

An introduction to EPIC+SUFI2 for calibrating EPIC crop growth model at different scales

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F	PIC Structure			Г				
					fort.51	8/6/2015 1:51 PM	51 File	676 KB
					EPIC0810	6/9/2011 10:40 AM	Application	3,824 KB
					AYEAR	4/4/2005 1:33 PM	DAT File	1 KB
			EDIC0910 ava		CMOD0810	9/10/2001 12:42 PM	DAT File	1 KB
					CROPCOM	5/26/2015 1:10 PM	DAT File	66 KB
			Read EPICRUN	N	EPICCONT	6/1/2015 6:24 PM	DAT File	1 KB
			Line by line		EPICERR	9/27/2010 9:16 AM	DAT File	1 KB
					epicfile	6/9/2011 10:01 AM	DAT File	1 KB
Enviror	mental Policy Integrated Climate model				EPICRUN	6/2/2015 2:52 PM	DAT File	1 KB
			. ↓		FERTCOM	5/4/2011 12:28 PM	DAT File	8 KB
			Controls the		MLRN0810	3/24/2008 10:18 AM	DAT File	1 KB
*	One of the most widely used crop model	s that			OPSCCOM	7/2/2015 6:46 PM	DAT File	1 KB
		•	execution proces	88	PARM0810	4/4/2011 10:14 AM	DAT File	2 KB
	simulate crop-related processes at a specifi	c site			PESTCOM	6/1/2007 10:14 AM	DAT File	21 KB
	On anotas an deile time atan				PRNT0810	7/2/2015 6:46 PM	DAT File	2 KB
***	Operates on daily time step				RTSOIL	3/21/2011 9:08 AM	DAT File	1 KB
	Offers different entions for agricultural				SITECOM	6/2/2015 2:54 PM	DAT File	1 KB
***	Otters unterent options for agricultural					6/2/2015 2:58 PM	DAT File	1 KB
	operations				TILLCOM	7/12/2015 5:24 PM	DAT File	60 KB
	operations				TR55COM	11/6/2007 10:30 AM	DAT File	6 KB
						6/3/2015 10:24 AM	DAT File	1 KB
					WIDXCOM	9/14/2005 2:27 PM	DAT File	8 KB
					WINDUSEL	12/2/2014 8:50 AM	DAT File	1 KB
					WORKSPACE	6/3/2015 10:24 AM	DAT File	1 KB
						6/3/2015 10:24 AM	DAT File	1 KB
		(Climate data			10/12/2004 9:38 AM	DATFILE	393 KB
						0/3/2013 10:24 AIVI	DLY File	903 KB
	Δα	ricultu	ral operation			2/2//2015 6:42 AIVI	ODS CI-	1 KB
	Ag	ficultui				7/2/2010 0:29 PIVI	OPS File	2 KB
	מ	hysios	raphic data			7/0/2013 5:00 PM		1 VD
	P	nysiogi	Tapine uata			6/2/2015 10:24 AM	SOL File	1 //P
						8/6/2015 10:24 AM	SUM File	1 KR
						4/14/2015 10:52 DM	WND File	2 KR
						6/3/2015 10:24 ΔM	WP1 File	2 KB



Objective 1: Extending its application from site-based to different scales (regional, county and continent)

Objective 2: Model calibration to validate that crop model is replicating historic period Drought vulnerability assessment

Other objectives

- A **user-friendly workspace** where the user manage settings of input data systematically;
- Setting agricultural operations in different ways;
- Setting of printing outputs;
- Different options for **EPIC parameterization**;
- Considering uncertainties in **operational data**, *PHU*, *N-P-K* application rate, Planting date;
- Considering sensitivity analysis
- Evaluating model performance based on different objective function;
- Speed up simulations on large scales;



EPIC+SUFI2 structure





EPIC+SUFI2 architecture





EPIC+							X
General settings	Operation settings Pa	rameterization	SUFI2 cali	bration			
Linux address	/mnt/project/kamaliba	/					
Windows address	E:\\PHD-SUMUP\\EPIC	+ SUF12				Bro	wse
Project name	Iran1	Resolution		0.5			
Select area	Iran 👻	Select crop		W-Whea	t	•	
Start year	1970	Number of yea	rs	43			
Warm-up years	20	Numbers of ru	ins 10				
Status							
Objec	v ctive-1	Object	v ive-2				



