Internationales Symposion
INTERPRAEVENT 2004 – RIVA / TRIENT

EVALUATION OF RUNOFF CHANGES DUE TO VEGETATION CHANGE IN CZECH HILLY BASINS

SIMULATIONS USING MODELS OF RAINFALL-RUNOFF PROCESS

DIE ENTWICKLUNG DER GEÄNDERTEN ABFLÜSSE INFOLGE DER VEGETATIONSÄNDERUNGEN IN DER TSCHECHISCHEN REPUBLIK

DIE MIT HILFE VON DEN REGEN- UND ABFLUSSMODELLEN DURCHGEFÜHRTE SIMULIERUNG

Josef Buchtele[1], Marie Buchtelova[1] and Magda Fortova[1]

ABSTRACT

Changes of water regime induced by landscape-use are an urgent problem nearly in all European countries with extensive urbanization and intensive agricultural activity. This subject is, for example, an important part of research projects within the International Geosphere-Biosphere Program (IGBP). Increasing difficulties have appeared in some part of Central Europe – so called Black Triangle area at the borders of the Germany, Czech Republic and Poland, where acid rains caused massive deforestation in headwaters areas in hilly regions, i.e. rainy areas with important water resources. Nowadays it is a topic of consideration about consequences namely for flood flows regime. The outputs of two hydrological models of different structure have been compared in these investigations: the conceptual model SAC-SMA - Sacramento soil moisture accounting and physically based 1-D model BROOK´90. The differences between observed and simulated discharge, which could show the tendencies in the runoff have been followed. They indicate increase of runoff after deforestation.

Key words: runoff change, rainfall-runoff simulation, deforestation

ZUSAMMENFASUNG

Nach den gefährlichen Hochwässsern besonders in den Einzugsgebieten der Flüsse Moldau und Elbe im August 2002 wurden viele - oft stürmische - Diskussionen geführt. Auch die Wirkung der Waldschläge nach der Beschädigung mit saueren Niederschlägen in Mittel-Europa kann zum Entstehen der Hochwässer beitragen. Dies hat einen neuen Anlass zur mathematischen Modellierung der Niederschlags- und Abflussprozesse in kleinen

1 Institute of Hydrodynamics AS CR, Pod Patankou 5, 166 12 Prague 6, Czech Republic
(Tel.: +420-233-109-026; Fax: +420-233-324-361; email: buchtele@ih.cas.cz)

Bergeinzugsgebieten der Tschechischen Republik mit verschiedenen Veränderungen der Waldbestände hervorgerufen.

Key words: Abfluss Veränderungen, Niederschlag – Abfluss Simulation, Waldschläge

INTRODUCTION

Discussions, sometimes having emotional character, appeared after recent large floods namely in the Vltava and Elbe river basins in August 2002. The influence of deforestation induced by acid rains in the Central Europe has been considered as important contribution to disastrous character of floods. This has been one of the impulses for simulations of rainfall-runoff process in several small basins in headwater areas at the Czech territory with different extent of vegetation change.

TOOLS AND DATA USED FOR EXPERIMENTS

Simulations have been carried out using daily time series mostly 40 - 50 years long. The catchment area of these basins is between 1 km^2 and 90 km^2. The outputs of two hydrological models of different structure have been also compared in these investigations: the conceptual model SAC-SMA - Sacramento soil moisture accounting and physically based 1- D model BROOK´90, which have been used in other similar experiments (BUCHTELE et al, 2002). The application of rainfall-runoff models means that random component represented by climatic variability is at least partly eliminated. Variability of flood flow regime and resulting uncertainties associated with evaluation of its artificial changes is illustrated in Table 1.

Tab. 1 Comparison of cases of large floods in different periods during last century - Vltava River - Praha
Tab. 1 Vergleich der Hochwasserspitzen in verschiedenen Zeitperioden im vorigen Jahrhundert - Moldau Fluss - Prag

Period	1890 –1900 (10 years)		Period	1901 -1990 (90 years)	
No.	Date	$Q_{max}[m^3/s]$	No.	Date	$Q_{max}[m^3/s]$
1	4/10 1890	3975	1	15/3 1940	3245
2	9/4 1900	2770	2	9/7 1954	2920
3	6/5 1896	2470	3	15/3 1947	2272
4	14/9 1899	2130	4	8/10 1915	2100
5	31/7 1897	2090	5	15/1 1920	2100

In this way we are able to follow just differences between observed and simulated values, what could be essential for ascertaining of anticipated trends. Similar approach has been used in several other cases (BRANDT et al, 1988, BUCHTELE et al, 2002).

