Supplement of

Oil palm modelling in the global land-surface model ORCHIDEE-MICT

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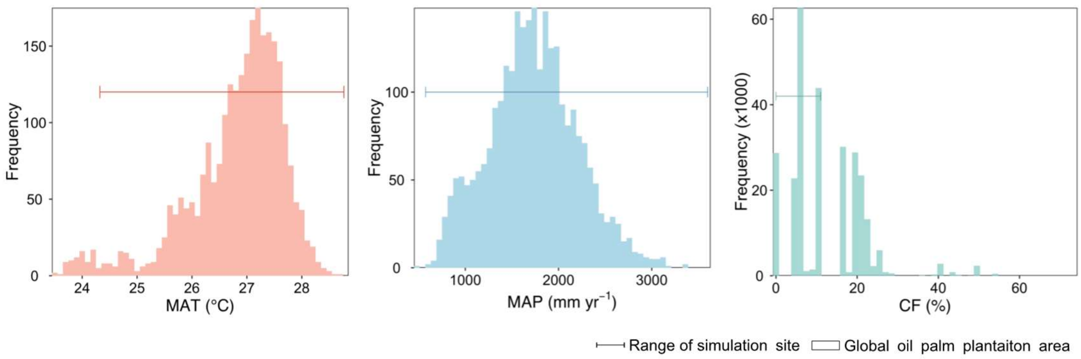


Figure S1. Representativeness of the collected observation sites in terms of mean annual temperature (MAT), mean annual precipitation (MAP) and clay fraction (CF) over the global oil palm plantation area. The lines show the range of the MAT, MAP and CF from the observation sites, while the bars show the frequency distribution of the three variables derived from the global oil palm plantation map (dataset from Cheng et al., 2018).

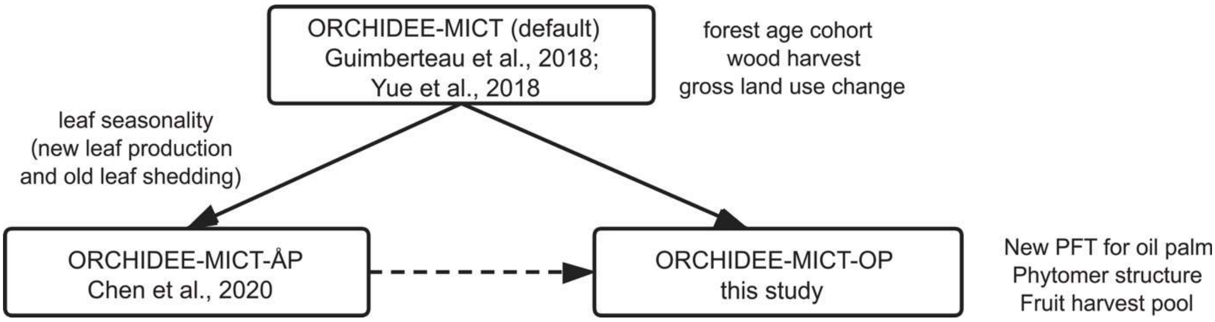
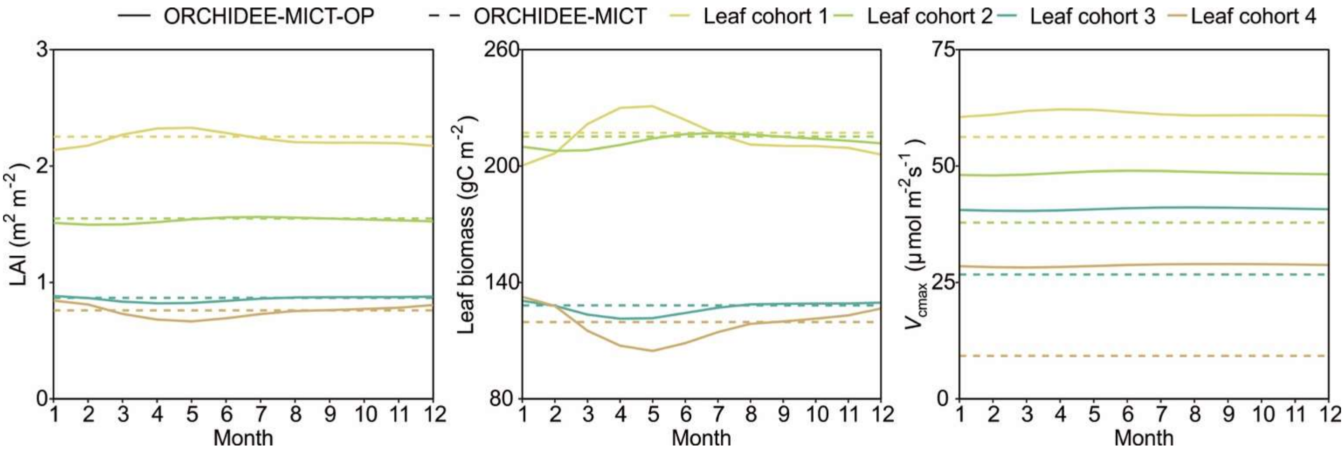


Figure S2. Different versions and developments of ORCHIDEE-MICT related to ORCHIDEE-MICT-OP.



