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Soil Quality and Sustainability Evaluation

to support soil-related policies of the EU

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European Commission Joint Research Centre, Institute for Environment and Sustainability, Land Management and Natural Hazards Unit

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SOIL QUALITY AND SUSTAINABILITY EVALUATION

AN INTEGRATED APPROACH TO SUPPORT SOIL-RELATED POLICIES OF THE EUROPEAN UNION

- A JRC POSITION PAPER -

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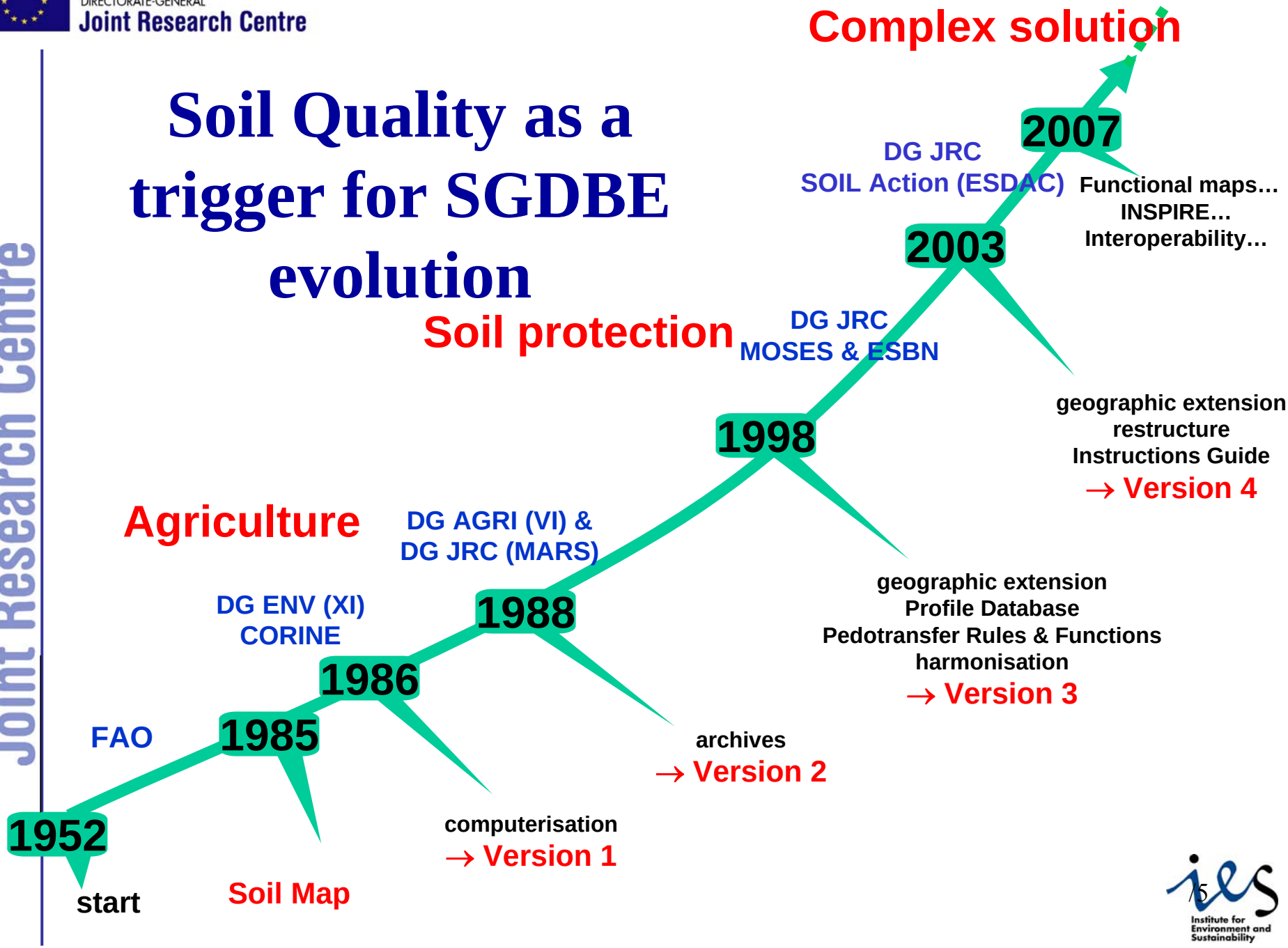
Outline

