**Water resources and wetlands**, *Editors: Petre Gâștescu, William Lewis Jr., Petre Brețcan* Conference Proceedings, 14-16 September 2012, Tulcea - Romania ISBN: 978-606-605-038-8

# DETECTING RISKS FOR TURKEY'S WETLAND SYSTEMS IN TERMS OF RIVER FLOWS AND ENVIRONMENTAL FLOW REQUIREMENTS

### Ali Gul, Gulay Onusluel Gul, Aysegul Kuzucu

Dokuz Eylul University, Faculty of Engineering, Department of Civil Engineering, Tinaztepe Campus, Buca, 35160, Izmir, TURKEY

#### Abstract

Wetlands in Turkey, as a significant component of the protected areas network additionally containing national parks. nature protection areas, special protection areas (SPAs) and wild-life development areas, represent a very diverse set of ecosystems. They are, however, subject to considerable risks of biodiversity loss also arising from the changes in their hydrology as an expected consequence of the breaks in their natural water regimes, due to damming of rivers, the overuse of water upstream as well as hydrologic impacts of climate change. Maintaining the full spectrum of naturally occurring flows in a river is almost impossible in Turkey's economically competing watersheds due to catchment landuse changes and accompanying water resources development. In this regard, environmental flow requirements, which generally refer to an ecologically acceptable flow regime designed to maintain a river in an agreed or predetermined ecological state, should represent a compromise between water resources development on one hand, and river ecology maintenance on the other. Quantifying this demand, however, is a difficult task due to the lack of both the understanding of, and quantitative data on, relationships between river flows and multiple components of river ecology. The major criteria for determining environmental requirements include the maintenance of flow variability. In the presented study, over 35 wetlands belonging to different ecological regions in Turkey are assessed together. The changes in the water regimes observed in the period 1960-2000 are considered together with concurrent ecological conditions (so-called environmental management classes). The desktop approach integrated into the Global Environmental Flow Computation (GEFC) software of the International Water Management Institute (IWMI) is implemented for all analyzed sites in several steps by considering, in the first step, a period-of-record flow duration curve (FDC), i.e. a cumulative probability distribution function of flows. Once such a curve is determined, it is possible to convert it into an environmental FDC for any present ecological condition and finally actual environmental monthly flow time series. The monthly series of environmental flows computed in this wise are further analyzed in the study for the set of selected wetlands in order to reflect the spatially varying risks on wetlands collectively arising from human intervention and changing climatic conditions. The results are presented in different forms of indicator-based risk maps and graphs to help correlate biodiversity loss in wetlands to the decrease in environmental flows in course of time.

Keywords: Turkey's wetlands, environmental flows, flow duration curve, GEFC

### INTRODUCTION

Wetlands that provide fundamental ecological services and play an important role in the hydrologic cycle are sources of biodiversity at all levels ranging from species to large ecosystems. Their benefits vary from constituting a resource of great economic, scientific, cultural, and recreational value for the community to the contribution into climate change adaptation and mitigation (Ramsar, 2008). The diversity of habitats in a watershed or larger landscape unit is important for ecological functions associated with wetlands. Therefore, progressive deterioration of wetlands causes serious and sometimes irreparable environmental damage to the provision of ecosystem services.

Wetlands in Turkey, as a significant component of the protected areas network additionally containing national parks, nature protection areas, special protection areas (SPAs) and wild-life development areas, represent a very diverse set of ecosystems. Recently, there have been efforts for assuring and even promoting sustainable use of Turkish wetlands. The project on "Adaptation to Climate Change and Protection of Biodiversity through Conserving and Sustainably Using Wetlands in Turkey", just as a significant example among others, aimed at protecting wetlands, their ecological and socio-economic functions and their different uses in order to preserve them for future generations while taking into the account the effects of climate change (IUCN, 2012). Besides, there are examples from international collaborations that mainly targeted enhanced management of these vital systems, such as the project known as "Greek-Turkish cooperation for the enhancement of conservation and management of wetland resources" that was developed as a co-initiative (MedWet, 2012). National Climate Change Action Plan, prepared by Turkish involved authorities in 2011 for the future planning period 2011-2023, considers the potential role of wetlands in climate change adaptation and emphasizes the needs towards "identification and planning of

water resources that supply water to wetlands; putting in place measures to supply water needed by wetlands (reservoirs etc.) in a way to ensure effective management and sustainability of ecosystem services; erosion and deposit (sedimentation) control" (MEU, 2011).