Objective 1:Extending its application to different scale



Larger scale, selecting a group of countries





Printing options

Standard Output		
Annual Output		
Annual cropman file (.ACM)	Average Annual Summary (.SUM)	
Annual summary (.ANN)	Annual Annual Soil organic table (.ACN)	
✓ Annual crop yield (.ACY)	Annual cost (.ACO)	
Annual biomass root weight (.ABR)	Annual tree growth (.ATG)	
Annual Pesticide (.APS)		
Monthly Output		
Monthly flipsim (.MFS)	Monthly Pesticide (.MPS)	
Monthly cropman (.MCM)	Annual water cycle (.ABR)	
Monthly Output to SWAT (.MSW)		
Daily Output		
Daily Hydrology (.DHY)	Daily Pesticide (.DPS)	
Daily soil temperature (.DTP)	Daily crop stress (.DCS)	
Daily soil organic (.DCN)	Daily general table (.DGN)	
Daily Soil table(.DSL)	Daily water cycle (.DWC)	
Daily (.DHS)	Daily grazing file (.DGZ)	
Daily soil water (.DWT)		
General Data		
Ending soil table (.SOT)	Summeray Operation Cost (.SCO)	
Organic C-N summary table (.SCN)		
Edit PRINT0810.DAT		



Agricultural operation

Agricultural operation	EPIC+					
- Brit briter of the second	 General settings	Operation settings	Parameterization SUFI2 cal	ibration		
settings	Linux address	/ /////project/horna lik	pa/			
	Windows address	E:\\PHD-SUMUP\\EP	IC+SUFI2		Bro	wse
	Project name	Iran1	Resolution	0.5		
	Select area	Iran	 Select crop 	W-Wheat	-	
	Start year	1970	Number of years	43		
	Warm-up years	20	Numbers of runs	10		
	Status					

- Select the sets of operations from planting date to harvesting date;
- Two options are available:

OPS1 \rightarrow planting date is considered as calibrating parameters

OPS2 \rightarrow planting date is not a calibrating parameter, but can change from one grid to another

OPS2

OPS2		4									×
Irrigation 🛛 📝 RainF	ed 🗌	RainFed-I	irrigati	ion							
Crop Maize	1	Number of	operat	tion 7							
Plant in Rows	CODE	136	•	Planting D	ensity	5.00		OPR-TIM	₩ E /I	mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Plant	Browse OPS time
Plant with drills	CODE	-	•	Planting D	ensity	5.00		OPR-TIM	₩ E /I	mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Plant	Browse OPS time
	PHU application 🕥 Fixed-PHU-RF 🔤 Var		🗸 Varia	able PHU-R	₹F /n	nnt/project/kamaliba/Database/managementData/maize/OPS-T2/PHU.t	Browse PHU-RF				
	Fixed PHU-IR - Variable PHU-IR /mnt/project/kamaliba/Database/managementData/maize/OPS-T2/PHU.t Browse PHU-IR					Browse PHU-IR					
✔ Tillage-l	CODE	157		OPR-Time	/mnt/	project/k	amaliba	a/Database	e/mana	agementData/maize/OPS-T2/Tillage_T2.b 🔻 Browse OPS time	
Tillage-2	CODE	-	-	OPR-Time	-					Browse OPS time	
Pesticide	CODE	-	• I	Pesticide-ID		-	•	OPR-TIM	E	-	Browse OPS time
	PEST-Ap	plication	Fixed	I-APP	-		📄 Var	riable-APP		-	Browse PEST
11:Irrigation	CODE	501	•	OPR-TIN	Æ -					Browse OPS Time	
rrigate Application (mm)	🔽 Fix	ed-Irrigation	on	200		📄 Vari	iable-Ir	rigation	-	·	Browse Irrigation
rrigate Rate	🔽 Fix	ced-Rate		0.85		📄 Vari	iable-Ra	ate	-		Browse Irr-Rate
12:Fertilizer-N	CODE	261	▼ Fe	etilizer-ID	5	52	•	OPR-TIME	. ,	/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Fertili	Browse OPS Time
13:Fertilizer-P	CODE	261	→ Fe	etilizer-ID	5	53	•	OPR-TIME		/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Fertili	Browse OPS Time
14:Fertilizer-K	CODE	261	→ Fe	etilizer-ID	5	54	•	OPR-TIME	. ,	/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Fertili	Browse OPS time
15:Fertilizer-A	CODE	-	₽ Fe	etilizer-ID		-	•	OPR-TIME	: [-	Browse OPS time
	FNP rate	e [kg/ha] 🛛	Fixed	IFNP	20		🔳 Va	ariable FNI	P	-	Browse FNP
	FM	fX N-app	Fixed	IFMX	80		Va Va	ariable FM	Х	$/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/NFM \\ \rangle$	Browse FMX
	BFT	0 Trigger 🛛	Fixed	I BFT0	0.85		📄 Va	ariable BF1	ГО	-	Browse BFT0
	М	ax P-App 📄	Fixed	l P-Apply	15		Va Va	ariable P-aj	PP	/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/PFMX	Browse P-app
	P	-app rate 📝	Fixed	l P-Rate	0.85		📄 Va	ariable P-ra	ate	-	Browse P-rate
	М	ax K-app 🛛	Fixed	l K-app	7		🔳 Va	ariable K-a	app	-	Browse K-app
	K	app rate 🐺	Fixed	l K-rate	0.85		📄 Va	ariable K-r	rate	-	Browse K-rate
	Max F	Fer-apply	Fixed	l Fer-app	-		🔳 Va	ariable Fer	-app	-	Browse Fer-app
Harvest without Kill(G)	CODE	292	•	OPV7	0.0	0	OPR-	TIME /m	nnt/pro	oject/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt	Browse OPS time
Harvest without Kill(F)	CODE	313	•	OPV7	0.0	0	OPR-	TIME /m	nnt/pro	oject/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt	Browse OPS time
HarvestOnce(G)	CODE	-	•	OPV7	-		OPR-	TIME /m	nnt/pro	oject/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt	Browse OPS time
HarvestOnce(F)	CODE	-	•	OPV7	-		OPR-	TIME /m	nnt/pro	oject/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt	Browse OPS time
Kill Crop	CODE	451	•	OPR-TIN	œ /	mnt/proj	ect/kan	naliba/Data	abase/	managementData/maize/OPS-T2/Kill_T/ Browse OPS Time	
Creat operation sched	lual										