- Evolution of Soil Quality assessment in Europe
- New concept of soil quality
- Methodology of SQ and sustainability evaluation
- SQ indices and soil-related policies

Soil Quality as a trigger for SGDBE evolution

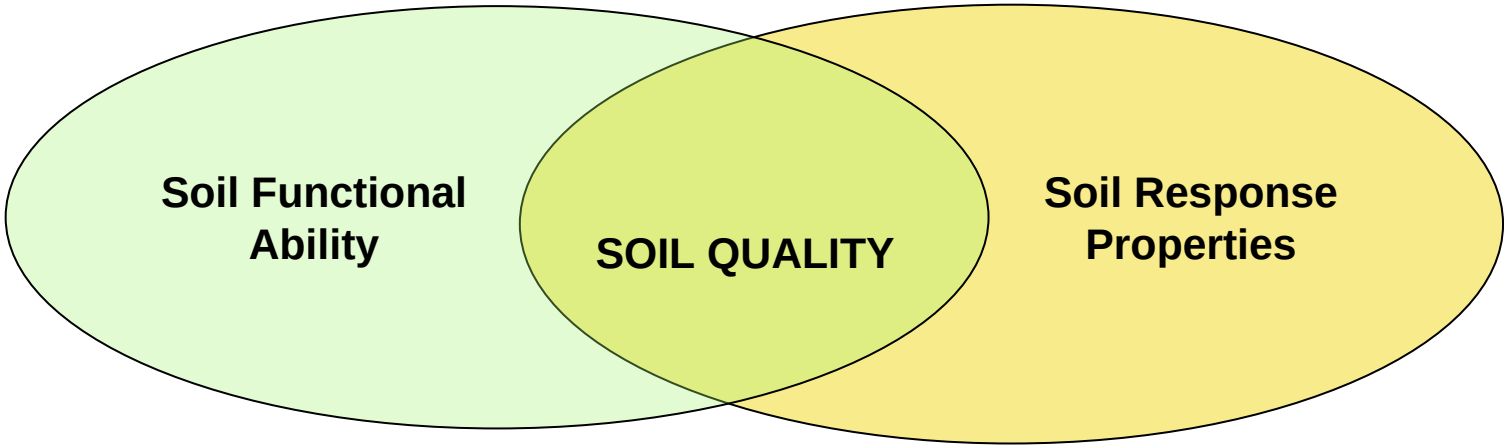


Soil quality

Soil quality (SQ) is an account of the ability of soil to provide ecosystem and social services through its capacities to perform its functions and respond to external influences.

The term soil quality encompasses a broad spectrum of features and considers functional ability together with the response properties of the soil.
SQ is therefore provides a complex information on the sum of different soil characteristics, with regards to the level of ecosystem services a soil can provide.

