IRRIGATION INFLUENCE ON CATCHMENT HYDROLOGY MODELLING WITH ADVANCED HYDROINFORMATIC TOOLS

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Abstract: *Agriculture is a significant user of water resources in Europe, accounting for around 30 per cent of total water use. Because water is essential to plant growth, irrigation is essentially to overcome deficiencies in rainfall for growing crops. Irrigation is a basic determinant of agriculture because its inadequacies are the most powerful constraints on the increase of agricultural production. Irrigation was recognized for its protective role of insurance against the vagaries of rainfall and drought. But the irrigation, besides the positive effects, has a significant environmental impact. The environmental impacts of irrigation are variable and not well-documented; some environmental impacts can be very severe. The main types of environmental impact arising from irrigation appear to be: water pollution from nutrients and pesticides; damage to habitats and aquifer exhaustion by abstraction of irrigation water; intensive forms of irrigated agriculture displacing formerly high value semi-natural ecosystems; gains to biodiversity and landscape from certain traditional or 'leaky' irrigation systems in some localized areas; increased erosion of cultivated soils on slopes; salinization, or contamination of water by minerals, of groundwater sources; both negative and positive effects of large scale water transfers, associated with irrigation projects. Minor irrigation schemes within a catchment will normally have negligible influence on the catchment hydrology, unless transfer of water over catchment boundaries is involved. Large irrigation schemes may significantly affect the runoff and the groundwater recharge through local increases in evapotranspiration and infiltration as well as through operational and field losses. To study the some effects of irrigation can be used advanced hydroinformatic tools, like MIKE11 by DHI, Rainfall – Runoff module, NAM methods. NAM method is a lumped, conceptual rainfall-runoff model, simulating the overland-, inter- flow, and base-flow components as a function of the moisture contents in four storages. The irrigation module of NAM may be applied to describe the effect of irrigation on the following aspects: the overall water balance of the catchment; local infiltration and groundwater recharge in irrigated areas; the distribution of catchment runoff amongst different runoff components (overland flow, interflow, base flow). This paper present and analyze the irrigation influence on catchment hydrology modeling with advanced hydroinformatic tools. It is performed and a case study, regarding to modeling these influences with MIKE11 software.*

Key words: *irrigation, hydrology, modelling, hydroinformatic tools.*

INTRODUCTION

Agriculture is a significant user of water resources in Europe, accounting for around 30 per cent of total water use. Because water is essential to plant growth, irrigation is essentially to overcome deficiencies in rainfall for growing crops. Irrigation is a basic determinant of agriculture because its inadequacies are the most powerful constraints on the increase of agricultural production. Irrigation was recognized for its protective role of insurance against the vagaries of rainfall and drought. (BALDOCK et al, 2000)

But the irrigation, besides the positive effects, has a significant environmental impact. The impacts stem from the altered hydrological conditions caused by the achievement and operation of the irrigation scheme. The environmental impacts of irrigation are variable and not well-documented; some environmental impacts can be very severe. Irrigation can affect the environment through:

· direct impacts upon quality and quantity of ground and surface water resources;

· direct impacts upon quality (through contamination) and quantity (through hydric erosion) of soils;
· direct impacts upon biodiversity and landscapes, by displacing former habitats and creating new ones, by degrading or maintaining existing habitats, and by affecting the diversity and composition of landscapes;
· secondary impacts arising from the intensification of agricultural production permitted by irrigation, such as increased fertilizer use.

These effects may be gradual (declines in certain species arising from pollution) or particularly dramatic (flooding a valley to create a reservoir for irrigation, or regularization of river and thereby reducing the stability of its flow conditions). (BALDOCK et al, 2000)

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An irrigation scheme draws water from groundwater, rivers, lakes or overland flow, and distributes it over an irrigated area. The effects on catchment hydrology conditions include reduction in downstream river flow, increased evaporation in the irrigated area, increased level in the water table as groundwater recharge in the area is increased and flow increased in the irrigated area. (ROSENBURG et al, 2000).

