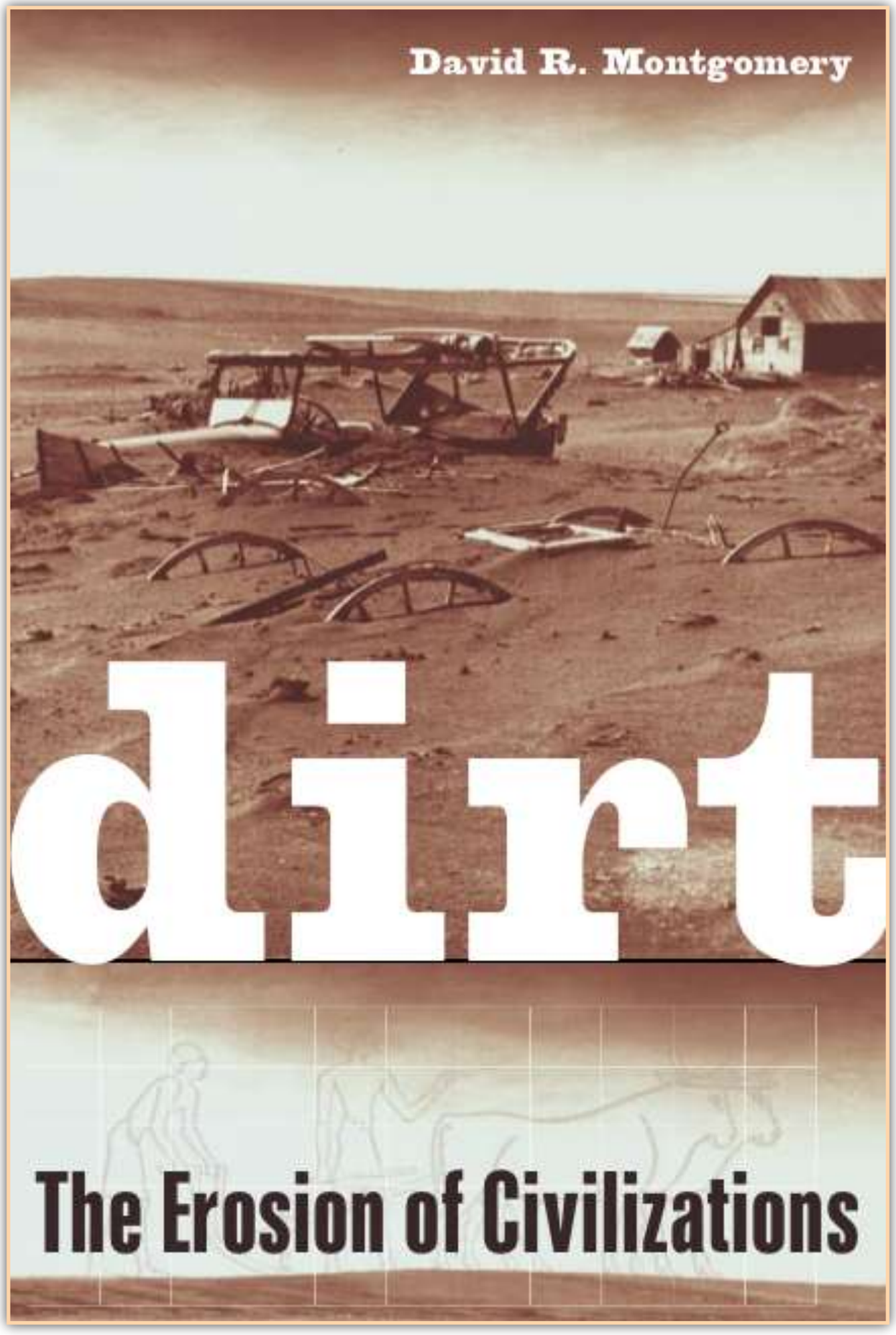
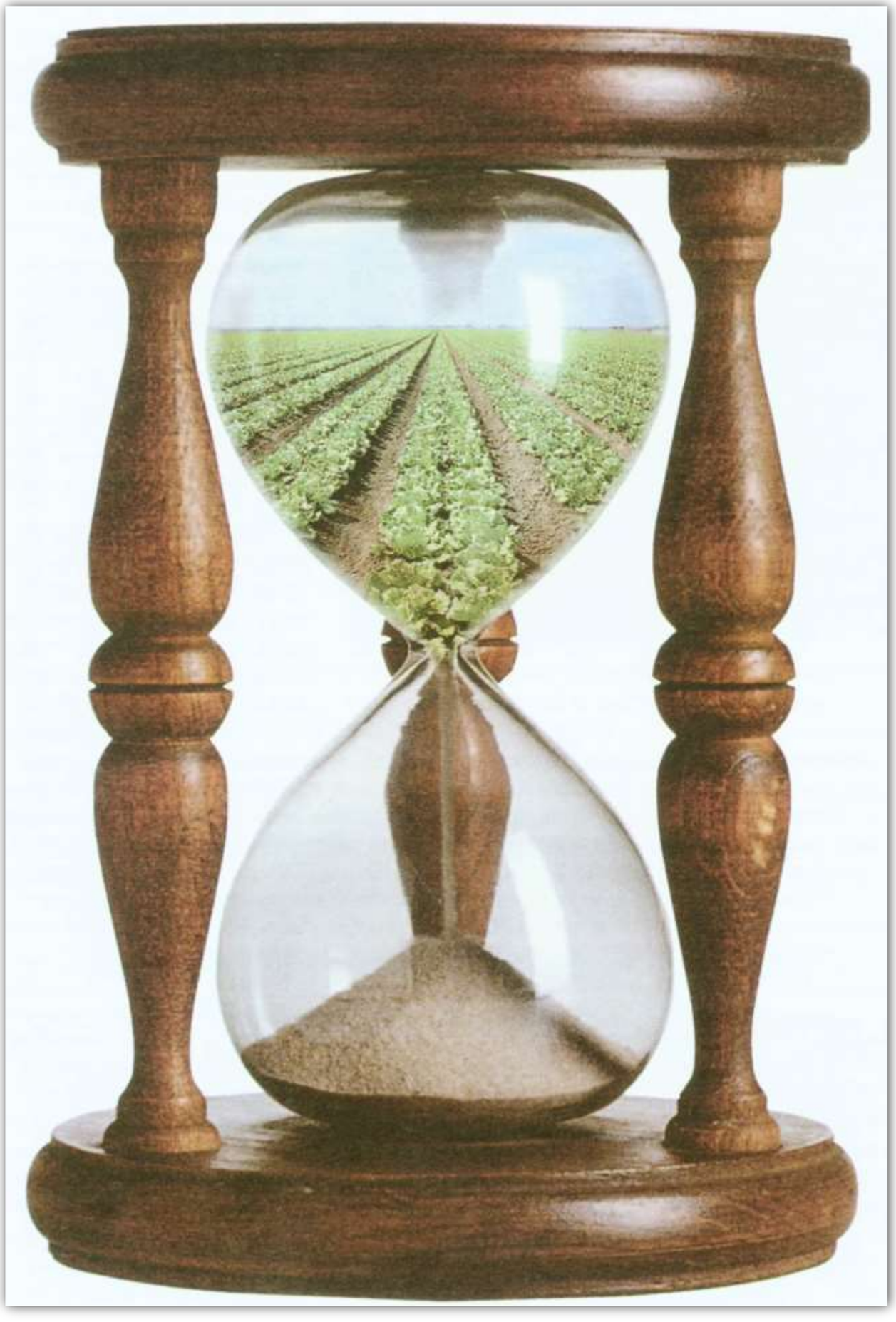

David R. Montgomery
dirt
The Erosion of Civilizations



Soil is a Strategic Resource

Soil degradation

Very degraded soil

Degraded soil

Stable soil

Without vegetation

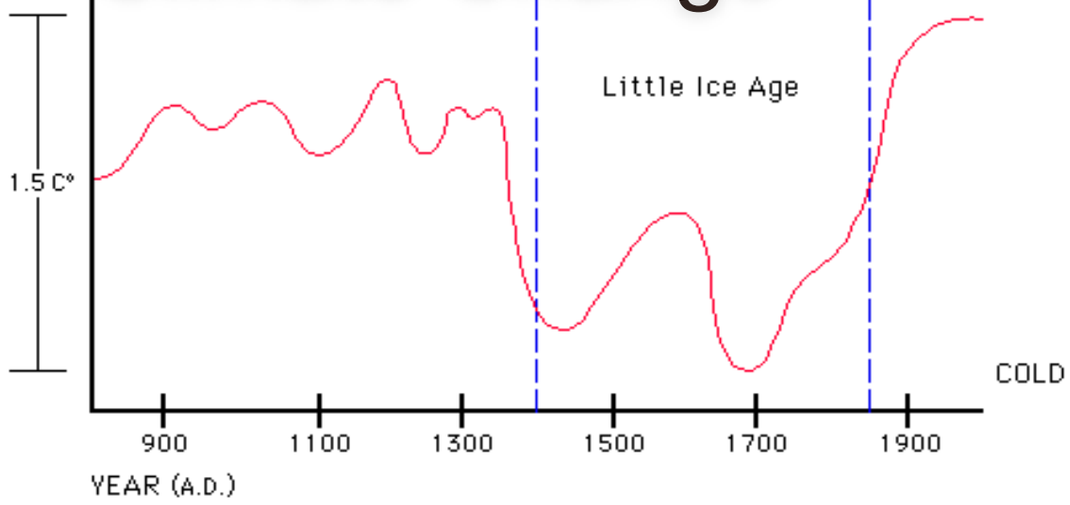
UNEP GRID Arendal

Since the Second World War soil erosion and degradation has caused farmers to abandon about 430 million ha of arable land, an area equivalent to about one-third of all present cropland.

Pimental et al., 1995

No real mystery that some of the key controls on the longevity of human societies are…

Climate Change



Air temperatures in eastern Europe over the past 1000 years based on H.H. Lamb's winter severity index. [Adapted from H.H. Lamb, "Climatic Fluctuations." In H. Flohn (Ed.), *World Survey of Climatology.* Vol. 2. *General Climatology.* New York: Elsevier, 1969, p. 236.]

