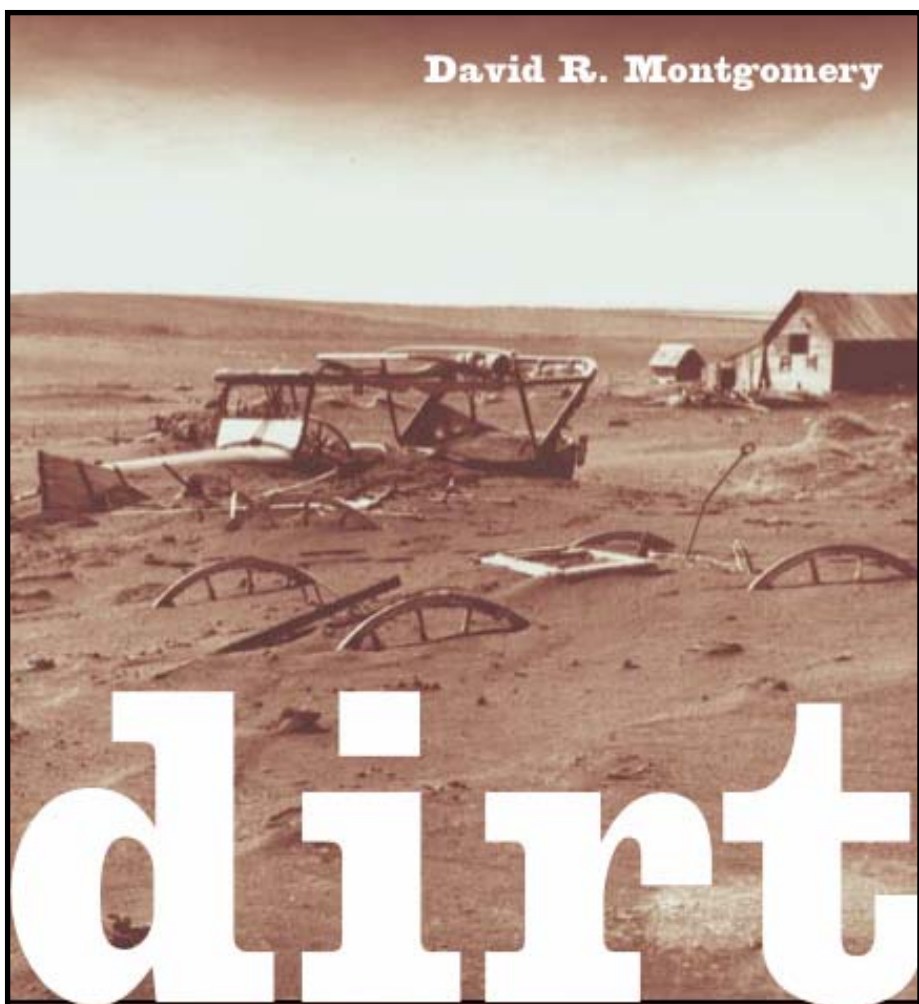


David R. Montgomery



dirt



The Erosion of Civilizations

KING OF FISH



THE THOUSAND YEAR FALL OF
SALMON

DAVID R. MONTGOMERY

Civilizations around the world have risen and declined. How much did past societies contribute to their own decline?

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are needed to see this picture.

**Mesopotamia
Minoans
Greece
Rome**

**Indus
Angkor Watt**

**Olmec
Maya
Inca**

What would be required to sustain a civilization?

Recognizing that >97% of our food comes from the soil, the fundamental condition for sustaining a civilization is sustaining the soil.

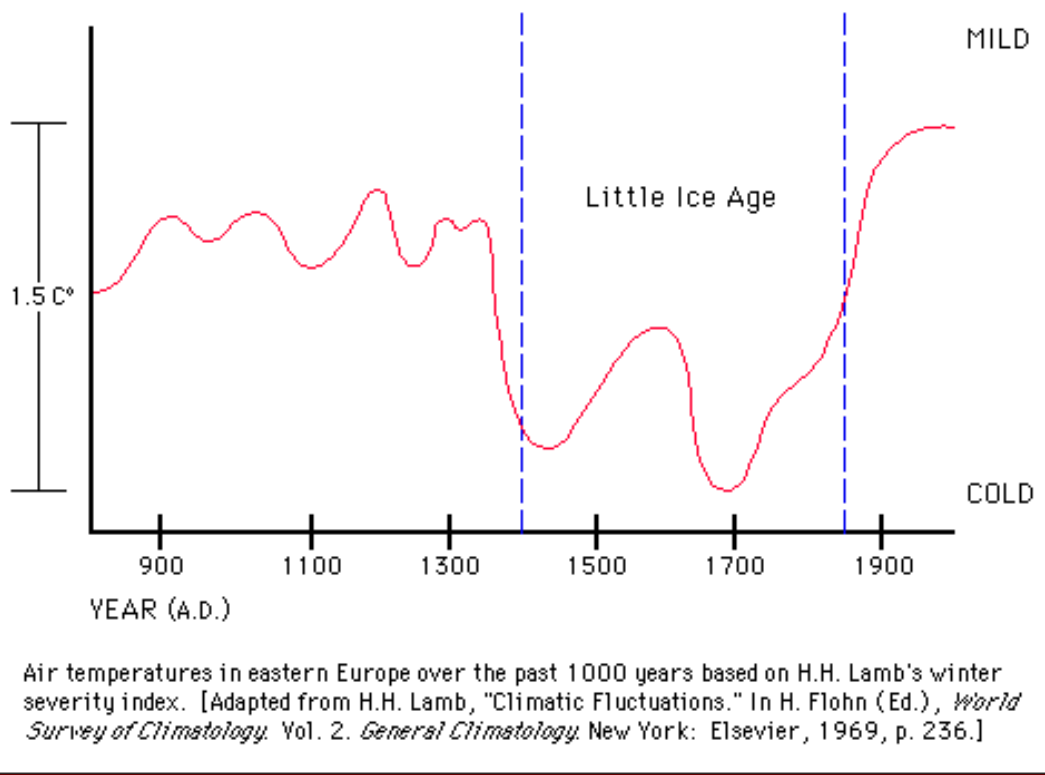
Can soil erosion limit the lifespan of civilizations?

Politics, Social Evolution, and Context

Every civilization has a unique historical and social setting and the specific social contexts that lead to warfare and institutional evolution/crises.



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are needed to see this picture.



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Climate Change

Volcanos, Earthquakes, and Floods

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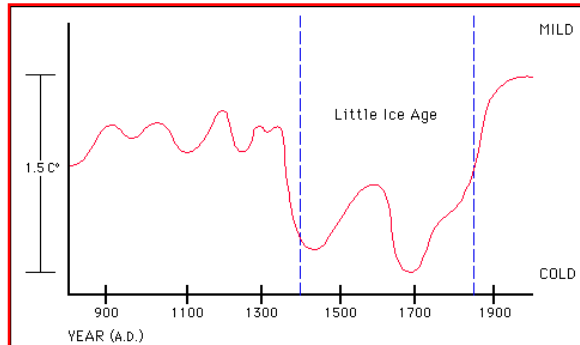


No particular time scale implied by:

Natural
Disasters



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.]

Politics and
Social Evolution

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are needed to see this picture.

Salinization, Overgrazing, and Deforestation

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K. Amman

Deforestation often blamed for historical soil erosion, but trees grow back rapidly...

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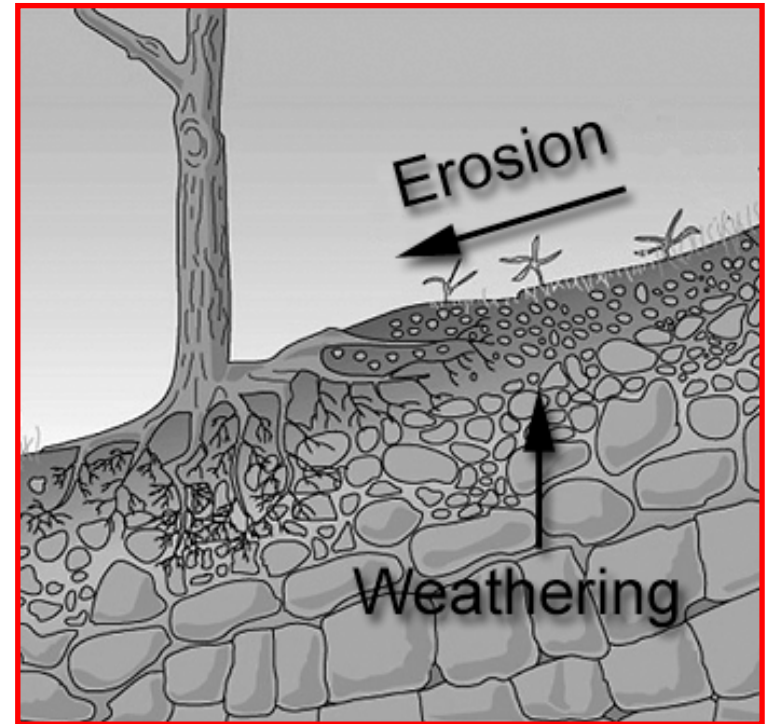
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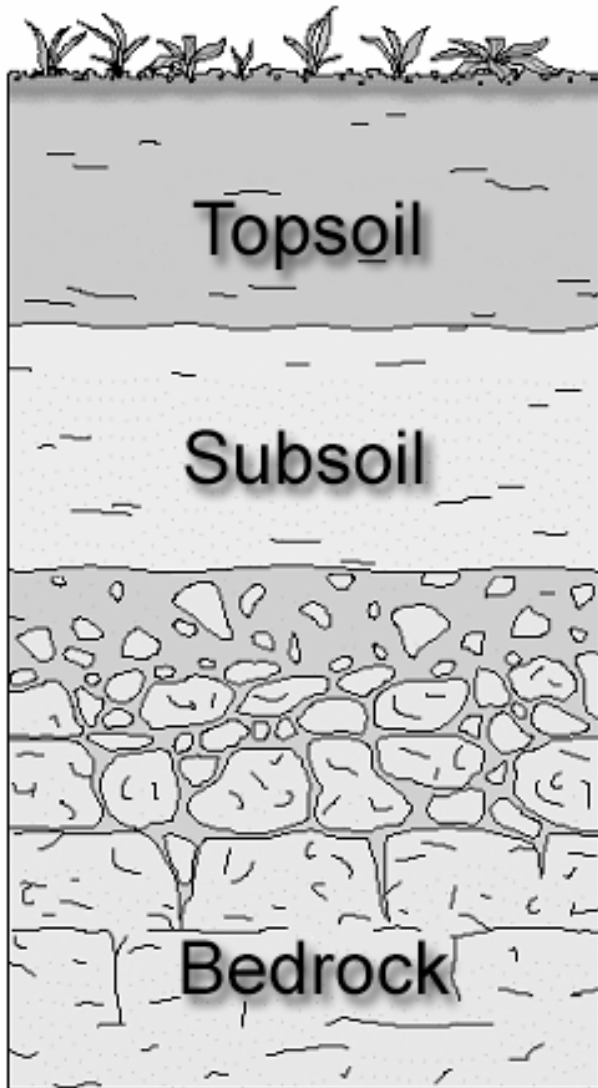
Major civilizations last about 500 to 2000 years...

Recent archaeological studies have 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.