Minor irrigation schemes within a catchment will normally have negligible influence on the catchment hydrology, unless transfer of water over catchment boundaries is involved. Large irrigation schemes may significantly affect the runoff and the groundwater recharge through local increases in evapotranspiration and infiltration as well as through operational and field losses. (DHI, 2014)

The impacts of irrigation on the environment are an essential consideration when design new irrigation projects and rehabilitation of old irrigation systems, respectively when establish the exploitation rules for irrigation systems. Their importance is underlined in recent years because the problems of the quality of the environment became so important, in context of climatic changes.

MATERIAL AND METHODS

Advanced hydroinformatic tools, like MIKE11 by DHI, are useful for to study the effects of irrigation on catchment hydrology. Hydroinformatics is integration of computational fluid dynamics and of artificial intelligence. Computational hydraulics is the fusion of numerical methods of applied mathematics, hydrodynamics and hydraulics. Hydroinformatics is about making the best use of information technologies to manage water in the environment. (http://en.wikipedia.org/wiki/Euro_Aquae)

MIKE11 is an advanced hydroinformatic tools, professional engineering software package for simulation of one-dimensional flows in estuaries, rivers, irrigation systems, channels and other water bodies. It was developed by DHI Water • Environment • Health, Denmark. MIKE 11 has the following modules: Hydrodynamic Module (HD), Rainfall-Runoff (RR) Module, Sediment Transport (ST) Module, Water Quality (WQ) Module.

Different types of Rainfall-Runoff models are available: NAM - a lumped, conceptual rainfall-runoff model, simulating the overland-, inter- flow, and base-flow components as a function of the moisture contents in four storages; UHM - the Unit Hydrograph Module includes different loss models (constant, proportional) and the SCS method for estimating storm runoff; SMAP - a monthly soil moisture accounting model; Urban - two different model runoff computation concepts are available in the Rainfall Runoff module for fast urban runoff: time/area method and non-linear reservoir (kinematic wave) method; FEH - Flood Estimation Handbook, a method for flood estimation in the UK; DRiFt (Discharge River Forecast) - a semi-distributed event model based on a geomorphologic approach; Combined - the runoff from a number of catchments, constituting parts of a larger catchment, can be combined into a single runoff series (figure 1). (DHI, 2014)

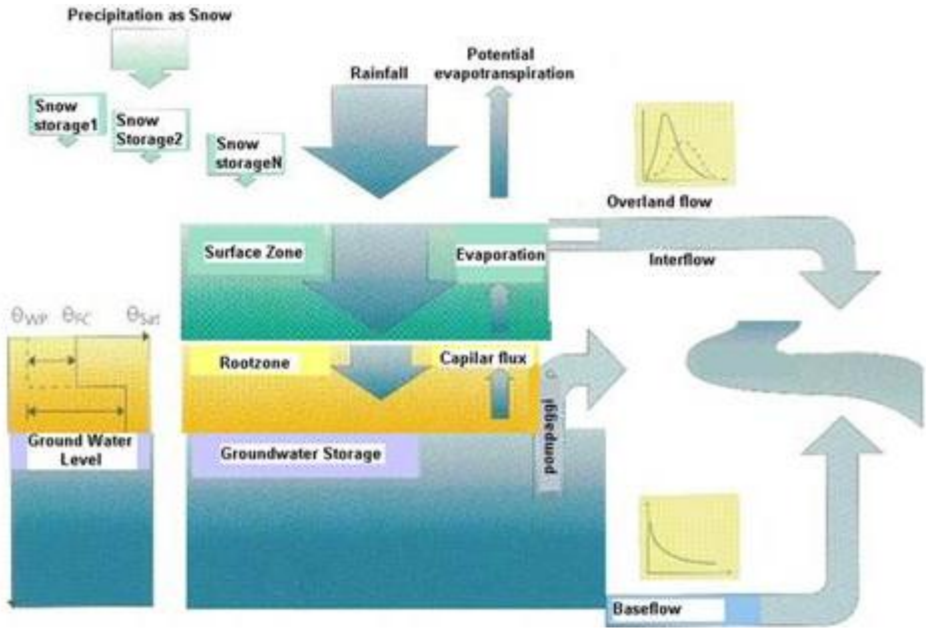

Figure 1. Rainfall – Runoff modelling with MIKE11 (DHI, 2014)

