crea Journals

ANNALS OF SILVICULTURAL RESEARCH
40 (1), 2016: 64-69

http://ojs-cra.cilea.it/index.php/asr

ASR

Assessing indicators of forest ecosystem health

Bertolotto P.[1], Calienno L.[2], Conforti M.[3], D'Andrea E.[1], Lo Monaco A.[2], Magnani E.[1], Marinšek A.[4], Micali M.[1], Picchio R.[2], Sicuriello F.[1], Spina R.[2], Venanzi R.[2]

Received 16/03/2016- Accepted 06/04/2016 - Published online 19/07/2016

C/N Ratio in soil

Full text The C/N ratio (C:N) or carbon-to-nitrogen ratio is a ratio of the mass of carbon to the mass of nitrogen in a substance.

Rationale All organic matter is made up of substantial amounts of carbon (C) combined with lesser amounts of nitrogen (N). The balance of these two elements in an organism is called the carbon-to-nitrogen ratio (C/N ratio). Forest management affects soil C and N storage, due to the variation of microclimatic characteristics and input of new organic matter. The general trends found by Johnson and Curtis (2001) indicate that high C/N ratio of residues are incorporated into soils over the short-term, with soil C re-equilibrating to lower levels and C/N ratios becoming more similar to background as time passes. Saw-log forest removal tend to increase the amount of carbon and nitrogen in the soil in the short term. This process is due to the rapid incorporation of small size carbon material into the soil, which allow microorganisms to decompose the carbon molecules and release the excess of nutrients to the soil. The abundance of carbon is taken by microbes which at the same time helps the immobilization of nitrogen in the soil. Bacteria play a very important role in the decomposition process. Bacteria quickly break down organic matter and most efficiently when their substratum source has a C:N ratio of about 25:1. This means that each part of bacteria substratum should contain, ideally, 25 times as much carbon as nitrogen. If C/N ratios are higher, decomposition will be slow.

Possible pitfalls This indicator was evaluated in a short period (two years), therefore it can be utilized only in the first years after the harvesting.

Methods

ISO 10694 (C), ISO 13878 (N);

Principle: dry combustion of sample (weights around 0.2 g) at temperature of 1350 °C, followed by IR and thermal conductance analysis of burned gases (CO_2 and N_2).

Measurement units No units. C/N is an index.

Measurement time Soil samples should be collected in autumn, after growing season. C and N from soil samples can be measured anytime in a laboratory.

Before [Y]

After [Y]

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Stand	3	3	Deadwood

Results from ManFor C.BD.

Indicator name	Site	Before	After
C/N ratio	Trnovo, Snežnik, Kočevski Rog (logged 50 % of growing stock)	32	41
C/N ratio	Trnovo, Snežnik, Kočevski Rog (logged 100 % of growing stock)	30	38
C/N ratio	Cansiglio Innovative	19	22
C/N ratio	Cansiglio Control	21	21
C/N ratio	Cansiglio Traditional	20	21
C/N ratio	Chiarano Traditional	18	21
C/N ratio	Chiarano Innovative 80	19	21
C/N ratio	Chiarano Innovative 40	19	20
C/N ratio	Mongiana Innovative	17	17
C/N ratio	Mongiana Control	18	18
C/N ratio	Mongiana Traditional	17	18

The indicator is well describing the phenomena of increasing C/N ratio in the case of Dinaric fir-beech forests, where high logging intensities were applied. On the base of average C/N ratio, it demonstrates increasing of C/N values towards an unfavourable ratio between C and N for the organic matter decomposition.

Humus form

Full text Sequence and "morpho-functional"

[1] CNR-IBAF, National Research Council of Italy, Institute for Agro-environmental and Forest Biology, Monterotondo (RM), Italy
[2] DAFNE - Department of Agriculture, Forests, Nature and Energy, Università della Tuscia, Italy
[3] CNR-ISAFOM, National Research Council of Italy, Institute for Agriculture and Forest Mediterranean Systems, Rende (CS), Italy.
[4] Department of Forest Ecology, Slovenian Forestry Institute, Ljubljana, Slovenia

http://dx.doi.org/10.12899/ASR-1214

features of organic (OL, OF, OH, H) and underlying organo-mineral horizons (A, AE, Aa) of soil.

