REMOTE SENSING AND GIS FOR URBAN FLOOD RISK ASSESSMENT: LOWER DON RIVER CASE STUDY

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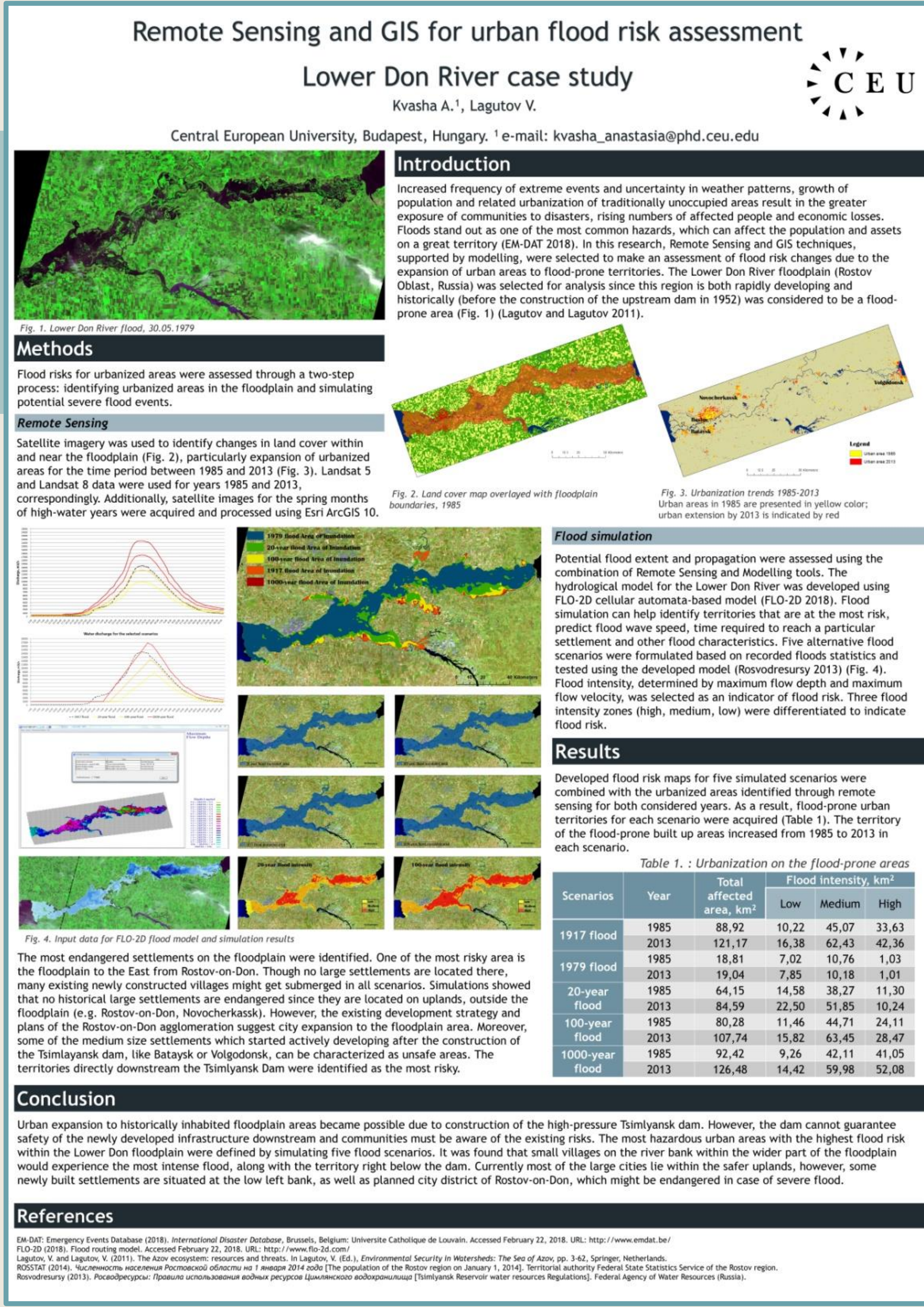
Floodplain Urbanization

- An assessment of changes in flood risk due to the 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 upstream dam in 1952) is considered to be a flood-prone area.