The NAM (Nedbør-Afstrømnings-Model) hydrological model simulates the rainfall-runoff processes occurring in the catchments (figure 2 and figure 3). NAM is a part of the rainfall-runoff (RR) module of the MIKE 11 River modelling system. The rainfall-runoff module can either be applied independently from hydrodynamic module or used to represent one or more contributing catchments that generate lateral inflows to a river network. It is possible to treat a single catchment or a large river basin containing numerous catchments and a complex network of rivers and channels within the same modelling framework. The NAM model can be characterized as a deterministic, lumped, conceptual model with moderate input data requirements (initial conditions, meteorological data – rainfall, potential evapotranspiration, temperature, solar radiation; streamflow data for model calibration and validation).

A mathematical hydrological model NAM is a set of linked mathematical statements describing, in a simplified quantitative form, the behavior of the land phase of the hydrological cycle. NAM represents various components of the rainfall-runoff process by continuously accounting for the water content in four different and mutually interrelated storages, the storages represents different physical elements of the catchment (snow storage, surface storage, lower or root zone storage and groundwater storage). (DHI, 2014)

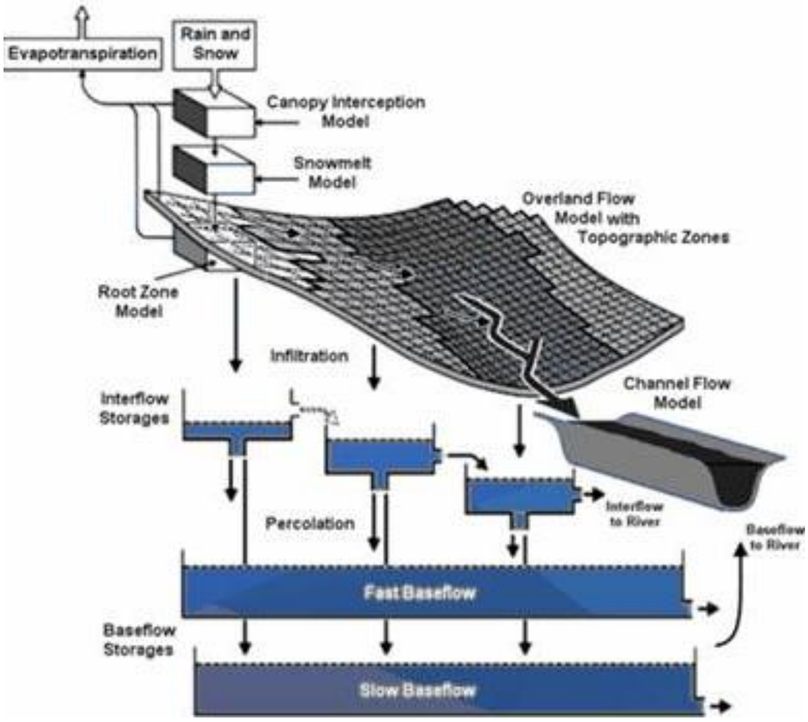

Figure 2. NAM concept (DHI, 2014)

