Functional Sensitivity Study of Pedotransfer Functions for Land Surface Models

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Background and Motivation

- different PTFs are in use in LSM and even more are available in literature
- Most LSM use class transfer functions (e.g., 12 USDA soil classes)
- Most LSM use Brooks-Corey parameterization

Model	Key references	Water movement approach	hydraulic model / function	PTF for hydraulic model / function	Additional point PTF
CABLE Community Atmosphere Biosphere Land Exchange model	Kowalczyk (2006), Wang et al. (2011)	diffusivity form of Richards equation	Campbell (1974)	Clapp and Hornberger (1978)	PWP & FC calculated from MRC
Catchment land surface model NASA_CATCHMENT_LSM	Ducharne et al. (2000) Koster et al. (2000)	Bucket model	Cambpell (1974)	lookup table according to Dirmeyer and Oki (2002) modiefied from Cosby et al. (1984)*	PWP & FC calculated from MRC
Community Land Model CLM 4.5	Oleson et al. (2013), Lawrence et al. (2011)	Richards equation (form is not provided)	Campbell (1974)	use of various PTFs for Campbell (1974) model based on Clapp and Hornberger (1978) and Cosby et al. (1984); for organic soils all parameters are modified	not reported
LEAF / OLAM version 4	Lee (1992), Lee and Pielke (1992), McCumber and Pielke (1981), Walko et al. (2000)	diffusivity form of Richards equation	Campbell (1974) or van Genuchten (1980)	Clapp and Hornberger (1978) or look up table for 12 soil classes for van Genuchten (1980) (source of parameters not provided)	PWP & FC calculated from MRC
JULES version 4.6	Best et al. (2011)	diffusivity form of Richards equation	Brooks-Corey (1964) or modified van Genuchten (1980)†	modified Cosby et al. (1986)§	PWP & FC calculated from MRC
JSBACH version 3.0	Roeckner et al. (2003)	diffusivity form of Richards equation	modified van Genuchten according to Disse (1995) for HCC and Campbell (1974) for diffusivity	use of various PTF for Campbell (1974) model based on Clapp and Hornberger (1978), Patterson (1990), Letts et al. (2000), Beringer (2001),and William and Ahuja (2003)	RZWHC according to Kleidon (2004) PWP according to Hagemann (2002) Z_r according to Dunne and Willmott (1996)
NOAH-MP version 3.0	Niu et al. (2011)	diffusivity form of Richards equation	Campbell (1974) or van Genuchten (1980)	Cosby et al (1984) for Campbel (1974), van Genuchten (1980) parameters derived from Cosby parameters	PWP & FC calculated from MRC
MPI-HM	Hagemann and Dümenil Gates (2003), Stacke and Hagemann (2012)	bucket model	none	soil water capacity and wilting point calculated from different unspecified sources	regresion based calculated from additional data (e.g., maximum rooting depth dataset)
ORCHIDEE rev3959	Ducharne (2016)	Fokker-Planck equation	van Genuchten (1980)	Carsell and Parrish (1988) look up table for 12 USDA classes	PWP & FC calculated from MRC
SSiB Simplified Simple Biosphere model Version 3.5	Xue et al. (1991), Zhan et al. (2003), Sun and Xue (2001)	bucket model	extended Campbell (1974) for partially frozen soils	Clapp and Hornberger (1978) for WR and modified Clapp and Hornberger (1974) according to Jame and Norum (1980) for HC	PWP according to Xue et al. (1991)
SURFEXv8.0 version 8.0	Masson et al. (2013)	force-restore approach or diffusivity form of Richards equation	Cambpell (1974)	continuous PTF according to Decharme et al., (2011) developed from Clapp and Hornberger (1978) and Cosby et al. (1984) database.	either PWP & FC calculated from MRC or by PTF based on Clapp and Hornberger (1978) database

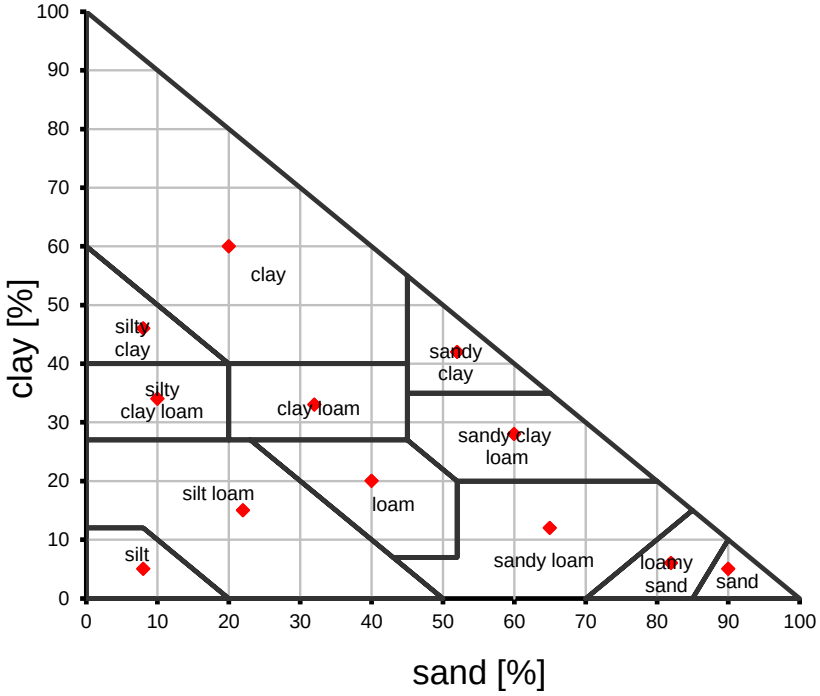
* revised version used for SMAP L4_SM (https://smap.jpl.nasa.gov/data/) used van Genuchten parameters according to Wösten et al. (2001)

† hereby van Genuchten function was coupled to Brooks-Corey parameters

§ reformulated to match metric units

Methods

- use of different PTFs and hydraulic models (Mualem-van Genuchten vs Brooks-Corey)
- 12 USDA classes
- water flow simulation using HYDRUS-1D with run-off
- 30 years climate data from North-Rhine Westfalia (daily values 19982- 2011)
- 200 cm deep, homogeneous bare soil profile



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Pedotransfer functions

- 13 PTFs
- 5 PTFs for Brooks and Corey
- 8 PTFs for Mualem van Genuchten
- 4 class transfer functions (2x MvG, 2x BC)

