Coastal Deltas of Big Rivers as Synergetic Transformation Elements of the Earth System—(An Example of the Don River Delta)

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Abstract

We discussed in this study the beginning of a new research initiative "Coastal deltas of big rivers as synergetic transformation elements of the Earth System" which the Southern Scientific Centre of the Russian Academy of Sciences is going to run on the case of the Don River delta. We suggested elaborating Delta Functional Types and quantifying these units according to the collected data. We compared energy and water management at the Don River with 100 major deltas of the world and concluded that our case study area is "coastal semi-arid with a relatively low energy and high-water management".

Keywords

Coastal delta • Earth System • Climate change

1 Introduction

Deltas of big rivers (with basins over 50,000 km^2) are playing a key role in transforming matter and energy fluxes in continuum land–ocean, and the fluxes are interacting with each other in a synergetic way. Thus, deltas of big rivers, which represent regions with diverse landscapes and ecosystems, belonging to the biosphere, hydrosphere and atmosphere, are important synergetic transforming elements of the Earth System. Besides their functions as biogeochemical (e.g. hydrological, carbon and nitrogen cycle) and energetic (e.g. wave and gravitational energy) transformers, deltas are providing geomorphological ecological and economic services (Chenchouni and Si Bachir 2010). These geomorphological, ecological and economic services can be used to define deltas sustainability (Day 2016) by estimating some integrative variables like accretion against sea-level rise (geomorphological sustainability), NPP of wetlands (ecological sustainability) and the delta total economic monetary value (economic sustainability). From the thermodynamic prospective, deltas are open systems for which permanent flows of matter and energy are necessary to sustain their functions in the Earth System and ecological, economic and geomorphological services. Thus, the status of a river basin, influenced by climate change and anthropogenic activities (e.g. water uptake, reservoir's construction) and the status of the adjacent ocean shelf (also highly influenced by climate change), will determine the deltas future structure and dynamics. Deltas are highly dynamic systems operating at different temporal scales, mainly determined by hierarchy of pulse inputs of energy and matter like daily tides, frontal wind passages, storms and associated storm surges and river floods. All pulse events in deltas are affected both by human activities and climate change, as well. Therefore, we can find both similarities and differences between different deltas of the world in relation to their climate zonation and anthropogenic pressure. From the view of Earth System Sciences, the major question regarding deltas is how to describe in qualitative and quantitative ways the functions of coastal deltas of big rivers and their geomorphological, ecological and economic services?

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2 Materials and Methods

The Southern Scientific Centre of the Russian Academy of Sciences has just launched the research initiative "Coastal deltas of big rivers as synergetic transformation elements of the Earth System" addressing the major questions of this abstract.

We started from the structure of dynamic global vegetation models where each unit of vegetation is defined as plant functional type (PFT) determined by certain quantitative constraints. As an analogy, we suggested using Delta Functional Types (DFT) as a subset of all Coastal Functional Types and take as an initial classification of deltas suggested by Day et al. (2016). We, however, proposed adding an additional qualitative attribute "water management", to Koppen climatic classification and "energy management". As an "energy management" attribute, "water management" attribute can be either "high" or "low". Our suggested classification aimed to be an intermediate complexity, being a trade-off between classifications based on mainly hydrological and geomorphic attributes as in Tagliapietra et al. (2009) and classifications based on functional traits of coastal deltas as in Levin et al. (2001). The intermediate complexity classification of coastal deltas fits the general approaches of Earth System Sciences and allows further inclusion in Earth System models.

For quantification of definition of Delta Functional Type, we took the Don River delta as a case study. The Don River is the eleventh largest river in Europe by discharge and the third by drainage area for tributes of the Azov-Black Sea. The Don River delta is the most important agricultural, industrial and fishing conservation area in South Russia. It is nowadays strongly affected by climate change and anthropogenic pressure.

3 Results

3.1 Definition of Delta Functional Type for the Don River

The Don River delta is situated in a semi-arid climate Koppen zone. We compared energy management and water management at the Don River to 100 major deltas of the world (http://www.geol.lsu.edu/wdd/publications/hcbk04/deltadata&images.pdf) and concluded that our case study area is "coastal semi-arid with relatively low energy and high-water management". High-water management was explained by the low-flow period in the region and the use of large Tsymlyansk Reservoir (2,700 km^2).

