CHARACTERIZATION OF STREAMFLOW AND SEDIMENT SOURCE AREAS FOR THE SAW KILL WATERSHED[1]

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ABSTRACT

An accurate depiction of water movement through the landscape forms the foundation of water resource management and many types of ecological research. Characterizing the complex interaction of terrain features, soils, vegetation, and land use is the necessary first step to understanding the structure and function of large, heterogeneous watersheds. A geographic information system (GIS) database was developed for these landscape elements in the Saw Kill watershed in northern Dutchess County, New York. This 6900 hectare area is the principal upland tributary for South Tivoli Bay in the Hudson River National Estuarine Research Reserve. The GIS was used to estimate rates of shallow subsurface flow and surface erosion. Maps of the primary streamflow and sediment source areas in the Saw Kill watershed were developed from the flow and erosion estimates. Both maps highlight the spatial variation that was expected within a watershed with complex surface topography and geologic structure, 34 soil types, and 21 classes of land use and vegetative cover. Less than 1 percent of the watershed generates one-half of the total annual soil erosion. Approximately one-third of the watershed is likely to generate the majority of the streamflow that reaches South Tivoli Bay. The results of this study and the GIS database can be used to guide research and management activities within the Saw Kill watershed.

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INTRODUCTION

An accurate depiction of water movement through the landscape forms the foundation of water resource management. Accurate predictions of water supply and water quality degradation, and their respective sources, are usually constrained by our ability to quantify the spatial variation and complex interaction of numerous elements. These watershed characteristics include: soil physical and hydraulic properties, slope, current and historical land use patterns, and vegetative cover. The climatic regime also has a direct effect upon the structure and function of watersheds.

The unwieldy task of systematically integrating heterogeneous data at the watershed scale has usually led to land capability classification or environmental impact assessments conducted on a site-by-site basis. These studies may neglect downstream impacts or be compelled to average disparate characteristics over large and diverse areas simply to complete the task at hand.

Some areas within a watershed contribute much more to streamflow than others. The spatial variation of the streamflow source area is directly influenced by a site's proximity to the stream channel network and soil hydraulic properties (e.g., infiltration capacity, permeability, porosity, etc.) (Brooks *et al.*, 1991; Dunne and Leopold, 1978; Pearce *et al.* 1986). Maintaining or improving the quality and availability of water largely depends upon effective land use management within these critical source areas. For example, a single family home may have minimal impact if it is placed on a well-drained sandy soil at a reasonable distance from the riparian zone. Conversely, the same house is likely to have a substantial adverse impact on water quality if it is located in poorly drained organic soil, immediately adjacent to a stream.

While basic biophysical information and common sense can guide assessments of individual projects, it is difficult to develop a comprehensive and objective view of land use-water quality interactions within large, heterogeneous watersheds. Recent advances in computer software (e.g., Eastman 1990; Tomlin 1990) have greatly improved spatial analysis and cartographic modeling capabilities. A Geographic Information System (GIS) allows researchers and managers to analyze these large databases, thereby providing the information necessary to adapt land uses to terrain, or when this is not feasible, to modify existing land uses to meet water quality goals. The GIS provides the opportunity to directly link upstream causes (land use changes) with the downstream effects (water quality changes). This paper describes the development and application of a GIS to characterize the hydrologic structure and function of the Saw Kill watershed in northwestern Dutchess County, New York. The analyses include the preliminary mapping of streamflow source areas and the estimation of annual soil losses.

OBJECTIVES

The primary objectives of this project were to:

1. Develop primary GIS layers (topography, soil type, vegetative cover/land use) for the Saw Kill watershed.

2. Develop secondary GIS layers (slope, soil thickness, porosity, permeability, erodibility) for the Saw Kill watershed.

3. Use the GIS to produce a spatially-referenced solution of Darcy's Law (the governing equation for flow through saturated soils) and the Modified Universal Soil Loss Equation (annual soil erosion in tons per acre) for the watershed.

4. Delineate source areas for streamflow and sediment, based upon the results of the analyses outlined above.

5. Estimate the current rate of sediment delivery to South Tivoli Bay.

SITE DESCRIPTION

The Saw Kill watershed encompasses 6886.5 hectares (17,017 acres or 26.6 square miles) in northwestern Dutchess County, New York (figure 1). The watershed includes portions of the Townships of Red Hook, Tivoli, and Milan. The Saw Kill is tributary to South Tivoli Bay, a shallow embayment on the east shore on the Hudson River (river mile 100). This site (with North Tivoli Bay) is one of four sites in the Hudson River National Estuarine Research Reserve.