Rationale The humus form is the part of the topsoil that is strongly influenced by organic matter and coincides with the sequence of organic (OL, OF, OH, H) and underlying organo-mineral horizons (A, AE, Aa) (Zanella et al. 2011a, Zanella et al. 2011b). Humus forms are influenced by biotic (litter amount and quality, soil-dwelling microbial and animal communities) and abiotic factors (climate, bedrock, soil type) according to a variety of key processes (Ponge 2003, Ponge et al. 2014, Andreetta et al. 2015). More recently, humus forms have been found to be significant indicators of soil organic carbon (SOC) storage (Andreetta et al. 2011, Bonifacio et al. 2011, De Nicola et al. 2014, De Vos et al. 2015), also in correlation with stand age and management of forest (Hedde et al. 2008, Faggian et al. 2012)

Systematics

Systematics of humus form follows the most recent "morpho-functional" classification (Zanella et al. 2011a, Zanella et al. 2011b) based on biological, ecological and pedological features of organic and organo-mineral horizons observed in the field. This systematics consists in a complete set of identification keys based on diagnostic horizons and environmental factors. It can be applied to every kind of soil (never water saturated and saturated – submerged soils) the upper part of which (topsoil) is not permanently disturbed by human activity.

In the 2013 (Jabiol et al. 2013) this systematics has been extended and modified, without any change in diagnostic horizons, in order to embrace a wide array of humus forms at worldwide level and it has been proposed for inclusion in the World Reference Base for Soil Resources (IUSS 2006).

Humus form ecology

Humus forms play a key central role in the functional biodiversity of terrestrial ecosystems. They are the stable, visible result of most animal and microbial life in the soil and, in a feedback process, they condition the development of terrestrial plant, animal and microbial communities (Ponge 2003, Ponge et al. 2013).

MULL, MODER and MOR, are the main “humus form system” (Zanella 2014) characterized by the same ecological determinants (biotic, abiotic or mixed), correspond to a scale of decreasing nutrient availability, biological diversity and activity and increasing colder conditions. Animals, microbes and plants are involved in positive (building forces) and negative (stabilizing forces) feed-back relationships most of them taking place in the humus profile (Ponge et al. 2010). AMPHI and TANGEL, insert more recently in the classification (Zanella et al. 2009), correspond respectively to a strongly seasonal and extremely high mountain climatic condition upon calcareous bedrock.

MULL is characterized by an intense mixing of organic matter with mineral matter with rapid turnover (≤ 3 years) and high activity of edaphic fauna especially of anecic earthworms. These forms develop on temperatures not limiting the biological activity and non-acid substrates, usually carbonate bedrocks and easily degradable litter (C/N <30). Both the mineralization and the humification are quick and organic horizons are generally limited to short and thick OL and OF horizons. Organic matter is decomposed in 1 or 2 years and SOC is mainly stored in the “Clay-Humic Complexes” within the A horizon.

MODER is characterized by a less rapid transformation of litter by meso and macrofauna arthropods, (springtails, isopods, Diptera etc.) and fungi, resulting in the accumulation of organic humus. These forms develop on low temperatures, from soil carbonates or acidified or with a easily biodegradable litter unfavorable to the life of anecic and endogeous earthworms. Moder is characterize by slow (2-7 years) decomposition and carbon is stored in both horizons organic (humic components) than in those organic-mineral.

MOR is characterized by slow transformation and accumulation of undecayed plant debris, with a sharp transition to the mineral soil. These forms develop on low temperatures, usually on silicate rocks or without easily biodegradable litter. The decomposition of litter occurs primarily to mushroom (often mycorrhizal) and the edaphic fauna activities is very poor. Mor is characterize by very slow (> 7 years) decomposition and SOC is stored in both horizons organic (humic components) than in those organic-mineral.

AMPHI (“twin humus”) develop on calcareous substrates and it shows both characters of Mull (biomacro-structured organo-mineral horizon) and Moder (accumulated organic humus), due to periodically milder (warmer and umid soil-climate conditions in strongly seasonal Alpine and Mediterranean environments. SOC is stored both in organic horizons (humic components) and in “Clay-Humic Complexes” within the A horizon.

