Anthropic Geomorphology – from global to local

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Anthropic geomorphology (Szabó et al, 2010)

- studies landform associations made by the human activity,
- investigates surface changes induced by these forms,
- predicts the consequences of disturbance of the natural equilibrium,
- makes recommendations for preventing damages.

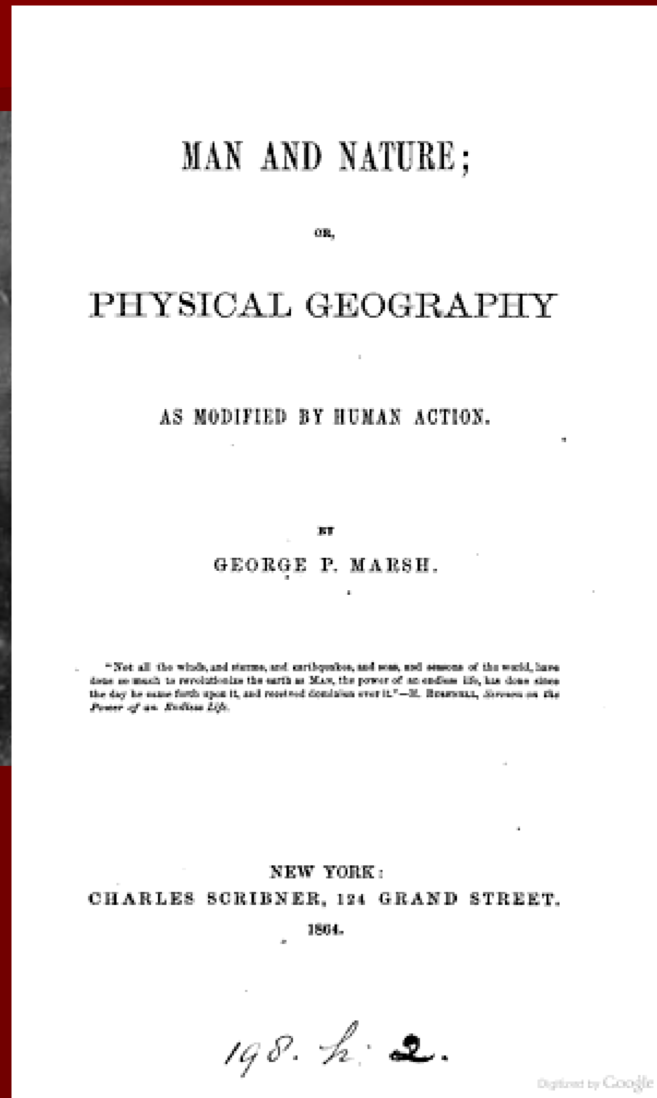
Systematization of anthropic geomorphology (Szabó et al, 2010)

- **Direct – Indirect**
  - Intentional or unintentional
  - primary or secondary
  - qualitative or quantitative

- **Excavation – Aggradation – Planation**

- **Agriculture, Mining, Riverbed and Shore Management, Industry, Transportation, Urban Construction, Turism and Sport, Warfare**

George Perkins MARSH (1801-1882)



MAN AND NATURE;

OR,

PHYSICAL GEOGRAPHY

AS MODIFIED BY HUMAN ACTION.

BY

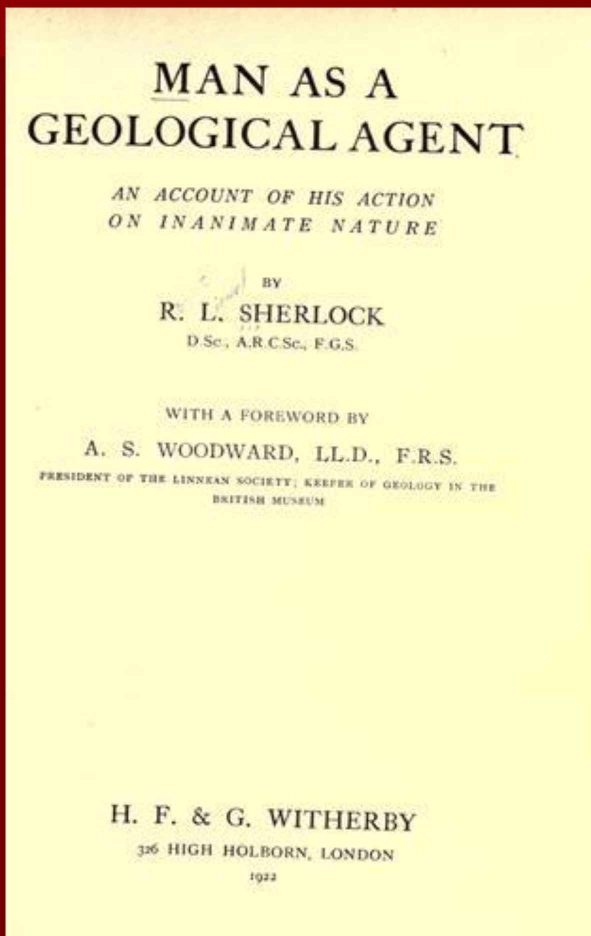
GEORGE P. MARSH.

NEW YORK:
CHARLES SCRIBNER, 124 GRAND STREET.
1864.

„Man is everywhere a disturbing agent. Whatever he plants his foot, the harmonies of Nature are turned to discord."

This work was the first systematic exploration of the extent and significance of the environmental changes wrought by man, and the first systematic exposition of the guiding principles and practices of conservationism; its influence on the subsequent development of American conservation thought and policy has been incalculable.

Robert Lionel SHERLOCK (1875-1948)


MAN AS A
GEOLOGICAL AGENT

AN ACCOUNT OF HIS ACTION
ON INANIMATE NATURE

BY
R. L. SHERLOCK
D.Sc., A.R.C.Sc., F.G.S.

WITH A FOREWORD BY
A. S. WOODWARD, LL.D., F.R.S.
PRESIDENT OF THE LINNEAN SOCIETY; KEEPER OF GEOLOGY IN THE BRITISH MUSEUM

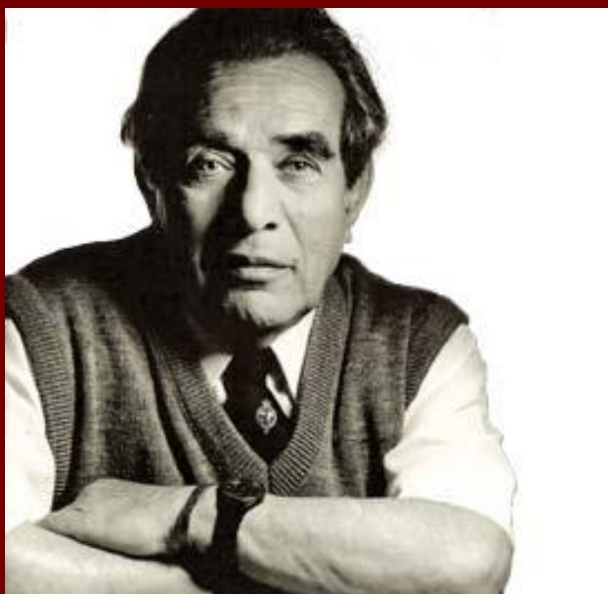
H. F. & G. WITHERBY
326 HIGH HOLBORN, LONDON
1922

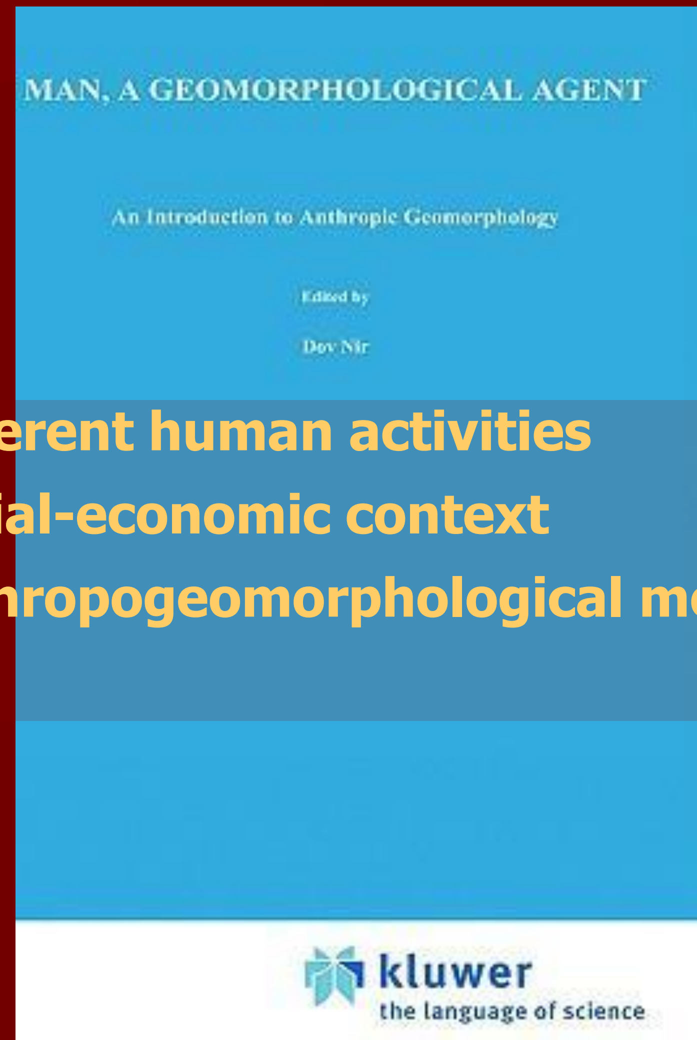
„ … it seems that the rate of denudation, as a whole, has been increasingly rapidly until the present time. (…) Will the rate continue to increase, or even be maintained at its present level, in the future? There are indications of diminution before long."

After World War II

- 1956: Proceedings of the symposium on „Man’s Role in Changing of the Face of the Earth”
- 1964: Golomb, B. & Eder, H.M.: Landforms made by man. Landscape 14. 4–7.
  - *antropogeomorphology*
- 1970: Brown, E.H.: Man shapes the earth. Geographical Journal, 136, 74–85.
  - *direct, direct but incidental human action, involuntary results of human action*

Dov NIR (1922 – 2011)



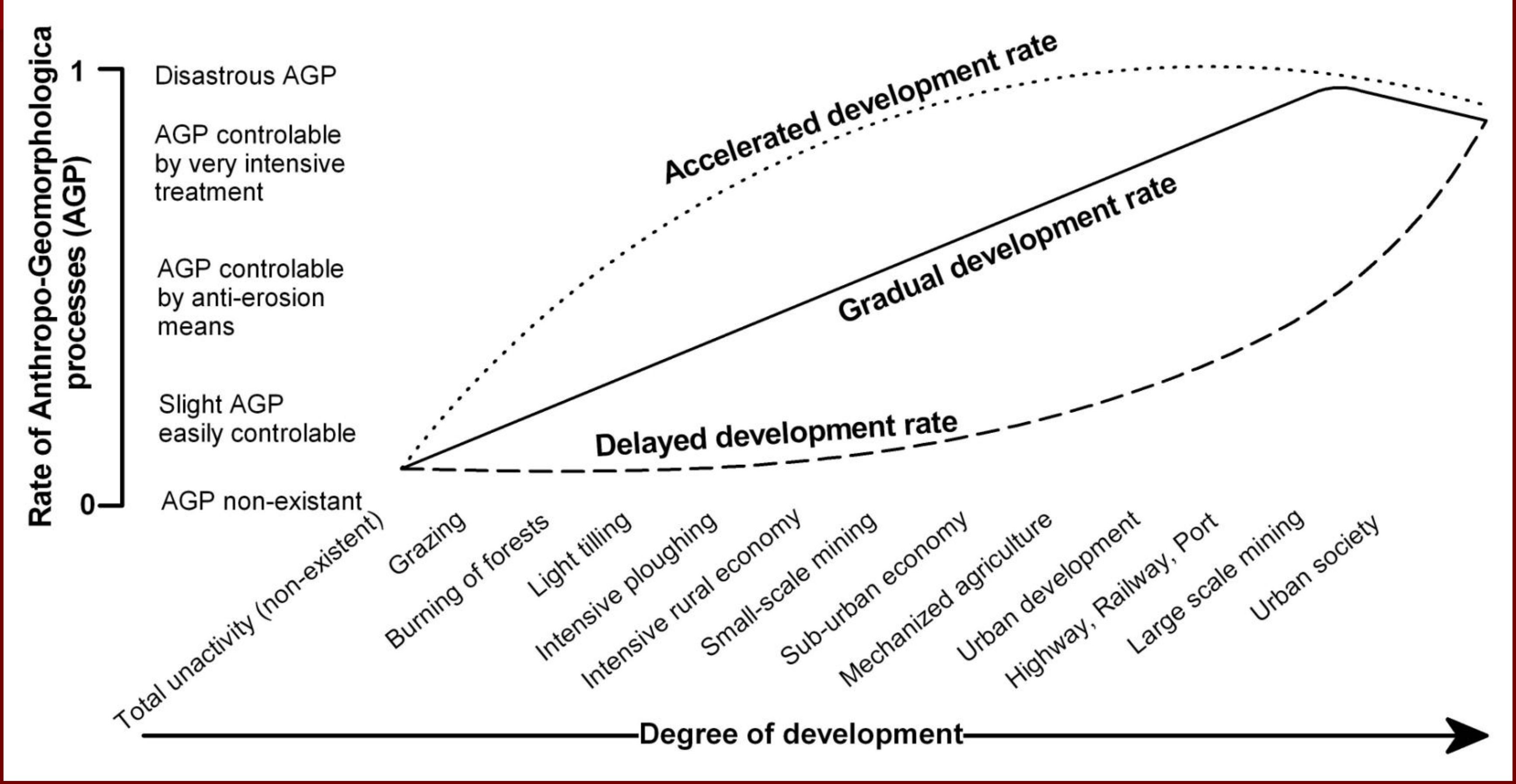


- Different human activities
- Social-economic context
- Anthropogeomorphological model