Natural Disasters

Politics, War, and Social Evolution

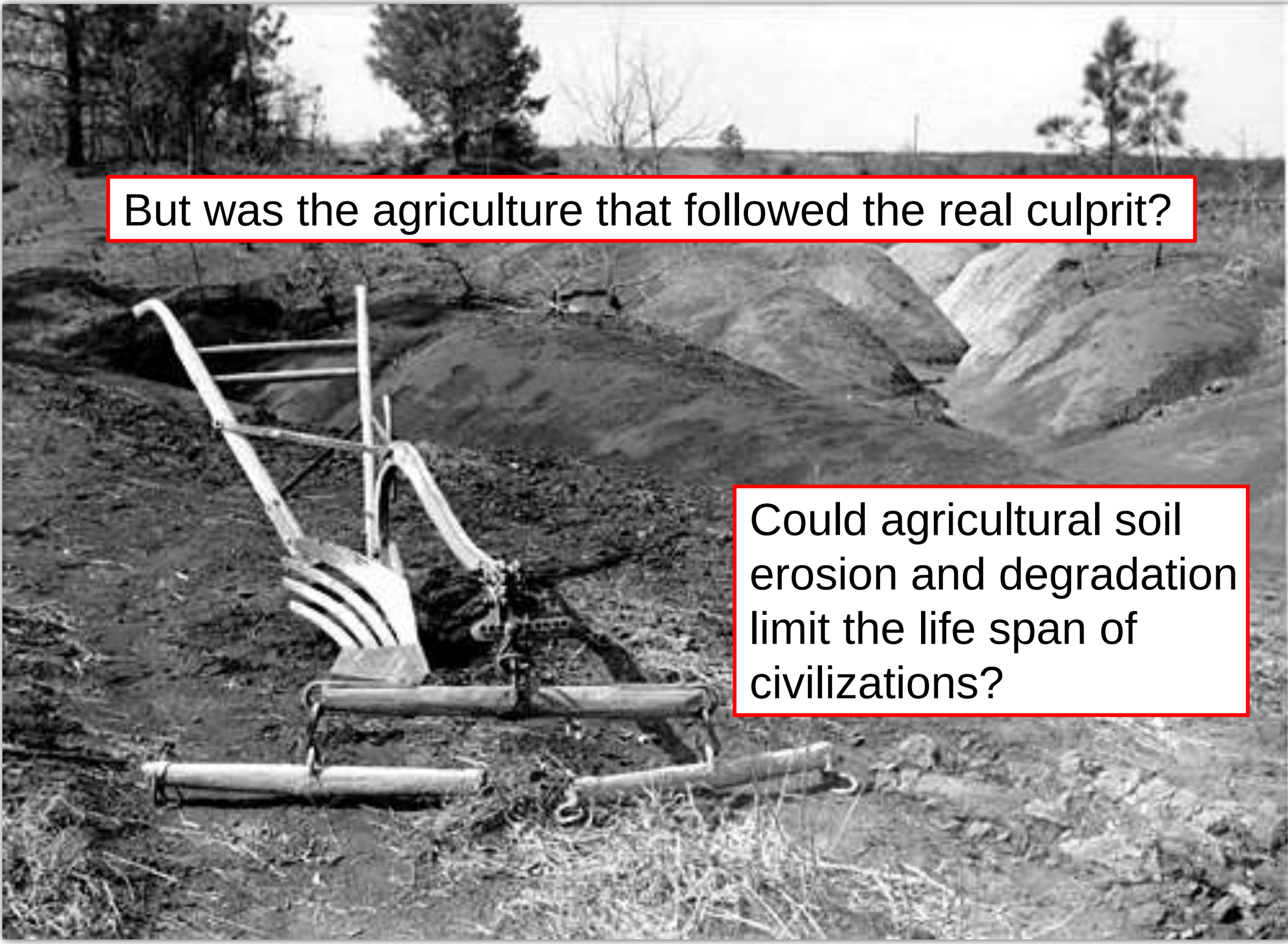
But what about soil? The fundamental condition for sustaining a civilization is sustaining the soil and its fertility.

Soil erosion resulting from deforestation has been proposed to explain the demise of civilizations around the world.

Mesopotamia
Minoans
Greece
Rome

Indus
Angkor Watt

Olmec
Maya
Inca


But was the agriculture that followed the real culprit?
Could agricultural soil erosion and degradation limit the life span of civilizations?

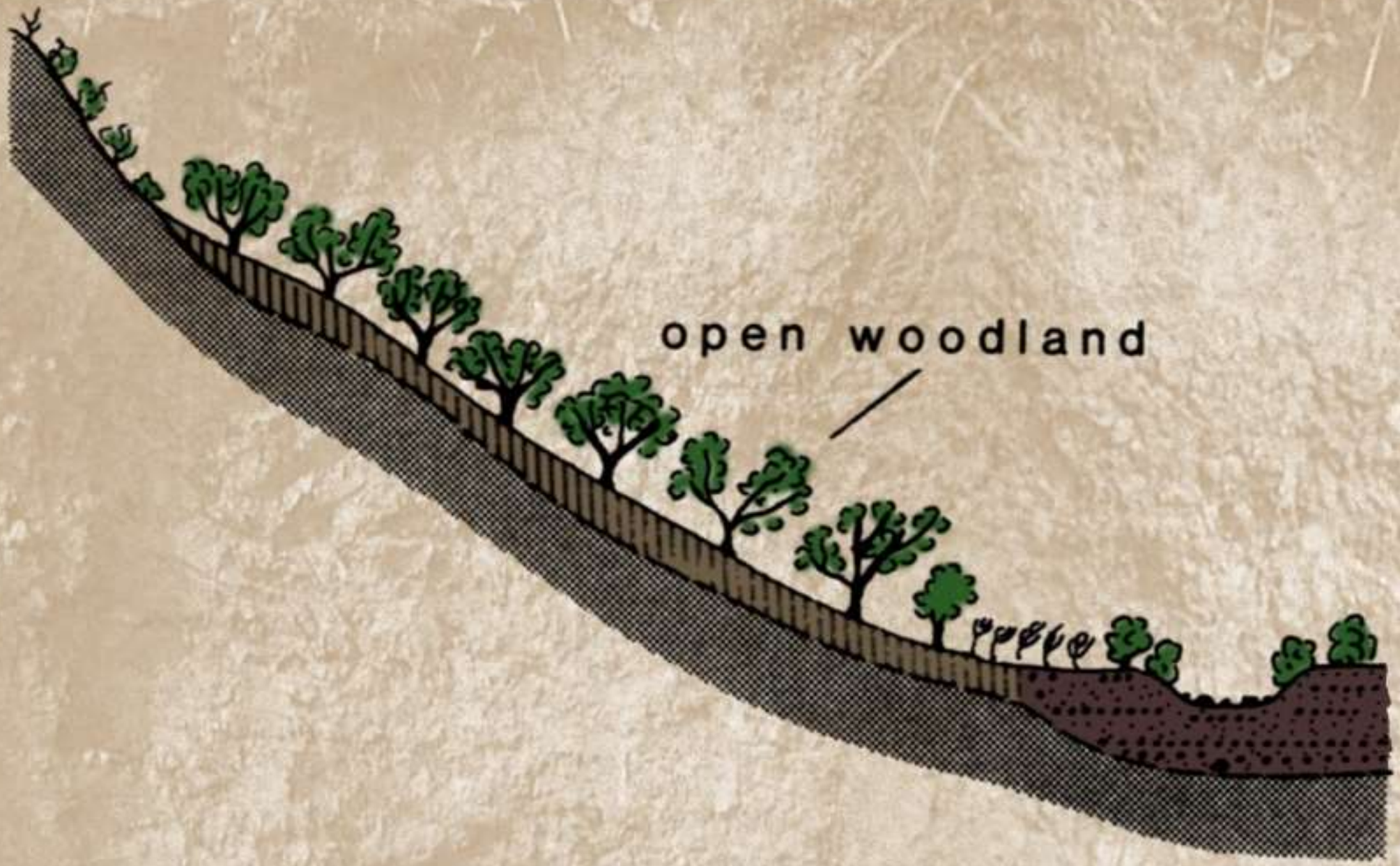
Recent archaeological studies showed that soil erosion played a role in the demise of ancient civilizations of Neolithic Europe, Classical Greece, Rome, the Southern United States, and Central America.

Erosion

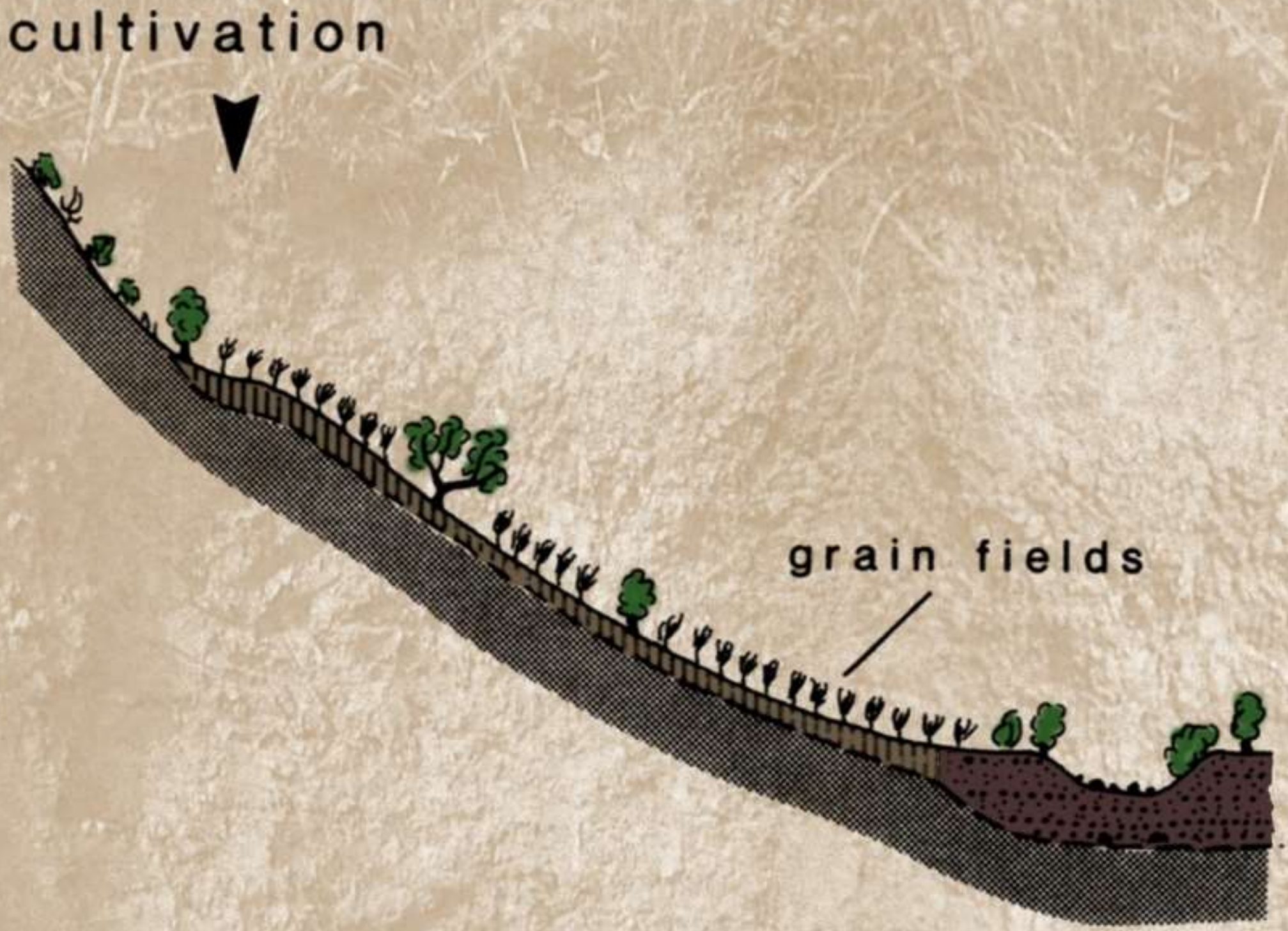
Weathering

Invention of the plow fundamentally altered the balance between soil production and soil erosion, dramatically increasing soil erosion…

