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IMPACT OF WATERSHED AND CLIMATE CHANGES ON RIVER BED MORPHOLOGY AND BIOTA

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There have been increasing concerns linking climate change and land use practices at the watershed level to destruction of habitats in rivers and estuaries. These changes are occurring concurrently with the acceleration in water reallocation and consumption, so it is difficult to assess the impact of individual factors and processes on the environment. We present a framework for a formal sensitivity analysis that can identify the critical parameters impacting the sustainability of riverine biota. The fundamental hypothesis is that erosion and sedimentation processes are responsible for changes in the aquatic habitat of wetlands and estuaries. Mitigation of these changes is currently limited due to our inability to accurately assess the propagation of hydrometeorological constraints through a non-linear hydrologic system. The processes involved are characterized by such vastly different spatial and temporal scales that until now studies of habitat sensitivity to land use changes have been qualitative. Morphological changes in an estuary typically take several decades to manifest themselves, as sedimentation rates increase slowly following urbanization or deforestation of parts of a watershed. The depth of water flow in the estuary is gradually reduced, the width of beaches increases, the wave patterns are altered and the balance of sand, mud, and water is modified.

The present approach aims at integrating large-scale watershed eco-hydrologic processes with long-term morphological changes in channel and estuary bathymetry. Furthermore, the proposed model interprets constituent hydro-geomorphic state information and directly translates it to habitat quality metrics, such as favorability indices of fish habitat. Due to the imposed mechanistic design, the present model permits experimentation with alternative land use and hydro-meteorological scenarios, thus allowing the determination of sensitivity patterns and the implementation of sustainable strategies for compensating human interference with the natural processes in the watershed. Thus, the proposed model can have a significant impact on our efforts to reverse unwanted morphological changes in wetlands and to restore damaged aquatic habitats.

The process-scale dynamics of hill-slope-channel erosion and streamflow sediment yield are strongly affected by the spatial heterogeneity in soil and bedrock, vegetation cover, and topography. The rainfall-runoff mechanism is the primary driver of these dynamics, exhibiting high heterogeneity over a number of spatial and temporal scales and a strong dependence on antecedent conditions. In the present framework, a large-scale watershed model represents the front-end to the proposed impact assessment model. The hydrological model ingests a variety of data that characterize watershed topography, vegetation, soil type, and land use properties. Additionally, the hydrological model accounts for general meteorological forcing, e.g. precipitation, radiation and atmospheric turbulence. In areas susceptible to erosion, the locally produced event-scale runoff is then translated into sediment yields. Using the generated runoff and eroded particles as input, a transport model simulates the redistribution of sediment both as bedload and as suspended load across the basin drainage network. The long-term simulations allow the representation of characteristic hydro-geomorphic seasonal dynamics. Thus, at the framework back-end, this provides the necessary information for the evaluation of rates of change of stream and estuary morphology, as well as changes in aquatic habitat quality.

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The propagation of sensitivity in a watershed-river-estuary model depends on the seamless integration of these models and the creation of common parameters. Therefore, the component models must be homogenized and overlapped rather than connected at heterogeneous boundaries. In particular, fluxes of mass, momentum and sediment must be continuous at the interfaces and sensitivity should be allowed to propagate without reflection or diffraction. In the present work this is accomplished by collocation of the watershed, hydrodynamic and sedimentation models and by linking the erosion process to the precipitation input, thus creating a direct link between meteorological forcing, drainage basin conditions and estuarine morphology. Each model passes conservative variable information to the next and establishes a bidirectional transfer of information through the common boundaries. This is accomplished by extending the hydrodynamics to the headwater and the erosion-sedimentation to the estuary. Once this coupling is accomplished, the land use practices that precede the increase in soil erosion and the source of sediment loading become transparent to the estuarine and wetland processes.

A mechanistic erosion model at the watershed scale with parameters that bear physical meaning is used in the present study. These parameters represent meteorological forcing, subsurface water pore pressure, vegetation cover and land use, topography, and human activities. It is also influenced by the soil's inherent properties such as erodibility, cohesiveness, and particle size distribution. Rainfall is partitioned into runoff and infiltration, as the latter is found to influence significantly soil erosion. Furthermore, size differences of bed material impact the load and spatial variability of sediment dynamics and impact on biota, especially since fine sediments tend to adsorb contaminants that impair water quality. The formulation differentiates composition of the bed into original and deposited soil layers, recognizing whether material has an intact or a loose condition, and allows for resuspension or deposition of particles.

Model validation is presented by comparison with analytical solutions and empirical data. Benchmark laboratory cases dealing with rainfall-induced erosion and overland flow-induced erosion are used. Furthermore, the model is applied at a catchment scale and validation of the simulations is carried out using observed data for several rainfall events. Results are also presented regarding the impact of river bed morphological changes on aquatic habitat. By using a statistical weather generator, changes in river bathymetry are computed for a hypothetical increase in mean air temperature. The results indicate a strong sensitivity between air temperature and aquatic habitat and suggest mitigation processes that may improve the sustainability of wetlands and estuaries.