A new land use impact assessment method for LCA: theoretical fundaments and field validation

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1. Introduction

- Many human activities have spatial needs, especially agriculture and forestry
- Land use impact category important in LCA's of these activities
- Several methods proposed, no consensus (COST E9)

⇒ Need for new method for land use impact assessment, based on strenghts of proposals

2.1. New method: basic concept and reference system

- Basic concept: *Ecosystem exergy*

  Goal function of all ecosystems is to maximize their exergy i.e. to maximize their buffering capacity for external energy flows (Bendoricchio and Joergensen 1997)
- Reference system: for any site the *potential natural vegetation* (climax) is the system with highest energetic control, highest natural exergy level for that site

2.2. New method: methodology impact assessment

(i) Stratification

(ii) Indicator assessment

(iii) Aggragation

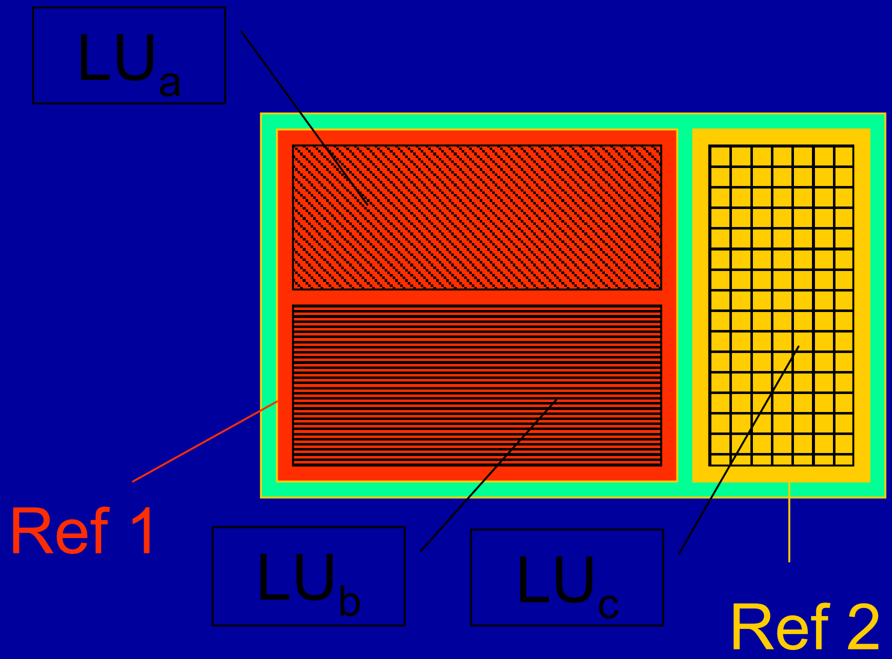
(iv) Expressing results per FU for land use and land use change

(i) Stratification

Area assessed is divided in homogenous sites according:

1/ reference system

2/ actual land use



(ii) Indicator assessment

- 17 quantitative indicators divided over 4 themes: soil, water, vegetation cover and biodiversity
- Indicator scores (ΔQ) indicate difference in quality between actual land use and reference state

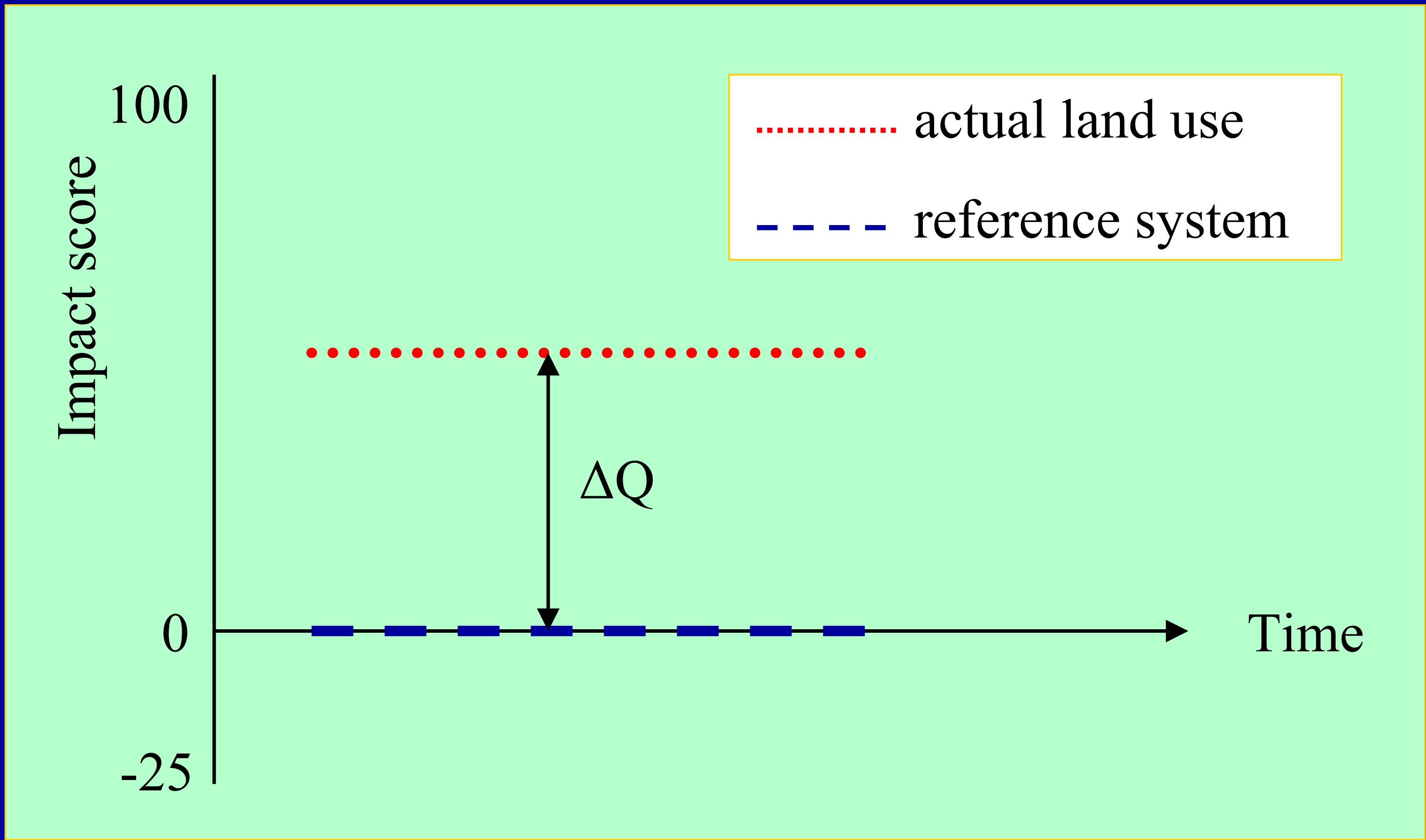
Code	Indicator	Calculation	Reference state
S1	Soil compaction	$\left(\frac{area_{aff} * \left(perm_{ref} - perm_{act}\right)}{area_{tot} * perm_{ref}}\right) * 100$	$perm_{ref}$
S2	Soil structure disturbance by ploughing, etc.	$\left(\frac{area_{aff} * depth}{area_{tot}} * \frac{times_{S2}}{rot}\right) * 100$	No soil work
S3	Soil erosion	$\left(\frac{100 * USLE}{Soil\,depth}\right) * 100$	soil erosion $_{ref}$
S4	Cation Exchange Capacity (CEC)	$\left(1 - \frac{CEC_{act}}{CEC_{ref}}\right) * 100$	CEC $_{ref}$
S5	Base Saturation (BS)	$\left(1 - \frac{BS_{act}}{BS_{ref}}\right) * 100$	BS $_{ref}$