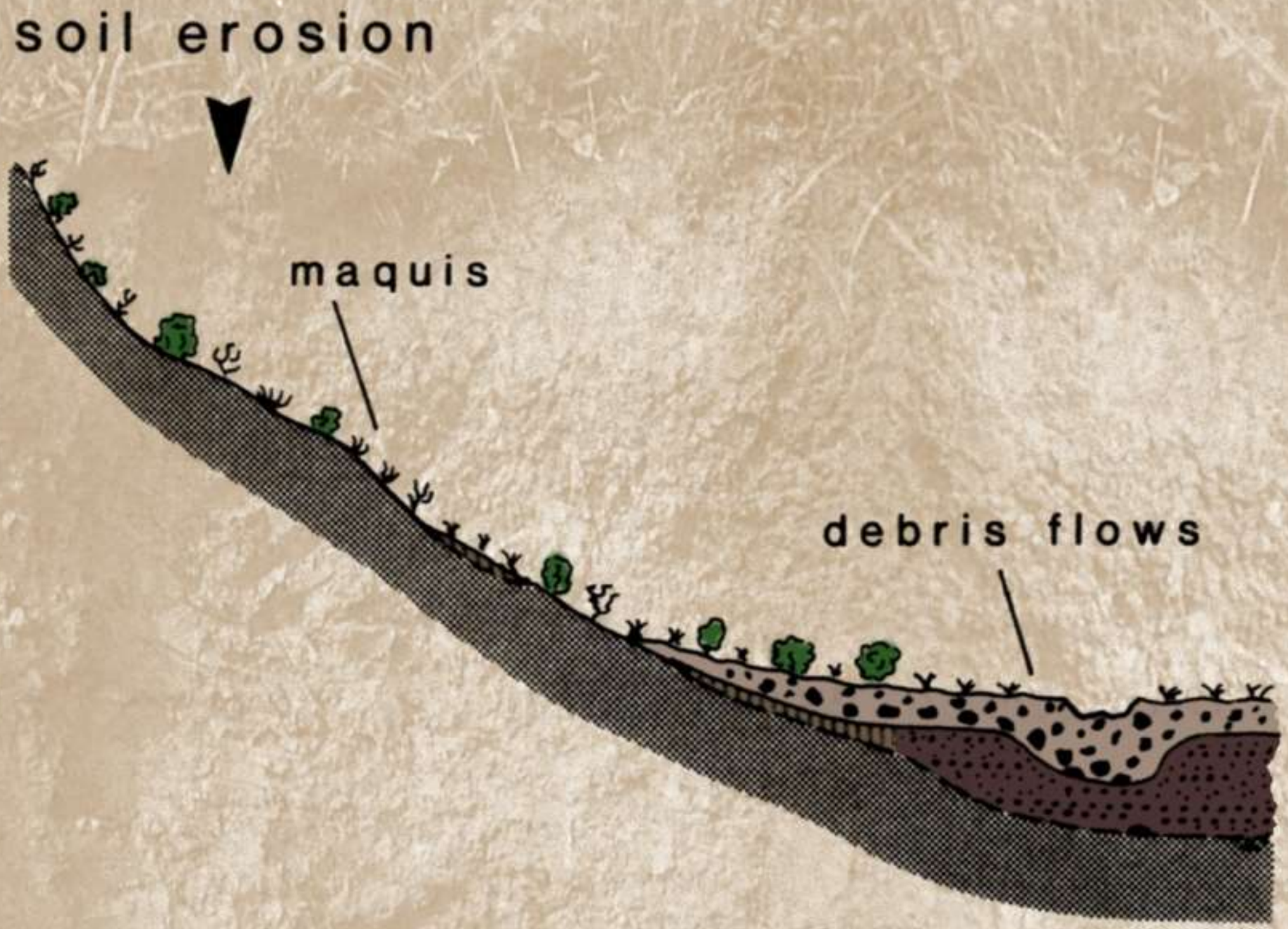
Cycles of erosion and soil formation in ancient Greece began with Bronze Age erosion after introduction of plow-based agriculture.



Van Andel and Runnels (1987)

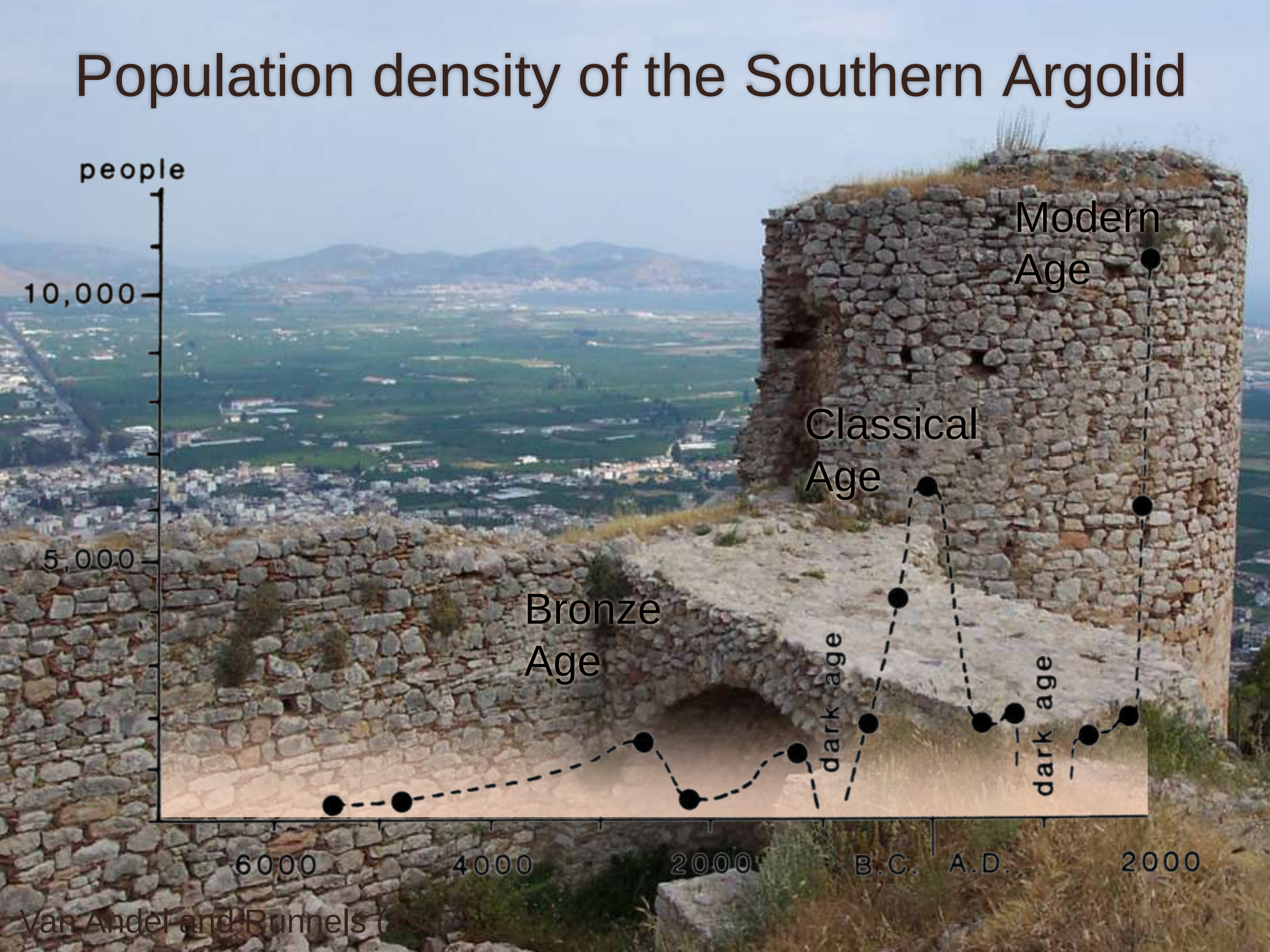


Van Andel and Runnels (1987)



Van Andel and Runnels (1987)

Population density of the Southern Argolid

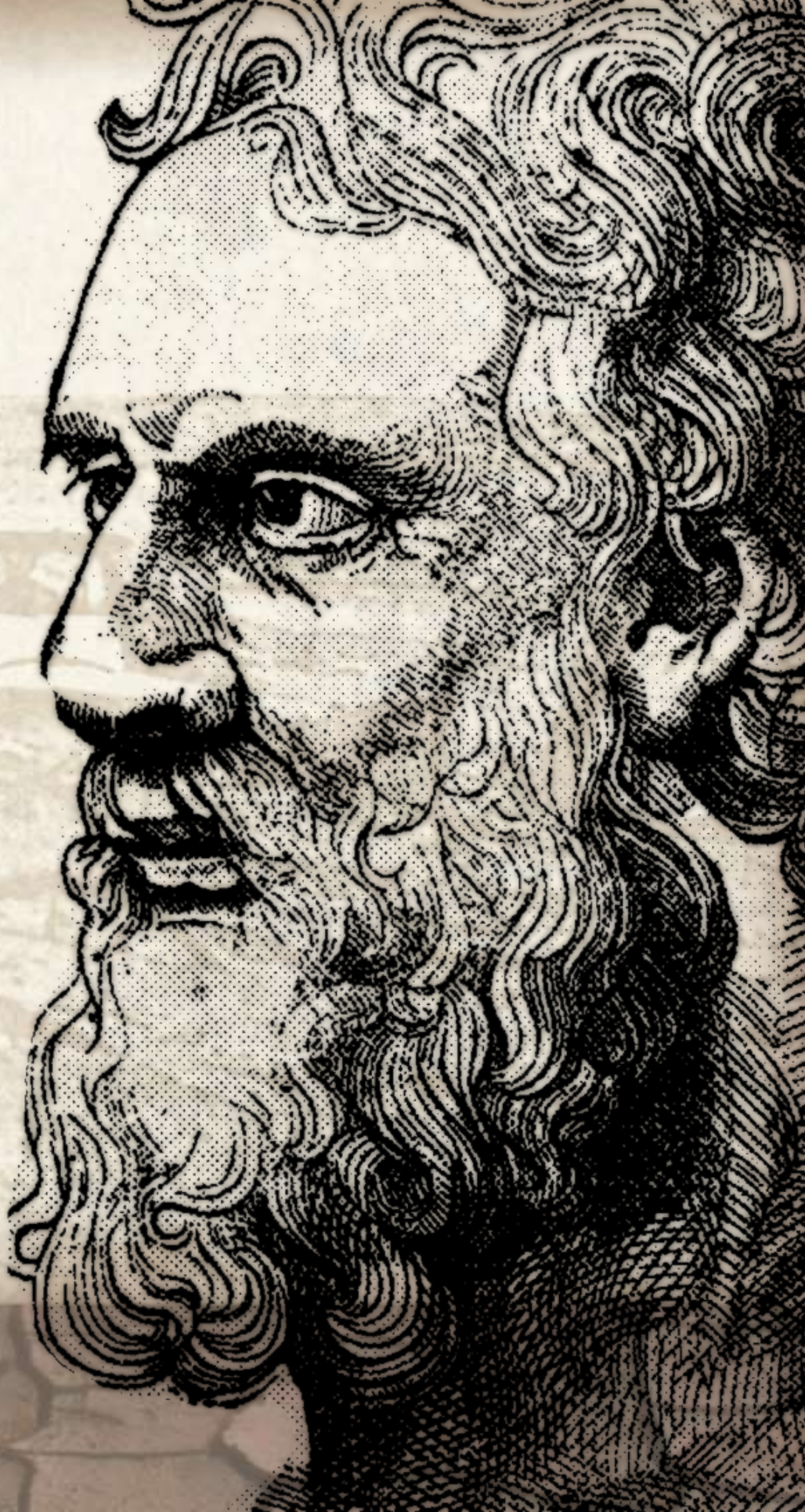


Van Andel and Runnels (1987)

Plato

427-347 B.C.