The Saw Kill provides approximately 90 percent of upland streamflow into South Tivoli Bay (Paul K. Barten, unpublished field notes and monitoring data). Figure 2 shows the watershed boundary, stream network, and primary transportation network. The Saw Kill watershed is located in the Hudson-Mohawk physiographic region, bounded to the west by the Hudson River and to the east by the Taconic Mountains.

Climate

The mid-Hudson River Valley climate is influenced by continental-polar and maritime air masses. Mean January and July air temperatures are -4 and 23 °C (25 and 73 °F), respectively. Annual precipitation typically ranges from 900 to 1,100 mm (36 to 44 inches) and is relatively uniform in distribution throughout the year (Dutchess County Department of Planning, 1985).

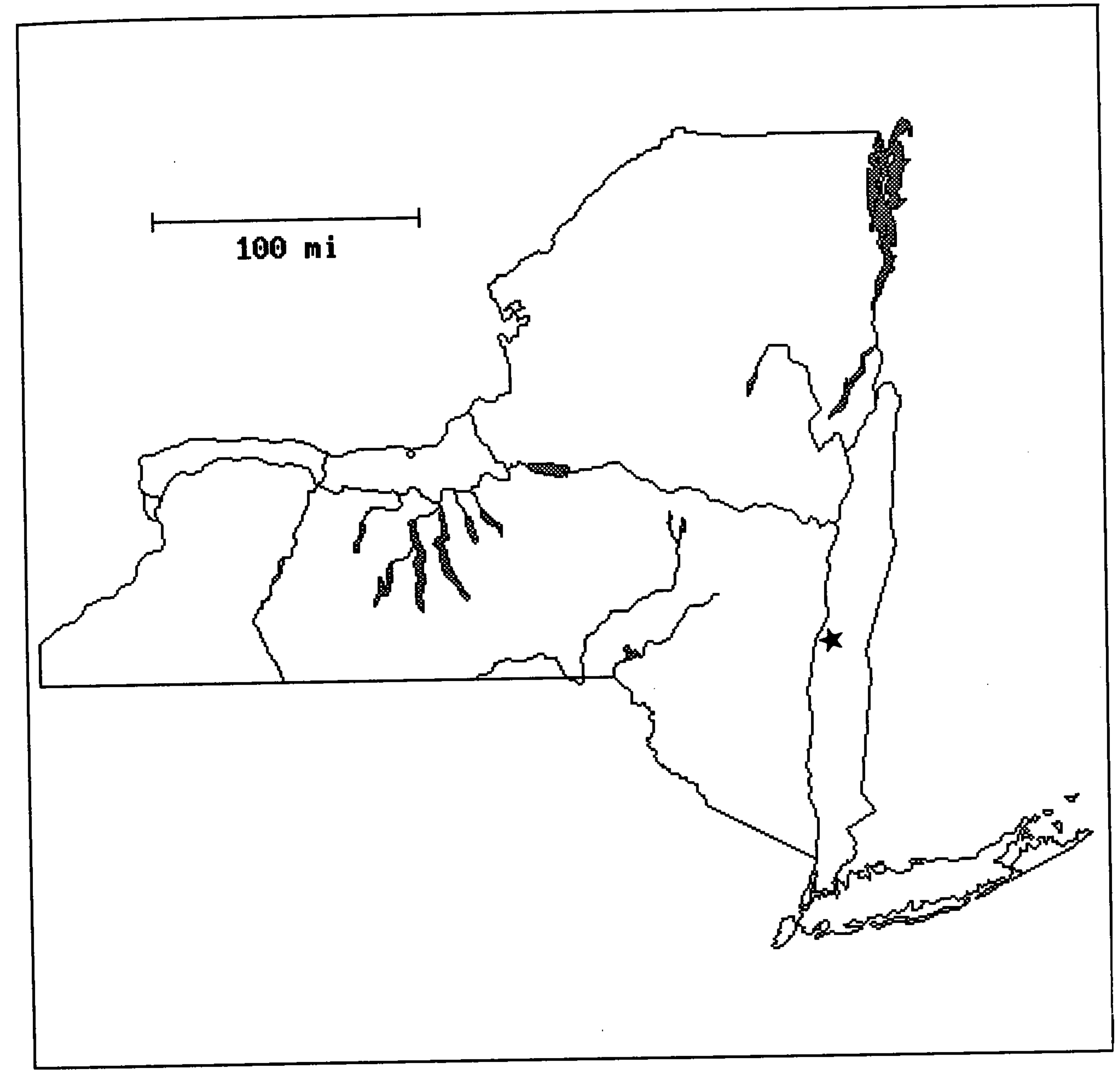
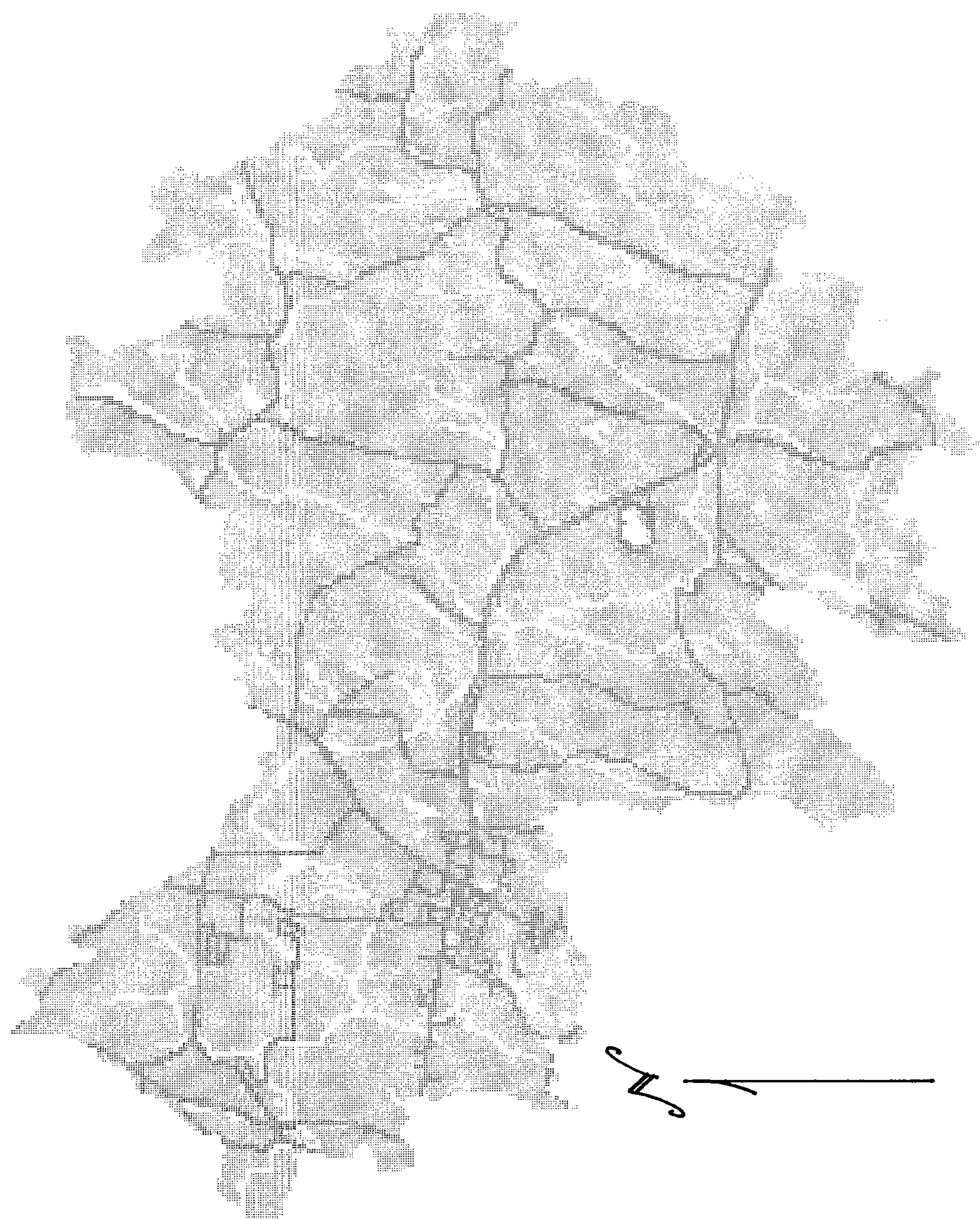


Figure 1: Location map for the Saw Kill watershed (marked with a star) and the Tivoli Bays (Hudson River) National Estuarine Research Reserve, Dutchess County, New York. Reprinted from PC Globe, Inc., Tempe, Arizona, USA.