Code	Indicator	Calculation	Reference state
W1	Evapotrans-piration (ET)	$\left(1-\frac{ET_{act}}{ET_{ref}}\right)*100$	ET_{ref}
W2	Surface runoff (SR)	$\frac{SR}{P-ET}*100$	SR_{ref}

Code	Indicator	Calculation	Reference state
V1	Total aboveground living biomass (TAB)	$\left(1-\frac{TAB_{act}}{TAB_{ref}}\right)*100$	TAB_{ref}
V2	Leaf area index (LAI)	$\left(1-\frac{LAI_{act}}{LAI_{ref}}\right)*100$	LAI_{ref}
V3	Vegetation height (H)	$\left(1-\frac{H_{act}}{H_{ref}}\right)*100$	H_{ref}
V4	Free Net Primary Production (fNPP)	$\left[1-\left(\frac{NPP_{act}-AH}{NPP_{ref}}\right)\right]*100$	NPP_{ref}
V5	Crop biomass	$\left(\frac{crop\ biomass}{total\ biomass}\right)*100$	No crop species or harvest

Code	Indicator	Calculation	Reference state
B1	Artificial change of water balance	$\left[\left(\frac{area_{irr} + area_{drain}}{total\,area}\right)\right] * 100$	No irrigation or drainage
B2	Liming, fertilisation, empoverish-ment	$\left[\left(\frac{area_{aff}}{area_{tot}} * \frac{times_{B2}}{rot}\right)\right] * 100$	No area affected
B3	Biocides	$\left[\left(\frac{area_{aff}}{area_{tot}} * \frac{times_{B3}}{rot}\right)\right] * 100$	No area affected
B4	Canopy cover of exotic plant species (Ex)	$\left(\frac{Ex}{total\ cover}\right) * 100$	100% native species
B5	Number of plant species (Sp)	$\left(1 - \frac{Sp_{act}}{Sp_{ref}}\right) * 100$	Sp_{ref}

Human impact ~ ecosystem exergy level



(iii) Aggregation

- 17 indicators are aggregated in 4 themes: soil (S), water (W), vegetation (V) and biodiversity (B)
- Within 1 theme: each indicator same weight