Remote Sensing and GIS for urban flood risk assessment

Lower Don River case study

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Fig. 1. Lower Don River flood, 30.05.1979

Introduction

Increased frequency of extreme events and uncertainty in weather patterns, growth of population and related urbanization of traditionally unoccupied areas result in the greater exposure of communities to disasters, rising numbers of affected people and economic losses. Floods stand out as one of the most common hazards, which can affect the population and assets on a great territory (EM-DAT 2018). In this research, Remote Sensing and GIS techniques, supported by modelling, were selected to make an assessment of flood risk changes due to the 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 upstream dam in 1952) was considered to be a flood-prone area (Fig. 1) (Lagutov and Lagutov 2011).

Methods

Flood risks for urbanized areas were assessed through a two-step process: identifying urbanized areas in the floodplain and simulating potential severe flood events.

Remote Sensing

Satellite imagery was used to identify changes in land cover within and near the floodplain (Fig. 2), particularly expansion of urbanized areas for the time period between 1985 and 2013 (Fig. 3). 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.

Fig. 2. Land cover map overlayed with floodplain boundaries, 1985

Fig. 3. Urbanization trends 1985-2013
Urban areas in 1985 are presented in yellow color; urban extension by 2013 is indicated by red

Flood simulation

Potential flood extent and propagation were assessed using the combination of Remote Sensing and Modelling tools. The hydrological model for the Lower Don River was developed using FLO-2D cellular automata-based model (FLO-2D 2018). Flood simulation can help identify territories that are at the most risk, predict flood wave speed, time required to reach a particular settlement and other flood characteristics. Five alternative flood scenarios were formulated based on recorded floods statistics and tested using the developed model (Rosvodresursy 2013) (Fig. 4). Flood intensity, determined by maximum flow depth and maximum flow velocity, was selected as an indicator of flood risk. Three flood intensity zones (high, medium, low) were differentiated to indicate flood risk.

Fig. 4. Input data for FLO-2D flood model and simulation results

Results

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

Table 1. : Urbanization on the flood-prone areas

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

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 are located there, many existing newly constructed villages might get 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. Moreover, some of the medium size settlements which started actively developing 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.

Conclusion

Urban expansion to historically inhabited floodplain areas became possible due to 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 existing risks. The most hazardous urban areas with the highest flood risk within the Lower Don floodplain were defined by simulating five flood scenarios. It was found that small villages on the river bank within the wider part of the floodplain would experience the most intense flood, along with the territory right below the dam. Currently most of the large cities lie within the safer uplands, however, some newly built settlements are situated at the low left bank, as well as planned city district of Rostov-on-Don, which might be endangered in case of severe flood.

