Generating catchment typologies on river basin systems in Turkey for setting priorities in flood mitigation

Gülay Onuşluel Gül
Dokuz Eylül University,
Dept. of Civil Eng.,
Buca
Izmir, Turkey
gulay.onusluel@deu.edu.tr

Ali Gül
Dokuz Eylül University,
Dept. of Civil Eng.,
Buca
Izmir, Turkey
ali.gul@deu.edu.tr

Abstract

Floods are still considered among the most common natural disasters in Europe and the adverse impacts associated with floods are widely estimated to diversify and intensify due to changing climatic conditions. Flood maps effectively address priority locations for further examination toward flood preparedness, control, mitigation and recovery. They principally help scientific communities in orienting research interests by allowing case-study selections from threatened areas as well as the involved authorities in making/ implementing flood policies, taking necessary decisions and accomplishing relevant measures for an effective flood mitigation strategy. Flood mapping substantially relies on the availability of spatial data sources on different components involved in flooding process as well as the accuracy and precision of the data itself. Flood research in Turkey that mostly concentrates on local case-studies needs upscaling toward geographically wider assessments. This necessitates generation and use of larger-scale geographic datasets and expanded repositories on topographic, hydrologic, hydromorphologic, hydrographic and meteorological information. The presented study involves endeavors for obtaining a spatial typology for river basin systems in Turkey for depicting the ranked priorities in flood assessments. The geodatabase resulted from the CCM initiative by JRC is used as the main spatial object basis to this end. Despite the analytical strength of the database and concordance with the historically recorded national datasets, spatial incompatibilities (e.g. faulty hydrologic connections, insufficient bifurcation) in the database for different parts of the river basins are also discussed. In the very general sense, however, strong needs for continuous improvements in such sources of spatial information are emphasized through recommendations for integrating precise datasets at sub-national and/or national scales.

Keywords: Flood mapping, catchment typology, CCM2 dataset, micro-catchments.

1 Introduction

Floods are still considered among the most common natural disasters in Europe and the adverse impacts associated with floods are widely estimated to diversify and intensify due to changing climatic conditions. Flood maps are generally used by many stakeholders for spatial planning to prevent the build-up of new risks, reduce existing risks and adapt to changing risk factors (due to changes in ambient conditions and climate) [1]. Maps prepared in forms of event-, risk- or potential-based views effectively address priority locations that require further examination and necessary measures for flood preparedness, control, mitigation and recovery. For similar needs appearing in Turkey, the Disaster and Emergency Management Presidency operating under the Turkish Prime Ministry published a comprehensive report from the records of disaster events experienced in the period 1955–2008, where a number of flood maps are provided for administrative units as well as major river basins [2]. Right along with the event maps, another basic type of flood mapping is the flood potential map where a spatial characterization for floods is depicted through certain flood related variables (topographic, meteorological, hydrologic, etc.) by taking no account of most features relevant to flood hydraulics (runoff depths, velocities, etc.) or flood event probabilities.

Due to estimated impacts of global warming and the resulting climate change, intensification and frequency increases for future floods are greatly foreseen as a primary factor that governs flood management strategies and orients research initiatives in the world. This poses new challenges to researchers, water managers and policy makers at different scales [3] while requiring thorough understanding and common consideration of climate change estimations and flood risk assessments.

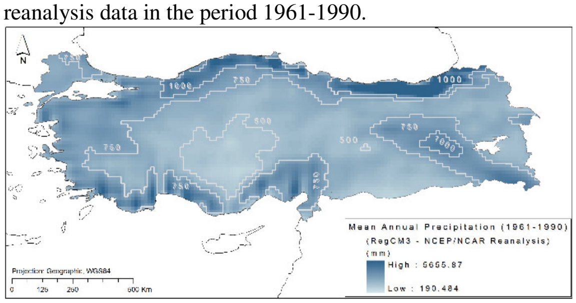
The presented study aims at providing a spatial basis for flood policy orientation in Turkey and is based on a relative assessment of a number of topographic, hydrologic and meteorological factors over the catchment units constituting river basin systems. A typology based on a spatial and multi-criteria characterization for micro-catchments is revealed with different flood potentials which eventually help spatially exhibit primary areas with notable flood potentials.

