SLOVENSKI STANDARD
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Metodologija za kvantifikacijo globalnega odtisa kmetijskih pridelkov, vključno z vplivi tal

Methodology to quantify the global agricultural crop footprint including soil impacts

Methodik zur Quantifizierung des globalen Fußabdrucks landwirtschaftlicher Nutzpflanzen einschließlich der Bodenbeeinflussung

Ta slovenski standard je istoveten z: CWA 17898:2022

ICS:

13.080.01	Kakovost tal in pedologija na splošno	Soil quality and pedology in general

SIST CWA 17898:2022 **en,fr,de**

CEN WORKSHOP AGREEMENT

CWA 17898

June 2022

ICS 13.080.01

English version

Methodology to quantify the global agricultural crop footprint including soil impacts

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European foreword

This CEN Workshop Agreement (CWA 17898:2022) has been developed in accordance with the CEN-CENELEC Guide 29 “CEN/CENELEC Workshop Agreements – A rapid prototyping to standardization” and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by a Workshop of representatives of interested parties on 2022-06-06, the constitution of which was supported by CEN following the public call for participation made on 2022-03-02. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

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Introduction

Loss of soil fertility and soil erosion are some of the threats facing mankind. Agricultural systems are complex systems made up of physical, chemical, and biological properties. Soil parameters or factors constitute these properties. A large number of factors involved in the cycles and processes occurring in the soil makes it necessary to study them using different parameters. Due to the complexity of soils, there is currently no consensus on how to assess loss of soil fertility and soil erosion, and they are not included in the usual environmental impact assessment methodologies.

This CWA proposes to use the exergy methodology to evaluate all the impacts of an agroecosystem, including those occurring in the soil. Exergy is a physical property based on the second law of thermodynamics and unifies into a single indicator; all soil parameters relevant for soil fertility assessment.

This CWA is an opportunity to further improve soil quality evaluation by introducing a thermodynamic indicator that will contribute to a rigorous assessment of agricultural processes' impact. The determination of a single comparable, reliable, accurate, and globally accepted indicator will be essential in the near future for the evaluation of soil fertility and agricultural processes efficiency and environmental sustainability.

1 Scope

This European CWA specifies a methodology for identifying, characterizing, and implementing a single indicator to assess the quality and degradation of agricultural soils and the overall impact of the agriculture processes. The agriculture impacts are assessed through the mechanical, fertilization and irrigation activities associated. Furthermore, soil impacts is evaluated accounting with soil erosion and parameters such as nutrients, texture, and organic matter. The developed methodology allows a simple but robust assessment of soil biogeochemical processes and the loss of fertility and degradation.

This European CWA also provides, in Annexes A and B, informative guidance on its use.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20951:2019, *Soil Quality — Guidance on methods for measuring greenhouse gases (*CO_2*,* N_2O*,* CH_4*) and ammonia (*NH_3*) fluxes between soils and the atmosphere*

ISO 11063:2020, *Soil quality — Direct extraction of soil DNA*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
exergy
the maximum amount of work that may theoretically be performed by bringing a resource into equilibrium with its surrounding environment by a sequence of reversible processes

The exergy of a system gives an idea of its evolution potential for not being in thermodynamic equilibrium or dead state with the environment. Unlike mass or energy, exergy is not conserved but destroyed by irreversibilities and lost in all physical transformations until the system reaches a dead state.

Exergy is an extensive property with the same units as energy.

3.2
eco-exergy
the working capacity of organisms due to the genetic information they possess [1]

3.3
crop exergy footprint
CEF
the energy required, considering the irreversibility of the different processes, to carry out the different activities involved in the agricultural process

3.4
impacts on soil
IoS
the energy required, considering the irreversibility of the different processes, to incorporate and replenish substances from a state where the soil and its components have undergone modifications due to the agricultural process to the initial state of the soil

3.5
life cycle assessment
LCA
a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service

4 Measuring soil quality

4.1 The methodology's stakeholders

4.2 General overview of the methodology

The approach described is a comprehensive methodology for assessing the impacts of agricultural processes and their efficiency, including the evaluation of soil quality and its degradation during the process. The approach is based on detailed exergy analysis of the pre-and post-process soil condition of an agricultural production system for:

— studying the resources and allow their exergy calculation for subsequent analysis and evaluation of the worsening or improvement of the agricultural system status;

— defining process constraints and requirements for maintaining or improving the quality of the system;

— identifying the process parameters and select the critical process parameters for process control and optimization.

To apply the methodology, the system boundaries for the main system and parameters shall be defined to apply all steps based on the same scope to ensure comparable results.