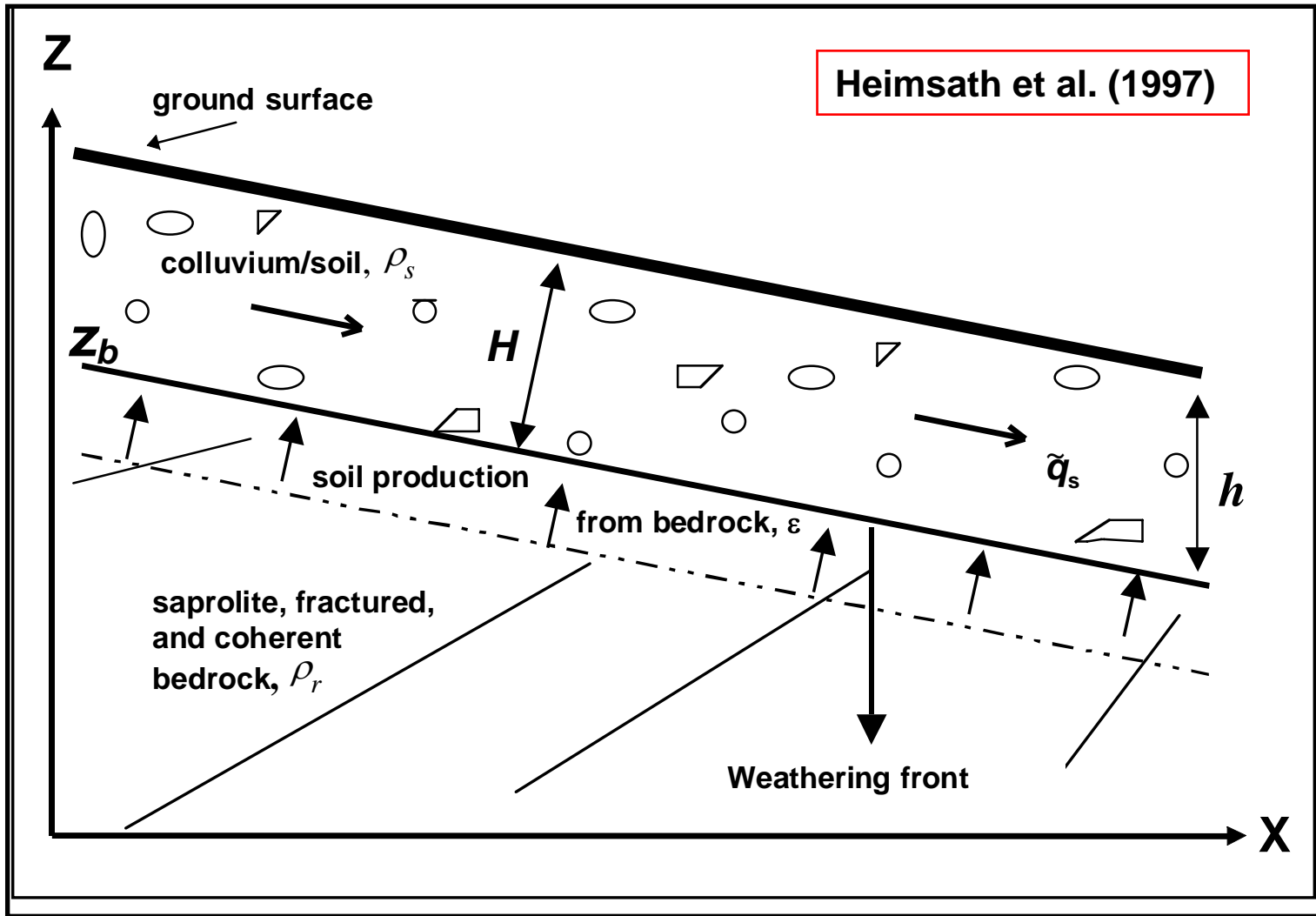
Invention of the plow fundamentally altered the balance between soil production and soil erosion





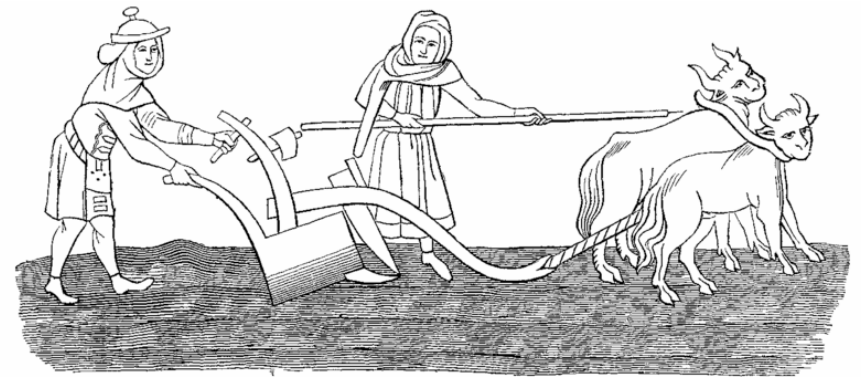
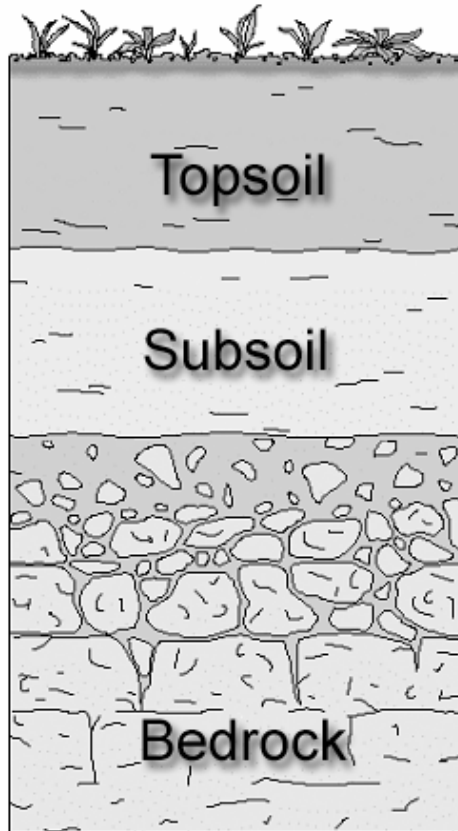
In the permanence ...of a coat of vegetable mould on the surface of the earth, we have a demonstrative proof of the continual destruction of the rocks; and cannot but admire the skill, with which the powers of the many chemical and mechanical agents employed in this complicated work, are so adjusted, as to make the supply and the waste of the soil exactly equal to one another.

- [Playfair, 1802, p. 106-7]

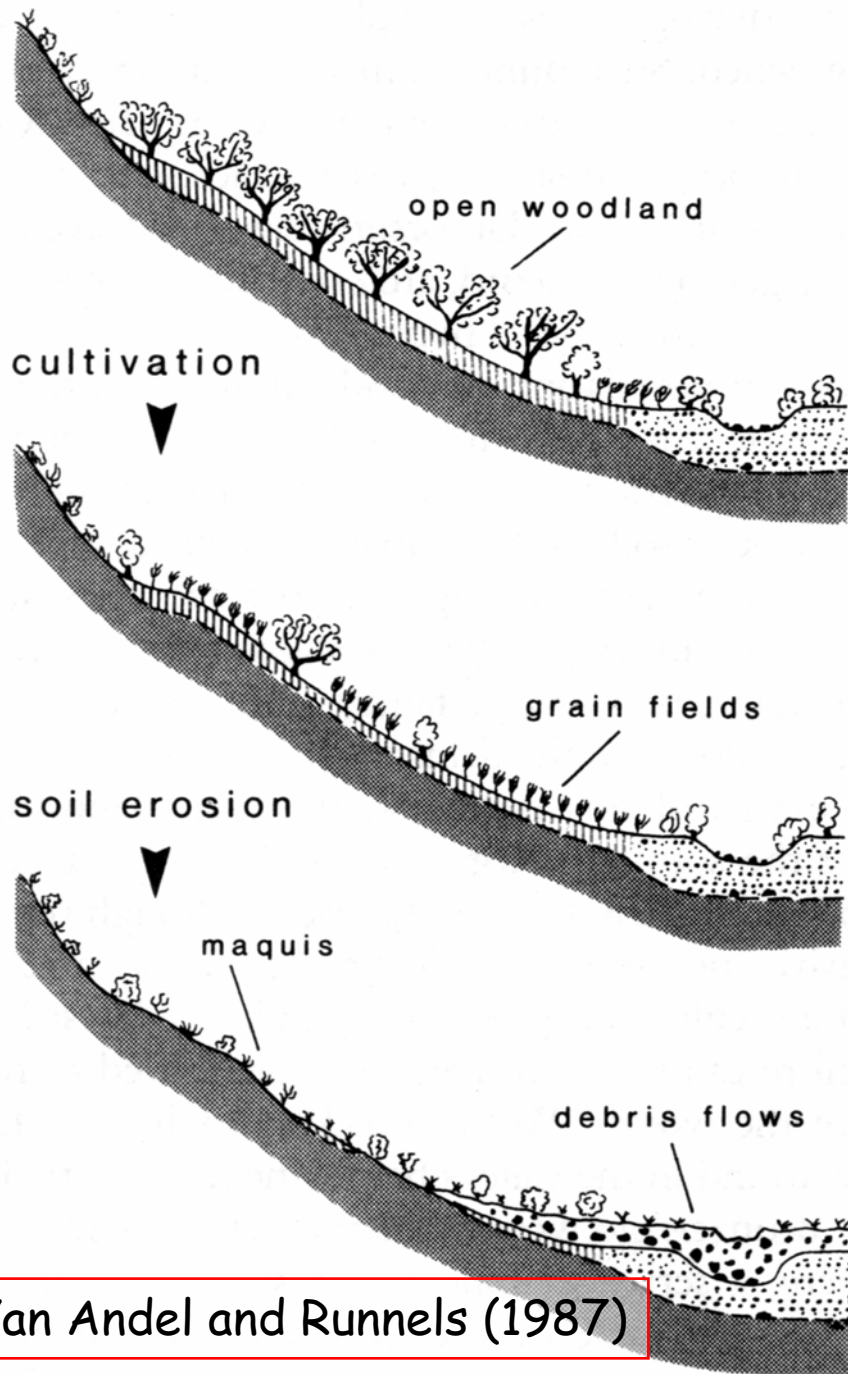


Geomorphology simply:
$$\frac{\partial z}{\partial t} = -\nabla \cdot \tilde{Q}_s + \textit{Tectonics}$$

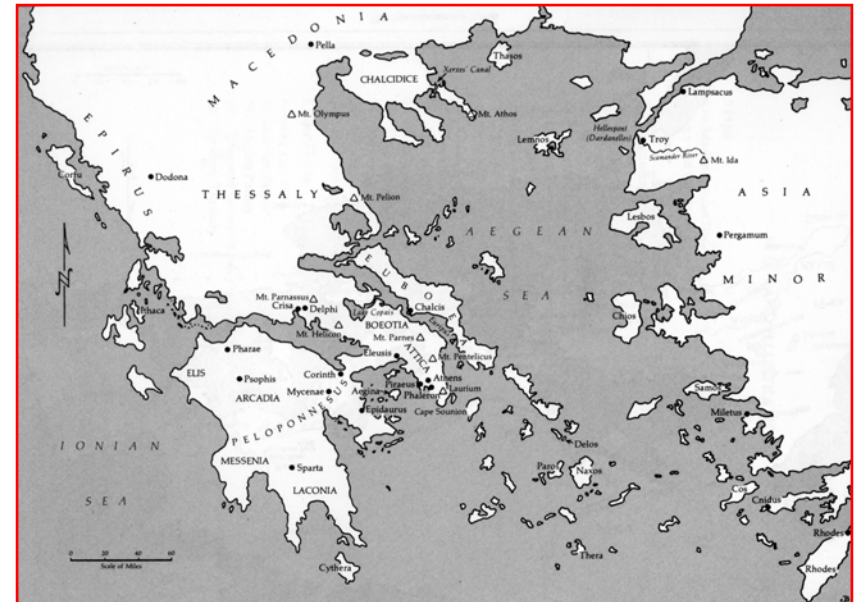
Conventional plow-based agriculture increased soil erosion by more than an order of magnitude...