Parameterization

- 13 operation parameters
- 56 crop parameter
- 85 EPIC parameters

Operation parameter	ters								×
Numbers of operat	tion parameter	rs 6	Number	rs of crop para	meters 6	Numbers o			
Total number of pa	Total number of parameters 14								
OPR-Param	Method	Default	Minimum	Maximum	OPR-Param	Method	Default	Minimum	Maximum
🔲 Planting-Date	rRelative 🔻	1	-0.15	0.15	PHU	rRelative 🔻	1	0.0257	0.0257
V Planting-Density	rRelative 🔻	1	-0.042857	-0.042857	Pesticide	rRelative 🔻	1	1	1
Irrigation-APP	rRelative 🔻	1	1	1	Irrigation-Rate	rRelative 🔻	1	1	1
FNP	rRelative 🔻	1	-0.4	0.4	FMX	rRelative 🔻	1	-0.008571	-0.008571
BFT0	rRelative 🔻	1	-0.128571	-0.128571	P-APP	rRelative 🔻	1	-0.068571	-0.068571
P-Rate	rRelative 🔻	1	1	1	K-APP	rRelative 🔻	1	0.017143	0.017143
🔲 K-Rate	rRelative 🔻	1.3	1	1					
	(Create Parm]				

Other parameters

85 EPIC parameters

											-				
					EPIC paramet	ters									
					CROP Para	m Method		Default	Minimum	Maximum	CROP Param	Method	Defa	ult Minimum	Maximum
					PARM01	rRelative	-	1.	1	1	PARM02	rRelative	▼ 2.	1	1
					PARM03	vReplace	-	.5	1	1	PARM04	rRelative	v 1.	1	1
					PARM05	vReplace	•	.5	0.487	0.487	PARM06	rRelative	▼ 1.	1	1
					PARM07	rRelative	•	.5	1	1	PARM08	rRelative	v 10.	1	1
					PARM09	rRelative	-	50.	1	1	PARM10	rRelative	v 100.	1	1
					PARM11	rRelative	-	-10.	1	1	PARM12	rRelative	▼ 1.5	1	1
					PARM13	rRelative	•	.6	1	1	PARM14	rRelative	▼ .5	1	1
					PARM15	rRelative	•	5.0	1	1	PARM16	rRelative	→ .10	1	1
					PARM17	rRelative	•	.000	1	1	PARM18	rRelative	- 1	1	1
					PARM19	rRelative	-	.0	1	1	PARM20	rRelative	- 1	1	1
					PARM21	rRelative	•	1000.	1	1	PARM22	rRelative	• .000	1 1	1
					PARM23	rRelative	•	.35	1	1	PARM24	rRelative	₹.3	1	1
					PARM25	rRelative	•	.5	1	1	PARM26	rRelative	▼ .50	1	1
					PARM27	rRelative	-	1.	1	1	PARM28	rRelative	▼ 1.25	1	1
n	aran	neter			PARM29	rRelative	•	.01	1	1	PARM30	rRelative	 ▼ 1. 	1	1
