Application of AGNPSm in German Watersheds
PART II

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1. Introduction and Objectives

The AGNPSm model (Agricultural Non-Point Source Pollution Model modified) (Grunwald et al., 1996; Grunwald, 1997) was used in this study for simulations of non-point source pollution in four different watersheds within Germany. Objectives have been the verification of AGNPSm model using measured values of surface runoff, peak flow, and sediment delivery at the drainage outlets. Some predictions calculated by AGNPS are shown for comparison. Both models **were** described in Part I (Grunwald, this issue). The study areas differed in size, land use, soil, and climate characteristics. In Figure I the location of the four different watersheds is shown. The size of Glonn G1 is 1.2 km^2 , Glonn G2 1.6 km^2, Weiherbach 3.5 km^2 , and Salzboede 81.7 km^2.

2. Methods

A brief site description of the watersheds is presented below. The Glonn watersheds fall within the Tertiary Moraine Landscape, whereas the soils are formed in glacial till material with some influence of loess resulting in sandy loam and loamy soils. The elevation varies between 512 - 550 m (G 1) and 515 - 560 m (G2) and the average slope is 7 % (G 1) and 6 % (G2), respectively. Average yearly precipitation is 850 mm. The total area in G I watershed covered by forest is 19.7 %, while 65.1 % is used as arable land (dominated by com and grain), and 15.2 % is used as meadow/pasture. In contrast G2 is covered by 56.3 % forest and 42.8 % arable land (dominated by com and grain).

The Weiherbach watershed is situated in South-West Germany close to Karlsruhe. Soils of the watershed are formed in deep deposits of loess material (up to 10 m) resulting in highly fertile soils, which are susceptible to soil erosion because of high silt content. The elevation varies between 162

- 248 m (average slope: 5 %). Climate is drier than in the Glonn watersheds (600 mnVa). Land use is dominated by arable land (83.3 % of the total area) especially grain, corn, and sunflowers are grown.

The Salzboede watershed is situated in the Hilly Midlands. Parent materials are diabase, grauwacke, slate, and shale. Weathered material of bedrocks are mixed with loess because of solifluction. Soil texture is sandy loam, loamy sand, and loamy clay. The elevation range is 190 564 m (average slope: 9 %). The total area covered by forest is 46.0 %, while 23.3 % is used as arable land (dominated by grain and corn), and 11.9 % is used as meadow/pasture. The average yearly precipitation is 786 mm.

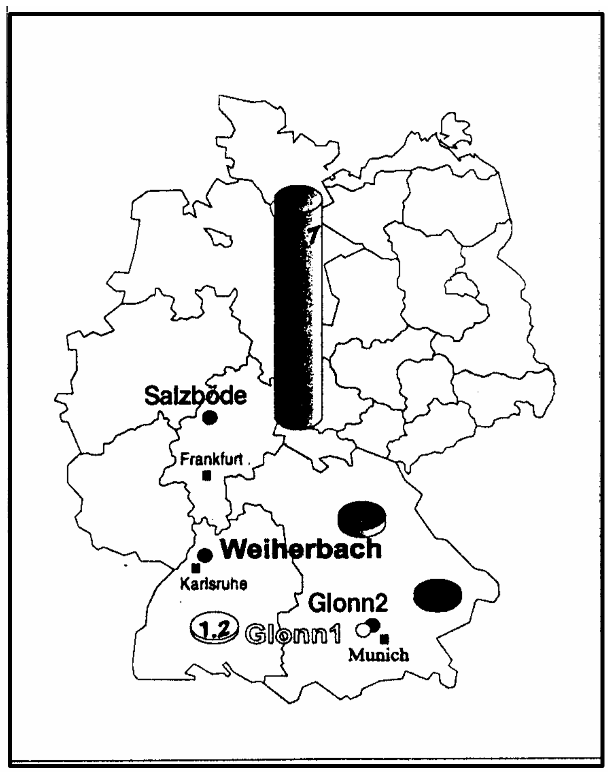

Fig. 1. Location and size of watersheds within Germany.