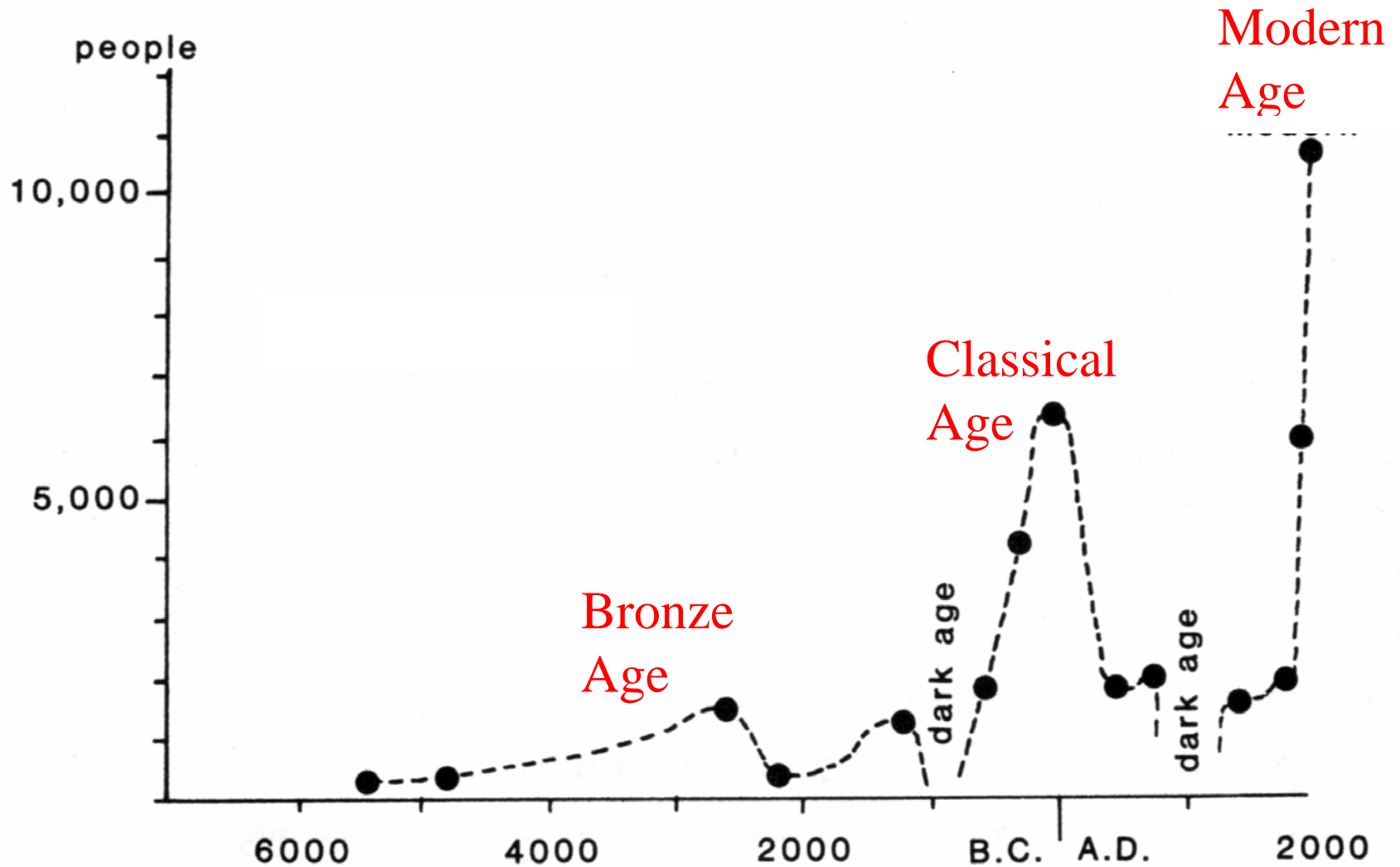
Cycles of erosion and soil formation beginning with Bronze Age erosion after introduction of plow-based agriculture.



Van Andel and Runnels (1987)



Population of the Southern Argolid



Van Andel and Runnels (1987)



Plato

427-347 B.C.

[T]he 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.

Erosion rates in the Roman heartland increased by an order of magnitude starting about the 2nd century B.C.



Judson (1963; 1968)

*You have all traveled through many lands;
have you seen any country more fully
cultivated than Italy? [Varro, 1.2.6]*

*It is also a science, which
explains what crops are to
be sown and what
cultivations are to be
carried out in each kind of
soil, in order that the land
may always render the
highest yields. [Varro, 1:3]*



Roman ruins in Northern Syria

Rome's North African colonies supported extensive olive and cereal plantations in the 1st through 3rd centuries A.D.



Goodchild (1953)



All places are now accessible, well known, open to commerce. Delightful farms have now blotted out every trace of the dreadful wastes; cultivated fields have overcome woods.... We overcrowd the world. The elements can hardly support us. Our wants increase and our demands are keener, while Nature cannot bear us.

- [Tertullian, *de Anima*, 30]

George Perkins Marsh

Man and Nature (1864)

A widely traveled Vermont lawyer, Marsh argued that people were reshaping Earth's surface and that civilizations influenced their own fate through deforestation, soil erosion and degradation, and water pollution.



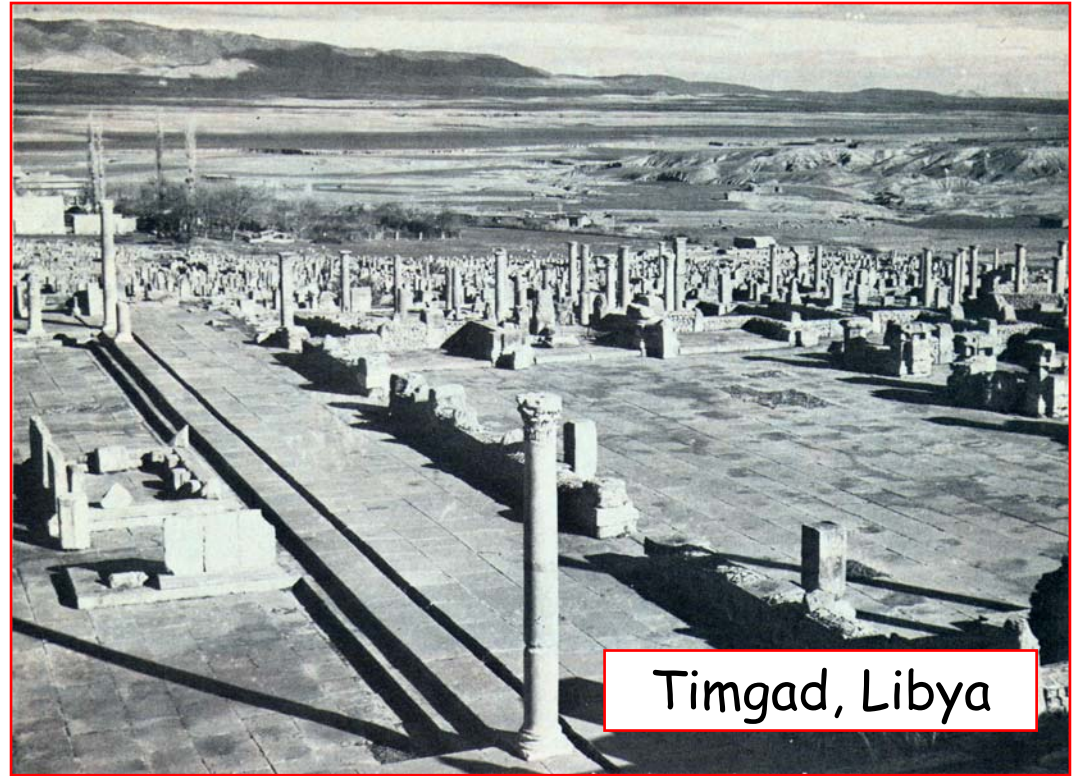
1801-1882



[T]erritory larger than all Europe, the abundance of which sustained in bygone centuries a population scarcely inferior to that of the whole Christian world at the present day, has been entirely withdrawn from human use, or, at best, is thinly inhabited. ... There are parts of Asia Minor, of Northern Africa, of Greece, and even of Alpine Europe, where the operation of causes set in action by man has brought the face of the earth to a desolation almost as complete as that of the moon; and though, within that brief space of time which we call "the historical period," they are known to have been covered with luxuriant woods, verdant pastures, and fertile meadows....

-[Marsh, 1864, p. 9, 42]

Walter Lowdermilk



Timgad, Libya

Over a large part of the ancient granary of Rome we found the soil washed off to bedrock and the hills seriously gullied as a result of overgrazing.

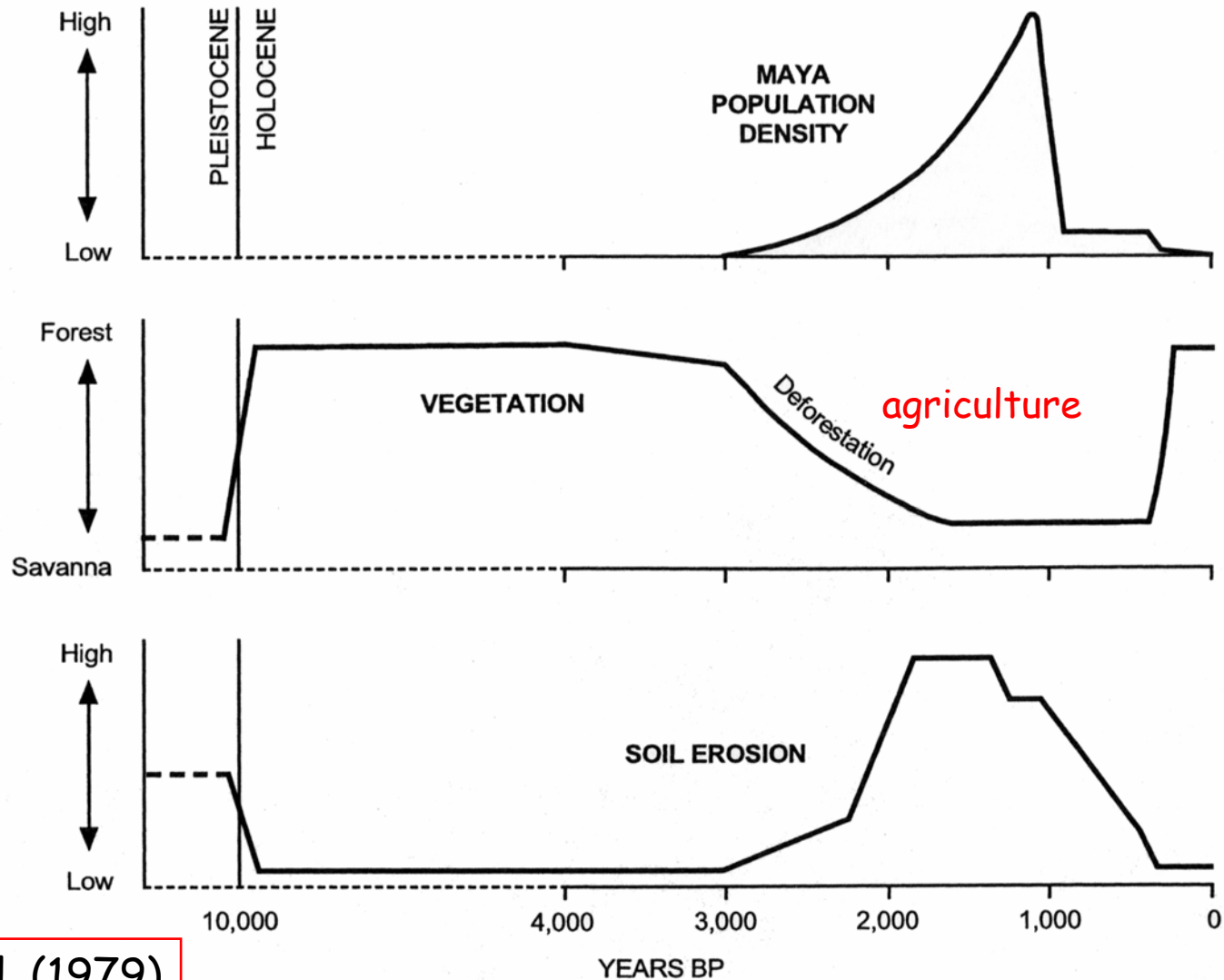
Overall, average annual soil erosion rates during the Maya period were > 5 t/ha over more than 2200 years, more than an order of magnitude faster than natural soil regeneration.