In this methodology, Crop Exergy Footprint (CEF) and Impacts on Soil (IoS) are used to analyse and evaluate the agricultural process, including the different activities carried out during cultivation, such as tillage, fertilization, and application of amendments, irrigation, and erosion. By means of these factors, it is possible to describe the state and quality of the soil in different operational states.

A detailed methodology to evaluate the exergy loss due to soil erosion is shown as part of IoS. Diffuse emissions are also accounted for in CEF. The production obtained by the agroecological system is the main output. Accordingly, this methodology evaluates agroecosystem processes considering all exergy flows entering and leaving the system allowing for a detailed analysis of the parameters that may have been affected by crop generation.

The impacts on the agricultural soil are evaluated by means of the Impacts on Soil (IoS), which assesses the hypothetical cost to return the system from the final state to the initial state before the agricultural process. Understanding the fertility of soils as an avoided cost that nature provides leads us to propose exergy replacement cost as a tool for the assessment of the loss of soil fertility due to agriculture practices.

A methodology has been established to evaluate the system in order to reduce the number of variables to be analysed to assess the quality and status of the system.

For an overview of the methodology, see Figure 1.

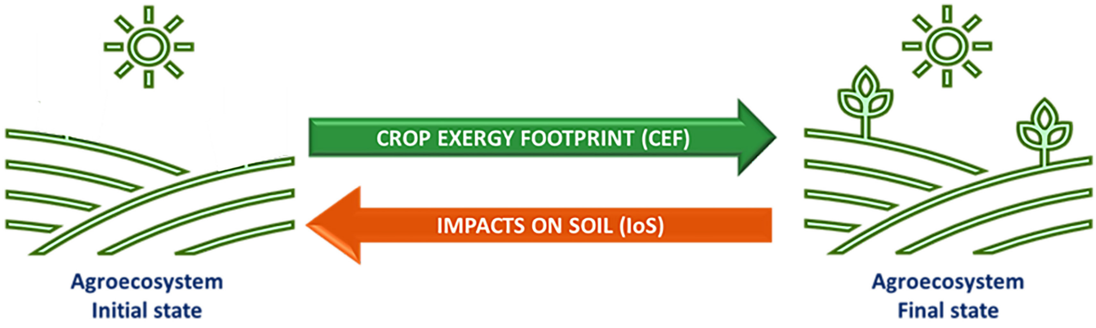

Figure 1 — Schematic overview of the methodology system

4.3 Process analysis

An essential step for the analysis and evaluation of soil quality and process impact is the definition of subfactors, which can be increased or decreased in value depending on their nature (used as an objective function for the evaluation). The methodology recommends the use of the following subfactors for the evaluation: mechanical processes, fertilizers, pesticides and phytosanitary supplies, water, erosion and soil losses and diffuse emissions in CEF. In the case of IoS, the use of the subfactors: nutrients amendment, organic matter amendment, salinity amendment, acidification amendment and erosion soil losses are recommended. These subfactors are described in the following sections and schematically represented in Figure 2 and Figure 3.

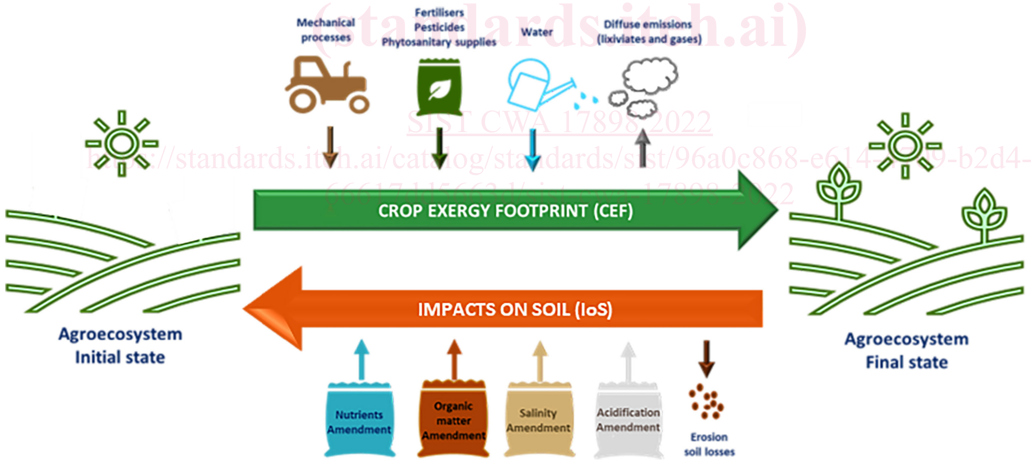

Figure 2 — Illustration of variables used for process and soil study and evaluation