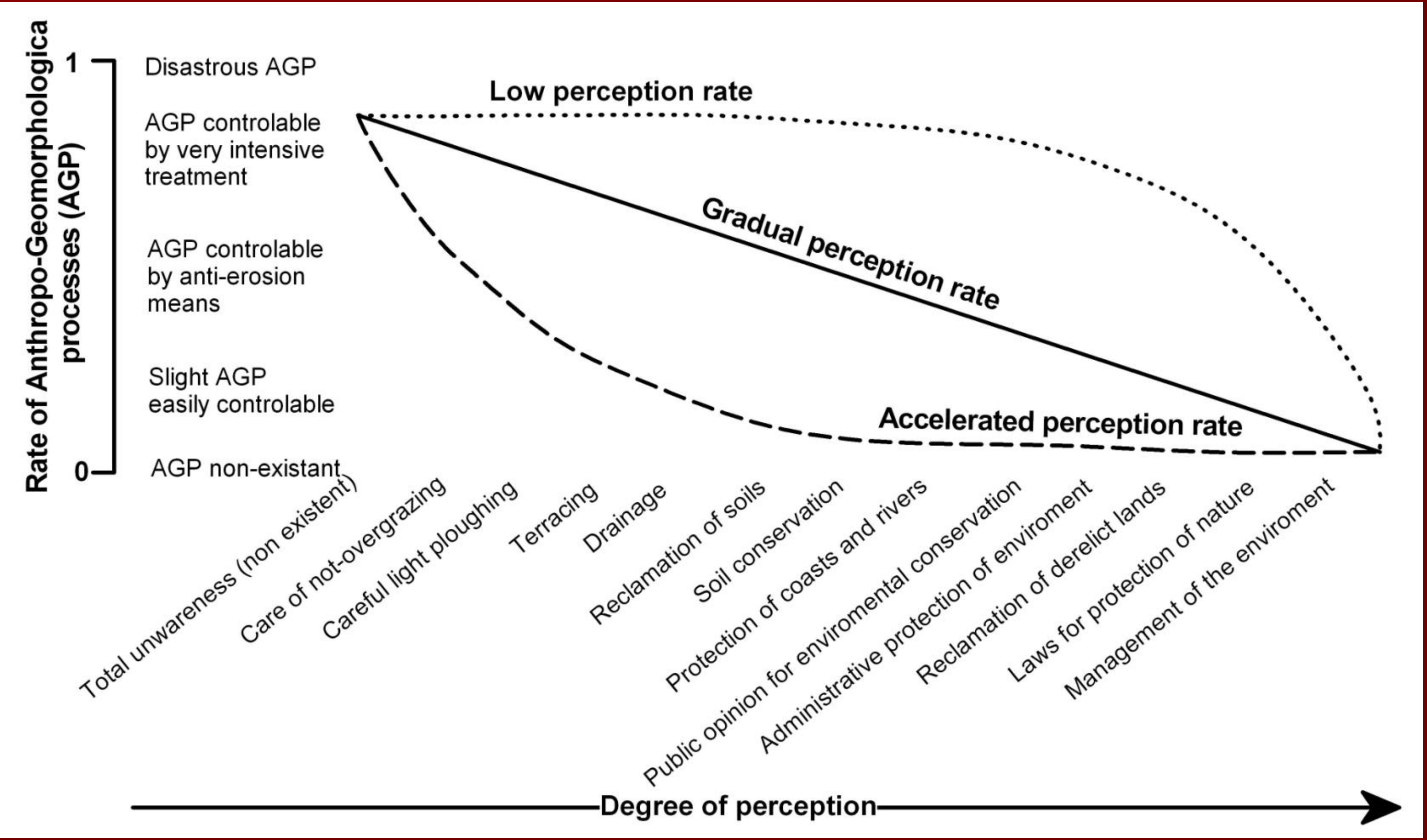
Effect of human activities on erosion according to Nir (1983)

Human intervention	**Material involved** (mrd t/yr)
forest clearing	1
grazing	50
tilling the land	106
mining	15
roads, railways, urban construction	1
TOTAL	**173**

Correlation between AGP and „degree of development” (Nir, 1983)



Correlation between AGP and „degree of perception" of their harm (Nir, 1983)

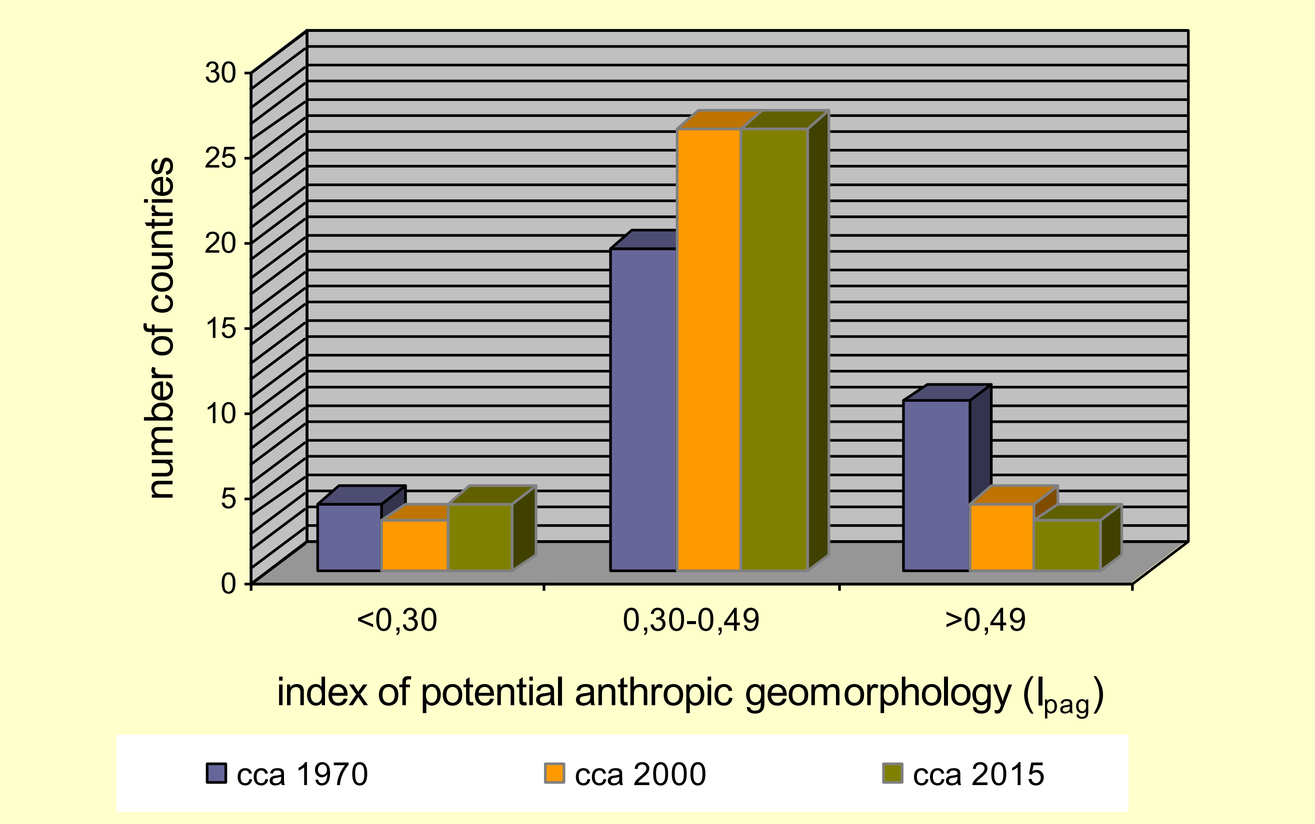


Index of potential anthropic geomorphology (Nir, 1983)

$$I_{pag} = \frac{UP + DI}{2} \cdot \frac{1}{100} \cdot \left(K_c + K_r\right)$$

- UP = percentage of urban population
- UI = percentage of illiteracy
- K_c = constant due to climatic conditions
- K_r = constant due to relief conditions

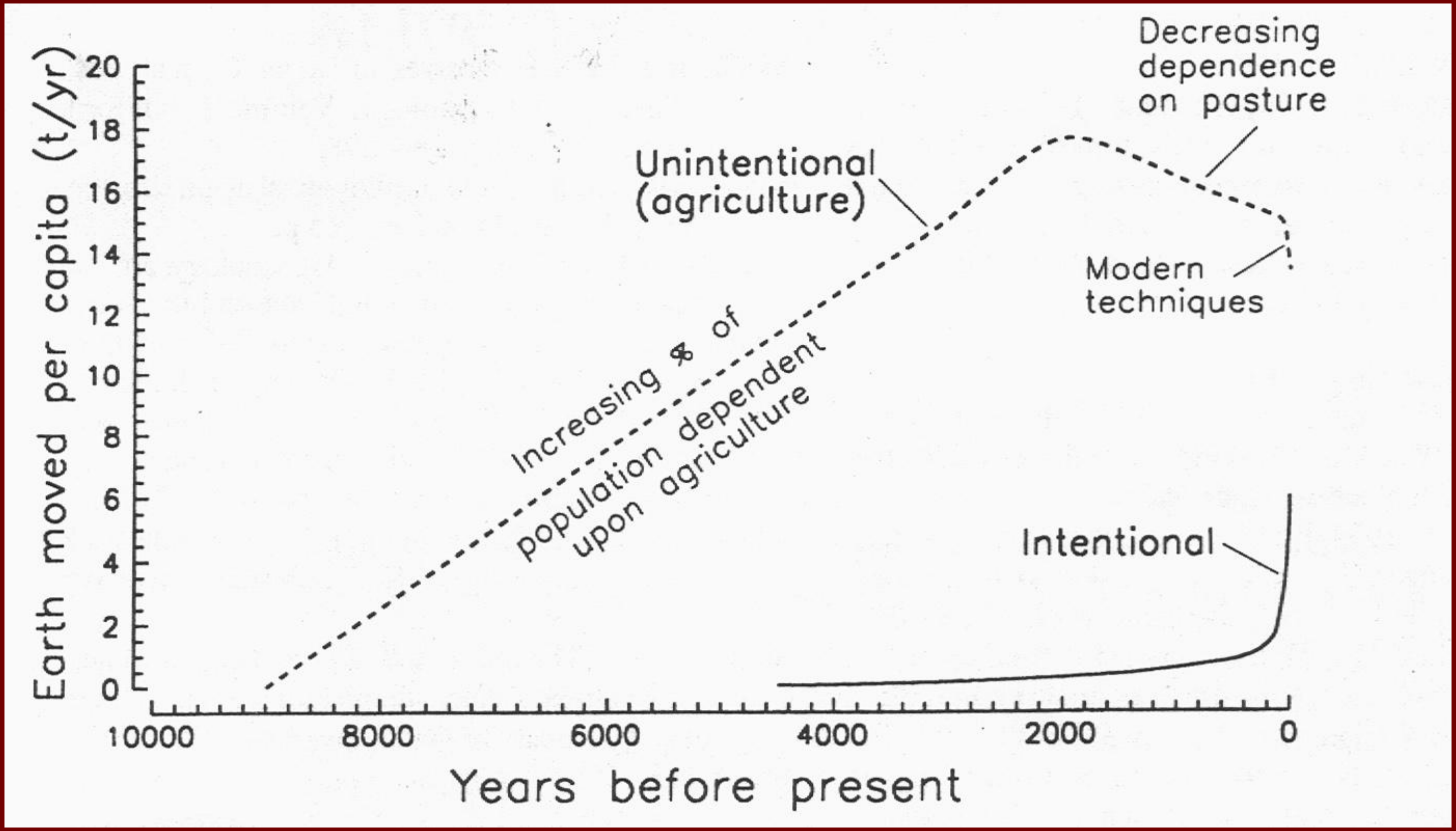
I_{pag} values for 33 countries in 1970, 2000, and 2015