Lago Salpeten, Guatemala

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Maya population, vegetation, and soil erosion



Deevy et al. (1979)

In the first few years following a clearing made in the mountains, excellent crops are produced because of the humus coat the forest has left. But this precious compost, as mobile as it is fecund, lingers not for long upon the slopes; a few sudden showers dissipate it; the bare soil quickly comes to light and disappears in its turn.

[Surell, 1870, p. 219]



France

Lowdermilk (1953)

[S]o it is at present that Tobacco swallows up all other Things, every thing else is neglected.... [B]y that time the Stumps are rotten, the Ground is worn out; and having fresh Land enough ... they take but little Care to recruit the old Fields with Dung.

[The Present State of Virginia, Hartwell, Blair, and Chilton, 1727, p. 6,7]

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are needed to see this picture.

In a 1796 letter to Alexander Hamilton...

It must be obvious to every man, who considers the agriculture of this country ... how miserably defective we are in the management of [our lands]. ... [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]

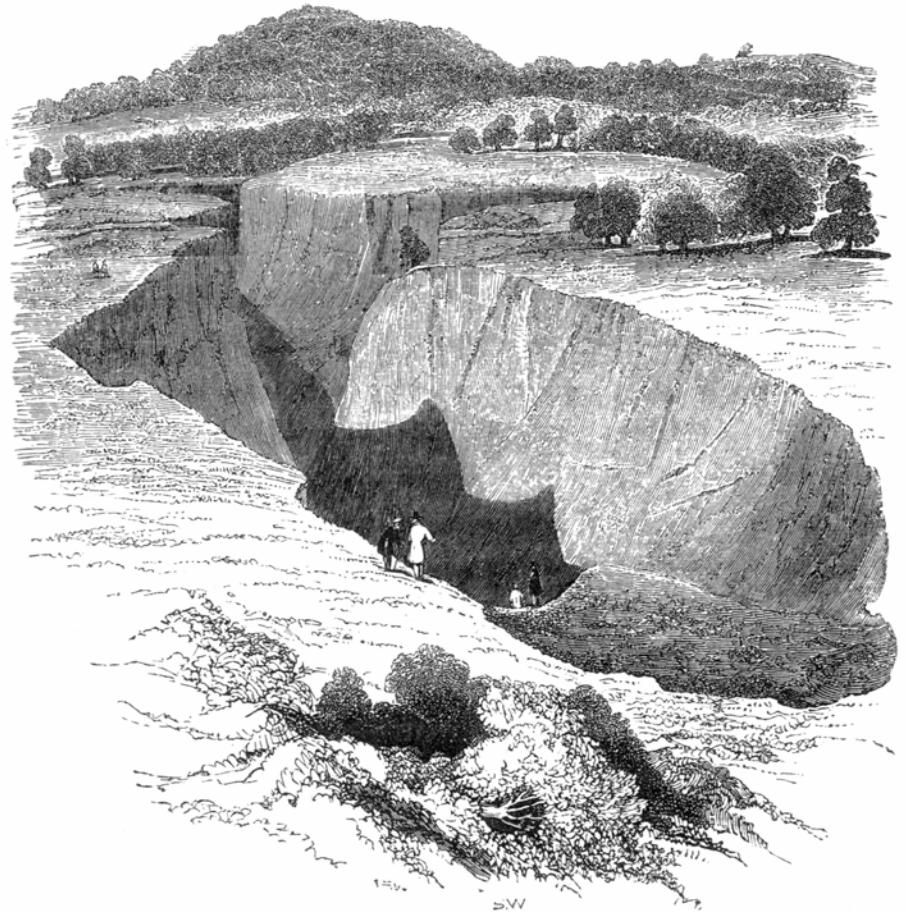
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The Americans appear to be ignorant that with water manure is every where made; and that with manure and water, there is not an inch of ground that cannot be made fertile. The land for this reason is there soon exhausted, and ... [t]he farmers of the United States resemble a people of shepherds, from their great inclination to wander from one place to the other.

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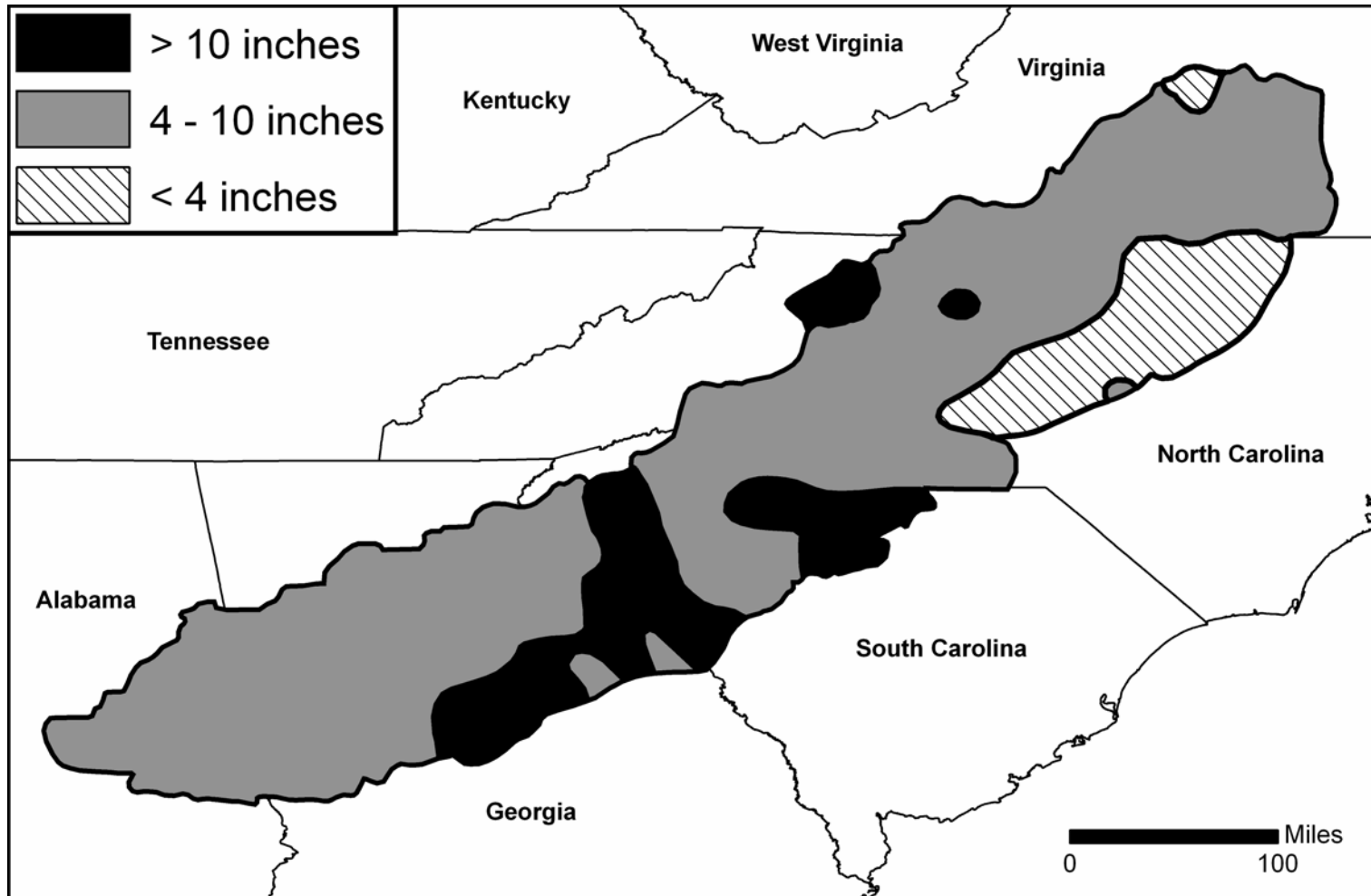
- [de Beaujour, 1814, p. 85-86]