TANGEL expresses particular characters at high elevation and on hard calcareous rocks with slow litter turnover due to low temperature, summer drought or excess of carbonates. For the most of the year faunal activities and decomposition of organic matter are strongly limited by mountain climate and temperature, continental distribution of rainfall, higher in summer. SOC is stored in organic horizons (humic components).

Methods

The experimental design was planned in three phases:

1. macroscopic description of humus form profile in the field;
2. samples collection for each horizon and storage at 4°C;
3. laboratory analysis: estimation of organic carbon ISO 10694, total nitrogen ISO 13878 and pH of A horizon ISO 10390;
4. determination of humus form.

Measurement units No units. Humus form is a quality indicator.

Measurement time

Humus samples should be collected in autumn, after growing season. C, N and pH from soil samples can be measured anytime in a laboratory.

Before [Y]

After [Y]

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Stand	3	3	Deadwood,Soil C/N

Results from ManFor C.BD.

The experimental design involved Cansiglio, Chiarano and Mongiana sites and it provided 27 samples of humus within each site (9 for each treatment), collected before and repeated after the implementation of the silvicultural treatments. Overall 162 profiles of humus were detected for a total of 477 analyzed samples. A wide range of humus forms has been found in the two samplings. All humus forms found in the three sites are "Terroform" that is never submerged and / or saturated in water, except for a few days a year. In Cansiglio and Chiarano sites, where the bedrock is limestone with pH of A horizon sub-acid to neutral ranging from 5.5 to 6.7, humus forms has been classified as MULL or AMPHI. In Mongiana site instead, bedrock is silicate and the organic-mineral horizon (A, AE, E) gives a reaction from strongly acid to acidic, with a pH ranging from 3.8 to 5.1, humus forms has been classified as MODER or MOR (Fig.1).

The effect of treatments has involved most OL and OF horizons with a trend from less active forms to more active ones. The opening of the canopy, which changes the amount of water and solar energy that reaches the soil and the different intake of litter, can lead to a change of micro-climatic conditions. In particular it has detected a change of the horizon thickness OF, diagnostic feature for humus forms determination.

In Cansiglio and Chiarano sites where predominate AMPHI and MULL humus systems has detected a decrease horizon OF probably because of increased activation of earthworms anecici responsible for the decomposition of litter and incorporation of organic matter within the A horizon.

In Mongiana site, where MODER and MOR were predominant, because of the acidic conditions not suitable for earthworms, we observed an increase of OF. This can be explained by the activation of the decompositor fauna of the soil (i.e. arthropodos).

Indicator name	Site	Time	EUMULL	MESOMULL	OLIGOMULL	DYSMULL	LEPTOAMPHI	EUMACROAMPHI	HEMIMODER	EUMODER	DYSMODER	HEMIMOR	HUMIMOR
Humus form	Cansiglio Innovative	Before				7	1	1					
		After			5	2		2					
Humus form	Cansiglio Control	Before				3		6					
		After		1		3	1	4					
Humus form	Cansiglio Traditional	Before			1	2		6					
		After		2	5	1		1					
Humus form	Chiarano Traditional	Before		2	3	2	1	1					
		After	2		3	4							
Humus form	Chiarano I80	Before	2		2	4		1					
		After	1	2	1	4	1						
Humus form	Chiarano I40	Before	2	2		5							
		After		3	3	3							
Humus form	Mongiana Innovative	Before							8				
		After							7	2			
Humus form	Mongiana Control	Before							4	4	1		
		After							5	2	2		
Humus form	Mongiana Traditional	Before							6		1		2
		After							4	1	3		1

Table 1- Number of humus forms collected before and after for each selvicoltural treatments.

GHG emissions - 2.1

The Criterion 2 (Maintenance of Forest Ecosystem Health and Vitality) includes the "Deposition and concentration of air pollutants on forest and other wooded land" among its indicators (FOREST EUROPE 2015).

Full text Deposition of air pollutants on forest and other wooded land, classified by N, S and base cations.

Rationale This indicator is one of the basic figures of forest operation planning and it is useful for various purposes. GHG emissions should be assessed. Planning, design and execution of forest operation in silvicultural treatments shall take into consideration also the potential impacts due to air pollutions.

Furthermore, this indicator is mainly linked to indicator 5.1, 5.2 (MCPFE 2003).