The rich, soft soil has all run away leaving the land nothing but skin and bone. But in those days the damage had not taken place, the hills had high crests, the rocky plain of Phelleus was covered with rich soil, and the mountains were covered by thick woods, of which there are some traces today.

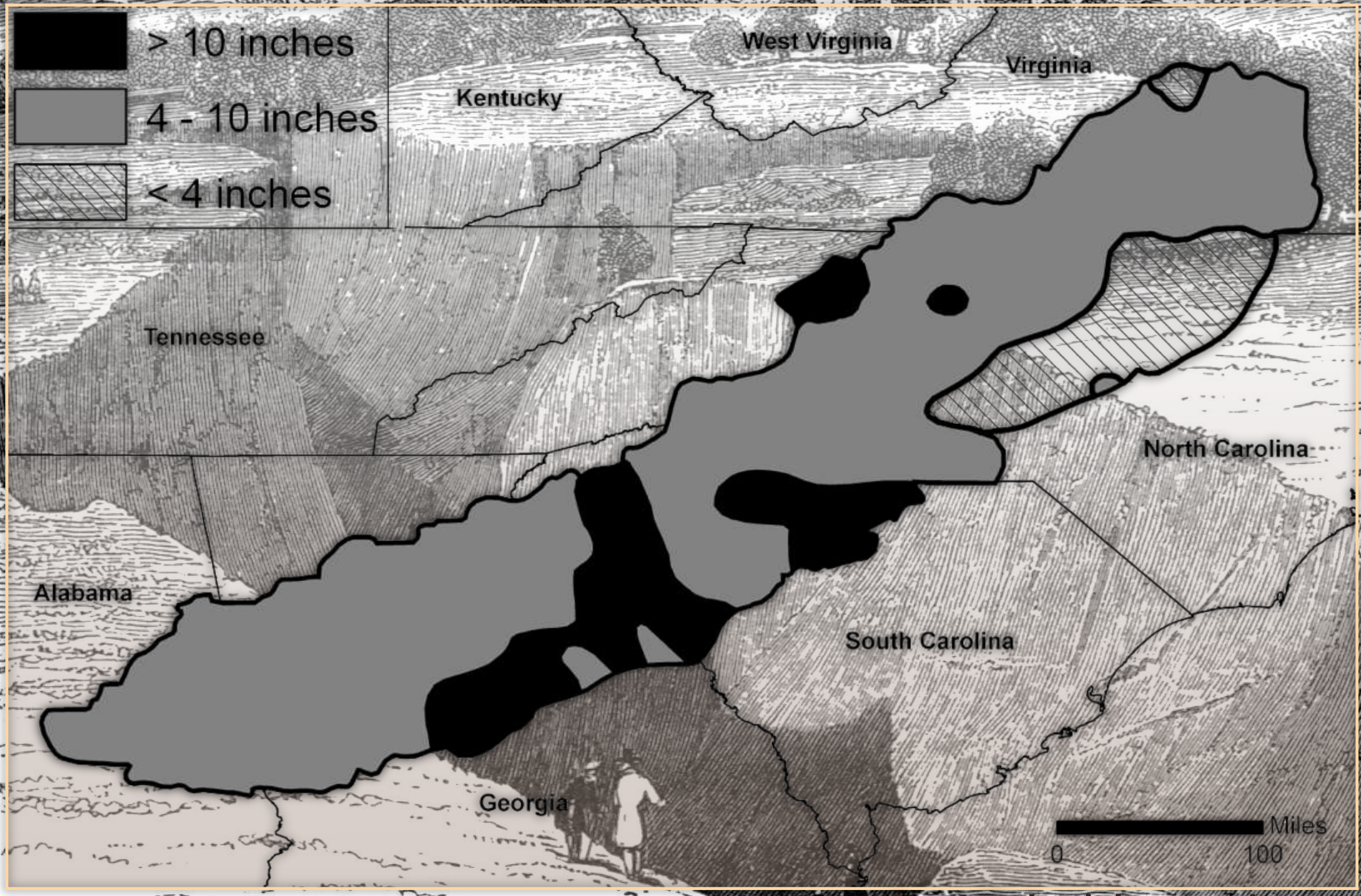


In a 1796 letter to Alexander Hamilton…

A few years more of increased sterility will drive the Inhabitants of the Atlantic States westward for support; whereas if they were taught how to improve the old, instead of going in pursuit of new and productive soils, they would make these acres which now scarcely yield them any thing, turn out beneficial to themselves.

- [G. Washington, 1892, v. XIII, p. 328-329]