2 Data requirements and sources

The CCM2 geodatabase resulted from the Catchment Characterisation and Modelling (CCM) initiative by JRC [4] was used as the main spatial object basis in the presented study. The database holds detailed information on hydrographic features in European river basin systems starting from the smallest hydrological units up to larger-scaled agglomerations which form parts of bigger river systems and corresponding drainage catchments. In the study, the smallest possible catchment units, so-called micro-catchments, were considered in the analyses with the use of complementary attribute information such as unit catchment areas, stream ordering and downstream drainage identification between neighbouring units.

Information on land use or land cover as proxy to land use was obtained from the Corine Land Cover (CLC) data sets generated for the years 2000 and 2006 in Turkey. The required climatic variables for characterizing catchments were mainly adapted from two sources. Rainfall depths for standard and relatively shorter time periods (from less than an hour up to 24 h) were obtained from the Frequency Atlas of Maximum Precipitation in Turkey [5]. Long-term annual averages of climate variables, on the other hand, were computed from the data outputs of a national research project implemented for contribution to the climate change assessments of Turkish State Meteorological Service (DMI) [6] (Fig. 1).

Figure 1: Mean annual precipitation based on NCEP/NCAR reanalysis data in the period 1961-1990.



All dams built with flood mitigation purposes in various reservoir capacities were extracted from the national database of the State Hydraulic Works as well as the international sources of ICOLD (International Commission on Large Dams).

3 Methodology

Priority ranking between catchment units with the final objective of performing a characterization based on flood assessment priorities was conducted in the study through a set of spatial indices derived from topographic, hydrologic, meteorological and land use-related phenomena.

3.1 Index-based characterization based on relative catchment characteristics

The indices included the average slope index (S) computed for individual micro-catchments to represent average terrain slopes within the corresponding drainage areas, the open spaces (OS) index expected to represent relative share of non-vegetated and impervious surfaces which trigger flood occurrence within catchment units, four other indices (PR, TR, PS, and TR) representing precipitation and temperature conditions in the reference period 1961-1990 and the selected scenario period 2010-2039 (Fig. 2), high altitudes share (HA) and temperature change in high altitudes (TCHA) indices to approximate snow melting impact on flood conditions in catchments (Fig. 3), forest cover index (FC) for representing the positive aspect of flood cover on flooding, reservoir storage index (RES) to involve the positive contribution of storage reservoirs to flood mitigation due to their operations, and a separate index (DPR) for taking account of the rainfall depths for standard durations (5, 10, 15, 30 min and 1, 2, 3, 4, 5, 6, 8, 12, 18, 24 hrs), which are estimated to have considerable significance on flood occurrence due to higher intensities.

Figure 2: Spatial distribution of the reference period precipitation index at the micro-catchments level.

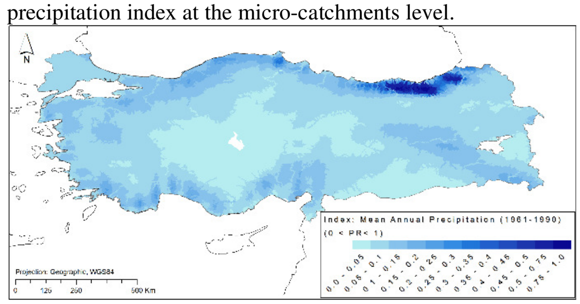
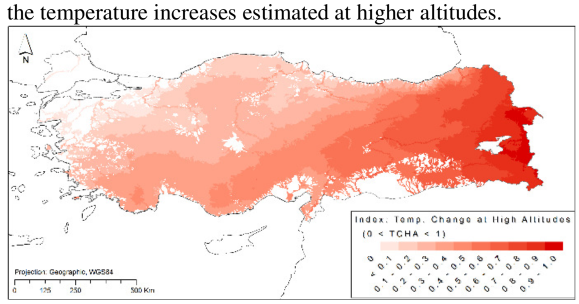


Figure 3: TCHA index generated for micro-catchments from the temperature increases estimated at higher altitudes.