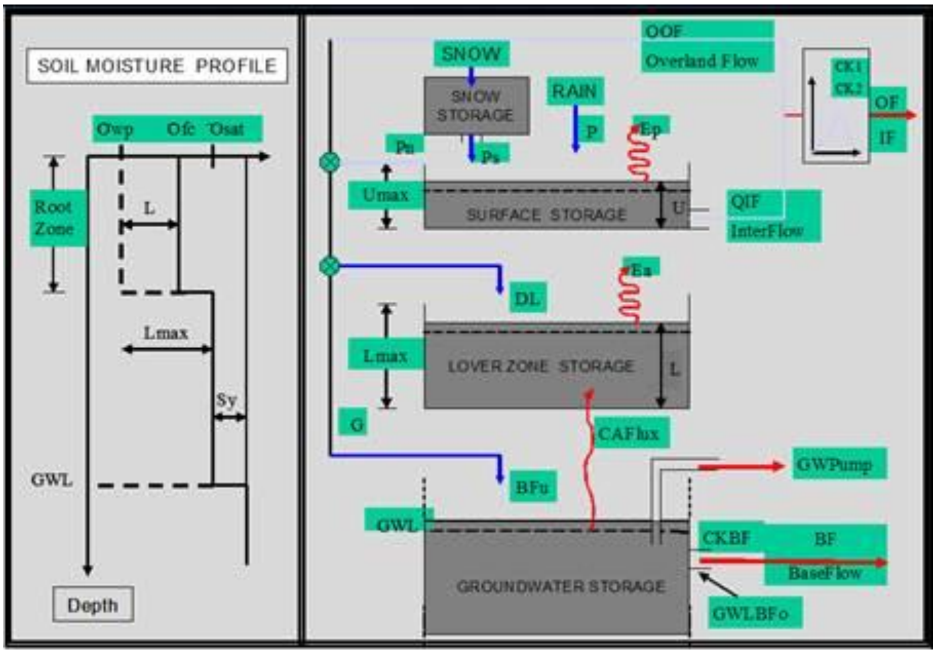

Figure 3. NAM model description (DHI, 2014)

The most important basic parameters are: U_{max} - maximum contents of surface storage (evaporation; small peaks); L_{max} - maximum contents of root zone storage (evaporation; water balance); CQ_{of} - overland flow coefficient(divides excess rainfall in runoff and infiltration); CK_1 ,CK_2 - time constant for routing overland flow (determines shape of peaks); CKBF - time constant for routing base flow (determines shape of base flow hydrograph); TIF - treshold value for Interflow (delays interflow recharge at the beginning of a wet season); TG - root zone threshold value for recharge (delays groundwater recharge at the beginning of a wet season); TOF - root zone threshold value for overland flow (delays overland flow at the beginning of a wet season); GWL BF_0 - max. ground water depth causing baseflow; GWL $_{MIN}$ - min. ground water depth; GWL FL_1 - ground water depth for unit capilar flux and S_Y - specific yield of groundwater storage. (DHI, 2014)

The NAM model permits also the modelling of human interventions in the hydrological cycle like irrigation and groundwater pumping systems, when time series of irrigation and groundwater abstraction rates are required. The structure of the irrigation module is illustrated in Figure 4.

