Chapter 77
The Historical Decrease of Soil Erosion in the Eastern United States – The Role of Geography and Engineering

Stanley W. Trimble

77.1 Introduction

Soil erosion has been a perennial problem in the eastern United States since European settlement and indeed was a crisis in many places during the 19th and early 20th centuries (Fig. 77.1). Why is this so? While there has been soil erosion during the last 2 or 3 millennia of western European history, it could rarely be described as extreme and seldom even serious (Fig. 77.2). Yet these western Europeans came to the eastern US, cultivated the soil, and erosion consequently became a real crisis in many places.

The answer to this puzzle has many components. Cheap land is certainly one answer: that which is cheap is wasted. As Gray (1933) put it, southern planters perceived land as an expendable commodity and "bought land as they would a wagon – with the expectation of wearing it out". Another explanation sometimes offered is that Americans were often illiterate and ignorant of soil conservation methods (Trimble, 1985). While this is true for many frontier farmers, some of the southern aristocracy were aware of soil erosion and were up on the latest methods (Hall, 1937, 1948). The problem was that these methods, mostly taken from Europe, did not work well in the eastern US (Meyer & Moldenhauer, 1985; Trimble, 1974, 2008). Related to this explanation but somewhat different was the existence of slavery and later tenancy (Trimble, 1974, 2008). In these cases there was a general ignorance augmented by the attitude "why preserve it if I don't own it." But there was also widespread tenancy in Western Europe without the attendant soil erosion.

Another explanation which might be offered is that more clean-cultivated crops like corn (maize), tobacco and cotton were grown in the US. While this is true, especially for some areas, it is well to remember how widespread clean-cultivated crops like potatoes are in Europe. Moreover, areas in the US also often too had close-growing crops like small grains (wheat, barley, rye and oats) and even these

S.W. Trimble (✉)
Department of Geography, University of California, Los Angeles, CA 90024, USA
e-mail: trimble@geog.ucla.edu

S.D. Brunn (ed.), *Engineering Earth*, DOI 10.1007/978-90-481-9920-4_77,

Fig. 77.1 A severely eroded field typical of large areas on the Southern Piedmont and other areas of the eastern US in the 19th and early 20th centuries. (Source: Trimble, 1974, 2008)

Fig. 77.2 A field in Wilshire, UK, 1995. Despite the long and steep slopes, the fact that the furrows run up and down the slope, and the lack of any erosion control methods, there is no apparent erosion

areas sometimes suffered extreme erosion. Nevertheless, the long-term cultivation of clean-tilled crops like cotton and corn certainly contributed to the disastrous erosion in the east. If one accepts the erosive effects of cotton and corn as unity, then small grains would have a value of only about 0.4 or 40% as much (Trimble, 1974, 2008; Troeh, Hobbs, & Donohue, 1999).

77.2 The Role of Climate

However, there is yet another variable that is quite overlooked, and that is climate. Western Europe has a Marine West Coast climate (Köppen: Cfb) while eastern North America has Humid Subtropical (Cfa) and Humid Continental (Dfa) More specifically, it is the intensity of rainfall, and the duration of these storms, that makes the difference. While the annual rainfall amounts in the UK and the eastern US are quite similar, the magnitude of any given return frequency is much greater for the more continental US than for the marine-influenced UK (Fig. 77.3).

The essential question is how much the rainfall intensity exceeds the infiltration capacity of the soil. Infiltration capacities are given by the US Department of Agriculture for US soils by Hydrologic Groups with Group A being the most permeable and D soils being the least (Troeh et al., 1999). Such groupings are not available for Europe but there seems to be no reason that there would be much difference between there and the US. As is illustrated (Fig. 77.4), the problem is excess rainfall which flows off the surface as overland flow thus creating the risk for erosion. Thus, the average excess rate for the most permeable soils (Group A soils) for the 5-year storm for the Southern Piedmont is about seven times what it would be in lowland UK. Not only does this excess rainfall cause soil erosion, it

