## *GEOLOGIC AND ACCELERATED EROSION*

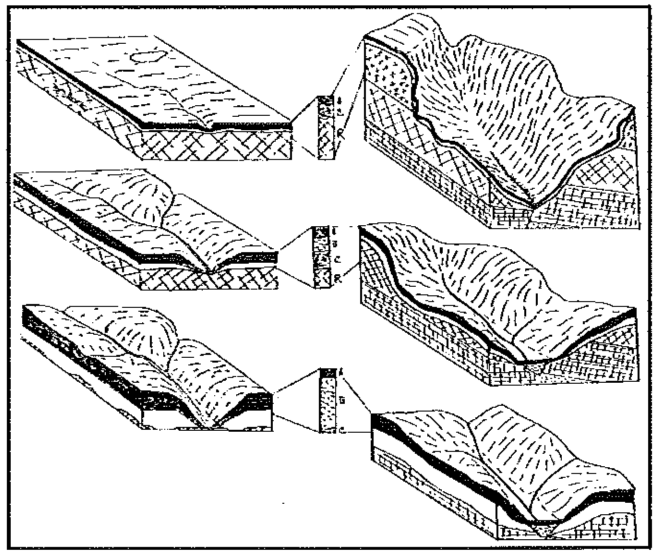
<u>*Geologic Erosion:*</u> natural process in landscape formation over geol. time.

– all landscapes tend to be reduced to rolling hills over geologic time due to erosion/deposition with watershed....

Processes:

- – hillslope erosion
- – downcutting of streams
- – deposition on floodplains

Not all soil leaves watershed in suspended sediment: redistribution..



Landscape development on initially flat and initially steep topography.

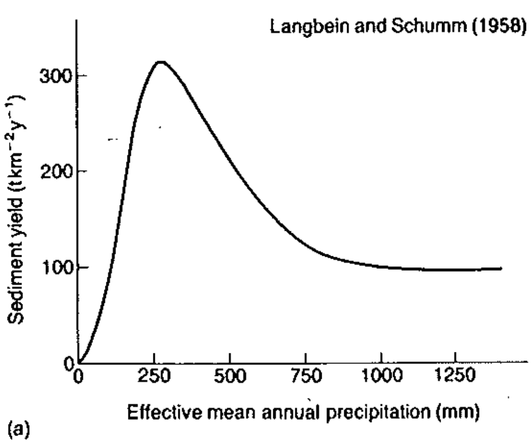
### <u>*Factors Affecting Rates of Geologic Erosion*</u>

**A. Climate**: largely annual rainfall totals

– 300 mm (12") / year gives max erosion / sediment yield ("semi-arid")
: enough to cause runoff, but low vegetation density

>300 mm: better vegetative cover, less exposed soil
<300 mm: not enough rainfall to generate much runoff

– with cover removed or controlled by humans– total rainfall, and annual dist'n important