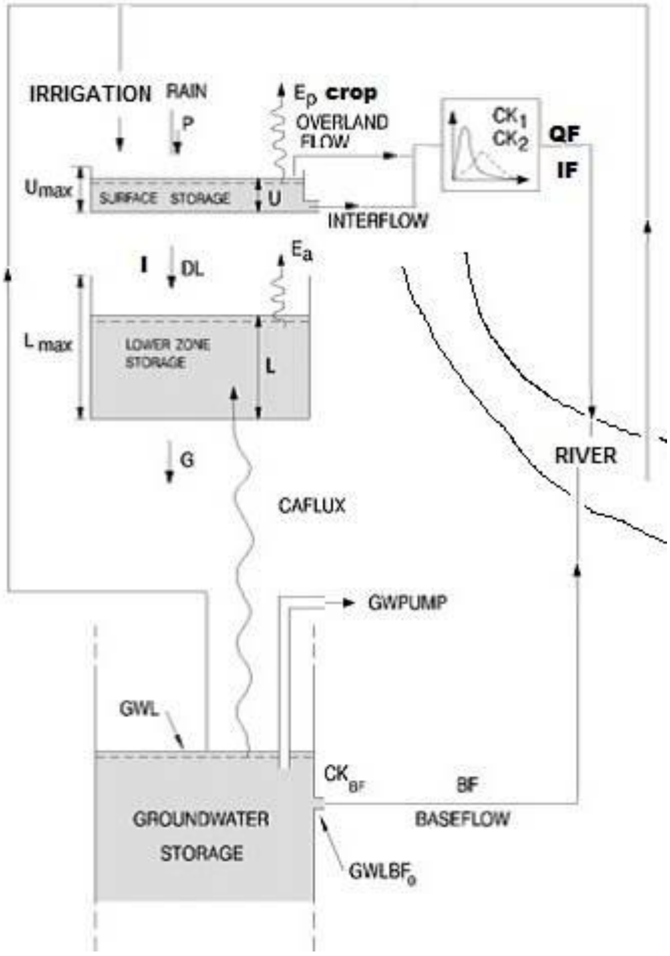

Figure 4. Structure of the irrigation module (after DHI, 2014)

Irrigation water can be derived from three different sources: local groundwater, local river and external river. Water supplied to the surface storage in irrigated areas will be a sum of precipitation and irrigation water. The potential evapotranspiration may vary with crop type and the stage of growth. Infiltration is taken directly from the surface storage to the lower zone and groundwater storages and is calculated as a function of the moisture content in the lower zone. A portion G of the infiltration is assumed to percolate deeper and recharge the groundwater storage. This portion is calculated as a function of the conditions in the lower zone storage. The remaining part is assumed to increase the moisture content in the lower zone. If the maximum surface storage Umax is exceeded, the general NAM model diverts the excess water into overland flow and infiltration.

A part of the water diverted for irrigation will be lost on its way to the fields. The losses may include evaporation and seepage from channels, illegal off-takes, and operational losses (i.e. water that is diverted to the irrigation area but is not being utilized), which contributing to overland flow. (DHI, 2014)

RESULTS AND DISCUSSIONS

To see the influence of irrigation on the hydrological regime of catchment has conducted a case study on an area of 290 hectares with the following rotation crop: 72.5 ha wheat (25%) and 217.5 ha corn (75%), for a period of one year. Irrigation scheme is given for April, May, June, July, August and September in Table 1.

Table 1

Irrigation scheme

Month / **Crop**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**
Wheat	1	2	0	0	0	0
Corn	0	0	0	2	2	0

The irrigation norma is the amount of irrigation water distributed throughout the growing period of the culture (cubic meter/ha) (table 2).

Table 2

Irrigation norma

Crop	**Wheat**	**Corn**
H (m)	0,5	0,75
Ni (cubic meter/ha)	1500	2800

All data were taken from tables, based on research conducted in various experimental fields stationary, representing monthly daily average water consumption during the growing of the main plant and irrigation water requirements on research points and crop. Soil hydrological group is C. The amount of time that give the water the entire area occupied by culture "i " is 10 days, the irrigation water source is the local river.

The input data in NAM model are shows in Figure 5 (rainfall, irrigation, temperature, evaporation) and in the Table 3 (values after autocalibration of model).

The result after simulation with MIKE11, NAM module are shows in Figure 6 (simulation without irrigation) and in Figure 7 (simulation with irrigation). The obtained results are the time series of runoff, overland flow, base flow, interflow, groundwater depth, groundwater recharge, capillary flux and infiltration.

