Non-Point Sources: Historical Sedimentation and 20th Century Geography

L. Allan James, University of South Carolina

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Abstract

Physical geography has long been concerned with sediment behavior in fluvial systems. This geographic research has contributed to applied and theoretical concepts of sediment transport, non-point source (NPS) pollution, and related channel-morphological changes that effect flooding. It arose in a context of changing Federal Government priorities from soil conservation to resource conservation, to the modern period of concerns over public health and environmental preservation and restoration. Since passage of the Clean Water Act (CWA) Amendments of 1987, study of NPS pollution has taken on a new sense of relevancy. Early geographic research in fluvial sediment is put into historical context and linked to modern NPS pollution concerns that represent a great body of on-going research by a new generation of geographers.

Introduction

Geographers have traditionally studied spatial relationships, human-land interactions, and the synthesis of this information on a regional basis. How better to integrate these foci than to study regional impacts of soil erosion and sedimentation following the introduction of European and African agricultural technology to North America? Physical geography has contributed greatly by elucidating concepts of fluvial sediment transport, non-point source (NPS) pollution, and channel-morphological changes that effect flooding. These intellectual traditions arose as Federal Government priorities were changing from soil conservation, to resource conservation, to modern concerns over public health and environmental preservation and restoration. Since passage of the Clean Water Act (CWA) Amendments of 1987, study of NPS pollution has grown in relevancy. This chapter puts early geographic research into a historical context and shows its importance to modern NPS pollution control and to a great body of on-going research by a new generation of geographers.

In spite of the early concern of physical geography for fluvial systems, few early 20th century North American geographers studied contemporary or historical soil erosion and sedimentation. As measured by a sampling of the research by past presidents of the Association of American Geographers (AAG), early geographers were interested in erosion primarily from a perspective of landform evolution (Table 66.1). By the 1920s, however, Marbut and H. H. Bennett (1943) began to note anthropogenic soil erosion and massive downstream effects. In the second half of the 19th century physical geography focused keenly on these impacts as a natural extension of traditional concerns. These studies were ahead of their time in respect to the approach taken by most other environmental sciences.

Outside of geography, water-quality studies in North America initially focused on the reach (local) scale of stream channels and on point sources of pollution with little regard for sediment or integrated basin processes. Recently, focus has progressed from a non-spatial perspective to practices that increasingly rely on geographic notions of space and scale as applied to watersheds (USEPA 1995). In response to a growing awareness of the importance of diffuse sediment to the production and storage of nutrients, metals, pesticides, and toxins, the 1987 CWA Amendments emphasized NPS sediment and associated pollutants. Consequently, the methods and concerns of other environmental sciences are coming into harmony with past geographic research that has gained substantially in stature and relevance.

Accelerated Erosion and Conservation Movements

Rates of erosion and sedimentation prior to anthropogenic disturbances, often referred to as the *geologic norm,* are far less than rates after human disruptions, referred to as *accelerated erosion* (Strahler 1956). Accelerated erosion followed the advent of agriculture and, therefore, has been substantial in most of North America. In the western world, it began with Neolithic agriculture in Mesopotamia, expanded through the Mediterranean region to woodland clearance in northern Europe, and followed the introduction of European agricultural practices to North America. Soil erosion was such a threat to land viability in the Colonies, that it was noted as a menace by Thomas Jefferson, and by the end of the 19th century, vast tracts of land were permanently damaged.

In the 1920s and 1930s a *soil conservation* movement initiated by Hugh Bennett focused farm policies on soil erosion. From the 1940s through 1970s this concern was expanded to *land conservation* emphasizing reduction of on-site damages and losses to natural resources. Not until the environmental movement gained momentum in the 1970s, however, did off-site damages of erosion begin to receive attention. The Section 319 NPS Management Program of the 1987 CWA Amendments called for studies of NPS pollution that represent the first substantial Federal mandate to study, manage, or mitigate off-site impacts of land use. Fortunately, geographers had not waited for government sanction to engage in research on the downstream effects of accelerated erosion. Arising from long-held traditions in human-land interactions and fluvial geomorphology, geographers were trained and motivated to examine these questions. Their predisposition to historical landscapes and spatial analysis anticipated by two decades the recent move towards a watershed-scale approach of the broader scientific community.