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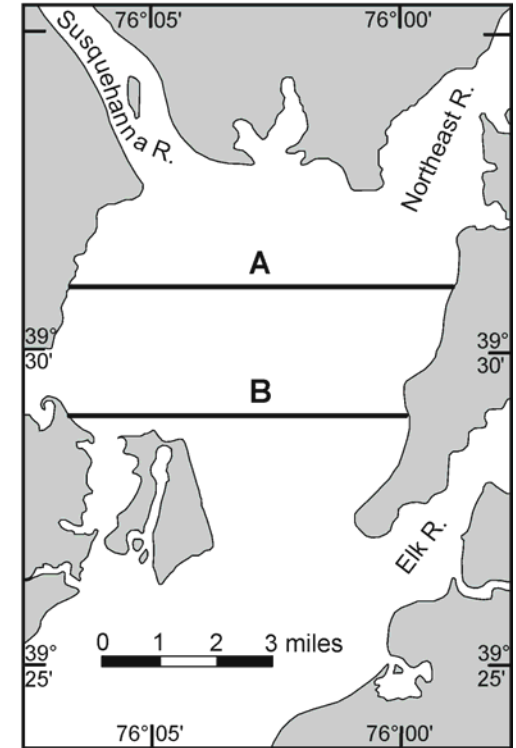
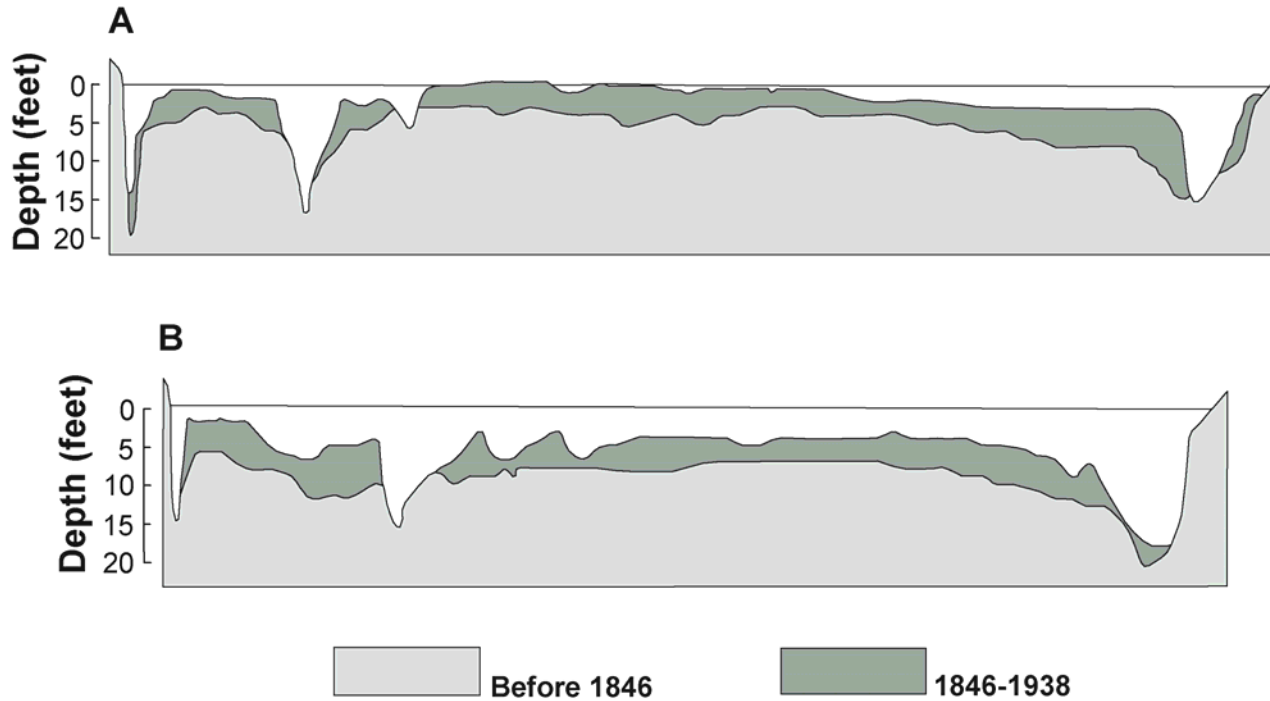


*I infer, from the rapidity of the denudation caused here
by running water after the clearing or removal of wood,
that this country has been always covered with a dense
forest, from the remote time when it first emerged from
the sea. [Charles Lyell, 1849, v. II, p. 24]*

Historical soil erosion in the Piedmont region

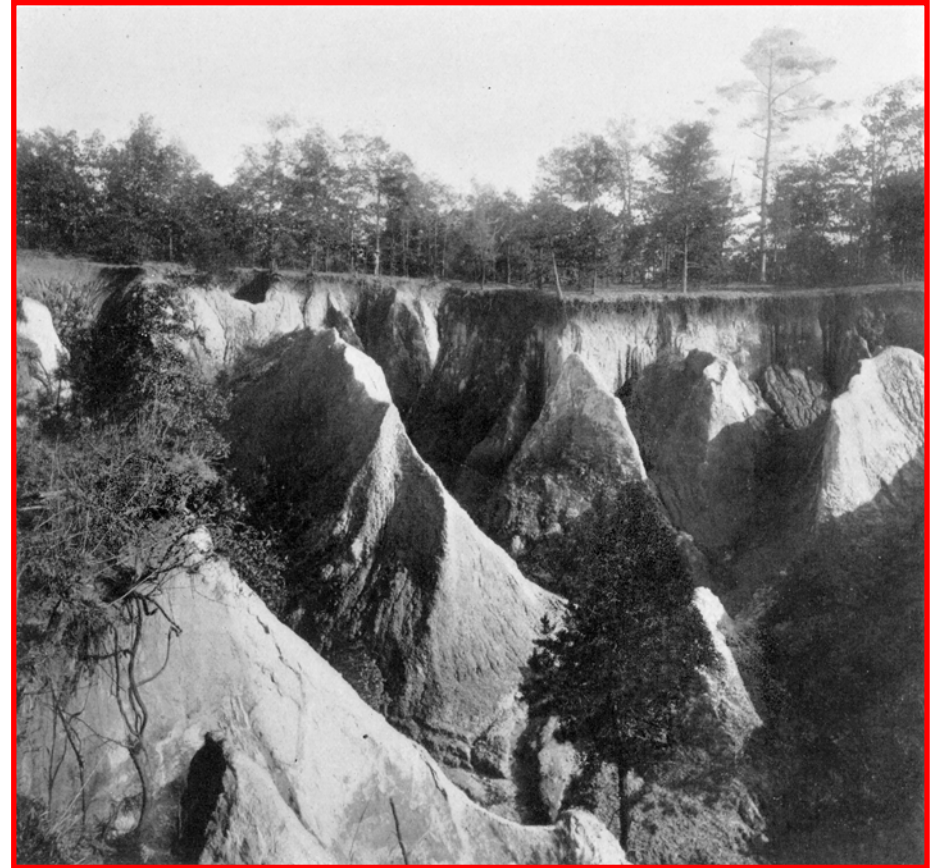


As farming spread across the colonies the head of Chesapeake Bay filled in with sediment



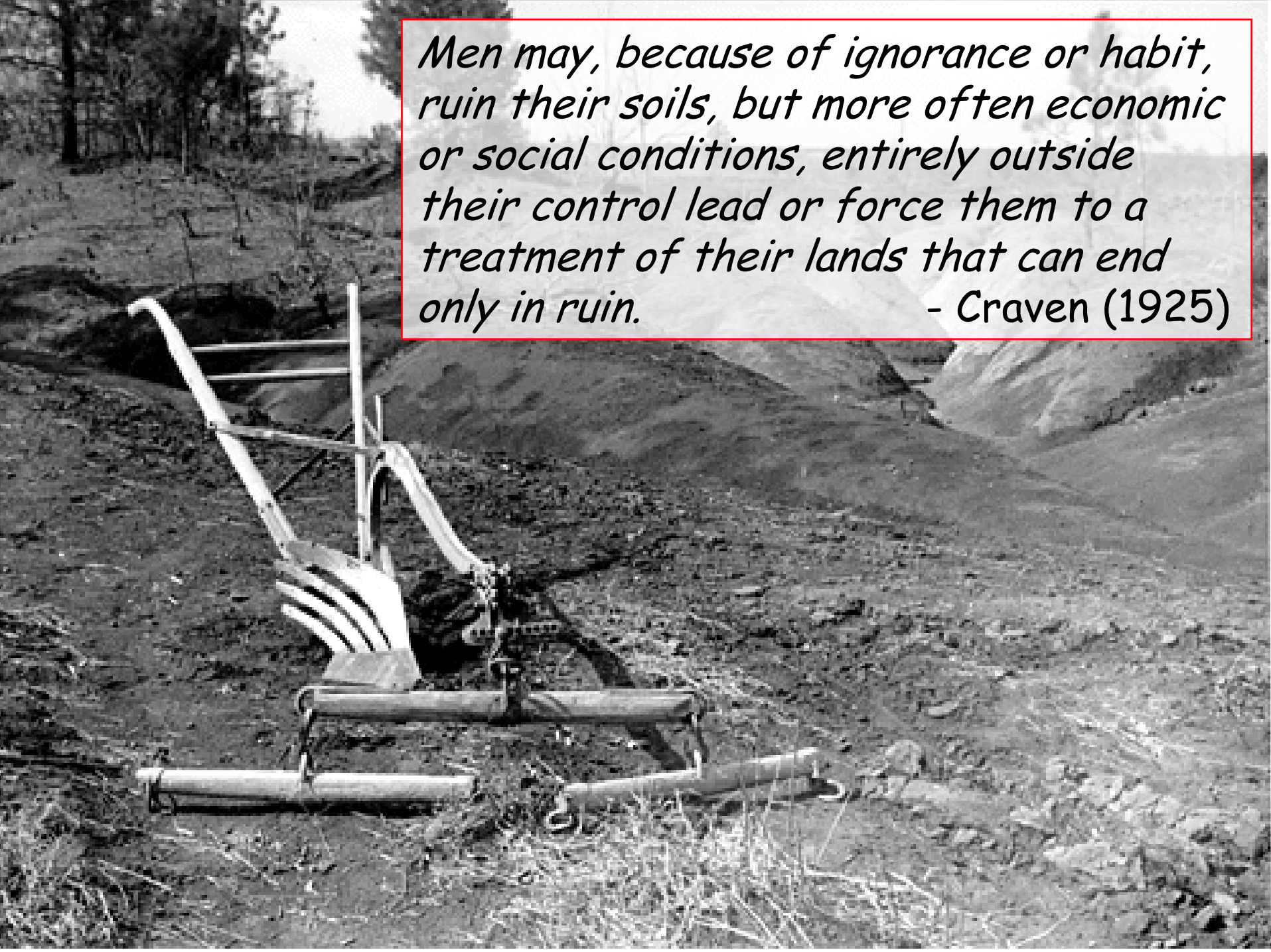
Today the Lincoln Memorial sits on ground where great merchant ships sailed in the eighteenth century.

Most of the erosion-control practices in use at the present time, such as the use of legumes and grasses, deep plowing, contour plowing and hillside ditching, the prototype of modern terracing, were either developed by the Virginia farmers or became known to them during the first half of the nineteenth century. - [Hall, 1937, p.]

