Modelling hydrological processes to evaluate alternatives for ecologic reconstruction in the Danube floodplain near Braila, Romania

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Keywords: Flooding, reconstruction, hydrological modelling, ROSPA0005, ROSCI0006, Danube floodplain

1 Introduction

The Small Island of Braila Natural Park (ROSPA0005 and ROSCI0006) is a wetland with international importance, declared Ramsar *site* and *Natura* 2000 *site*. The Natural Park preserves on 245 km^2 the last wetland complex of flood-free ecosystems after the impoundment of Braila and Ialomita marshes (i.e. of former Danube Inner Delta 2,413 km^2, Vadineanu et al. 2001). The uniqueness of the area is given by the structure and location of the Park between the Danube branches, which limited the anthropogenic impact. The only anthropogenic changes are produced both by optimizing the use of fisheries resources and by the use of the herbaceous and forests vegetation as food for animals (pig, cattle rearing, etc.) or as timber. The reference state is represented by a characteristic morpho-hydrographic structure which resulted from the long-term sedimentation and erosion processes, which led to the development of a network of banks / natural dams, ponds and canals (Iordache et al. 2005a, Bodescu & Iordache 2008). Most of these banks obstruct the natural channels so that many areas of the basin are in various stages of clogging; the channels are invaded by vegetation, or temporarily or permanently covered by water. The current study of the surface waters in the Fundu Mare Island shows the cumulative effects of the increased sedimentation processes, which clog the ponds, inland lakes and channels connected to the Danube River.

2 Materials and methods

Mathematical models such as numerical modelling of the hydrological processes through automated cells have been used. The models are showing the flooding area and the specific parameters, the velocity and level of flooding waters.

In conjunction with the measured sediment load of the flood water we could assess processes such as sedimentation and erosion (Nicolas 2005). For the hydrologic modelling we used CAESAR and TRACER models proposed by Coulthard (2001) and Coulthard et al. (2005). After developing the digital elevation model (DEM) of Fundu Mare Island and identifying the existing data on the flow dynamics and suspended sediment content of the Danube water, model parameterization was performed for the specific algorithm of CAESAR.

Running the model showed the possibility to simulate both the extreme and normal events. In view of assuring the model quality and to validate the model results we have selected four cases specific for each quartile interval with similar and continuous intervals of simulation, so that their expansion and variability can be compared with LANDSAT-type satellite images (Smith 1997). After hydrological model validation we simulated the specific conditions to show, using the TRACER model, the processes of sedimentation and erosion before and after sediment sampling and assessment for heavy metals load.

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The dynamics of the Danube water flow, as shown by hydrometric measurements conducted at the main regional stations, Harsova and Braila, reveals a high variability. Analyzing the discharge between 1997 and 2002 allowed us to document a variability of the Danube water flow that can be characterized statistically by the values presented in Table 1. Thus, daily discharge in the Danube ranges from <2000 m^3/s to >12,000 m^3/s (quartile limits Q1 to Q3 are presented in Table 1).

A number of 21 available satellite images with an acceptable degree of cloud cover could be identified for the analyzed period, of which 4 were selected for the validation of the numerical model results in terms of extending water flooding at specific values in the lower and upper quartile.

To validate the model we selected CAESAR images for each quartile interval. For each of them a period of 7 days was selected, before the date on which the image was taken and it was parameterized, as in the simulations below to highlight the selected area.