$$\Delta Q_S = \frac{\sum_{i=1}^{n} \Delta Q_{Si}}{N} \quad where \quad N = 5$$

$$\Delta Q_W = \frac{\sum_{j=1}^{m} \Delta Q_{Wj}}{M} \quad where \quad M = 2$$

$$\Delta Q_V = \frac{\sum_{p=1}^{x} \Delta Q_{Vp}}{X} \quad where \quad X = 5$$

$$\Delta Q_B = \frac{\sum_{q=1}^{y} \Delta Q_{Bq}}{Y} \quad where \quad Y = 5$$

(iv) Expressing results per FU for land use

use of land during certain time

$$S_S = \Delta Q_S * (area \times time)_{FU} * FU^{-1}$$

$$S_W = \Delta Q_W * (area \times time)_{FU} * FU^{-1}$$

$$S_V = \Delta Q_V * (area \times time)_{FU} * FU^{-1}$$

$$S_B = \Delta Q_B * (area \times time)_{FU} * FU^{-1}$$

(iv) Expressing results per FU for land use change

abrupt change in ecosystem quality by land use change

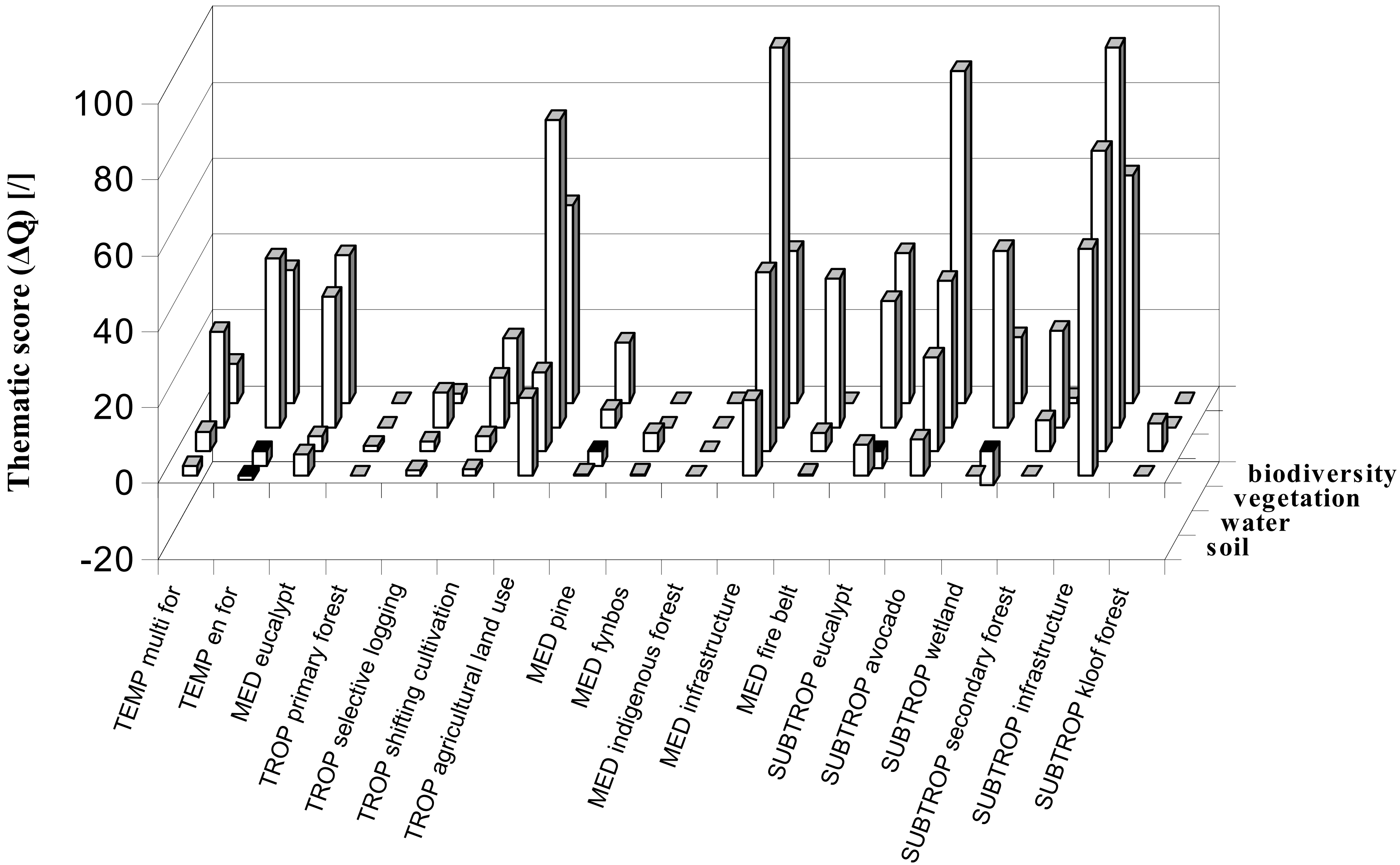
$$S_i = \left[\Delta Q_2 - \Delta Q_1\right] * \left(area \times time\right)_{FU} * FU^{-1}$$

for i = soil, water, vegetation and biodiversity

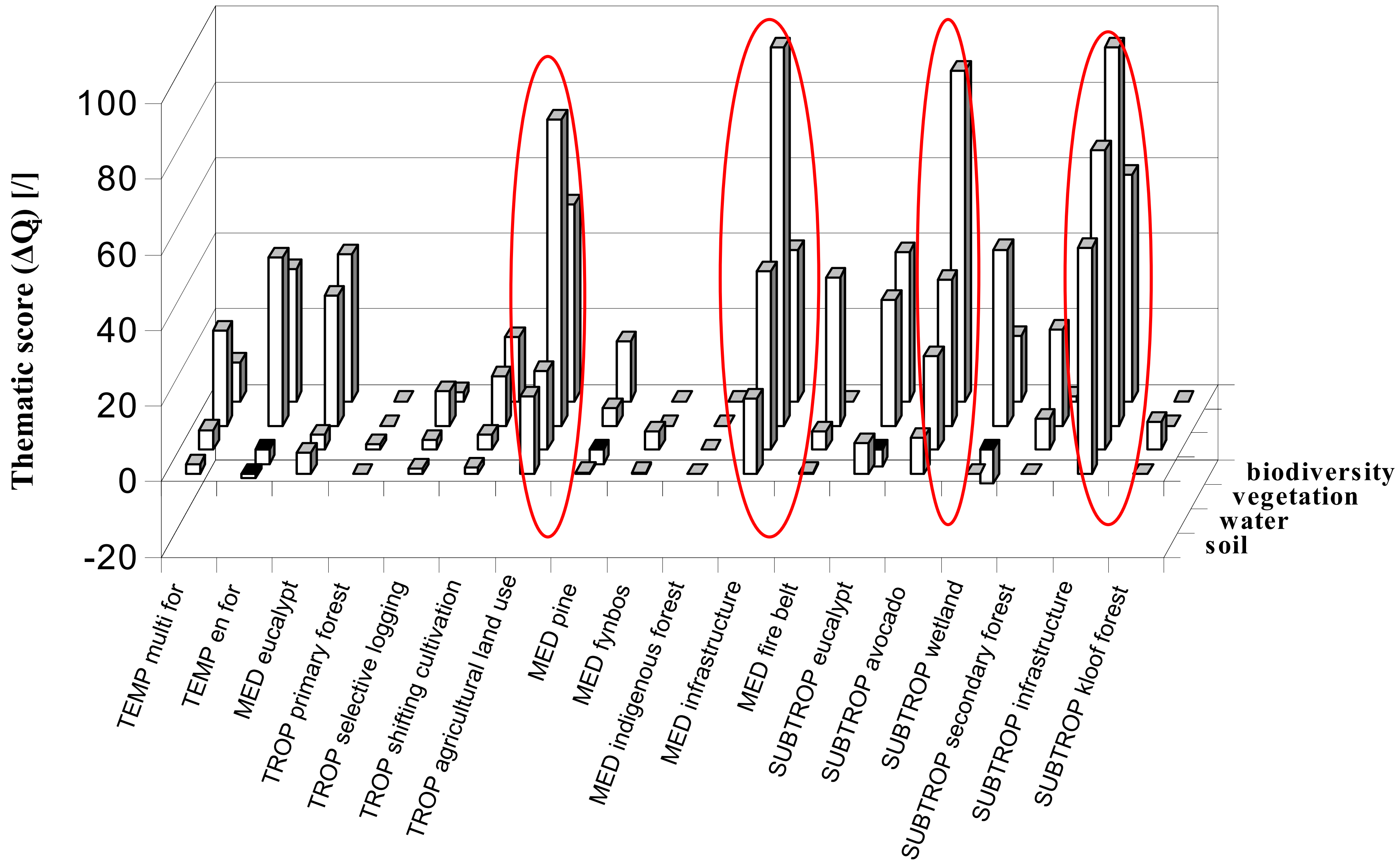
3. New method: field validation
3.1. Test scenario definition