References

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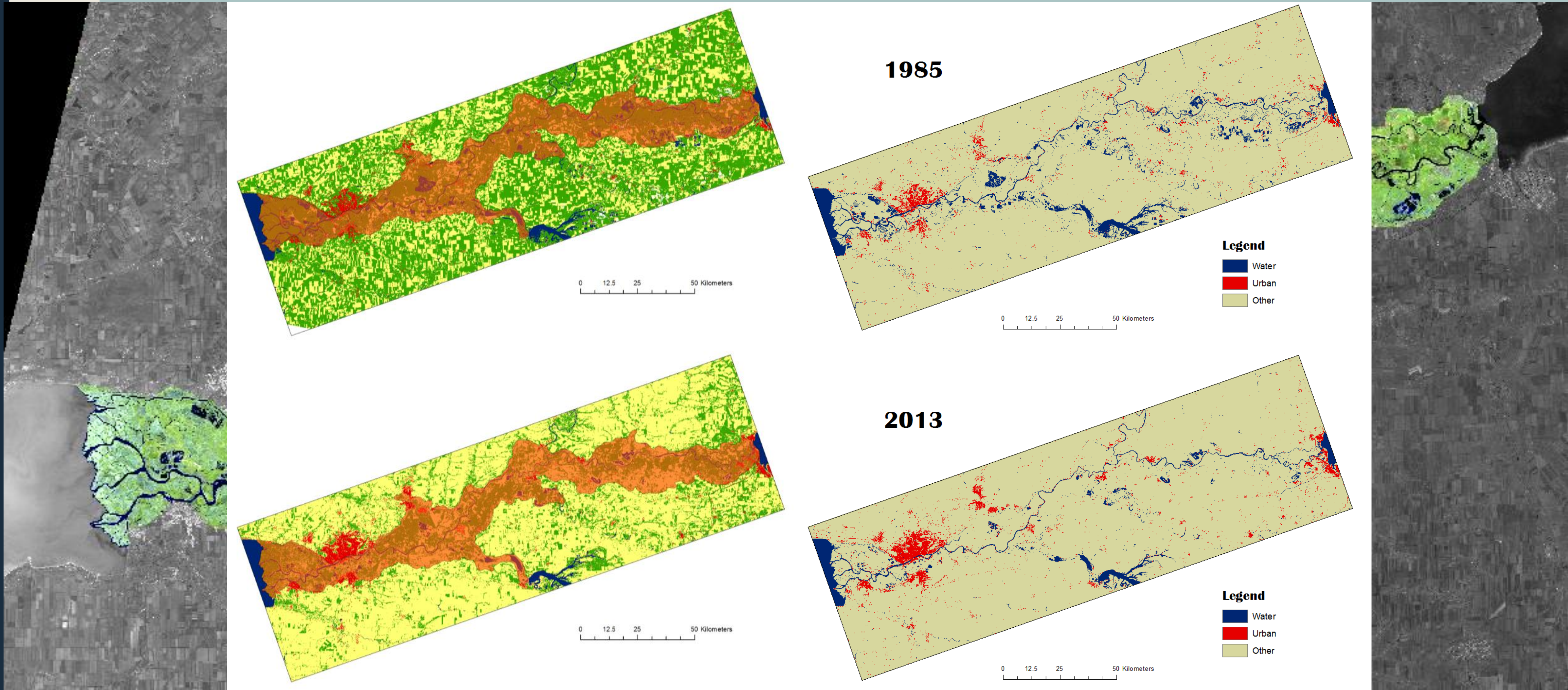
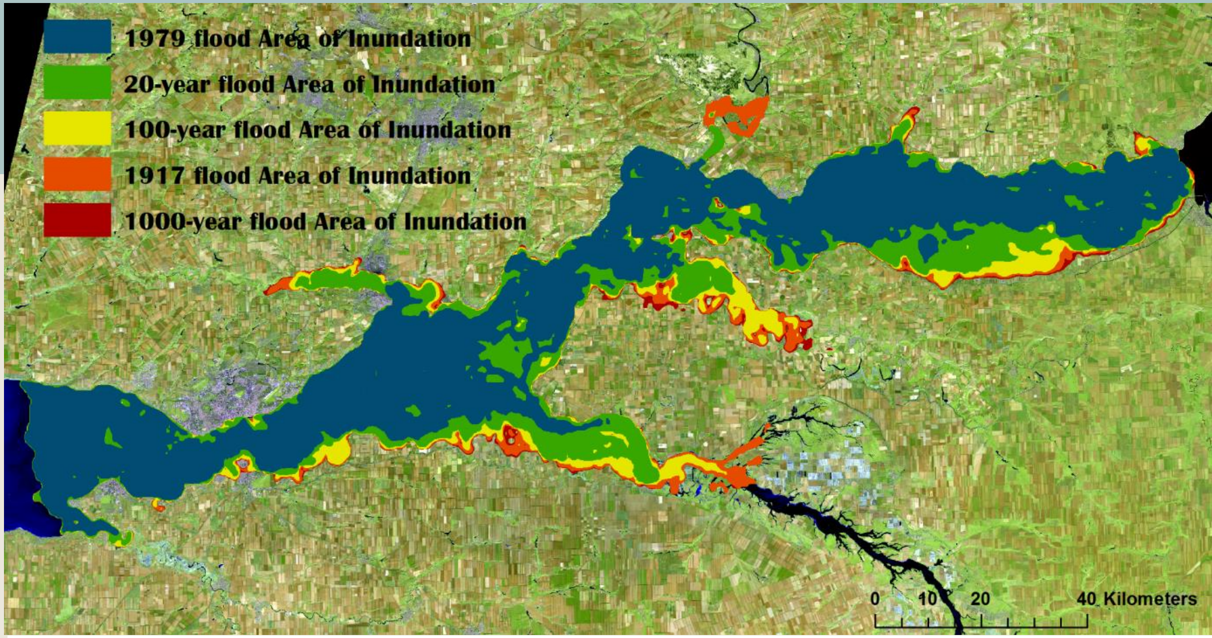
Identifying Urban Areas