SENSITIVITY OF RAINFALL-RUNOFF SIMULATION TO INPUT CHANGES

Table 2 is an illustration of accuracy of inputs used for simulation in long-term scale. It shows the possible impact of global climate warming and the change of evapotranspiration may illustrate also the role of vegetation cover in runoff change.

Fig. 1 presents the comparison of observed and simulated flows in two hydrological years and during one high flood in the experimental basin Raztoka ($P = 1\ km^2$). It should illustrate the acceptable accuracy of results of model calibration. The differences between observed and simulated discharge in the 50 years period in Fig. 1c exhibit clear long term tendencies, which seem to be in agreement with the changes of vegetation cover in the basin. In the beginning of observation whole area was forested and in the second half of sixties its parts were gradually deforested and new aforestation started. Details see (CHLEBEK- JARABAC , 1995).

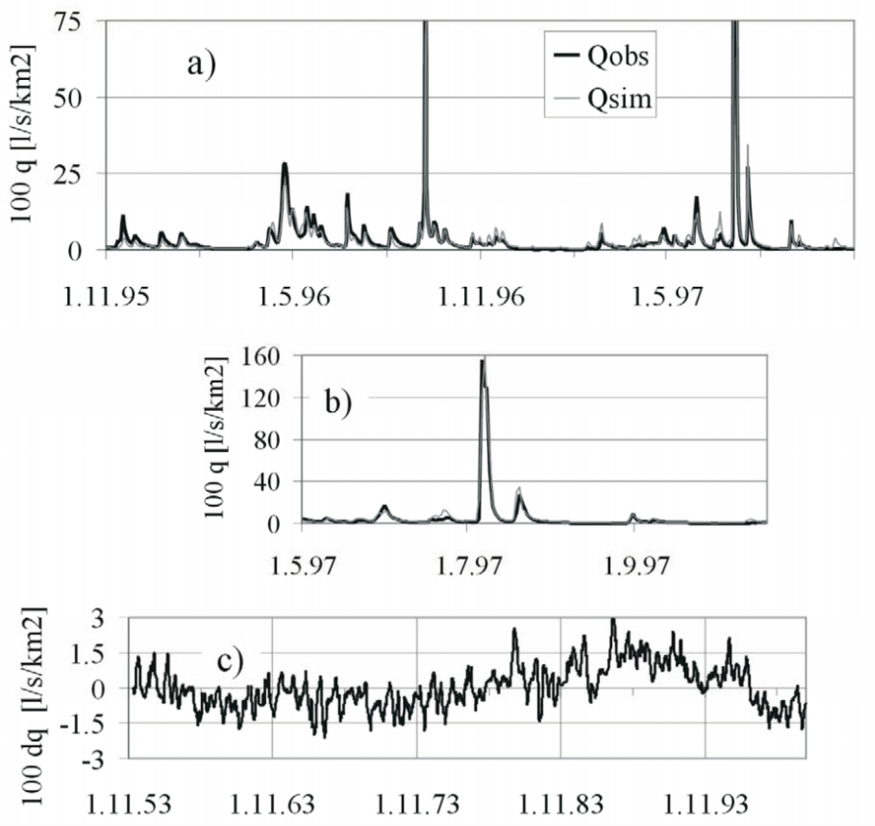

Fig. 1 a, b) Comparison of observed and simulated discharge of the experimental basin Raztoka
c) differences between observed and simulated daily discharge in the 50 years long period - smoothing with $m \approx 100$ days

Abb. 1 a, b) Vergleich der gemessenen und simulierten Abflüsse im experimentellen Einzugsgebiet Raztoka
c) Unterschiede zwischen den simulierten und gemessenen Tagesabflüssen in dem 50-jährigen Zeitraum mit der 100-tägigen Ausgleichung der Daten

Other scales and a bit modified version of moving averages (6 years) of annual runoff series has been applied in Fig. 2 for experimental basin Uhlirska ($P = 4\ km^2$) in Jizera Mts. in northern Bohemia. Acid rains caused that this basin has been nearly completely deforested in eighties. The deforestation has resulted in higher observed flows in comparison with values obtained by simulation using SAC-SMA model. However, gradually the tendency is being opposite, probably due to recovering of diverse vegetation cover. Seasonal differences in Fig. 2b indicate that the effect of vegetation change is most pronounced in spring seasons, probably due to quicker snowmelt in open areas.