Despite all efforts, Turkey's wetlands are still being threatened by drainage from the wetland area (mainly for agricultural utilization, etc.), prevention of natural water flows to wetlands by dam constructions, urban development on wetlands and/or surroundings (urban/industrial utilization), chemical contamination due to the industrial and household pollution, invasion of foreign/exotic species and unsustainable hunting/fishing/plant picking practices (Karadeniz et al., 2009). With regard to water-related problems, environmental flows prove herein to be a significant component for the maintenance of river ecology. These typical flows broadly refer to an ecologically acceptable flow regime designed to maintain a river in an agreed or predetermined ecological state. Environmental flow assessment and maintenance are, however, relatively new practices, especially in developing countries like Turkey (Karimi et al., 2012).

In the presented study, over 35 wetlands belonging to different ecological regions in Turkey are assessed together in terms of environmental flow requirements, and the changes in the water regimes observed in the period 1960-2000 are considered together with concurrent ecological conditions.

### Significance of Wetland Systems in Turkey

As regards the geographic extent of wetland systems as well as distinctive characteristics of biological diversity and particular features of ecosystem services valid in those areas, Turkey has a remarkable place both in Europe and the Middle East. Another important reason that Turkish wetlands hold global significance is the fact that two of the most important Western Palearctic bird migration routes pass through Turkey so that wetlands play a vital function for over than 457 different bird species (IUCN, 2012). This reasoning forced Turkey not to become a party to Ramsar Convention in 1994, but also to make targeted policies and produce legislative background for wetland protection. The Regulation on the Protection of Wetlands issued in 2002 and amended in 2005 is the primary legislative reference that directly serves for the implementation of the rules brought by the Ramsar Convention.

As the result of national surveys performed by the (obsolete) Ministry of Environment & Forestry (MEF) in Turkey to date, 135 wetlands that conform to the Ramsar definition reading that "wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres" were designated in Turkey. All these sites with international significances and conservation priorities occupy a total land of 2,155,045 ha. 13 of these; namely, Sultan Marshes in Kayseri, Lake Manyas in Balikesir, Lake Seyfe in Kirsehir, Goksu Delta in Mersin, Akyatan and Yumurtalik Lagoons in Adana, Kizilirmak Delta in Samsun, Lake Uluabat in Bursa, Gediz Delta in Izmir, Lake Burdur in Burdur, Kizoren Obrouk (Pothole) and Meke Maar in Konya and Lake Kuyucuk in Kars, have been given the "Ramsar Wetland" status within the framework of the Ramsar Convention. Apart from those areas, it is estimated that there are more than 500 smaller wetlands in Turkey which do not meet international designation standards as agreed for today. The ministry prepared wetland management plans for a set of wetlands with the contributions from local authorities, NGOs and interest communities for introducing sustainable management strategies in those areas.

### Selection of Study Wetlands and Data Harvesting

All wetland locations which were designated by MEF based on international standards were examined in the presented study versus river flow measurements that would help estimate environmental flow requirements by the wetland systems. River flow discharge data were compiled from the records of the two main authorities, Electrical Power Resources Survey & Development Administration (EIE) (obsolete) and State Hydraulic Works (DSI), which are jointly responsible for collecting data through their in-situ measurement facilities over the river systems. Assessments indicated that only 37 out of 135 wetlands could be included within the analyses set forward by the study due to the limitations with flow gauging stations that help adequately represent the flows arriving at corresponding wetlands. Fig. 1 shows the spatial distribution of the final selection for study sites on a display of 8 ecological regions slightly different from the geographic regions identified in Turkey.

For each of the selected sites, at least one monitoring station with sufficient temporal coverage and solid list of records was selected. As it always very difficult to assign stations located at the boundaries of wetlands where river flows enters into the wetland area, river discharge values were conveniently transposed into representative figures through weighting the numbers by the ratios of corresponding drainage areas. This would not bring in significant distortions between the originally recorded and transposed values as the

distances from actual station locations to wetland boundaries were quite small based on the selection criteria for the set of monitoring stations.



Figure 1. Spatial distribution of the studied wetlands in Turkey.

In computing drainage areas upstream to both the selected wetlands and flow gauging stations, CCM (Catchment Characterisation and Modelling) database, which was developed by the Joint Research Centre (JRC) and is composed of micro-catchments for all river tributaries and connected river segments, was utilized mainly (Fig. 2). In this wise, monthly average flow dataset was compiled as a collection of actual flow measurements from the stations and slightly converted values.



Figure 2. (a) Lake Beysehir wetland area and (b) river network, wetland boundary, flow gauge locations displayed onto the micro-catchments adapted from the CCM database.

