GDAŃSK UNIVERSITY OF TECHNOLOGY

Influence of layered soil structure on groundwater recharge rates and contaminant travel time: A numerical study using SWAP model and comparison with simplified methods

Adam Szymkiewicz[1], Julien Savard[2], Beata Jaworska-Szulc[1]

[1] Gdańsk University of Technology, Gdańsk, Poland [2] Conservatoire National des Arts et Métiers Champagne-Ardenne, Paris, France, [3] Nancy Agency, SADE-CGTH, Malzéville, France

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Motivation

- Estimation of contaminant travel time in the unsaturated zone is important for assessing aquifer vulnerability, delineating wellhead protection zones, planning monitoring and remediation, predicting the effects of land use and climate change on groundwater quality.
- Travel time can be computed using several methods of varying complexity, based on either transient or steady flow assumption, but comparative studies are limited.

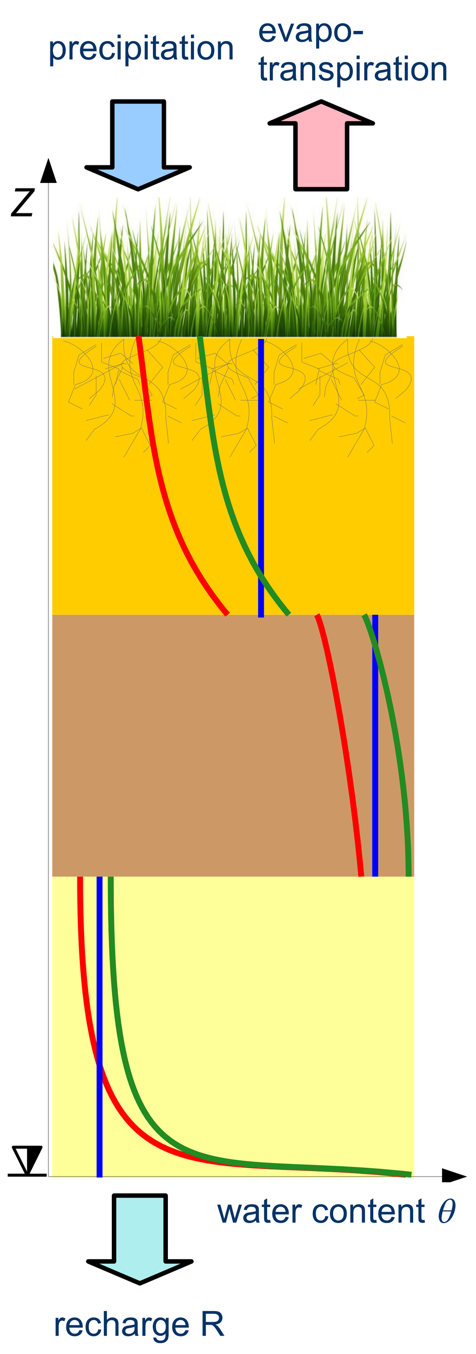
Objectives

- Comparison of recharge rates and solute travel time obtained from transient flow and transport with simple methods based on the assumptions of steady state flow and advective transport
- Investigation of the influence of layered soil structure

Recharge and travel time calculations

Transient simulations

- SWAP numerical code (Kroes et al. 2017)
- Richards equation for transient water flow
- Weather data from Gdańsk, Poland
  - Average precipitation 550 mm
- Bare soil and grass cover scenarios
- Solute transport by advection and dispersion
- Constant solute concentration in infiltrating water
- Output:
  - Recharge rates (variable in time)
  - Time of solute arrival at groundwater table (1% and 99% of the input concentration)



Steady-state methods

- Average recharge rate R obtained from transient simulations
- Transport only by advection
- Water content θ constant in time
- Travel time: $dt = \frac{dz\,\theta(z)}{R}$