Pedotransfer Function	*MvG*	*BC*	*class*	*continuous*	*texture*	*BD*	C_{org}	*Porosity*	*pH*	*CEC*
Rosetta SSC (Schaap et al., 2001)	x			x	x					
Rosetta SSC+BD (Schaap et al., 2001)	x			x	x	x				
Wösten et al. (1999)	x			x	x	x	x			
Rawls and Brakensiek (1985)	x			x	x			x[1]		
Rawls and Brakensiek (1985)		x		x	x			x[1]		
Weynands et al. (2009)[2]	x			x	x	x	x			
Tóth et al., (2015) topsoil	x			x	x	x	x		x	
Carsel and Parrish (1988)	x		x							
Tóth et al., (2015) Annex Tab.19	x		x							*x*
Cosby et al. (1984) SC		x								
Cosby et al. (1984) SSC		x								
Rawls et al. (1982)		x	x							
Clapp and Hornberger (1978)		x	x							

[1] porosity was calculated from bulk density by *Porosity* = 1-(*BD*/2.62)

[1] Weynands et al. (2009) in combination with Weihermüller et al., (2017)

SC = sand and clay, SSC = sand, silt, and clay, SSC+BD = sand, silt, caly, and bulk density

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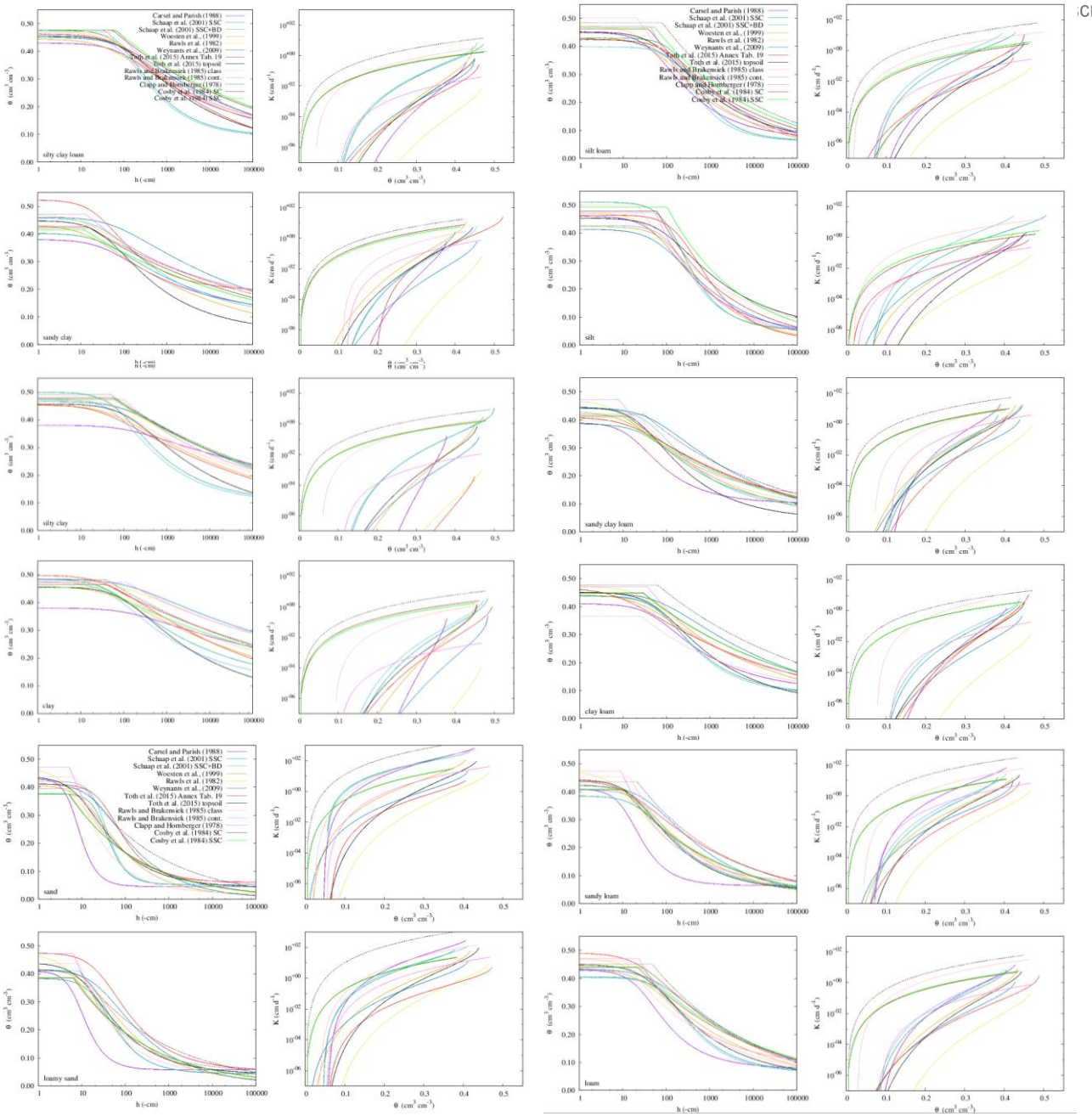
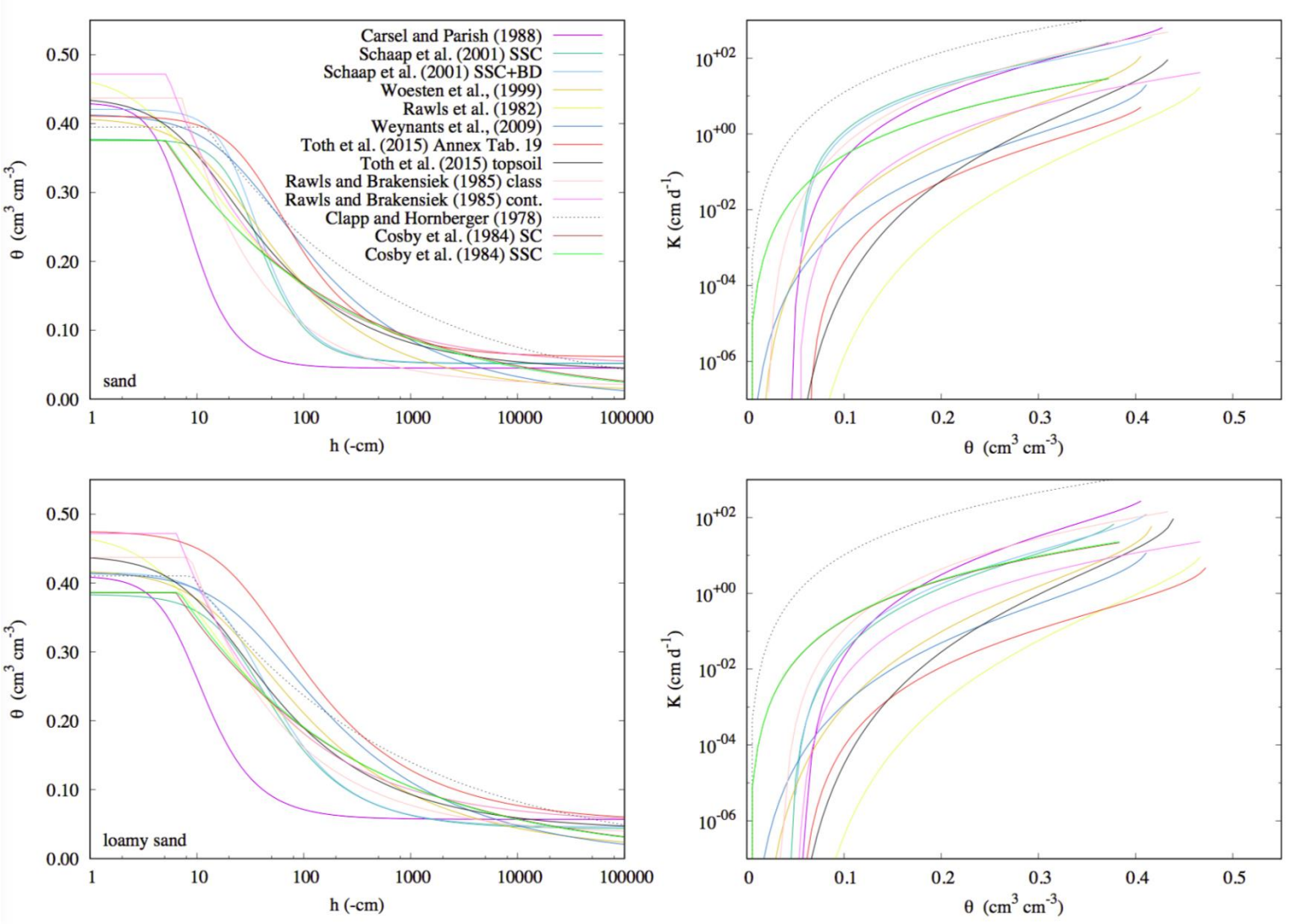
Retention & conductivity curves