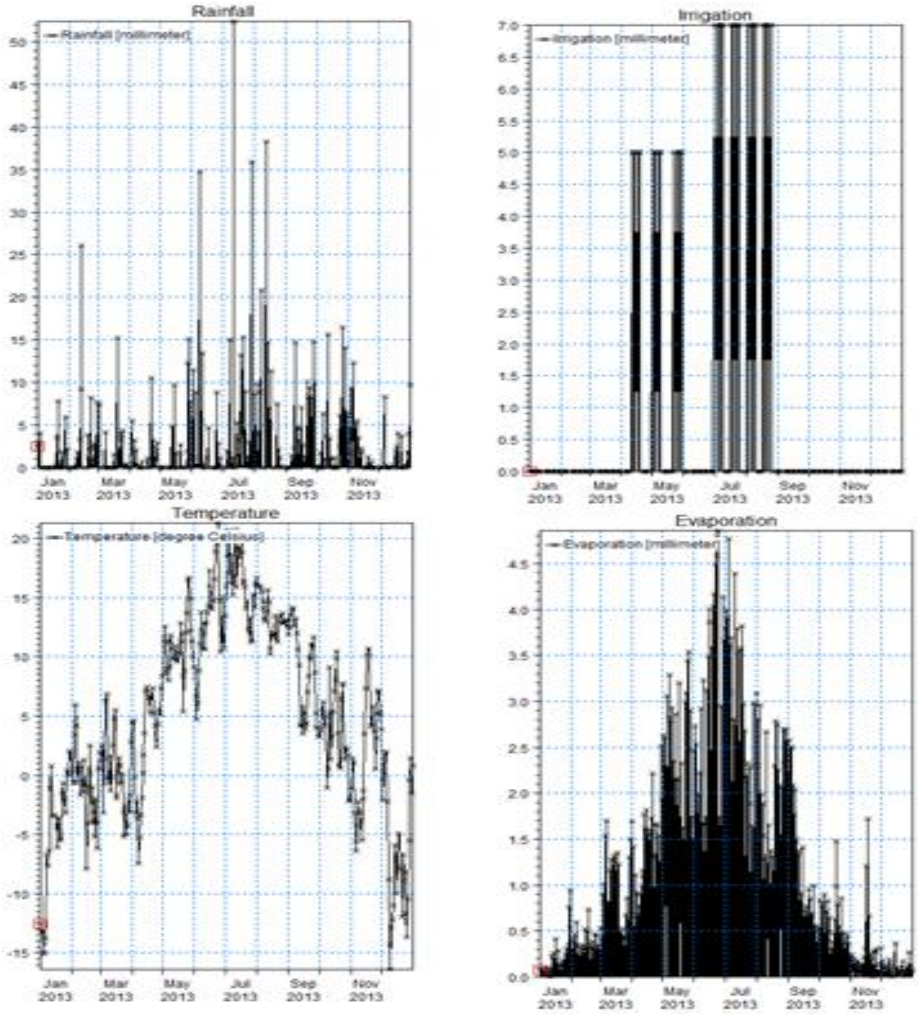

Figure 5. The input data in NAM mode

Table 3

NAM model parameters

Parameter	On/Off	Initial value for simulation without irrigation	Initial value for simulation with irrigation	Lower bound	Upper bound
Umax	1	10.6	13.3	10	20
Lmax	1	101	100	100	300
CQOF	1	0.981	0.314	0.1	1
CKIF	1	210	568.3	200	1000
CK1.2	1	16.3	33.4	10	50
TOF	1	0.016	0.465	0	0.99
TIF	1	0.218	0.794	0	0.99
TG	1	0.0266	0.00394	0	0.99
CKBF	1	1156	1001	1000	4000
CK2	0	16.3	33.4	10	50
CQLOW	0	0	0	0	100

