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KINEROS model implementation for the analysis of the representative watershed Ciurea – Tinoasa, IAŞI County

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Abstract: The paper presents the utilization of the Kineros model for the hydrological study of a representative watershed. Kineros is a physical process-oriented model describing the events for interception, infiltration, drainage and surface erosion in small river basins, agricultural and urban areas.

Keywords:KINEROS,interception, infiltration,drainage, surface erosion.

1. INTRODUCTION

The KINEROS model is a physically based model describing the processes of interception, infiltration, surface runoff and erosion from small agricultural and urban watersheds, developed at the University of Tucson, and can be used to evaluate scenarios such as urban development.

The watershed is represented by a cascade of planes and channels.

The partial differential equations describing overland flow, channel flow, erosion and sediment transport are solved by finite difference techniques.

The spatial variation of rainfall, infiltration, runoff, and erosion parameters can be accomodated.

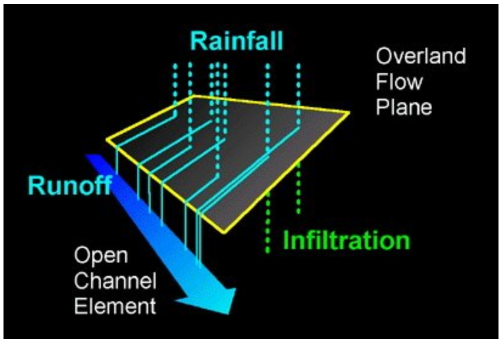

Fig.1 - Components and processes of the Kineros Model

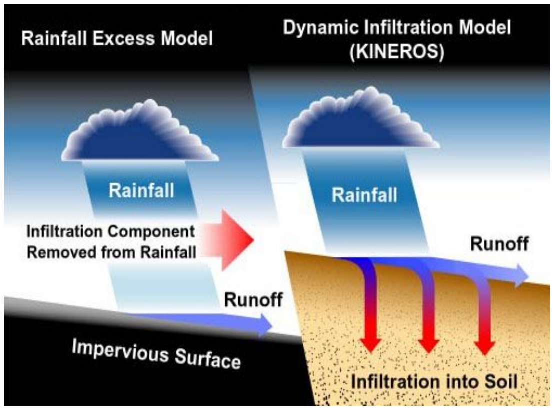

Fig.2 - Dynamic model of Infiltration (KINEROS)

2. MODEL IMPLEMENTATION

As shown in the documentation of the model, the main elements used in water storage modeling are: seepage through the wetted area, rainfall on the pond itself, and initial storage.

The infiltration algorithm will handle a two-layer soil profile and incorporates a new method, based on soil physics, to redistribute soil water during rainfall interruptions.

The open channel algorithm has been extended to allow a compound cross section with an overbank level where hydraulic and infiltration parameters can differ from those in the main section.

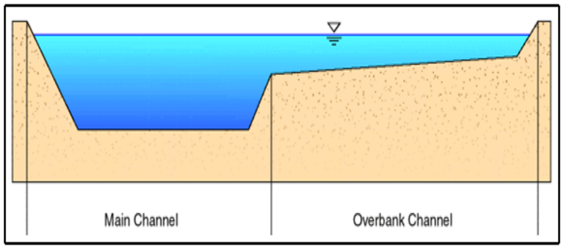

Fig.3 - The cross section of the open channel used in KINEROS

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KINEROS will automatically interpolate multi-gage rainfall intensity input to each routing element based on the spatial relationship between the element's areal centroid and the rain gage network.

Data from the nearest three gages which enclose the centroid determine a plane in (x, y, z) space, where z is accumulated depth, for each time, from which the intensity at the centroid is computed. If the centroid lies outside of the network, and certain geometric criteria are met, two gages are used. Otherwise, data from the closest gage alone is used.

The appearance of free water on the soil surface, called ponding, gives rise to runoff in the direction of the local slope (Figure 4).

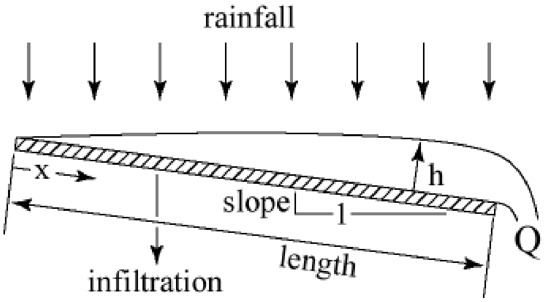


Fig.4 – Overland Flow

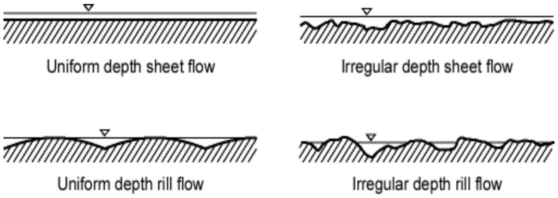
Viewed at a very small scale, overland flow is an extremely complex three-dimensional process. At a larger scale, however, it can be viewed as a one-dimensional flow process in which flux is related to the unit area storage by a simple power relation:

$$Q = \alpha h^{m} \qquad (1)$$

where Q is discharge per unit width and h is the storage of water per unit area.