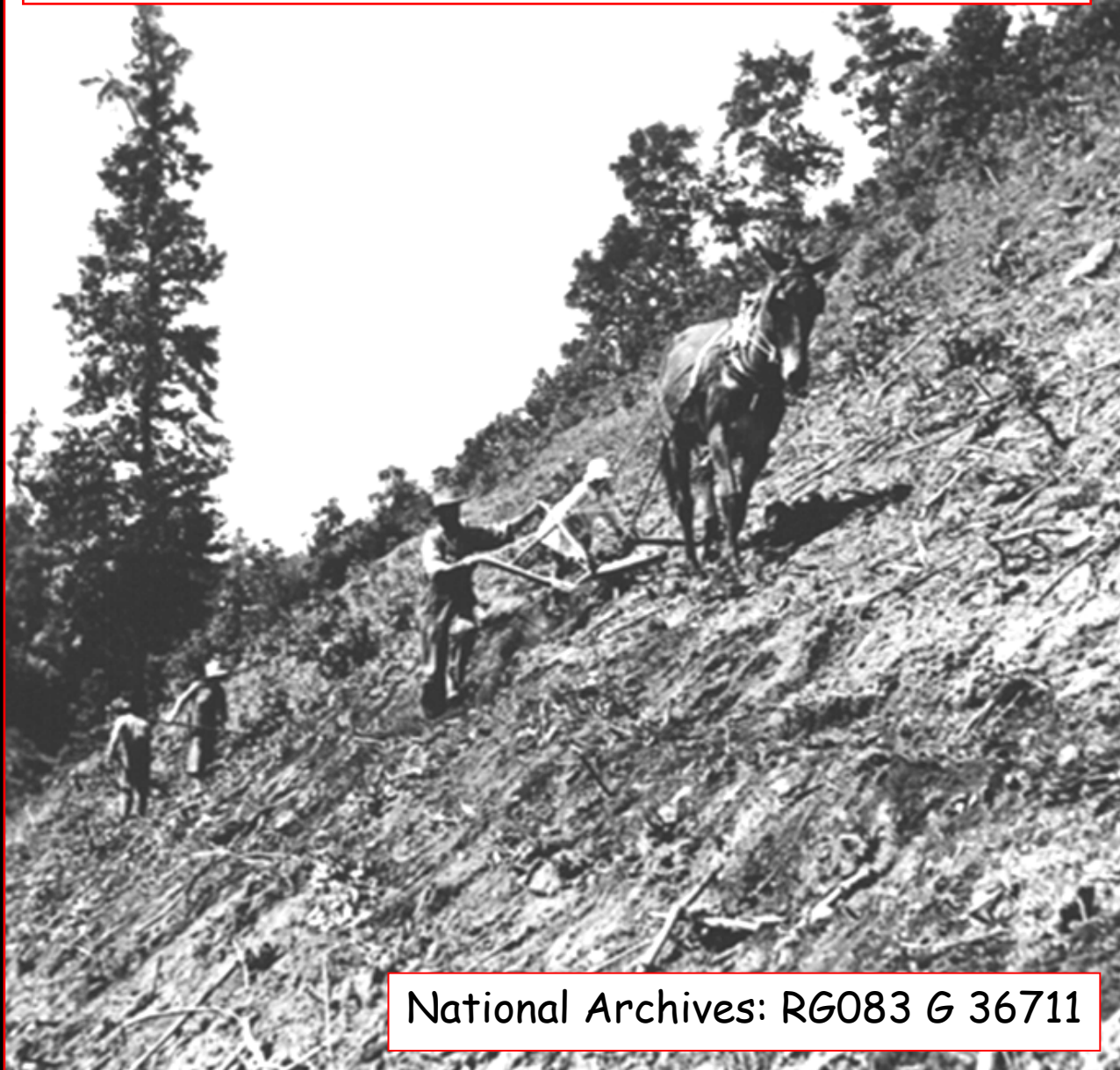


Men may, because of ignorance or habit, ruin their soils, but more often economic or social conditions, entirely outside their control lead or force them to a treatment of their lands that can end only in ruin.

- Craven (1925)



Plowing a hillslope, ca. 1935



National Archives: RG083 G 36711

The [First] World War and the following inflation pushed the price of wheat to new high levels and caused a remarkable extension of the area planted to this crop. When the price collapsed during the post-war period Great Plains farmers continued to plant large wheat acreages in a desperate endeavor to get money with which to pay debt charges, taxes, and other unavoidable expenses. They had no choice in the matter. Without money they could not remain solvent or continue to farm. Yet to get money they were obliged to extend farming practices which were collectively ruinous.

[Great Plains Committee,
1936, p. 4]



[S]oil has been cultivated when extremely dry, and no effort has been made, in most cases, to return organic matter to the soil. ... When cultivated in a dry condition such a soil became loose and dusty. There are individual farmers throughout the region who have followed good methods of soil management and have found it possible to prevent soil blowing on their farms, except where soil blown from adjoining farms encroached upon their fields.
[Throckmorton and Compton, 1938, p. 19-20]



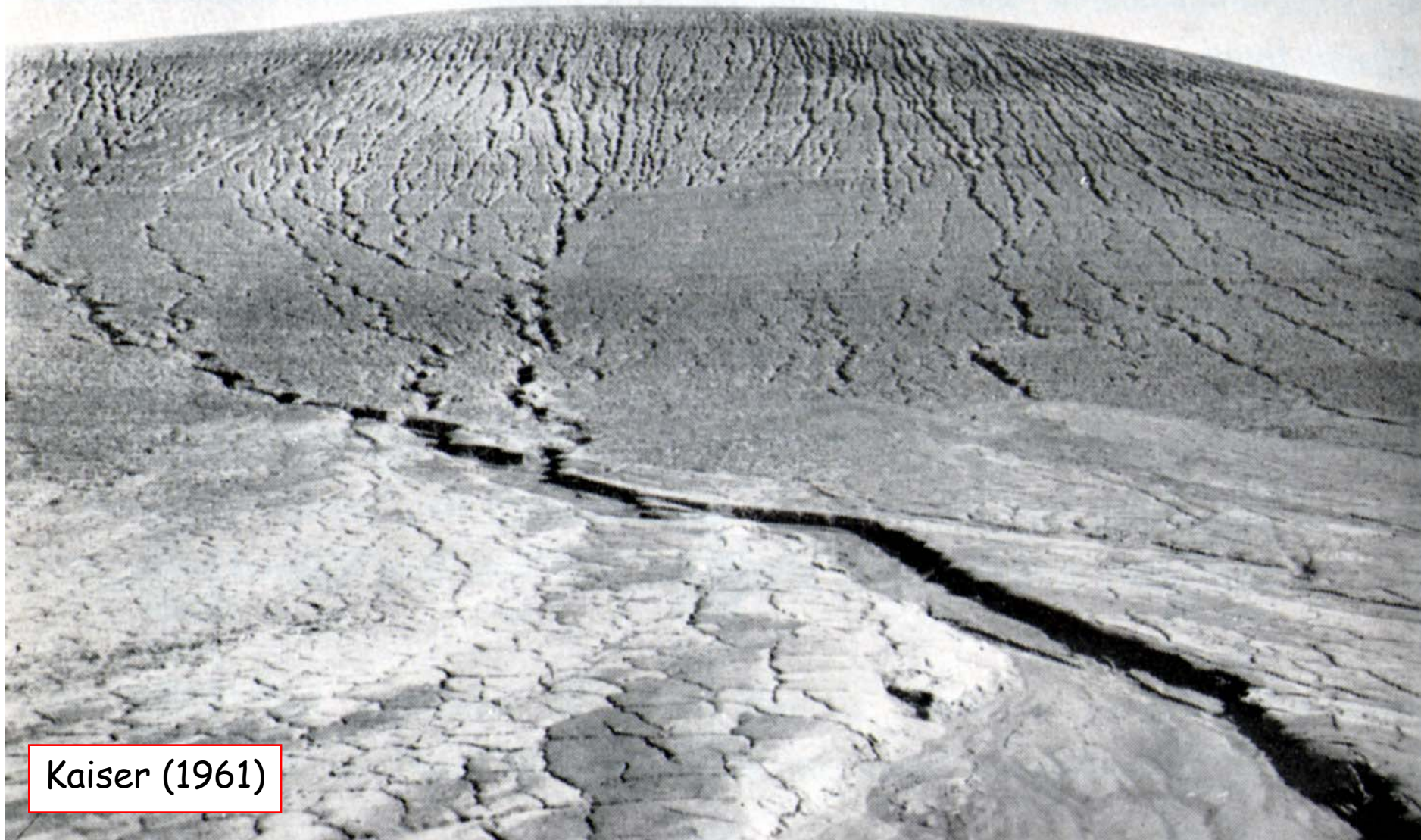


I suspect that when people along the seaboard of the eastern United States began to taste fresh soil from the plains 2,000 miles away, many of them realized for the first time that somewhere something had gone wrong with the land.

- Soil Conservation Chief Hugh Bennet, 1941

Palouse, Washington

1950s



Kaiser (1961)



1970s

Palouse, Washington

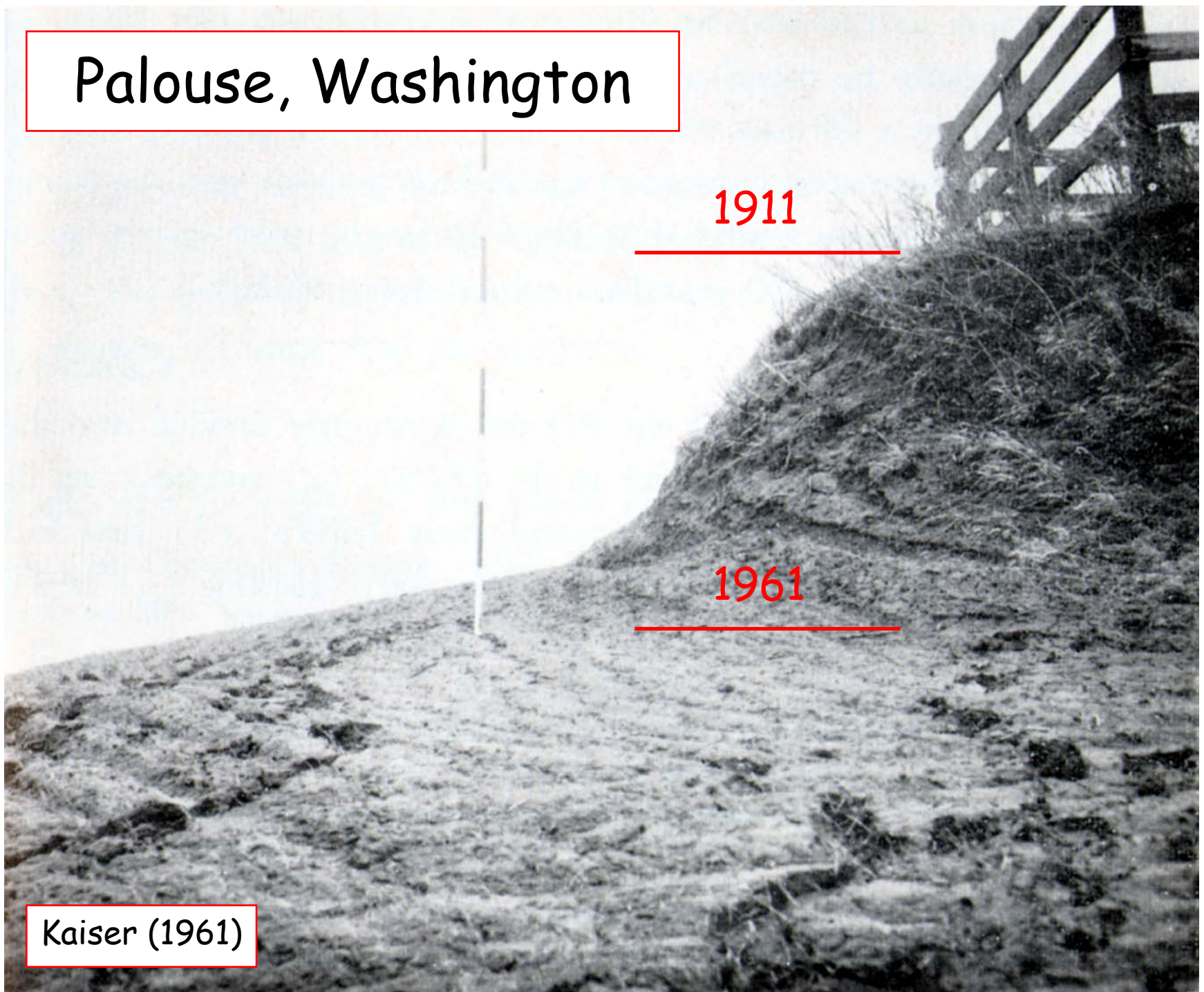
USDA (1979)

Palouse, Washington

1911

1961

Kaiser (1961)



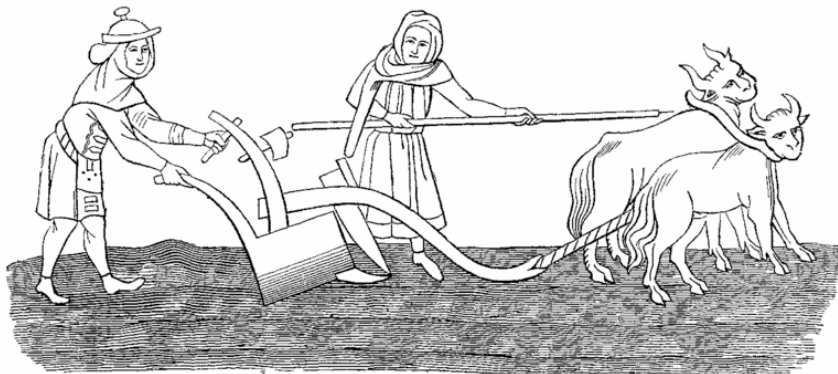
The true aim ... of a conservative agriculture ... is to bring about and keep the balance between the processes of rock decay and erosion. ... With rare exceptions, the fields of all countries have been made to bear their crops without the least reference to the interests of future generations.