Methods

Yard pollutant emissions due to the extraction operations were determined as described in Vusic et al. (2013). Emissions generated from the fuel were calculated as the sum of emissions produced by fuel combustion (Efc) and emissions produced during the fuel production, transport, and distribution (Efp). The emissions related to lubricant consumption were calculated as the sum of the emissions produced by both the production processes (Eop) and the reprocessing of used oils for the purposes of combustion (Eor). The values were referred to CO2eq.

Measurement units

Status: g

Changes: g per m^3

Measurement time

During [Y]

Before [N]

After [N]

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Single yard or typology	2 (inventory technician)	2	5.1-5.2

Results from ManFor C.BD.

Indicator name	Site	Value
CO2eq (g m^{-3})	Cansiglio Traditional	54000
CO2eq (g m^{-3})	Cansiglio Innovative 1	51000
CO2eq (g m^{-3})	Chiarano Traditional	13500
CO2eq (g m^{-3})	Chiarano Innovative 1	12900
CO2eq (g m^{-3})	Chiarano Innovative 2	13100
CO2eq (g m^{-3})	Mongiana Traditional	75000
CO2eq (g m^{-3})	Mongiana Innovative 1	78000
CO2eq (g m^{-3})	Tarvisio Traditional	98100
CO2eq (g m^{-3})	Tarvisio Innovative 1	94800
CO2eq (g m^{-3})	Tarvisio Innovative 2	99100

Tree wounds - 2.4

The Criterion 2 (Maintenance of Forest Ecosystem Health and Vitality) includes the "Forest and other wooded land with damage, classified by primary damaging agent (abiotic, biotic and human induced)" among its indicators (FOREST EUROPE 2015).

Full text Forest and other wooded land with damage, classified by primary damaging agent (abiotic, biotic and human induced) and by forest type.

Rationale This indicator is one of the basic figures of after harvesting evaluation and useful for various purposes. An important aspect to be considered in forest operation planning is the impacts on the environment, especially on residual trees. A range of 0–30% of damaged trees due to forest operations may be considered tolerable. Furthermore, this indicator is mainly linked to indicator 1.2, 1.4.

Methods

Above ground damage was determined by visually inspecting all standing trees. Once a wound was detected, the following data were recorded: tree diameter at breast height (DBH); hierarchical and geographical positions of the tree within the stand; location, size, and depth of the wound. These parameters were translated into numerical classes. Wound size and depth classes were multiplied each other to obtain a synthetic damage severity index. Wounds with an index larger than 6 were considered severe, and capable of affecting tree growth, quality and survival.

Measurement units

Status: %

Changes: % per ha

Measurement time

Before [N]

After [Y]

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Single yard or typology of silvicultural operation	2 (inventory technician)	2	1.2-1.4

Results ManFor C.BD.

Indicator name	Site	Value
Trees wound (%)	Cansiglio Traditional	0 %
Trees wound (%)	Cansiglio Innovative	0 %
Trees wound (%)	Chiarano Traditional	44 %
Trees wound (%)	Chiarano Innovative 40	50 %
Trees wound (%)	Mongiana Traditional	38 %
Trees wound (%)	Mongiana Innovative	20 %
Trees wound (%)	Tarvisio Traditional	6 %
Trees wound (%)	Tarvisio Innovative 1	2 %
Trees wound (%)	Tarvisio Innovative 2	0 %
Trees wound (%)	Chiarano Innovative 80	56 %

QBS-ar variation

Full text Variation of Soil Biological Quality.

Rationale An important aspect to be considered in forest operation planning is the impact on the environment, especially on soil during forest operations (compaction, rutting, soil mixing and displacement). This indicator is one of the basic figures of after harvesting evaluation and useful for various purposes.

Methods

For the microarthropods extraction and QBS-ar index application, three soil cores 100 cm^2 and 10 cm deep were sampled in each soil typology. Microarthropods were extracted using a Berlese-Tüllgren funnel; the specimens were collected in a preserving solution and identified to different taxonomic levels (class for Myriapoda and order for Insecta, Chelicerata and Crustacea) using a stereo microscope. Soil quality was estimated with the QBS-ar index (Parisi et al. 2005, Blasi et al. 2013).

Measurement units

Status: %

Changes: % per ha

Measurement time

Before [Y]

After [Y]

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Single yard or typology	2 (inventory technician)	2	---

Results from ManFor C.BD.

