# Assessing flood risk for urban areas in the Lower Don River using GIS and Remote Sensing

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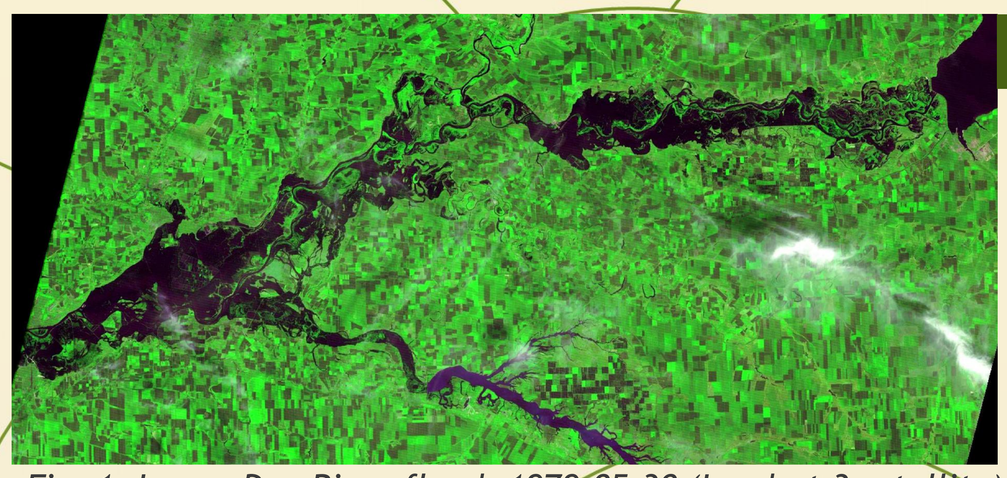

*Fig. 1. Lower Don River flood, 1979-05-30 (Landsat 3 satellite)*

## Introduction

The increased frequency of extreme events and uncertainty in weather patterns, accompanied by growth of urban population, related urbanization and corresponding increase in disaster exposure, contribute to rising numbers of affected people and economic losses from natural disasters. Floods stand out as one of the most common hazards, which can affect the population and assets on a great territory (EM-DAT 2016). This research was focused on assessment of changes in flood risk caused by expansion of urban areas to flood-prone territories. The Lower Don River floodplain (Rostov Oblast, Russia) was selected for analysis, since this region is both rapidly developing and historically (before the construction of the Tsimlyansk dam in 1952) was considered to be a flood-prone area (Fig. 1) (Lagutov and Lagutov 2011).

## Methods

The urban area flood risks were identified through a 2-step process: identifying urbanized areas in the floodplain and simulating potential severe flood events.

***Remote Sensing and GIS***

Satellite imagery was used to identify changes in land cover, particularly expansion of urbanized areas in the floodplain from 1985 to 2013 (Fig. 2). Landsat 5 and Landsat 8 data were used for years 1985 and 2013, correspondingly. Additionally, satellite images for the spring months of high-water years were acquired and processed using Esri ArcGIS 10.

***Simulation***

The potential flood extent and propagation were assessed using the combination of remote sensing and modelling tools. Flood simulation using modelling package can allow identify territories that are at the most risk, flood wave speed, time required to reach a particular settlement and other flood characteristics (Fig.3). The hydrological model for the Lower Don River was developed using FLO-2D cellular automata-based model (FLO-2D 2016). Five alternative flood scenarios were formulated based on recorded floods statistics and tested using the developed model (Rosvodresursy 2013).

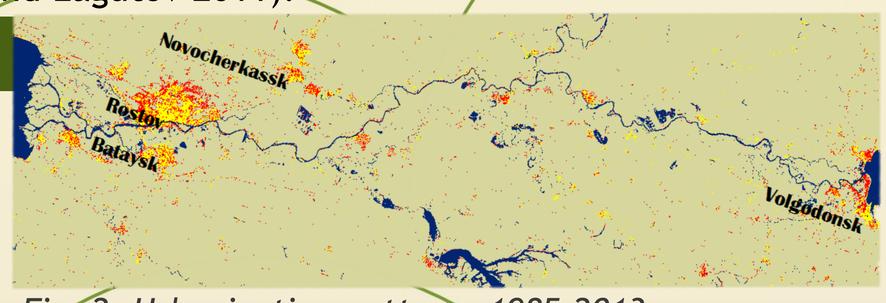


*Fig. 2. Urbanization patterns 1985-2013*
Urban areas in 1985 are presented in yellow color; urban extension is indicated by red