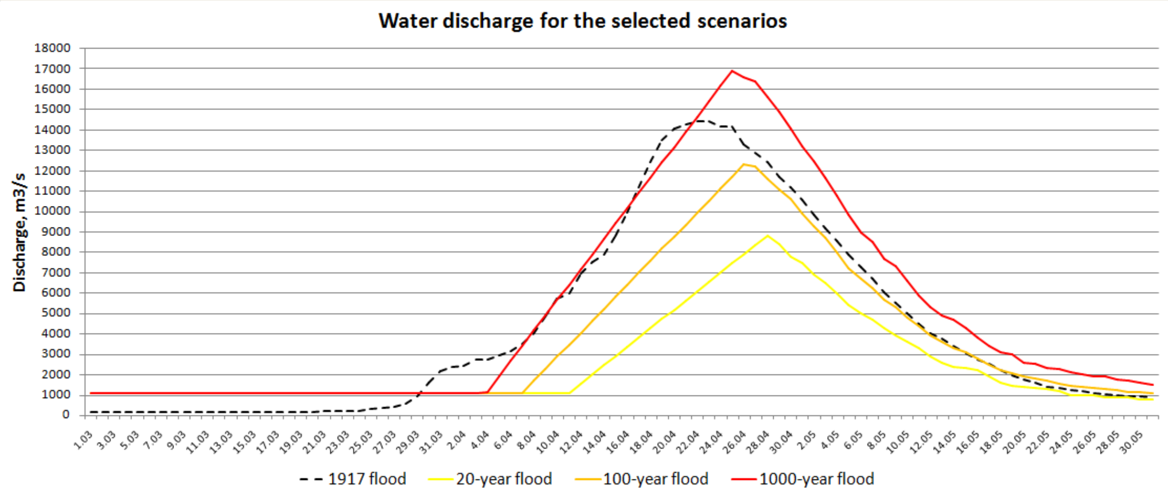


Flood Simulation

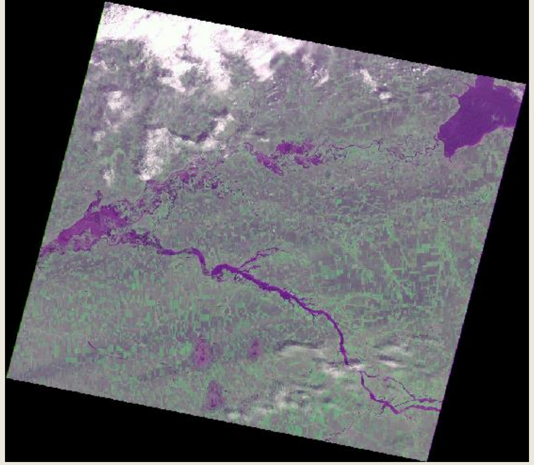
Five scenarios:

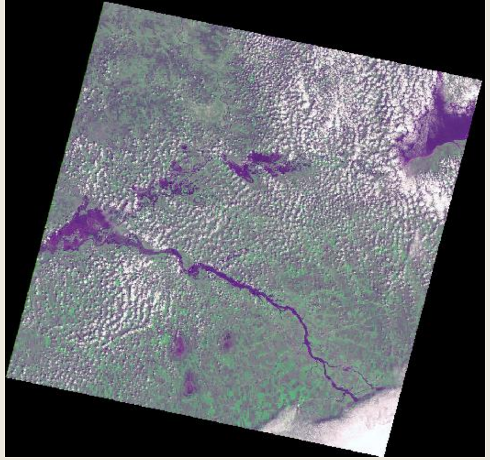
- 1917 flood;
- 1979 flood;
- 20-year flood (5% probability);
- 100-year flood (1% probability);
- 1000-year flood (0,1% probability).