Retention & conductivity curves



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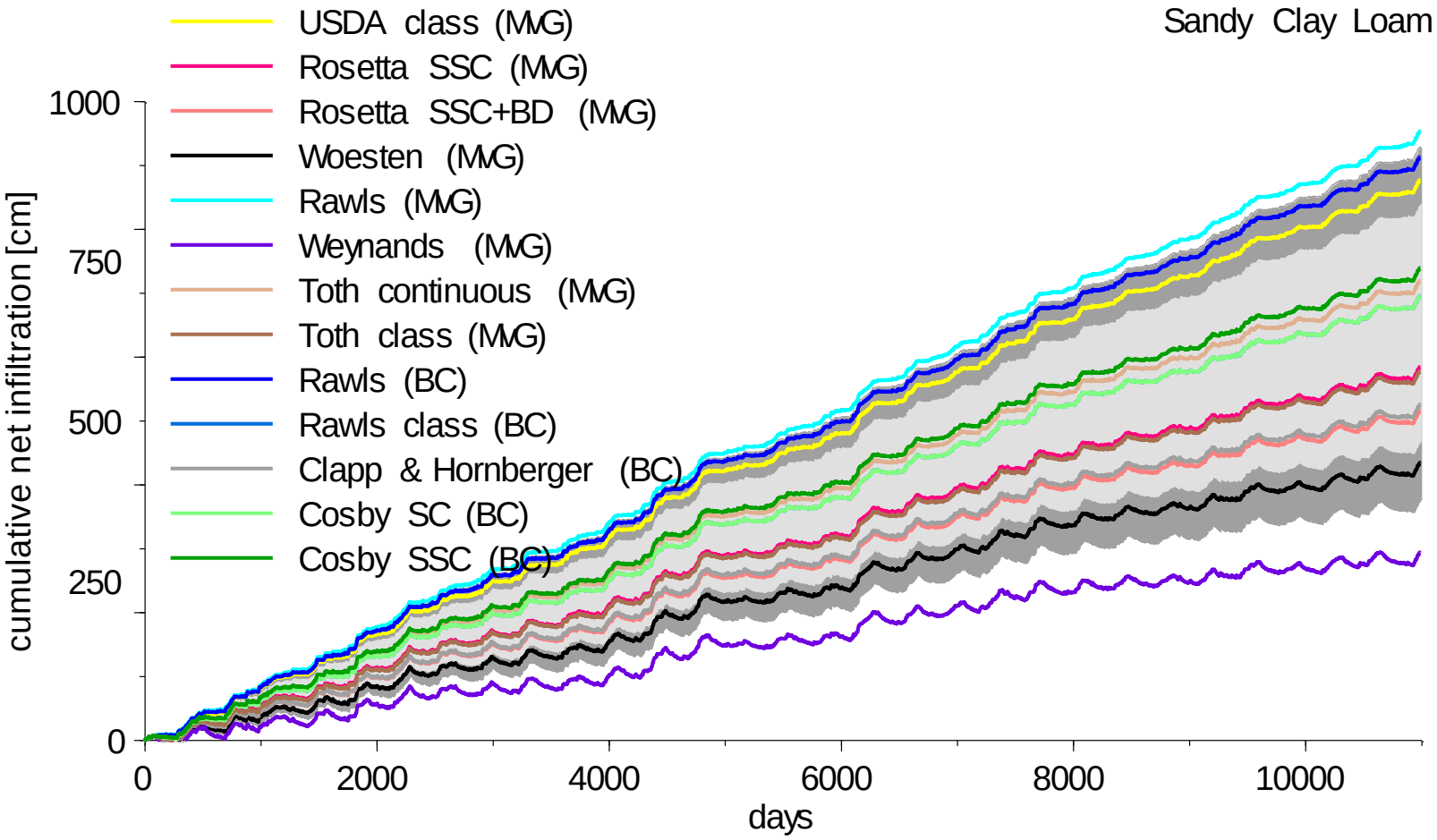
Net infiltration into Sandy Clay Loam



mean annual net infiltration [cm]

