Application of the DPSIR model in a transboundary river basin (Aoos/Vjosa): success or failure to achieve good ecological status

Nıtsa T.[1], Latinopoulos D.[1] And Kagkaloy I.[1,*]

[1] Dept. of Civil Engineering, School of Engineering, Democritus University of Thrace, Xanthi, Greece,

*corresponding author:

e-mail: ikagkalo@webmail.duth.gr

Abstract.

The European Water Policy introduced the necessity to apply new methodological approaches for water resources sustainable management. The incorporation of the EU Water Framework Directive (WFD) – 2000/60/EC and the "Sister Directives" (Flood and Habitat), as an obligation by all Member States, set the basis for catchment-based governance for successful water quality and quantity management in transboundary river basins. Aoos/Vjosa is the largest river of Epirus geographical region (NW Greece) flowing through Albania and discharging into Adriatic Sea. The Driving Force-Pressure-State-Impact-Response (DPSIR) model was applied as framework for the case study of the transboundary Aoos river basin. The ecological classification of the Aoos River, based on WFD criteria, indicated definite impact caused by human activities. The results of the present paper might support an integrated management identifying the restoration priorities for the study area

Keywords: DPSIR, WFD, Pollution Assessment, Transboundary River Basin Management

1. Introduction

It is nowadays broadly accepted that the qualitative and quantitative status of freshwater resources reflect the societies' wellbeing (Millennium Ecosystem Assessment, 2005). On the same time, the anthropogenic pressure on freshwater resources is escalating and the way different stressors, caused by human activity, interact with each other synergistically, is getting more and more complex, causing issues of augmented importance and degradation problems (Osmerod *et al*., 2010 Latinopoulos *et al*., 2016). Thus, a necessity to develop water resources management methods that can approach such issues in a holistic manner, arises. Greece is considered to be a country with a complicated administrative and legislative framework dealing with water (Podimata & Yannopoulos 2013). The Water Framework Directive came to improve management practices aiming at coordination of all "players". The river basin, as the study unit, refers to the ecological, hydrological and geological system ignoring national or other legislative borders. So all transboundary waters needed to be identified and included in special River Basin Management Plans (RBMPs). The development of monitoring protocols, prediction tools and management strategic plans for transboundary river basins promotes the environmental safety and builds strong relations between "stake-holding" States, easing interstate cooperation and coordination (Mylopoulos & Kolokytha, 2008).In such attempts, models can play a crucial role in growth and application of strategic management plans providing a general framework, where the diversity of several scenarios and solutions can be analyzed (Brugnach & Pahl-Wostl 2007), predictions can be made and indexes can be formed (Erturk *et al*., 2010). Conceptual models that provide comprehensive basis for the design of management projects can be used supplementary as decision support systems (Arhonditsis & Brett 2004). Aim of the present paper is the investigation and quantification of pressures in Aoos river basin and their correlation to the ecological status of the river bodies found in GR 11 Water District, in Epirus Geographical Region (EL05) as shown in Figure 1. For this attempt, the use of DPSIR model (EEA, 1999) set the conceptual framework as the better fitting tool serving and promoting WFD objectives.

2. Methodological approach

2.1. Study area

Aoos river basin is a transboundary one whose area (2141 km2) is shared between Greece (by 3 Prefectures) and Albania. A mixture of natural, environmental, economic and social characteristics makes it an intriguing field of study. Aoos River (length of 261 km) is the unique Greek upstream transboundary river that runs 70 km in Greek territory and the rest through Albania discharging into Adriatic Sea carrying $1150x10^6$ m^3 water annually. At its springs is established a hydropower station that diverts significant amount of water to an adjacent water system. The Epirus Water District is one of the most robust in Greece (Leontiadis & Nicolaou,1999). Aoos' two main tributaries are Sarantaporos and Voidomatis forming 3 sub-basins in Greek territory (Fig 1). The entire river basin has a highly mountainous terrain and is characterized as a biodiversity hot-spot including habitats under protection by both National (e.g. Vikos-Aoos National Forest, Northern Pindos National Park) and European (NATURA 2000 network) legislation (Fig 1). İn the same time is an area of important cultural heritage, touristic and economic activity.