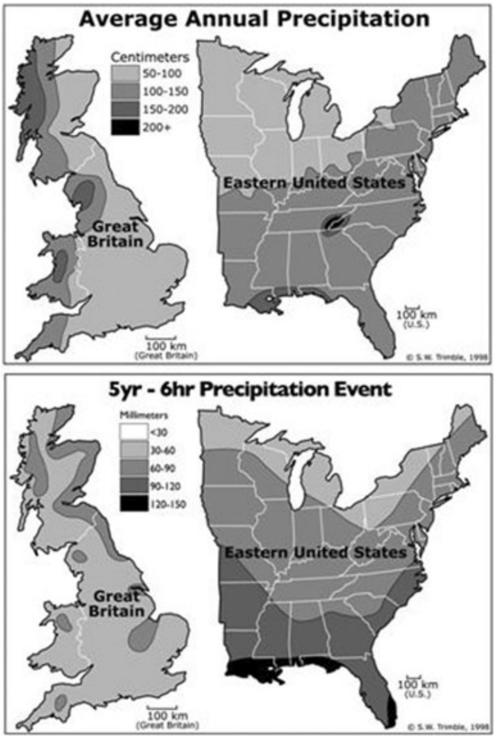

Fig. 77.3 Average annual precipitation compared to precipitation intensity, UK and eastern US. Note that while averages are similar, intensities are much greater in the US

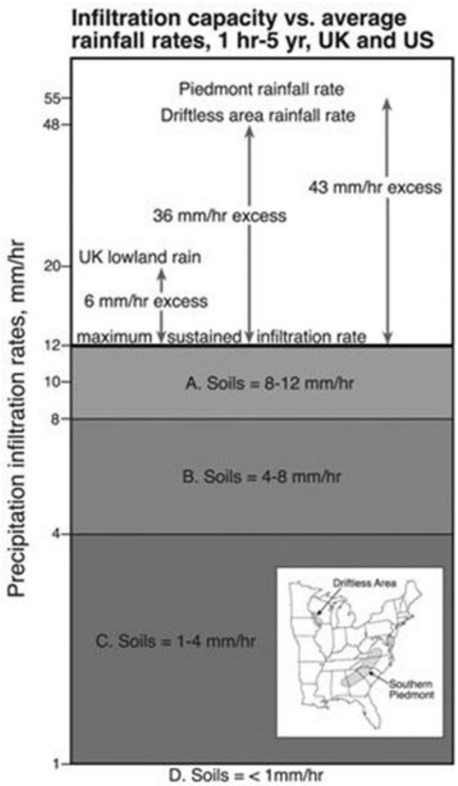

Fig. 77.4 Infiltration capacities of soil vs. average rainfall rates, UK and eastern US. Note that excesses in the US are several times those in the UK

causes more severe flooding in small basins as the water rushes off the slopes and into the streams. Thus, control of erosion in the eastern U.S. must depend on some engineering/agronomic solutions.

77.3 Early Soil Conservation Practices

The problem was that while many Americans desired to practice soil conservation, the available techniques were simply not adequate to control erosion in more intense rainfall of the eastern US. For example, contour plowing had been promoted since the time of Thomas Jefferson (Hall, 1937) but there are strong limitations for slope and rainfall intensity with this practice (Troeh et al., 1999). Since water is held in the contour rows, any breach of the rows allows a cascade of water to flow down the slope. So once the input of rainfall exceeds the infiltration capacity and the rows fill up, water overflows at some point and erosion starts, thus releasing the stored water in the rows, often starting a gully.

Terracing was another practice advocated from the mid-19th century through the early 20th. However these terraces were poorly designed and executed and thus tended to concentrate flow, often increasing soil erosion rather than decreasing it (Hall, 1948, Hendrickson, Barnett, Carrker, & Adams, 1963; Sauer, 1934). Again, the intensity of the rainfall was just too great for these terraces to handle. Another problem was that surveying instruments were inadequate and that land grading equipment was not available.

Crop rotations had long been used in Europe but there the old three- field rotation was adequate to maintain soil infiltration capacities which would mitigate overland flow and soil erosion. As practiced in the Driftless Area, this consisted of one year cleaned-tilled crop, one year of small grains, and one year of grass (Trimble & Lund, 1982). But this rotation system was inadequate to curtail soil erosion in the US.