Historical soil erosion in the Piedmont region



after Trimble and Meade

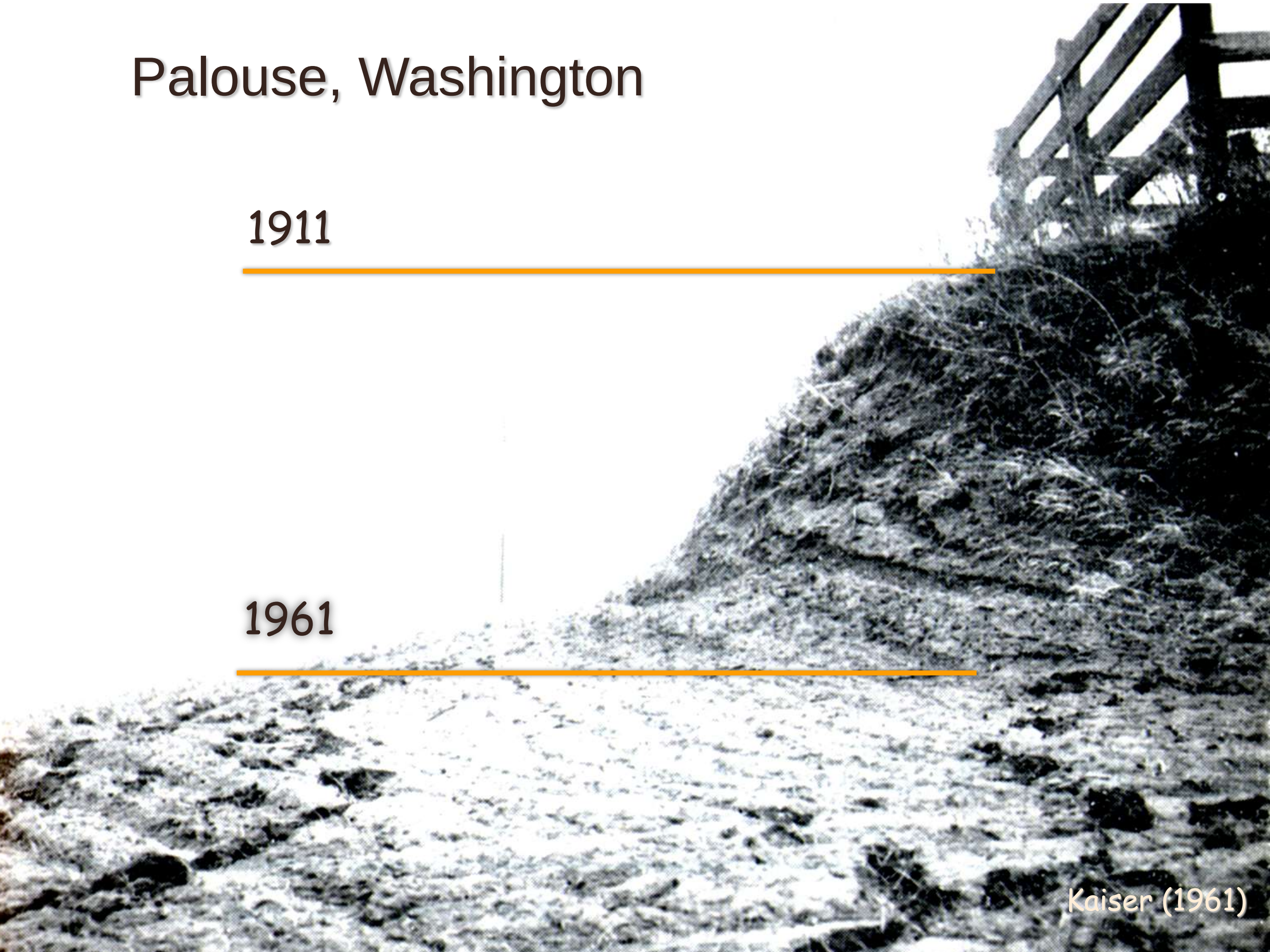
Palouse, Washington

1970

Palouse, Washington

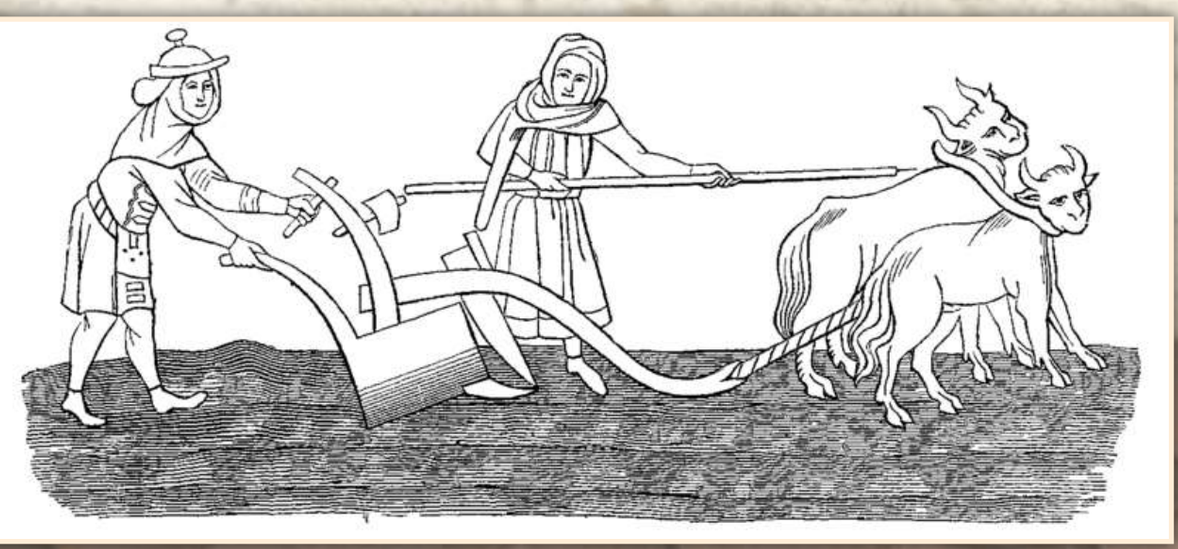
1911

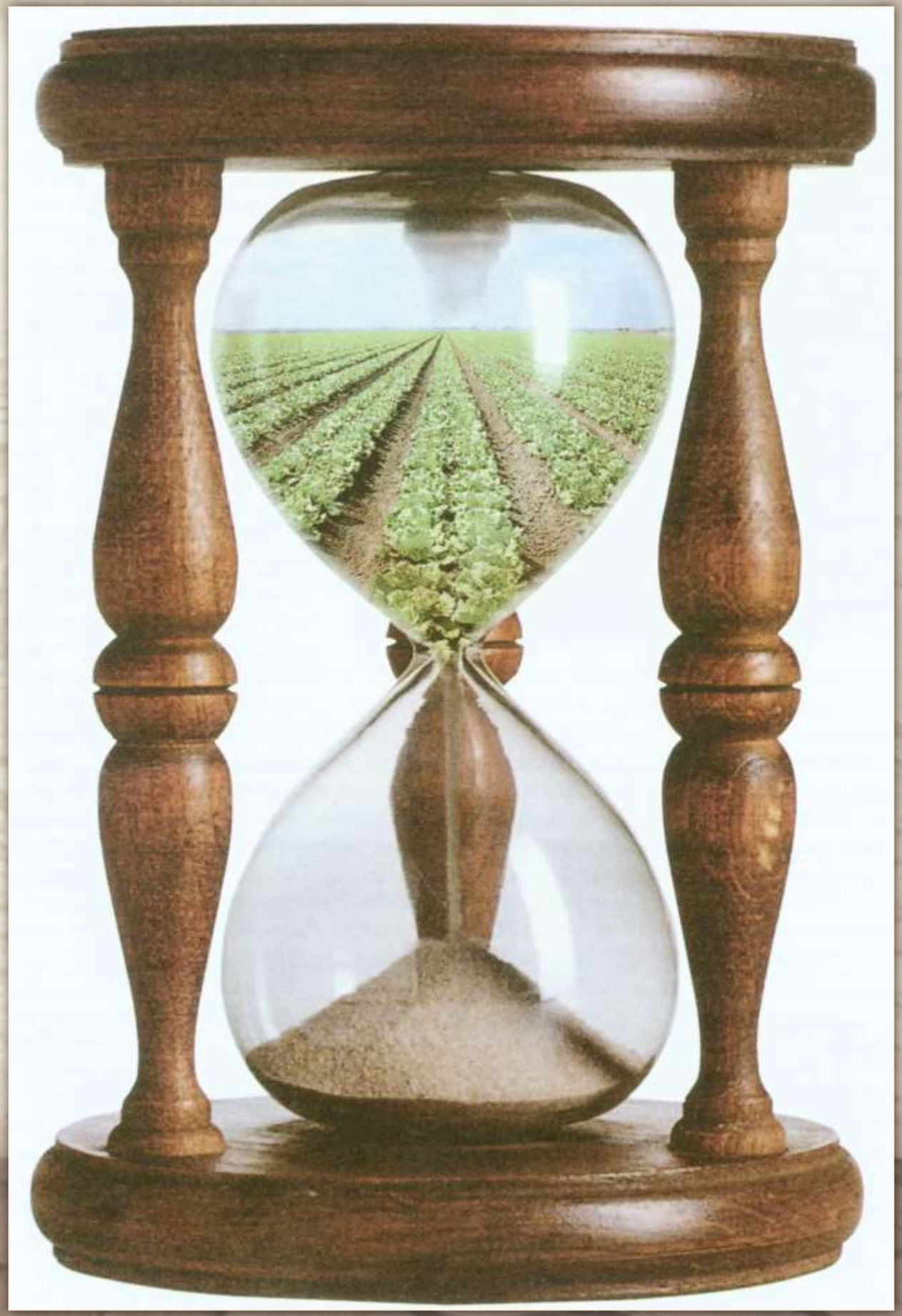
1961



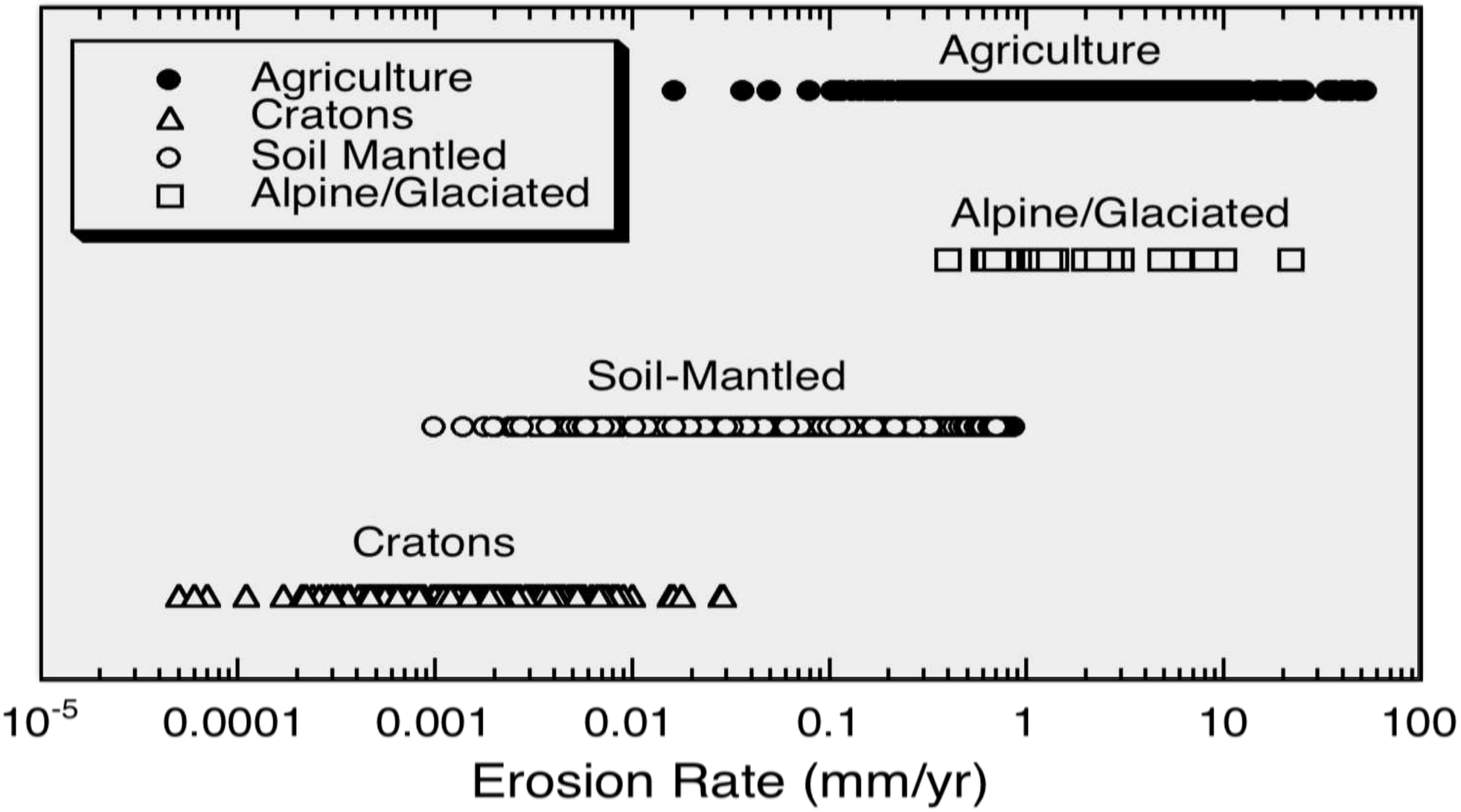
Kaiser (1961)

In researching the book, I began compiling additional data on both contemporary and long-term (geological) erosion rates—and agricultural erosion rates in particular.





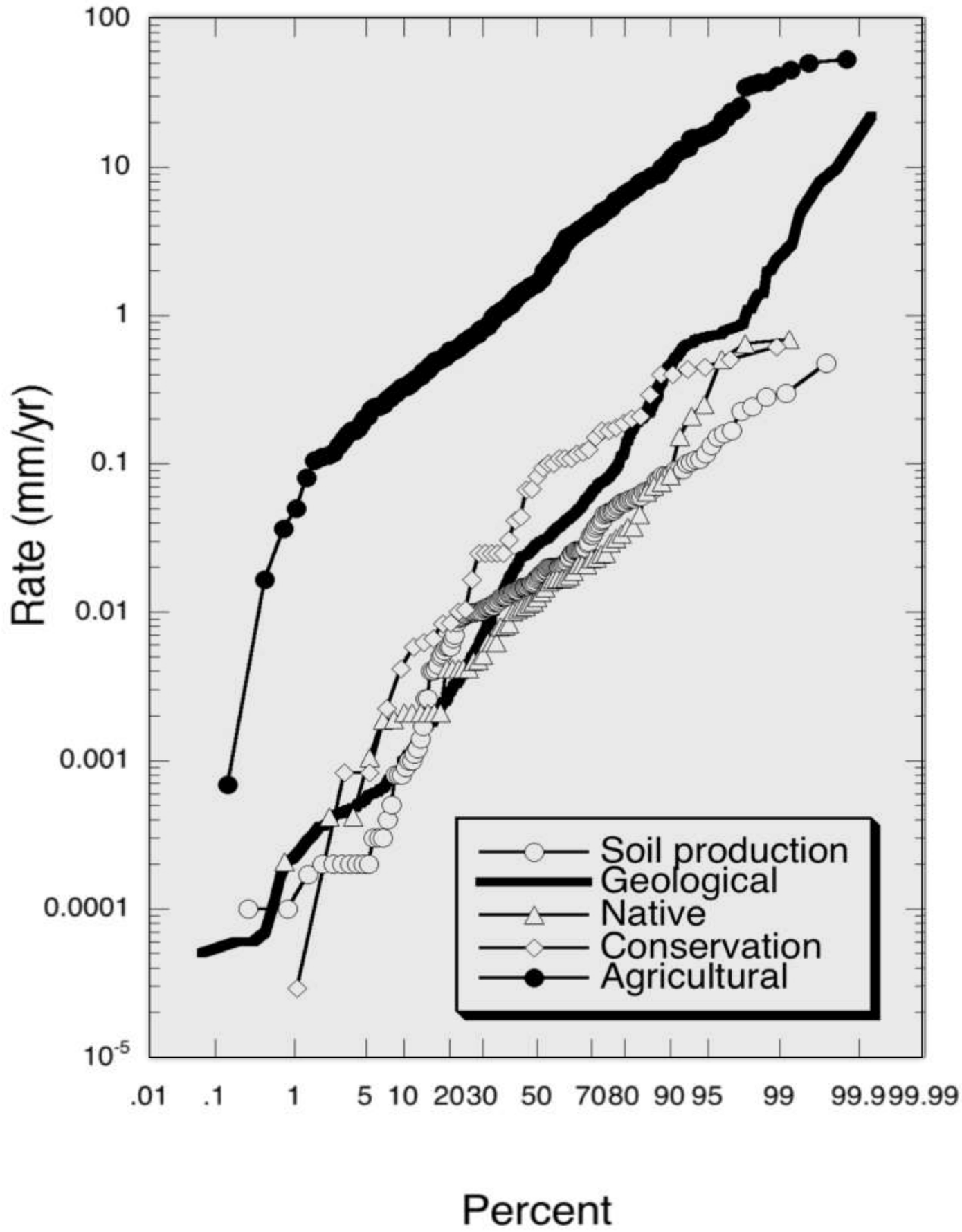
1402 measurements of agricultural and geological erosion rates



Conventionally plowed farms erode like alpine topography
Conventional agriculture unsustainable in soil-mantled landscapes

Probability distributions for geological erosion rates, erosion under native vegetation, and by no-till agriculture are all comparable.