3.2 Thematic combination of catchment indices for spatial characterization

Separate indices generated for the micro-catchments belonging to larger river basin systems are mainly designed for a generic typology of the basin systems to reflect the priorities for a more targeted orientation of potential flood studies in the future. Each index gives an insight into the local/regional classification with respect to the specific issue of concern, but individually is somehow insufficient to reflect the general view especially when the flood phenomenon with its multi-criteria nature is considered. To this end, all spatial indices were transferred into spatial index groups to acquire thematic compositions with more rational indications on flood priorities (Fig. 4).

As the index components considered in generating the final distribution of priority catchments were primarily employed to represent average conditions for various physical, hydrologic, topographic and meteorological factors in the associated drainage areas, the resulting priority ranks actually indicate the priorities assigned to the micro-catchments due to the physical characteristics of their upstream (Fig. 5).

Figure 4: Setting priorities for catchment units based on the overall index combination.

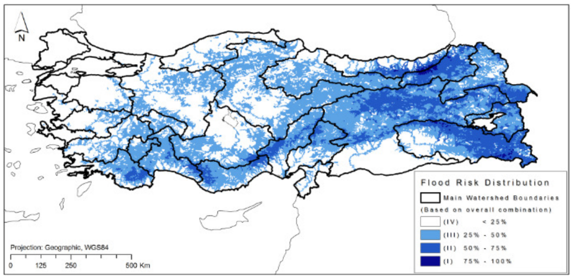
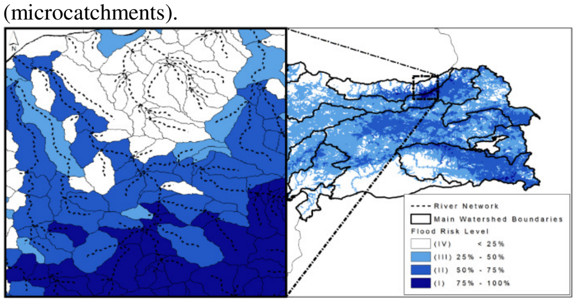


Figure 5: Zoomed display of analytical catchment units (microcatchments).

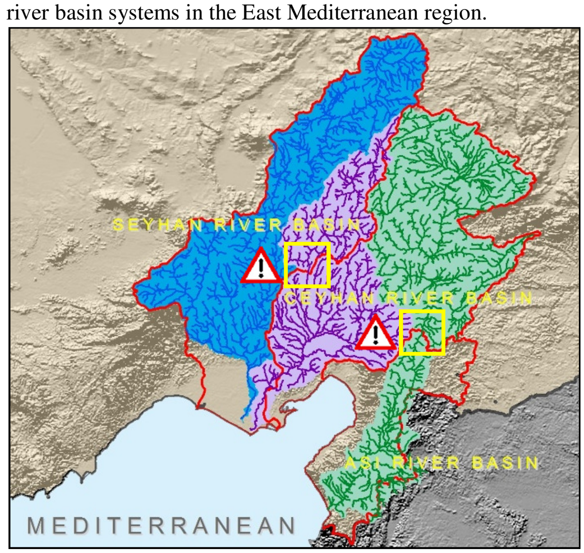


The highest flood potentials were estimated in the Eastern Black Sea River Basin System. This was an expected outcome as far as the dense precipitation pattern, potential snowmelt contribution and comparably higher terrain slopes are considered. Relatively smaller but still considerable flood potentials extend in the Eastern Black Sea region, in the upper sections of Fırat River Basin, Çoruh Basin, Dicle Basin and partially along the Mediterranean coastline.

