegionaleStandards/DemografischeStandardsInfo.html?nn=173768

destatis.de/DE/Methoden/Klassifikationen/Klassifikationsserver_012014.pdf?__blob=publicationFile

destatis.de/DE/Publikationen/StatistikWissenschaft/Band16_AnonymisierungEinzeldaten_1030816109004.pdf?__blob=publicationFile

destatis.de/DE/Publikationen/StatistikWissenschaft/Band18_MethodenGeheimhaltung030818109004.pdf?__blob=publicationFile

destatis.de/DE/Publikationen/StatistikWissenschaft/Band10_Berichterstattung1030810079004.pdf?__blob=publicationFile

desta-tis.de/DE/Publikationen/StatistikWissenschaft/Band15_Tabellengestaltung1030815109004.pdf?__blob=publicationFile

Digital Curation Centre (DCC): dcc.ac.uk/resources/metadata-standards/list

Dryad Digital Repository: datadryad.org/

ecoinvent: ecoinvent.org/

Ecological Society of America: esapubs.org/archive/

EngMath (Ontology): ksl.stanford.edu/knowledge-sharing/papers/engmath.html

EPPO Plant Protection Thesaurus (EPPT): eppt.eppo.org/search.php

EPSG Codes: epsg-registry.org/

ESeC: iser.essex.ac.uk/archives/esec/user-guide

EUROVOC: eurovoc.europa.eu/drupal/?q=de/node

F1000 Research Ltd: f1000research.com/

FAO-ICC: fao.org/fileadmin/templates/ess/documents/world_census_of_agriculture/appendix4_r7.pdf

Field Book Registry (CGIAR): research.cip.cgiar.org/gtdms/fieldbook/

FNN: stmelf.bayern.de/mam/cms01/agrarpolitik/dateien/a6_codierung_fnn.pdf

focus group: assessment.trinity.duke.edu/documents/How_to_Conduct_a_Focus_Group.pdf

dx.doi.org/10.1093/intqhc/mzm042

GEMET: eionet.europa.eu/gemet/about?langcode=en

Geolicense: geolizenz.org/

GESIS: gesis.org/en/home/

GeoRSS: georss.org

Giga Science: academic.oup.com/gigascience

GlobalSoilMap: globalsoilmap.net

GODAN Agrisemantics Map: vest.agrisemantics.org/about/structure?qt-content_organization_tabs=3#qt-content_organization_tabs

GRIB (WMO): wmo.int/pages/prog/www/WDM/Guides/Guide-binary-2.html

GRIS: wheatpedigree.net/

Guideline Foresight (JRC): ec.europa.eu/jrc/sites/default/files/jrc-foresight-study-web_en.pdf

Handle system: handle.net/

Juha Hakala 2010: persid.org/downloads/PI-intro-2010-09-22.pdf and metadaten-twr.org/2010/10/13/persistent-identifiers-an-overview/

Hindawi Publishing Corporation: hindawi.com/journals/dpis/

HS Codes: foreign-trade.com/reference/hscode.htm

ICC (Code Lists): iccsafe.org/

INSPIRE Code List register: inspire.ec.europa.eu/codelist

ISO/TC23 – Tractors and machinery: iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=47002&published=on&includesc=true

KldB: statistik.arbeitsagentur.de/Navigation/Statistik/Grundlagen/Klassifikation-der-Berufe/KldB2010/KldB2010-Nav.html

LinkedIN: linkedin.com

Metadata list (DCC): dcc.ac.uk/resources/metadata-standards/list

MIAPPE: miappe.org/

National Agricultural Library: nal.usda.gov/

Natural Resource Conservation Service (NRSC): nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849

nestor: langzeitarchivierung.de

netCDF: unidata.ucar.edu/software/netcdf/docs/faq.html#whatisit

OAI-PMH: openarchives.org/pmh/

OGC Networks: ogcnetwork.net/wcs

Ontology Lookup Service (OLS): ebi.ac.uk/ols/index

Ontology of Units and Measures (OM): wurvoc.org/vocabularies/om-1.6/

OpenAIRE: openaire.eu

Open Database License (ODbL): opendatacommons.org/licenses/odbl/

OpenGeoSpatial: opengeospatial.org/standards/wms

Open Tree of Life (taxonomy): opentreeoflife.org

ORCID: orcid.org

Quali-Service: qualiservice.org/

Quantities, Units, Dimensions and Types (QUDT) (ontology): qudt.org/release2/qudt-catalog.html