77.4 Improvements in Soil Conservation Practices

The forgoing practices were known to be often ineffective in the US but there were no alternatives. As a result, some states began a program of experimental agricultural plot studies in the early 20th century and the USDA joined in 1929 (Meyer & Moldenhauer, 1985). These studies were to both increase productivity and to decrease erosion. Different crops were grown on various slopes and soils with different management practices as devised by agricultural engineers, and both erosion and productivity were measured. By the 1930s, some results of this experimental work were available in a form suitable for application to farms (Meyer & Moldenhauer, 1985). The megaengineering aspects of this are (1) the large extent of the experiments taking in varied climates and soils, and (2) the application to huge areas of agricultural land.

To bring this new technology to farmers, a new federal agency, the USDA Soil Erosion Service, was formed in 1933. This agency, known after 1935 as the Soil Conservation Service, joined state agencies, land grant universities, and county farm agents in encouraging, teaching and often subsidizing farmers to use these new methods. This was often a difficult task because many farmers were reluctant to change their long-held methods. One effective way of convincing them was to implement soil conservation demonstration areas where it could be shown that the new conservation measures would work (Held & Clawson, 1965). The first of these, Coon Creek Wisconsin was begun in 1933 and was the brainchild of Aldo Leopold (Trimble, 1985).

77.5 Regional Examples of Accelerated: Soil Erosion and Recovery

The history of soil erosion in two regions of the eastern US has been well documented. These regions are the Driftless Area (also known as the Upper Mississippi River Hill Country or Paleozoic Plateau) and the Southern Piedmont (see inset map on Fig. 77.4).

The Driftless Area. This was settled by western Europeans in the mid-19th century. It was an area of very good and mostly deep soils, some of which were Mollisols. The initial cash crop was usually wheat but that was soon replaced by corn (maize) (Johnson, 1976).The expansion of agriculture was rapid and had reached its maximum by 1900 (Trimble & Lund, 1982). Because the deep fertile soils had so much resilience, there was little erosion at first. But by the second decade of the 20th century, erosion became rampant with frequent flooding from the excess overland flow and so much sediment that roads, bridges, farms, and even villages were being buried. Most cultivated fields bore the scars of overland flow and erosion with rills and gullies visible, especially from the air (Fig. 77.5, top). By

Fig. 77.5 Before and after soil conservation engineering, Coon Creek, Wisconsin. *Top*: Early 1934. Note rectangular fields and gully systems extending into upland fields. *Bottom*: 1967. Note contour strip cropping. (Source: Trimble & Lund, 1982)

the early 1930s the region was in an erosion crisis with floodplains aggrading about 15 cm per year from the erosional debris.

Organized conservation efforts in the Driftless Area by state and federal agencies began in late 1933. The newly developed techniques were brought to farmers in a very organized way. A survey considering crops, slopes and soils was made of each farm and a plan was devised. Because public subsidy of this problem was involved, farmers had to sign a contract to receive full benefits.

The most commonly implemented new technique introduced was contour strip cropping. Mentioned earlier was the problem with contour plowing alone, but experimentation showed that adding contour strips of grass at intervals down the slope helped to curtail erosion because the grass allowed infiltration of overland flow and entrapment of soil particles. Reshaping the landscape of rectangular fields into contour strips was a spectacular and aesthetic change (Fig. 77.5). At first, many farmers rejected what they called "crazy quilt farming" But by 1975, over half the cropland in the area was in contour strips (Trimble & Lund, 1982). This proportion is compatible with good management because the areas not in strip contouring are generally on mild slopes.

Another widespread improvement was in crop rotations. By experimentation, it was found that an additional 2 years of grass cover greatly improved soil structure, increasing infiltration capacity and the entrapment of transported soil particles. The old, ubiquitous 3-year rotation with just one year in grass cover was modified to have 3 or even 4 years with grass. By 1975, 97% of cropland had at least 3 years of grass in the rotation.