USDA class	Rosetta SSC	Rosetta SSC+BD	Wösten	Rawls MvG	Rawls BC	Rawls BC Class	Weynands	Toth_cont	Toth_class	Clapp& Horn.	Cosby SC	Cosby SSC
29,2	19,5	17,2	14,5	31,8	30,4	23,2	9,8	24,0	19,3	17,5	23,2	24,6

mean annual precipitation = 82.8 cm

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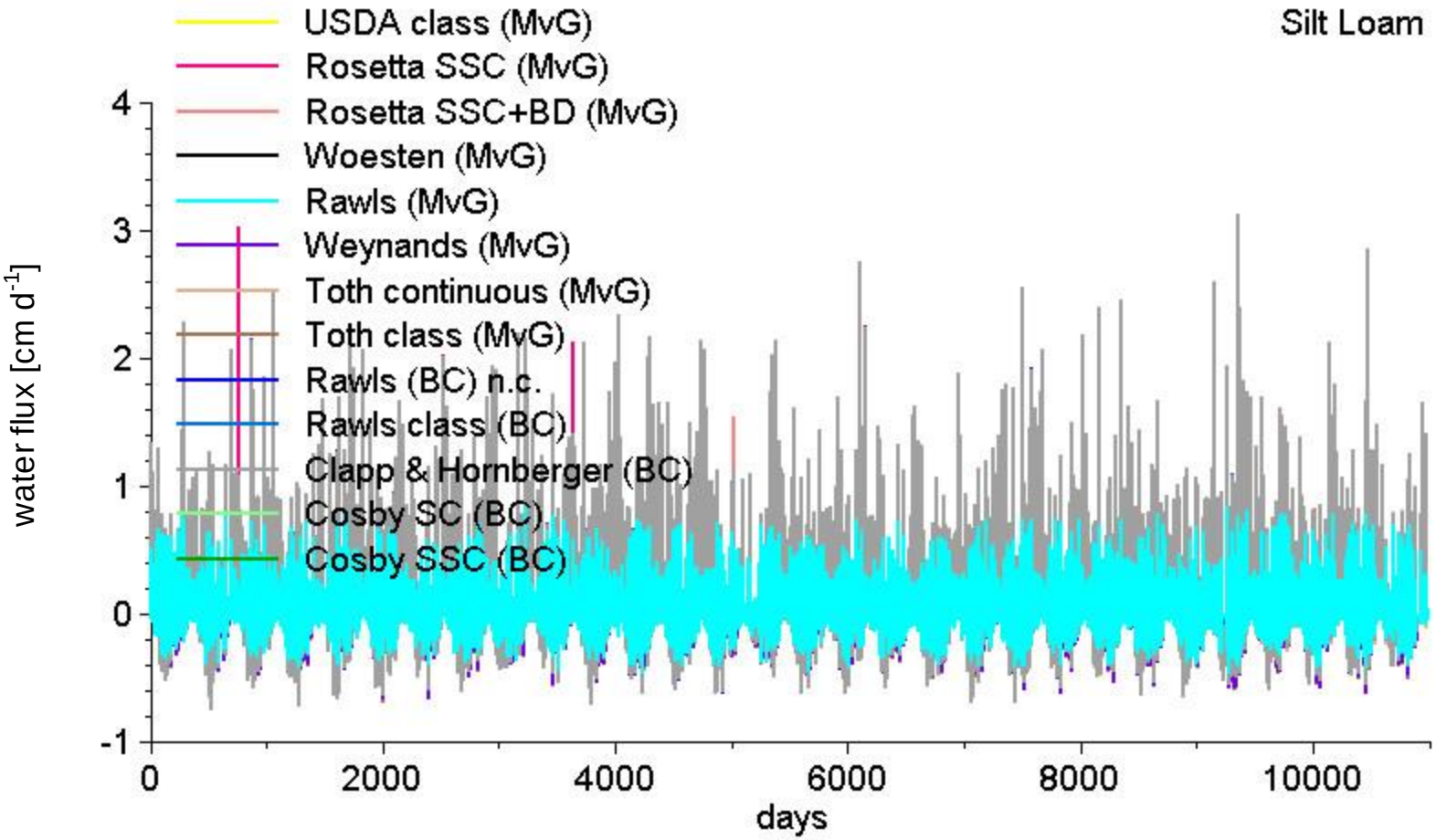
Instantaneous infiltration Silt Loam



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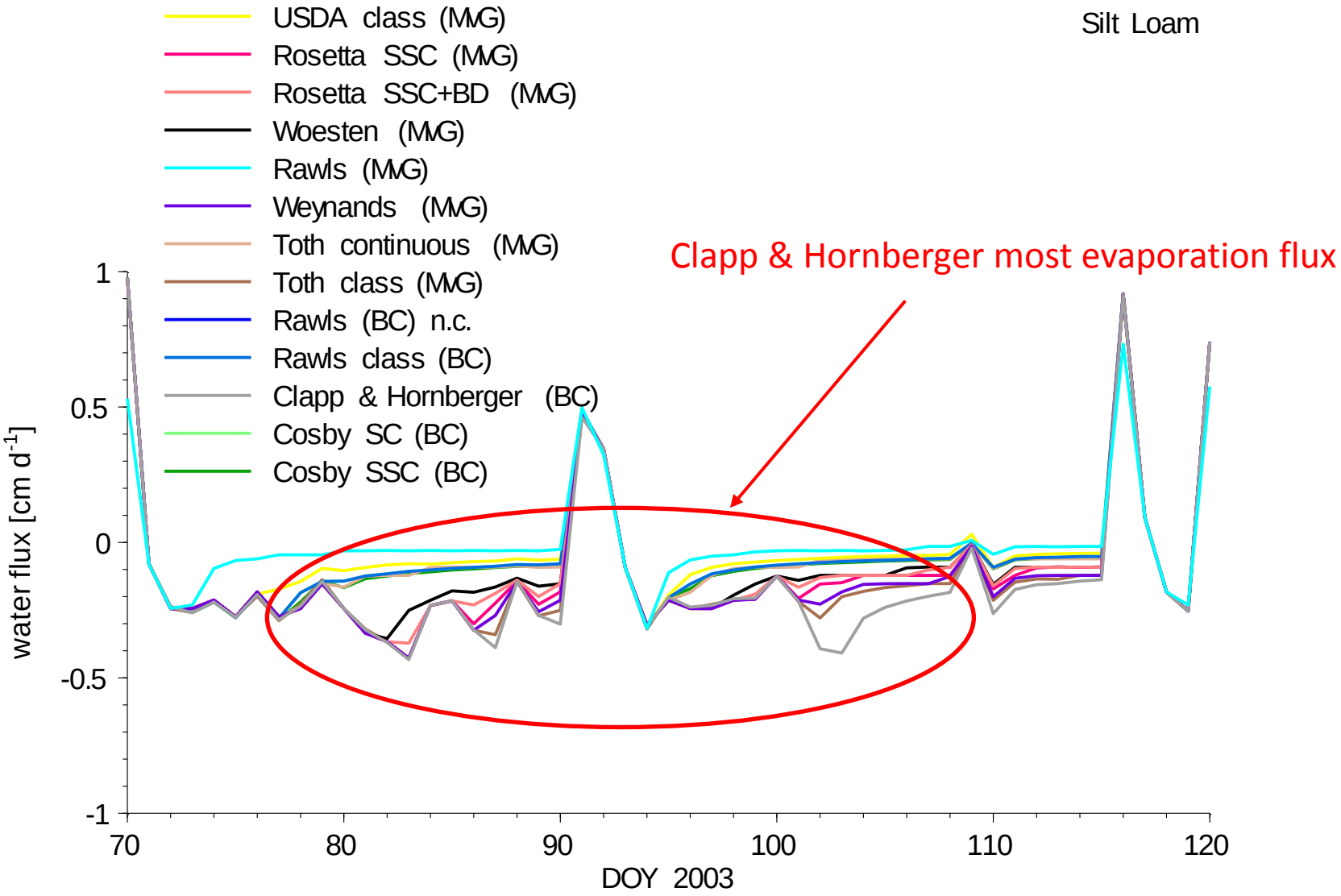
Instantaneous fluxes for extreme conditions