Pensoft: biodiversitydatajournal.com/

PIAF: gil.de/dokumente/berichte/DDD/R9_19990112.pdf

re3data.org: re3data.org

ReDBox: redboxresearchdata.com.au/

Research Gate: researchgate.net

ResearcherID: researcherid.com

Scholix: scholix.org/

Scopus: scopus.com

Sustainability Reporting Guidelines: globalreporting.org/information/g4/Pages/default.aspx

Trac (List of data journals): proj.badc.rl.ac.uk/preparde/blog/DataJournalsList

UNESCO: uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf

Unified Code for Units of Measure (UCUM): unitsofmeasure.org/trac

Uniform Fertilizer Tonnage Reporting System (UFTRS): agriculture.ks.gov/docs/default-source/pest---fert-uftrs/pf-uftrs-codes.pdf?sfvrsn=0

University of Bremen (metadata schemas): elib.suub.uni-bremen.de/edocs/00103310-1.pdf

VocBench: aims.fao.org/vest-registry/tools/vocbench

Wiley: onlinelibrary.wiley.com/journal/10.1002/(ISSN)2049-6060

5 Reference List

Standards

aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus (Aug-25-2017)

ANSI/NISO Z39.85-2012: The Dublin Core Metadata Element Set

ANSI/NISO Z.39.84-2005: Syntax for the Digital Object Identifier

ASTM E1910 / E 1910M - 15: Standard Test Method for Agricultural pH Control Agents, Measurement of pH Change and Buffering Capacity

BS ISO 11788-1:1997: Electronic data interchange between information systems in agriculture. Agricultural data element dictionary

DIN 1301-1:2010 - Einheiten - Teil 1: Einheitennamen, Einheitenzeichen

DIN 1313:1998-12: Quantities

DIN 1319-1:1995-01: Fundamentals of Metrology. Part 1: Basic Terminology

DIN 4220:2008-11: Bodenkundliche Standortbeurteilung - Kennzeichnung, Klassifizierung und Ableitung von Bodenkennwerten

DIN 7807:1995-02: Agricultural drive wheel tractor tyres in radial construction - Service description (load index - speed symbol) marked tyres

DIN 8113:2009-02: Weigh-in-Motion of Road Vehicles

DIN 11389:1988-04: Tractors and agricultural machinery - Combines - Definitions, Characteristics, Performance

DIN 13303-1:1982-05: Stochastics; probability theory, common fundamental concepts of mathematical and of descriptive statistics; concepts, signs and symbols

DIN 13303-2:1982-11: Stochastics - mathematical statistics; concepts, signs and symbols.

DIN 18121-2:2012-02: Soil, investigation and testing – Water content – Part 2: Determination by rapid methods

DIN 18123:2011-04: Soil, investigation and testing – Determination of grain-size distribution

DIN 18128:2002-12: Soil - Investigation and testing - Determination of ignition loss

DIN 18709-6:2016-04: Concepts, abbreviations and symbols in geodesy - Part 6: Geodetic reference systems and reference surfaces

DIN 18916:2002-08: Vegetation technology in landscaping - Plants and plant care

DIN 18917:2002-08: Vegetation technology in landscaping — Turf and seeding

DIN 19682-1:2007 - Soil quality - Field tests - Part 1: Determination of soil color

DIN 19682-2:2014 - Soil quaility - Field Tests - Part 2: Determination of soil texture

DIN 19682-5:2007 - Soil quaility - Field Tests - Part 5: Determination of soil moisture

DIN 19682-7:2015 - Soil quaility - Field Tests - Part 7: Determination of infiltration rate by double ring infiltrometer

DIN 19682-8:2012 - Soil quaility - Field Tests - Part 8: Determination of the hydraulic conductivity by auger hole method

DIN 19682-9:2011 - Soil quaility - Field Tests - Part 9: Determination of air permeability

DIN 19682-10:2014 - Soil quaility - Field Tests - Part 10: Description and evaluation of soil structure

DIN 19682-13:2009 - Soil quaility - Field Tests - Part 13: Determination of carbonate, sulfide, pH-value and iron(II)-ions