Other soil conservation methods obtained from experiments were also used in the region, the most common being crop residue management whereby corn stalks or other organic material was ground up and spread across fields. An approximate index or surrogate to full implementation of the full array of new techniques is the proportion of farmers cooperating with the SCS. While by 1975 only 62% were cooperating *fully* (Trimble & Lund, 1982), most of the remainder cooperated to some degree.

The result of these modern soil conservation measures was to greatly curtail soil erosion. While a highly imperfect model, use of the Universal Soil Erosion Equation suggests that the erosion rates of 1975 had been reduced to about one-fourth those of 1934 (Trimble & Lund, 1982). However, the *measured* rates of downstream sediment accumulation were only about 6% of the earlier rates (Trimble, 1999)! The disparity between erosion rates from the uplands and the sedimentation rates in valleys is explained by sediment entrained from tributaries and also from errors of estimation of erosion and measurement of sediment deposits.

Perhaps the best criterion of soil erosion and stream sediment loads is biological rather than physical. The original dominant fish, brook trout, had, by the early 20th century, been mostly extirpated by the flooding and high sediment concentrations. By the late 20th century, they could not only live in regional streams, but they could also again reproduce there (Trimble & Crosson, 2000). By whatever measure, soil erosion in the Driftless Area is only a fraction of what it was in the early 20th century.

The Southern Piedmont (see inset map on Fig. 77.4). The region was settled starting about 1700 from east to west and the last land was taken up in west Georgia and eastern Alabama about 1840. Tobacco was important from the first, mostly in Virginia, and cotton was grown mainly from South Carolina westward. Although local relief is somewhat less than in the Driftless Area, rainfall is even more intense (see Fig. 77.4), and crop rotations of any kind were uncommon there. The net result was that erosion in both regions was on the same scale, although over a longer time scale for the Piedmont. The effect on streams was similar to the Driftless Area with burial of farms, roads, bridges, and mills.

While many of same improvements in soil conservation techniques were implemented on the Southern Piedmont, strip cropping could not be used as effectively because most farmers had few cattle and therefore grew little grass. Thus, effective terracing became much more important. As already indicated, terracing as practiced early on the Piedmont may have augmented erosion. But again, during the period of experimentation, terrace design was greatly improved as was the machinery to build terraces to the required precision. Although covered in pasture grass, the general layout of these improved terraces can be seen in Fig. 77.6.

But there is a component in the stabilization of the Piedmont landscape not seen in the Driftless Area and that is the reversion of cropland to forest and pasture. What is now a sea of forest (see Fig. 77.6) was a sea of row crops in the early 20th century. Why did this happen? One might point to the eroded soils of the Piedmont (see Fig. 77.1) which discouraged continuing cropping, especially those

Fig. 77.6 Former cropland, now reverted to forest, Southern Piedmont. The forested land is either too eroded for cultivation or is simply economically marginal to better cropland elsewhere in the US. Such reverted land is common and even dominant in many areas of the eastern US. (Source: Trimble, 1974, 2008)

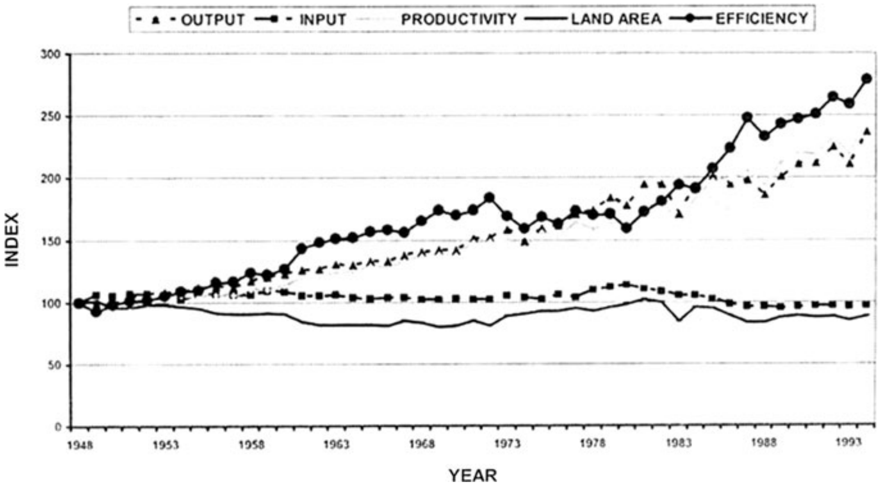

Fig. 77.7 Productivity and efficiency of agricultural land use, 1947–1994. Note that land area declined about 10% but productivity increased almost 150%. (Source: Helms, 2003)