Γ	ar ar				PARM31	rRelative		1.5	1	1	PARM32	rRelative	 ✓ .050 	1	1
						Intelacive	-		1	1	PARM34	rRelative	▼ 1.0	1	1
								×	1	1	PARM36	rRelative	v 2	1	1
	Manimum	CROBBanan	Mathad	De	fault Mini				1	1	PARM38	rPolativo	- 003	2 1	1
	Maximum	CKOFFaram	Method	De		mum Ma	4075	<u> </u>	1	1		rPolative	- 0	1	1
98 998	36.224998	V HI	vReplace	▼ 0.	40 0.4	9/5 0	.4975		1	1	PARM42	rRelative	- 12	11	18
999	34.299999	V IBSC	vReplace	▼ 8.	00 7.0	5 /	.05		1	1		Peologo	- 5	1 220922	1 220922
	1	DLAI	rRelative	→ 0.	80 1	1			1	1		Polativo	- 50	1.520055	1
	1	DLAP2	rRelative		0.95 1	1			1	1		Deletive	- 000	012 1	1
	1	RBMD	rRelative	▼ 1.	. 1	1			1	1		Deletive	- 00	1	1
	1	GSI GSI	rRelative	→ 0.	0070 1	1			1	1		Deletive	- 10	1	1
	1	SDW	rRelative		0.00 1	1			1	1		-Deletive	▼ 10.	1	1
	1	RDMX	rRelative		00 1	1			1	1		Relative	 J. 10 	1	1
	1	CNY	rRelative	0	13 1	1			1	1		Relative	• 10.	1	1
	1	СКҮ	rRelative	▼ 0.	0032 1	1			1	1		rkelative	▼ 0.	1	1
33	0.025833	PST	rRelative	→ 0.	60 1	1			1	1		rkelative	▼ Z.	1	1
	1	PRYG	rRelative	- 10	03.16 1	1			1	1		rRelative	▼ 5.	1	1
	1	WCY	vReplace	→ 0.	15 0.1	515 0	1515		1	1		rRelative	▼ .5	1	1
	1	BN2	rRelative	.0 ▼	15 1	1			1	1		rKelative	▼ .01 20	1	1
	1	BP1	rRelative	→ 0.	0062 1	1			1	1		Relative	✓ 20.	1	1
	1	BP3	rRelative	v 0.	0018 1	1			1	1		rKelative	▼ 0.	1	1
	1	BK2	rRelative	v 0.	0120 1	1			1	1		rRelative	▼ 3.	1	1
	1	BW1	rRelative	▼ 0.	433 1	1			1	1	PARIVI/4	rKelative	 ▼ 1. 0. 	1	1
	1	BW3	rRelative	v 0.	213 1	1			1	1	PARIVI/6	rKelative	 ▼ 0. 0. 	1	1
	1	ERST1	rRelative	v 5	15 1	1			1	1		rRelative	♥ 0.	1	1
	1	WAVP	rRelative	- 8	00 1	1			1	1		rKelative	▼ 0.	1	1
	1		Relative	- 0. - 1	75 1	1			1	1		rRelative	▼ 31.	1	1
	1	PW/PC2	r Polative	- 0	20 1	1			1	1	PAKIVI84	rRelative	▼ .57	1	1
	1		Deletive	- 4	47 1	1			1	1					
	1	E FFLFI	ricelative		12 1	1									
	1		rKelative	▼ 0.	12 1	1									
	1	BLGI	rRelative	▼ 0.		1									
	1	WUB	rRelative	+ 10	0.2 1	1									
	1	FLT	rRelative	▼ 0.	00 1	1									