### **Environmental Flow Requirements and GEFC Software**

Environmental flows for wetland systems are supplied by the quantities of water released into the river from a water storage facility or allocated from a natural flow with the intention of providing adequate amount of water for sustaining ecosystem functioning in wetlands (Onusluel Gul et al., 2010). In desktop approaches as a basic means of computing environmental flow requirements, monthly observed or modeled time-series data are assessed together with corresponding flow duration curves (FDC) provided that the monthly data would carry sufficiently representative information about flow variability for any meaningful hydrological analysis (Smakhtin and Anputhas, 2006).

The software package, Global Environmental Flow Calculator (GEFC), developed by the International Water Management Institute (IWMI) uses this rationale and provides a rapid desktop assessment of environmental flows from monthly records (Fig. 3). The objective ecosystem conditions are described in six environmental management classes ranging from unmodified to critically modified conditions, and the management class best suited for the river in question is to be selected in environmental flow calculations. Although it is widely known that the ecological integrity of river ecosystems depends on their natural dynamic character, maintaining natural flow patterns in rivers is normally impossible due to

water resources development and catchment land-use changes (Smakhtin and Eriyagama, 2008). Considering this, environmental flows do not necessarily require restoring the natural, pristine flow patterns but, instead, are intended to produce a broader set of values and benefits from rivers than from management focused strictly on water supply, energy, recreation, or flood control. Environmental flows should therefore be seen as a compromise between river basin development and maintenance of river ecology and considered as means of maintaining an ecosystem in, or upgrading it to, a desired future state through selection of environmental management class and a complementary strategy (Smakhtin and Anputhas, 2006; Smakhtin and Eriyagama, 2008).



Figure 3. Sample view from GEFC software interface.

## **Applied Methodology**

As part of the comparative assessments on the selected set of wetlands in terms of long-term average river flow and environmental flow conditions required for sustaining biodiversity and ecosystem functioning in these systems, a series of spatial analyses were performed. In the first run of spatial assessments, a basic indicator was generated by comparing surface areas of wetlands (WA) to total drainage areas (DA) that contribute to river flow draining downstream up to wetland boundaries (Fig. 4). For spatial display purposes, the computed ratios originally ranging in a quite different scale were then transposed into new figures by stretching indicator values between 0 and 1 by means of dividing each figure by the computed maximum. In this approach as for the computations based on area proportioning, it is always possible to obtain similar figures both for larger drainage areas feeding larger wetlands and much smaller areas draining into comparable smaller wetlands. This indicator gives anyway the possibility of roughly comparing between relative shares of drainage areas that correspond to unit wetland sections.



Figure 4. Spatial distribution of the rate of wetland drainage area to wetland surface area

However, relative size of a drainage catchment in proportional terms of wetland areas does not carry enough knowledge about the conditions of wetland systems aimed to receive desired quantities of water for sustainable wetland management. Indeed, there are other factors such as local meteorological conditions, physiographic characteristics of drainage areas, catchment land uses, etc. which collectively makes impact upon mean annual runoff (MAR) quantities arriving at wetlands. In this regard, another comparison was followed in the study based on MAR values that were computed from monthly discharges in the period 1961-2000 in order to include enough indication on average flow conditions and total resource capacities as a consequence of all factors significant in catchment-wide runoff generation (Fig. 5).



Figure 5. Comparing wetlands in terms of MAR quantities computed in the period 1961-2000

Although MAR estimates provide some sort of indication about water availability, it is environmental flows that actually indicate the quantities of water consumed through wetland ecocsystem functioning and required for securing/promoting an effective wetland management in environmental terms. For computing environmental flow requirements with the use of GEFC in the study, environmental management classes were first needed to be estimated. For these estimations, biological diversities and ecological health states in the selected 37 wetland systems were estimated through certain analyses. Fig. 6 indicates the spatial distribution of species from different taxonomic groups which were mainly considered in computing biodiversity estimates. Species distribution information for 6 wetlands in totally 37 (Firtina Stream, Karadere, Avlan, Kovada and Nazik Lakes, and Aksu Delta) were, however, lacking in the reference document prepared by Doga Dernegi, an NGO acting on environmental protection (Eken et al., 2006).

For generating biodiversity estimates, the biological concept of species evenness, which was developed through the mathematics of information theory and which refers to how close in numbers each species in an environment are, was used as a measure of biodiversity to quantify how equal the community is numerically. Fig. 7 shows the variation of biological diversity between different wetlands considered in the study, again lacking some figures for the aforementioned 6 wetlands with missing species information.