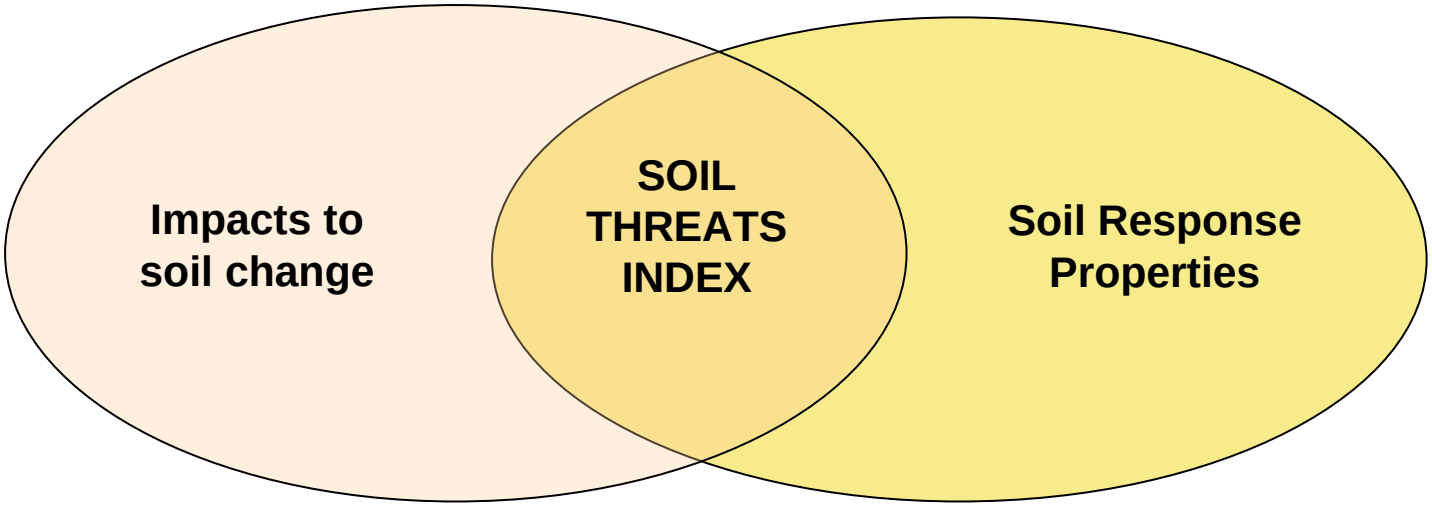
Components of soil quality



Soil Functional Ability (SFA)
The SFA refers to the number and composition of functions a given soil is able to provide and the level on which functions are provided.

Soil Response Properties (SRP)
The SRP are particular characteristics that determine the soil's responses to environmental (or human) influences and thus mark different potentials of Soil Functional Ability. SRP determine both the direction and magnitude how soil responds to a disturbance or change.

The measure of risk to soil functions: The Soil Threats Index



Soil Threat Index (STI)

The STI is a composite indicator of degradation-related Soil Response Properties and external factors (climate, land use) expressing the level of risk on which the soil is exposed to the main degradation threats.

For applications in the EU, STI refers to the (comparative risk of) five major threats (erosion, salinization, compaction, loss of organic matter, landslides).

The measure of soil degradation: Cumulative Degradation Effect (CDE)

CDE is the result of cumulative stress.

Cumulative stress marks the gradient of degradation.

CDE represents the extension of Soil Threat Index with the time factor (Δt).

The concept of Soil Sustainability Index (SSI)

SSI:

Comparative measure of Soil Quality across a gradient of stress or disturbance.

The expression also contains the stability of soil characteristics in time and the internal and/or external environmental interactions of soil, thus it also relates to the degradation threats.

Within the context of the Soil Protection Strategy of the EU, Soil Sustainability Index is proposed as an indicator of soil functional ability and degradation-related hazards with a time perspective.