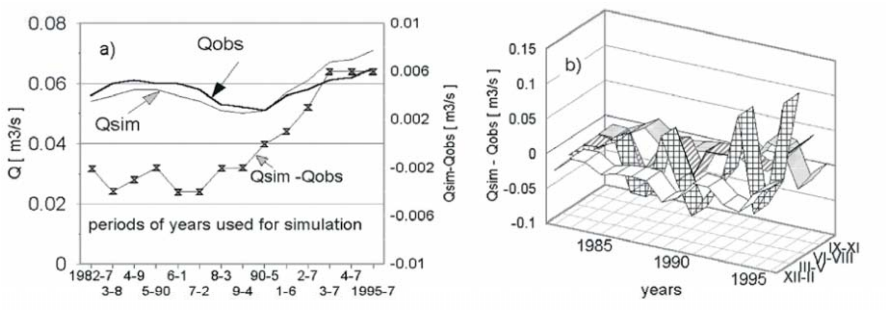

Fig. 2 Differences between simulated and observed discharges in the experimental basin Uhlirska (Jizera River) in different time scales

Abb. 2 Unterschiede zwischen den simulierten und gemessenen Abflüssen im experimentellen Einzugsgebiet Uhlirska (Iser Fluss) in verschiedenen Zeitabständen

Tab. 2 Sensitivity of simulated runoff to input changes - differences between observed and simulated values in the basin Metuje River in the period 1961-90

Tab. 2 Die Empfindlichkeit der simulierten Abflüsse gegen die Veränderungen der Elementeneintritte - Unterschiede zwischen der gemessenen und simulierten Daten im Einzugsgebiet des Metuje Flusses in dem Zeitabschnitt zwischen 1961-1990.

Input Change		**Long-term averages** Bias [%]	|Δ| [%]	σ [%]	**Correl. Coeff.** R
Optimal simulation		+ 0.2	17.1	24.6	*0.838*
Evapotranspiration	+ 5 %	- 4.6	*16.9*	25.1	*0.838*
Precipitation	+ 4 %	7.9	19.2	26.8	*0.838*
- “ -	- 4 %	- 7.3	17.1	26.1	0.837
- “ -	- 5 %	- 9.2	17.5	26.9	0.836
Temperature	+4°C	-5.8	27.2	43.8	0.592

R ..... correlation coefficient of simulated and observed daily discharge

|Δ| ..... absolute standard error of mean monthly runoff

σ ..... root mean square error of monthly average runoff

Concerning the changed water volumes, evapotranspiration plays the decisive role. Fig. 3 shows not only its different amounts for forested experimental basin Liz ($P = 1\ km^2$) in southern Bohemia and for assumed grass cover as it has been simulated by BROOK´90 model. The proportions of its main components visible in Fig. 3 indicate important role of rain interception in this forested hilly basin for water ´losses´.

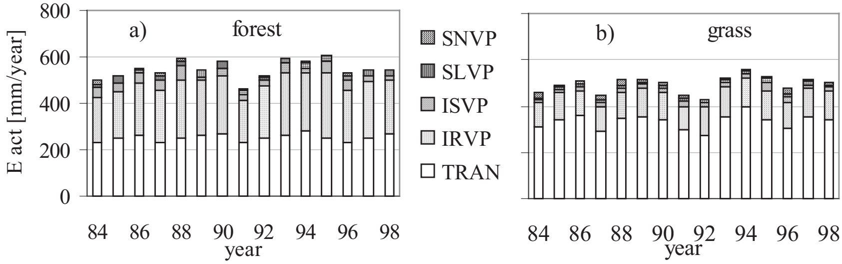

Fig. 3 Simulated evapotranspiration components using the BROOK model - Liz basin
TRAN .... transpiration, IRVP .... rain interception, ISVP .... snow interception
SLVP .... soil evapotranspiration, SNVP .... snow evaporation

Abb. 3 Simulierte Elemente der Evapotranspiration mit dem BROOK-Modell, Liz Einzugsgebiet
TRAN .... Transpiration, IRVP .... Regeninterzeption, ISVP .... Schneeinterzeption
SLVP .... Bodenvaporisation, SNVP .... Schneevaporisation.

Peak flood flows are assumed to be highly influenced by surface runoff component. An illustration proportions of different runoff components is provided in Fig. 4. It is an example from hilly basin Raztoka mentioned above. In the used year 1965 important snow deposits existed and high flows appeared in the spring and summer months, but, contribution of simulated surface runoff components using the SAC-SMA model was not decisive. The average values presented in Table 3 for period 50 years show that surface runoff is not greater than 20 % while interflow and baseflow are quite substantial even in these hilly basins.