- [Shaler, 1905, p. 123-4, 128]

In its primitive state the soil is each year losing a portion of its nutrient material, but the rate at which the substances go away is generally not more rapid than the downward movement of the layer into the bed rock. ... But when tillage is introduced, the inevitable tendency of the process is to increase the rate at which the soil is removed until the destruction begins to trench upon its depth and fertility.

- [Shaler, 1891, p. 330]

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



David R. Montgomery

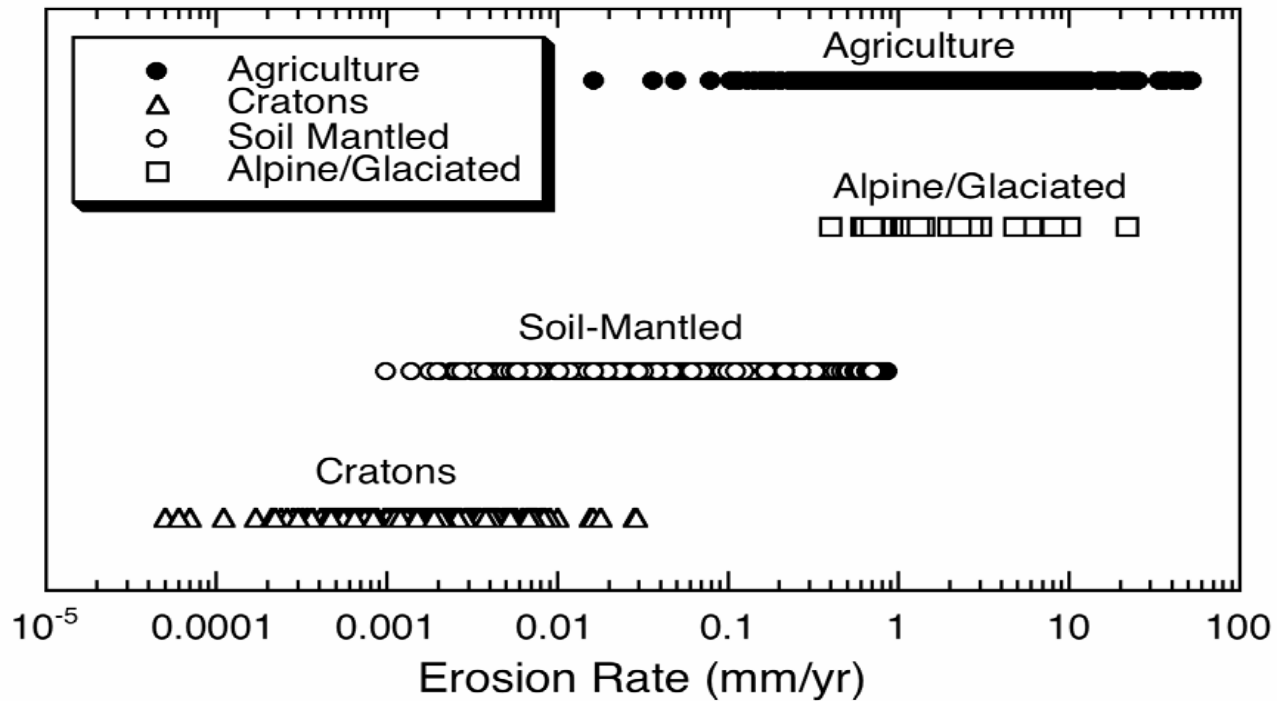
A photograph of a desolate, eroded landscape. In the foreground, several pieces of abandoned farm equipment, including a plow and a wheelbarrow, are scattered on the sandy, eroded ground. In the background, a small, dilapidated wooden house stands amidst the barren terrain. The sky is a pale, hazy blue.

dirt

A faint, light-colored illustration of a man plowing with oxen, similar to the one in the middle-left section, serving as a background for the title.

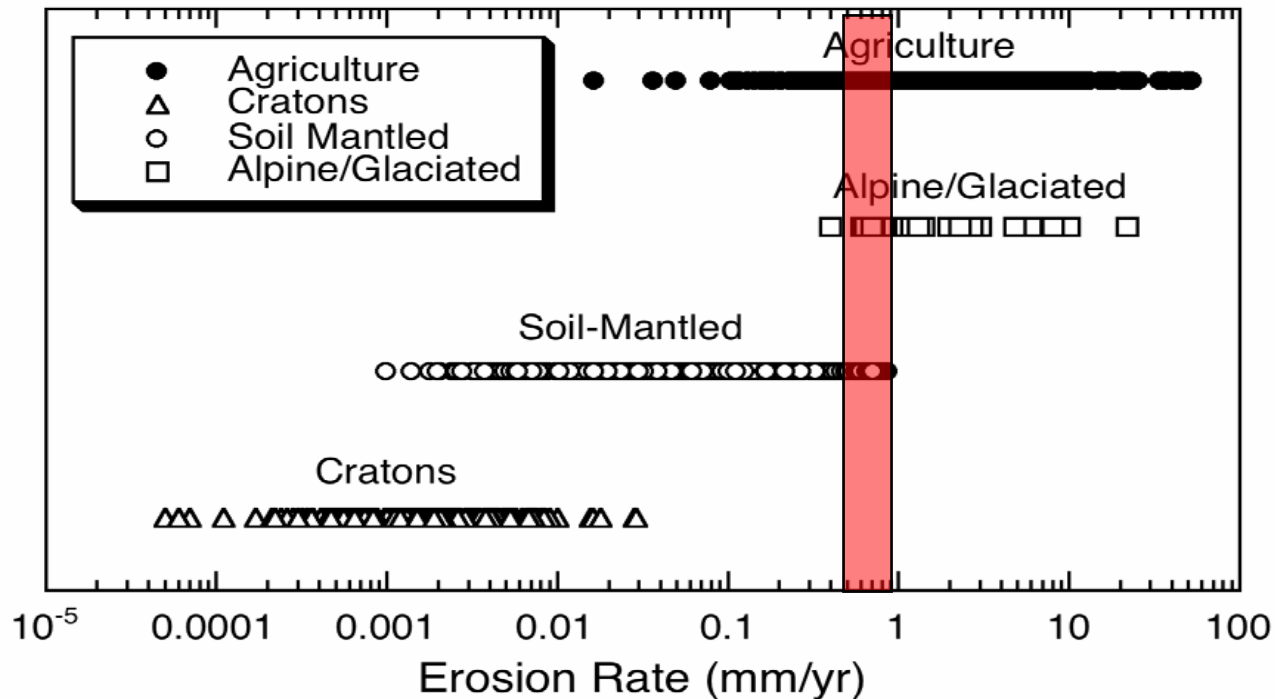
The Erosion of Civilizations

1402 measurements of agricultural and geological erosion rates



Did not include sediment yield and USLE-based studies

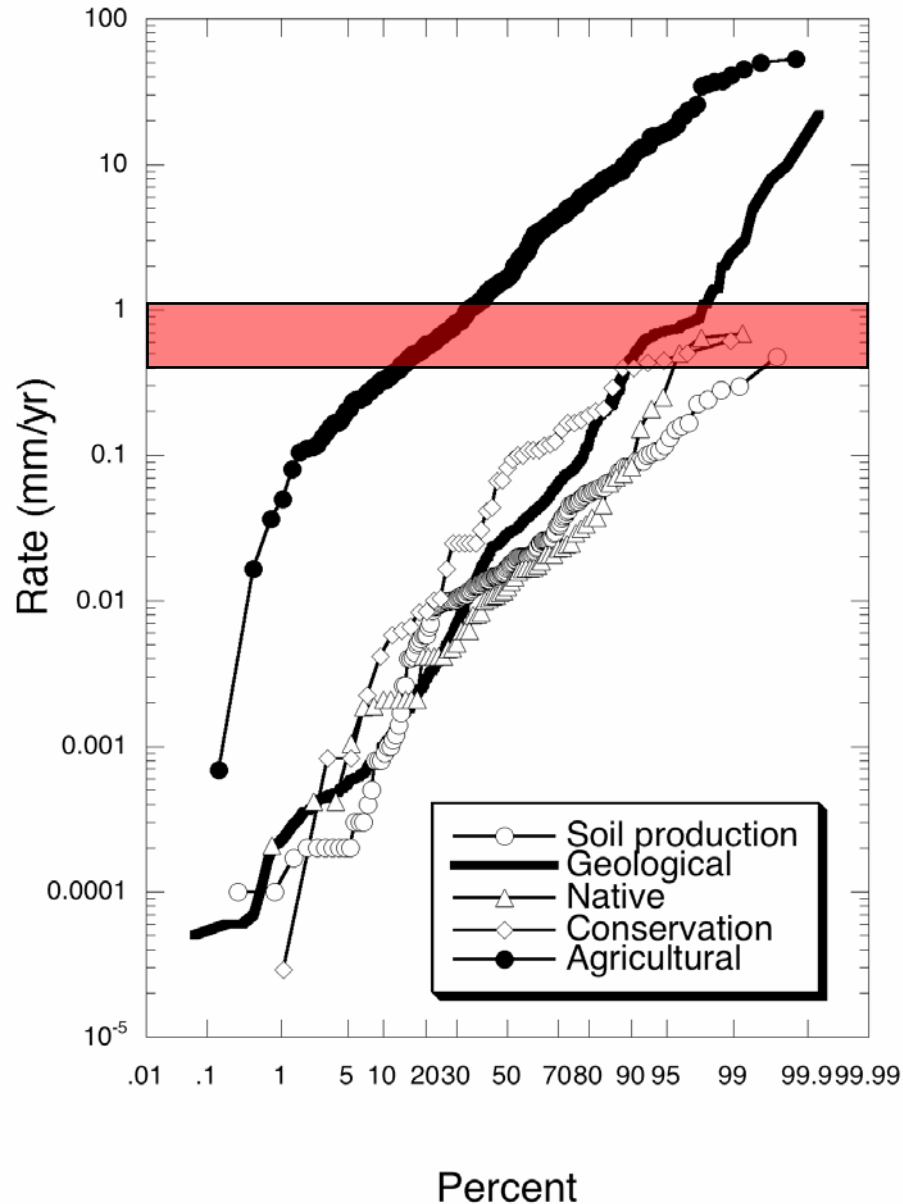
USDA soil loss tolerance values range from 0.4 to 1 mm/yr