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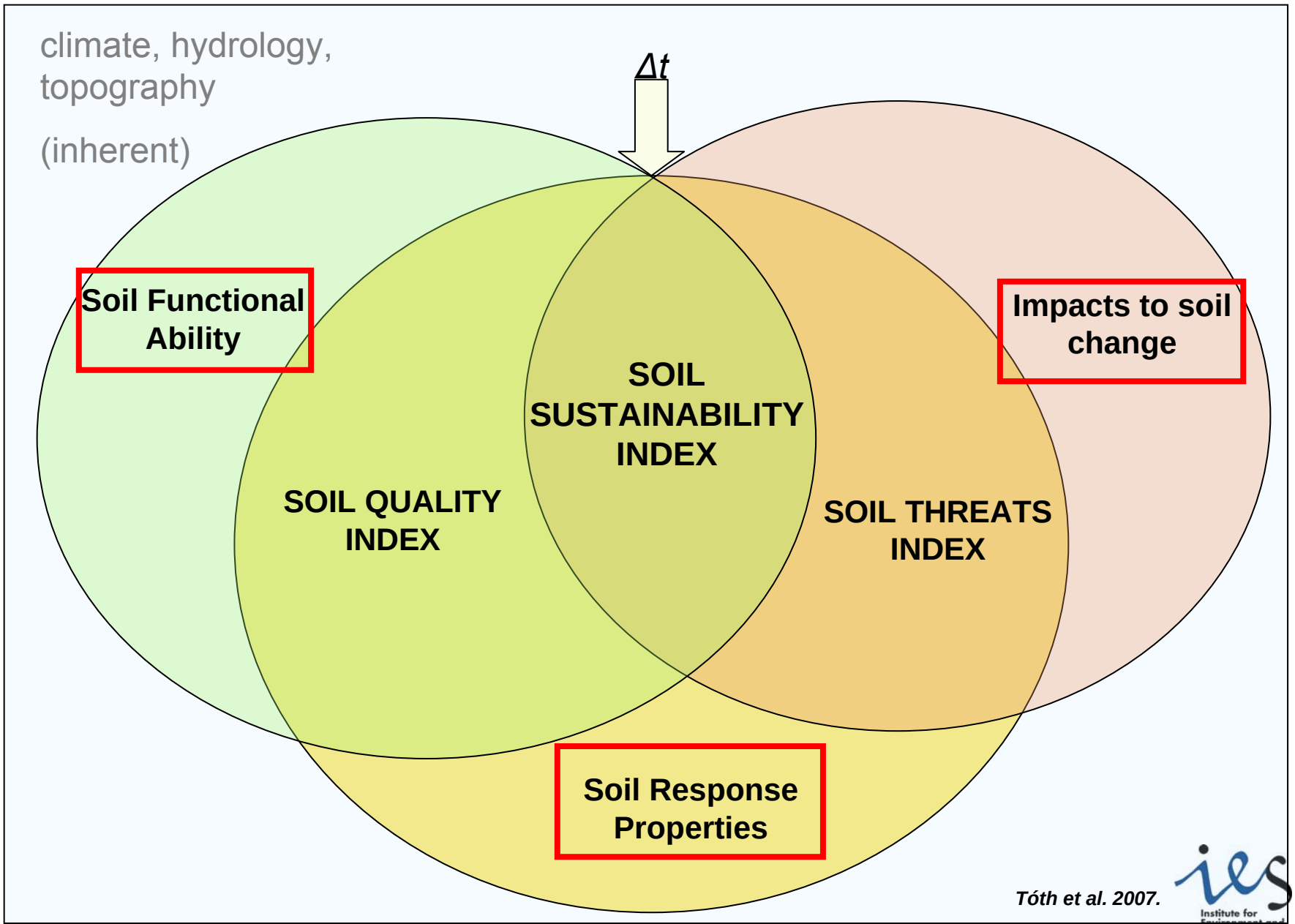
Clusters of soil sustainability



Tóth et al. 2007.