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Discusssion

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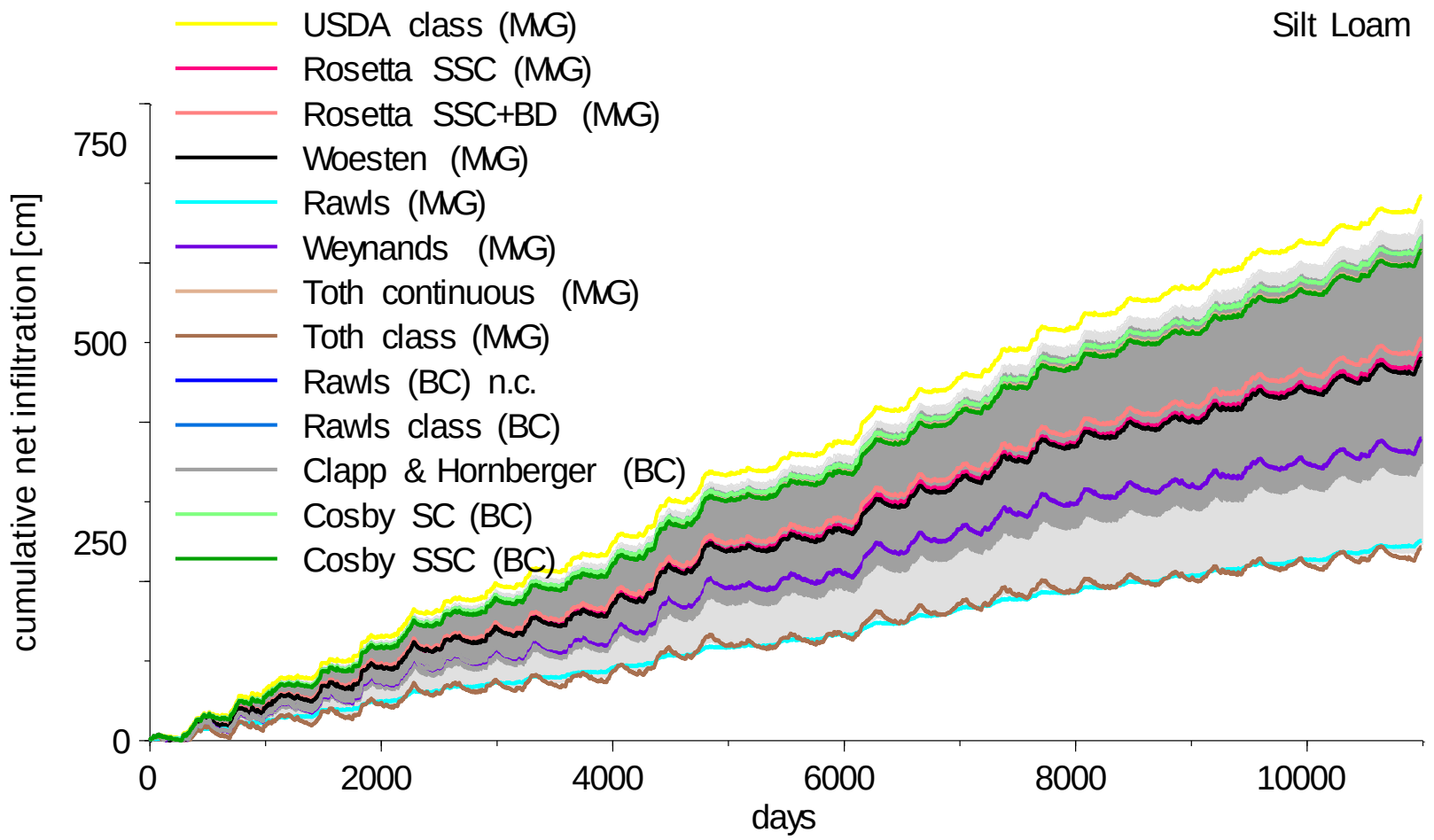
Net infiltration into Silt Loam



mean annual net infiltration [cm]

USDA class	Rosetta SSC	Rosetta SSC+BD	Wösten	Rawls MvG	Rawls BC	Rawls BC Class	Weynands	Toth_cont	Toth_class	Clapp& Horn.	Cosby SC	Cosby SSC
22,8	16,2	16,8	16,0	8,4	n.c.	21,0	12,7	20,5	8,1	13,3	21,0	20,5