Hydrostatic method

- $\theta(z)$ corresponds to hydrostatic pressure distribution

Steady flow method

- $\theta(z)$ obtained from steady flow equation with flux = R

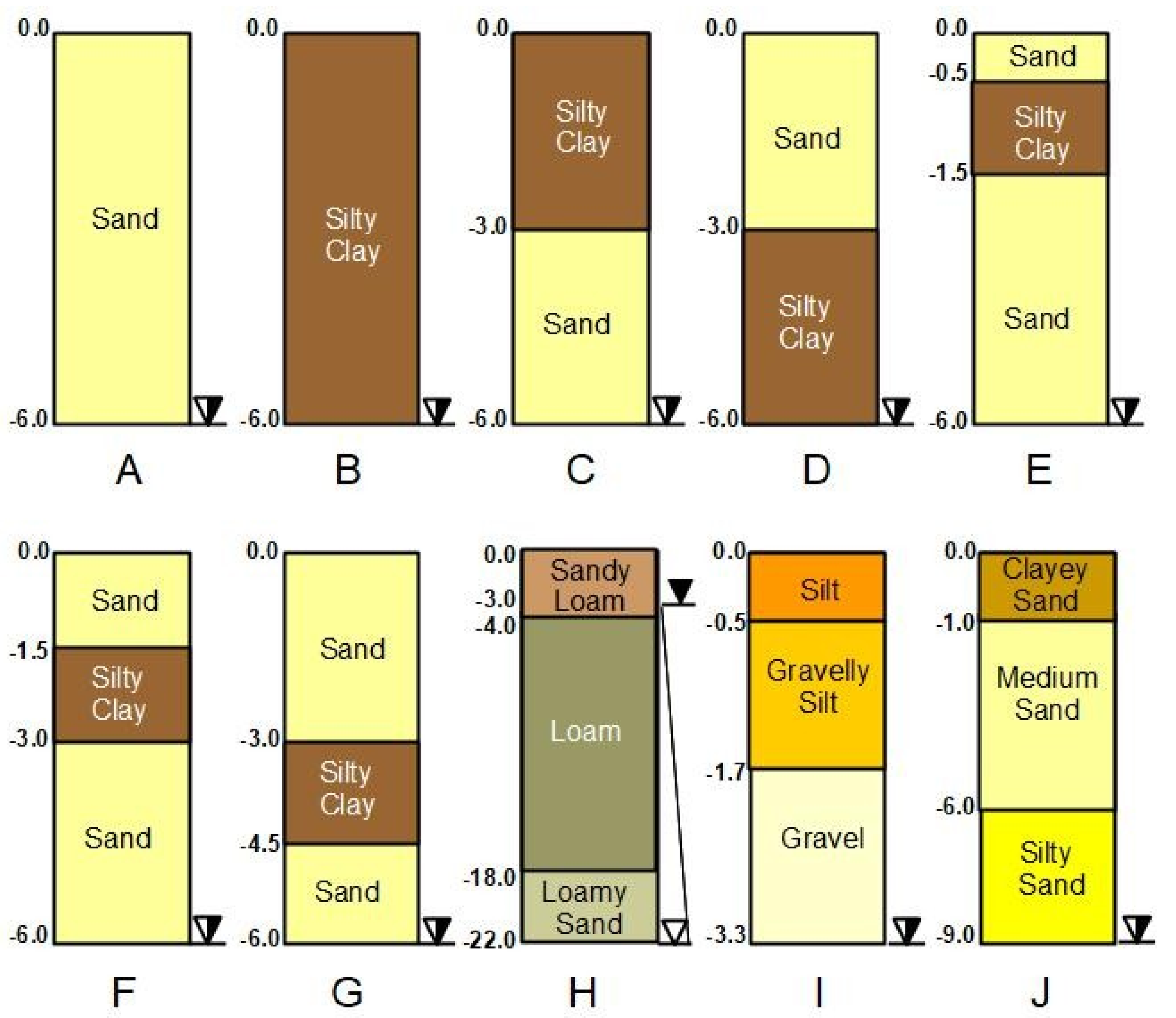
Charbeneau & Daniel (1993)

- θ constant in each layer, corresponds to flux = R (gravity flow only)