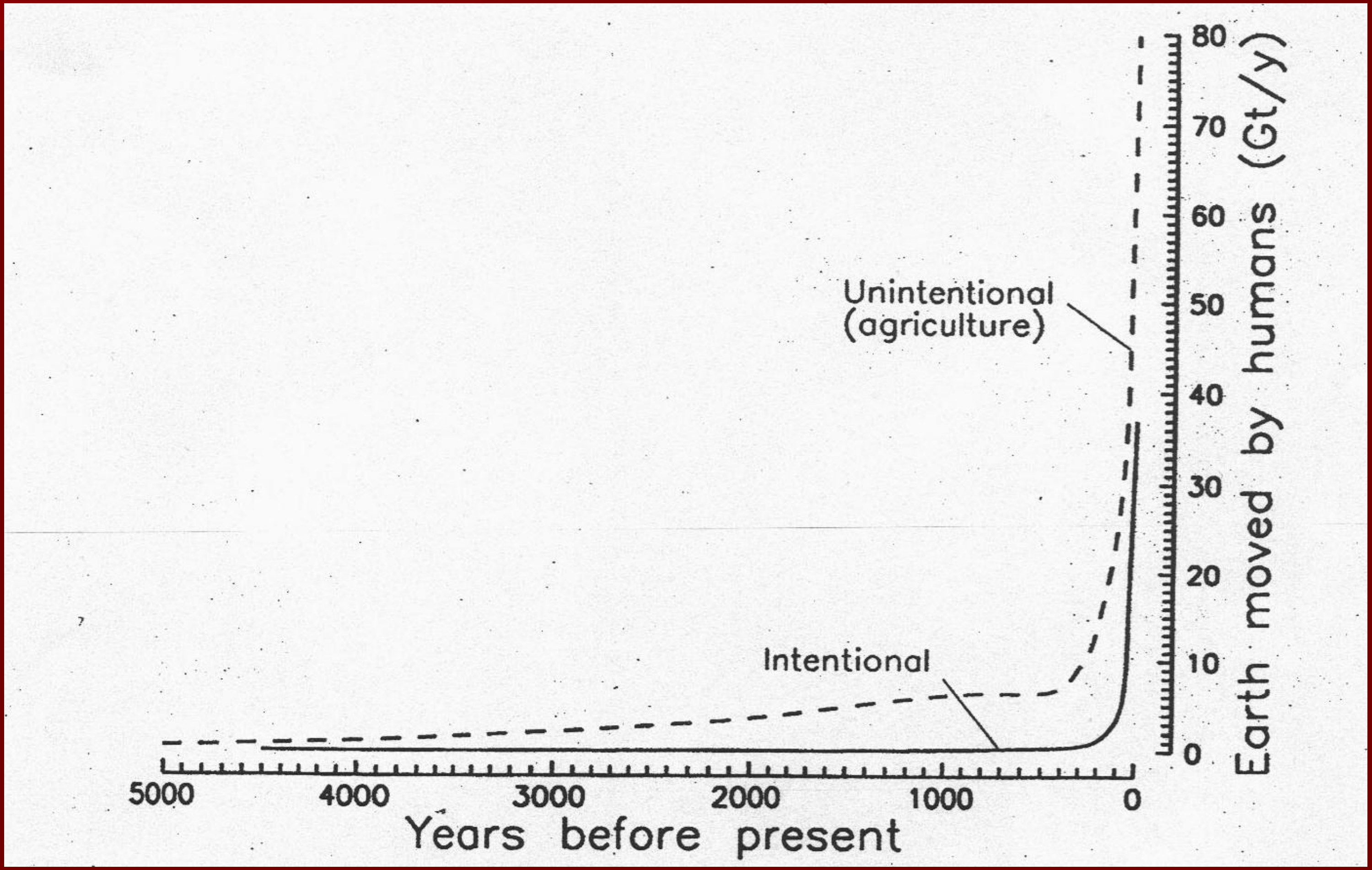
After Nir

- Roger LeB. Hooke: On the history of humans as geomorphic agents. September 2000 *Geology*.

Estimate of earth moved annually per capita by humans from 9000 BP (Hooke, 2000)

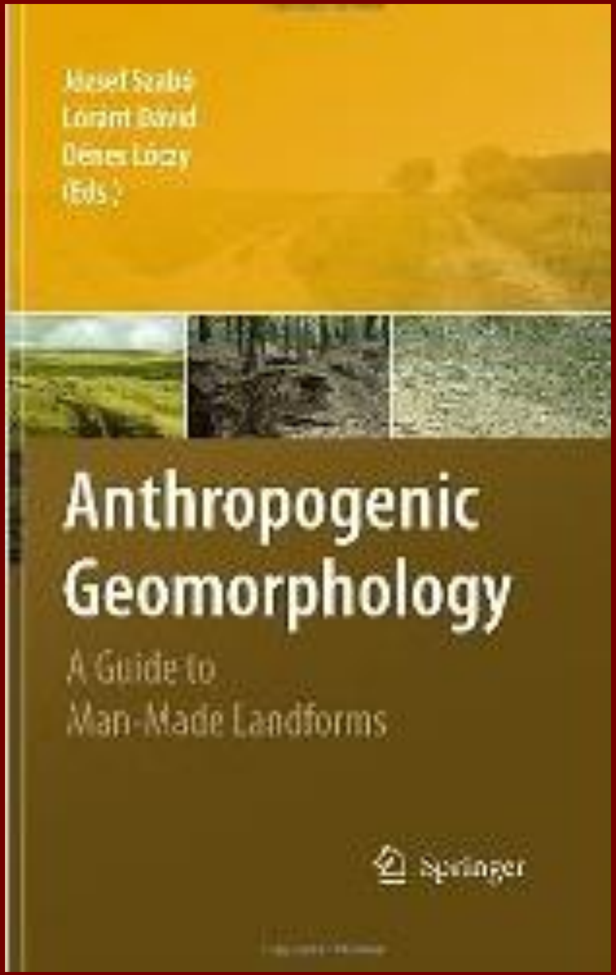


Estimate of total amount of earth moved annually by humans from 5000BP (Hooke, 2000)



After Nir

- J. Szabó – L. Dávid – D. Lóczy (eds): *Anthropogenic Geomorphology: A Guide to Man-Made Landforms*. Springer, 2010



Index of potential anthropic geomorphology

(Nir 1983)

Environmental factors

$$I_{pag} = \frac{UP + DI}{2} \cdot \frac{1}{100} \cdot (K_c + K_r)$$

Anthropogeomorphological processes (AGP)

UP = percentage of urban population,

DI = percentage of illiteracy,

K_c = constant due to climatic conditions,

K_r = constant due to relief conditions.

The basic conceptual problems of the model

- Data representing socio-economic factors concern countries, climate and relief conditions concern regions;
- countries may have extremely varying relief and climatic features;
- consequently, characterization of climate and relief conditions of a country by one constant each can led to **sweeping generalization**.

On the AGP …

- **percentage of urban population** (*UP*) *may* indicate **the degree of development**

- **percentage of illiteracy** (*DI*) *may* indicate **the degree of perception**

But …

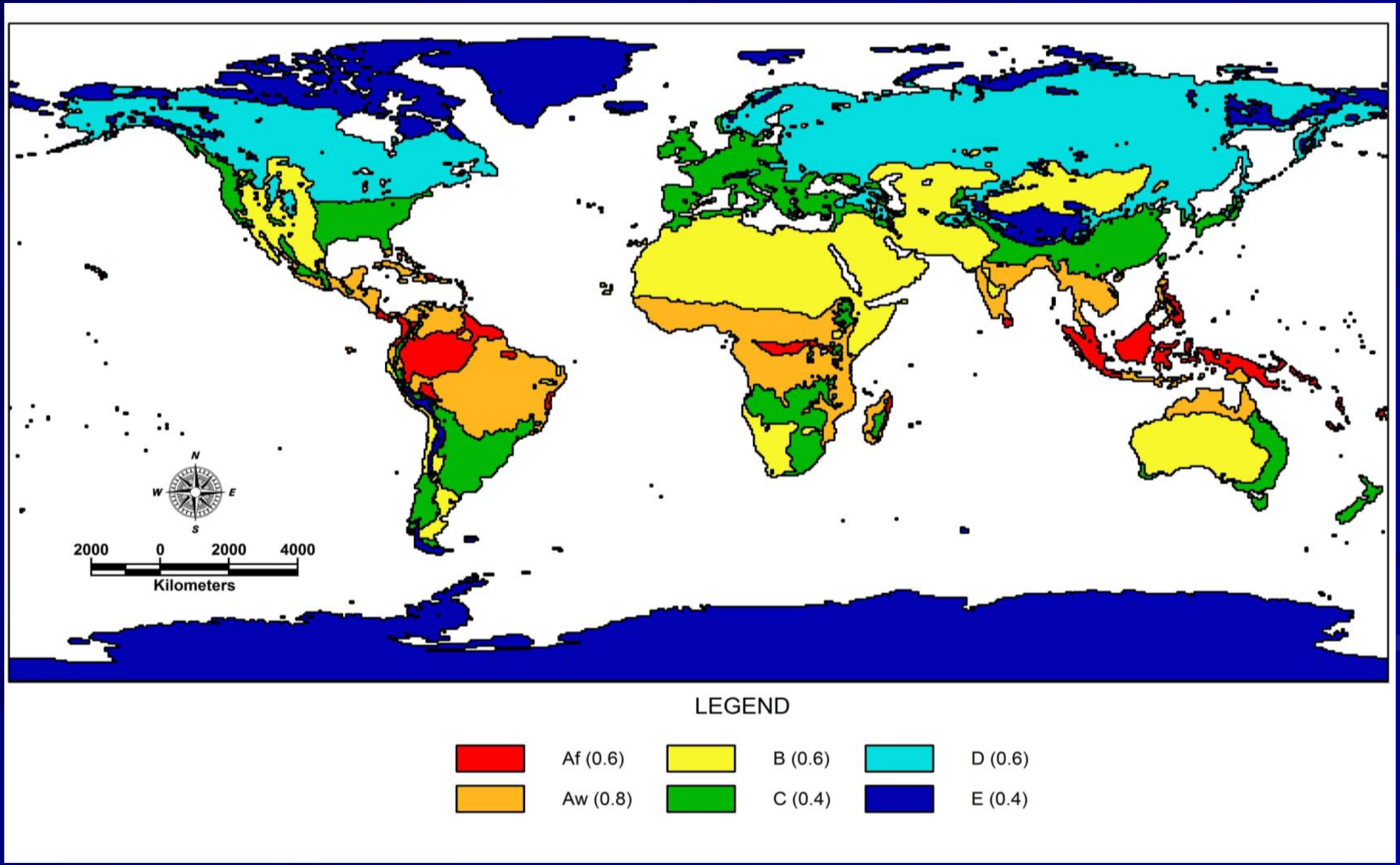
- Because <u>percentage of urban population</u> is rather an *administrative-statistical* than a *social-economic category*, to use it as a parameter that indicates the degree of development **may be misleading**.

- Due to *anti-illiteracy campaigns* it is also **questionable** that <u>percentage of illiteracy</u> really indicates the *level of education*, i.e. it can be used as a parameter indicating the degree of perception.

The values of K_c (Nir, 1983)

Equatorial	0,6	Af
Monsoon-savannah	0,8	Aw
Arid and semiarid	0,6	B
Temperate	0,4	C
Cold	0,6	D
Arctic	0,4	E

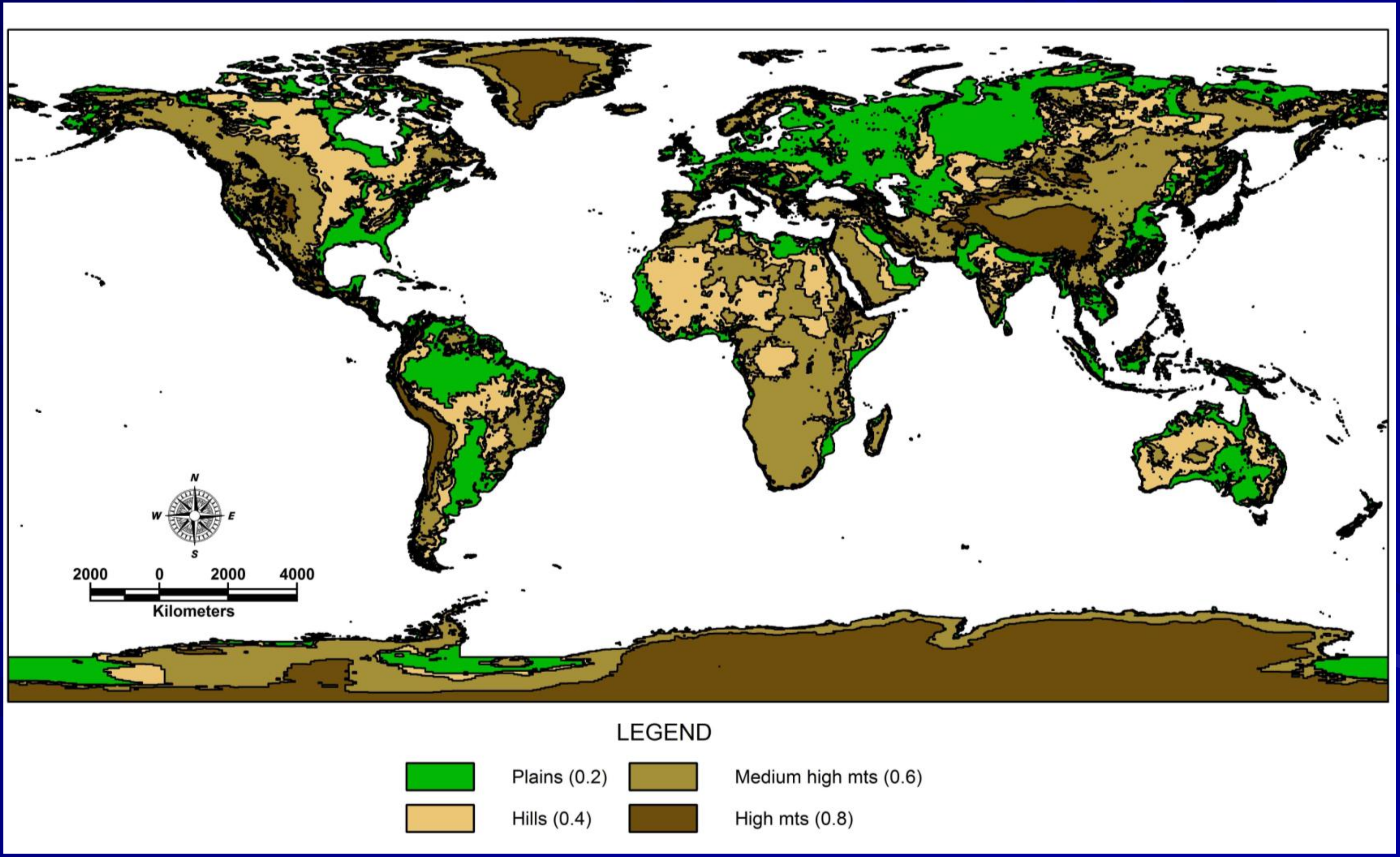
Global pattern of K_c values



The values of K_r (Nir 1983)

Plains	**0,2**	**0–200** m *a.s.l.*
Hills	**0,4**	**200–500** m *a.s.l.*
Plateaus	**0,5**	**--**
Medium-high mountains	**0,6**	**500–1500** m *a.s.l.*
High (Alpine) mountains	**0,8**	**>1500** m a.s.l.