Figure 2 shows the modeling framework. A Geographic Information System (GIS) SPANS (SPatial ANalysis System) by Tydac (1991) was used to store and manage the spatial input data (land use, contour management, street and alley system, soil data, elevation, and slope lengths). The program Digital Elevation Drainage Network Model (DEDNM) by Garbrecht et al. (1993) derived the watershed boundary, flow direction, and drainage network for the watersheds based on elevation data. Rain station data were used to derive precipitation input, duration and energy intensity values for each rainfall-runoff event. An interface program links the GIS data, climate data, and data generated by DEDNM to the AGNPSm model. Within the interface program all AGNPSm input data are derived by primary and secondary data derivation. The output interface is used to transfer AGNPSm-ASCII data to the GIS SPANS to show the results of surface runoff, peak flow rate, and sediment delivery in a distributed form. The interface program is described in detail by Grunwald (1997).

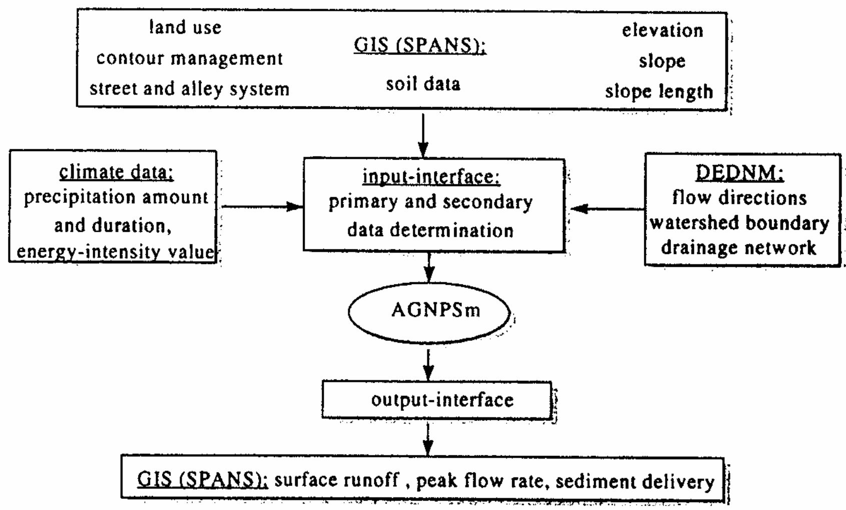

Fig. 2. Modeling framework.

The coefficient of efficiency (E) (Nash et al., 1970) was used as a measure of fit between actual and predicted data. *E* is given by:

$$E = \frac{\sum_{i=1}^{n}(m_i - \overline{m})^2 - \sum_{i=1}^{n}(p_i - m_i)^2}{\sum_{i=1}^{n}(m_i - \overline{m})^2} \quad i = 1,2,\ldots,n \tag{1}$$

where:
m_i *: measured variable*

p_i*: predicted variable*

$\overline{m}$ *: arithmetic mean of* m_i *for all events i=1 to n*

The calculation of E is a procedure which essentially is the sum of the deviations of the observations from a linear regression line with a slope of 1. If the measured variable is predicted exactly for all observations the model E is 1. Low values of E show high deviations between measured and predicted values. If E is negative predictions are very poor and average value of the output is a better estimate than the model prediction.

Field monitoring was carried out by the Bavarian Water Authority (1984) for the Glonn watersheds, by a BMFT-Project (1992) for Weilierbach watershed, and by Rode (1995) for Salzboede watershed.

3. Results

The predictions of surface runoff and peak flow rate at the drainage outlet are shown in Table 1. Calibration of Curve Number method (SCS, 1972) was used to fit surface runoff predictions by AGNPS to watershed characteristics. The coefficient of efficiency *(E)* was 0.93 (Glonn G1) and 0.76 (Glonn G2) for 18 and 12 validation events, respectively. The deviations between measured medians and predicted medians for surface runoff were 1.4 min (Glorm G1) and 1.5 mm (Glonn G2). Slightly better results in surface runoff predictions were calculated using Lutz method (Lutz, 1984), because rainfall-runoff characteristics were described with more detail: the E for surface runoff in Glonn G1 watershed was 0.96, in Glonn 02 watershed 0.83**,** in Weilierbach watershed 0.88, and in Salzboede watershed 0.87. Deviations between predicted and measured medians were 0.5 mm (Glonn G1), 0.8 mm (Glonn G2), and 0.1 mm, in Salzboede watershed. Excellent predictions were calculated for surface runoff using AGNPSm in all four watersheds. Slightly poorer predictions in surface runoff were calculated using AGNPS.