56 crop

Crop paramete	rs								
CROP Param	Method		Default	Minimum	Maximum	CROP Param	Method	Default	Minim
🔽 WA	vReplace	•	40.00	36.224998	36.224998	I HI	vReplace -	0.40	0.49
TOPC	vReplace	•	25.00	34.299999	34.299999	TBSC	vReplace 🔻	8.00	7.05
DMLA	rRelative	•	6.00	1	1	DLAI	rRelative 🔻	0.80	1
DLAP1	rRelative	•	15.05	1	1	DLAP2	rRelative 🔻	50.95	1
RLAD	rRelative	•	1.00	1	1	RBMD	rRelative 👻	1.	1
🔲 ALT	rRelative	•	3.00	1	1	GSI GSI	rRelative 👻	0.0070	1
CAF	rRelative	•	0.85	1	1	SDW	rRelative 👻	20.00	1
🔲 HMX	rRelative	•	2.00	1	1	RDMX	rRelative 🔻	2.00	1
WAC2	rRelative	•	660.45	1	1	CNY	rRelative 🔻	.013	1
СРУ	rRelative	•	0.0025	1	1	СКҮ	rRelative 👻	0.0032	1
WSYF	vReplace	•	0.01	0.025833	0.025833	PST	rRelative 🔻	0.60	1
CSTS	rRelative	•	3.45	1	1	PRYG	rRelative 🔻	103.16	1
PRYF	rRelative	•	80.22	1	1	WCY	vReplace 🔻	0.15	0.15
BN1	rRelative	•	0.0440	1	1	BN2	rRelative 🔻	.015	1
BN3	rRelative	•	.01	1	1	🔲 BP1	rRelative 🔻	0.0062	1
BP2	rRelative	•	0.0023	1	1	BP3	rRelative 🔻	0.0018	1
BK1	rRelative	•	0.0150	1	1	🔲 BK2	rRelative 🔻	0.0120	1
BK3	rRelative	•	0.0090	1	1	🕅 BW1	rRelative 🔻	0.433	1
BW2	rRelative	•	0.433	1	1	BW3	rRelative 🔻	0.213	1
IDC IDC	rRelative	•	4.	1	1	FRST1	rRelative 🔻	5.15	1
FRST2	rRelative	•	15.95	1	1	WAVP	rRelative 🔻	8.00	1
VPTH	rRelative	•	0.50	1	1	VPD2	rRelative 🔻	4.75	1
RWPC1	rRelative	•	0.40	1	1	RWPC2	rRelative 👻	0.20	1
🔲 GMHU	rRelative	•	100.00	1	1	PPLP1	rRelative 👻	4.47	1
PPLP2	rRelative	•	7.77	1	1	STX1	rRelative 👻	0.12	1
STX2	rRelative	•	1.70	1	1	BLG1	rRelative 🔻	0.01	1
BLG2	rRelative	•	0.10	1	1	WUB	rRelative 🔻	10.2	1
FTO	rRelative	•	0.00	1	1	FLT	rRelative 🔻	0.00	1
			Create Parm						

eawag aquatic research 0000



Calibration

- Similar structure to SUFI2 in SWAT-CUP
- Latin hypercube sampling
 - Replacement: Parameters are changed between maximum and minimum;
 - Relative: An existing parameter is multiplied by a relative value defined between a maximum and minimum;
- A python script is prepared for each iteration;
- Considering different objective functions





Speed up Simulations

- The Linux scripts were prepared.
 - Splitting each iteration in one cluster to do parallel processing







Case Studies

-

lcoupe

Browse

(Not Responding)

Press to run Python script

The Python-based EPIC (PEPIC) Model (Not Responding)

Project Locat

TPIC Bate File

ent PEPIC-Settings PEPIC-CUP First Test

D: Bahareh/J/EWversion_baha

0: Øshareh WEW version, bahareh Database VpicBasef Ve'origi

BaharehWEWversion bahareh/Database/FixedData/G

Sahareh/VEV/version bahareh/Datab

· Select Crop



Country level calibration

Maize

Sorghum

Wheat

Model calibration on provincial level and based on wheat yield

region	Mean Square Error	P-factor	R-factor
NKRB	0.13	0.52	1.1
CKRB	0.073	0.45	1.04
SKRB	0.096	0.55	1.17

Sub-Saharan Africa

R2	P-factor	R-factor		
0.42	0.60	1.3		

R2	P-factor	R-factor			
0.32	0.55	1.1			

R	22	P-factor	R-factor		
0.2	28	0.68	1.2		

Final ranges of parameters

Sensitivity Analysis

One at once sensitivity analysis: Model calibration to validate that crop model is replicating historic period

$$S = \frac{\Delta X}{\Delta b} \frac{b}{X}$$

Global sensitivity analysis: Long-term model calibration and validation were needed to

$$g = \alpha + \sum_{i=1}^{m} \beta_i b_i$$

Summary

- EPIC+SUFI2 is a practical for crop yield calibration on different scales
- The results for Sub Saharan Africa and Iran were satisfactory;
- The final ranges of parameters will always need user's interpretation, so that they are physically meaningful;
- This is the first version of the model, improvement in different perspective will certainly be needed.

Thanks for your attention

2015 International SWAT Conference / ITALY

2016 International SWAT Conference in Beijing, China

The impact of climate change on rainfed yield in KRB

GCM Name	Institute full name
HadGEM2-ES	Met Office Hadley Centre and Instituto Nacional de Pesquisas Espaciais
IPSL-CM5A-LR	Institute Pierre-Simon Laplace
GFDL-ESM2M	NOAA Geophysical Fluid Dynamics Laboratory