- Multifunctional forest in Belgium (TEMP multi for)
- Short rotation coppice in Belgium (TEMP en for)
- Eucalypt plantation in Spain (MED eucalypt)
- Tropical rainforest conservation (TROP land use)
- Mediterranean pine plantation (MED land use)
- Subtropical agroforestry plantation (SUBTROP land use)

3.2. Results



Thematic score (ΔQ$_i$) [/]
100
80
60
40
20
0
-20
TEMP multi for
TEMP en for
MED eucalypt
TROP primary forest
TROP selective logging
TROP shifting cultivation
TROP agricultural land use
MED pine
MED fynbos
MED indigenous forest
MED infrastructure
MED fire belt
SUBTROP eucalypt
SUBTROP avocado
SUBTROP wetland
SUBTROP secondary forest
SUBTROP infrastructure
SUBTROP kloof forest
biodiversity
vegetation
water
soil



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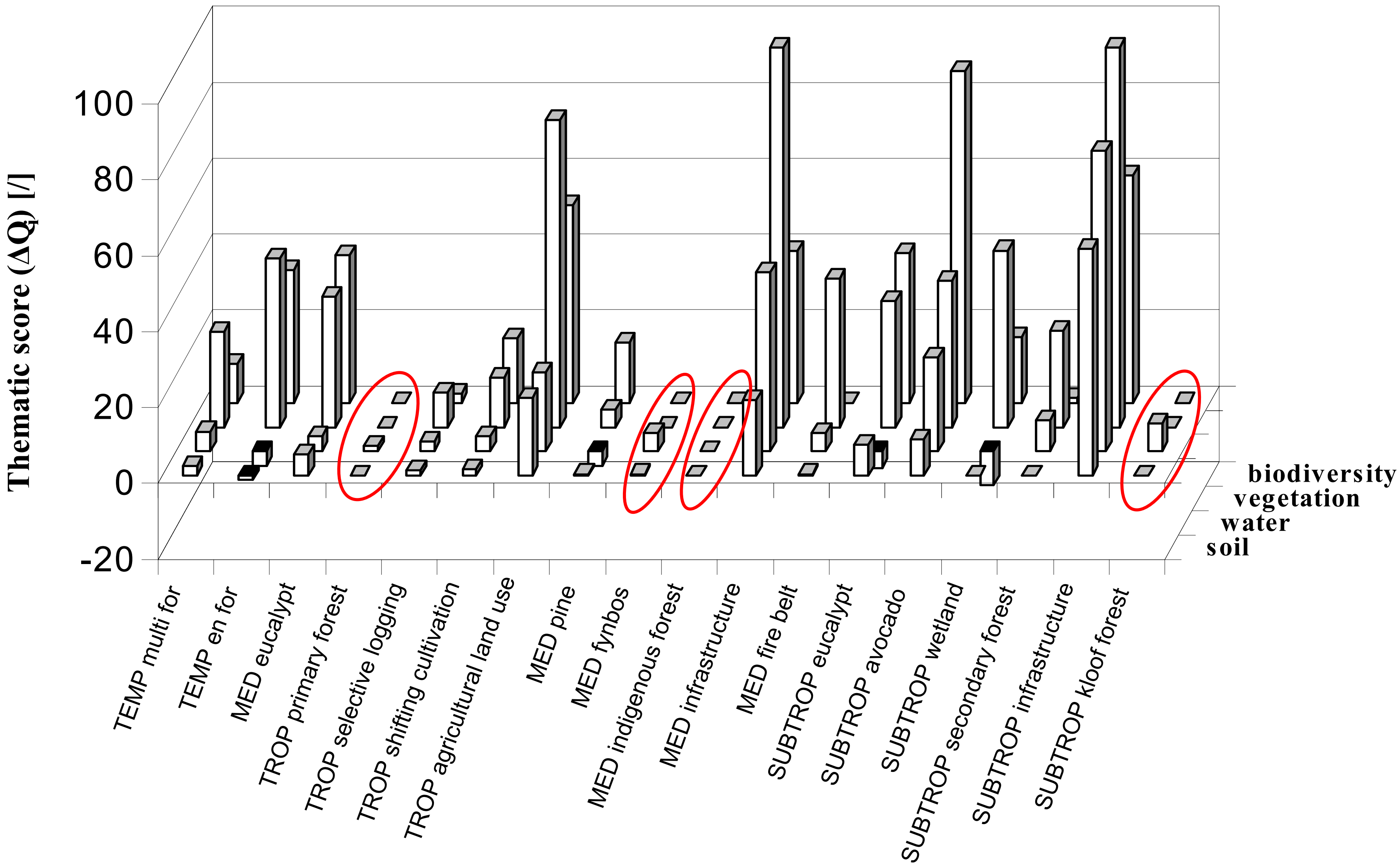