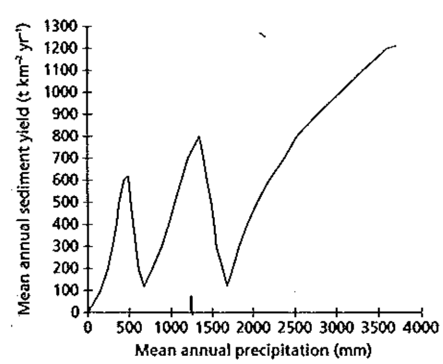




**Fig. 1.1** Relationship between sediment yield and mean annual precipitation (after Walling & Kleo 1979).

**Fig. 1.2** Proposed relationships between sediment yield and (*a*) effective mean annual precipitation

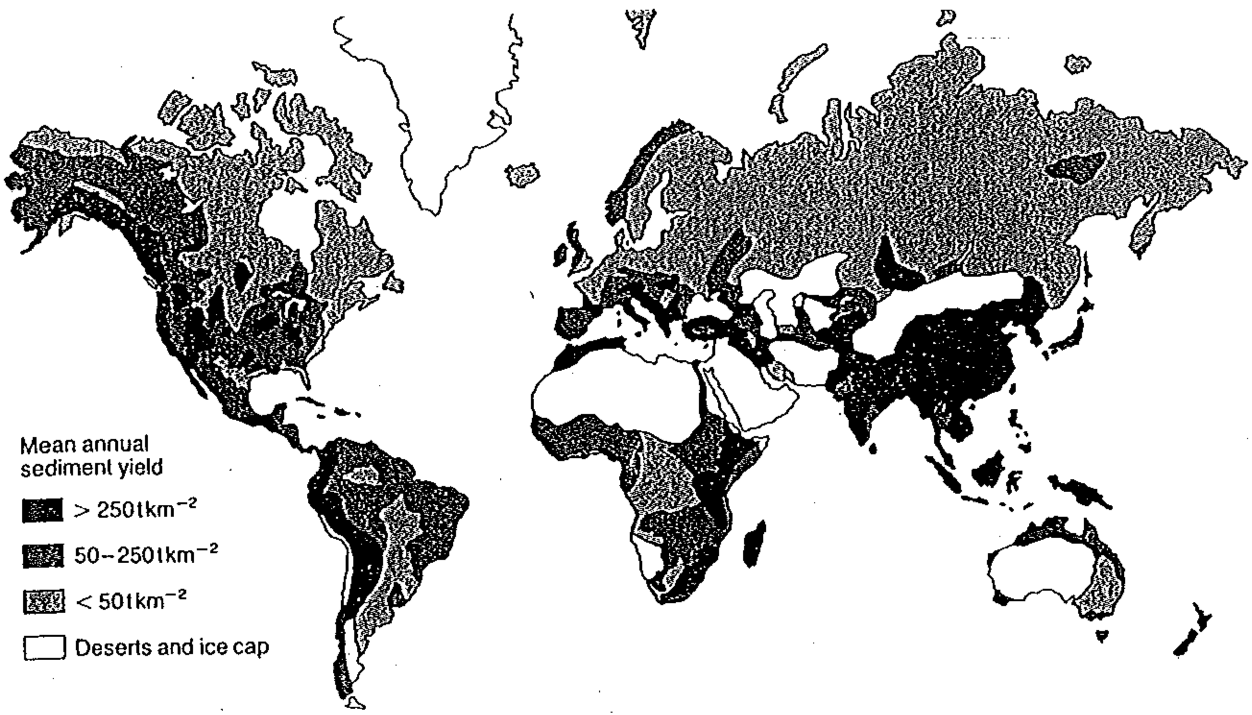



**Fig. 1.2** A tentative map of global variations in suspended sediment yield (after Walling & Webb 1983).

**B. Vegetation:** largely determined by climate (also altitude, aspect, etc.)

– residue (ie, forest floor) and canopy (leafy cover) reduce rainfall impact energy, prevent soil crusting, reduce runoff, enhance water use by ET, etc.

: with intact litter and 100% cover, very low rates of erosion . . . . .

– major cover disturbing effects: fires, disease outbreaks, earthquakes, volcanoes

– remove vegetative cover, expose bare soil to rainfall, increase runoff & erosion
– major forest fires occur every 150-250 yrs in undisturbed forests . . . .

: "catastrophic" theory of geol. erosion– occurs irregularly in large events, not uniformly over time . . . . .
:climatic also– hurricanes, tornadoes all result in much greater than "average" rates of erosion

**C. Relief**: steep vs. flat . .

– local effect: soil erodes from steep areas, deposited on flatter areas; overall levelling....