Peak flow calculations (Q_{max}) were highest in the Glonn watersheds with an *E* of 0.84 and 0.82 (Glonn GI and G2, respectively). The deviations between predicted and measured peak flow in Glonn GI, G2, and Salzboede watershed were 52 Us, 14 Us, and 150 Us. Poor results were calculated for peak flow rate in Weiherbach watershed *(E.* 0.36) but only few rainfall-runoff events were available for verification. Summing up the predictions in hydrology were reliable using AGNPSm model.

Table 1. Validation Results: Surface runoff (QD) and Peak Flow (Q_{max})

watershed	output	coefficient of efficiency (E)	median measured values	median predicted values	number of validation events
G I	Q_D (CN method)[1]	0.93	3.8 mm	5.2 mm	18
	Q_D (Lutz Method)[2]	0.96		4.3 mm	
	Q_{max}	0.94	313 l/s	261 l/s	
G2	Q_D (CN method)	0.76	2.0 nun	3.5 mm	12
	Q_D (Lutz method)	0.83		2.8 mm	
	Q_{max}	0.82	76 1/s	62 l/s	
Weiherbach	Q_D (Lutz method)	0.88			7
	Q_{max}	0.36			
Salzboede	Q_D (Lutz method)	0.87	8.6 mm	8.7 mm	16
	Q_{max}	0.57	8250 l/s	81	

[1]surface runoff calculated by AGNPS
[2]surface runoff calculated by AGNPSm

The sediment calculations were carried out by using the Lutz method (AGNPSm). Table 2 shows the validation results for sediment delivery in all four watersheds. Different calculation methods are listed for Glonn G I watershed showing the differences between sediment delivery calculated by AGNPS (Sed) and AGNPSm (Sed_{sp}: LS factor calculated based on stream power theory; Sed_v: LS factor calculated based on stream power theory and channel scouring linked to flow velocity). The coefficient of efficiency could be improved from 0.26 (Sed) to 0.57 (Sed_{sp}) up to 0.90 (Sed_v) in Glonn G1 watershed. Deviations between measured and predicted medians in sediment delivery were lowest for Sed_v (0.1 t). Similar results in sediment delivery predictions were calculated in watershed Glonn Gl (E: 0.72 and 0.1 t deviation between measured and predicted medians). The sediment delivery in Salzboede watershed was calculated with less predictive power. A detailed study comparing sediment delivery calculations by AGNPS and AGNPSm is given by Grunwald et aL (1997).

Table 2. Validation Results: Sediment delivery (Sed)

watershed	Output	coefficient of efficiency (E)	median measured values [t]	median predicted values [t]	number of validation events
GI	Sed	0.26	2.1	0.8	18
	Sed_{sp}	0.57		1.1	
	Sed_v	0.90		2.0	28
G2	Sed_v	0.72	3.0	3.1	24
Salzboede	Sed_v	0.49	-	-	8

Sed: USLE (Wischmeier et al., 1978) - AGNPS

Sed_{sp}: LS factor calculated based on stream power theory (Moore et al., 1986) - AGNPSm

Sed_v: LS factor calculated based on stream power theory and channel scouring linked to flow velocity – AGNPSm

4. Conclusions

The complexity of the AGNPSm model seems to be sufficient to match predicted to measured values of surface runoff and sediment delivery at the drainage outlet in the watersheds examined. The predictive power of AGNPSm was robust in watersheds differing in size, land use, soil, and climate characteristics. Still there are uncertainties linked to predictions in peak flow (Salzboede and Weiherbach watershed) and sediment delivery (Salzboede watershed). Shortcomings in **sediment delivery predictions in Salzboede watershed are e.g. due to errors in peak** flow calculations, Prediction errors are linked not only to model complexity but also to parameterization, which is highly dependent on data quality. Therefore further research is necessary to transfer data-grid to model-grid information considering the spatial variability of parameters.

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