DIN 19706:2013-02: Soil quality - Determination of the soil erosion risk caused by wind

DIN 19707:2004-05: Soil quality - Classification of the nutrient supply conditions of soil

DIN 19708:2017-08: Soil quality - Predicting soil erosion by water by means of ABAG

DIN 19745:2006-10: Soil quality – Principles of the determination of the water content by Time Domain Reflectometry (TDR) and Time Domain Transmissometry (TDT)

DIN 19746:2005-06: Soil quality - Determination of mineral nitrogen (nitrat and ammonium) in soil profiles (Nmin laboratory method)

DIN 19747:2009-07: Investigation of solids – Pre-treatment, preparation and processing of samples for chemical, biological and physical investigations

DIN 31644:2012-04: Information and documentation – Criteria for trustworthy digital archives

DIN 32645:2008-11: Chemical analysis – Decision limit, detection limit and determination limit under repeatability conditions – Terms, methods, evaluation

DIN 32646:2003-12: Chemical analysis - Limit of detection and limit of determination (quantitation) as processing parameters - Estimation in an interlaboratory test under reproducibility conditions; Terms, meaning, proceeding

DIN 38402-1:2011-09: German standard methods for the examination of water, waste water and sludge – General information

DIN 53804-1:2002-04: Statistical evaluation - Part 1: Continuous characteristics

DIN 55350-100: 2017 - Concepts for quality management and statistics – Part 100: Quality management

DIN 66115:1983-02: Particle size analysls - Sedimentation analysis in the gravitational field - pipette method

DIN 66270:1998: Information technology — Software document evaluation — Quality characteristics

DIN 70020-5:1986-12: Automotive engineering - tyres and wheels - concepts and measuring conditions

DIN EN 15309:2007 - Characterization of waste and soil – Determination of elemental composition by X-ray fluorescence

DIN EN 15587:2014 - Cereals and cereal products – Determination of Besatz in wheat (Triticum aestivum L.), durum wheat (Triticum durum Desf.), rye (Secale cereale L.) and feed barley (Hordeum vulgare L.)

DIN EN 25663:1993 Water quality - Determination of Kjeldahl nitrogen - Method after mineralization with selenium

DIN SPEC 35810:2014-11: Stakeholder Engagement - Guidelines for decision making processes dealing with climate change

EN 709:1997: Agricultural and forestry machinery – Pedestrian controlled tractors with mounted rotary cultivators, motor hoes, motor hoes with drive wheel(s) – Safety;

EN 12527:1998: Castors and wheels — Test methods and apparatus

EN 15934:2012: Sludge, treated biowaste, soil and waste – Calculation of dry matter fraction after determination of dry residue or water content

EN 15936:2012: Sludge, treated biowaste, soil and waste – Determination of total organic carbon (TOC) by dry combustion

EN 16760:2015: Bio-based products – Life Cycle Assessment

EN ISO 6709:2009: Standard representation of geographic point location by coordinates

EN ISO 19101-1:2014: Geographic information – Reference model - Part 1: Fundamentals

EN ISO 19105:2005: Geographic information – Conformance and testing

EN ISO 19106:2006: Geographic information – Profiles

EN ISO 19107:2005: Geographic information – Spatial schema

EN ISO 19108:2005: Geographic information - Temporal schema

EN ISO 19111-2:2012: Geographic information – Spatial referencing by coordinates – Part 2: Extension for parametric values

EN ISO 19111:2007: Geographic information – Spatial referencing by coordinates

EN ISO 19112:2005: Geographic information – Spatial referencing by geographic identifiers

EN ISO 19116:2006: Geographic information – Positioning services

EN ISO 19118:2011: Geographic information – Encoding

EN ISO 19123:2007: Geographic information – Schema for coverage geometry and functions

EN ISO 19125-2:2006: Geographic information – Simple feature access – Part 2: SQL option.

EN ISO 19128:2008: Geographic information – Web map server interface

EN ISO 19131:2008: Geographic information – Data product specifications

EN ISO 19133:2007: Geographic information – Location-based services – Tracking and navigation.