*Rates of Geologic Soil Erosion*

– *sediment yields from watershed:*

sediment conc in rivers (lbs/gal) × discharge (gal/yr) / watershed area (ac) = lbs/ac/yr

not too reliable– big variation year to year in sediment loads
doesn't take into account unusual "catastrophic" events
most watersheds have human influence (farming, etc)

*Example:* central GA, present day: 20" runoff/yr, ave sediment conc. = 0.1 g/L

0.5 m runoff × 10,000m$^2$ / ha × 1,000 L / m$^3$ × 0.1 g sediment / L = 500,000 g /ha

× 1 kg / 1000g × 2 lbs / kg × 1 ac / 2.5 ha = 400 lbs / ac annual erosion

– *landscape lowering based on geologic formations:*

estimate landscape lowering in relation to geologic formation of known age . . . .

:need formation with known age . . . Estimate soil loss over time relative to that.

*Example:* Stone Mt.: emplaced 300 million years ago at depth of 7 km (4 mi)
[estimated from crystal size of granite during cooling and radio-dating)

– currently 900' above surrounding countryside (weathered metamorphic rock)

– 22,000ft lost in 300,000,000 yr = 0.00007 ft / yr, or 1"/1000 yr . . . . .
150 tons/ac/1,000yr = 0.15 t / y = 300 lbs /ac / yr

Average of about **0.2 t /a/ y** geologic erosion . . . . . . .

Some have suggested this as a maximum "acceptable" rate of erosion today . . . . . ???

– typical rates of erosion under cotton farming, pre-1930 : 20-50 t /a y

– current rates of erosion, row cropped lands, Ga : 3-8 t /a /y

– erosion rates under no-till agriculture (potential) : 0.5-1 t/a/y

*Temporal Variation in Erosion*

**Seasonal:** distribution of rainfall, rainfall intensity, and vegetative cover –

Vegetative cover varies with temperature, rainfall, etc . . .

In ag systems, varies with planting / cultivation / harvest cycles

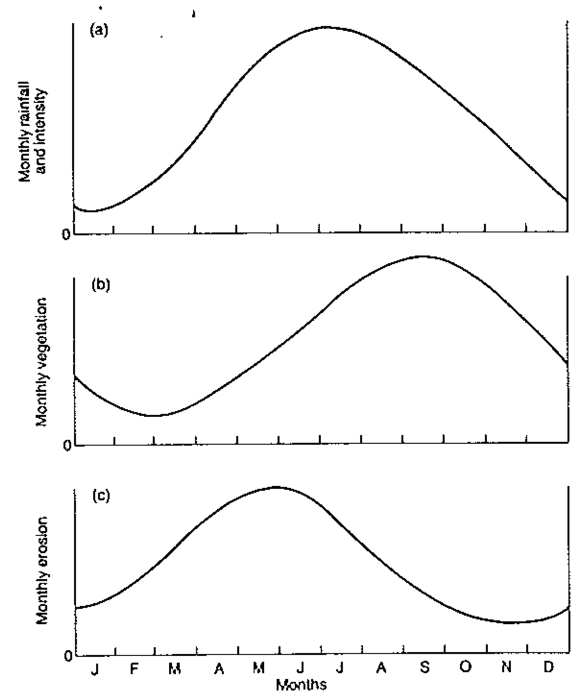



**Fig. 1.4** Seasonal cycles of rainfall, vegetation cover and erosion in a semi-humid climate (after Kirkby, 1980).

**Over Years:**

– seasonal rainfall can vary +/- . . . .
In Athens, 40 yr mean is 48" . . 1/10 yrs will be >63", 1/10 yr will be <40"

– seasonally wet years (hurricanes, major fronts) – 2-4 times as much erosion as normal year (most of excess rain occurs in spring/summer, increasing erosion)

*Accelerated Erosion*

– human land management dates back 10-20,000 years . . .
: burning as a hunting aid (US Great Plains, buffalo culture)
: early agriculture (5-8,000 yr ago, Middle East, China)

– agriculture *by definition* will increase erosion (selective removal of canopies)

: cannot eliminate erosion, must be controlled/limited to some "acceptable" level

A Short History of Soil Erosion

*Beginnings*

Erosion entered the American consciousness in 1934; despite previous warnings (Thomas Jefferson had bemoaned the loss of topsoil from Virginia Piedmont topsoils in the 1790's), it was only when dust clouds blew towards the East coast that the tragedy of the Dust Bowl became apparent. H. H. Bennett, then Secretary of Agriculture, used the occasion to address Congress, establishing the Soil Erosion Service (later, Soil Conservation Service, now the Natural Resource Conservation Service) as dust settled on the desks in the U.S. capitol buildings.