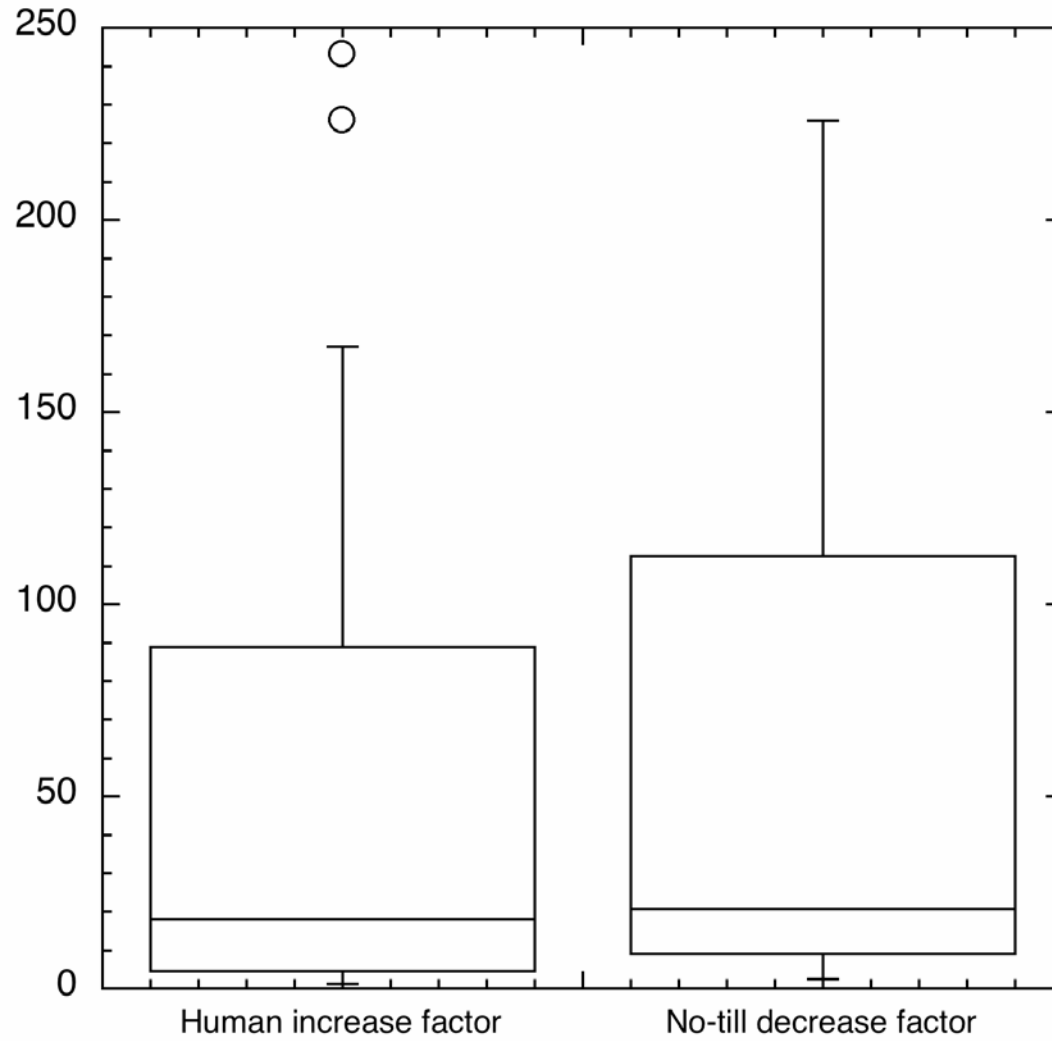


Farms erode like alpine topography
Conventional agriculture unsustainable in soil-mantled
landscapes

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

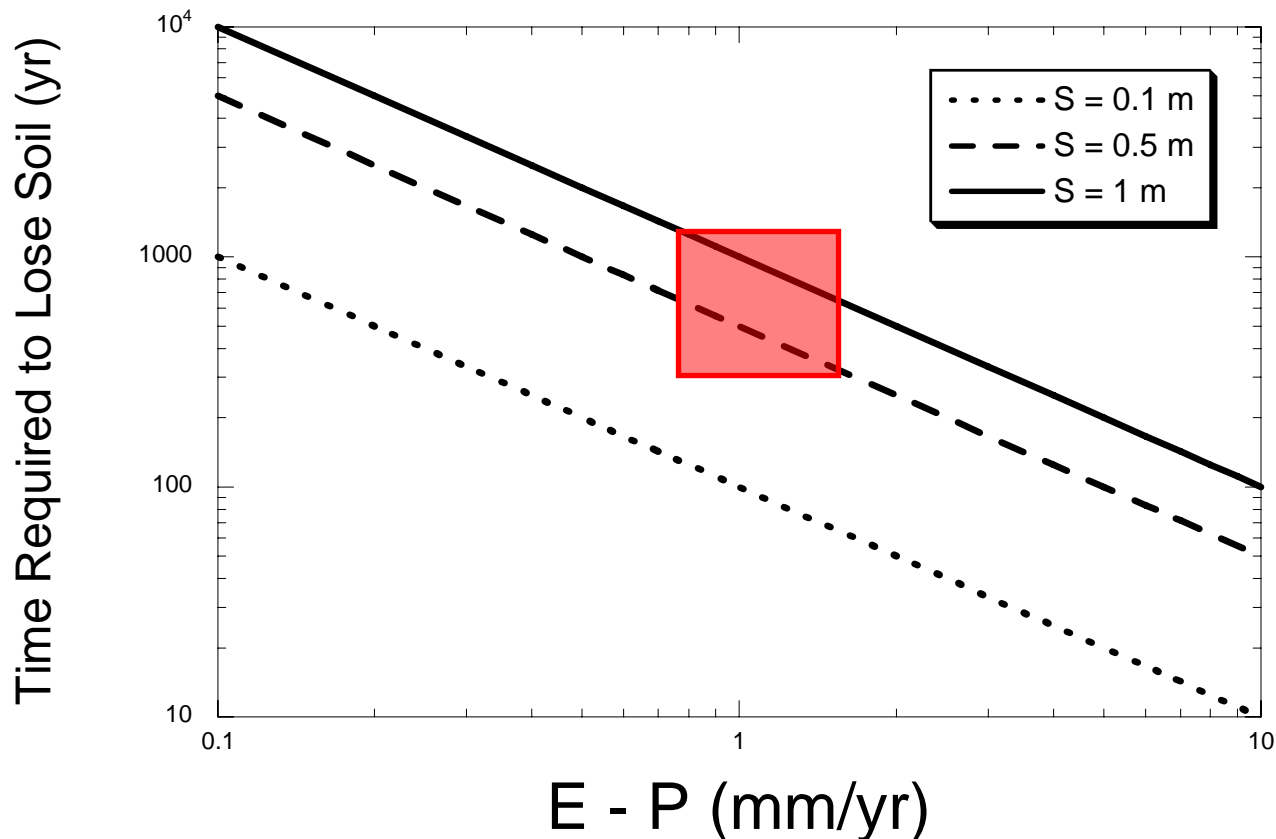
Erosion from conventionally plowed fields generally exceeds T values





Simplest model of time required (T_c) to lose soil thickness (S) as a function of difference between erosion (E) and soil production (P)

$$T_c = S / (E - P)$$





1 to 2 order of magnitude increase in soil erosion under conventional agriculture implies that erosion of a typical 0.5 - 1 m thick soil could occur in roughly 500 to 2000 years; approximately the lifespan of most civilizations...

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]

Global erosion rates have increased by about an order of magnitude due to human activity...

Average rate for last 500 million years* = 1 inch / 1400 yrs

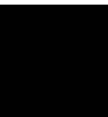
Average rate of soil erosion at present* = 1 inch / 60 yrs

Average rate of soil production at present = 1 inch / 500 yrs

(* Bruce Wilkinson, GSA abstract 2004)

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are needed to see this picture.

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Global erosion rates have increased by about an order of magnitude due to human activity...

Average rate for last 500 million years = 1 inch / 1400 yrs

Average rate of **soil erosion** at present = **1 inch / 60 yrs**

Average rate of **soil production** at present = **1 inch / 500 yrs**

Sometimes things happening the slowest are most difficult to stop.

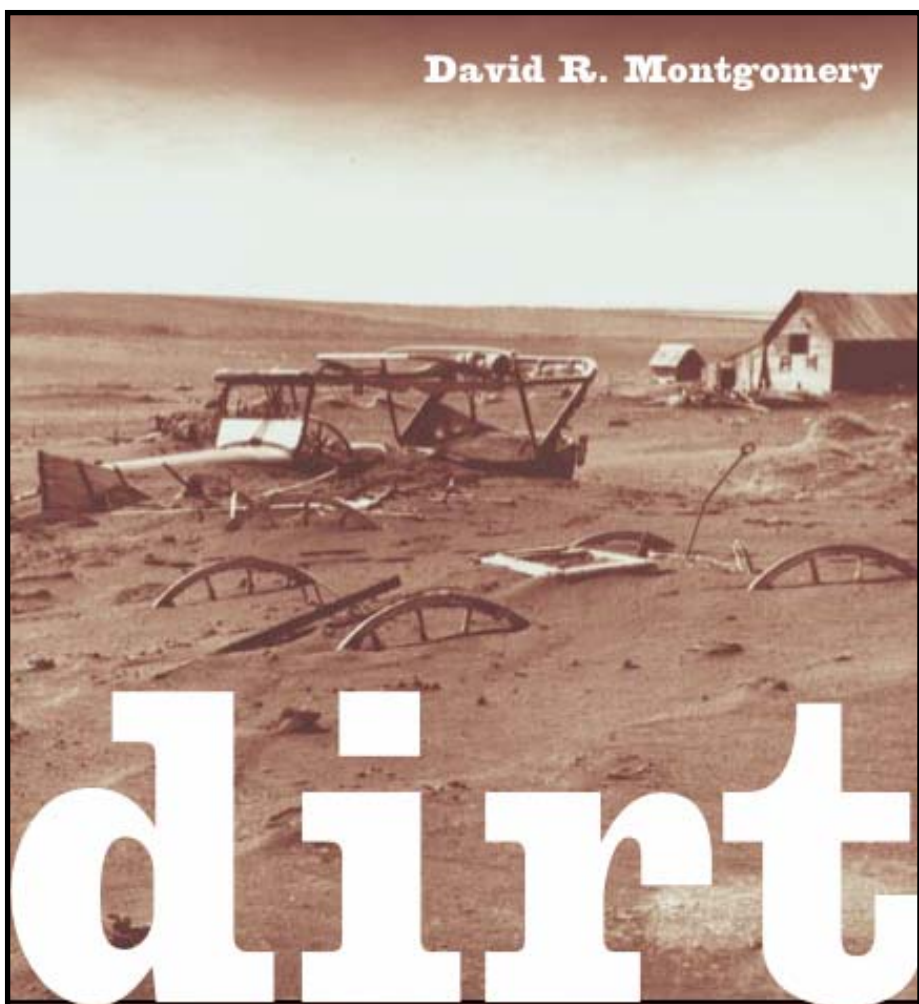
A nation that destroys its soils, destroys itself.

- President Franklin D. Roosevelt, Feb. 26, 1937.



National Archives: 114 SC 5089

David R. Montgomery



dirt



The Erosion of Civilizations

KING OF FISH



THE THOUSAND YEAR FALL OF **SALMON**

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