Global pattern of K_r values



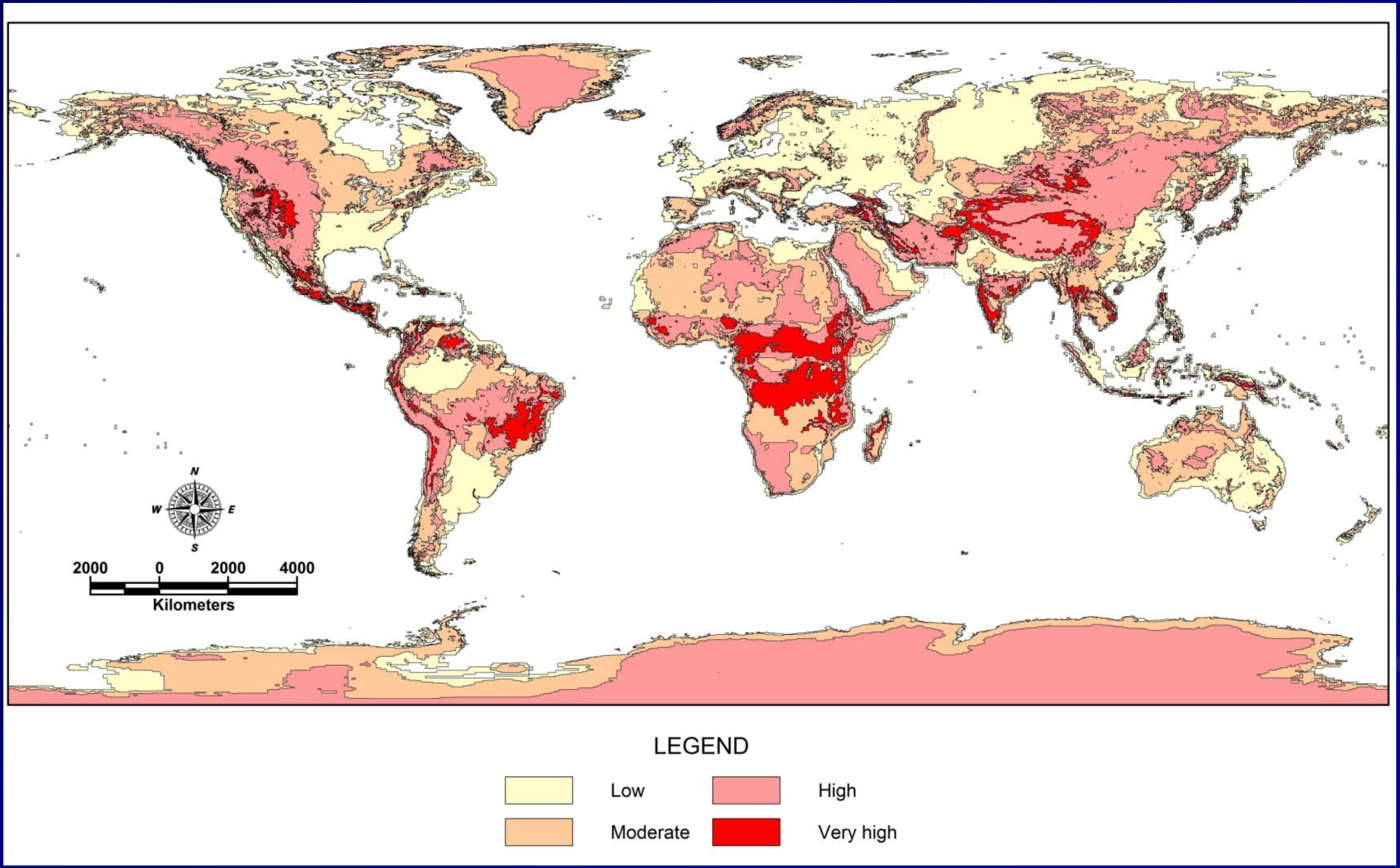
Possible values of (K_c+K_r)

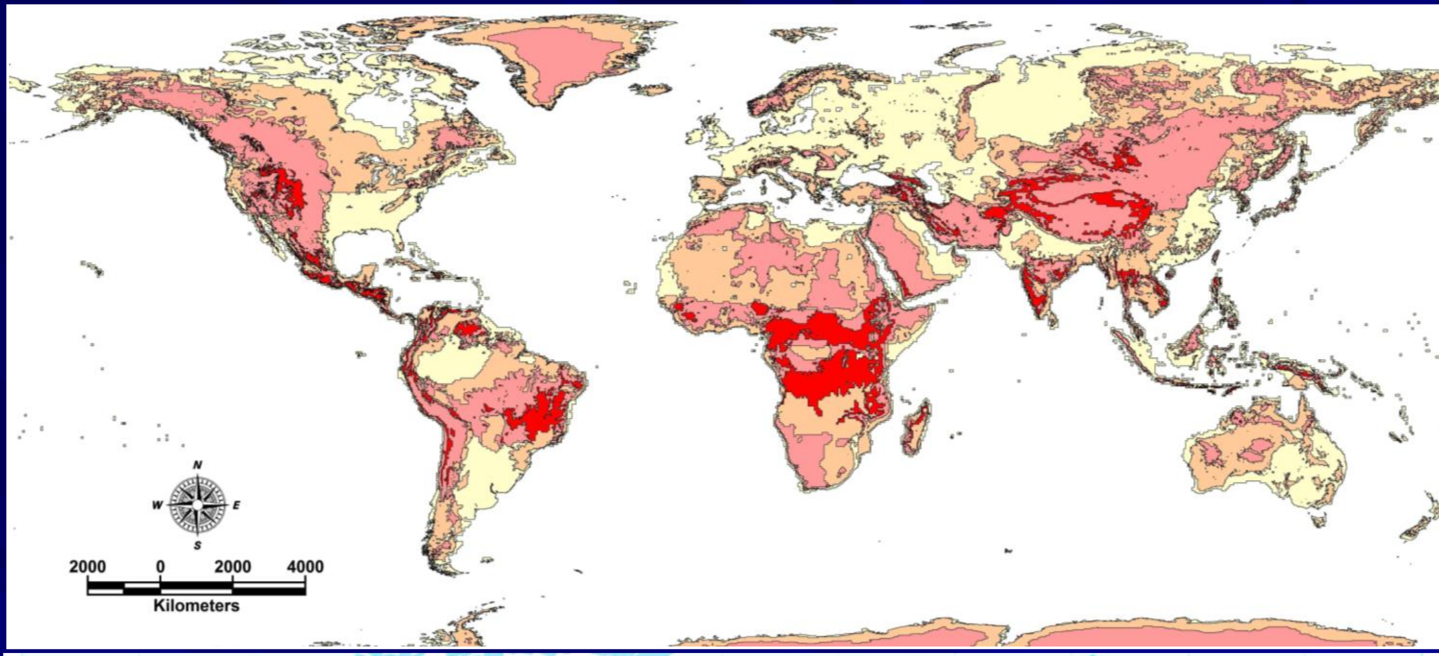
= Anthropic geomorphological sensitivity (Rózsa & Novák, 2011)

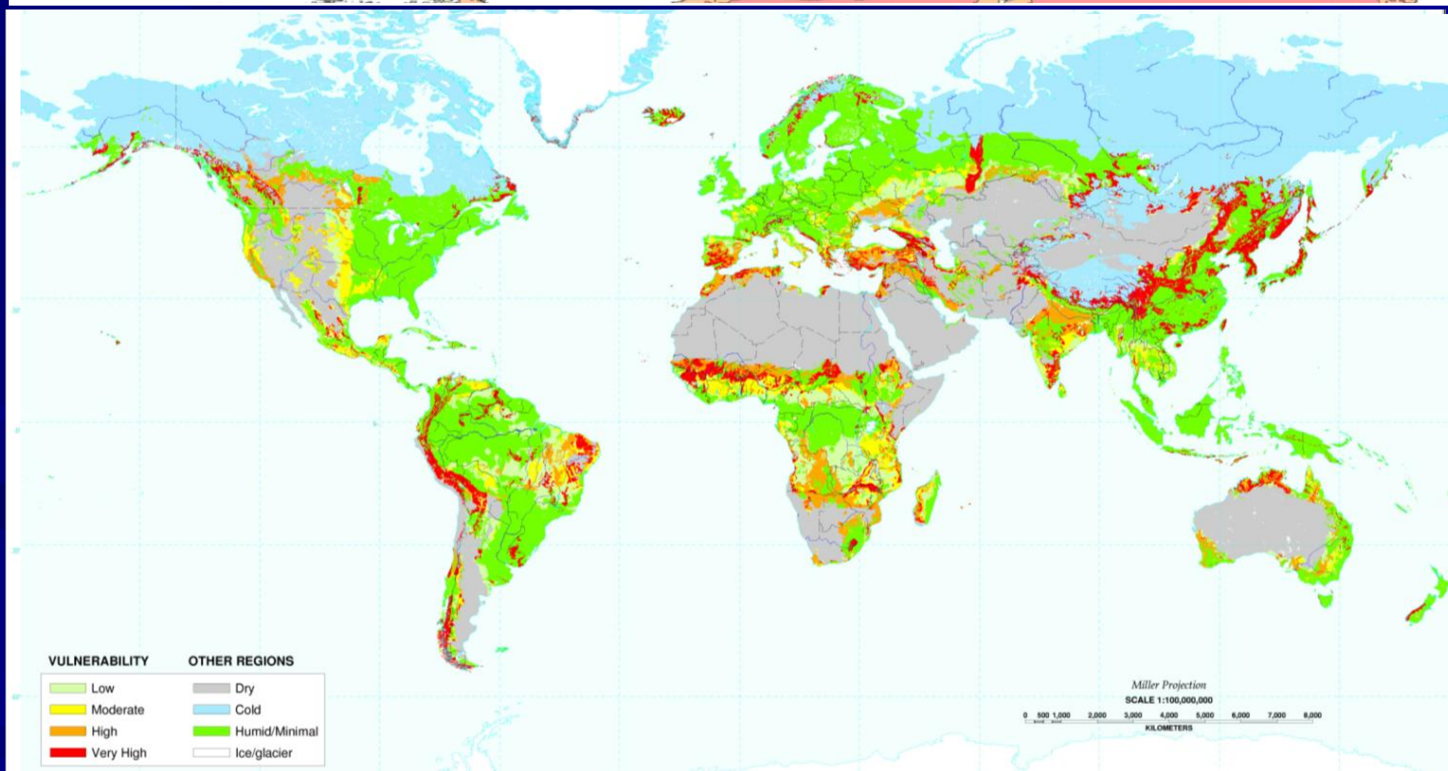
relief / climate	*plains*	*hills*	*m-high mts*	*high mts*
Equatorial	0,8	1,0	1,2	1,4
Monsoon-savannah	1,0	1,2	1,4	1,6
Arid and semiarid	0,8	1,0	1,2	1,4
Temperate	0,6	0,8	1,0	1,2
Cold	0,8	1,0	1,2	1,4
Arctic	0,6	0,8	1,0	1,2

low	moderate	high	Very high

Global pattern of anthropic geomorphological sensitivity (Rózsa & Novák, 2011)




N
W
E
S
2000 0 2000 4000
Kilometers


VULNERABILITY
Low
Moderate
High
Very High
OTHER REGIONS
Dry
Cold
Humid/Minimal
Ice/glacier
Miller Projection
SCALE 1:100,000,000
0 500 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000
KILOMETERS