Parameters α and m are related to slope, surface roughness, and flow regime.

Figure 5 illustrates some of the possible configurations that the flow may assume in relation to local cross-slope microtopography.


Uniform depth sheet flow

Irregular depth sheet flow

Uniform depth rill flow

Irregular depth rill flow

Fig.5 - Examples of several types of overland flow (Wilgoose and Kuczera, 1995)

Microtopographic relief can play an important role in determining hydrograph shape. The effect is most pronounced during recession, when the extent of soil covered by the flowing water determines the opportunity for water loss by infiltration.

KINEROS2 provides for treatment of this relief by assuming the relief geometry has a maximum elevation, and that the area covered by surface water (see Figure 5, above) varies linearly with elevation up to this maximum.

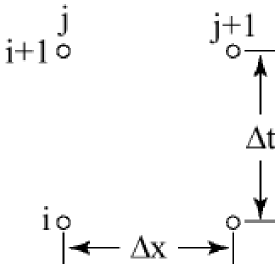


Fig.6 - Time and space discretization in KINEROS

A solution is obtained by Newton's method (sometimes referred to as the Newton-Raphson technique).

While the solution is unconditionally stable in a linear sense, the accuracy is highly dependent on the size of Δx and Δt values used.

The difference scheme is nominally of first order accuracy.

Unsteady, free surface flow in channels is also represented by the kinematic approximation to the equations of unsteady, gradually varied flow.

Channel segments may receive uniformly distributed but time-varying lateral inflow from overland flow elements on either or both sides of the channel, from one or two channels at the upstream boundary, or from an area at the upstream boundary.

The dimensions of overland flow units are chosen to completely cover the watershed, so rainfall on the channel is not considered directly.

The continuity equation for a channel with lateral inflow is:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} - q_c(x,t) \qquad (2)$$

where A is the cross-sectional area, Q is the channel discharge, and $q_c(x,t)$ is the net lateral inflow per unit length of channel. Under the kinematic assumption, Q can be expressed as a unique function of A and equation (2) can be rewritten as:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial A}\frac{\partial A}{\partial x} = q_c(x,t) \qquad (3)$$

The kinematic assumption is embodied in the relationship between channel discharge and cross-sectional area such that:

$$Q = \alpha R^{m-1} A \qquad (4)$$

where R is the hydraulic radius.

KINEROS2 contains a new soil infiltration model which allows more detailed specification of the soil profile for each hydrologic element, including specification of the characteristics of the bed for an infiltrating channel.

KINEROS can simulate the movement of eroded soil along with the movement of surface water.

KINEROS accounts separately for erosion caused by raindrop energy and erosion caused by flowing water, and continue the simulation through channel and pond elements.

One necessary limitation is that, because a single mean particle size is used to characterize the eroded material, the effective soil particle size needs to be similar for all the eroding elements.

The general approach to sediment transport simulation for channels is nearly the same as that for upland areas.

Rainfall data is entered as time-accumulated depth or time-intensity breakpoint pairs.

Rainfall is modeled as spatially uniform over each element, but varies between elements if there is more than one rain gauge.

3. RESULTS AND DISCUSSIONS

The following example illustrates the use of Kineros to simulate liquid runoff and suspended load transport in the Tinoasa Ciurea representative basin, which has an area of 4.7 square kilometers.

The watershed is covered with mixed grass and low shrub, with broad swales contributing to a network of incised channels, and is equipped with ten weighting-type recording rain gages.

The first step of simulation consists in subdividing the watershed into overland flow and open channel elements, typically using a topographic map.

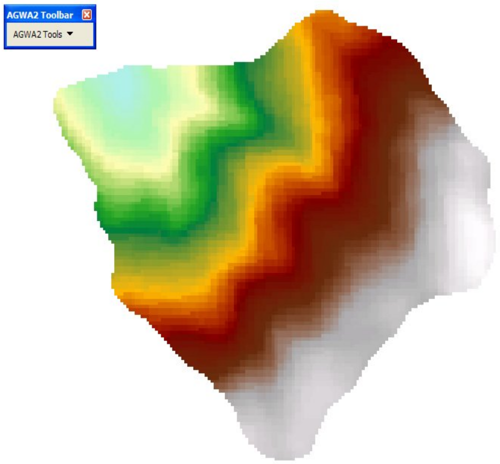


Fig.7 – DEM of the representative watershed

The 2nd step uses the geoprocessing algorithms embedded in Kineros in order to calculate the spatial features used in the hydrologic analysis of the Ciurea – Tinoasa watershed. The delineation of subwatersheds, hydrographic network and relevant points (watershed outlet, rain gauges, river junctions) are made in this step.