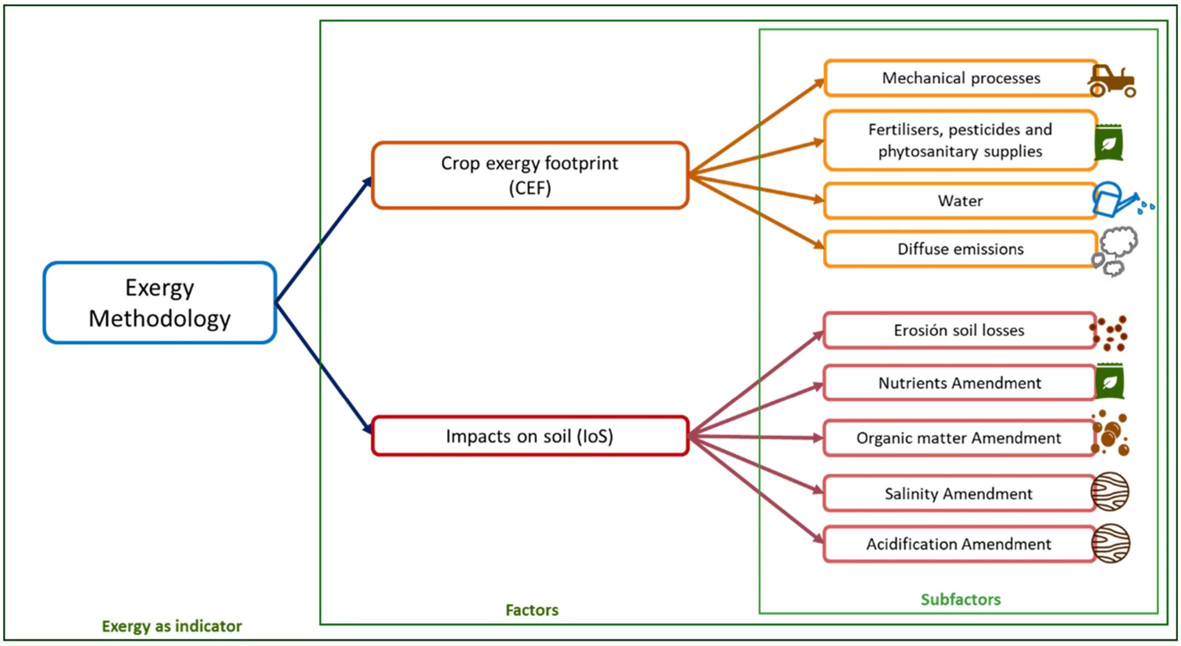

Figure 3 — Methodology concepts diagram

4.3.1 Crop exergy footprint (CEF)

4.3.1.1 General

The Crop exergy footprint (CEF) is the indicator that allows evaluating the energy needed to carry out the activities involved in the cultivation process, considering all the irreversibilities of the processes. This indicator is applied to the agroecosystem as a whole, evaluating all inputs and outputs to the field.

The following exergy inputs to the agricultural system are considered: water, fertilizers and other phytosanitary products, and the energy required in the different mechanical processes.

Two sets of subfactors shall be used within the methodology: Input Subfactors, which focus on the direct activities and processes that are performed on the cultivation system, and Output Subfactors, which focus on environmental impacts associated with the agricultural activities.

Three Input Subfactors are proposed to constitute the main CEF in the methodology:

— Mechanical processes [MJ/ha].

— Fertilizers, pesticides, and phytosanitary products [MJ/ha].

— Water [MJ/ha].

$$\boldsymbol{CEF_1 = \text{Mechanical processes} + \text{Fertilizers, pesticides} + \text{Water}}$$

Where "ha" stands for hectare, which represents the quantity of the main soil of the process under study.

These subfactors provide information on the three main activities used: tillage, irrigation, and fertilization. The exergy indicator alone covers all these processes and provides a quality-weighting factor based on rigorous thermodynamics.

Output subfactors are proposed to constitute the CEF in the methodology:

— Diffuse emissions [kg Element/ha].

CEF_2 = Diffuse emissions

This subfactor is selected to focus on the environmental impact of the agricultural processes. Diffuse emissions complement the Input Factors and allow a joint and global evaluation of the whole process.

All of these subfactors are detailed in the following sections.

4.3.1.2 Mechanical processes

This subfactor is defined as the activities and tasks necessary to prepare the system and improve its capacities and qualities before and after cultivation. Mechanical processes include tillage, sowing, fertilizing, and harvesting. They are responsible to a great extent for the energy consumed in agriculture.