3.3 Major drawbacks encountered with the use of spatial data sets

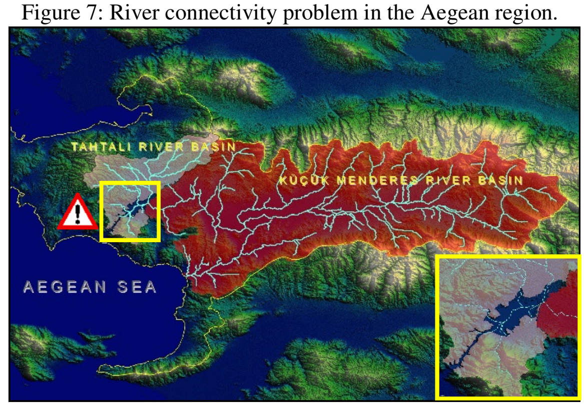
The accuracy of the series of computations and spatial operations followed in the presented study is correlated up to a great extent with the accuracy and precision of the spatial data sets. Spatial features embedded in the CCM2 database holds primary significance in this respect as they constitute the analytical basis of the spatial computations performed in the study. Despite the analytical strength of the database and concordance with the national datasets, spatial incompatibilities (e.g. faulty hydrologic connections, insufficient bifurcation) are still observed in the database for different parts of the river basin systems in Turkey. The level of accuracy in representing the hydrographic features and their mutual relationships is primarily governed by the digital terrain model considered and the inabilities arise from the poor definition of terrain elevations therein. Figs. 6-8 indicate such incompatibilities between the CCM2 data set and the national repositories in terms of the spatial display of hydrographic features. The most prominent problem stands with the inaccuracies in river connectivity, and thus the associated streamline ordering and basin area definitions. Three major river basins, Seyhan, Ceyhan and Asi Basins, neighbouring each other in the Eastern Mediterranen region are shown (in red) in Fig. 6. As can be seen from the figure, the mis-connectivity of the rivers results in significant problems in the spatial definition of the river basin boundaries. CCM2 river and subcatchment features extracted for this region seem to wrongly connect the river branches in the Eastern part of the Seyhan Basin with the Ceyhan River, while a greater part of the Ceyhan River connects again wrongly with the Asi River System in the south.

Figure 6: Mis-connectivity or loss of connectivity problem for river basin systems in the East Mediterranean region.



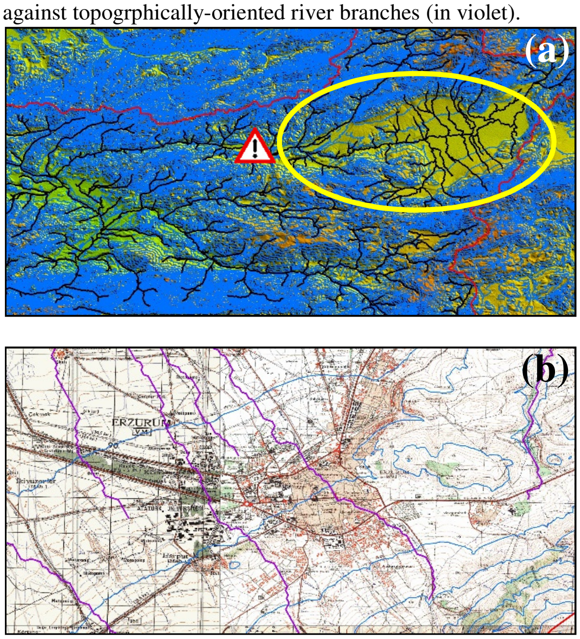
A similar drawback originating from the mis-connectivity of the stream lines in the CCM2 database results primarily from the available water bodies in the river network, where the connectivity rules go wrong without traversing the reservoir body, but jumping onto neighbouring basin systems. In Fig. 7, this inconsistency due to the presence of the Tahtalı reservoir in the Tahtalı Basin is shown in detail.

Figure 7: River connectivity problem in the Aegean region.