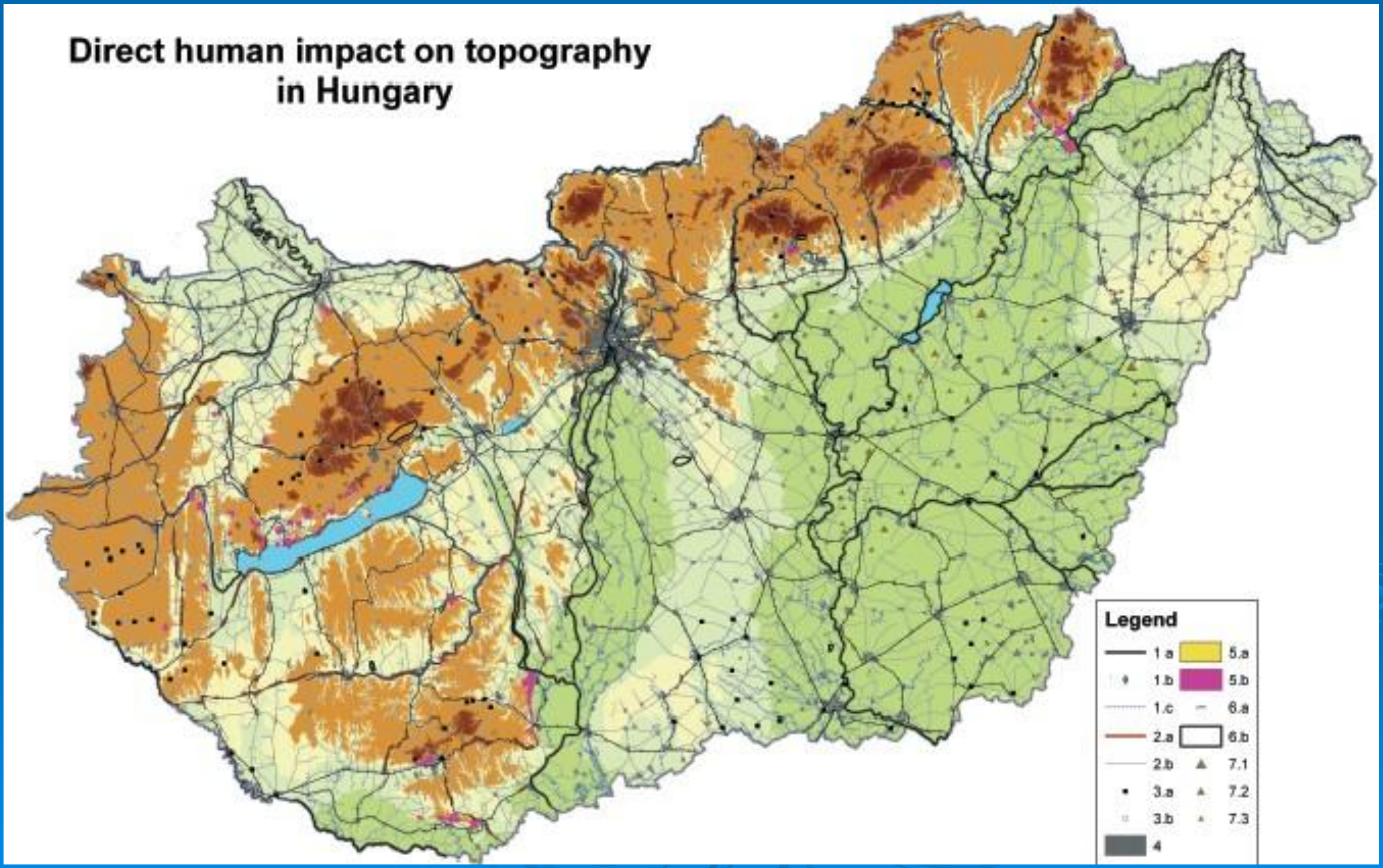
Conclusions

- Socio-economic and environmental factors of potential human geomorphological impact can be hardly expressed by one combined index.
- Percentage of UP and PI may be misleading for indicating degree of development and degree of perception.
- Environmental conditions can be quantified by (K_c+K_r) values.
- By mapping of the possible (K_c+K_r) values, anthropic geomorphological sensitivity map can be compiled on global scale.
- Comparing to global water and wind erosion vulnerability maps, the AGSM provided additional information, and may be useful for broad comparison and to demonstrate that given human activity may represent different natural risks under different climatic and/or relief conditions.

Mapping direct human impact on topography of Hungary (Lóczy & Pirkhoffer, 2009)

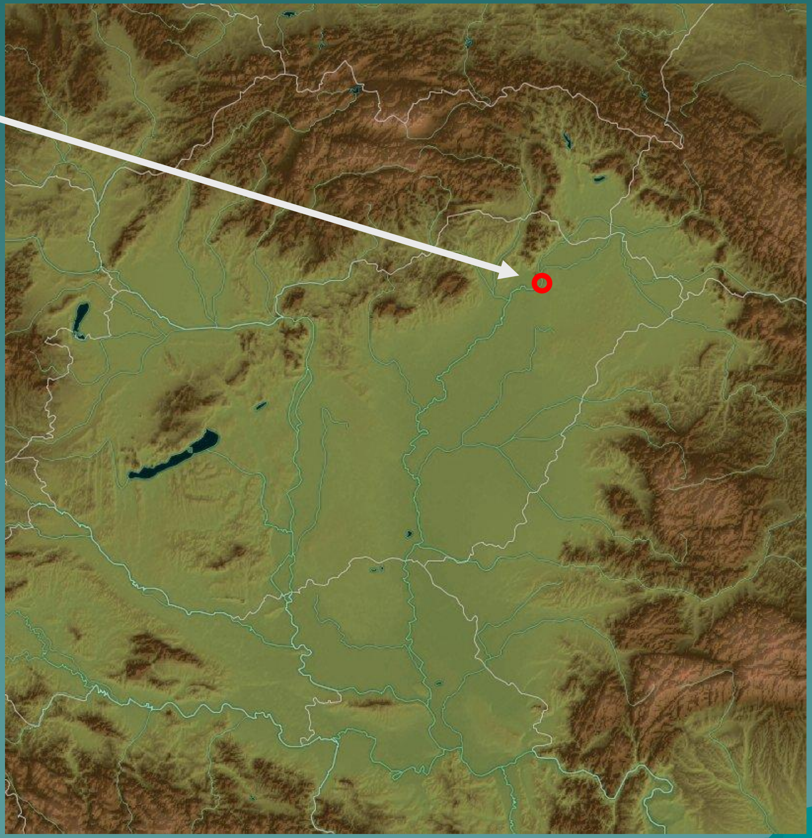
- 1.a. Flood-control dykes; 1.b. Dams; 1.c. Canals;
- 2.a. Railway embankments; 2.b. Public roads;
- 3.a. Areas of deep mining (spoil heaps, ground subsidence); 3.b.Opencast mining (pits and spoil heaps).
- 4. Sealed surfaces;
- 5.a. Levelled surfaces; 5.b. Areas with agricultural terraces and hollow roads;
- 6.a. Sports areas (car racing circuit); 6.b. Military areas (training fields);
- 7. Tumuli: 7.1 = clustered; 7.2 = low concentration; 7.3 = sporadic.

Generalized map of direct human impact on topography in Hungary (Lóczy & Pirkhoffer, 2009).



Characteristics of the study-area

TOKAJ, NAGY-HILL



- **Volcanic hilly landscape**
- **Diverse anthropogenic landuse**
- **Typical landscape-transformation procesess**
- **Well-documented area**

Qualitative groups of the Human Impact

1. No human impact (only natural processes)
2. Accelerated areal erosion/accumulation due to agricultural activity
3. Accelerated linear erosion/accumulation due to agricultural activity (gullies)
4. Agricultural landscaping (terracing, drainage, etc.)
5. Quarries
6. Human controlled geo-environment (built-up areas, permanent long-term surface management)

Quantification of the processes

$$\frac{V_a}{V_n} = R_{ag}$$

= **ratio of the anthropogeomorphologic transformation**

V_a – earth movement caused by human activities (tons/ha/yr)

V_n – earth movement caused by natural processes (tons/ha/yr)

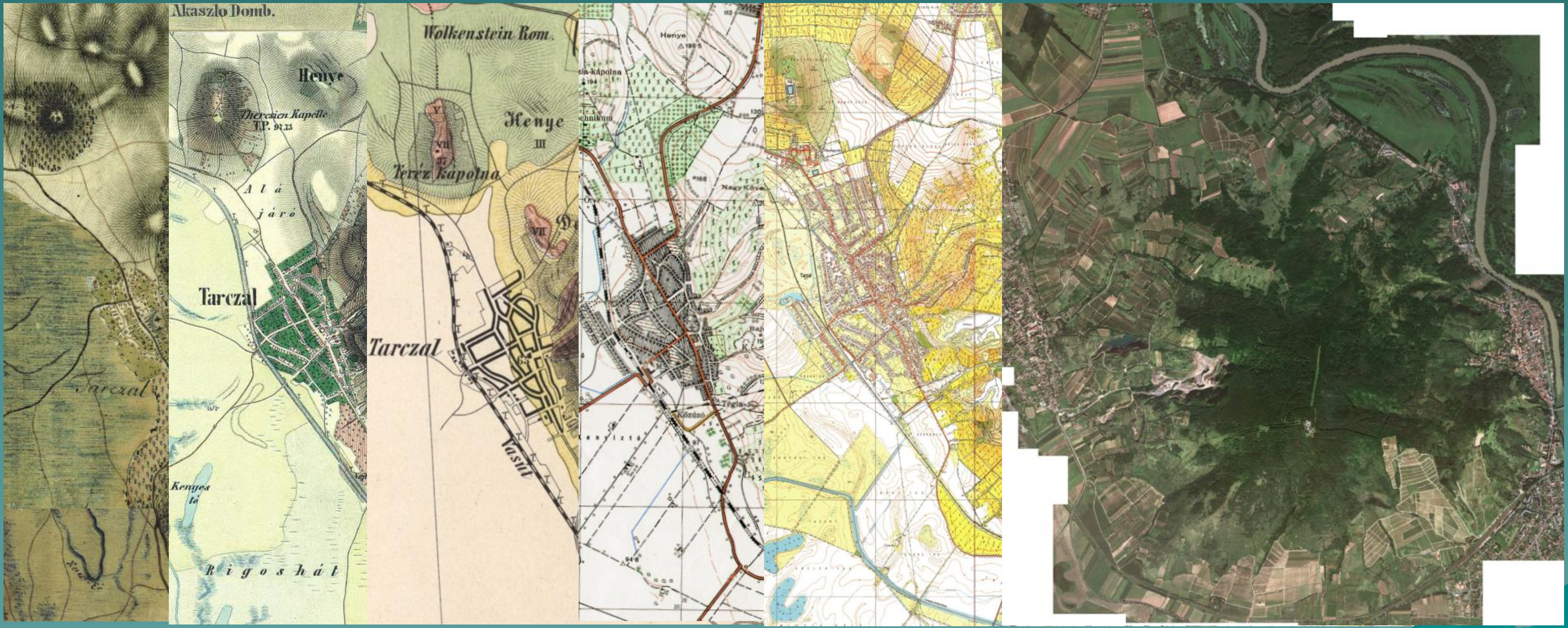
Mapping the processes

- **No human impact** – never cultivated area *(based on historic maps)*
- **Accelerated areal erosion/accumulation due to agricultural activity** – cultivated or formerly cultivated areas *(based on historic maps)*
- **Accelerated linear erosion/accumulation due to agricultural activity** *(based on topographic maps, satellite images, field-work)*
- **Agricultural landscaping** *(based on topographic maps, satellite images, field-work)*
- **Quarries** *(based on topographic maps, satellite images, field-work)*
- **Human geo-environment** *(based on topographic maps, satellite images, field-work)*

Quantification of the mapped units

1. **No human impact** – *not quantified*
2. **Accelerated areal erosion/accumulation due to agricultural activity** – *field measurements of the erosion processes (from the '70s to the mid-90s)*
3. **Accelerated linear erosion/accumulation due to agricultural activity** – *field measurements of the erosion processes (from the '70s to the mid-90s)*
4. **Agricultural landscaping** – *field-work in progress*
5. **Quarries** – *calculation of the excavated material*
6. **Human geo-environment** – *not quantified*

Historic maps

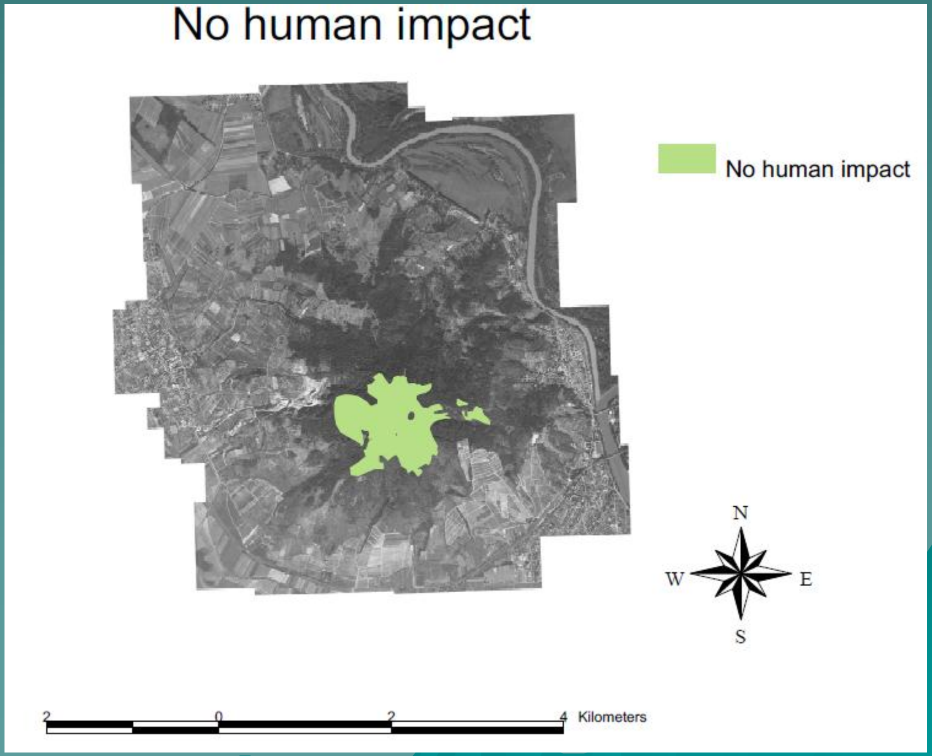


No human impact

$$\frac{V_a}{V_n} = 0$$

- only natural processes are present,
- natural vegetation inhibits erosional processes

0-1,5 tons/ha/yr

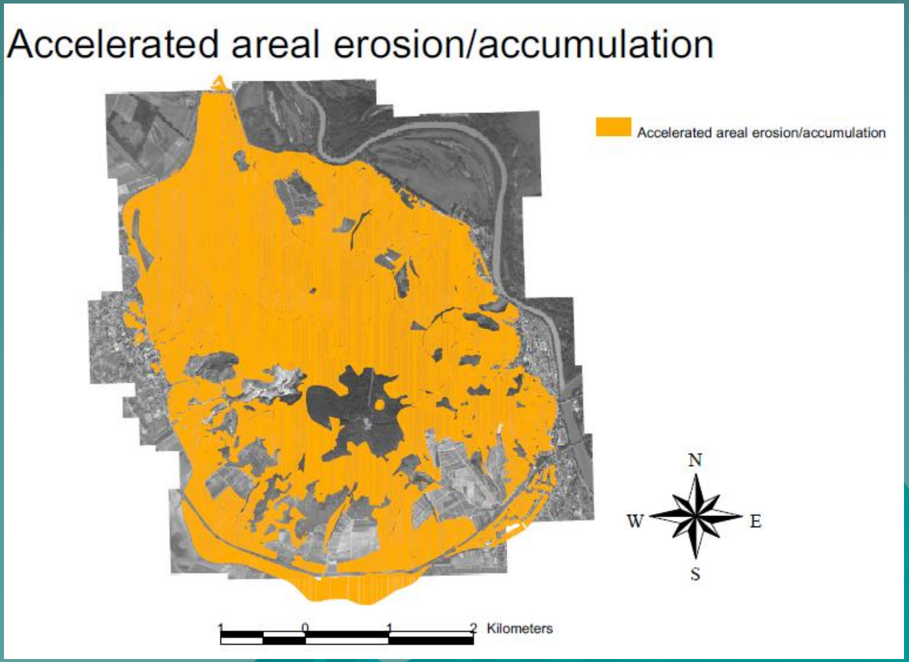


Accelerated areal erosion or accumulation due to agricultural activity

$$\frac{V_a}{V_n} = 10$$

- **volume of transported material estimated by calculations based on field measurements made by *Boros, Pinczés, Kerényi* from the '70s to the mid-90s**