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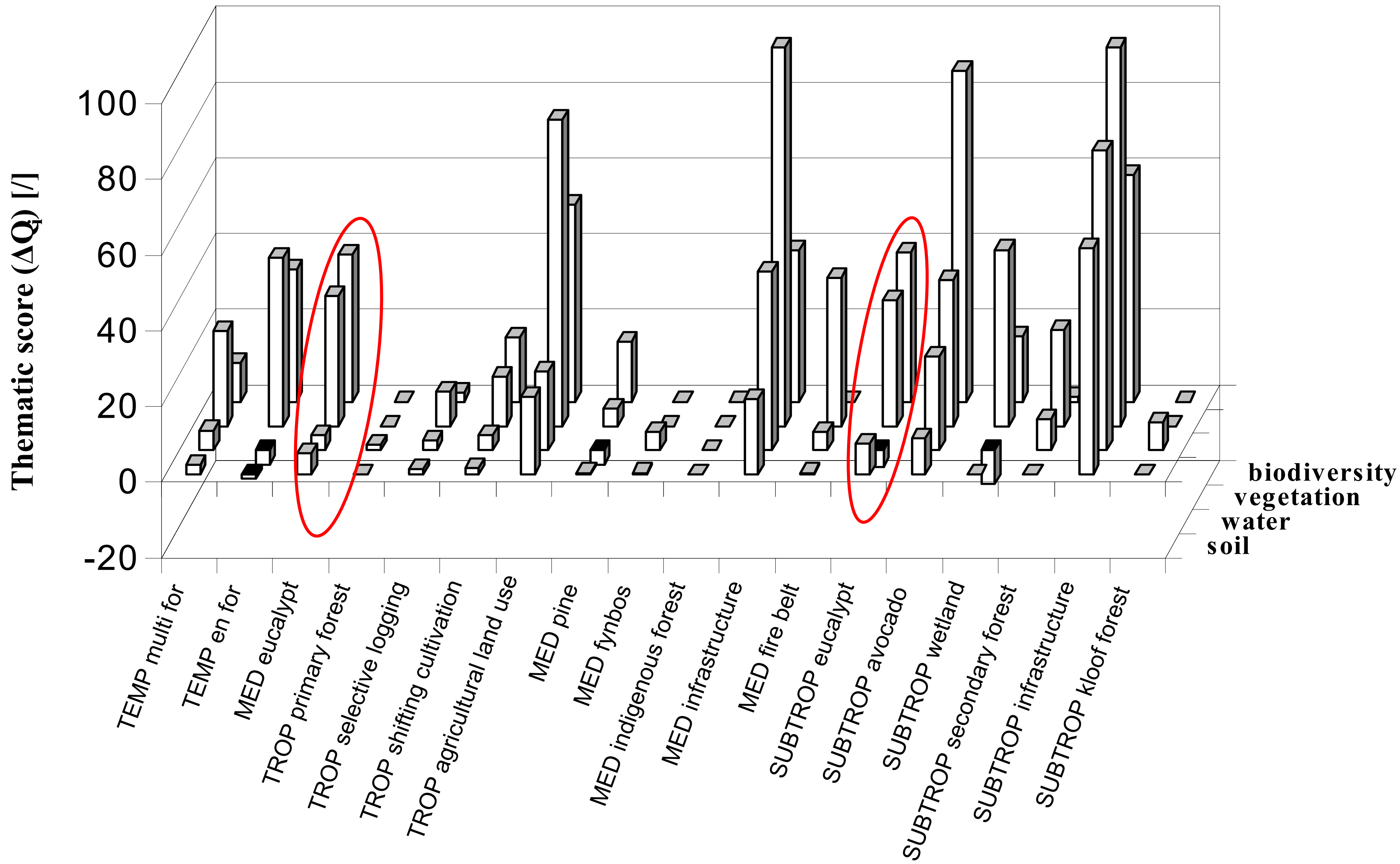
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