A basic solution for overcoming spatial accuracy problems as such can be the revision of the CCM data set through the use of the updated version of the ASTER GDEM elevation model in the place of or in combination with the SRTM model. The use of national datasets, which may include elevation contours and points digitized from photogrammetric materials, vector layers of storage reservoirs and natural water bodies, etc., may also be considered in support of increased accuracies over the globally-defined digital terrain models. Yet, some problems with the adequacy of the national vector data sources can still be expected in these efforts. In Fig. 8, a spatial example about the inability of vector elevation contours which especially relates to plain terrains is displayed. As can be seen in Fig. 8(a), elevation contour lines become wide apart around the plains of the Erzurum province in the East Anatolia, making it difficult to model flow accumulation lines in the river network. Besides, man-made hydraulic interventions in the forms of canals or closed conduits along the flow of drainage water bring in additional difficulties for displaying river connectivity and identifying catchment boundaries for different river segments (Fig. 8(b)). The level of detail gained through this consideration may not be so significant, and even, may be very difficult to attain when generating large-scale spatial data sets. However, it should be assured that slight divergence in spatial representations from the natural network conditions will not lead to improper connectivity for the rivers, and more importantly, will not end up with inaccurate catchment delineations.

Figure 8: Potential problems confronted when using national data sets in support to global DEMs. (a) Less frequent elevation contours in the lowlands of Erzurum, and (b) Raster image from the central Erzurum showing improved conveyance systems against topogrphically-oriented river branches (in violet).



4 Conclusions

Flood mapping, especially with extensive coverage, substantially relies on the availability of spatial data sources on different components involved in flooding process as well as the accuracy and precision of the data itself. Flood research in Turkey that mostly concentrates on local case-studies needs upscaling toward regional (or much wider in the sense of geographic representation) assessments. This necessitates the generation and use of larger-scale geographic datasets and expanded repositories on topographic, hydrologic, hydromorphologic, hydrographic and meteorological information, which would contribute to mapping accuracy and thus the performance of comprehensive assessments. This is indeed essential also for standardizing common spatial layers that will be used in different studies/projects with the desired accuracy and confidence.

Data sets originating from international sources may contain spatial errors at very local levels (e.g. river connectivity and basin delineation errors contained in the CCM2 database for Turkey's catchments) and faulty attributes assigned. As a matter of fact, one can expect this as far as the broad assessment objectives set for the generation of these data sets and exhaustive workload of collecting and combining data from quite heterogeneous sources are considered. Nevertheless, quality assurance for international data sets should be seen as an integral part of the studies at the national level to secure the derivation of accurate and consistent results. Periodic updates through the use of improved international datasets, integration of data from sub-national levels and national expert consultation can be considered useful to this end.

References

[1] G. Onusluel Gul. Estimating flood exposure potentials in Turkish catchments through index-based flood mapping. *Natural Hazards*, 69(1):403-423, 2013.

[2] O. Gokce, S. Ozden¸ A. Demir. *Spatial and statistical distribution of disasters in Turkey*: inventory of disaster information. Turkish Ministry of Public Works and Settlement, Ankara (in Turkish), General Directorate of Disaster Affairs, 2008.

[3] L. Feyen, R. Dankers, J. I. Barredo, A. de Roo, C. Lavalle. Climate change and floods in Europe. *Climate Change and Natural Hazards series 8*, Directorate-General for Research, 2007.

[4] A. L. de Jager and J. V. Vogt. Development and demonstration of a structured hydrological feature coding system for Europe. *Hydrological Sciences Journal*, 55(5):661-675, 2010.

[5] State Hydraulic Works (DSI). *Frequency atlas of maximum precipitation in Turkey*, vol. 1: Frequency analysis of point precipitations. Ankara, 1990.

[6] B. Onol, Y. S. Unal, H. N. Dalfes. Modelling the impacts of climate change scenarios on Turkey. *ITU Journal*, 8(5):169-177, 2009.