5 -15 tons/ha/yr

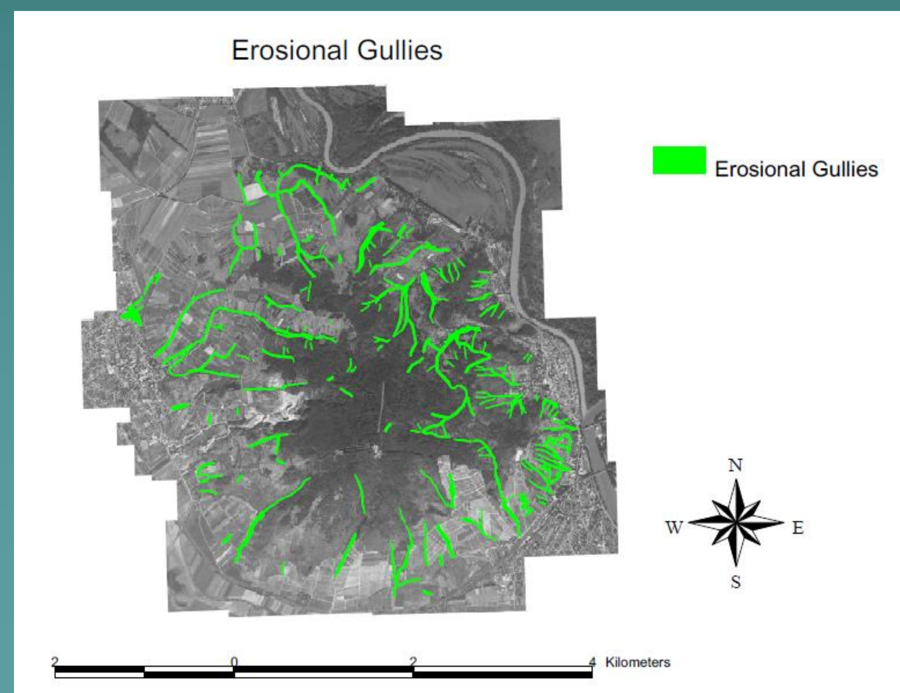


Accelerated linear erosion due to agricultural activity

$$\frac{V_a}{V_n} = 308$$

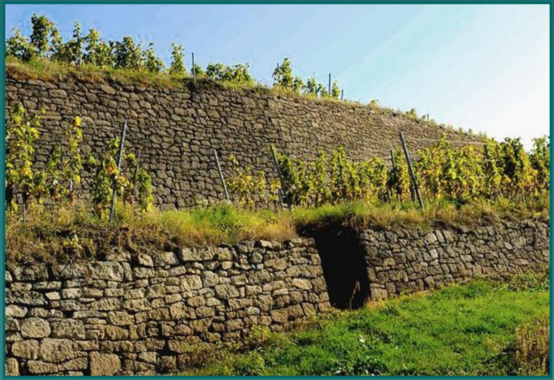
- volume of material estimated by width, depth and length of erosional gullies and hollow roads (field measurements of ***Boros***, ***Pinczés***, ***Kerényi*** from the '60s to the mid-90s)

400 tons/ha/yr



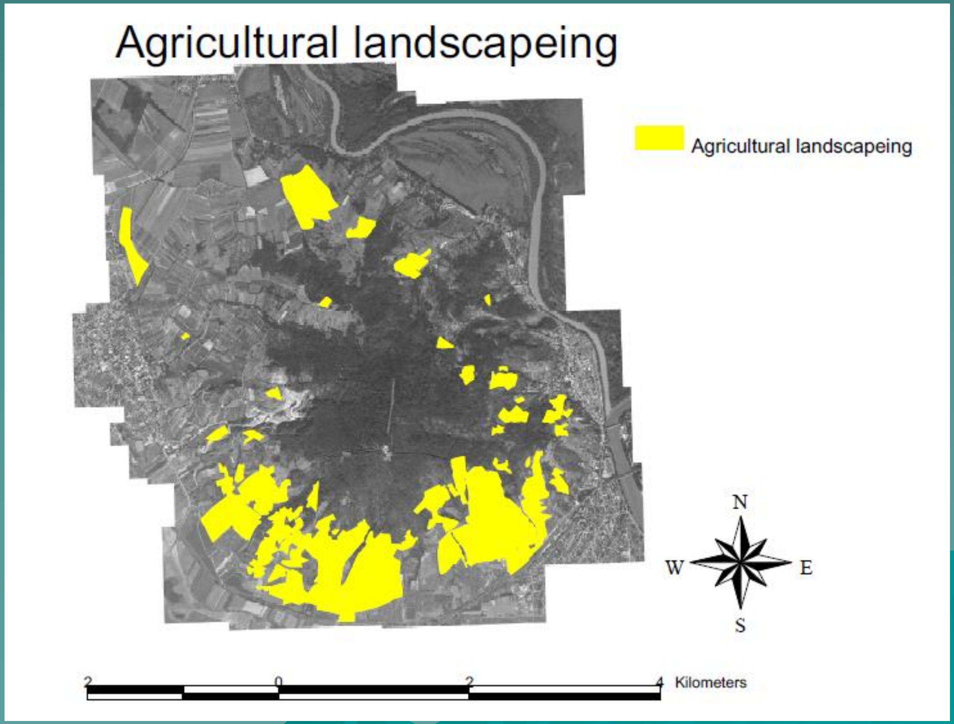
Agricultural landscaping

$$\frac{V_a}{V_n} = 25$$



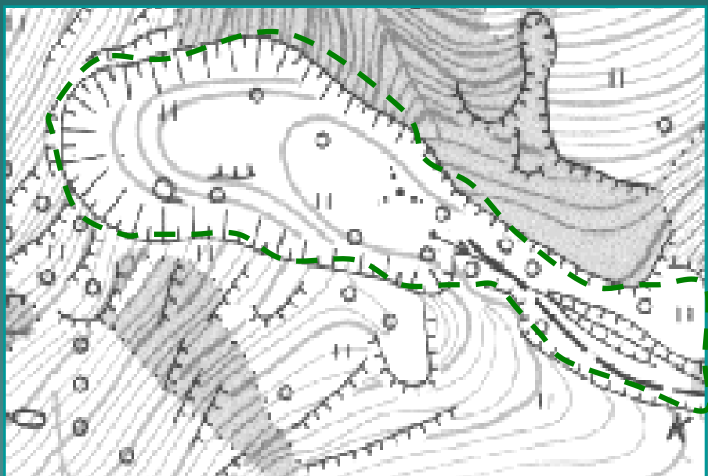
- volume of material estimated by measurements of terraced slopes

  33 tons/ha/yr



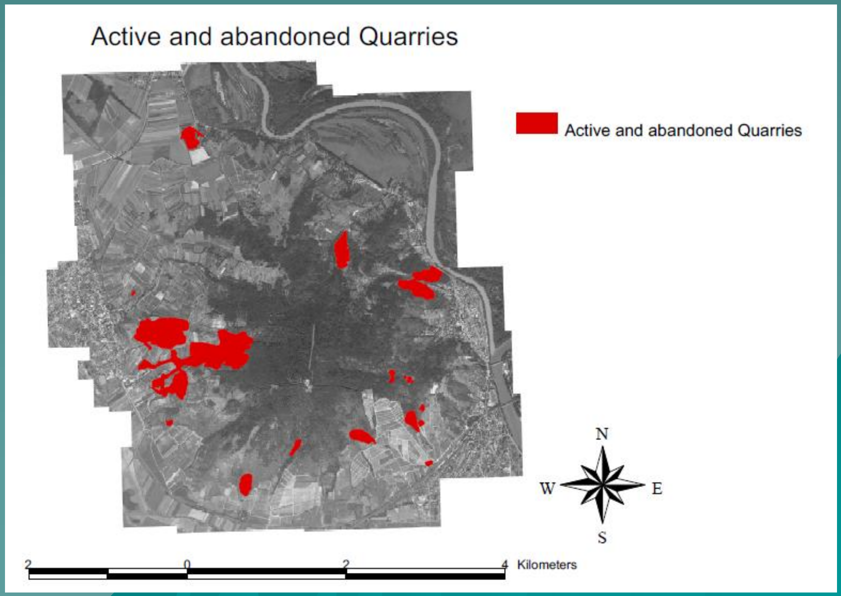
Quarries

$$\frac{V_a}{V_n} = 10385$$



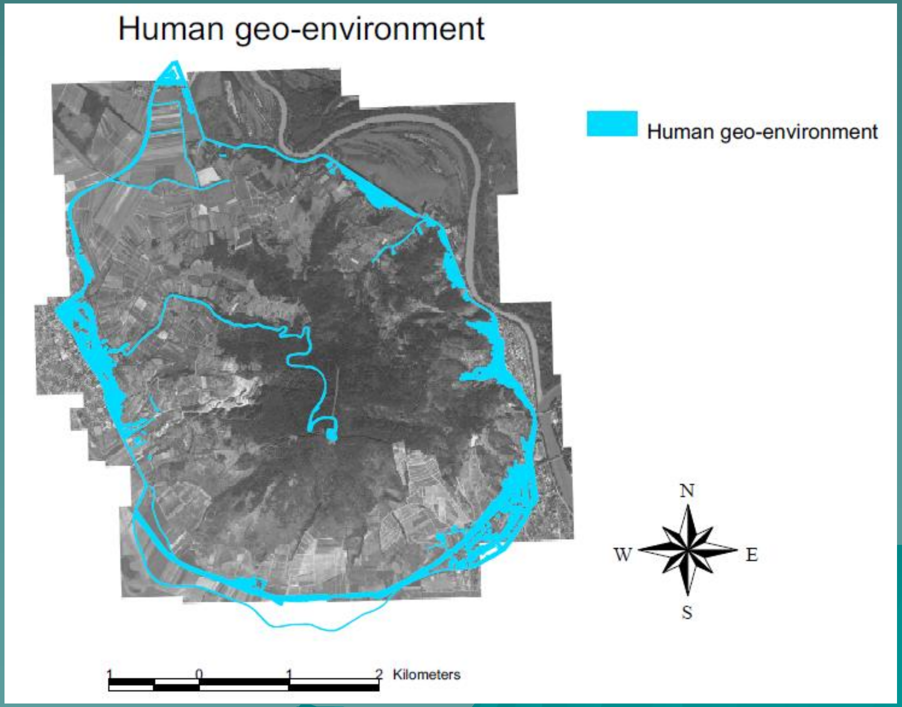
- **volume of material estimated by area of quarries (maps) and field measurements (height and shape of walls)**

13 500 tons/ha/yr

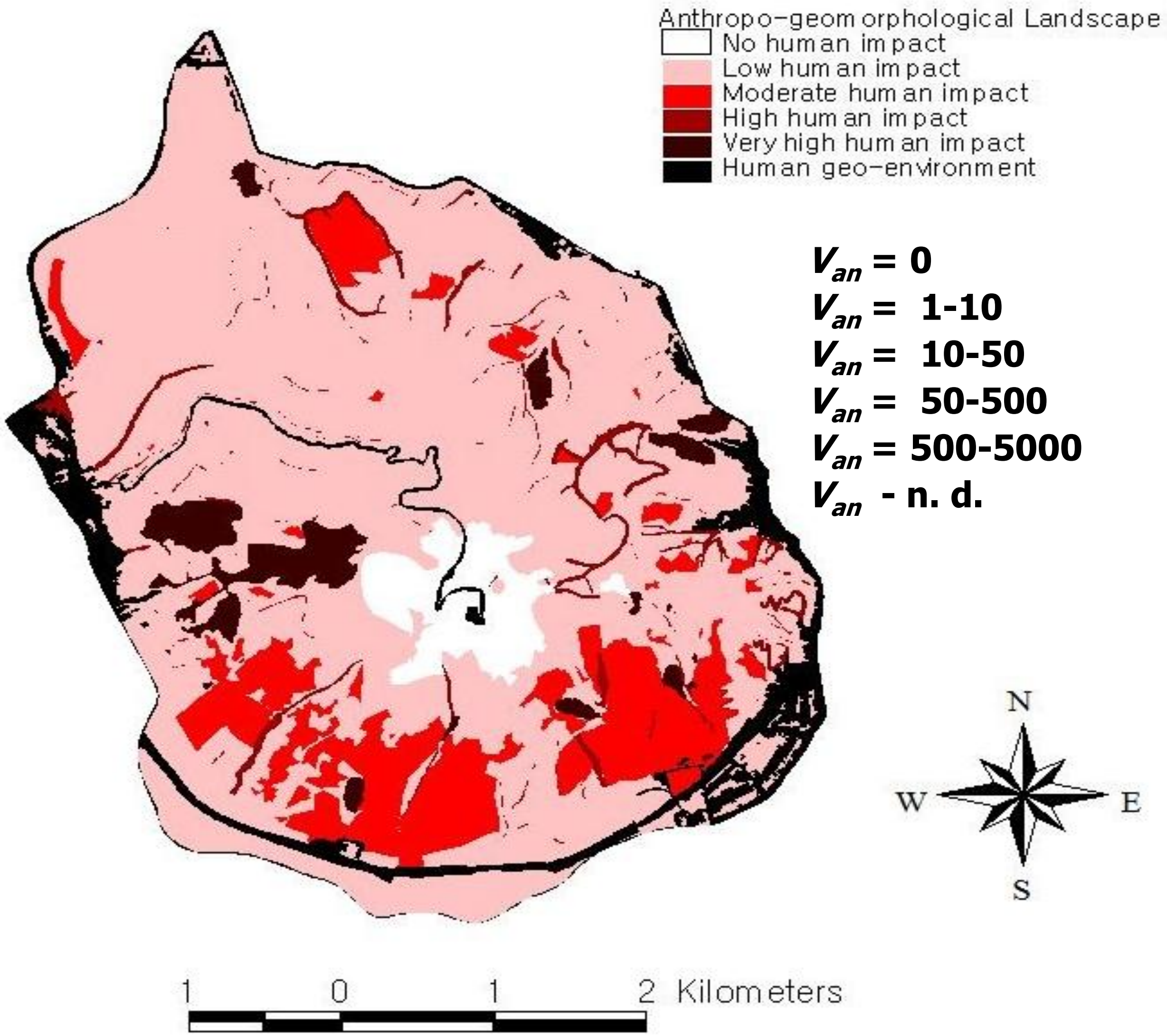


Human geo-environment

- Natural geomorphological processes are completely blocked, or compensated due continuous interventions (built up areas, roads, railways)