2.2. DPSIR model as framework

This model was first developed by the European Environment Agency (1999) as a means to deploy status assessment indicators. İt is widelly used in case studies dealing with the aplplication of WFD since it can depict a dynamic situation as an actual one through snapshots-instants of a continuusly evolving system and highlighting the relations between its components. According to the DPSIR framework, there is a chain of causal links starting with "driving forces" through "pressures" to "states" and "impacts" on ecosystems and eventually leading to "responses" (policy).

2.3. Source of information, Data sets

The data sets used for the purpose of this research were the most updated available ones. From the Hellenic Statistical Authority (ELSTAT) derived the intensity of touristic activity (2015 annual inventory), of aquacultures' capacity and other industrial uses of water (2014 annual inventory), and the population for domestic and shepherd livestock as long as the areas of arable land and the type of crops (2013 annual inventory). When there was a gap of information, like in the case of the aviaries, the data were provided by the Payment and Control Agency for Guidance and Guarantee Community Aid (OPEKEPE 2015). Corine Land Cover 1990-2000-2006-2012 were used for the identification of land uses and their alteration during the last 20 years. Especially for the selection of the eligible forage areas, Corine Land Cover 2012 data were evaluated taking into consideration the guidelines of a technical review by the Ministry of Rural Development and Food. Physical and chemical status along with the biological status based in macroinvertebrates index were adopted from the First revised report of EL05 RBMP.

2.4. Pollution coefficients, rates and assumptions

Trying to be in line with the reviews to come for the RBMP we adopted fully the guidelines set by First Revision For the Management Plans for the 14 Greek Water Districts and the anthropogenic induced Pressures and Impact Assessment (Ministry of Environment and Energy 2015) concerning all rates and pollution coefficients deriving from all sort of activities. Different coefficients were applied depending on the type of crops and the intensity of cultivation, or the animals bred and the way their manure is handled. Diffuse pollution was calculated directly as loads on surface water in relation to soil permeability. Point sources were calculated as point pollution loads according to the treatment of waste produced by each activity. Facing unavailability of data and deficient service by the responsible authorities, several compromisations and assumptions had to be made. Since no Waste Water Treatment Plants (WWTP) are found in the river basin, we assumed all inhabitants are served by septic tanks. Domestic livestock was perceived as point sources along with the local community loads since the dynamics of holdings were low. Dealing with the 5 aviaries ($212x10^3$ chicken mostly for meat production) in the river basin, despite there were information on their position and functioning, no information was available for the 3 of them about their dynamics or waste treatment. In an attempt to not overestimate the production of pollution loads we assumed waste production coming only from their breeding and their manure being handled properly. Data on aquaculture were available for 3 units with large capacity of a total of 9 holdings recorded in the first RBMP. So we assumed that the rest 6 aquacultures have a capacity equal with the average capacity of freshwater aquacultures functioning in Ioannina Prefecture. Finally, data for touristic activity was available for the 42% of the available beds found in the Aoos Basin. Given the economic crisis no assumption was made for the rest of them and were perceived as empty throughout the year.

3. Results

Figure 1. *Aoos River basin - GR 11 showing the Natura 2000 network designated areas*

***Table 1**. Corine Land Cover changes from 1990 version until 2012 version in selected codes*

DESCRIPTION	CORINE CODE	AREA (km^2)			
		1990	*2000*	*2006*	*2012*
Permanently irrigated land	**212**	14.93	17.67	17.69	17.69
Complex cultivation patterns	**242**	18.45	15.69	12.48	12.48
Land principally occupied by agriculture	**243**	40.04	40.05	33.56	33.56
Broad-leaved forest	**311**	447.48	452.08	447.62	448.10
Coniferous forest	**312**	462.98	455.28	424.51	418.00
Mixed forest	**313**	255.77	255.36	254.92	252.53
Natural grasslands	**321**	244.71	237.96	226.65	225.62
Moors and heathland	**322**	9.17	9.17	6.77	6.77
Sclerophyllous vegetation	**323**	84.93	84.59	73.69	73.69
Transitional woodland-shrub	**324**	414.30	417.07	448.89	454.74
Bare rocks	**332**			18.06	18.06
Sparsely vegetated areas	**333**	79.56	79.18	101.01	101.01