Table 1. Research of Selected Early AAG Presidents

Name	Year of Term	Focus of Writing
W.M. Davis	1905 & 1909	Landform Evolution.
G.K. Gilbert	1908	Landform Evolution; Theories of Sediment Production and Transportation.
R.S. Tarr	1911	Landform Evolution and Glacial Erosion.
R.D. Salisbury	1912	Landform Evolution; Textbook on Physiography Estimated Denudation Rates from Sediment Concentrations.
N.M Fenneman	1918	Landform Evolution; Textbook on Physiography Mentioned Historical Soil Erosion and Gullies in Southern Piedmont.
C.F. Marbut	1924	Father of Modern Soil Classification.
D.W. Johnson	1928	Landform Evolution.
Lawrence Martin	1930	Landform Evolution.
Isaiah Bowman	1931	Landform Evolution.
Francois Matthes	1933	Landform Evolution.
Wallace Atwood	1934	Landform Evolution.
Carl O. Sauer	1941	Advocated Study of Soil Erosion
Hugh H. Bennett	1943	Soil Erosion and Conservation.

Geographic Concerns with Sedimentation

At the turn of the 20th century, geomorphology in North America was examining long-term landform-evolution processes (Davis 1900). Erosion and sedimentation were emphasized as processes explaining the formation of drainage systems, hill-slope profiles, and regional topography in general. While landform evolution dominated geomorphology for the first half of the 20th century, the stage was being set for studies of erosion and aggradation on historical time scales. G.K. Gilbert (1914; 1917) was an early contributor to the study of accelerated aggradation. He wrote two classic monographs on the transport of hydraulic mining sediment. Data from his flume experiments are still used in hydraulic calculations of sediment transport and spatial-temporal concepts of long-distance sediment transport from the other study are still prevalent in fluvial geomorphology.

Neglect of downstream impacts of historical erosion by geographers during the first half of the 20th century was in accord with the national policy of ignoring off-site impacts of soil erosion. It also reflects a shift in North American geography away from physical geography at the time. Sauer (1941; 2) referred to the period beginning in the 1920s as "the Great Retreat" when geography separated from geology departments and moved away from physical and historical geography. He lamented that, in seeking an area of study independent of geology, "American geography gradually ceased to be a part of Earth Science." Ironically, few geologists in North America were interested in human impacts on the environment until recent decades, so geographers' apparent perception of redundancy with geology was distorted. Sauer lauded the early work of George Marsh and advocated the study of humans as an agent of physical geography. Although he stopped short of following erosion impacts downstream, he signaled the need to study soil erosion as an agent of change:

> "The incidence of soil erosion may be a major force in historical geography. Did soil losses sap the Mediterranean civilizations? Were the Virginians great colonizers because they were notable soil wasters? Geographical field work should embrace thorough search for full, original soil profiles and note the characteristic diminution or truncation of soil profiles in fields and pastures." (Sauer 1941: 18).

This call to arms heralded a prolific new era of research soon to be initiated by geographers.

In the 1950s, physical geography began to experience a metamorphosis and resurgence propelled by the quantitative revolution. The mathematical concepts of Robert Horton's hydrology were enhanced to incorporate concepts of erosion and equilibrium from geomorphology (e.g., Strahler 1956; Figure 66.1). The emphasis during this period was on process geomorphology, however, and there remained a dearth of historical geomorphology studies concerned with human impacts on hill-slope or river sedimentation. This was soon to change as geographers began to raise questions about human impacts on the Earth. For example, Karl Butzer, recognizing the importance of human disturbance to Quaternary stratigraphic sequences in the Mediterranean region, criticized Vita-Finzi's prominent explanation that was based on a simple model of two climatic intervals and little human impact (Butzer 1969).

In the 1970s and 1980s a new movement in fluvial geomorphology took root that merged traditions in historical geography and geomorphology to examine downstream consequences of accelerated erosion. Spatial and temporal patterns of anthropogenic hydrologic changes, soil erosion, sediment delivery, and channel morphologic change began to emerge. In the upper Midwest, Knox (1972; 1977; 1987) presented detailed evidence from field and documentary data to show the impacts of European agricultural and mining technology on floodplain stratigraphy. Knox's biogeomorpho-logical response model (Figure 66.2) has been widely influential and reproduced in the literature. In the southern Piedmont, Trimble (1974) examined the history of soil erosion and stream sedimentation. He identified several spatial patterns including the progression of plowing up hill slopes, and the timing of stream aggradation related to stream order. In the Southwest, Graf examined arroyo cutting in response to boom-and-bust mining activities (Graf 1979), and documented spatial patterns of radionuclides in fluvial systems related to stream power (Graf 1990).