Indicator name	Site	Value
QBS-ar variation (%)	Cansiglio Traditional	65 %
QBS-ar variation (%)	Cansiglio Innovative	40 %
QBS-ar variation (%)	Chiarano Traditional	72 %
QBS-ar variation (%)	Chiarano Innovative 40	33 %
QBS-ar variation (%)	Chiarano Innovative 80	53 %
QBS-ar variation (%)	Mongiana Traditional	57 %
QBS-ar variation (%)	Mongiana Innovative	49 %
QBS-ar variation (%)	Tarvisio Traditional	72 %
QBS-ar variation (%)	Tarvisio Innovative 1	33 %
QBS-ar variation (%)	Tarvisio Innovative 2	53 %

Other potential indicators related to forest ecosystem health

In forest Ecosystem, dynamics are quite slow and the lifespan of the project ManFor C.BD. did not allow to follow them. Other useful indicators will presented here, but without testing them to avoid the creation of misleading data.

Recruitment

Full text Recruitment of forest habitat type (FHT) dominant species (Lexerød and Eid, 2005).

Rationale The recruitment is defined as the share of dominant and co-dominant tree species with diameter at breast height ≥ X cm.

Recruitment (addressed by Klopčič and Bončina 2011, Nagel et al. 2014 and many others) is well investigated and explained in the ecosystem disturbance studies while the biodiversity studies mostly neglect it. However, because one of the items of the conservation status definition (the conservation status of its typical species is also favorable) directly addresses the viability of the tree-species composition of a FHT, the indicator is relevant. The context of the conservation status of FHT also should be understood as sustainable development of FHT. In this context, recruitment is the indicator of the possibility of a FHT to survive in the long run.

Methods

Counting tree species individuals with certain dimensions on the permanent sample plots.

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Stand	2	2	Regeneration

Regeneration

Full text Regeneration of forest habitat type (FHT) dominant species.

Rationale The regeneration may be defined as the process of stand renewal by means of self-sown seeds, root suckers (adventitious roots), coppicing or artificially-sown seeds. The result of regeneration is an established young growth with the height ranging between $0 \text{ m} < h < 1.3$ m.

Successful regeneration is the precondition of sustainable forest habitat type development. A sufficient number of saplings and small trees is also an indicator of good environmental conditions (local climate, wildlife carrying capacity).

Methods

Counting tree species saplings and small trees ($h < 1.3$ m) on the permanent sample plots.

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Stand	2	3	Regeneration

Herbivories damage on regeneration

Full text Herbivory may be defined as the process whereby the animal eats or browses palatable tree species such as white fir, maple sp., etc.

Rationale Herbivory/browsing is the process that undermines successful regeneration of forest stands.

Methods

Counting damaged small trees (completely or partly browsed tops) on the permanent sample plots.

Feasibility

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Stand	2	3	Wildlife carrying capacity, Regeneration

References

Andreetta A., Cecchini G., Bonifacio E., Comolli R., Vingiani S., Carnicelli S. 2016 - *Tree or soil? Factors influencing humus form differentiation in Italian forests.* Geoderma 264: 195-204.

Andreetta A., Ciampalini R., Moretti P., Vingiani S., Poggio G., Matteucci G., Tescari F., Carnicelli S. 2011 - *Forest humus forms as potential indicators of soil carbon storage in Mediterranean environments*. Biol. Fertil. Soils 47: 31-40.

Bonifacio E., Falsone G., Petrillo M., 2011 - *Humus forms, organic matter stocks and carbon fractions in forest soils of northwestern Italy.* Biol. Fertil. Soils 47: 555-566.

Brêthes A., Brun J.J., Jabiol B., Ponge J.F., Toutain F. 1995 – *Classification of forest humus forms: a French proposal.* Ann Sci For, 52: 535-546. http://dx.doi.org/10.1051/forest:19950602 Chauvat.

De Nicola C., Zanella A., Testi A., Fanelli G., Pignatti S. 2014 - *Humus forms in a Mediterranean area (Castelporziano Reserve, Rome, Italy): Classification, functioning and organic carbon storage.* Geoderma 235-236: 90-99.