3.1Driving Forces - Pressures

Main economic activities recognized in Aoos River Basin are agriculture, livestock, tourism, freshwater aquaculture and forestry. A Corine Land Cover analysis since 1990 reveals the loss of forest lands of about 47 km^2 and a shift towards shrubs and sparsely vegetated areas, possibly correlated with not demarcated grazing, and incorrect logging (Table 1). The arable lands were identified in local community basis. Extensive cultivation is found primarily in the northwestern part of the basin (Plain Konitsa) whereas in other areas is much more limited due to the relief and the climate. 5050 ha of arable land in the basin are covered by 38% with cereal and corn and 44% by crops for animal feed like clover or alfalfa. Diffuse pressure originating from agriculture can be summed as 33.2 tn/yr Nitrogen (N), 34.6 tn/yr Phosphorus (P), from whom 9.6 tn N and 1.04 tn P end up in surface waters. The majority of the loads being produced in Aoos sub basin (about 65%) as depicted in Figure 2. Accordingly, pastoring livestock farming seems to be the most aggravating economic activity in diffuse sources of pollution. Such activity creates 468,3 tn/yr of N, 239,7 tn/yr of P and 1476.7 tn/yr of Biological Oxygen Demand (BOD_5) with the majority of the loads being produced in Sarantaporos sub-basin (more than 45% depending on the type of livestock bred) as depicted in Figure 2. From the above loads 89.4 tn N, 5.02 tn P and 279.6 tn BOD end up in surface waters. Dealing with the point sources of pollution, touristic activity enhanced by about 5% the loads generated by the permanent population in each of the 68 local community. This percentage is relatively low compared to the loads created by domestic sheep and goats (Figure 2). 2 large aviaries in Aoos sub-basin produce in tn/yr: 61and 52 BOD_5, 17 and 14 N, 9 and 8 P, respectively. Three more Aviaries are located in Voidomatis sub-basin generating all together 31.5 tn of BOD_5, 5 tn of N and 2.7 tn of P (Figure 2). Aquacultures cumulatively produce 255 tn of BOD_5, 51 tn of N and 8.5 tn of P probably affecting directly the streams, generating tn/yr on average 15 BOD_5, 3 N and 0.5 P per small dynamics aquaculture.

3.2. State

Nutrient-pollution concentrations, chemical state and biological state of water bodies within the river basin are shown in Figure 3,as adopted by the First revision of EL05 RBMP, and refer to the lowest values recorded during 2013 . The relatively good status can be explained partly by the high precipitation throughout the year, the existence of springs due to karstic soils, the inexistence of industries or high touristic activity and the sparsely populated area (5 inhabitants/km^2).