Table 1. *Multiannual water debits statistic indicators (1997-2002) (m^3/s)*

Min	*1431*
Mean	*6870*
Max	*11667*
Q1	*5375*
Q2(me)	*6837*
Q3	*8312*

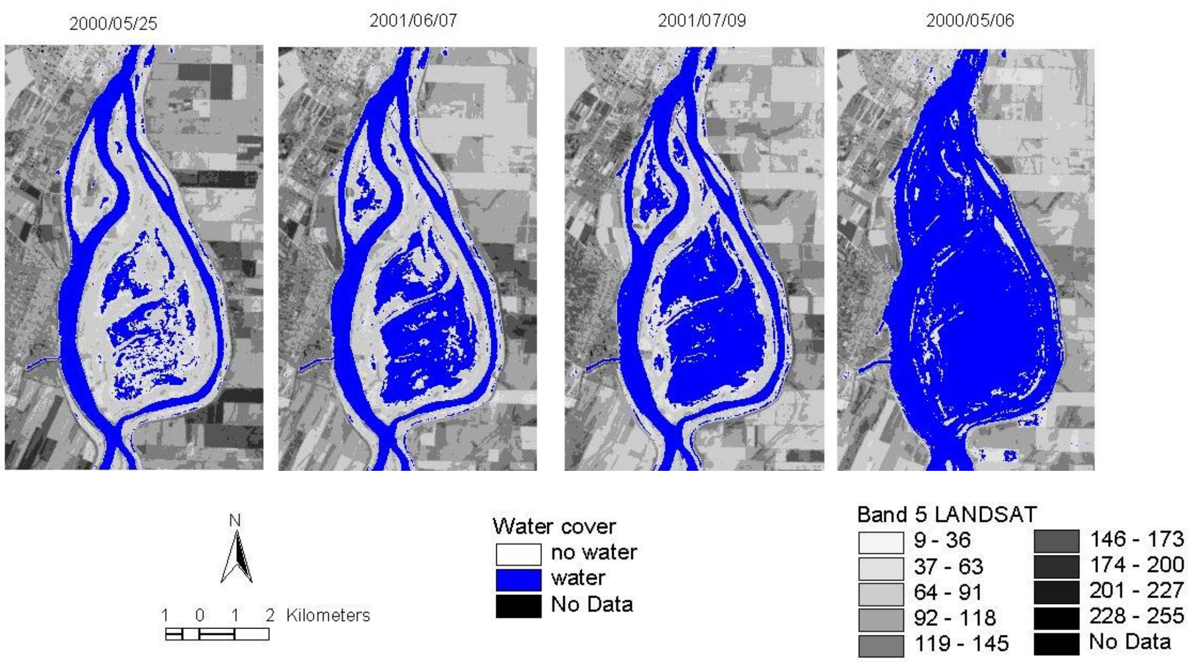

Figure 1. *Flooding water cover of Fundu Mare Island*

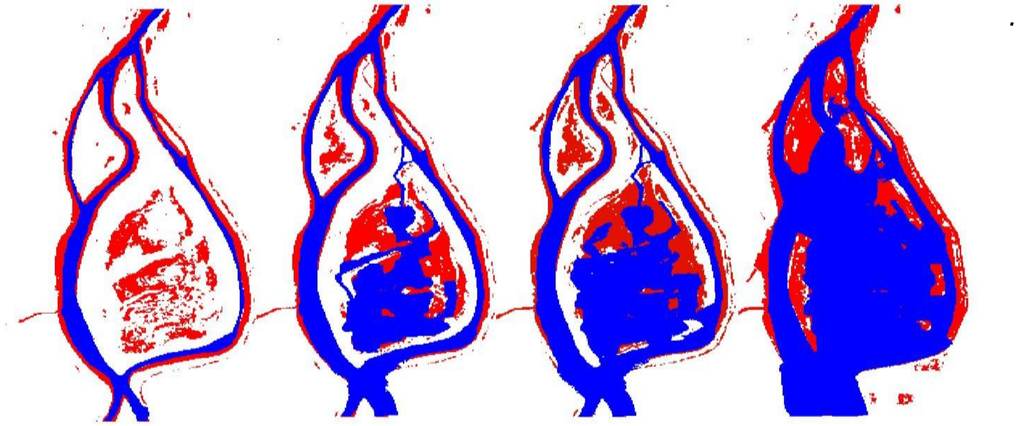

Figure 2. *Comparative analyses of flooding water cover: estimated on LANSAT satellite images classification (red) and by CAESAR model (blue)*

The satellite images were classified using the method of Frazier & Page (2000), which allows the differentiation of the flooding areas using band 5 with up to 96% confidence. Figure 2 shows band 5 for the 4 mentioned images. The method was adapted to the specific conditions, so that using band 5 from the multispectral image good results were observed for interval 8-52 to highlight the flooded areas (see Figure 1).

3 Restoration site: The Fundu Mare Island

Over the past 40 years, especially in the period 1965-1970, national strategies and policies were implemented to increase the area of agricultural land and to enhance the exploitation of available areas. In the Danube Valley this policy resulted in a more than 80% reduction of the natural floodplains (Vadineanu et al. 2001). These measures had major implications both for the agricultural systems and for the systems remaining under natural flooding conditions, as the Small Island of Braila is part of the former wetlands Great Island of Braila. The changes consisted in the alteration (modification) of the hydrologic regime, which narrowed the amplitude of the Danube water level fluctuation. Hence, under natural flooding conditions, fewer areas were inundated, the ponds of the Small Island of Braila became shallow and the load of sediments decreased. These changes are due to dam constructions in the Danube (Iron Gates I and II) and major tributaries. In addition to changes at regional and sub-regional levels, local changes have taken place such as blocking the Păioasa channel from Fundu Mare Island, in the framework of forest and navigation management. In other words, a part of the sediment observed in the lakes of Fundu Mare Island is due to anthropogenic impact.