De Vos B., Cools N., Ilvesniemi H., Vesterdal L., Vanguelova E., Carnicelli S. 2015 - *Bench-mark values for forest soil carbon stocks in Europe: results from a large scale forest soil survey.* Geoderma 251-152: 33-46.

Faggian V., Bini C., Zilioli D. M. 2012 - *Carbon stock evaluation from topsoil of forest stands in NE Italy.* International journal of phytoremediation 14(4): 415-428.

Hedde M., Aubert M., Decaëns T., Bureau F. 2008 - *Dynamics of soil carbon in a beechwood chronosequence forest.* Forest Ecology and Management 255(1): 193-202.

IUSS, ISRIC, FAO 2006 - *World reference base for soil resources - a framework for international classification, correlation and communication.* World Soil Resources Report. 103 p.

Jabiol B., Zanella A., Ponge J. F., Sartori G., Englisch M., Van Delft B., Le Bayon, R. C. (2013). *A proposal for including humus forms in the World Reference Base for Soil Resources (WRB-FAO).* Geoderma 192: 286-294.

Johnson D.W., Curtis P.S. 2001 - *Effects of forest management on soil C and N storage: meta analysis.* Forest Ecology and Management 140: 227-238.

Klopcic M., Boncina A. 2011 - *Stand dynamics of silver fir (Abies alba Mill.) - European beech (Fagus sylvatica L.) forests during the past century: a decline of silver fir?* Forestry 84: 259-271.

Lexerød N., Eid T. 2005 - *Recruitment models for Norway spruce, Scots pine, birch and other broadleaves in young growth forests in Norway.* Silva Fenn. 39: 391-406.

Nagel T.A., Diaci J., Jerina K., Kobal M., Rozenbergar D. 2014 - *Simultaneous influence of canopy decline and deer herbivory on regeneration in a conifer-broadleaf forest.* Can. J. For. Res. 45: 266-275.

Ponge J. F., Zanella A., Sartori G., Jabiol B. 2010 - *Terrestrial humus forms: ecological relevance and classification.* DOI: 10.13140/RG.2.1.3713.5521, HAL, Id:hal-00521337 version 1.

Ponge J.F. 2003 -- *Humus forms in terrestrial ecosystems: A framework to biodiversity.* Soil Biol. Biochem. 35: 935-945.

Ponge J.F. 2013 - *Plant-soil feedbacks mediated by humus forms: A review.* Soil Biol. Biochem. 57: 1048-1060.

Ponge J.F., Sartori G., Garlato A., Ungaro F., Zanella A., Jabiol B., Obber S. 2014 - *The impact of parent material, climate, soil type and vegetation on Venetian forest humus forms: A direct gradient approach.* Geoderma 226-227: 290-299.

Vusič D., Šušnjar M., Marchi E., Spina R., Zečić T., Picchio R. 2013 - *Skidding operations in thinning and shelterwood cut of mixed stands - Work productivity, energy inputs and emissions.* Ecological Engineering 61: 216-223.

Zanella A. 2015 – *Novità sulle forme di humus.* In: Atti del II Congresso Internazionale di Selvicoltura. Progettare il futuro per il settore forestale, Firenze, 26-29 novembre 2014. Firenze: Accademia Italiana di Scienze Forestali. Vol. 1:81-90. ISBN 978-88-87553-21-5. http://dx.doi.org/10.4129/2cis-az-nov

Zanella A., Jabiol B., Ponge J. F., Sartori G., De Waal R., Van Delft B., Englisch, M. 2009 - *Toward a European humus forms reference base.* Studi Trentini di Scienze Naturali 85: 145-151.

Zanella A., Jabiol B., Ponge J.F., Sartori G., De Waal R., Van Delft B., Englisch M. 2011a - *A European morpho-functional classification of humus forms.* Geoderma 164: 138-145.

Zanella A., Jabiol B., Ponge J.F., Sartori G., de Waal R., Van Delft B., Graefe U., Cools N., Katzensteiner K., Hager H., Englisch M., Brêthes A., Broll G., Gobat J.M., Brun J.J., Milbert G., Kolb E., Wolf U., Frizzera L., Galvan P., Koli R., Baritz R., Kemmers R., Vacca A., Serra G., Banas D., Garlato A., Chersich S., Klimo E., Langohr R. 2011b - *European Humus Forms Reference Base.*