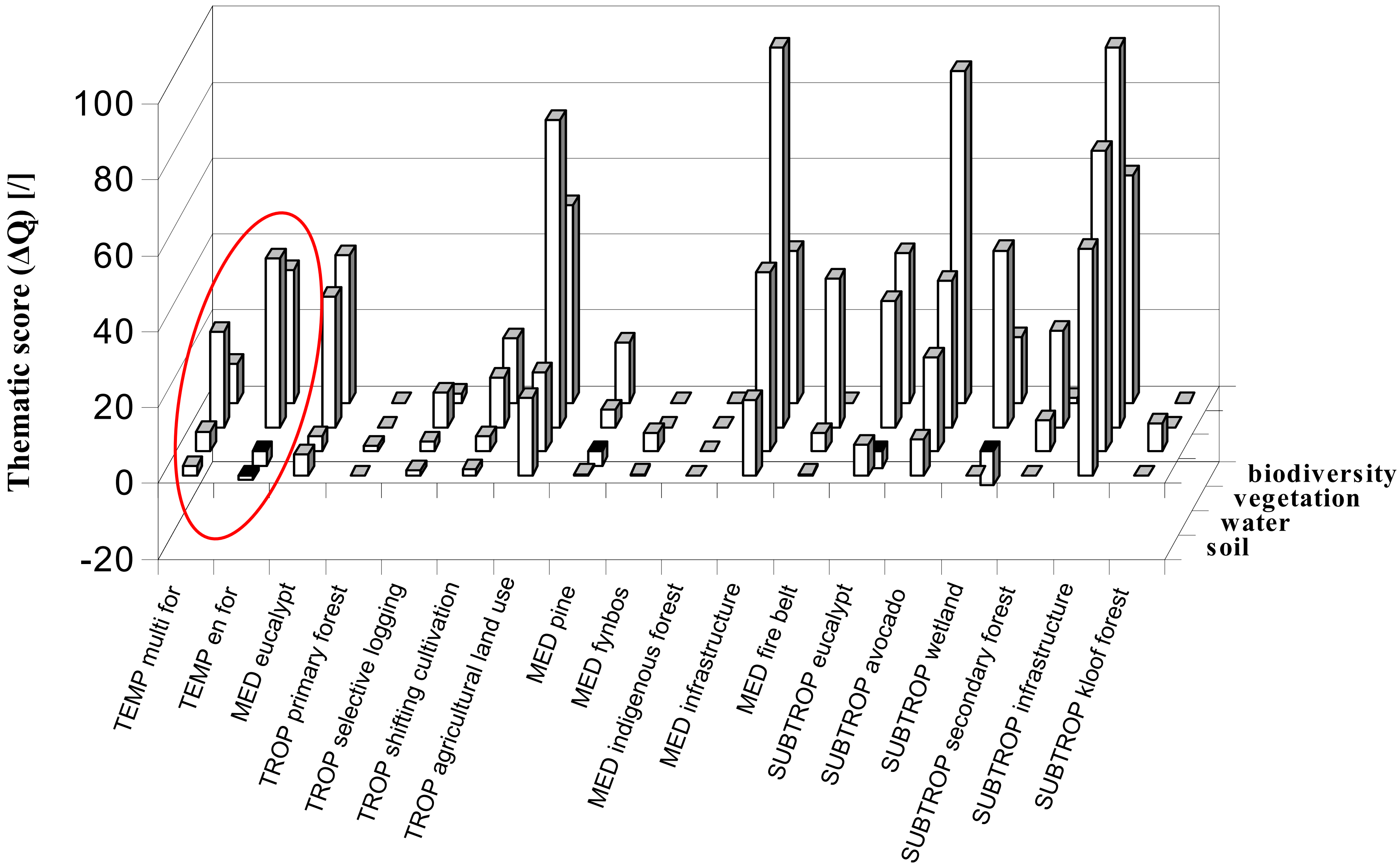
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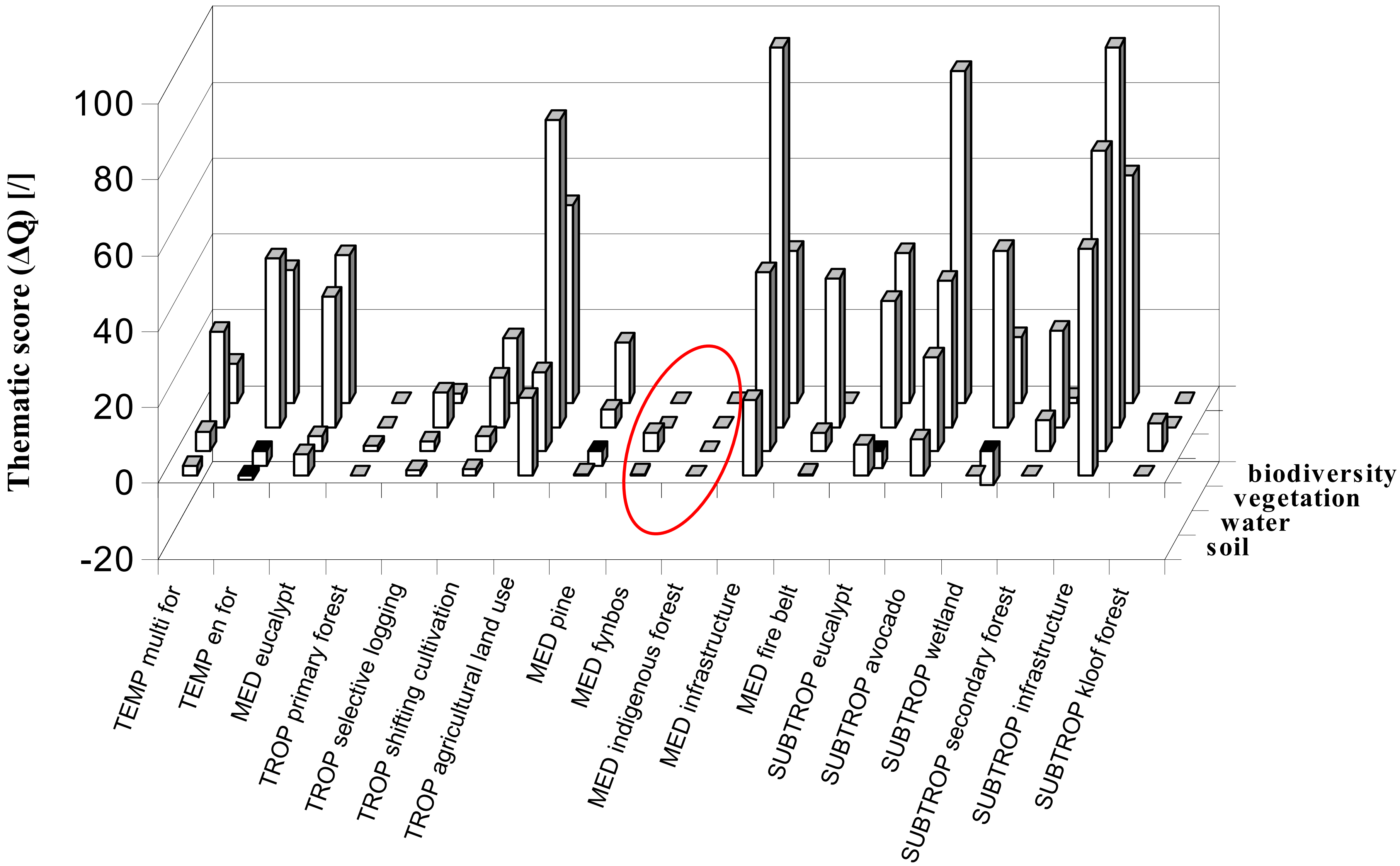