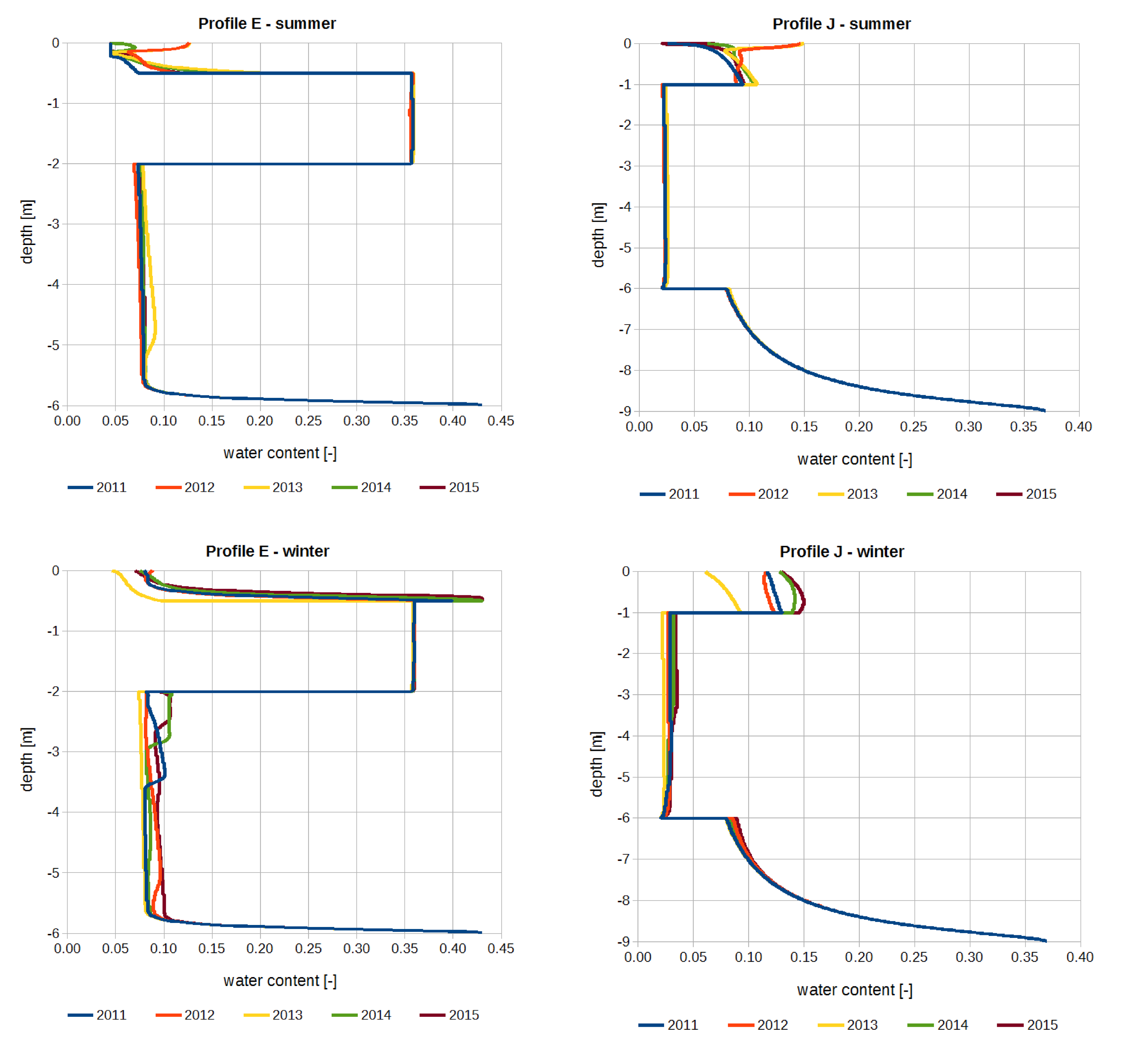
Witczak & Żurek (1994)

- θ constant in each layer, taken from field measurements or literature

Soil profiles



Water content profiles from transient flow simulations



Results for bare soil

Profile	Mean recharge [mm/yr]	Travel time [days]				
		Transient	Hydrostatic	Steady flow	Charbeneau & Daniel	Witczak & Żurek
A	312	424–661	383	655	629	491–702
B	62	7962–10010	12011	12650	11445	8477–11303
C	61	4460–6198	7106	7948	7164	5565–7539
D	325	895–1535	1325	1545	1453	1044–1415
E	316	746–1030	849	1124	1030	758–1044
F	319	736–1022	879	1155	1057	780–1074
G	320	738–1020	880	1141	1045	770–1163
H	247	10512–12642	12512	12747	12590	12728–13078
I	98	808–1524	1334	2121	1419	1661–2875
J	195	794–1308	1111	1310	830	2003–2883

Results for soil with grass cover

Profile	Mean recharge [mm/yr]	Travel time [days]				
		Transient	Hydrostatic	Steady flow	Charbeneau & Daniel	Witczak & Żurek
A	220	531–806	543	892	857	697–995
B	38	11782–13555	19598	20550	18392	13832–21900
C	38	6336–8706	11407	12630	11271	8933–13832
D	223	1480–1876	1880	2170	2027	1482–2295
E	215	851–1526	1283	1661	1514	1146–1732
F	224	834–1503	1241	1598	1457	1100–1662
G	224	830–1501	1257	1598	1457	1100–1662
H	195	12956–15477	15849	16120	15926	16116–16565
I	52	963–1852	2513	3905	2454	3131–5419
J	156	1314–1660	1388	1623	1011	2504–3603

Conclusions

- Differences between transient and steady-state methods are smaller for bare sandy soils and larger for vegetated soils with fine-textured layers
- Overall performance of all steady-state methods is similar, no one is clearly superior to others
- Due to hydrodynamic dispersion the travel time should be considered as an inerval rather than a single value

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