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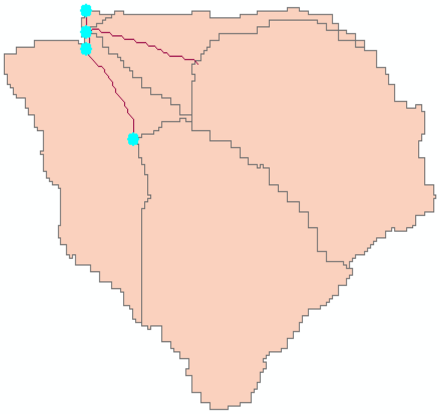
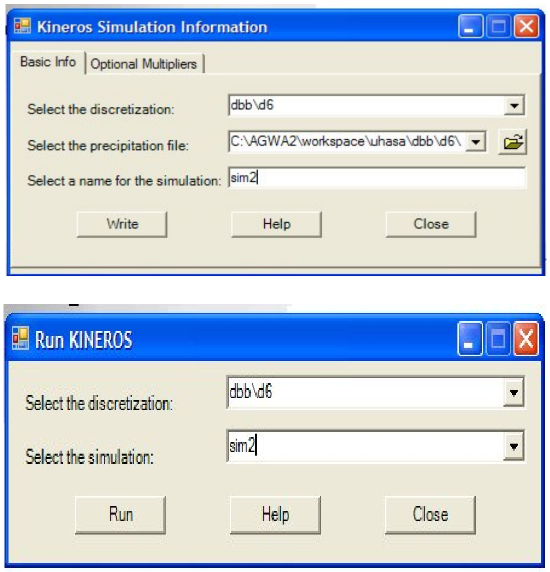


Fig.8 – Spatial delineation

The 3rd step consists in creation of the required spatial parameters geodatabase, including soil characteristics and landcover for the studied area. These data and relevant precipitation data represent the input data requirements for simulations running in KINEROS.

The 4th step implements the preprocessing phase and run of the KINEROS model.



Select the discretization: dbb\d6

Select the precipitation file: C:\AGWA2\workspace\uhasa\dbb\d6\

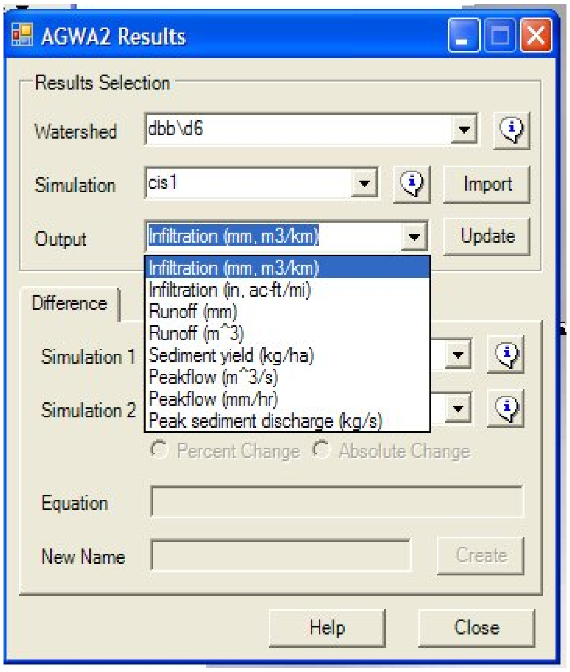
Select a name for the simulation: sim2

Select the discretization: dbb\d6

Select the simulation: sim2

Fig.9 a.), b). Preprocessing and model run

The 5th step allows the selection, display and analysis of the results of the simulation.



Watershed: dbb\d6

Simulation: cis1

Output: Infiltration (mm, m3/km)

Results of simulation

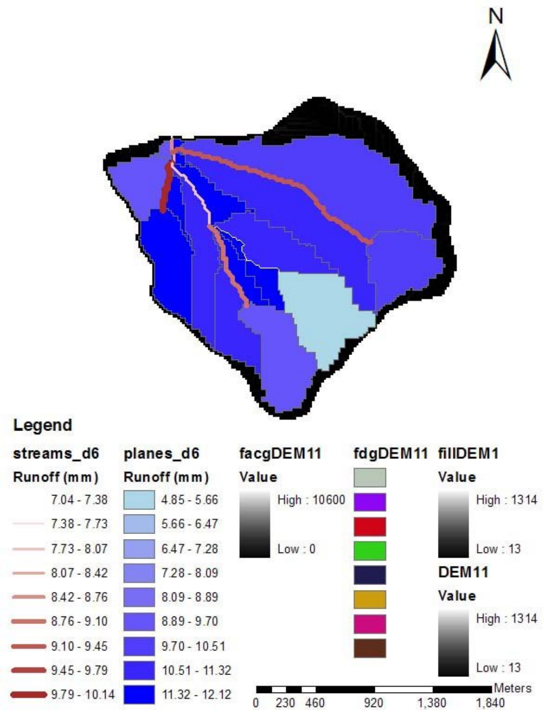


Fig.nr.10 a) ,b). Results of simulation

4. CONCLUSIONS

The KINEROS model uses the kinematic wave equations for simulation of the overland, natural channel, reservoirs and pipes flows.

A simulation of the flow was made for the representative watershed Ciurea – Tinoasa. The infiltration and liquid runoff and suspended load transport were calculated, using terrain and climatic specific data.

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