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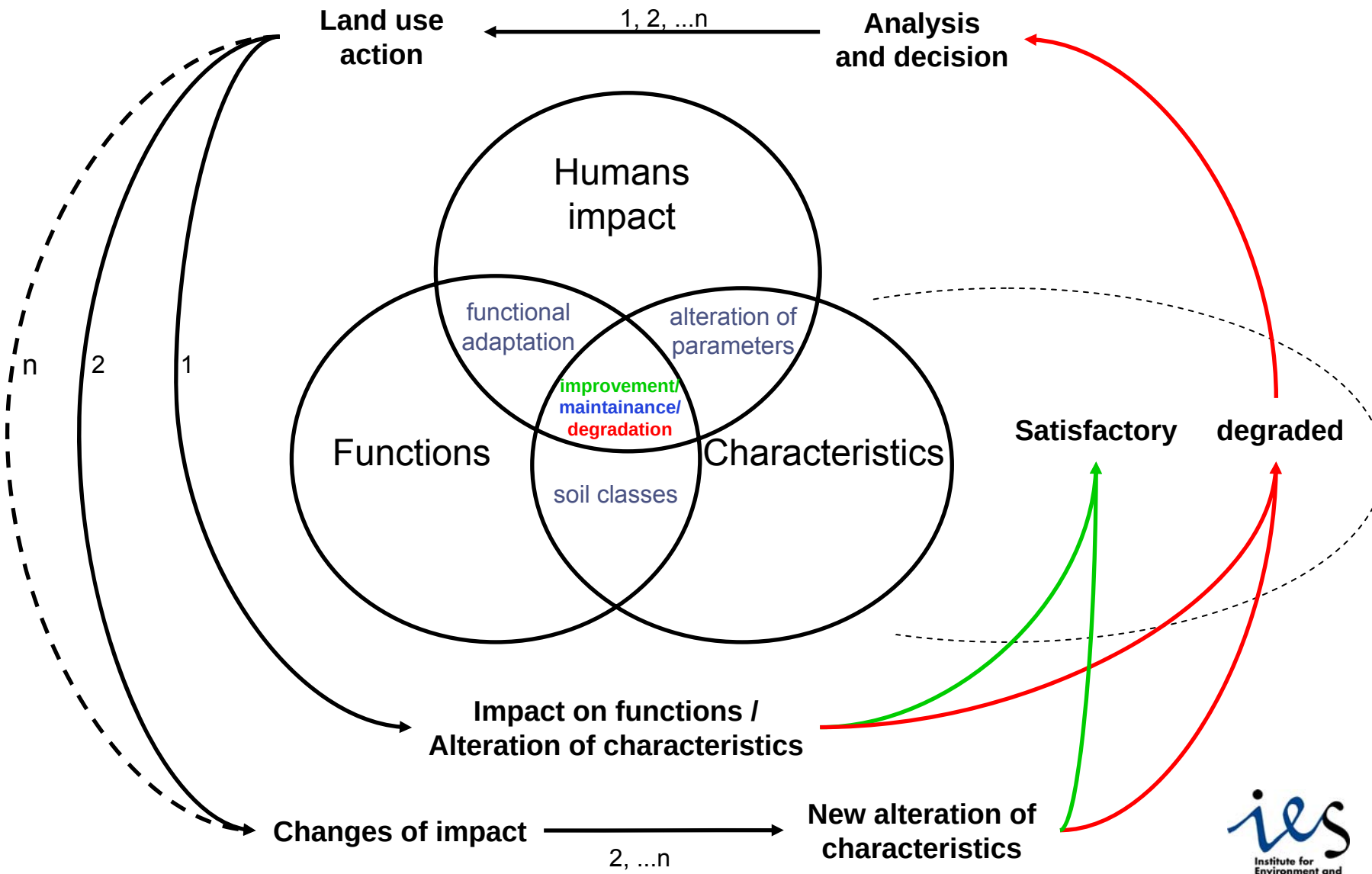
The soil quality loop



Categorization of soil use options

SQ
Excellent
Good
Average
Poor
Inadequate

X

CDE
Exponentially increasing
Linear sharp increase
Linear slow increase
Quick increase followed by a balance
Steady
Improving
••
••

Soil Sustainability Index Category
Excellent performance/ improving
••
Excellent performance/ degrading
••
Average performance/ sustainable
••
Average performance/ degrading
••
Poor performance/ improving
••
Poor performance/ degrading