The Dust Bowl was a result of several years of drought in northern Texas and Oklahoma, a region that had recently been plowed up (using newly developed tractors) from the native prairies and planted to corn, wheat, and cotton. The marginal, sporadic rainfall of the region failed for 3 years, and the prairie winds stripped feet of topsoil off the land, blowing it into dunes and raging dust storms. Entire farms were lost; millions of farmers went bankrupt, beginning a migration of several million "Okies" to the Northern cities and the West coast vividly described in John Steinbeck's *Grapes of Wrath*.[i]

Almost at the same time, the sharecropper system of cotton cultivation in the American Southeast also collapsed. As farm credit failed due to the Great Depression, the boll weevil (imported from Mexico) ravaged cotton fields, already declining in yield due to 100 years of erosion losses from the plantation system of cultivation where fields were left bare much of the year under intense rainfall. Sharecroppers, especially blacks, left in huge numbers, migrating to northern cities like Chicago and Detroit to find work in the new industries developing there.[ii] In the 1930's many southern states actually lost population; huge land areas of the Southern Piedmont were abandoned. Many soils on these landscapes had lost one foot or more of topsoil, and farms were torn by deep gullies running through the fields.

This occurred during a time of industrial growth and urbanization in America that was destined to change the country, regardless of erosion. Mechanization, fertilizers, pesticides, and improved crops were all developed at this time, to a large degree offsetting yield losses due to erosion. These erosion events, however, hastened the transition of this country from a rural agrarian society to an urban industrial population, just as technological advances made labor a much smaller input in agricultural production.

The newly inaugurated Soil Conservation Service enthusiastically promoted erosion control throughout the 40's and 50's. One of their efforts was to demonstrate that erosion had been the bane of civilization since the dawn of mankind.

*Erosion through History*

W.C. Lowdermilk, a USDA soil scientist, published *Conquest of the Land Through Seven Thousand Years* in 1948 as an argument that erosion had materially accompanied (or, *caused*) the fall of many an ancient civilization. Much of the focus was on the Middle East, particularly using Biblical sources to argue that the "land of milk and honey" of 1000 BC was now largely a desert due to over-grazing and excessive cultivation. Similar scenarios were proposed for Mesopotamia (siltation of irrigation canals), Greece and Mediterranean Europe (overgrazing), and even parts of China (excessive cultivation due to overpopulation). This apocalyptic argument has been recently echoed by Daniel Hillel (*Out of the Earth*) and other writers who attempt to show that poor soil management has resulted in the fall of civilizations. Hillel, to his credit, cites other issues such as salinity build-up due to faulty irrigation management as contributing factors, and also notes that other civilizations (Asian paddy rice cultivation, Nile valley farming) did *not* seem to succumb to erosional catastrophes. Much of Lowdermilk's original essay was unsubstantiated speculation, and has not stood up to scrutiny; however, the debate continues. The fall of the Mayan civilization in the Yucatan of Central America, never fully explained, has been blamed on upland erosion based on thick sediment layers excavated and dated in local lakes.

Erosion obviously accelerates nutrient loss and soil degredation, resulting in yield loss in agricultural systems where inputs are not available, and it does so in a gradual manner that is not easy to detect, perhaps until it is too late. Thus it impacts the "sustainability" of these systems over time spans of scores or hundred of years—or even less, in the case of the Dust Bowl. Interestingly, much of the Dust Bowl region today is back in cultivation, using modern farming methods (including irrigation and wind breaks). The basic principle, however—that human manipulation of the earth can result in unintended, potentially dangerous consequences—has resonated in our current concerns for a range of environmental threats ranging from acid rain to urban sprawl to global climate change.