CKLOW	0	1.00E+04	1.00E+04	1.00E+03	3.00E+04

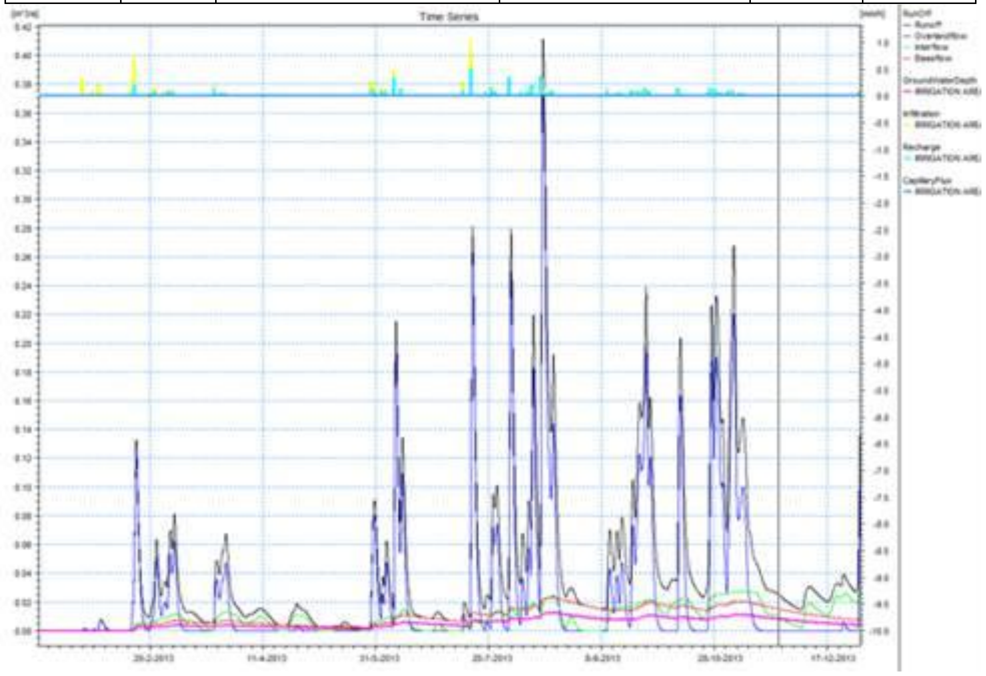

Figure 6. The results of simulation without irrigation

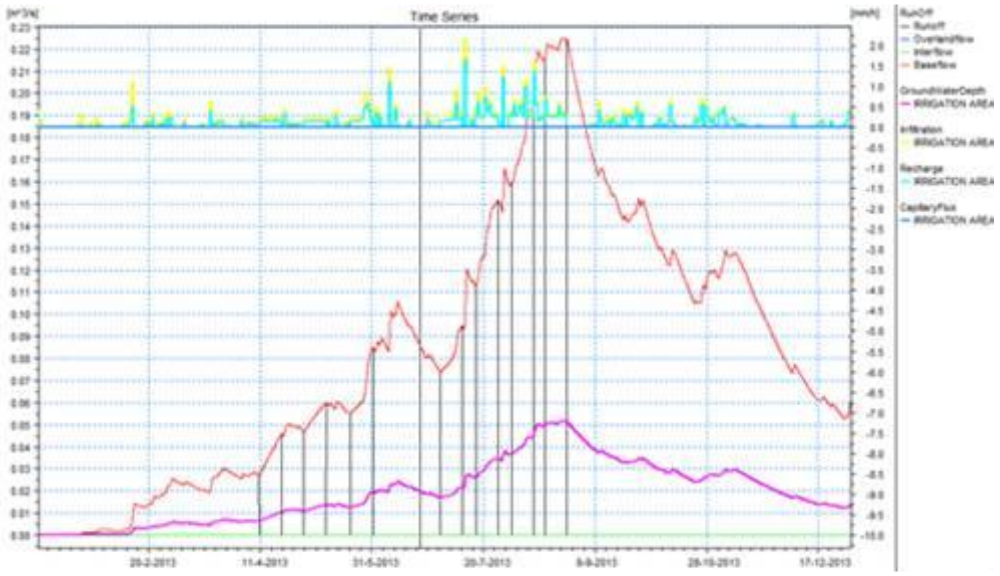

Figure 7. The results of simulation with irrigation

After comparing the results of the two simulations (without and with irrigation) can be seen that runoff and overland flow values are higher in case of simulation without irrigation. (Figure 8). In case of simulation with irrigation, the values of base flow, groundwater depth, infiltration and groundwater recharge are higher than in case of simulation without irrigation (Figures 9 and 10; black line – results without irrigation, red line – results with irrigation).