A working example: matching agricultural production and soil degradation effects

Step 1. Assessment of SQ,

SFA = productivity

SRP = water, nutrient reaction

Step 2. Assessment of CDE

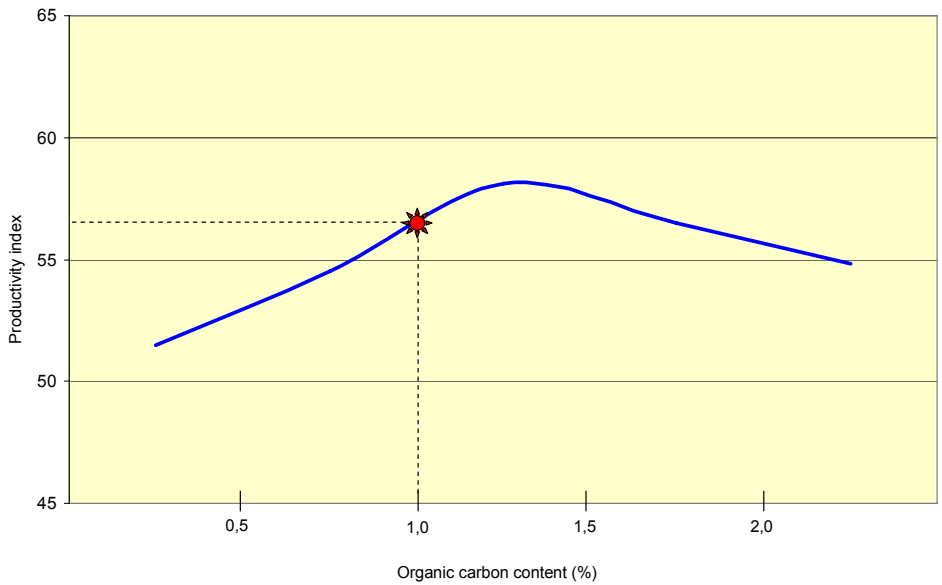
a) Degradation related SRP = organic carbon dynamics
External factors of degradation = land use (, climate)

b) Degradation related SRP = sensitivity to erosion
External factors of degradation = land use (terrain, climate)

c) Δt to express temporal dynamics of a) and b)

Step 3. SSI is developed as a composite of (1) and (2a,b) with the consideration of temporal dynamics (Δt)

