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CALCULATION OF SEDIMENT REDUCTION AT THE OUTLET OF NESTOS RIVER BASIN DUE TO THE DAMS

M. ANDREDAKI, V. HRISSANTHOU AND N. KOTSOVINOS

DEPARTMENT OF CIVIL ENGINEERING
DEMOCRITUS UNIVERSITY OF THRACE
67100 XANTHI, GREECE

INTRODUCTION

- Nestos River flows through two European countries, Bulgaria and Greece, and discharges its water into the Aegean Sea
- Nestos River basin: 5100 km²
- Two dams in the Greek part of Nestos River:
  Thisavros Dam and Platanovrysi Dam

- Reduction of sediment yield at the outlet of Nestos River basin
- Coast erosion

- Calculation of sediment yield before and after the dams construction

MATHEMATICAL MODEL

"RUNERSET" (RUNoff – ERosion – SEdiment Transport)

<u>Three submodels</u>:

- **Hydrological submodel**
- **Soil erosion submodel (Schmidt, 1992)**
- **Stream sediment transport submodel (Yang and Stall, 1976)**

- **The calculations were performed on a monthly time basis**
- **Final result: Mean annual value of sediment yield**

HYDROLOGICAL SUBMODEL

Simplified water balance model for the root zone of the soil:

$$S_n' = S_{n-1} + N_n - E_{pn}$$

S: available soil moisture [mm]

N: rainfall amount [mm]

E_p: potential evapotranspiration [mm]

n: index for the time step

HYDROLOGICAL SUBMODEL

If $S_n' < 0$, then $S_n = 0$, $h_{on} = 0$, $IN_n = 0$

If $0 \leq S_n' \leq S_{max}$, then $S_n = S_n'$, $h_{on} = 0$, $IN_n = 0$

If $S_n' > S_{max}$, then $S_n = S_{max}$, $h_{on} = K(S_n' - S_{max})$, $IN_n = K'(S_n' - S_{max})$
where $K' = 1 - K$

h_o: direct runoff [mm]
IN: deep percolation [mm]
S_{max}: maximum available soil moisture [mm]
K, K′: proportionality coefficients

SOIL EROSION SUBMODEL
(Schmidt, 1992)

$$\varphi_r = Cr\rho Au_r \sin\alpha$$

φ_r: momentum flux by the droplets [kg m/s²]

C: soil cover factor

r: rainfall intensity [m/s]

ρ: water density [kg/m³]

A: sub-basin area [m²]

u_r: mean fall velocity of the droplets [m/s]

α: mean slope angle of the soil surface [º]

SOIL EROSION SUBMODEL

$$\varphi_f = q\rho bu$$

φ_f: momentum flux by the runoff [kg m/s^2]

q: direct runoff rate per unit width [m^3/(s m)]

ρ: water density [kg/m^3]

b: width of the sub-basin area [m]

u: mean flow velocity [m/s]

SOIL EROSION SUBMODEL

$$q_{rf} = (1.7E\text{-}1.7)10^{-4} \qquad E = (\varphi_r + \varphi_f) / \varphi_{cr} \qquad (E>1)$$

q_{rf}: available sediment discharge per unit width [kg/(m s)]

φ_r: momentum flux by the droplets [kg m/s²]

φ_f: momentum flux by the runoff [kg m/s²]

φ_{cr}: critical momentum flux [kg m/s²]

SOIL EROSION SUBMODEL

$$q_t = c_{max} \rho_s q$$

q_t: sediment transport capacity by overland flow [kg/(m s)]

c_{max}: concentration of suspended particles at transport capacity [m^3/m^3]

ρ_s: sediment density [kg/m^3]

q: direct runoff rate per unit width [$m^3/(s\ m)$]

SOIL EROSION SUBMODEL

Estimation of sediment ES reaching the main stream from the respective sub-basin area_

If $q_{rf} > q_t$, then $ES = q_t$

If $q_{rf} < q_t$, then $ES = q_{rf}$

q_t: sediment transport capacity by overland flow

STREAM SEDIMENT TRANSPORT SUBMODEL

Estimation of sediment load FLO at the outlet of the main stream of a sub-basin

$$\text{If } ESI > q_{ts}, \text{ then } FLO = q_{ts}$$

$$\text{If } ESI < q_{ts}, \text{ then } FLO = ESI$$

ESI: available sediment load in the main stream considered

q_{ts}: sediment transport capacity by streamflow

STREAM SEDIMENT TRANSPORT SUBMODEL

$$\log c_t = 5.435 - 0.286\log(wD_{50}/\nu) - 0.457\log(u_*/w) + [1.799 - 0.409\log(wD_{50}/\nu) - 0.314\log(u_*/w)]\log(us/w - u_{cr}s/w)$$