EN ISO 19135:2015: Geographic information – Procedures for item registration

EN ISO 19136:2009: Geographic information – Geography Markup Language (GML)

EN ISO 19142:2010: Geographic information – Web Feature Service

EN ISO 19143:2012: Geographic information – Filter encoding

EN ISO 19156:2013: Geographic information – Observations and measurements

EN ISO 20988-2007: Air quality – Guidelines for estimating measurement uncertainty

EN ISO 80000-1:2013: Quantities and units – Part 1: General

ISO 500-1:2014: Agricultural tractors - Rear-mounted power take-off types 1, 2, 3 and 4 - Part 1: General specifications, safety requirements, dimensions for master shield and clearance zone

ISO 520:2010: Cereals and pulses – Determination of the mass of 1 000 grains

ISO 639-1:2002-07: Codes for the representation of names of languages - Part 1: Alpha-2 code

ISO 639-2:1998-11: Codes for the representation of names of languages - Part 2: Alpha-3 code

ISO 1636:2012-02: Space data and information transfer systems - Audit and certification of trustworthy digital repositories

ISO 2057:1981: Agricultural tractors Remote control hydraulic cylinders for trailed implements

ISO 2332:2009: Agricultural tractors and machinery - Connection of implements via three-point linkage - Clearance zone around implement

ISO 2709:2008: Information and documentation - Format for information exchange

ISO 3166-1:2013: Codes for the representation of names of countries and their subdivisions – Part 1: Country codes

ISO 3534-1:2006: Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability

ISO 3534-2:2006: Statistics – Vocabulary and symbols – Part 2: Applied statistics

ISO 3600:2015: Tractors, machinery for agriculture and forestry, powered lawn and garden equipment - Operator's manuals - Content and format.

ISO 3767-2:2008: Tractors, machinery for agriculture and forestry, powered lawn and garden equipment - Symbols for operator controls and other displays - Part 2: Symbols for agricultural tractors and machinery

ISO 4002 (1-2): Equipment for sowing and planting

ISO 4004:1983: Agricultural tractors and machinery - Track widths

ISO 4197:1989: Equipment for working the soil - Hoe blades - Fixing dimensions

ISO 4223-1:2017-12: Definitions of some terms used in tyre industry - Part1: Pneumatic tyres

ISO 4226:2007: Air quality – General aspects – Units of measurement

ISO 4254 (1-12): Agricultural machinery –Safety

ISO 5527:2015: Cereals – Vocabulary

ISO 5663:1984-05: Water quality; Determination of Kjeldahl nitrogen; Method after mineralization with selenium

ISO 5678:1993: Agricultural machinery; equipment for working the soil; S-tines: main dimensions and clearance zones

ISO 5679:1979: Equipment for working soil - Disks -Classification - Main fixing dimensions and specifications

ISO 5680:1979: Equipment for working soil - Tines and shovels for cultivators - Main fixing dimensions

ISO 5687:1999-09: Equipment for harvesting - Combine harvesters - Determination and designation of grain tank capacity and unloading device performance

ISO 6107 (1-9): Water quality – Vocabulary

ISO 6165:2012: Earth-moving machinery – Basic types – Identification and terms and definitions

ISO 6689-1:1997: Equipment for harvesting - Combines and functional components - Part 1: Vocabulary

ISO 6880:1983: Machinery for agriculture; Trailed units of shallow tillage equipment; Main dimensions and attachment points

ISO 7168-1:1999: Air quality – Exchange of data – Part 1: General data format

ISO 7256 (1-2): Sowing equipment - Test methods

ISO 7867-1: 2005 Tyres and rims (metric series) for agricultural tractors and machines — Part 1:Tyre designation, dimensions and marking, and tyre/rim coordination

ISO 7971 (1-3): Cereals - Determination of bulk density, called mass per hectolitre

ISO 8524:1986: Equipment for distributing granulated pesticides or herbicides -Test method

ISO 8601:2004: Data elements and interchange formats – Information interchange – Representation of dates and times

ISO 8664:2005(E) - Tyres for agricultural tractors and machines — Code-designated and service-description marked radial drive-wheel tyres

ISO 8909-1:1994: Forage harvesters - Part 1: Vocabulary

ISO 8910:1993: Machinery and equipment for working the soil - Mouldboard plough working elements- Vocabulary

ISO 8945:1989: Equipment for working the soil - Rotary cultivator blades - Fixing dimensions

ISO 8947:1993: Agricultural machinery - equipment for working the soil - S-tines - test method