### *The Cure for Erosion*

In the U.S. erosion control on farmland in the 40's and 50's focused on the terrace, contoured diversion ditches that led runoff from the field into protected channels (grassed waterways). They were difficult to construct and maintain, and interfered with cultivation.

Then (the story goes) a Tennessee hill farmer sometime back in the 1950's looked from his gullied corn field into the adjacent woodlot, and had an epiphany. With its layer of leaves intact on the ground, there was no visible erosion under the hardwoods; how could he make his cornfield behave like that? Thus was born the vision of "no-till" or "mulch-till": growing a crop in the residue from the previous year, somehow avoiding the traditional plowing and tillage, so that the intact mulch could stop erosion.

For a decade farmers themselves experimented with new types of planters and herbicides to develop systems to make no-till a reality. In the 1970's researchers at agricultural colleges finally caught on and started to help out; planters were developed to cut through the mulch and get the seed in the ground, new herbicides controlled weeds, and fertilizer methods were developed to get nutrients into the soil. Amazingly, no-till turned out to be economically competitive with conventional tillage for many crops, giving equivalent or better yields with lower costs, and was widely adopted in many parts of the U.S. by the 1990's.

In some areas, the improved control of agricultural erosion did *not* result in an equivalent lowering of suspended sediment (*turbidity*) in rivers and lakes. Water quality concerns had begun to drive issues related to erosion, focusing of sources of sediment other than agriculture. In Georgia, a range of investigations are looking at forest harvesting, urban construction, and unimproved rural roads as sediment sources; one theory holds that "legacy" sediments, deposited in river channels during previous periods of historical high erosion rates, are being resuspended by modern flows, causing high turbidities.

### *The Rest of the World*

Western nations (U.S., Europe) have an array of technology that can be devoted to erosion control, and the wealth and the will to make it a reality. Such is not commonly the case in developing countries, which are still relatively poor, agrarian, and without access to capital or technology.

Much of the farming practiced around the world is done by small-holder farmers, using very limited technology, working on marginal (steep, infertile) land. Erosion rates are often high on these farms; while the effects of erosion on yields are not apparent from year to year, over generations nutrient depletion and overall soil degredation will result in productivity losses, and this has undoubtedly already occurred in many parts of the developing world.

Use of mulching or no-till, the Western solution to erosion, is not easy to implement in these systems since planting and weed control must be done by hand (the mulch just gets in the way). Terracing, grass strips, crop rotation, and other "traditional" methods have been modified and adapted to farming systems around the world to try to develop effective erosion control approaches, but many of these practices are unpopular with farmers looking to maximize yield (for their families' survival) for the current year.

The greatest challenge for erosion and conservation science today is to develop conservation practices for small farms in developing countries. That quest ultimately affects us all: successful small farmers will eventually rise economically, afford inputs and further increase their productivity, then be able to buy radios and washing machines and keep their wives happy, and they will be a lot less likely to grow poppies or coca, or foment fundamentalist revolutions. At that point, maybe then we can all live happily ever after.

*References*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[i] Woody Guthrie was an Oklahoman growing up during the Dust Bowl years, and hitch-hiked out of the Great Plains in the 1930's to become one of the originators of popular American folk music. Many of his songs deal with the poor and displaced, and his concern for social justice later inspired Bob Dylan and the 60's folk tradition. He was referred to as the "Dust Bowl Balladeer".

[ii] The "Great Migration" of blacks to Midwestern cities in the 30's and 40's included many musicians who carried the Southern and Delta blues to Chicago, St. Louis, and New York; Muddy Waters' arrival in Chicago in 1940 popularized Southern blues, which in the 1960's had a huge influence on British pop musicians such as Jimmy Page, Mick Jagger, and Eric Clapton.