There are two options for the estimation, option 1: when energy consumption in terms of fuel is known; option 2: when no energy consumption is known (Figure 4).

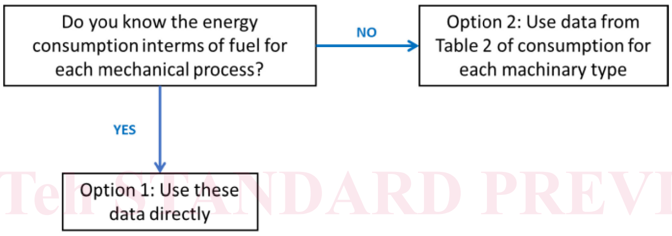

Figure 4 — Diagram explaining the method of calculating the energy consumed during the mechanical process based on the different possible starting data available

The exergy of the mechanical processes (Ex) is proportional to the amount of fuel used (Formula 1). If this amount is known, the conversion to energy units will be performed.

$$Ex\left(\frac{MJ}{ha}\right) = \frac{Fuel(l)\cdot Density\left(\frac{kg}{l}\right)\cdot HHV\left(\frac{MJ}{kg}\right)}{Land\ surface\ (ha)} \tag{1}$$

If the real amount of diesel used is unknown, the following values for the HHV (High Heating Value) and density shall be used (Table 1).

Table 1 — High heating value (HHV) of fuels

	Diesel
HHV (MJ/kg)	45.6
Density (kg/l)	0.84

Tillage processes demand the largest amount of energy, depending on the type of soil and depth of the process. According to the study performed by IDAE [2], the exergy due to different types of tillage can be found in Table 2; a simple classification is made according to texture, light (corresponding to sandy and loamy textures), and heavy (corresponding to clay textures).

Figure 5 shows how the classification of textures is divided according to whether they are considered light or heavy, showed in green or brown, respectively.

A classification is made according to the working depth, which can be either high or low, for depths higher than 15 cm or lower than 15 cm, respectively. However, the classification of low or high depth will depend on each tillage activity and on the working machinery and its technical specifications.

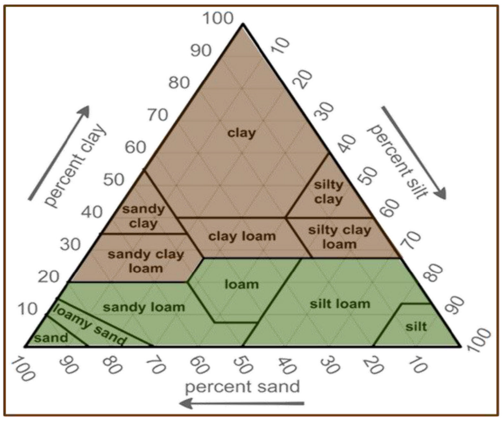

Figure 5 — Texture classification scheme, showing the division between light textures (green) and heavy textures (brown)

In the case of fertilizer or amendment application processes and the seeding process in the cropping system, a data collection shall be used (Table 2), distinguishing two consumptions, which are related to the width of the implement and work in the labour or application rate of the product, called "Normal" and "High". Exergy values according to the doses of product applied should be estimated, based on dose data (kg/ha or l/ha) (Formula 2).

$$Ex\left(\frac{MJ}{ha}\right) = \sum Machinery\ energy\left(\frac{MJ}{ha}\right) \quad (2)$$

Regarding the machinery, within the group of harvesters, there are different types depending on the type of crop (corn, cereal, sunflower, among others). Data are also available for balers, windrowers, and mowers (Table 2).

Table 2 — Energy data on the consumption of tillage implements, seed drills, and harvesters

	Energy (MJ/ha)			
	Light/low	**Light/high**	**Heavy/low**	**Heavy/high**
Subsoiler	687,01	877,85	1 030,51	1 145,02
Mouldboard plow	687,01	839,68	992,35	1 145,02
Disc plow	572,51	725,18	877,85	1 030,51
Chisel plow	343,50	458,01	572,51	687,01
Rolling cultivator	458,01	534,34	687,01	763,34
Disc harrow	229,00	267,17	343,50	381,67
Spring tine cultivator	152,67	229,00	305,34	381,67
Vibrocultivators	229,00	229,00	229,00	229,00
Spike-tooth harrow	190,84	190,84	190,84	190,84