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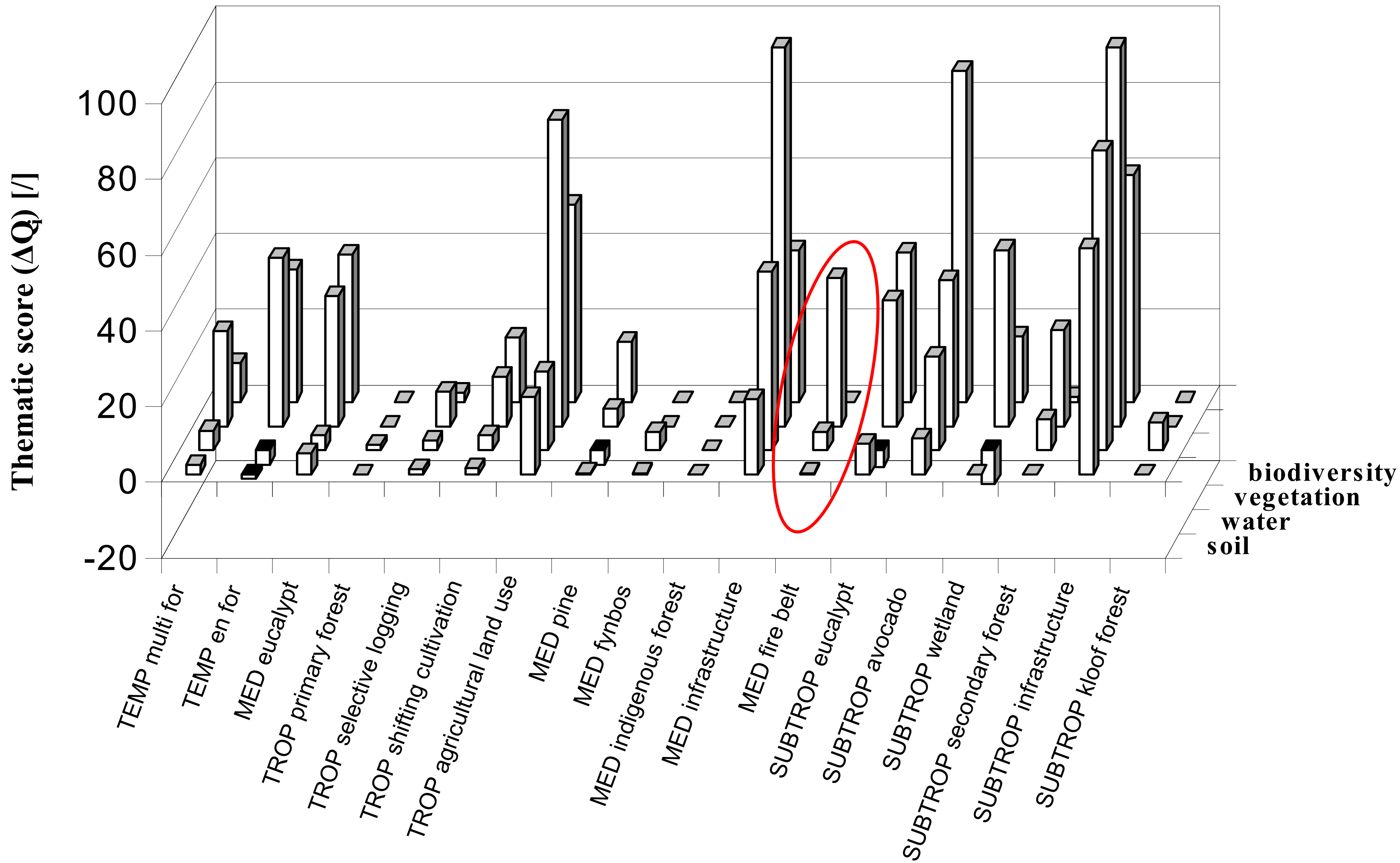
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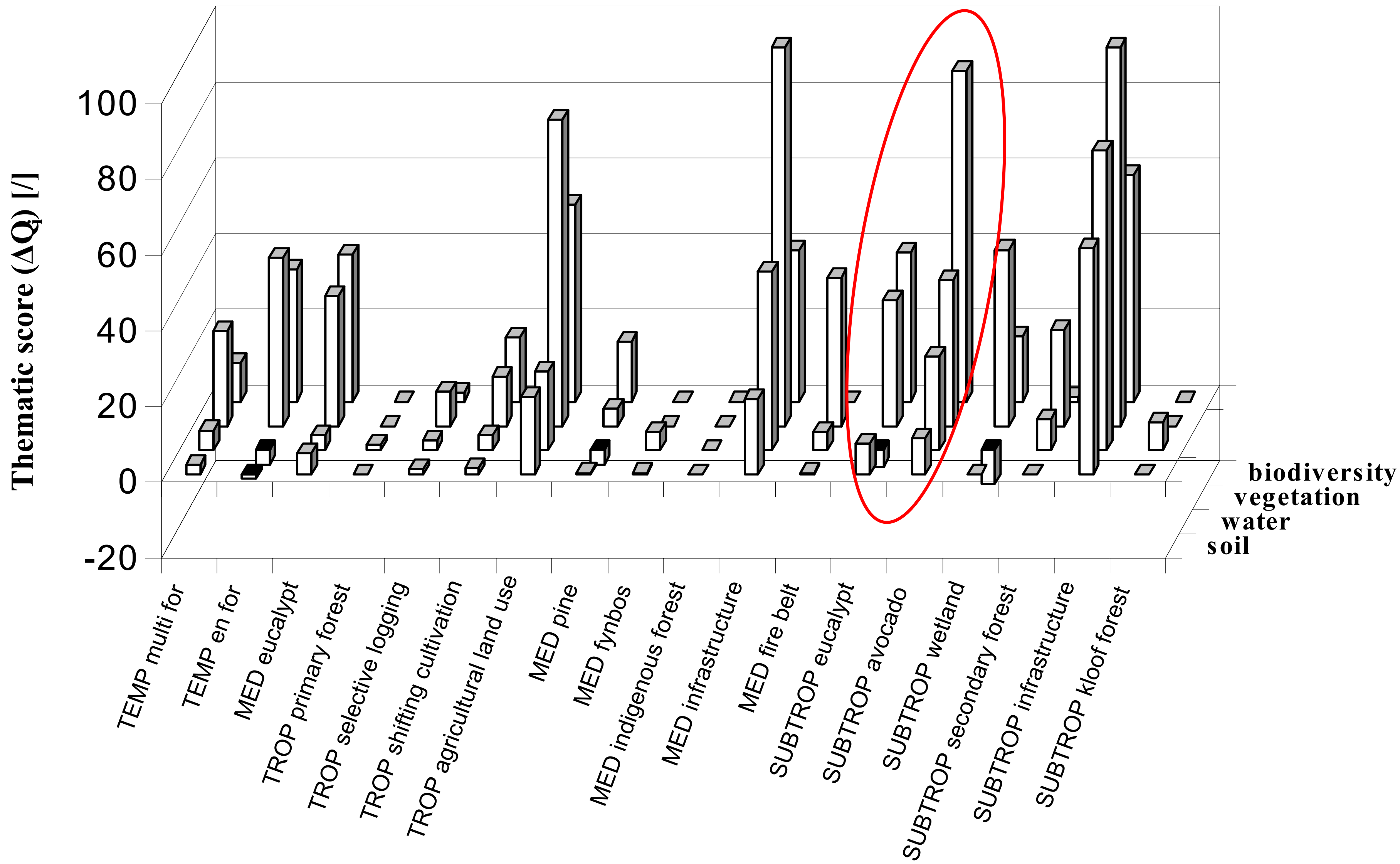