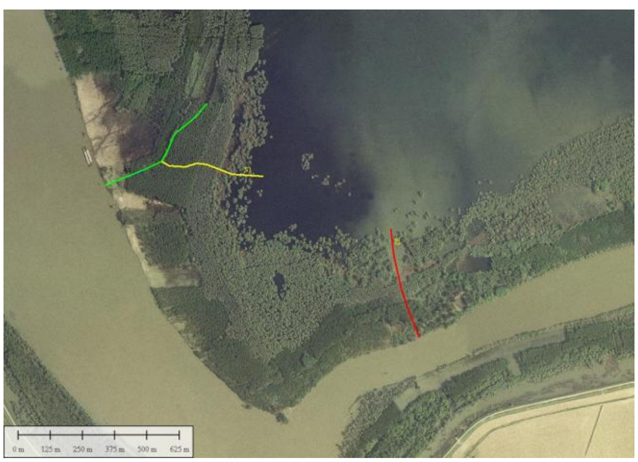

Figure 3. *Alternative scenario of reconstruction (S1 – light green; S2- red; S3 – pink and yellow)*

Restoration of ecological systems is addressing geo-morphological, hydrological and biological factors. For a specific sector of Fundu Mare Island (near Braila, Romania), we tested two hypotheses: the first one implies an increase of erosion near the shallow lakes and channels, achieved by opening connection channels to the upstream Danube arms; the second hypothesis implies that natural erosion and deposition will balance the retention and mobilization of heavy metals.

The bottom of floodplain lakes is above the low-water level of the Danube. Therefore, they loose water during the low flow period (from summer until autumn) through surface flow and/or exfiltration. We should also notice that in the state of reference, the islet lakes were usually supplied from the upstream channel and the outflow was located downstream (Antipa 1910, Vadineanu et al. 2001, Iordache et al. 2005b). This ensured a drainage system for the streams, internal canals and lakes and a low sedimentation rate. In fact, the sedimentation processes were much more intense than in the present days, but the hydrological dynamics, intensified by a second channel, washed out the deposits during floods so that the net sedimentation rate was lower than today.

Actually, in Fundu Mare Island there is just one channel for the inflow and the outflow. As a result, the flow velocity decreased drastically and the sediments are trapped in the inner lakes of the island and the canals. Obviously, the high sedimentation rates reduced lake depth, affecting directly the main species of birds *(Nycticorax nycticorax, Ardeolla ralloides* etc.) and fish from the Small Island of Braila. Further, water quality deteriorated since water residence time increased: lower dissolved oxygen concentrations, increased nitrogen and phosphorus concentration, and reduced transparency indicated eutrophication (Vadineanu et al. 2001, Iordache et al. 2005a). This process was supported by poor management – using the dam at the end of Chiriloaia channel and disconnecting the Danube.

4 Simulation results and discussion

Under this context, modelling the hydrological processes is used to test and validate various integrated management solutions both for the control of diffuse pollution with heavy metals and for the exploitation of fisheries and forestry resources. We selected for the analysis three alternative scenarios (figure 3). Scenario 1 is the reactivation of former Paioasa channel; the second scenario is the creation of a new channel following the shortest upstream connection from the lake to the Danube arm; the third scenario is a combination of the first two scenarios, where Paioasa channel is reactivated and connected to a new channel linking the upper inland lake.

After, correction of the digital elevation model to reflect the inconsistencies identified by the testing method, we applied the specific parameterization of each scenario for the proposed channels (figure 4). The effect of scenario 1 is mainly to activate the former channel but at this moment this will have a small beneficiary effect as sedimentation will continue, with a smaller rate. In the second scenario the activation of the proposed channel will strongly enhance erosion in the island lakes and channels. The last scenario is preferred, because it will keep the equilibrium between erosion and deposition.

	S1	*S2*	*S3*
Water depth			
Flow velocity	Lowest	Higher	Medium

Deposition/erosion	 deposition	 erosion	 deposition / erosion

Figure 4. *Comparative analysis of the alternative scenarios*

5 Conclusions

The inconsistencies in the comparative analysis of the flood prone area identified between the numerical model and the interpretation of the satellite images may be attributed primarily to the lack of detail of the digital model and secondly, to the underestimation of the flooded area that was not fully detected by the sensor because of the density and height of the riparian vegetation. The differences in the inter-quartilic intervals 2 and 3 may be due mainly to the anthropogenically maintained (controlled) water from the inland lakes.

Our recommendation is the use of the third scenario that has been completely analyzed in an integrated feasibility study and accepted by the scientific and administrative councils of the Small Island of Braila Natural Park (ROSPA0005 and ROSCI0006). We showed that the proposed methodology is a viable tool for the analysis of flooding processes in a specific river sector and for modelling the processes of erosion and sedimentation (essential hydrological processes with relevance to the mobility of heavy metals).

Acknowledgements

This study was supported by the MECOTER project; project no 271, CNCSIS (www.mecoter.cesec.ro).

Reviewing comments from Jürg Bloesch and Dieter Gutknecht to focus this paper are greatly appreciated.

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