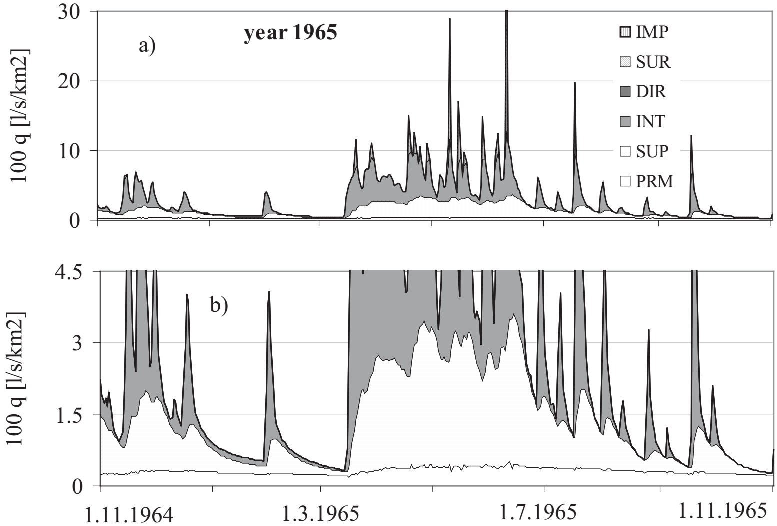

Fig. 4 a) Runoff components in the Raztoka Creek basin in the year 1965 simulated using SAC-SMA model
b) the flows in the scale appropriate for primary baseflow component

Abb. 4 a) Abflusskomponente im Raztoka Bach im Jahr 1965 simuliert mit Hilfe des SAC-SMA Modells
b) Teile der Grundwasserabflüsse

Tab. 3 Runoff components in two small basins simulated using SAC-SMA model
Tab. 3 Komponente des Ablusses in zwei kleinen Einzugsgebieten festgestellt mit Hilfe SAC-SMA Models

Basin	Runoff components / % /						SUM
	PRM	SUP	INT	DIR	SUR	IMP	
Raztoka	11.3	31.2	45.4	0	12.1	0	100
Cervik	19.5	26.7	33.8	2.0	16.2	1.7	100

PRM … primary (long-term) baseflow
SUP … supplementary (seasonal) baseflow
INT … interflow
DIR … direct runoff
SUR … surface runoff
IMP … runoff of impervious areas

The unique data of the mentioned flood in August 2002 has been used for assessment of effect of increased rainfall intensity. The hydrograms of this flood at Modrava (P = 90 km^2) in hilly part of south-western Bohemia are presented in Fig. 5. The comparison of observed flows and values simulated using SAC-SMA model show some discrepancies, probably due to scarcity of recording raingauges, but the course of both hydrograms is still acceptable. This permits experiments with scenarios of increased rainfall intensity. In the given case the duration of precipitation after peak intensity (approx. 35 mm/hr) has been shortened on its half value and the amount of this rain has been shifted to the new time interval after peak intensity. Comparison of simulated peak flows for actual rain situation and for assumed increase of rain intensity shown in Fig. 5d indicates large increase of discharge maxim, which had recurrence interval approx. 100 years.

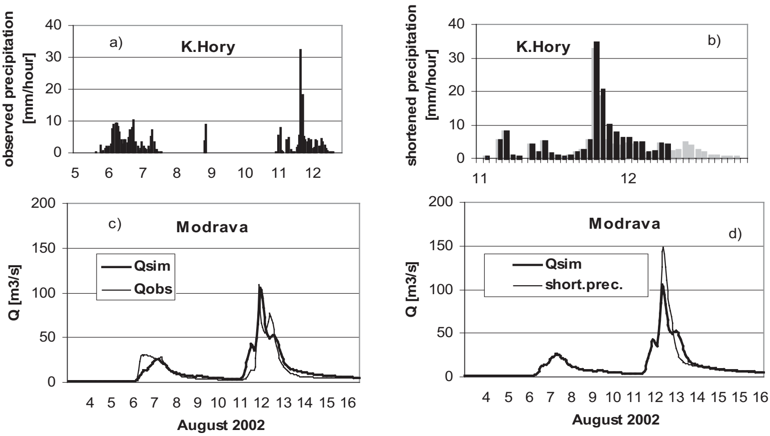

Fig. 5 Simulated increase of peak flood fows for assumed higher intensity of rainfall
Abb. 5 Simulierte Erhöhung der Abflussspitzen für die vorausgesetzte höhere Regenintensität

CONCLUSIONS

Models of rainfall - runoff process are appropriate tools for identification of changes in water regime due to vegetation change. Increased volume of runoff and higher peaks of flood waves can be ascertained in this way in hilly basins in Central Europe. Courses of differences between observed and simulated discharge permit to follow the dynamics in appearing changes. Difficulties exist namely when change is gradual and/or when random changes in basin appear.

ACKNOWLEDGEMENTS: This research has been partly supported by Grant Agency of the Czech Republic (Grant No. 205/03/0468).

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