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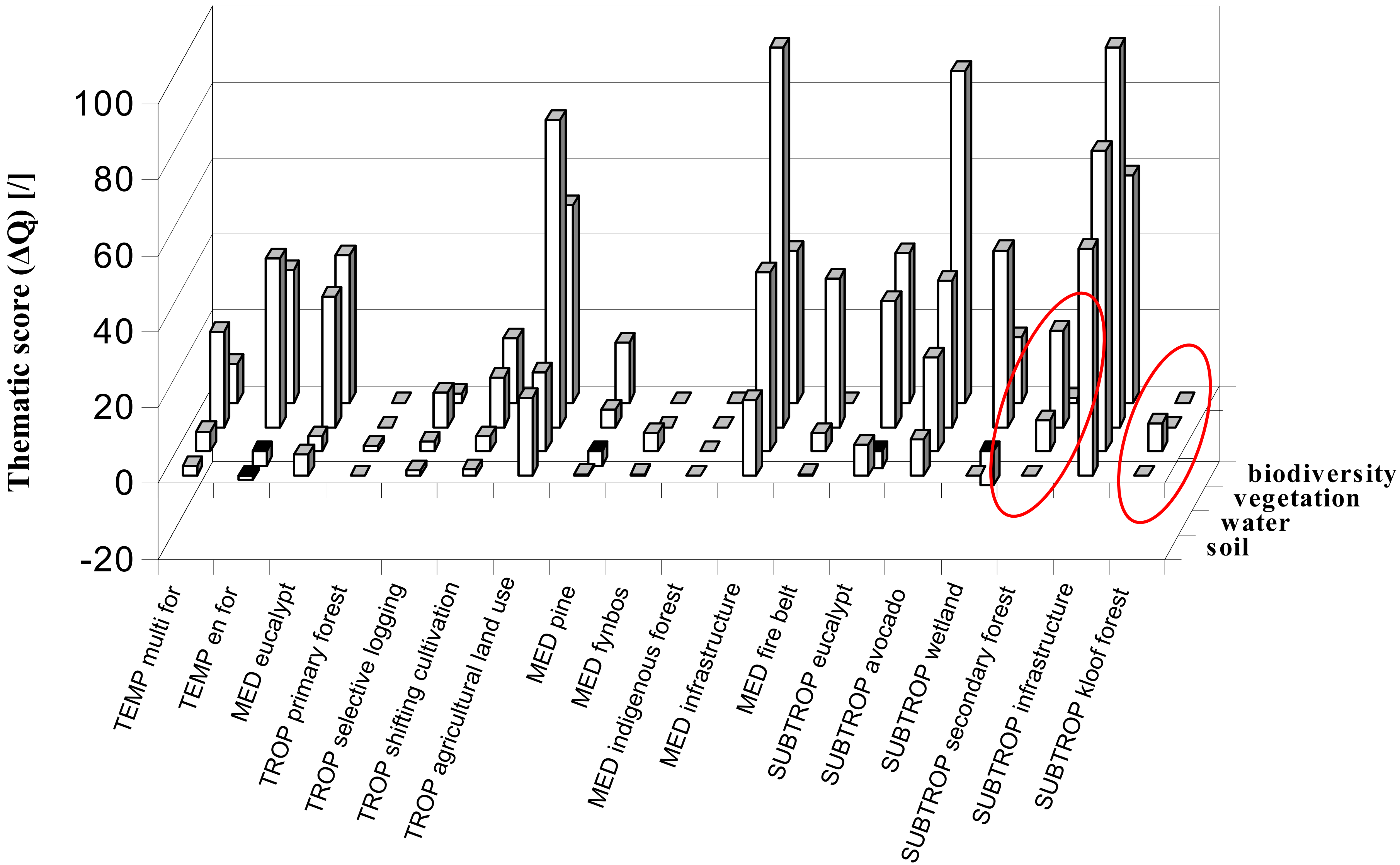

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4. Discussion and conclusion

- Assessment fully quantitative
- Assessment in different climatic and geographical regions operational
- Workable definition of reference system
- Comparing land use from different sites & climates possible
- Results can be expressed per FU
- Linearity requirement satisfied: doubling FU leads to double impact score

5. Recommendations

- Further method testing is needed, with special attention for indicator selection.
- Minimum indicator score threshold of –25 should be revised to solve sensitivity problems.
- Vegetation with highest exergy level i.e. potential natural vegetation is a workable reference vegatation but problems rise when no natural patches are left. Literature data can be used with lower reliability.

- Indicators S2 (soil erosion) and W2 (surface runoff) should be redesigned, so that the reference vegetation has the 0 score.
- Themes are not comparable within the same land use assessment.

Thanks!