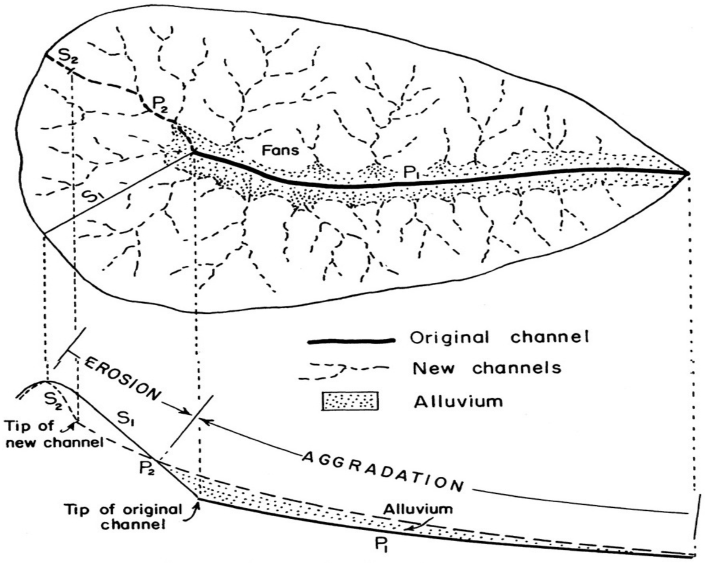

Fig. 66.1. Relationship between gully erosion, channel network extension, and tributary aggradation. (Strahler, 1956)

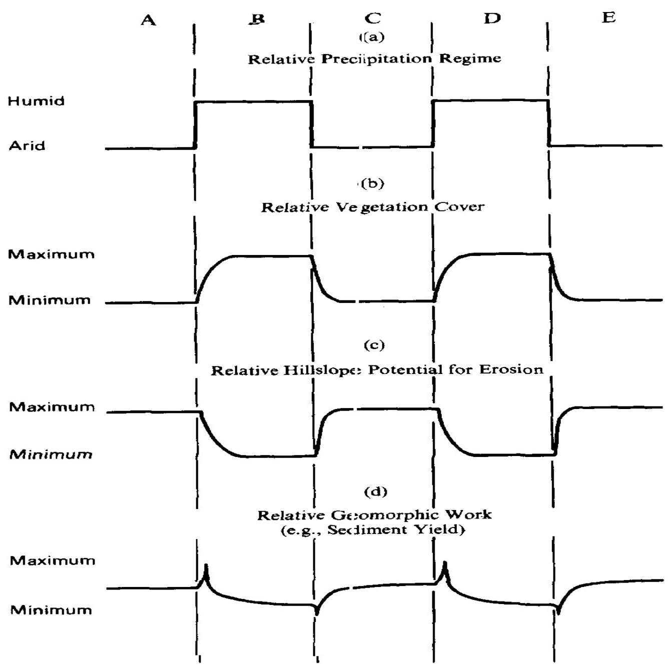

Fig. 66.2. Biogeomorphic response model. (Knox, 1972)

Currently, a large new generation of fluvial geomorphologists is combining physically based process geomorphology, stratigraphy, and historical research to the study of human-induced aggradation (cf., Abrahams and Marston 1993). The convocation of fluvial geomorphologists at the annual AAG meetings has flourished for more than 25 years and continues to examine questions of fluvial sedimentation. These on-going studies are contributing to a much-needed understanding of watershed dynamics and potential sources of non-point source pollution.

Conclusion

Geographic traditions spawned important research on downstream effects of sediment production that are now relevant to major policy initiatives mandated by the Federal Government. Knowledge of the extensive historical deposits left by episodic erosion is essential to watershed management aimed at protecting water quality and water-resources infrastructure. These deposits may be unstable and can introduce toxic, hazardous, or carcinogenic materials such as metals, radio nuclides, and agricultural chemicals adsorbed on sediment grains. They are also essential to understanding pre-historic channel conditions for reconstructing reference channels in aquatic restoration projects. The demand for this expertise is growing, as is interest by non-geographers in this research and the perspective of physical geographers. As the skills of physical geography are solicited by outside interests, however, it is important to remember and cherish the deep geographic traditions that brought us to this juncture.

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