Figure 6. Distribution of species in the selected wetlands

Ecological health issue with regard to the biodiversity loss, or the sustainability of ecosystem functioning in much general terms, was assessed through the list of criteria set forward as red list by the International Union for Conservation of Nature (IUCN). In this assessment, some ranked indices were

assigned to the categories ranging from "extinct" species to those with "least concern", an overall index for each wetland was computed by population-weighted averaging and biodiversity health conditions were finally assigned based on the finally ranked indices that again correspond to individual categories within the IUCN red list (Fig. 8).



Figure 7. Biodiversity (species evenness) index computed for the analyzed wetlands



Figure 8. Assessments for ecological health conditions in the analyzed wetlands.

In the final step of environmental management class determination, biodiversity and ecological health indices were combined in the form of a compound index obtained by geometric averaging. In the light of this final index, suitable environmental management classes were assigned for the analyzed wetlands for taking account of management strategies in the computation of environmental flow requirements. Normally, increased quantities of environmental flows are intended to be allocated for sites either with higher indications of biological diversity or for those areas accommodating critically threatened species to restore functioning of ecosystems. While allocating environmental management strategies for the analysed set of wetlands in the study, this logic was considered so that sites with higher index values (resulting from higher biodiversity and poorer ecological health indices) would get bigger quantities. Fig. 9 shows the direct assignments of desired environmental management classes for the 37 wetland systems. Here, the management classes E and F that indicate comparably poorer ecosystem conditions (or may result in considerable deterioration in conditions) are sometimes not considered acceptable from the management perspective and the intention is to promote management plans up to the least acceptable Class D (DWAF, 1997; Smakhtin and Anputhas, 2006). For this reason, the only site, Kocacay Delta, which was originally

grouped in Class E was again considered to be managed by Class D strategy, thus foreseeing to allocate slightly higher flows than the quantities originally dictated by its corresponding index value.



Figure 9. Assignments of the desired environmental management classes for the wetland systems.

According to the assigned management strategies, environmental flow requirements were then computed as time-series data by using the GEFC software. In these computations, the entire period 1960-2000 was equally divided into two periods and the period 1960-1980 were selected as the reference period. Environmental flows were then computed for the period 1980-2000 accordingly. The rationale behind this process was simply that the underlying criteria (biodiversity and ecological health indices) that were used in defining desired environmental management strategies (or classes) substantially represent ecological conditions estimated for the period 1980-2000. Prior to the computation of environmental flow requirements for the second period, flow duration curves (FDC) (or cumulative distribution functions of flows) were generated both for the periods 1960-1980 and 1980-2000, and the recorded river discharges of the second period were adapted to the FDC of the first period by considering the same exceedance probabilities. This allowed generation of two different time-series for environmental flow requirements, first by using the original river discharge series observed in the period 1980-2000 and second by considering the adapted discharges again for the same (i.e. second) period, but assuming that flow conditions of the first period is preserved. In Fig. 10, FDCs obtained from the two different periods are shown for two different-styled variations; decrease in discharges for the Gediz Delta case against the increased discharges of the Firtina Stream between the two periods.





### **Results and Discussion**

River flow data obtained from the records of stations identified for individual wetlands in the study were classified into seasonal groups and long-term seasonal average flows were computed for two

subsequent periods 1960-1980 and 1980-2000. Figs. 11-13 shows the mean seasonal flows for wetlands grouped under a certain combination of ecological regions designated in Turkey.



Figure 11. Seasonal average flows observed for wetlands in the Aegean, Mediterranean-Transition and Mediterranean ecological regions



Figure 12. Seasonal average flows observed for wetlands in the Black Sea and Marmara-Transition ecological regions

The analyses performed by adapting river discharges of the period 1980-2000 to those of the previous (or reference) period 1960-1980 for assessing on-going environmental flow demands by the biological assets inherited from the reference period, and then by computing environmental flow time-series considering both the adapted flow conditions and the actual conditions of the period 1980-2000 provided results that served potentials for computing deficits and/or surpluses in environmental flow terms. Fig. 14 displays environmental flow time series estimated under the adapted and original flow conditions in the period 1980-2000. As can be seen in the figure, environmental flow requirements for the Gediz Delta case seem to be much higher than those originally provided (both estimated under the same kind of environmental management), while for the Firtina Stream wetland case, current conditions seem to allow slightly higher environmental flow entries into the wetland area than those of the reference period, with a potential indication of upturn in terms of ecological performance of the wetland.