Agricultural soil loss is not because humanity farms but arises from how we farm — from using the



Erosion Rates

Measurement type (sample size)	median (mm/yr)	mean (mm/yr)
Conventional (448)	1.537	3.939
Conservation (No-till) (47)	0.082	0.124
Native Vegetation (65)	0.013	0.053
Soil Production (188)	0.017	0.036
Geological (925)	0.029	0.173

Net soil loss of ≈ 1 mm/yr implies that erosion of a typical 0.5 - 1 m thick hillslope soil could occur in roughly 500 to 1000 years; approximately the lifespan of most major civilizations outside of major river floodplains…

Here in a nutshell, so to speak, we have the underlying hazard of civilization. By clearing and cultivating sloping lands—for most of our lands are more or less sloping—we expose soils to accelerated erosion by water or by wind…. In doing this we enter upon a regime of self-destructive agriculture.

- [Lowdermilk, 1953, p. 26]

A nation that destroys its soils, destroys itself. – President Franklin D. Roosevelt, Feb. 26, 1937.

National Archives: 114 SC 5089

Is Soil Restoration Possible?

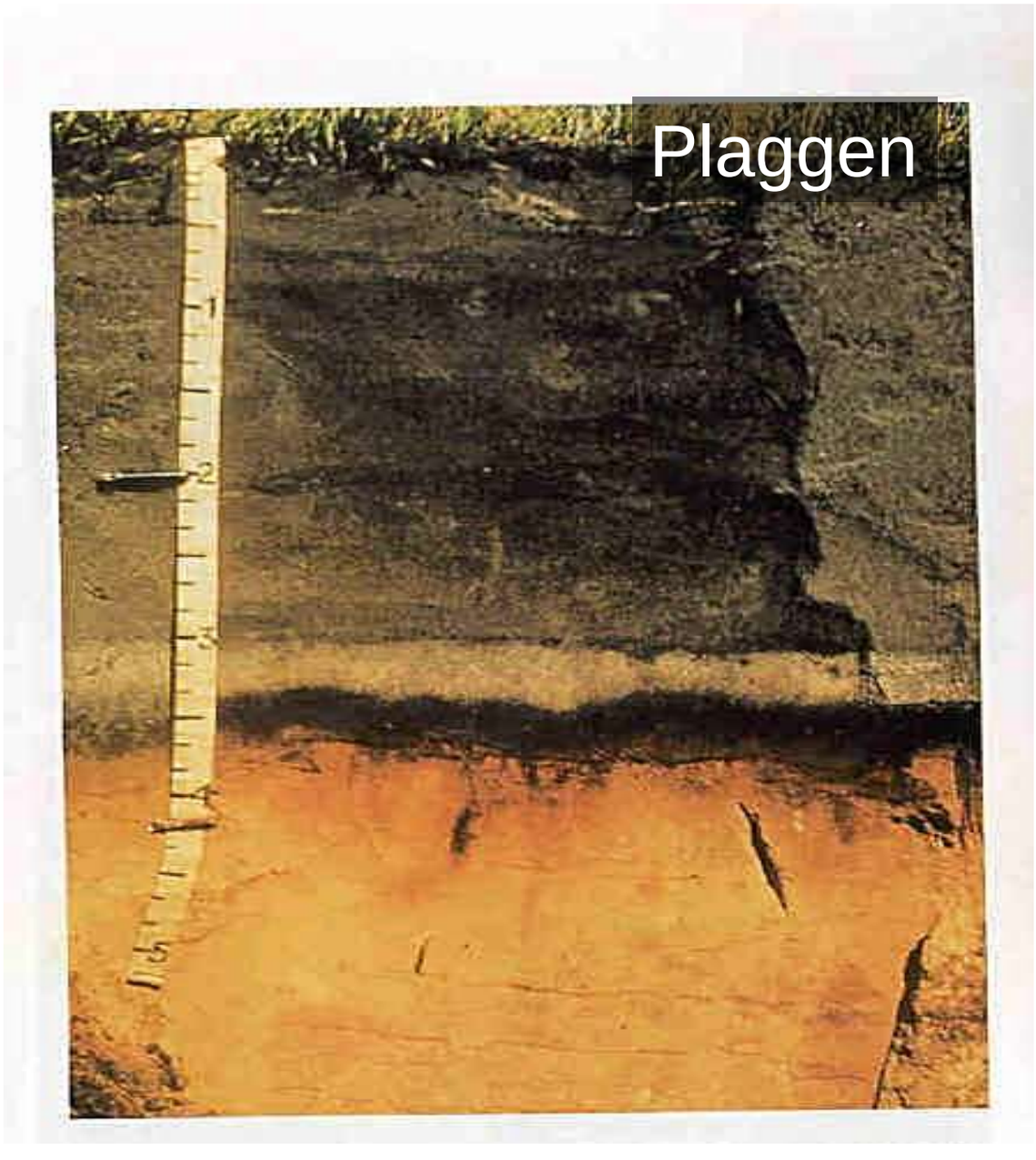
Can we reverse the historical pattern?

Rebuilding Soil

We can build soil surprisingly fast — faster than nature does…

It takes organic matter, effort (labor/energy), and biological assistance (microbes).

Fertile carbon-rich soils built by anthropogenic activity in the Amazon and reclaimed sea beds in northern Europe.



Why bother restoring soils?
To Address Global Challenges of the 21st Century

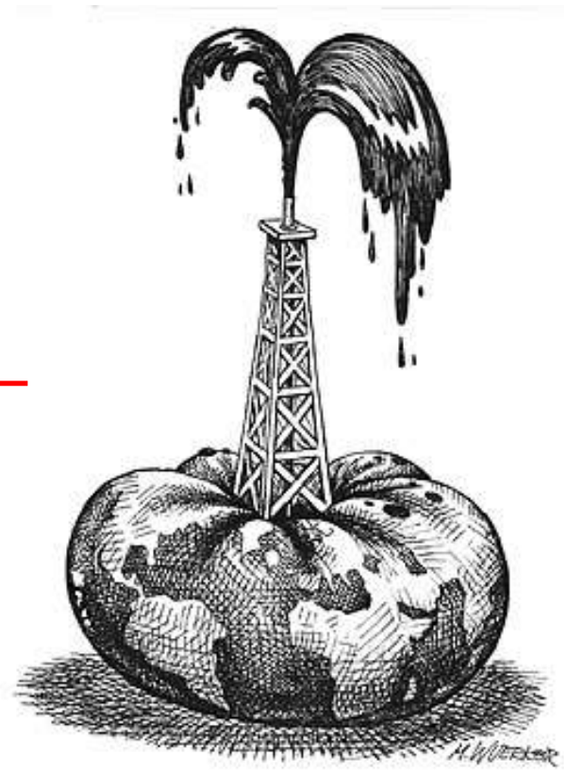
Feeding a Post-Oil World

Carbon Sequestration
(Climate Change)

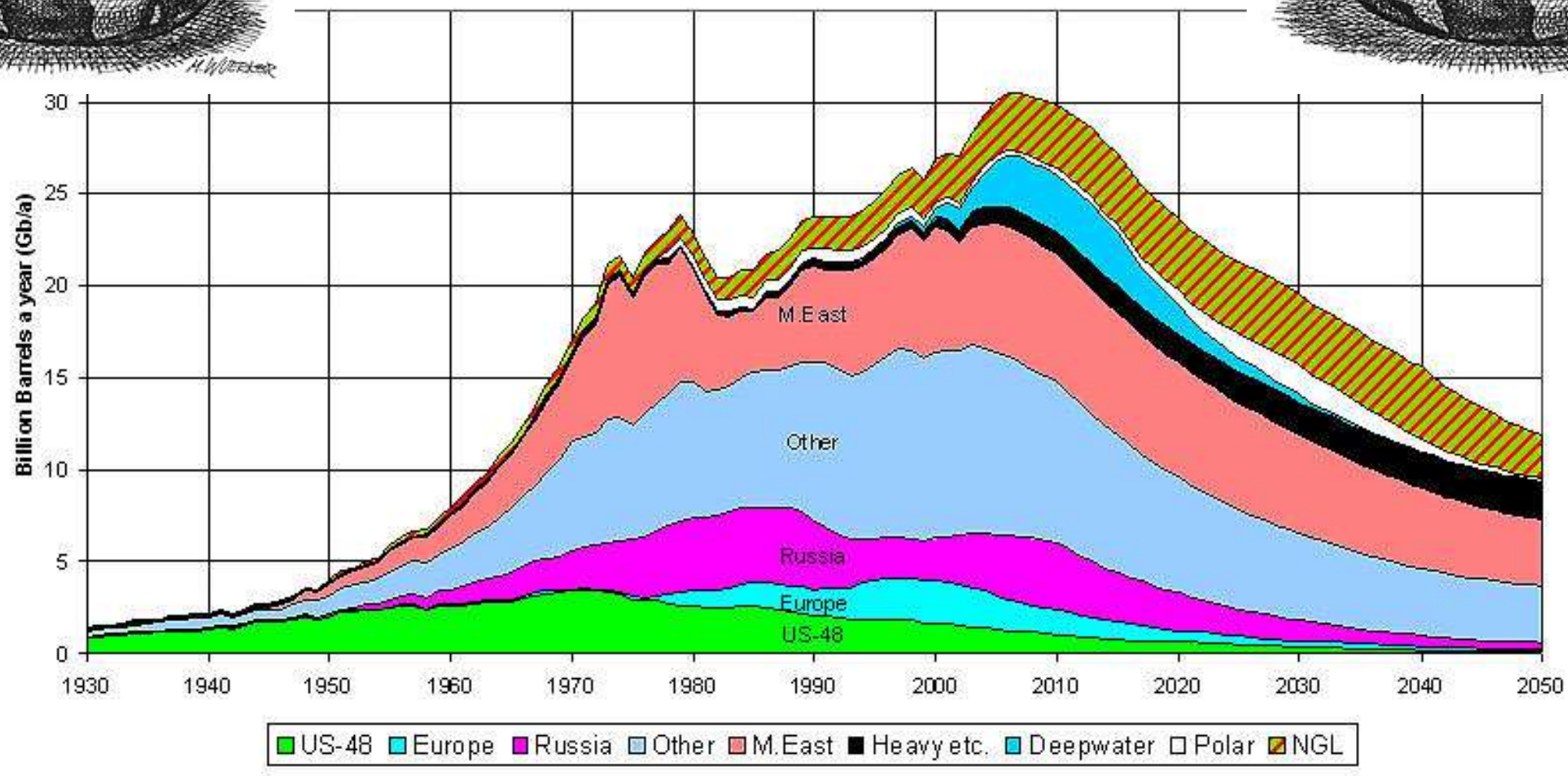
Public Health / City Livability

Biodiveristy / Environmental
Degradation

Peak Oil
A Question of When



OIL AND GAS LIQUIDS
2004 Scenario



How will we feed a post-oil world without cheap fertilizer-intensive agriculture?

A Greener Revolution?

With cover cropping and diverse rotations, crop yields from no-till and organic agriculture can compete with those from conventional agriculture, and over time exceed them on degraded land …

Rebuilding soil and soil fertility on degraded land will be essential for sustaining agriculture in a post-oil (and post-cheap fertilizer) world.

Soil and Climate Change

By the late 20th Century, a third of carbon added to atmosphere since the Industrial Revolution came from degraded soil organic matter.