SFA evaluation: productivity function

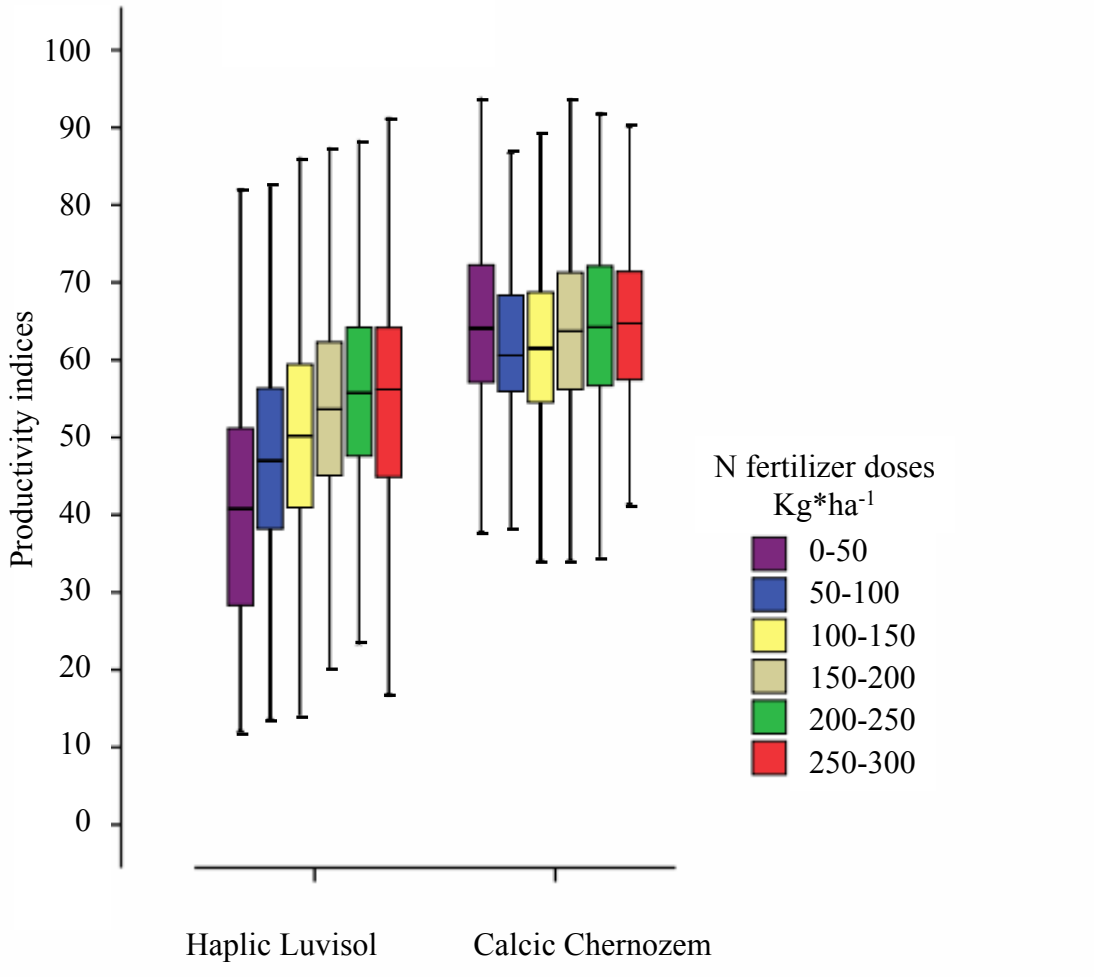


SFA = 57

Average wheat productivity indices of Haplic Luvisols with different organic matter content (Tóth 2003)

A working example

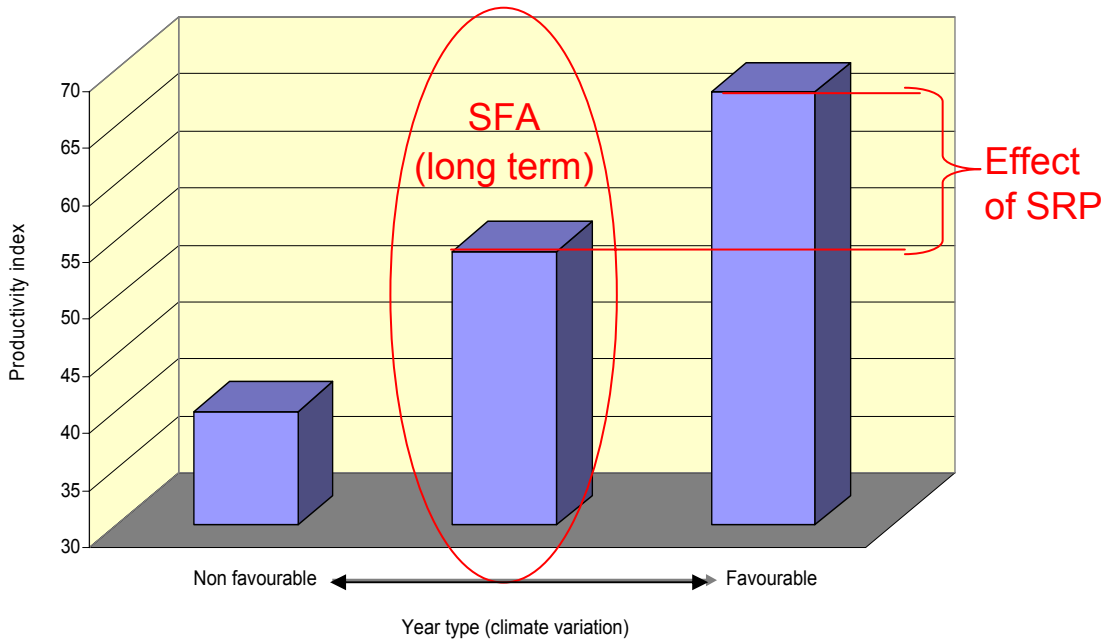
SRP evaluation: response to fertilization (input level)



$SRP_1 = 85$

The effect of N fertilization on wheat productivity of Haplic Luvisols (Tóth et al. 2005.)