areas too gullied for use but the reason was economic as much as physical. As part of the aforementioned experimentation, new methods of cultivation, use of fertilizer and pesticides, and crop plant improvement allowed great increases of productivity and that improvement has continued. Since 1948 cropland in the US has declined slightly, but output has increased almost threefold (Helms, 2003, Fig. 77.7).

The increased productivity has occurred on the best soils of the country so that marginal soils, like those on most of the Piedmont have gone out of production. Why grow corn in Georgia where one might get 50 bushels per acre when it can be grown in Iowa with yields of over 200 bushels per acre? Of course, there are environmental costs in maximizing productivity on the nation's best non-irrigated soils, the most salient being the excessive use of fertilizer and resulting movement of these plant nutrients, especially nitrogen, into natural waters. The result is a degradation of ambient water quality. Perhaps the most egregious result is the large anoxic zone in the Gulf of Mexico caused by excessive use of nutrients in the Midwestern US. Excessive soil erosion can be a problem also but is overshadowed by the nutrient problem (National Research Council, 2008).

Like the Piedmont, much of the present forest extending from Texas to Maine is old cropland which has reverted to forest and much of that has occurred over the past 70 or so years (McCleery, 1992). The effect of cropland reversion plus soil conservation measures on the remaining Piedmont cropland was to greatly reduce erosive land use and thus to reduce erosion to very low levels. The "sea of forest" shown in Fig. 77.6 is has significance far beyond reduction of soil erosion. First, it has been a huge carbon sink as the forest grows and as more carbon is incorporated into the soil. No exact values are available but North American forests contain about 170 billion tons of carbon (SOCCR, 2007). The second effect is that this reversion of farmland to forest has greatly enhanced wildlife habitat, especially the return of once-scarce animals like deer and turkeys (McKibben, 1995). The third major effect is that the increased transpiration from expanding forests has decreased stream flow (Price 1998; Trimble, Weirich, & Hoag, 1987). The irony is that as reforestation increased water quality, it decreased quantity.

77.6 Engineering Advances in Soil Conservation Since the 1930s

While the soil conservation measures of the 1930s were a great advance over the practices of the past, agricultural engineering improvements since that time are of the same order of magnitude. The ultimate technology at this point is the no-till method whereby the soil is not plowed but rather the seeds are drilled or inserted directly into the soil. During the previous crop harvest, all the crop residues (stalks and leaves) are mulched and left on the surface, protecting it from erosion during the next year. By using this method, farmers are now free to use their large machinery to cultivate very large fields with long, steep slopes. In addition to greatly reducing soil erosion, no-till causes increases of biological activity in the soil, sequestration, of organic carbon and decrease of bulk density, all resulting in increased infiltration capacity and decreased erosion. These improvements in soil condition can also improve crop yields by as much as 200% (Montgomery, 2008).

By the mechanism of incorporating carbon into the soil, no-till methods also reduce atmospheric carbon dioxide and thus potentially reduce global warming. Implementation of no-till methods on a world scale, an unlikely scenario, is estimated to be capable of absorbing 90% of global carbon emissions over the next few decades. By 2004 no-till methods were used on about 25% of US farmland, but Canada had already converted one-third of its cropland to no-till by 1991 (Montgomery, 2008)

77.7 Conclusions

Amelioration of the excessive historical soil erosion in the eastern US came only in the mid 20th century with new soil conservation techniques developed by agricultural engineers with widespread regional experimentation. Additionally, greatly enhanced productivity allowed US agriculture to use only the better soils allowing vast areas of poorer soils to revert to forest. Not only has soil erosion been reduced, but significant amounts of carbon have been sequestered, wildlife habitat has been improved, and we have much larger forest reserves. The downside of enhanced agriculture has been excessive use of nutrients with their movement into natural waters.