We can put that much (and more) back in the ground through:

(1) increasing soil organic matter

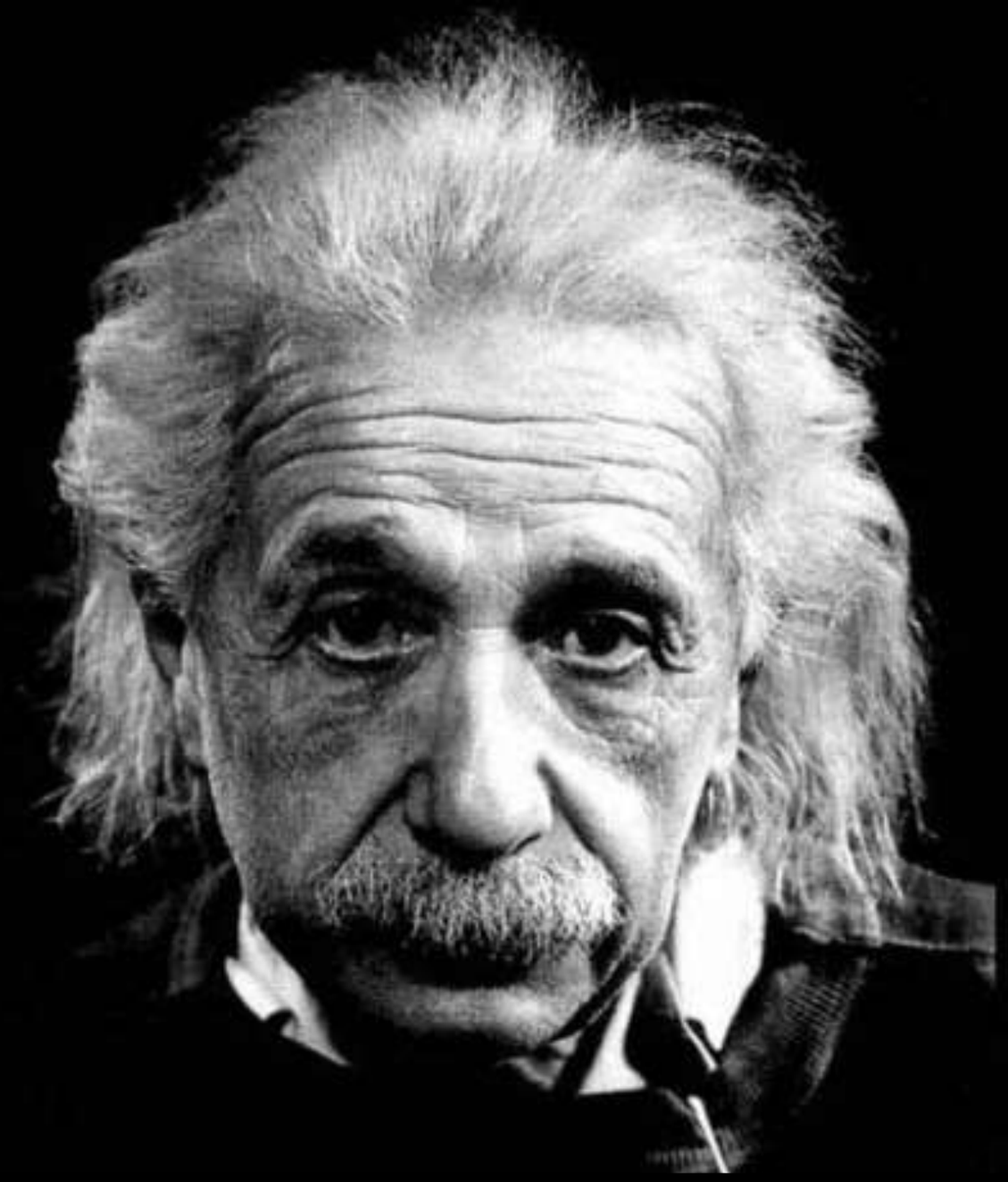
(2) biochar

Global Agriculture, Land Use and Carbon Emissions

Amundson (2001) noted that cultivation and deforestation releases >4 Gt C per year, equivalent to more than half global fossil fuel emissions.

Lal (2004) estimated that changes in agricultural practices could sequester 0.4 to 1.2 Gt C per year, enough to offset 5-15% of global fossil fuel emissions.

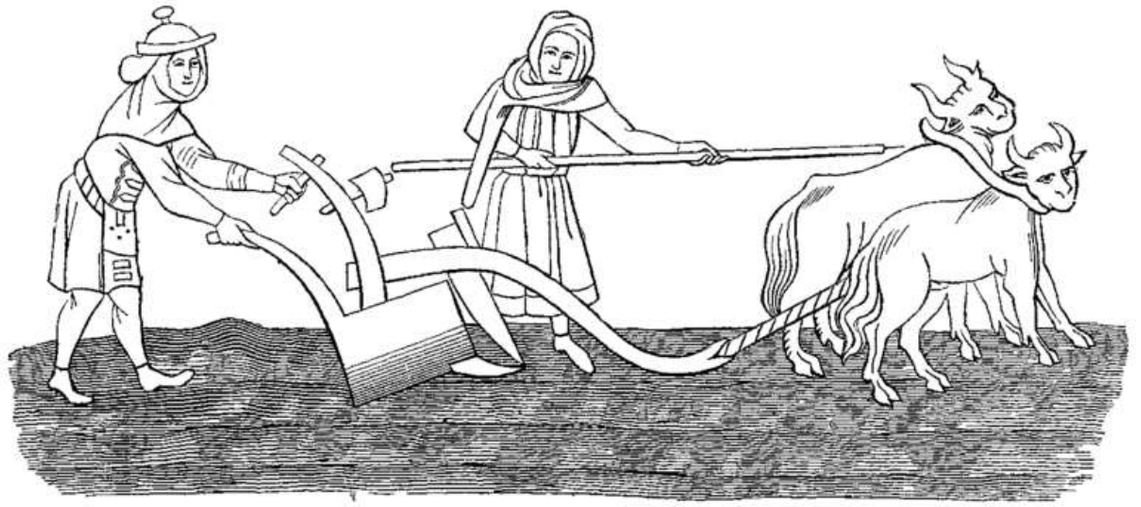
Time For A New View of Soil?



“The significant problems we face cannot be solved at the same level of thinking we were at when we created them.”

Soil as a mystery, fertility to be personified, deified and revered.

Soil as a means to a living, land to be worked.



Soil as a decipherable mystery, something to be studied and understood.

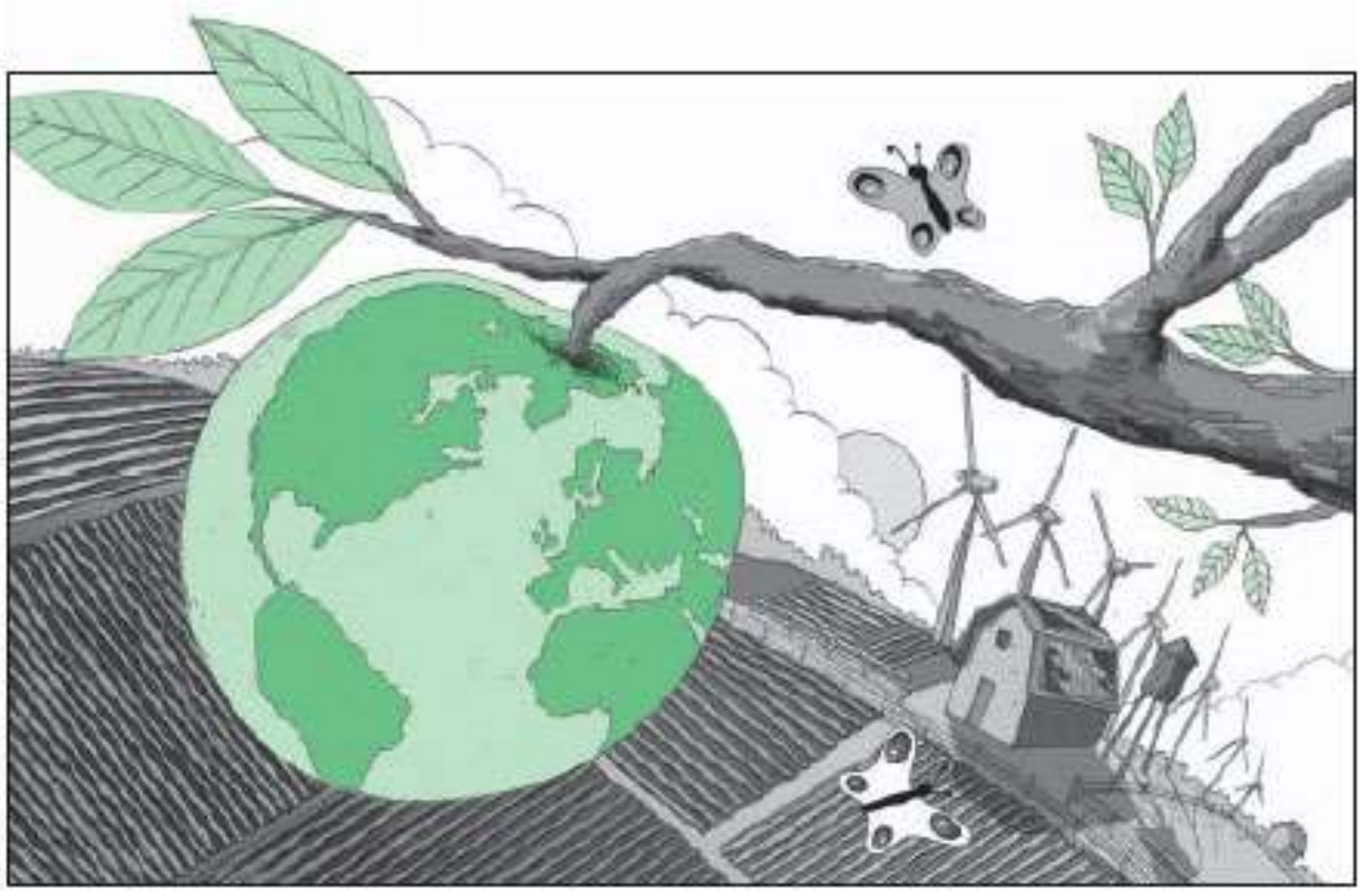
We know more about the movement of celestial bodies than about the soil underfoot.

- Leonardo da Vinci

Soil as a chemical reservoir, a medium to be fertilized as needed.

Soil as an industrial commodity to be used (and used up).

Soil as an ecosystem to be understood and worked with...



Soil Ecology — the Future of Agriculture…

We need to integrate the insights of soil ecology with agricultural technology if we are to feed the world based on ecological processes and nutrient cycling.

Principles of Conservation Agriculture (FAO)

- minimal or no disturbance / direct planting of seeds (e.g., no-till)

- permanent ground cover (retain crop residues and include cover crops in rotations)

- diverse crop rotations (to maintain soil fertility and break up pathogen carryover)

This is not really a question of low tech organic versus GMO & agro-tech…

Question is how to apply an understanding of soil ecology and soil building to the applied problem of profitably increasing — and sustaining — crop yields in a post-cheap oil environment.

Healthy Soil: No Silver Bullet, But A Secret Weapon?