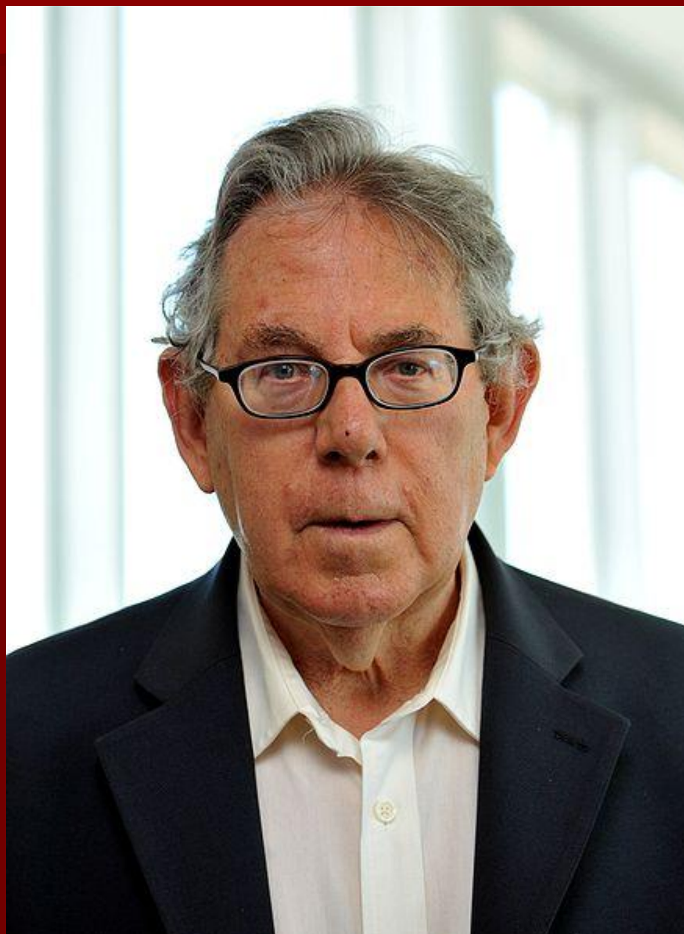


Anthropogeomorphological Landscape Transformation Map



V_{an} = 0	no human impact
V_{an} = 1-10	low human impact
V_{an} = 10-50	moderate human impact
V_{an} = 50-500	high human impact
V_{an} = 500-5000	very high human impact
V_{an} - n. d.	human geoenvironment

„Anthropocene"



Paul Jozef Crutzen (*1933)

Geology of mankind

Paul J. Crutzen

For the past three centuries, the effects of humans on the global environment have escalated. Because of these anthropogenic emissions of carbon dioxide, global climate may depart significantly from natural behaviour for many millennia to come. It seems appropriate to assign the term 'Anthropocene' to the present, in many ways human-dominated, geological epoch, supplementing the Holocene — the warm period of the past 10–12 millennia. The Anthropocene could be said to have started in the latter part of the eighteenth century, when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane. This date also happens to coincide with James Watt's design of the steam engine in 1784.

Mankind's growing influence on the environment was recognized as long ago as 1873, when the Italian geologist Antonio Stoppani spoke about a "new telluric force which in power and universality may be compared to the greater forces of earth," referring to the "anthropozoic era". And in 1926, V. I. Vernadsky acknowledged the increasing impact of mankind: "The direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings." Teilhard de Chardin and Vernadsky used the term 'noösphere' — the 'world of thought' — to mark the growing role of human brain-power in shaping its own future and environment.

The rapid expansion of mankind in numbers and per capita exploitation of Earth's resources has continued apace. During the past three centuries, the human population has increased tenfold to more than 6 billion and is expected to reach 10 billion in this century. The methane-producing cattle population has risen to 1.4 billion. About 30–50% of the planet's land surface is exploited by humans. Tropical rainforests disappear at a fast pace, releasing carbon dioxide and strongly increasing species extinction. Dam building and river diversion have become commonplace. More than half of all accessible fresh water is used by mankind. Fisheries remove more than 25% of the primary production in upwelling ocean regions and 35% in the temperate continental shelf. Energy use has grown 16-fold during the twentieth century, causing 160 million tonnes of atmospheric sulphur dioxide emissions per year, more than twice the sum of its natural emissions. More nitrogen fertilizer is applied in agriculture than is fixed naturally in all terrestrial ecosystems; nitric oxide production by the burning of fossil fuel and biomass also overrides natural emissions. Fossil-fuel burning and agriculture have caused substantial increases in the concentrations of 'greenhouse' gases — carbon dioxide by 30% and methane by more than 100% — reaching their highest levels over the past 400 millennia, with more to follow.

So far, these effects have largely been caused by only 25% of the world population. The consequences are, among others, acid precipitation, photochemical 'smog' and climate warming. Hence, according to the latest estimates by the Intergovernmental Panel on Climate Change (IPCC), the Earth will warm by 1.4–5.8 °C during this century.

Many toxic substances are released into the environment, even some that are not toxic at all but nevertheless have severely damaging effects, for example the chlorofluorocarbons that caused the Antarctic 'ozone hole' (and which are now regulated). Things could have become much worse: the ozone-destroying properties of the halogens have been studied since the mid-1970s. If it had turned out that chlorine behaved chemically like bromine, the ozone hole would by then have been a global, year-round phenomenon, not just an event of the Antarctic spring. More by luck than by wisdom, this catastrophic situation did not develop.

Unless there is a global catastrophe — a meteorite impact, a world war or a pandemic — mankind will remain a major environmental force for many millennia. A daunting task lies ahead for scientists and engineers to guide society towards environmentally sustainable management during the era of the Anthropocene. This will require appropriate human behaviour at all scales, and may well involve internationally accepted, large-scale geo-engineering projects, for instance to 'optimize' climate. At this stage, however, we are still largely treading on *terra incognita*. ■

The Anthropocene

The Anthropocene could be said to have started in the late eighteenth century, when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane.

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FURTHER READING

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Zalasiewitz et al, 2008: Are we now living in the Anthropocene? *GSA Today*

Are we now living in the Anthropocene?

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ABSTRACT

The term *Anthropocene*, proposed and increasingly employed to denote the current interval of anthropogenic global environmental change, may be discussed on stratigraphic grounds. A case can be made for its consideration as a formal epoch in that, since the start of the Industrial Revolution, Earth has endured changes sufficient to leave a global stratigraphic signature distinct from that of the Holocene or of previous Pleistocene interglacial phases, encompassing novel biotic, sedimentary, and geochemical change. These changes, although likely only in their initial phases, are sufficiently distinct and robustly established for suggestions of a Holocene–Anthropocene boundary in the recent historical past to be geologically reasonable. The boundary may be defined either via Global Stratigraphic Section and Point ("golden spike") locations or by adopting a numerical date. Formal adoption of this term in the near future will largely depend on its utility, particularly to earth scientists working on late Holocene successions. This datum, from the perspective of the far future, will most probably approximate a distinctive stratigraphic boundary.

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INTRODUCTION

In 2002, Paul Crutzen, the Nobel Prize–winning chemist, suggested that we had left the Holocene and had entered a new Epoch—the Anthropocene—because of the global environmental effects of increased human population and economic development. The term has entered the geological literature informally (e.g., Steffen et al., 2004; Syvitski et al., 2005; Crossland, 2005; Andersson et al., 2005) to denote the contemporary global environment dominated by human activity. Here, members of the Stratigraphy Commission of the Geological Society of London amplify and extend the discussion of the effects referred to by Crutzen and then apply the same criteria used to set up new epochs to ask whether there really is justification or need for a new term, and if so, where and how its boundary might be placed.

THE HOLOCENE

The Holocene is the latest of many Quaternary interglacial phases and the only one to be accorded the status of an epoch; it is also the only unit in the whole of the Phanerozoic—the past 542 m.y.—whose base is defined in terms of numbers of years from the present, taken as 10,000 radiocarbon years before 1950. The bases of all other periods, epochs, and ages from the Cambrian onward are defined by—or shortly will be defined by—"golden spikes" (Gradstein et al., 2004), in which a suitable section is chosen as a Global Stratotype Section, the "golden spike" being placed at an agreed point within it, giving rise to a Global Stratigraphic Section and Point, or GSSP.

To bring the definition of the base of the Holocene into line with all other Phanerozoic boundaries, there are intentions to create a GSSP for the base of the Holocene in an ice core, specifically in the North Greenland Ice Core Project (NGRIP) ice core, at the beginning of an interval at which deuterium values (a proxy for local air temperature) rise, an event rapidly followed by a marked decrease in dust levels and an increase in ice layer thickness (ICS, 2006). This level lies very near the beginning of the changes that ushered in interglacial conditions, but is some 1700 yr older than the current definition for the base of the Holocene. One might question whether ice is a suitably permanent material, but in this instance it is important that the GSSP is a tangible horizon within a stratigraphic sequence, a "time plane" marking an elapsed, distinctive, and correlatable geological event rather than an arbitrary or "abstract" numerical age. We note here, though (and discuss further below), that this logic need not *necessarily* be followed in any putative definition of the beginning of the Anthropocene.

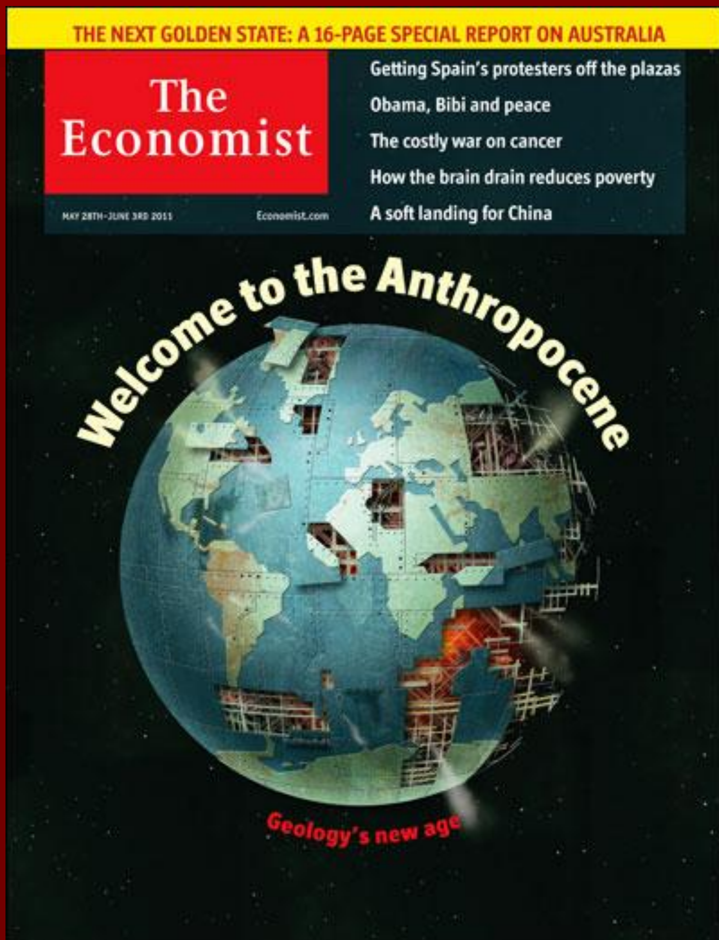
The early Holocene was a time of pronounced rises in global temperature, stabilizing at ca. 11,000 cal. yr B.P., and sea level, stabilizing at ca. 8000 cal. yr B.P. (Fig. 1). Temperatures and sea

„Sufficient evidence has emerged of stratigraphically significant change (both elapsed and imminent) for recognition of the Anthropocene—currently a vivid yet informal metaphor of global environmental change—as a new geological epoch to be considered for formalization by international discussion. The base of the Anthropocene may be defined by a GSSP in sediments or ice cores or simply by a numerical date."

J. Zalasiewitz – M. Williams – W. Steffen – P.J. Crutzen, 2010: The New World of the Anthropocene. *Environ. Sci. Technol*. 44/7, 2228–2231.

„The Anthropocene represents a new phase in the history of both humankind and of the Earth, when natural forces and human forces became intertwined, so that the fate of one determines the fate of the other. Geologically, this is a remarkable episode in the history of this planet."