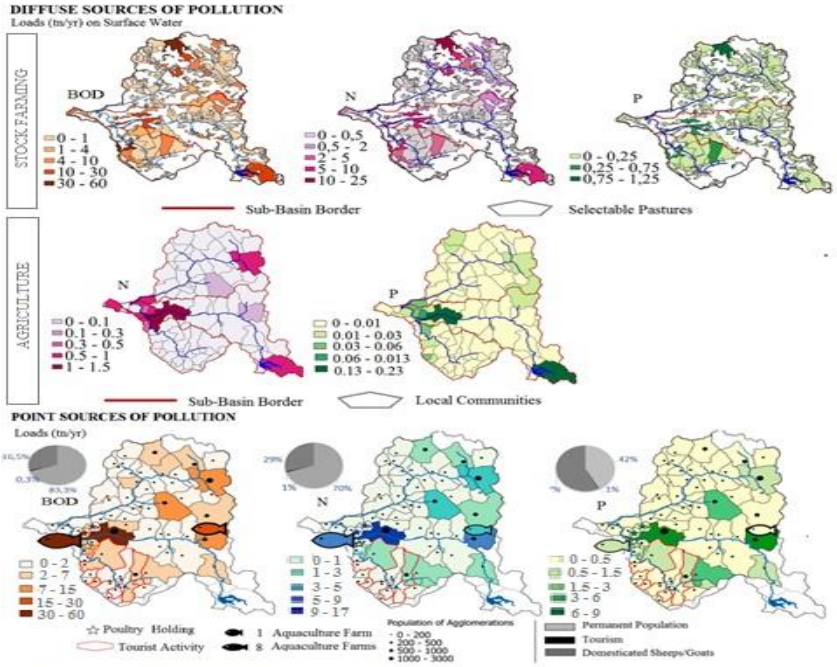

Figure 2. Diffuse and Point Sources Pollution Maps

3.3. Impact

The decline of forest areas and the shift towards shrubs and sparsely vegetated areas might be augmented if certain areas (even protected ones) continue to be used as meadows. The area "Zagorohoria" is a pole of touristic attraction and should be used as one, but if the existing (deficient) infrastructures will not be updated or evolve in order to serve the tourists, extra burden will be placed on freshwater resources. The pollution loads from anthropogenic activities cannot pose serious threats to the ecological status but the divergence from high status, give the above circumstances indicated definite impact. Especially, the moderate biological status in upper Sarantoporos could be due to hydromorphological alterations taken place last years. Riverine activities, related to flow alterations and uncontrolled gravel extraction might have impacts on the connectivity of the lotic ecosystem affecting also the mobility of the aquatic populations, their diversity and their refuges.

3.4. Responses

Aoos/Vjosa is among the less studied river basins in Greece even its transboundary character. Chatzinikolaou *et al*. (2008) revealed that the river can be regarded as almost unpolluted with high ecological quality. Last years the increase of the diffuse and point pollution sources constitute a major threat for the water quality since the expectations for the whole basin are to maintain the undisturbed conditions. . Septic tanks were assumed but there is high probability part of the loads being diverted unprocessed directly to the water bodies in the basin. The designation of zones applying environmental-friendly agricultural practices, the maintaining of the ecological flow during all year should be among the main priorities. In the river basin of Aoos there are plans for about 25 authorizations for hydropower plants (55 MW) ,the majority of them within sub-basin of Sarantaporos, a pressure that might affect the ecological status. It is worth note that among pressures exerted on the river basin within Albania are also the construction of hydropower dams (www.balkanrivers.net) that might lead in change of the "free flowing" character of the river with consequences to its biodiversity. Since this river satisfies a great variety of uses (irrigation, aquaculture, energy, recreation, etc.) and the basin area serves stakeholders with various preferences and expectations, a variety of parameters should be considered. Albania even is a downstream country should agree on a package of sustainable development priorities concerning Aoos/Vjosa protection.

4. Concluding remarks

n Greece, the river basins are mainly agro-ecosystems, hence, the restoration and management strategy should target on the ecological effects of the relative pressures, rather than the effects of the pollution itself. The DPSIR analysis of Aoos/Vjosa river basin revealed that socioeconomic forces exert various pressures. All water bodies in the basin remain undisturbed except one of them falling at moderate ecological status. Both countries face the need for long-term arrangements to address their new developments projects under the light of the Aoos/Vjosa conservation.

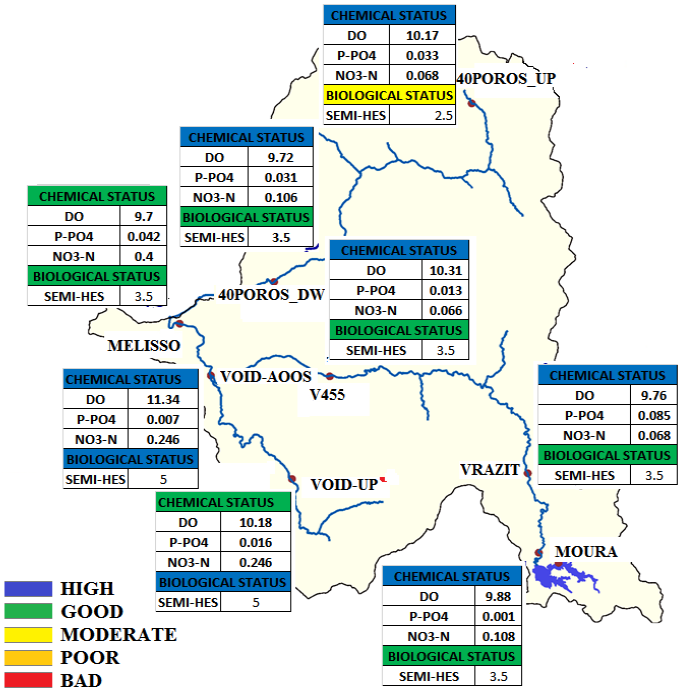

Figure 3. *Chemical parameters (mg/l), Chemical and Biological status presentation in colour scale at monitoring points*

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