mean annual precipitation = 82.8 cm

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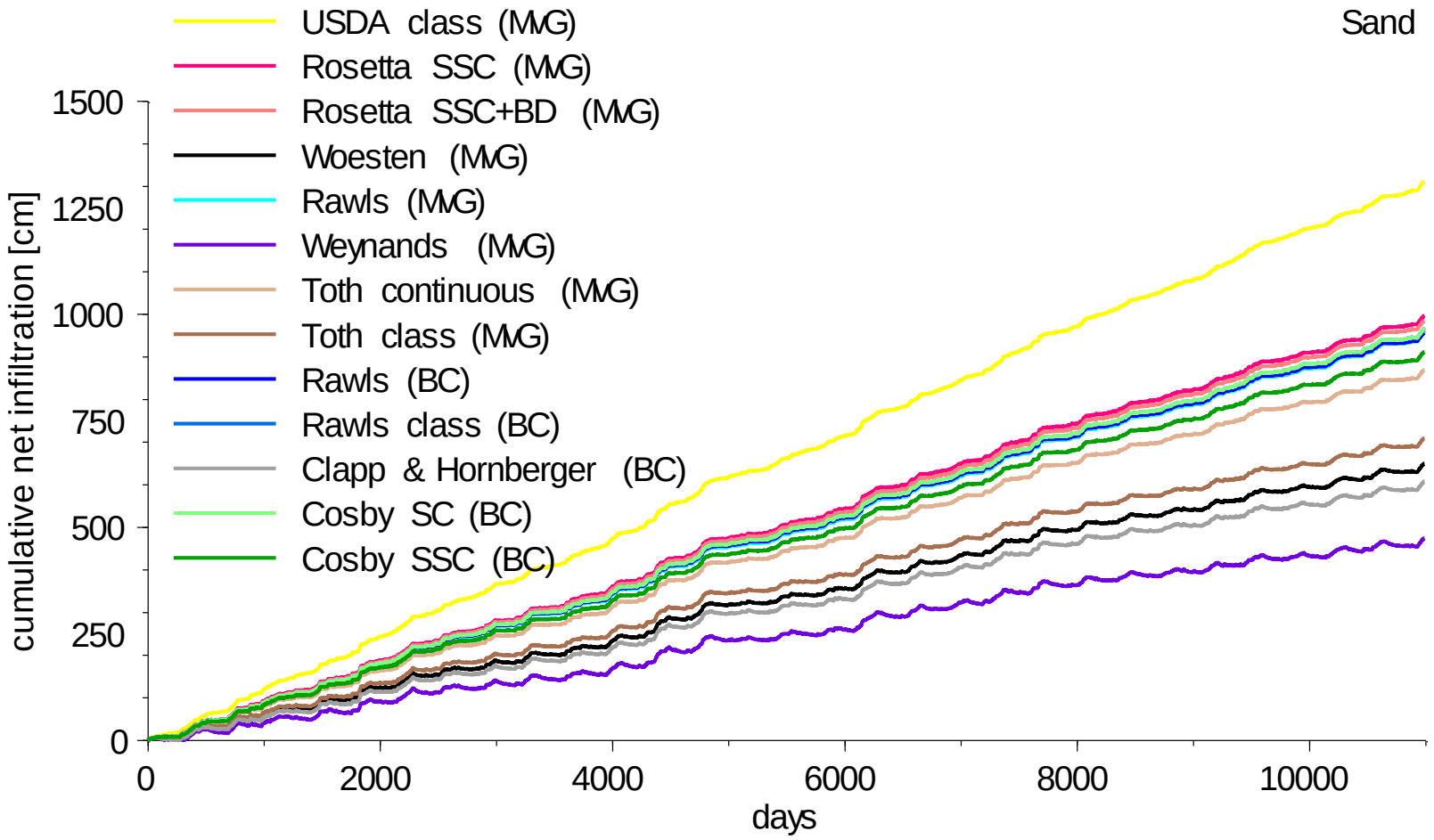
Net infiltration into Sand



mean annual net infiltration [cm]

USDA class	Rosetta SSC	Rosetta SSC+BD	Wösten	Rawls MvG	Rawls BC	Rawls BC Class	Weynands	Toth_cont.	Toth_class	Clapp& Horn.	Cosby SC	Cosby SSC
43,7	33,2	32,8	21,6	31,9	31,9	32,2	15,8	29,0	23,6	20,2	32,2	30,4

mean annual precipitation = 82.8 cm

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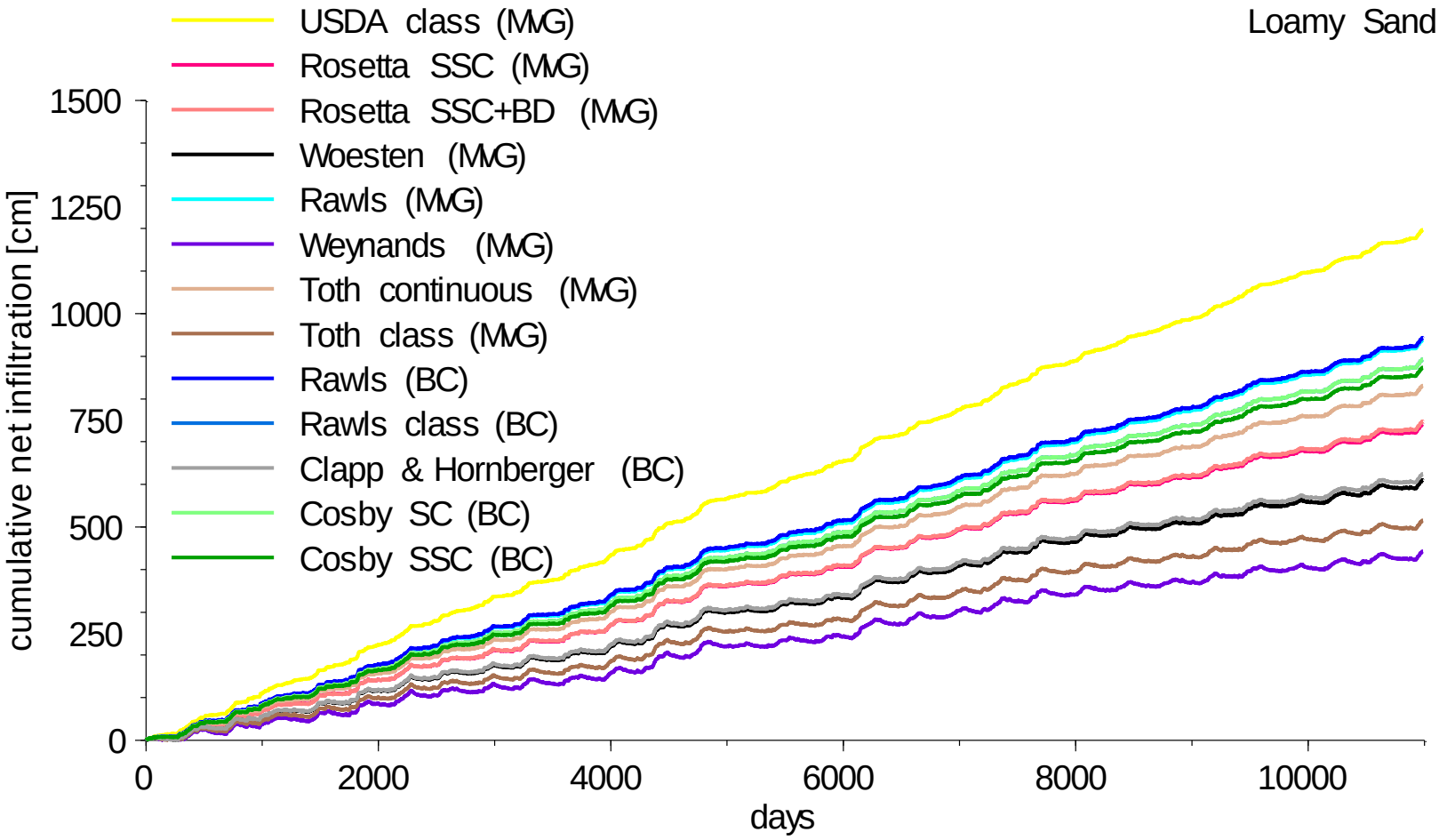
Net infiltration into Loamy Sand



mean annual net infiltration [cm]