South Tivoli Bay and the Hudson River

Figure 2: Base map of the Saw Kill watershed, Dutchess County, New York (watershed = light gray; water features = white; roads = dark gray)

Topography

Figure 3 (raised relief) and figure 4 (slope map), both produced with the GIS, illustrate the topography of the Saw Kill watershed. The watershed's highest elevations and steepest slopes are found in its eastern region. The maximum elevation is 263.5 meters (865 feet). Slopes range from 0 to 37 percent, with a median slope of approximately 7 percent.

The watershed has two topographically distinct sections. While the watershed spans approximately 17.6 km (8 miles) along its major (east-west) axis, the majority of the 263.5 meter decrease in elevation occurs over a 9 km (4 mile) section of the eastern region. In the next 8 km, the Saw Kill and its tributaries meander through an extensive glacial outwash plain before dropping over the steep escarpment at the 43 meter (140 foot) contour, to South Tivoli Bay, which lies slightly above sea level. This glacially-formed landscape has directly influenced the Saw Kill's north-south tributary structure and meandering drainage. Shale bedrock ridges and glacial till formed drumlins and kames (Carey and Waines 1987), at a relatively uniform spacing in a northeast/southwest direction, which led to a dendritic-trellised drainage pattern.

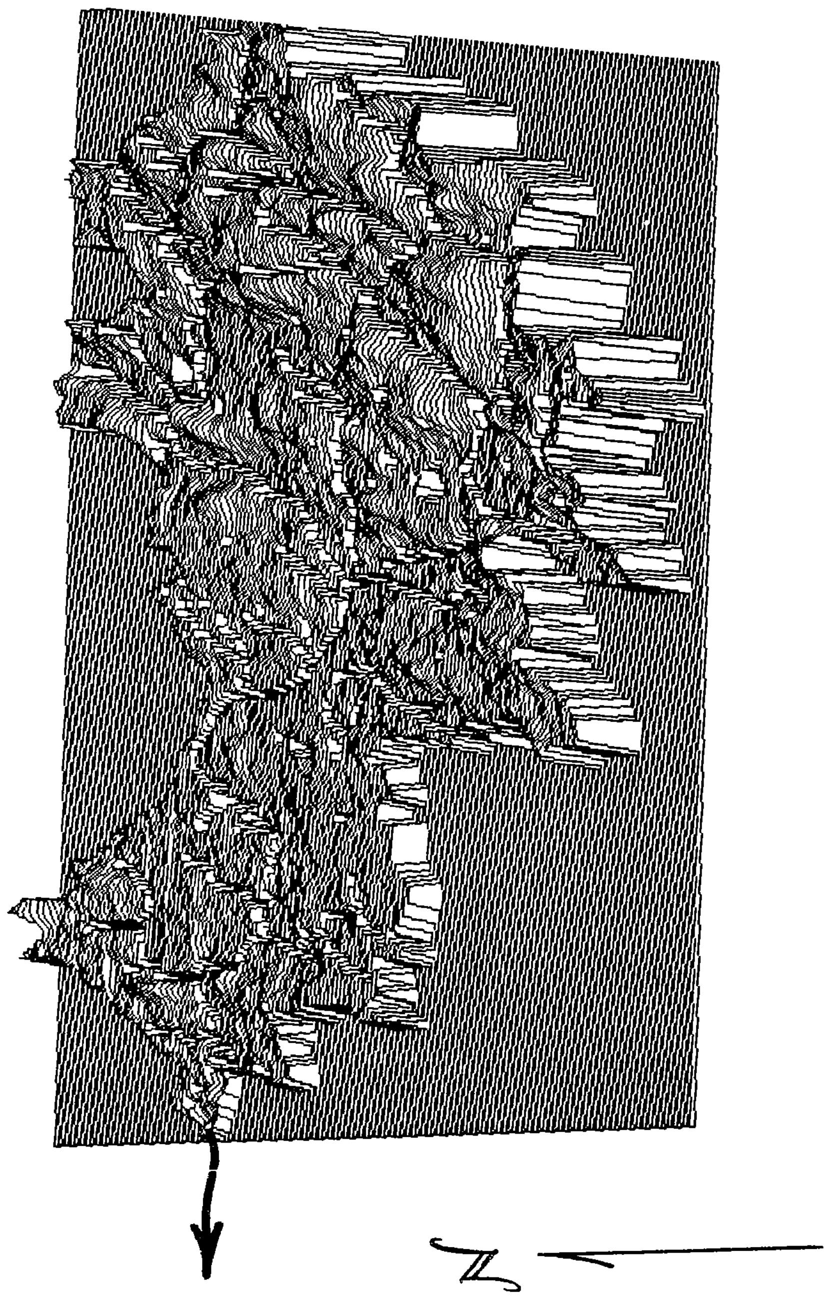


Figure 3: Raised relief map (U.S. Geological Survey National Mapping Program digital elevation data) for the Saw Kill watershed, Dutchess County, New York

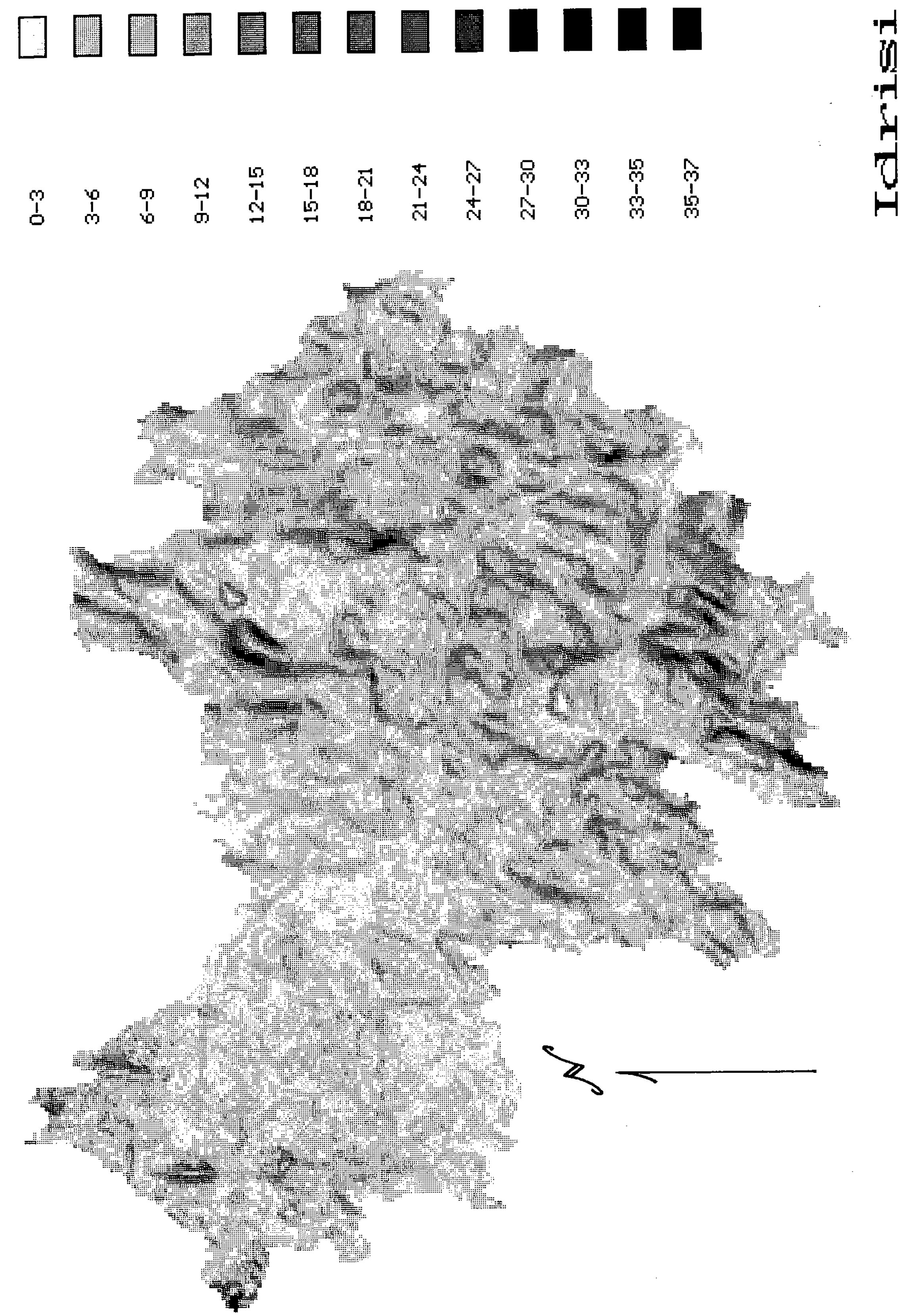


Figure 4: Slope map (percent) of the Saw Kill watershed, Dutchess County, New York