ISO 9000:2015: Quality management systems – Fundamentals and vocabulary

ISO 9001:2015: Quality management systems – Requirements

ISO 9004:2009: Managing for the sustained success of an organization – A quality management approach

ISO 9169:2006: Air quality –Definition and determination of performance characteristics of an automatic measuring system

ISO 10005:2005: Quality management systems – Guidelines for quality plans

ISO 10006:2003: Quality management systems - Guidelines for quality management in projects

ISO 10007:2003: Quality management systems - Guidelines for configuration management (ISO 10007:2003)

ISO 10012:2003: Measurement management systems – Requirements for measurement processes and measuring equipment

ISO 10014:2006: Quality management - Guidelines for realizing financial and economic benefits

ISO 10381-1:2003-08: Soil quality - Sampling - Part 1: Guidance on the design of sampling

ISO 10390:2005 - Soil quality - Determination of pH

ISO 10627-2:1996: Hydraulic agricultural sprayers -- Data sheets -- Part 2: Technical specifications related to components

ISO 10693:1995: Soil quality – Determination of carbonate content – Volumetric method

ISO 10694:1995-03: Soil quality - Determination of organic and total carbon after dry combustion (elementary analysis)

ISO 11047:2003-05: Soil quality - Determination of cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc in aqua regia extracts of soil - Flame and electrothermal atomic absorption spectrometric methods

ISO 11063:2012: Soil quality – Method to directly extract DNA from soil samples

ISO 11074:2015: Soil quality – Vocabulary

ISO 11260:1994: Soil quality – Determination of effective cation exchange capacity and base saturation level using barium chloride solution.

ISO 11261:1995: Soil quality - Determination of total nitrogen - Modified Kjeldahl method

ISO 11263:1996 - Soil quality - Determination of phosphorus - Spectrometric determination of phosphorus soluble in sodium hydrogen carbonate solution

ISO 11265:1994 - Soil quality - Determination of the specific electrical conductivity

ISO 11272:1998: Soil quality – Determination of dry bulk density

ISO 11274:1998: Soil quality – Determination of the water-retention characteristic – Laboratory methods

ISO 11276:1995: Soil quality – Determination of pore water pressure –Tensiometer method

ISO 11277:1998: Soil quality – Determination of particle size distribution in mineral soil material – Method by sieving and sedimentation

ISO 11461:2001: Soil quality – Determination of soil water content as a volume fraction using coring sleeves – Gravimetric method

ISO 11464:2006 - Soil quality - Pretreatment of samples for physico-chemical analysis

ISO 11466:1995: Soil quality - Extraction of trace elements soluble in aqua regia

ISO 11783-1:2007: Tractors and machinery for agriculture and forestry — Serial control and communications data network - Part 1: General standard for mobile data communication

ISO 11786:1995: Agricultural tractors and machinery - Tractor-mounted sensor interface - Specifications

ISO 11843-1:2004-09: Capability of detection. Part 1: Terms and Definitions

ISO 12782-1:2012: Soil quality - Parameters for geochemical modelling of leaching and speciation of constituents in soils and materials – Part 1: Extraction of amorphous iron oxides and hydroxides with ascorbic acid

ISO 12782-2:2012: Soil quality – Parameters for geochemical modelling of leaching and speciation of constituents in soils and materials – Part 2: Extraction of crystalline iron oxides and hydroxides with dithionite

ISO 12782-3:2012: Soil quality – Parameters for geochemical modelling of leaching and speciation of constituents in soils and materials – Part 3: Extraction of aluminium oxides and hydroxides with ammonium oxalate/oxalic acid

ISO 12782-4:2012-09: Soil quality – Parameters for geochemical modelling of leaching and speciation of constituents in soils and materials – Part 4: Extraction of humic substances from solid samples

ISO 12782-5:2012: Soil quality – Parameters for geochemical modelling of leaching and speciation of constituents in soils and materials – Part 5: Extraction of humic substances from aqueous samples

ISO 13065:2015: Sustainability criteria for bioenergy

ISO 13196:2013 - Soil quality – Sreening soils for selected elements by energy-dipersive X-ray fluorescence spectrometry using a handheld or portable instrument

ISO 13878:1998: Soil quality -- Determination of total nitrogen content by dry combustion ("elemental analysis")

ISO 14001:2015: Environmental management systems – Requirements with guidance for use

ISO 14021:2016: Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)

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