(Yang and Stall, 1976)

c_t: total sediment concentration by weight [ppm]

w: terminal fall velocity of suspended particles [m/s]

D_{50}: median particle diameter of bed material [m]

ν: kinematic viscosity of the water [m^2/s]

u: mean flow velocity [m/s]

u_{cr}: critical mean flow velocity [m/s]

u_*: shear velocity [m/s]

s: energy slope

APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN

Basin of Nestos River:

- **Division into 60 sub-basins:**

- **Basin of Thisavros Dam (Bulgarian and Greek parts): 31 sub-basins**
- **Basin of Platanovrysi Dam (Greece): 9 sub-basins**
- **Basin downstream of Platanovrysi Dam: 20 sub-basins**

- **Meteorological data (rainfall and temperature): from 22 meteorological stations in Greece and Bulgaria**

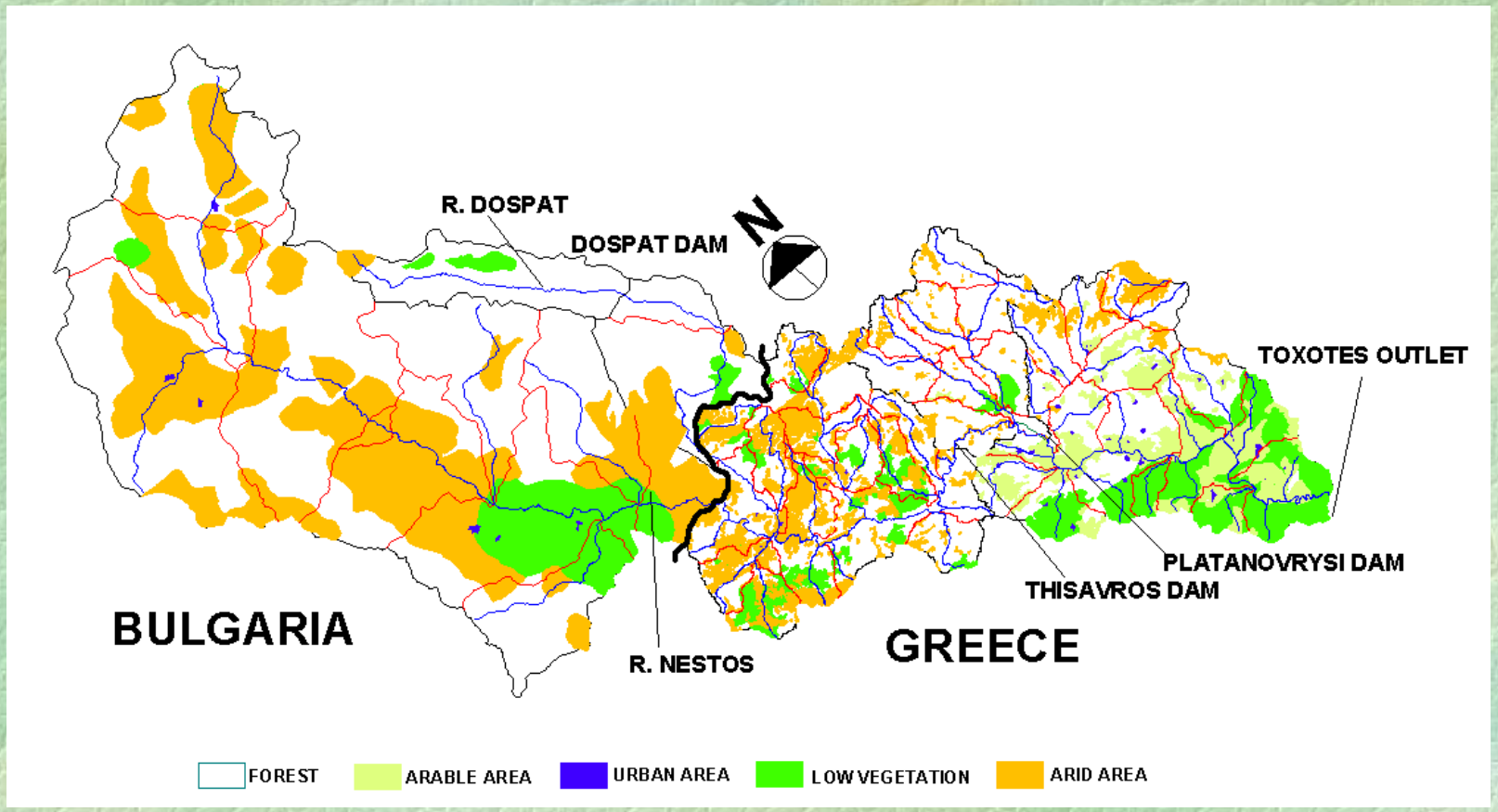
APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN

Thematic maps:

- **Altitude contours map**
- **Main streams map**
- **Soil cover map**
- **Geological map**
- **Thiessen polygons map**

APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN

Main streams and soil cover map



APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN

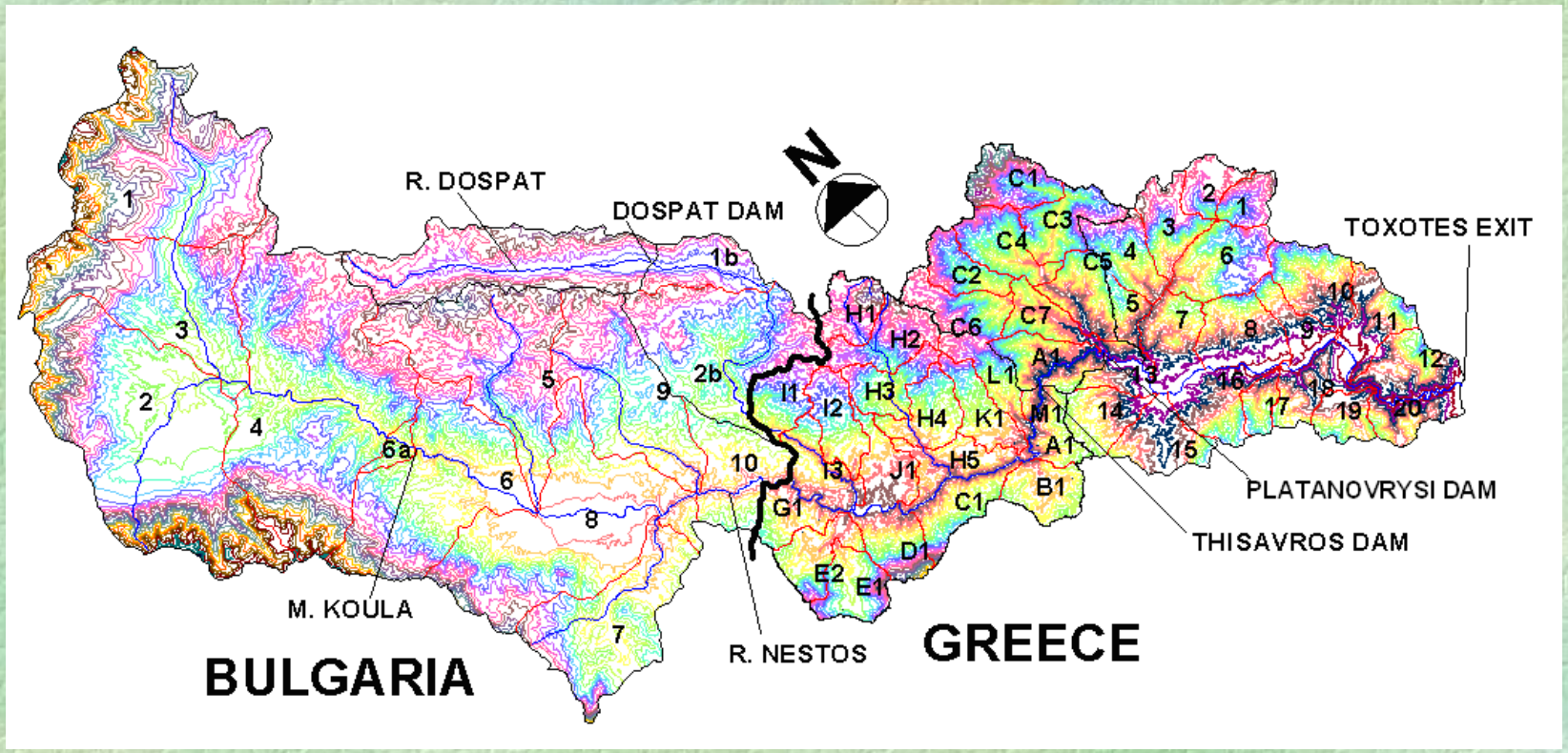
Geological map

APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN

Thiessen polygons map

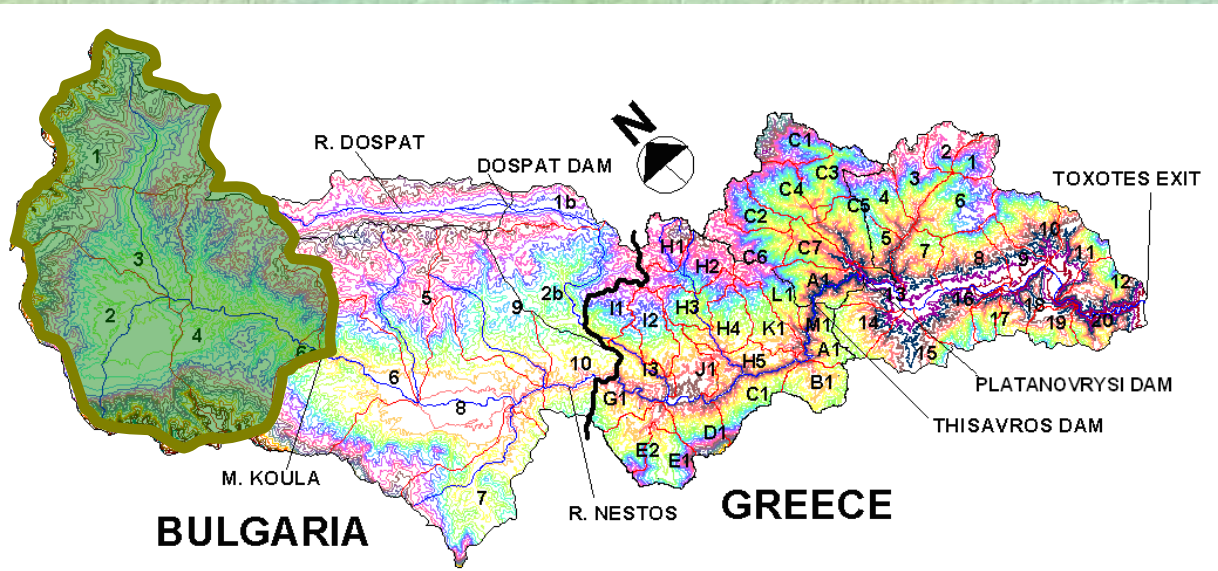
APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN

Altitude contours map



APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN
Model testing

- Sediment (suspended load) measurements of 53 years (1937–1989) at the location "Momina Koula" (Bulgaria)
- Basin area: 1511 km²
- Mean annual suspended sediment yield: 202 t/km²
- Assumption: Bed load / Suspended load = 0.25
- Mean annual sediment yield (measured): 252.5 t/km²
- Mean annual sediment yield (computed): 208 t/km²
- Underestimation: 18%



APPLICATION OF "RUNERSET" TO NESTOS RIVER BASIN

Calculations

- Time period of 11 years (1980-1990)
- Mean annual sediment amount inflowing into Thisavros Reservoir from the Bulgarian part (3052 km²) and from the Greek part (804 km²) of Nestos River basin.
- Mean annual sediment amount inflowing into Platanovrysi Reservoir from the corresponding basin (405 km², Greece)
- Mean annual sediment yield at the outlet of Nestos River basin (Toxotes) originating from the basin part downstream of Platanovrysi Dam (840 km², Greece)

COMPUTATIONAL RESULTS

- Mean annual sediment yield at the outlet of Nestos River basin, before the dams construction: 2×10^6 t
- Mean annual sediment yield at the outlet of Nestos River basin, after the dams construction: 0.33×10^6 t
- Decrease of sediment yield due to the dams construction: 84%

- Consequence: Erosion of Nestos River mouth and the neighbouring coastline