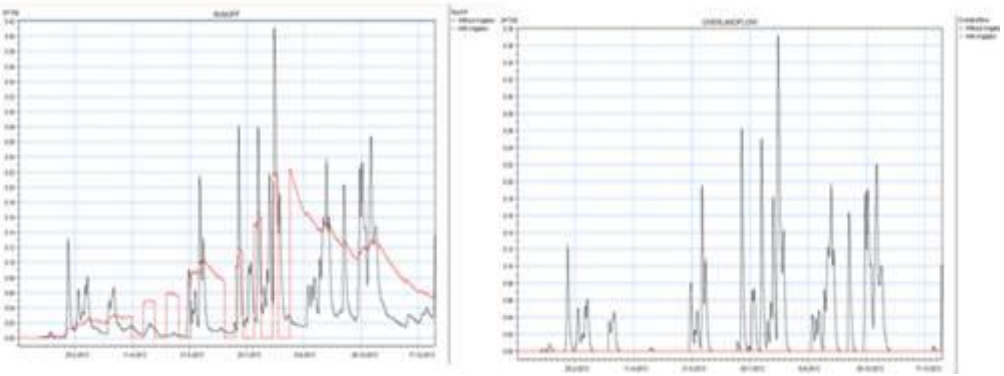

Figure 8. Obtained time series of runoff and overland flow

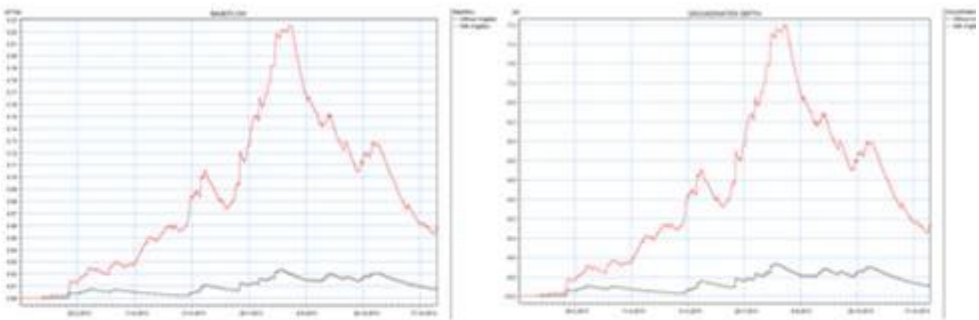

Figure 9. Obtained time series of base flow and groundwater depth variation

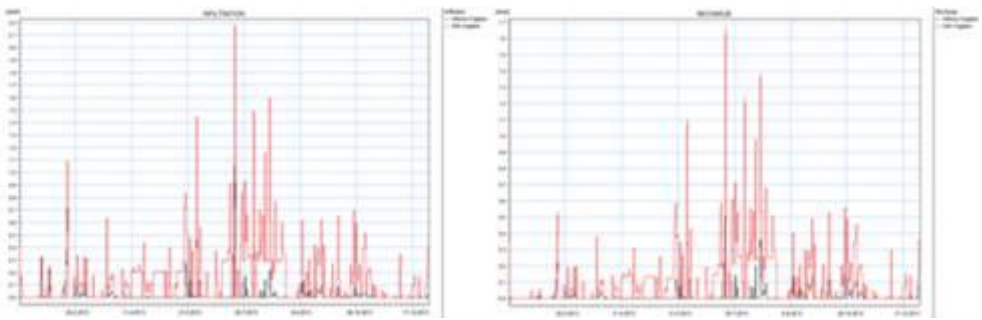

Figure 10. Obtained time series of infiltration and groundwater recharge

CONCLUSIONS

The measures helping to make irrigation sustainable and with less negative effects on environment and catchments hydrology can be the follows: planning, construction and management of irrigation schemes in accordance with a sound environment; use of irrigation water of a suitable quality; prevention of the rise of groundwater in the irrigated area (especially in arid and semiarid areas); effective and correctly performed leaching; introduction of an effective drainage system; prevention of movement of chemicals; and improvement and suitable management of existing irrigation and drainage systems. (HOLY, 2013)

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