Figure 13. Seasonal average flows observed for wetlands in the Central and Eastern Anatolia ecological regions



(b)

Figure 14. Difference between the environmental flow requirements computed from original river flows in the 1980-2000 period and flows adapted from the 1960-1980 period: (a) Gediz Delta and (b) Firtina Stream cases

Similar results are presented in Fig. 15 for all wetland systems analyzed in the study in terms of the average deficit/surplus discharges as an indication of the differing conditions between the two evaluated periods. When the wetlands are examined in term of environmental flows, different patterns can easily be distinguished between the eastern and western wetland systems in Turkey with general deficiency indications in the west in contrast to the slightly positive figures of the East. Besides, estimated impacts of changes between the observed conditions of the second period (i.e. 1980-2000) and "business-as-usual" scenario conditions adapted from the reference period again for the second period are normally more remarkable for wetland systems fed from larger drainage areas.



Figure 15. Spatial distribution of EFR deficit/surplus quantities computed for wetlands based on differences between original and adapted flow conditions

### CONCLUSIONS

Apart from site-specific indications about river and environmental flow quantities arriving at the analysed wetland systems, observed impacts of changes in environmental flow conditions, potential drawbacks in terms of ecological performances and associated ecosystem vulnerabilities, some general conclusions that may be achieved by assessing the general analytical framework in the presented study can be listed as follows:

- (1) Enhancements in spatial data and improvements in spatial processing techniques greatly contribute to the performance of comprehensive studies as such for assessing wetland conditions in terms of the desired sustainability objectives. Major gaps in necessary data and associated data quality problems prevent and/or negatively affect the overall performance expected from the study.
- (2) Although flow monitoring networks have been considerably improved in Turkey for many years in a way to achieve an optimized network structure, the fact that river flow gauges are mostly located for some specific purposes such as flood control, design and operation of hydraulic structures, river flow data that would help adequately represent flows arriving at wetlands or other areas of environmental priorities is still very limited in spite of the fact that environment today is recognized as a sector that needs to be properly integrated within water management schemes. Some stations dedicated for measuring the flow of water into wetlands would contribute to wetland management through facilitated analytical assessments.
- (3) Assessments on water quantities will unquestionably help assess wetland conditions in terms of the needs for water, but water quality component is always to be considered as integral part in these assessments especially for river systems under heavy pollution loads. For wetland management strategies, this will additionally require collection of simultaneous data on water quality as well.
- (4) There is always the need for integrating climate change concerns into similar studies in order to effectively estimate feature conditions, anticipate potential future threats on wetland systems and take necessary proactive measures.

### Acknowledgements

The authors thank to Vladimir Smakhtin (IWMI) and the GEFC team for sharing their experiences and the software, and also to M. Sahin Dogan for his contribution into the early stages of the presented study.

### REFERENCES

Eken G, Bozdogan M, Isfendiyaroglu S, Kilic DT, Lise Y. (2006). Significant Nature Areas in Turkey. Doga Dernegi, Ankara, Turkey.

IUCN (2012). "Adaptation to Climate Change and Protection of Biodiversity through Conserving and Sustainably Using Wetlands in Turkey" project, implemented by the Turkish Ministry of Forestry and Water Affairs in Turkey and National Parks and GIZ – German International Cooperation. http://iucn.org/about/union/secretariat/offices/Europe/?9779/ Adaptation-to-climate- change-throughwetlands (accessed 01 June 2012).

- Karadeniz N, Tırıl A, Baylan E. (2009). Wetland management in Turkey: Problems, achievements and perspectives. African Journal of Agricultural Research Vol. 4 (11), pp. 1106-1119.
- Karimi SS, Yasi M, Eslamian S. (2012) Use of hydrological methods for assessment of environmental flow in a river reach. International Journal of Environmental Science and Technology Vol. 9 (3), pp. 549-558.
- MedWet (2012). Greek-Turkish cooperation for the enhancement of conservation and management of wetland resources. http://medwet.org/2010/03/greek-turkish-cooperation (accessed 10 June 2012).
- MEU (Turkish Ministry of Environment and Urbanization) (2011). National Climate Change Action Plan 2011-2023, coordinated by The Ministry of Environment and Urbanization, General Directorate of Environmental Management, Climate Change Department, Ankara, Turkey.
- Onusluel Gul G, Rosbjerg D, Gul A, Ondracek M, Dikgola K. (2010). Assessing climate change impacts on river flows and environmental flow requirements at catchment scale. Ecohydrol. 3, pp. 28–40.
- Ramsar (2008). The introductory Ramsar brochure, 3rd ed., The Ramsar Convention on Wetlands.
- Smakhtin, V, Anputhas, M. (2006). An assessment of environmental flow requirements of Indian river basins. Colombo, Sri Lanka: International Water Management Institute. 42p. (IWMI Research Report 107).
- Smakhtin VU, Eriyagama N. (2008). Developing a software package for global desktop assessment of environmental flows. Environmental Modelling & Software, Vol.23 (12), pp. 1396–1406.