*Fig. 3. 100-year flood inundated area*

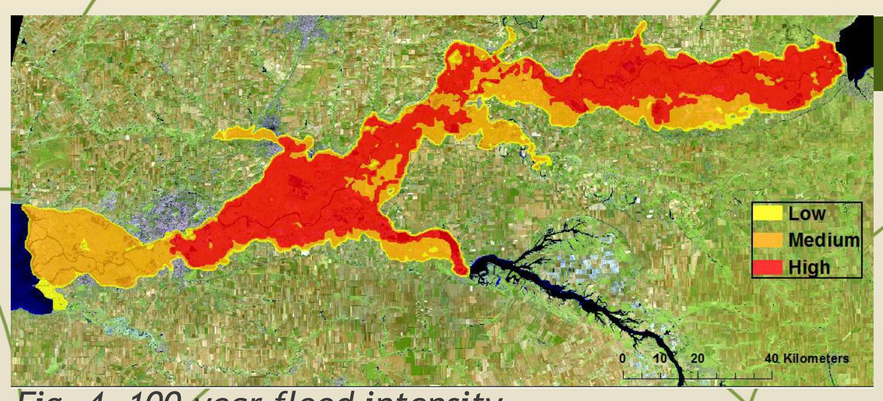


*Fig. 4. 100-year flood intensity*

## Results and Discussion

The urbanized areas in the Don floodplain were identified using supervised classification of Landsat satellite imagery. Although the total population of the Rostov Oblast in the considered time period slightly decreased (ROSSTAT 2014), the population within the study area, especially in the large and economically important cities, grew following the global urbanization trend (Fig. 2). The total built up area within the considered region (Fig. 2) increased by the 171 km2 from 1985 to 2013.

A flood routing model FLO-2D was used to define flow characteristics, delineate flood threatened areas and assess the risks. Five scenarios were selected for the simulations: 1) 1917 flood; 2) 1979 flood; 3) 20-year flood (5% probability); 4) 100-year flood (1% probability); 5) 1000-year flood (0,1% probability). Flood intensity, determined by maximum flow depth and maximum flow velocity, was selected as an indicator of flood hazard. Three flood intensity zones (high, medium, low) were differentiated to indicate flood risk. Taking the 100-year flood simulation as an example, we can see how areas with different flood intensity are distributed within the floodplain (Fig. 3).

The developed flood risk maps for the five simulated scenarios were combined with the urbanized areas identified through remote sensing for both considered years. As a result flood-prone urbanized territories for each scenario were acquired (Table 1). The territory of the flood-prone built up areas increased from 1985 to 2013 for each scenario.

The most endangered settlements on the floodplain were identified. One of the most risky area is the floodplain to the East from Rostov-on-Don. Though no large settlements located there, many existing newly constructed villages will be submerged in all scenarios. Simulations showed that no historical large settlements are endangered, since they are located on uplands, outside the floodplain (e.g. Rostov-on-Don, Novocherkassk). However, the existing development strategy and plans of the Rostov-on-Don agglomeration suggest city expansion to the floodplain area (Lagutov and Lagutov 2011). Moreover, some of the medium size settlements which were actively developed after the construction of the Tsimlayansk dam, like Bataysk or Volgodonsk, can be characterized as unsafe areas. The territories directly downstream the Tsimlyansk Dam were identified as the most risky.

| Scenarios | Year | Total affected area, km² | Flood intensity, km² | | |
|---|---|---|---|---|---|
| | | | Low | Medium | High |
| 1917 flood | 1985 | 88,92 | 10,22 | 45,07 | 33,63 |
| | 2013 | 121,17 | 16,38 | 62,43 | 42,36 |
| 1979 flood | 1985 | 18,81 | 7,02 | 10,76 | 1,03 |
| | 2013 | 19,04 | 7,85 | 10,18 | 1,01 |
| 20-year flood | 1985 | 64,15 | 14,58 | 38,27 | 11,30 |
| | 2013 | 84,59 | 22,50 | 51,85 | 10,24 |
| 100-year flood | 1985 | 80,28 | 11,46 | 44,71 | 24,11 |
| | 2013 | 107,74 | 15,82 | 63,45 | 28,47 |
| 1000-year flood | 1985 | 92,42 | 9,26 | 42,11 | 41,05 |
| | 2013 | 126,48 | 14,42 | 59,98 | 52,08 |

*Table 1. : Urbanization on the flood-prone areas*

## Conclusion

The urban expansion to the historically inhabited floodplain areas became possible due to the construction of the high-pressure Tsimlyansk dam, however, the dam cannot guarantee safety of the newly developed infrastructure downstream and communities must be aware of the risks. The most hazardous urbanized areas within in the Lower Don floodplain with highest flood hazard risk were defined, by simulating flood intensity for five scenarios. It was found that generally small villages on the river bank within the wide part of the floodplain would experience the most intense flood, together with the territory right under the dam. Currently most of the large historical cities lie within the safe uplands, however, some newly built settlements are situated at the of the low left bank as well as planned city district of Rostov-on-Don, which might be submerged in case of severe flood. The results acquired through this research might be of interest not only to local stakeholders (urban planners, local population), but also to a broader research community.

## References

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