USDA class	Rosetta SSC	Rosetta SSC+BD	Wösten	Rawls MvG	Rawls BC	Rawls BC Class	Weynands	Toth_cont.	Toth_class	Clapp& Horn.	Cosby SC	Cosby SSC
39,9	24,7	24,9	20,3	31,3	31,4	29,8	14,8	27,7	17,2	20,8	29,8	29,1

mean annual precipitation = 82.8 cm

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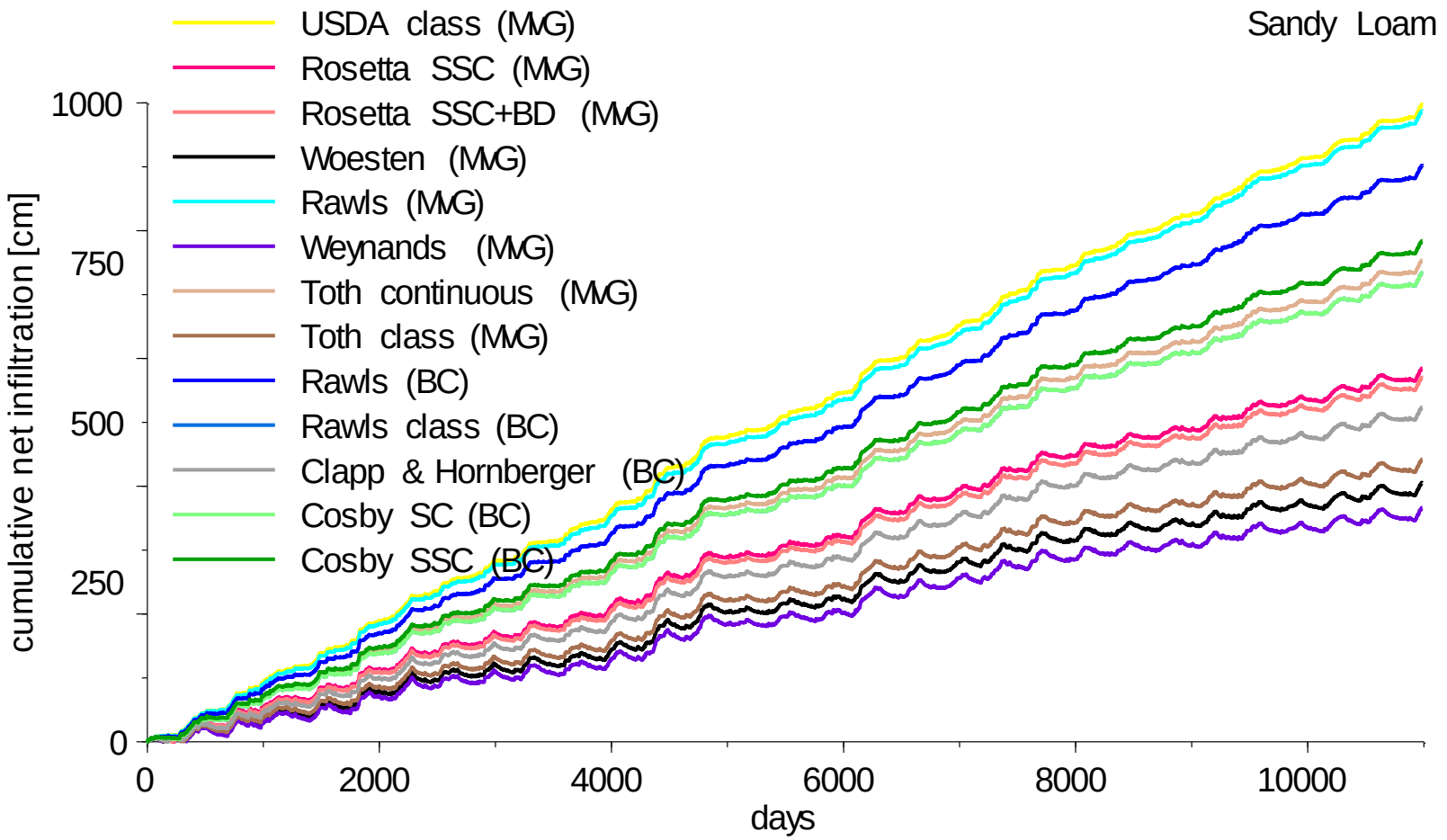
Net infiltration into Sandy Loam



mean annual net infiltration [cm]

USDA class	Rosetta SSC	Rosetta SSC+BD	Wösten	Rawls MvG	Rawls BC	Rawls BC Class	Weynands	Toth_cont	Toth_class	Clapp& Horn.	Cosby SC	Cosby SSC
33,2	19,5	19,0	13,5	32,9	30,1	24,5	12,2	25,1	14,7	17,5	24,5	26,1

mean annual precipitation = 82.8 cm

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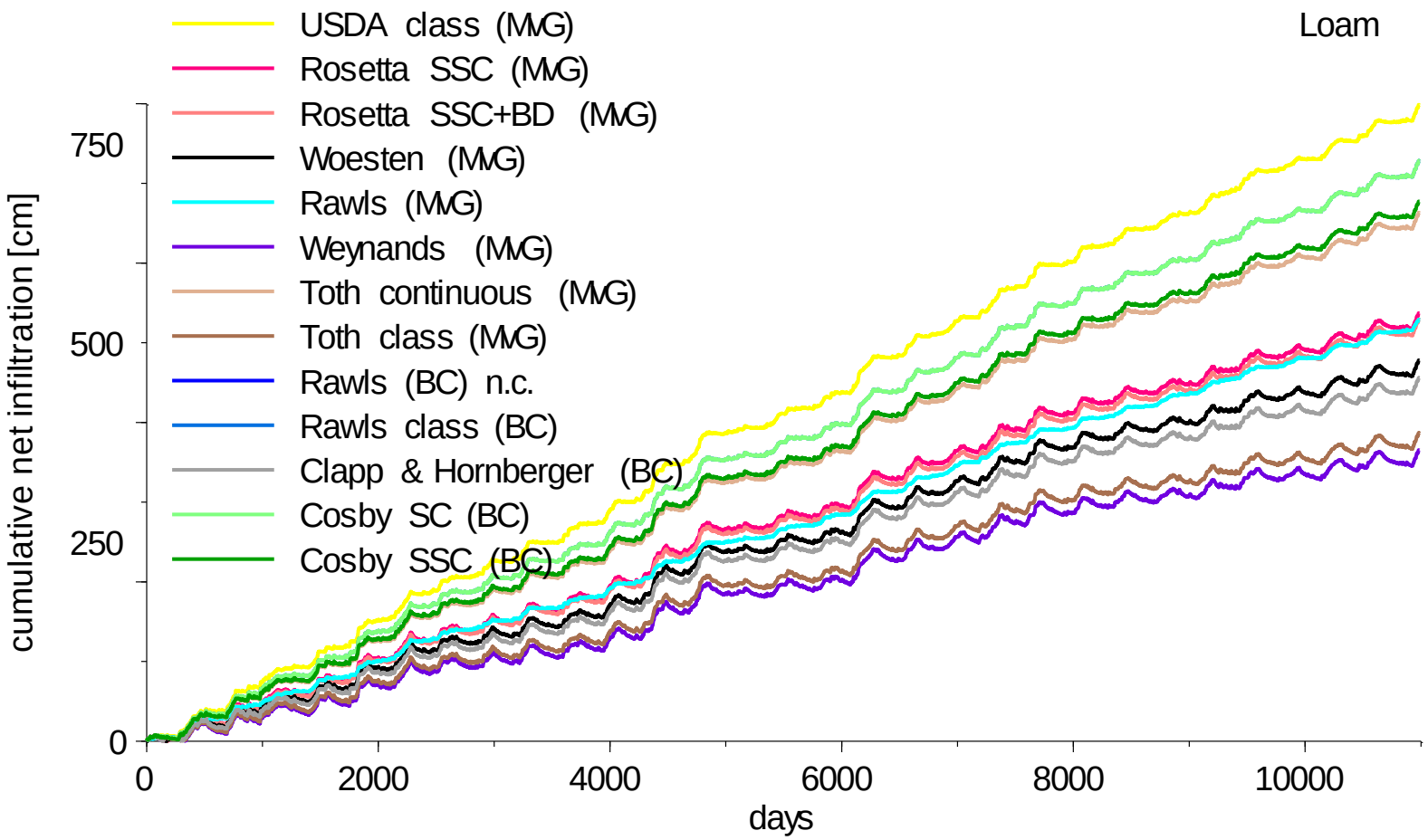
Net infiltration into Loam