Journalism vs scientific term



GROUNDWORK

Furthering the Influence of Earth Science

Is the Anthropocene an issue of stratigraphy or pop culture?

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THE ANTHROPOCENE DEBATE

The term *Anthropocene* recently entered into the rhetoric of both the scientific community and the popular environmental movement. Scientific proponents argue that global industrialization drives accelerated Earth-system changes unrivaled in Earth's history. The discussion now filters into geological stratigraphy with proposals to amend formal time stratigraphic nomenclature (Zalasiewicz et al., 2008, 2010). Environmentalists suggest that terms like Anthropocene foster broad social and cultural awareness of human-induced environmental changes. Advocates argue that greater awareness of humanity's role in environmental change encourages sustainable resource utilization.

Formal recognition of a new geologic epoch helps the broader scientific community solidify the idea of humanity as an Earth-system driver. Before the scientific community ventures too far, we wish to offer comment that considers the practicality of the Anthropocene to geological stratigraphy, the science to which it ultimately applies.

SUMMARY OF THE TERM ANTHROPOCENE

Crutzen and Stoermer (2000) suggest that modern technology initiated the transformation of Earth-system behavior and altered environmental processes. They offer the term Anthropocene for the time interval dominated by human activities and indicate that the onset of the human ability to significantly shape Earth's environment became notable with the Industrial Revolution. Steffen et al. (2011) argue that The Great Acceleration after World War II records a dramatic departure in monitored Earth processes from Holocene proxy trends. In contrast, Ruddiman (2005) infers that Holocene-scale anthropogenic greenhouse effects began when humans abandoned hunter-gatherer lifestyles for subsistence settlement, animal domestication, and cultivation agriculture.

The idea that humans interact with nature is not new, and philosophical ideologies about human responsibility permeate historical thinking (Hamilton, 2010; Steffen et al., 2011). *Anthropocene* offers a concept fundamentally different from many precursors. Present human society does not have a symbiotic relationship with nature. Humanity now modifies natural processes, such as biogeochemical cycles, ocean-atmosphere transfers, and flux of surficial sediments (Steffen et al., 2011). Accelerated mass transfer of sediments (Hooke, 2000; Wilkinson, 2005) has particular interest because erosion and sedimentation produce stratigraphic records.

RELEVANCE TO STRATIGRAPHIC PRACTICE

The Anthropocene has taken root in popular culture as a new time term, and scientists embroiled in research and debate on anthropogenic climate change should benefit from formal stratigraphic adoption. However, identification of a basal boundary for the Anthropocene and the suggestion that the concept can be validated with a global stratigraphic marker is at best a bit premature. A distinct stratigraphic marker should have been forming since anthropogenic change began. As practicing stratigraphers, we are taken aback by the claim that scientists currently have sufficient evidence to define a distinctive and lasting imprint of our existence in the geologic record.

Formal stratigraphic practice (ISSC, 1994; NACSN, 2005) uses a codified approach to the development, recognition, and amendment of a timescale relevant to Earth's history. Concepts for stratigraphic units require criteria that allow for the definition, delineation, and correlation of stratiform sequences of Earth materials. Time stratigraphic units represent layers of rock containing lithologic, fossil, mineral, chemical, or geophysical signatures that allow for the recognition and measurement of geologic time.

Because the strata anticipated by the Anthropocene has not yet fully developed and it is only currently possible that a recognizable basal boundary separates it from the Holocene epoch, researchers should find difficulty in using this concept in stratigraphic practice. Stratigraphic boundaries commonly appear as abrupt in the rock record but are often imprecise in time. A boundary as broad as a few thousand years resolves most problems in deep-time stratigraphy but would be of little use to identify a boundary intended to separate events of recent centuries. Definition and delineation of a basal Anthropocene boundary would be sufficient to introduce the term, but the boundary could be potentially arbitrary if it lacks temporal precision. For example, a global marker could be diachronous across millennia if human-accelerated sedimentation were the specific attribute used to mark the basal Anthropocene.

Formal stratigraphic hierarchy (ISSC, 1994; NACSN, 2005) implies that Anthropocene would either hold the rank of epoch if equivalent to the Holocene or age if defined as a subset of the Holocene. Either way, a stratotype that records a continuous, preferably marine, sedimentation record and separates the Anthropocene from underlying units needs to be identified and correlated into the global time stratigraphy. This is a daunting task that may or may not generate significant gains in the

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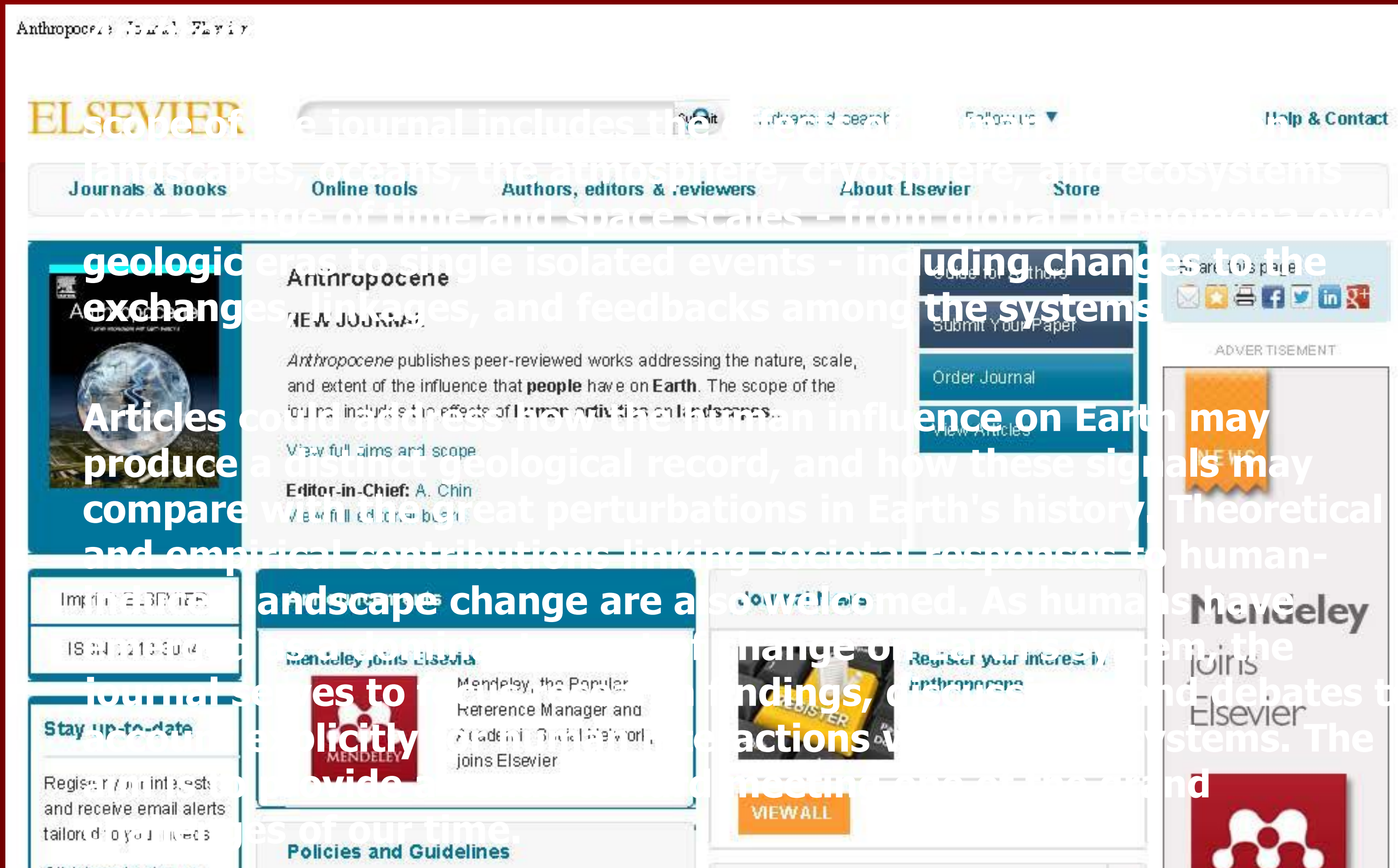
(Autin & Holbrook, 2012)

Scope of the journal includes the landscapes, oceans, the atmosphere, cryosphere, and ecosystems over a range of time and space scales - from global phenomena over geologic eras to single isolated events - including changes to the exchanges, linkages, and feedbacks among the systems.

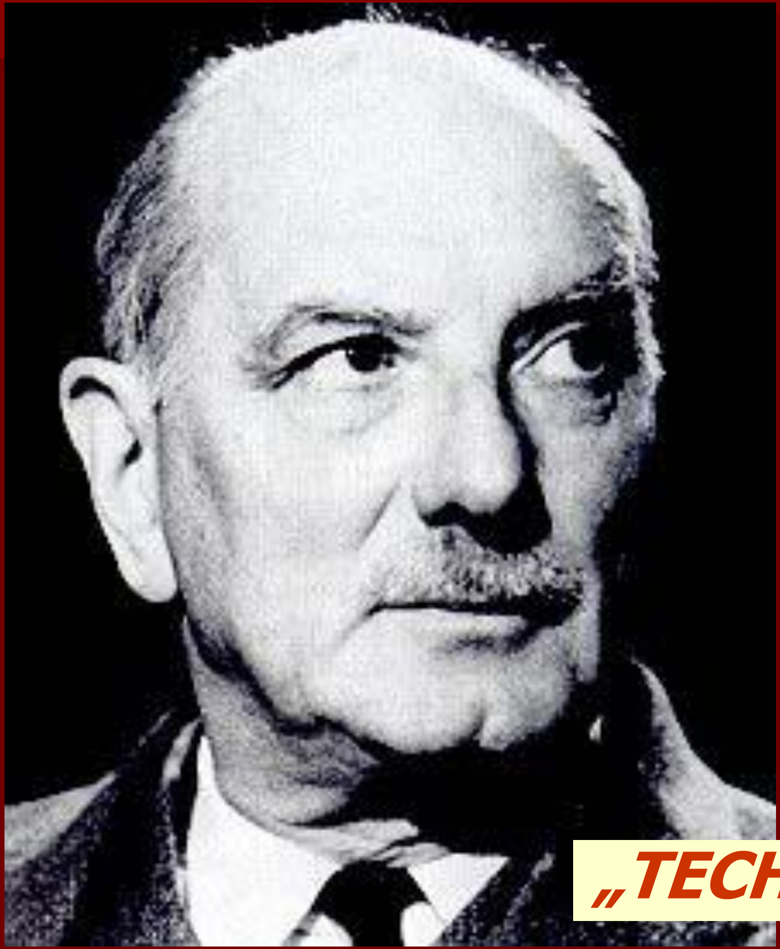
Articles could address how the human influence on Earth may produce a distinct geological record, and how these signals may compare with the great perturbations in Earth's history. Theoretical and empirical contributions linking societal responses to human-landscape change are also welcomed. As humans have [illegible] change on [illegible] system, the journal serves to [illegible] findings, [illegible] and debates to [illegible] explicitly [illegible] actions [illegible] systems. The [illegible] provide [illegible] connecti[illegible] and [illegible] es of our time.

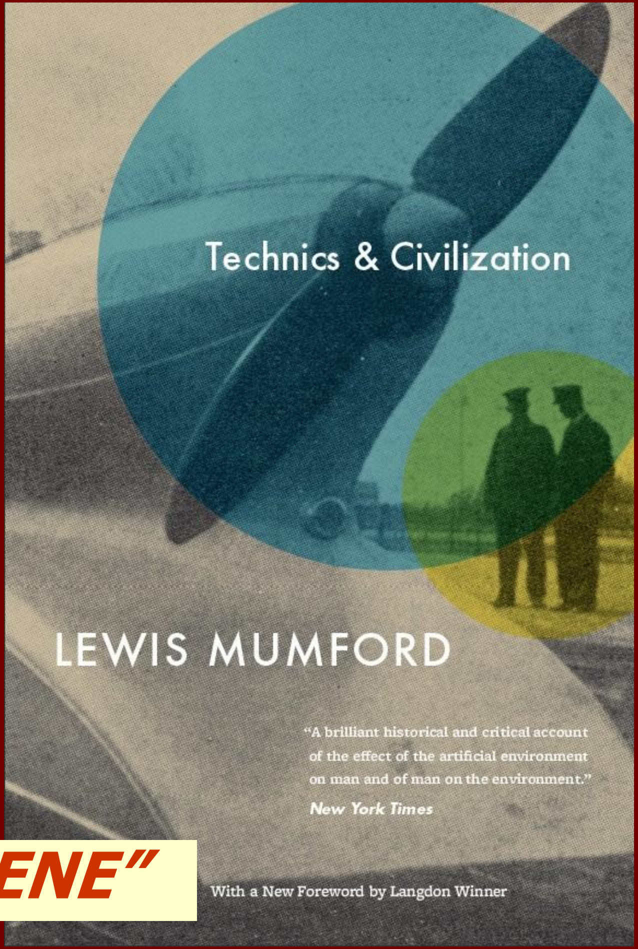


Earth moved by humans activities and natural processes (Hooke, 2000)

Geomorphological agent		Earth moved (mrd t/yr)
MAN	Intentional based on GNP	30
	Intentional based on energy consumption	35
	Unintentional (grazing, tilling, etc.)	99
TOTAL ANTHROPOGENIC		**129–134**
NATURE	Rivers	53
	Glaciers	4
	Mass movement	1
	Wave action	1
	Wind	1
	Orogeny	44
	Sedimentation in oceanic basins	7
TOTAL NATURAL		**111**

Lewis Mumford (1895–1990)





„TECHNOCENE"

Thank you for your attention!