	Energy (MJ/ha)		
	Normal	High	
Centrifugal spreader	57,25	28,63	
Locator spreader	229,00	152,67	
Row seed drill	267,17	152,67	
Direct row seed drill	419,84	229,00	
Single seed drill	248,09	171,75	
Direct single seed drill	267,17	190,84	
Inter-row cultivators - Spreader	171,75	133,59	
Inter-row cultivators	171,75	133,59	
Roller	190,84	152,67	
Hydraulic spray	41,98	28,63	
Spray pump	152,67	76,33	
Manure distributor trailer	267,17	190,84	
	Dose (kg/ha o l/ha)	**Energy (MJ/kg)**	
		Normal	**High**
Centrifugal spreader	250,00	0,229	0,115
Row seed drill	140,00	1,908	1,090
Direct row seed drill	145,00	2,895	1,579
Inter-row cultivators - Spreader	200,00	0,859	0,668
Hydraulic spray	250,00	0,168	0,115
Spray pump	850,00	0,180	0,090
	Energy (MJ/ha)		
	Normal	**High**	
Cereal harvester	572,51	343,50	
Corn harvester	763,34	458,01	
Sunflower harvester	305,34	152,67	
Sugar beet leaf stripper	458,01	381,67	
Sugar beet uprooter	343,50	267,17	
Sugar beet loader	419,84	305,34	
Potato harvester	1 259,52	954,18	
Rotary mowers	286,25	229,0	
Cutter bar	286,25	229,0	
Mower conditioner	267,17	229,0	
Fodder windrow rake	152,67	38,17	

Packer (conventional)	381,672	209,92
Loading bales	45,80	30,53
Wrapping machine	95,42	76,33
Self-loading trailer	95,42	57,25
Hay combine harvester	954,18	763,34
Corn combine harvester	1 374,02	1 030,51

4.3.1.3 Fertilisers, pesticides and phytosanitary supplies

The exergy embodied in all the processes associated with the production of fertilizers, pesticides, and any other phytosanitary supplies applied to the agroecosystem needs to be accounted for. The energy consumed in the transport of the raw materials to the factory and then to the field are also considered. If detailed information is known, this can be calculated for each situation following a life cycle assessment approach (Figure 6). If not, this methodology provides average data for each nutrient obtained after a careful revision of bibliography sources[3], [4], [13]–[15], [5]–[12]; Ecoinvent 3) furthermore a constant transport distance of 500 km in rail and 400 km by trail is considered[16], [17] (Table 3).

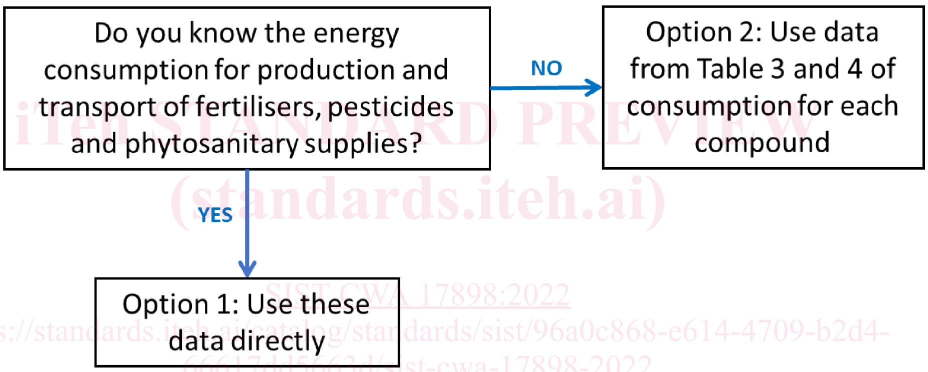

Figure 6 — Diagram explaining the method of calculating the energy consumed during the mechanical process based on the different possible starting data available

Formula 3 should be applied if option 1 is possible, through the data on the nutrient content of the fertilizers used, the fertilizer dose applied, and the exergy involved in the production of the nutrient (Table 3).

$$Ex\left({}^{MJ}\!/_{ha}\right)=\sum\left(Nutrient\ content\ in\ compound\left(\frac{kg\ Nut}{kg\ comp}\right)\cdot Dose\left(\frac{kg\ comp}{ha}\right)\cdot Exergy\ nutrient\ (Table\ 3)\left({}^{MJ}\!/_{kg\ Nut}\right)\right) \quad (3)$$

Table 3 — Average exergy contribution associated to the production and transport of nutrients

Inorganic nitrogen	**67,8**	**MJ/kg N**
Phosphorus	50,87	MJ/kg P
Potassium	15,06	MJ/kg K
Calcium	22,89	MJ/kg Ca
Magnesium	31,2	MJ/kg Mg
Copper	222,94	MJ/kg Cu