mean annual net infiltration [cm]

USDA class	Rosetta SSC	Rosetta SSC+BD	Wösten	Rawls MvG	Rawls BC	Rawls BC Class	Weynands	Toth_cont	Toth_class	Clapp& Horn.	Cosby SC	Cosby SSC
26,6	17,9	17,6	15,9	17,6	n.c.	24,3	12,2	22,1	12,9	15,2	24,3	22,6

mean annual precipitation = 82.8 cm

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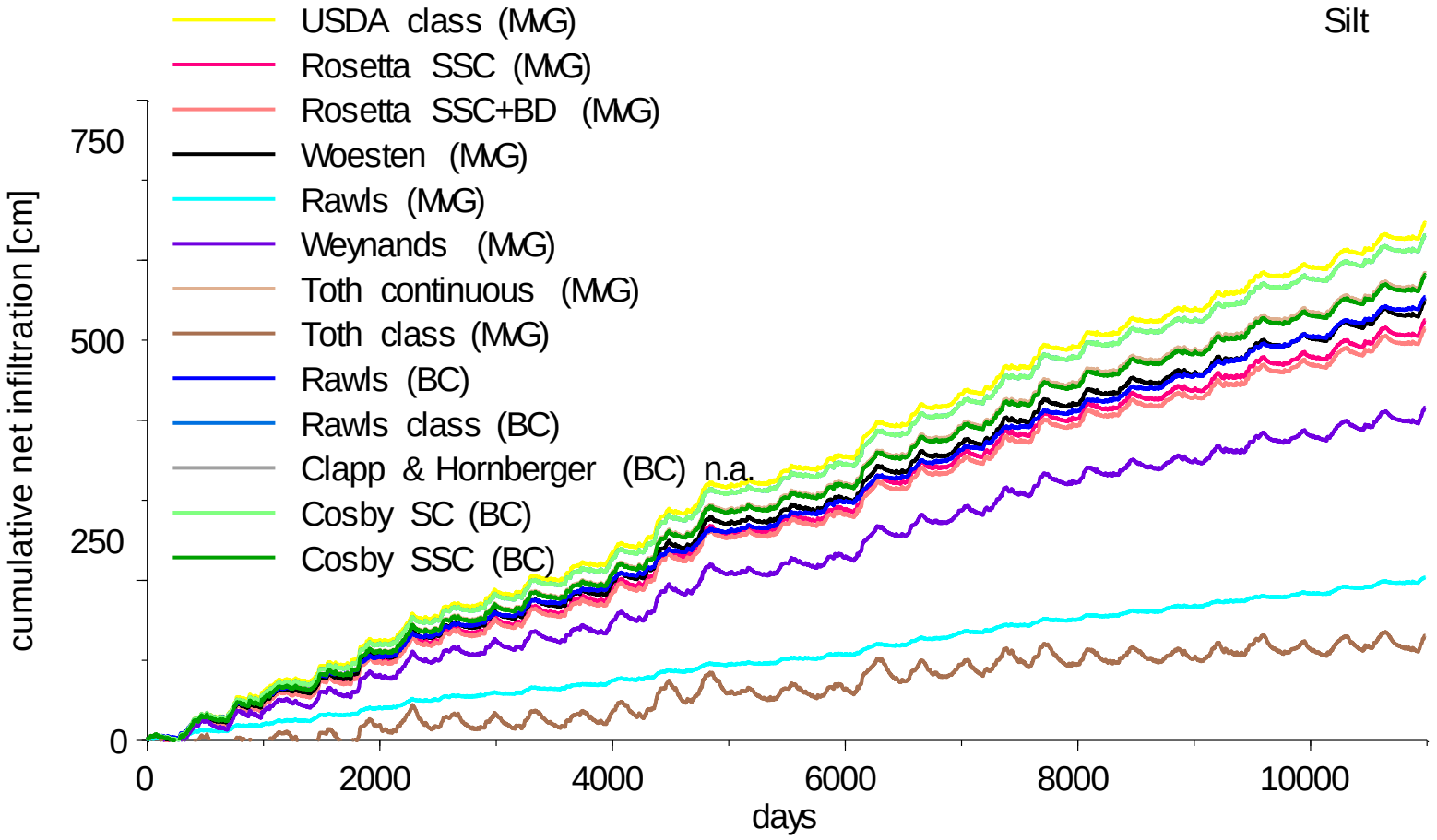
Net infiltration into Silt



mean annual net infiltration [cm]

USDA class	Rosetta SSC	Rosetta SSC+BD	Wösten	Rawls MvG	Rawls BC	Rawls BC Class	Weynands	Toth_cont	Toth_class	Clapp& Horn.	Cosby SC	Cosby SSC
21,5	17,5	17,2	18,3	6,8	18,5	21,0	13,9	19,5	4,4	n.a.	21,0	19,4

mean annual precipitation = 82.8 cm

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