Acknowledgement I wish to thank Douglas Helms for his careful and critical reading of the paper.

References

Gray, L. C. (1933). *History of Agriculture in the Southern United States to 1860* (2 Vols.). Washington, DC: Carnegie Institute.

Hall, A. R. (1937). *Early Erosion Control Practices in Virginia*. USDA Miscellaneous Publication 256.

Hall, A. R. (1948) *Soil Erosion and Agriculture on the Southern Piedmont: A History*. Unpublished PhD dissertation, Duke University.

Held, B. R., & Clawson, R. M. (1965). *Soil conservation in perspective*. Baltimore: The Johns Hopkins Press.

Helms, J. D. (2003). The evolution of conservation payments to farmers. In N. DeCuir, A. Sokolow, & J. Woled (Eds.), *Compensating landowners for conserving agricultural land* (pp. 123–132). Davis: University of California Community Studies Extension.

Hendrickson, B. H., Barnett, A. P., Carrker, J. R., & Adams, W. E. (1963). *Runoff and Erosion control studies on Cecil soils of the Southern Piedmont*. USDA Technical Bulletin 1281.

Johnson, H. B. (1976). *Order upon the land*. New York: Oxford University Press.

McCleery, D. (1992). *American forests: A history of resilience and recovery*. Durham, NC: Forest History Society.

McKibben, B. (1995). An explosion of green. *Atlantic Monthly, 275*, 61–83, April.

Meyer, L. D., & Moldenhauer, W. C. (1985). Soil erosion by water: The research experience. In D. Helms & S. Flader (Eds.), *The history of soil and water conservation* (pp. 90–102). Washington, DC: The Agricultural History Society.

Montgomery, D. R. (2008). Agriculture's no-till revolution? *Journal of Soil and Water Conservation, 63*: 64A–65A.

National Research Council. (2008). *Mississippi river water quality and the clean water act*. Washington, DC: National Academy of Sciences.

Price, A. P. (1998). *The effect of climate and land use on the hydrology of the upper Oconee River basin, Georgia*. Unpublished Ph.D. dissertation, University of California, Los Angeles, CA.

Sauer, C. O. (1934). The extension of geomorphic research to the Piedmont, memorandum to H.H. Bennett, dated 31 Dec 1934. Files of the Section of Climatic and Physiographic Research, erosion History, Record Group 114, Entry 336, Box 82-87. National Archives Building, Washington, DC.

State of the Carbon Cycle Report (SOCCR). (2007). North American carbon budget and implications for the global carbon cycle. Chapter 11, North American Forests. Retrieved May 2008, from www.climatescience.gov/Library?sap/sap/2-2/finalreport/default.htm

Trimble, S. W. (1974, 2008). *Man-induced soil erosion on the Southern Piedmont*. Ankeny, IA: Soil and Water Conservation Society

Trimble, S. W. (1985). Perspectives on the history of soil erosion control in the eastern United States. *Agricultural History, 59*, 162–180.

Trimble, S. W. (1999). Decreased rates of alluvial storage in the Coon Creek Basin, Wisconsin, 1975–93. *Science, 285*, 1244–1246.

Trimble, S. W., & Crosson, P. (2000). U.S. soil erosion rates-myth and reality. *Science, 289*, 248–250.

Trimble, S. W., & Lund, S. (1982). *Soil conservation and the reduction of erosion and sedimentation in the Coon Creek basin, Wisconsin*. USGS Professional Paper 1234.

Trimble, S. W., Weirich, F. H., & Hoag, B. (1987). Reforestation and the reduction of water yield on the Southern Piedmont. *Water Resources Research, 23*, 425–437.

Troeh, F. R., Hobbs, J. A., & Donohue, R. L. (1999). *Soil and water conservation*. Upper Saddle River NJ: Prentice Hall.