3.2 Don River Delta Mapping

We started the creation of a GIS for the Don River delta (see Fig. 1). This delta contains natural land cover types like wetlands important for birds' conservation (including charismatic local Russian Red Book ibis), riparian vegetation and grasslands, meaning that anthropogenic agricultural and urban areas, roads, industrial enterprises and fishery harbours may affect the delta.

3.3 Collection of Databases for the Don River Delta

The Southern Scientific Centre of RAS collected significant amount of data based on permanent field observations and historical records. A simplified version of the metadata is presented in Table 1. This database was used for quantitative

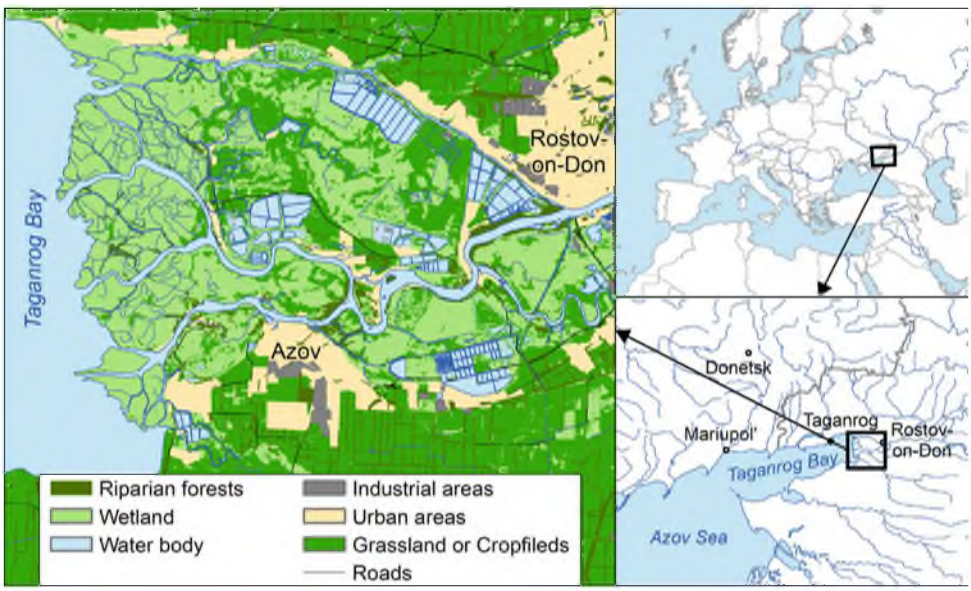

Fig. 1 Don River delta map with major land-use types

Table 1 Simplified metadata on the *Don River* delta (Mikhailov 2014, 2008, 1997)

Type of data	From	To	Periodicity
Weather parameters	2004	2018	Once every 10 min
Water level	2007	2018	Once every 10 min
River discharge	2002	2018	By day
Sediment load	1936	2016	By month
Water temperature	2004	2018	Once every 10 min
Mineralization	2004	2018	Once every 10 min
Chemistry	2006	2018	By month
Carbon in water	2006	2018	By month
Chlorophyll a	2008	2018	By month
Biology (zooplankton, benthos)	2005	2018	By season
Water use	2000	2018	By year

estimation of sustainability and function variables for the *Don River* delta.

4 Discussion

Our approach in defining the Delta Functional Type as a subset of Coastal Functional types in the Earth System is quite novel and needs discussion with terrestrial and marine ecosystems researchers for further refining and quantification of these broad-scale ecosystems. For example, deltas classification in the Russian hydrological science is based mainly on river typology and coastal shelf geomorphological typology. So, according to Mikhailov (1997) the Don River delta is classified as "No tide with abundant channels and shallow shelf". We may argue, however, that a broader classification definition, accounting not only for geomorphological features, but also for climatic and anthropogenic pressure features is necessary for purposes of general Earth System analysis.

5 Conclusion

The dataset acquired on the *Don River* delta is enough for the definition of "coastal semi-arid with relatively low energy and high-water management" Delta Functional Type. It is also possible to make a long-term and short-term integrated assessment of the *Don River* function within the Earth System and geomorphological, ecological and economic sustainability of this River delta.

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