Soils

The Saw Kill watershed has 34 soil mapping units and complexes (USDA SCS, in press). These 34 soil units were grouped according to their primary textural class (proportion of sand, silt, and clay) to create the GIS layer depicted in figure 5. The limited number of gray shades available in the GIS software necessitated this simplication.

The soils of the Hudson-Mohawk physiographic region have a systematic spatial distribution. Approximately 12-15,000 years ago, Glacial Lake Albany extended well beyond the current Hudson River shoreline to the 250 foot (76 meter) contour (Carey and Waines 1987; USDA SCS, in press). Lacustrine sediments, fine silts, and clays, were thickly deposited in this area. To the east, sand and gravel were deposited in Lake Albany's delta and shoreline. Glacial till overlying shale bedrock replaces the sands and gravels as the slope and distance from the Hudson River increase. In general, these soils are now composed of thick layers of silty loams or silty clays over sand, gravel or channery sediments. While soil drainage properties range from well-drained to poorly-drained, clay and silt layers frequently restrict drainage within the soil mantle (Dutchess County Department of Planning, 1985).

Dutchess-Cardigan and Nassau-Cardigan complexes cover 45 percent of the watershed. These soil complexes are silt loams derived from glacial till on hilltops and slopes. They are

Figure 5: Saw Kill watershed soils grouped by textural classes (USDA Soil Conservation Service, in press)

shallow (0.8 meters to bedrock) to moderately deep (2.3 meters to bedrock), with a relatively well-drained surface layer underlain by a poorly-drained layer. Silt loam alluvial deposits (the Wayland, Sun, and Livingston series) are among the most erodible soils in the watershed.

Land Use and Vegetative Cover

Figure 6 illustrates the spatial distribution of land uses and vegetative cover in the Saw Kill watershed. Table 1 provides a detailed classification of land use, along with corresponding areas, for each major category. The extensive forested area (51.1%) is largely second growth deciduous and coniferous forest, and includes forested strips along streams. Agricultural land uses, primarily hayfields (10.7%), account for 25.8 percent of watershed land use. Residential use (including farmsteads) accounts for 13.6 percent. High density residential and commerical development is largely centered in the Village of Red Hook. Low and medium density residential land use occurs as subdivision development in patches throughout the watershed. Examples of this are found along the high eastern ridges with panoramic views of the Catskill or Taconic Mountains, and throughout the extensive glacial outwash plain just north of Red Hook. Commercial use occupies only 2.8 percent of the Saw Kill watershed. Bare soil sites, accounting for only 1 percent of land area, are primarily, active construction sites (1990-91) and the Red Hook-Rhinebeck landfill.

Table 1: Land use and vegetative cover within the Saw Kill watershed, Dutchess County, NY (April 1990 aerial photographs, July/August 1991 field check)

Land Use or Cover Type	Area (ha)[4]	Fraction of watershed (%)
Forest		
Deciduous	2,276.5	33.1
Coniferous	964.9	14.0
Mixed	271.0	4.0
Agricultural		
Hayfield	740.3	10.7
Fallow field	174.8	2.5
Row crop	353.1	5.0
Pasture	253.3	3.7
Orchard	215.0	3.1
Tree farm	46.2	0.7
Livestock feeding area	0.5	<0.1
Urban		
Farmstead	47.5	0.7
Residential, low density	519.1	7.5
Residential, med. density	227.3	3.0
Residential, high density	164.8	2.4
Commercial, low density	101.0	1.5
Commercial, med. density	92.5	1.3
Commercial, high density	9.0	<0.1
Water Features		
Lakes, ponds	106.7	2.0
Wet areas	212.7	3.0
Bare Soil		
Dumps, excavated sites	69.8	1.0
Other		
Cemetery, playground, etc.	40.5	0.6
Total Watershed Area	6,886.5	100.0

[4] 1 ha = 1 hectare = 10,000 m^2 = 2.471 acres