Restoring soils can help address:

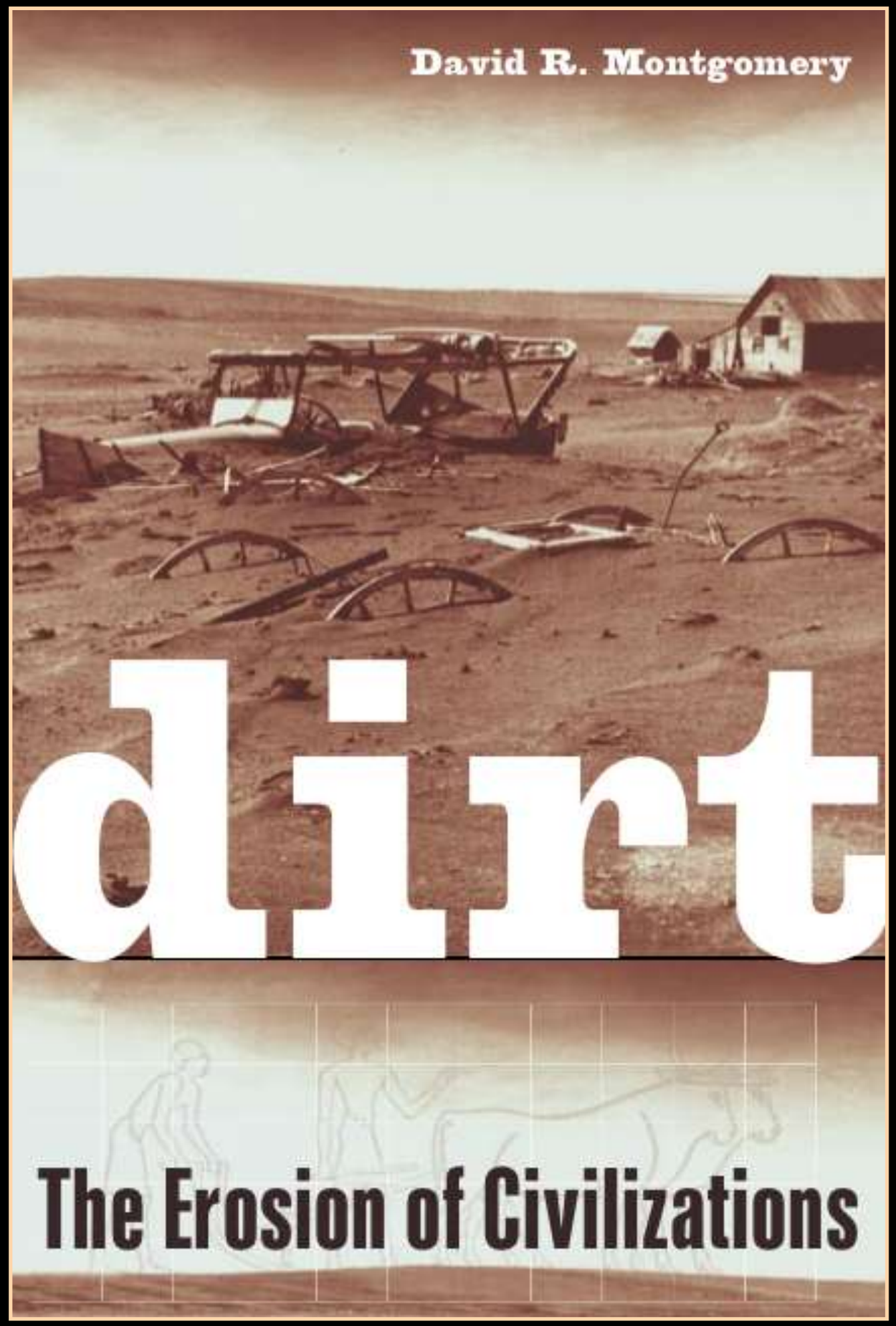
- Feeding the World
- Climate change
- Public health (physical, mental, and social)

Healthy soil is the foundation upon which human health and environmental health are built.

It all starts with the ground beneath our feet.

First and foremost soil restoration means …

… we have to stop treating soil like dirt!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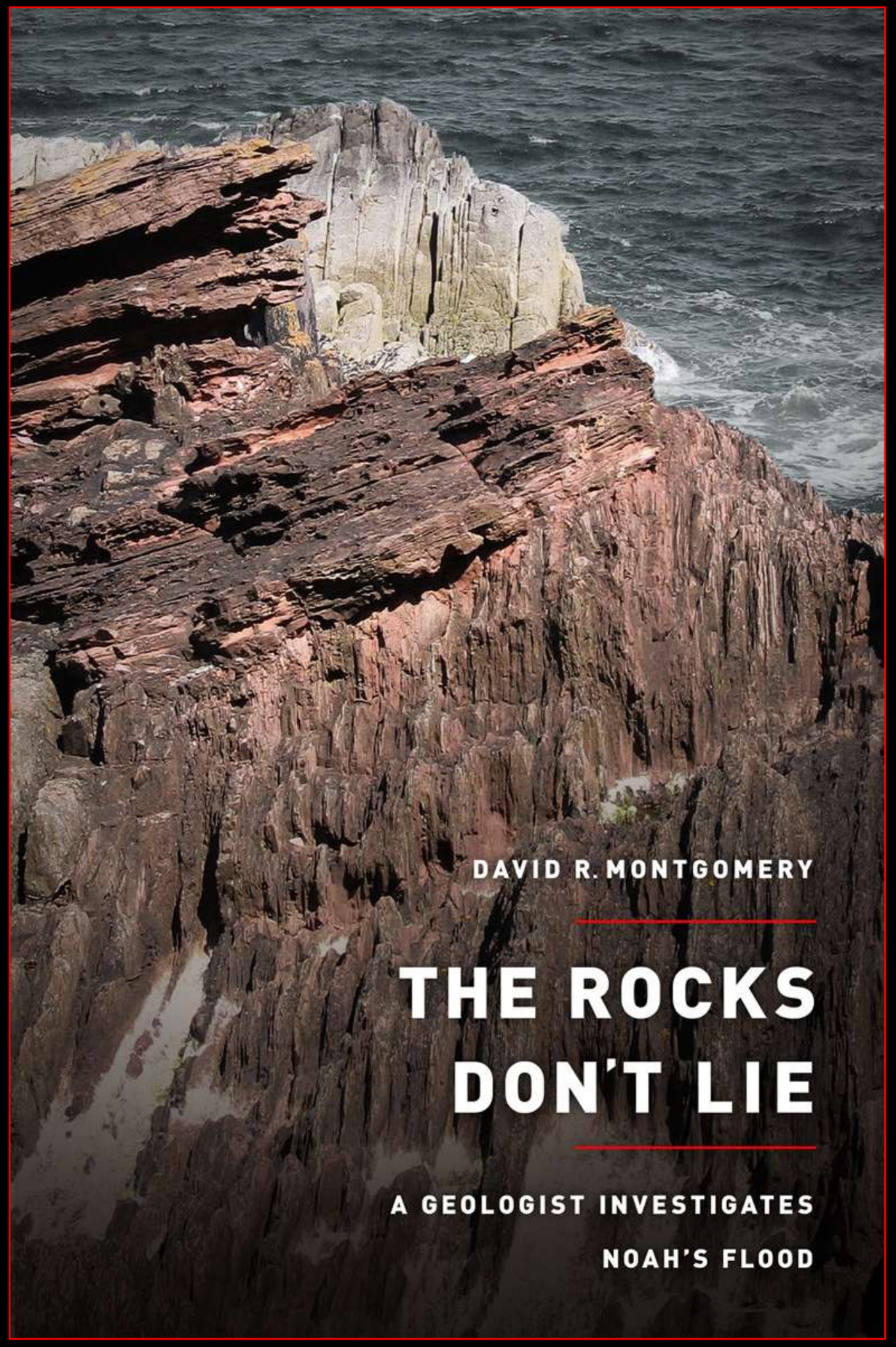
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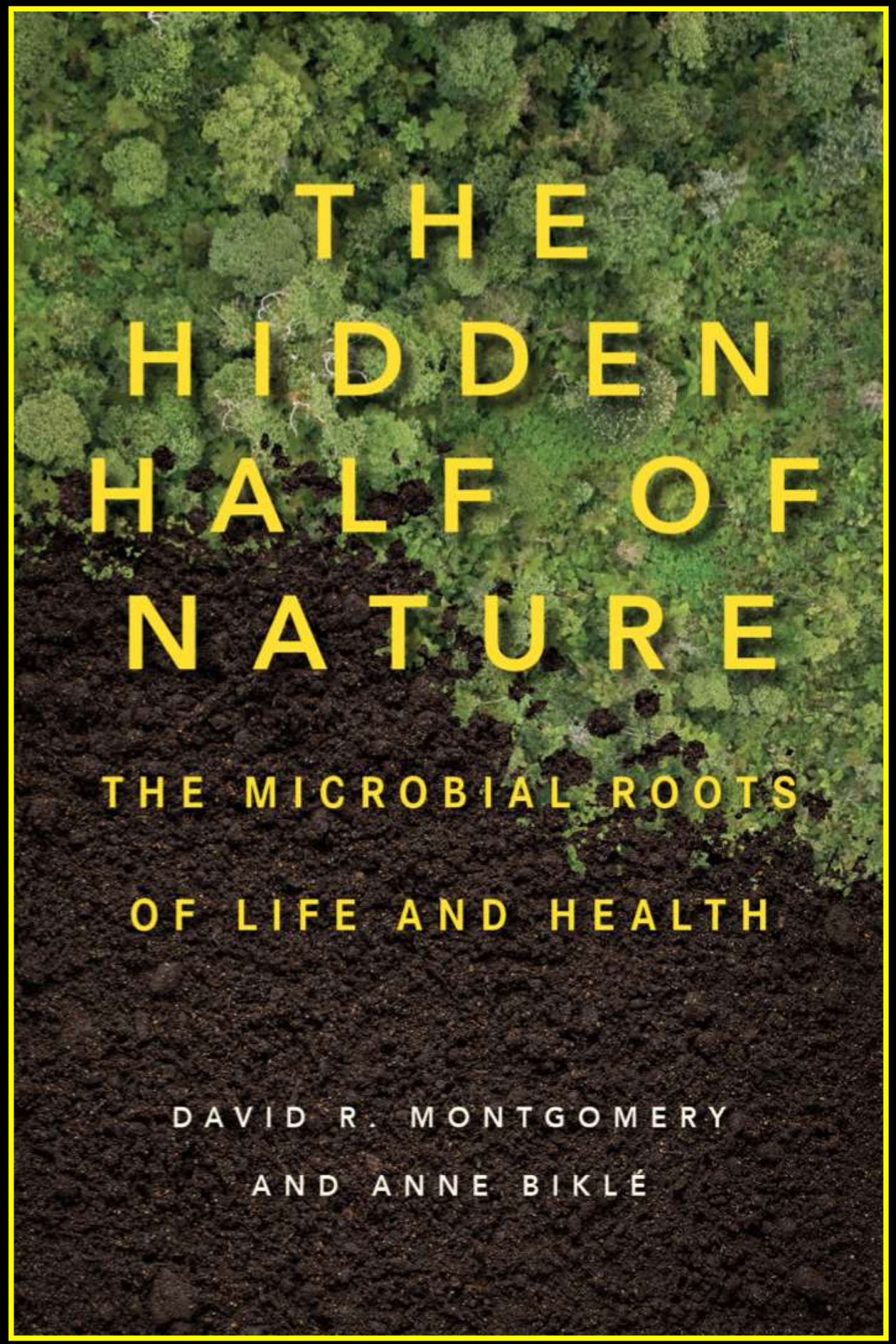
THE ROCKS DON'T LIE
A GEOLOGIST INVESTIGATES NOAH'S FLOOD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