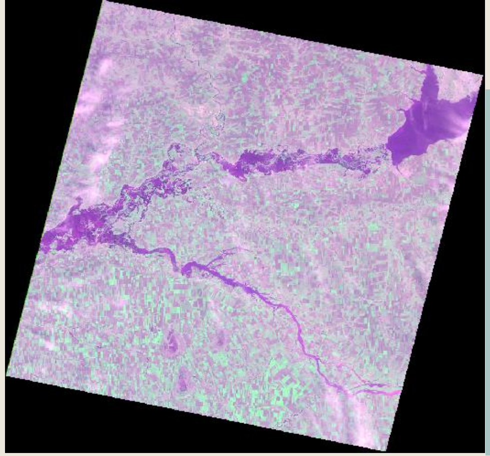


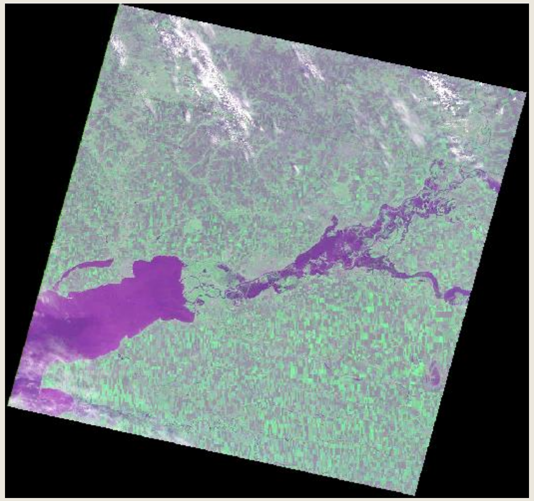


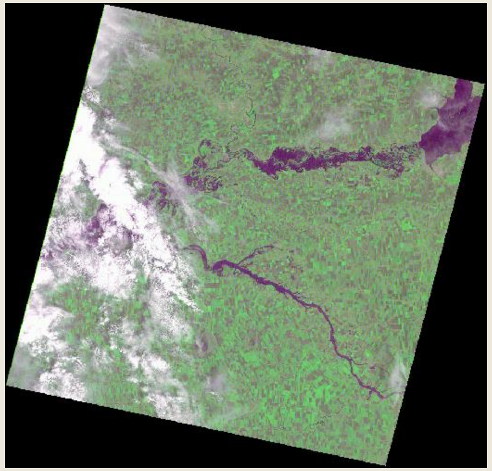
Lower Don River floods in 1979 and 1981

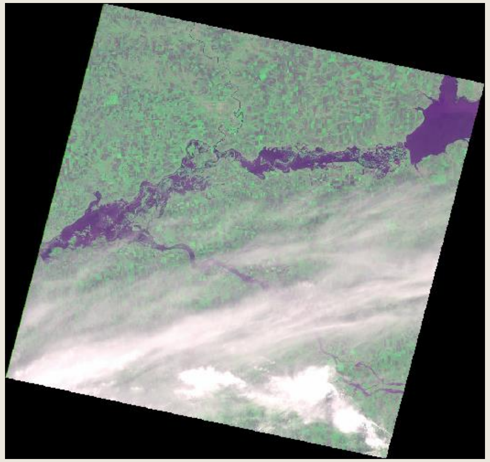


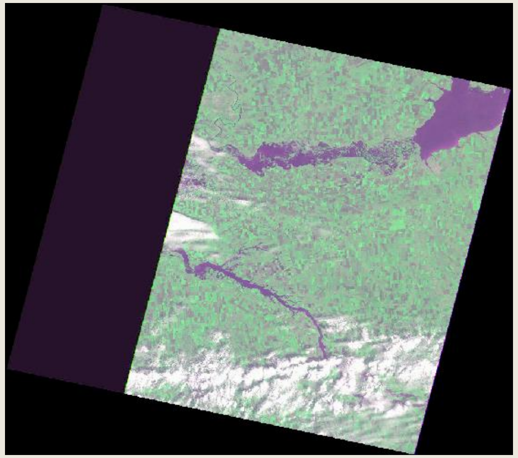


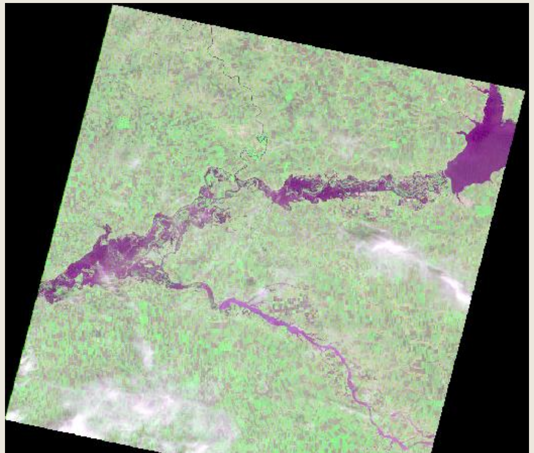


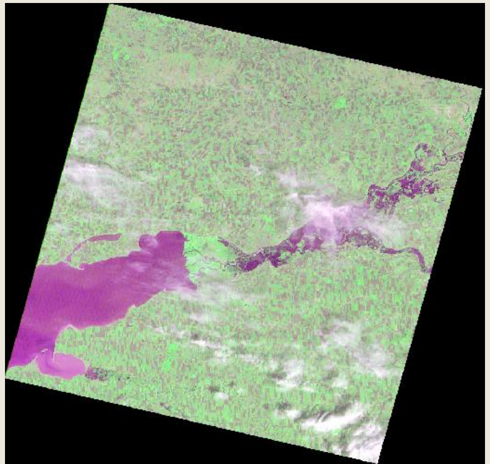


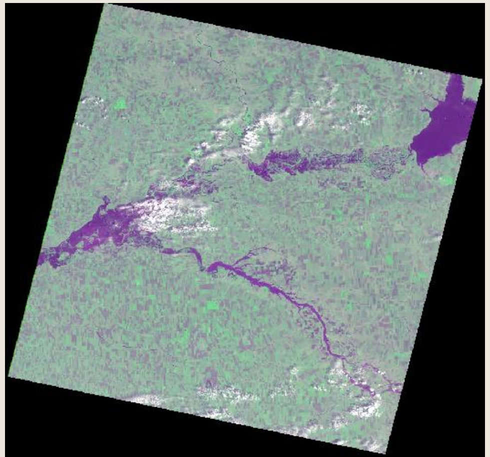


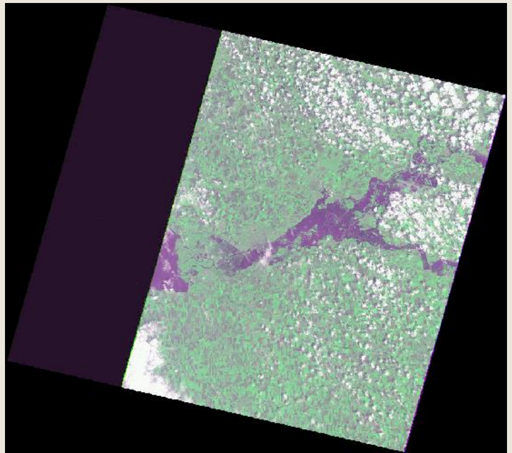