SRP evaluation: response to climate variability



$SRP_2 = 60$

The effect of climate variation on wheat productivity index of Haplic Luvisols (Debreczeni et al. 2003

CDE evaluation: erosion, loss of organic carbon

Constant high erodibility of Haplic Luvisol (with given land use, slope and climate)

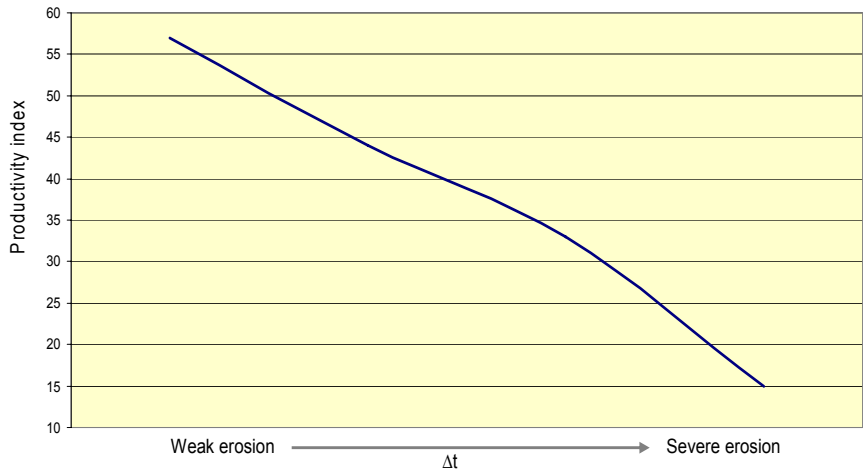
CDE (erosion) = 74

Sharp loss of OC in Haplic Luvisol (with given land use, slope and climate)

CDE (OC loss) = 80

A working example

Soil Sustainability Index



Productivity decline of a Haplic Luvisol due to erosion and associated loss of organic carbon (After Tóth 1996)

SSI = SQI X (100 – CDE)

SSI= 67*{100-(74*80)=45

SSI= 45 [67'77]

SQ		CDE		Soil Sustainability Index Category
Good	X	Linear slow increase	⇨	Good performance/ slowly degrading

Summary

❖ **Soil sustainability evaluation** method has **flexible** design **to** cover **soil quality** and complex **degradation threats**.

❖ The **evaluation includes**:

1) Soil Sustainability Index

- for the comparative measurement of soil quality across a gradient of stress or disturbance

2) Soil Quality Index

- to express the ability of soil to perform ecosystem and social services

3) Soil Threat Index

- to express the level of risk on which the soil is exposed to degradation threats

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Thank you !

The need for soil quality definition in support of the Soil Protection Strategy

Optimisation of soil-resources-use have to be based on

- **knowledge on potentials (traditional approach)**
- **knowledge on potentials and risks (integrated approach)**

The term soil quality has diverse understanding and interpretation in the scientific literature, among planners and land users

Formulas in the soil quality / sustainability domain (I.)

Soil Functional Ability (SFA) can be defined as:

$$SFA = (F_{i,n} \text{ X } E_{Fi,n})/n$$

Where:
$F_{i,n}$ are the considered functions from i to n,
E is the efficiency (level) of how functions from i to n are performed individually,
n is the number of functions included in the evaluation.

Soil Response Properties (SRT) can be defined as:

$$SRP = \Sigma_{fi,n} (\Sigma SC)$$

Where:
f is a (non linear) function describing the response (both its direction and magnitude) to an impact, determined by,
ΣSC that represents soil characteristics.

Soil Quality Index (SQI) can be defined as:

$$SQI = SFA \text{ X } SRP$$

Where:
SFA and SRP as defined in eq. 1 and eq. 2 respectively.

Formulas in the soil quality / sustainability domain (II.)

The indicator of degradation risk of soils is defined with the Soil Threats Index (STI):

$$STI = SRP \times DI_{i,n}$$

Where:
SRP as described in eq. 2
DIi,n is the Degrading Impacts, the external factors of degradation (e.g. soil management, climate change) from i to n.

Cumulative Degradation Effect is defined as:

$$CDE = STI \times \Delta t$$

Where:
STI as described in eq.4
Δt is the time period of observation

Soil sustainability Index (SSI) is defined as:

$$SSI = SQI \times (100 - CDE)$$

Where:
SQI is the Soil Quality Index,
CDE is the Cumulative Degradation Effect (the gradient of the degradation processes),