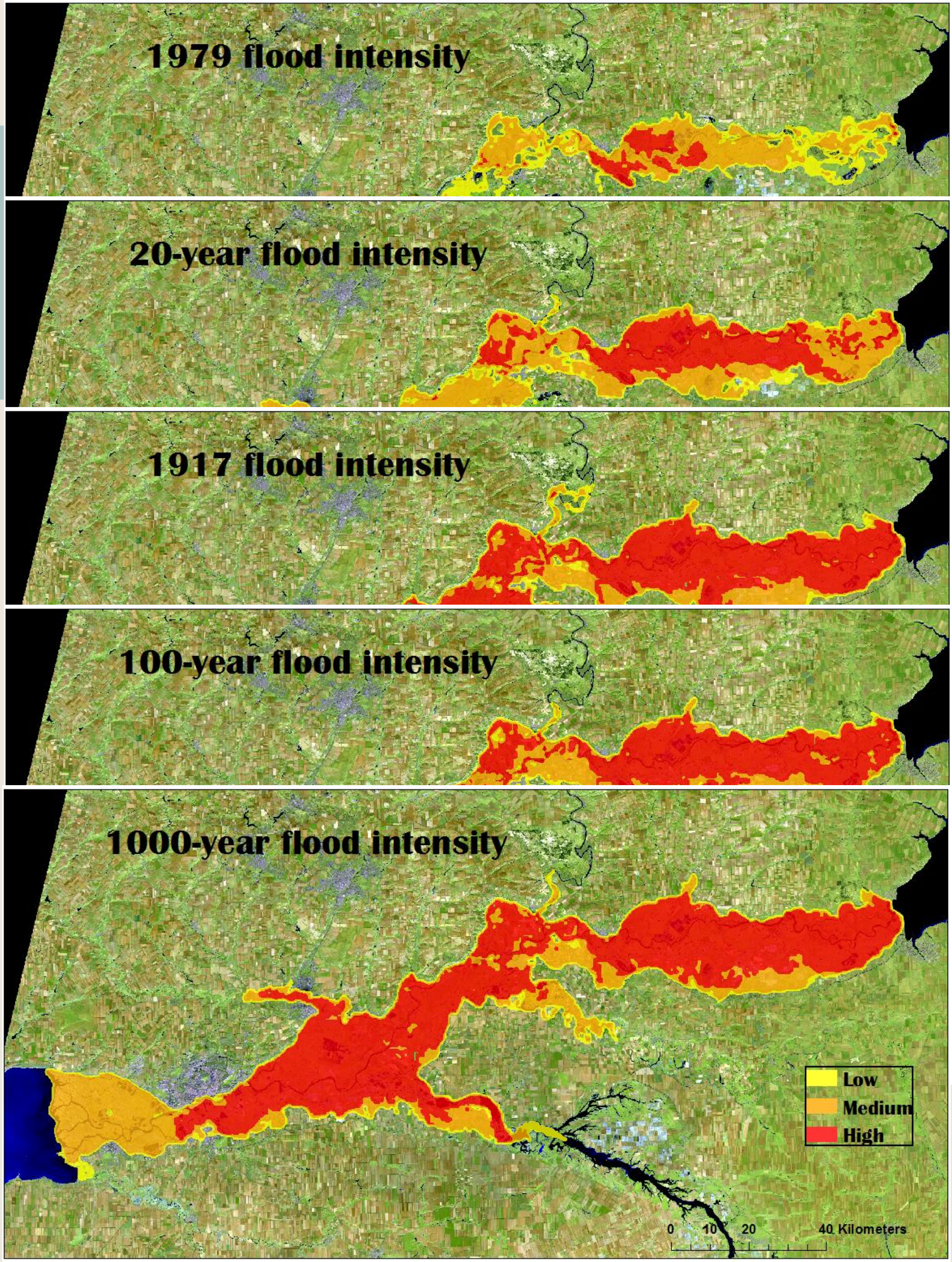






Results

Scenarios	Years	Total affected area, km2	Flood intensity					
			Low		Medium		High	
			km2	%	km2	%	km2	%
1979 flood	**1985**	18,81	**7,02**	37,32	**10,76**	57,20	**1,03**	5,48
	2013	19,04	**7,85**	41,23	**10,18**	53,47	**1,01**	5,30
20-year flood	**1985**	64,15	**14,58**	22,73	**38,27**	59,66	**11,30**	17,61
	2013	84,59	**22,50**	26,60	**51,85**	61,30	**10,24**	12,11
1917 flood	**1985**	88,92	**10,22**	11,49	**45,07**	50,69	**33,63**	37,82
	2013	121,17	**16,38**	13,52	**62,43**	51,52	**42,36**	34,96
100-year flood	**1985**	80,28	**11,46**	14,28	**44,71**	55,69	**24,11**	30,03
	2013	107,74	**15,82**	14,68	**63,45**	58,89	**28,47**	26,42
1000-year flood	**1985**	92,42	**9,26**	10,02	**42,11**	45,56	**41,05**	44,42
	2013	126,48	**14,42**	11,40	**59,98**	47,42	**52,08**	41,18



THANK YOU

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