35 **Figure S3 Comparison of the mean seasonality of simulated LAI, leaf biomass and $V_{c,max}$ across all sites between ORCHIDEE-MICT-OP and the default ORCHIDEE-MICT version. Leaf cohorts 1-4 indicate the youngest leaf cohort to the oldest. The new leaf phenology scheme in ORCHIDEE-MICT-LC (Chen et al., 2019) was implemented in ORCHIDEE-MICT-OP.**

Table S1 site level data information.

Site #	Site Name	Reference	Country	Type	Variable	Age	Measurement	soil
1	Harapan region PTPN-V1 Pompa Air	(Fan et al., 2015;Kotowska et al., 2015;Meijide et al., 2017)	Indonesia	industrial plantation industrial plantation 2186 ha smallholders 5.7 ha	Yield,NPP AGB,BGB,Biomass NPP component WUE	~13	field measurement and allometiric equation	loam Acrisols
2	Bukit Duabelas region	(Kotowska et al., 2015)	Indonesia	industrial plantation	Yield,NPP AGB,BGB,Biomass NPP component	~10	field measurement and allometiric equation	clay Acrisols
3	Genting plantation	(Tan et al., 2014)	Malaysia	industrial plantation,2815 ha	Yield, Biomass Biomass component	0-25	field measurement and allometiric equation statistical harvest data empirical equation	/
4	SMART, Kandista Estate	(Legros et al., 2009)	Indonesia	Research Institute, 30 ha	Yield	13	field measurement	sandy loam
5	Batu Mulia Estate	(Legros et al., 2009)	Indonesia	Research Institute, 9 ha	Yield	13	field measurement	silty clay loam
6	close to Kluang station	(Tan et al., 2011)	Malaysia	industrial plantation	GPP, LAI	mature	field measurement	/
7	Marihat Research Station	(Lamade and Bouillet, 2005)	Indonesia	Research station	NPP	8	field measurement	/
8	SOCFINDO industrial plantation	(Lamade et al., 1996)	Benin	industrial plantation	Yield, NPP	20	field measurement	ferrallitic soil
9	PTPN XIV-Persero	(Sunaryathy et al., 2015)	Indonesia	industrial plantation,23625 ha	AGB	1-3 4-10 11-20	field measurement	/
10	SSSB	(Morel et al., 2011)	Malaysia	industrial plantation	AGB	3 4-19	field measurement and allometiric equation	/
11	close to Pasoh Forest Reserve	(Adachi et al., 2011)	Malaysia	/	Biomass	27.5	field measurement and allometiric equation	sandy clay loam
12	Teluk Intant Research station	(Henson and Dolmat, 2003)	Malaysia	Research Institute, 21.45 ha	Yield, NPP, GPP Biomass GPP/NPP component Biomass component	0-16	field measurement	deep peat soil
13	ESPEK estate	(Henson and Harun, 2005)	Malaysia	industrial plantation	NPP	4	field measurement, eddy tower	sandy clay loam
14	Sebungan and Sabaju Oil Palm Estate	(Lewis et al., 2020)	Malaysia	industrial plantation, 10200 ha	AGB	3-12	field measurement	clay, deap peat

Table S2 Summary of adjusted parameters for the new oil palm PFT in this model. Values of the default TBE tree PFT are also shown for comparison.

				PFT2, tropical broad-leaved evergreen	**PFT14, oil palm**	
Symbol	**Parameter**	**Description**	**Unit**	**Value**	**Value**	**Reference**
Photosynthesis parameter						
sla	SLA SLA_MAX/SLA_MIN	specific leaf area	$m^2g^{-1}C$	0.0153	CFT 1: 0.012 CFT 2: 0.011 CFT 3: 0.010 CFT 4: 0.009 CFT 5: 0.008 CFT 6: 0.008	Varies from 0.008-0.016 in different studies (Kotowska et al., 2015;Legros et al., 2009;Van Kraalingen et al., 1989)
$V_{c,max25}$	VCMAX25	Maximum rate of Rubisco activity-limited carboxylation at 25 °C	mol/m^2s^{-1}		CFT 1: 35 CFT 2: 40 CFT 3: 45 CFT 4: 60 CFT 5: 75 CFT 6: 70	Varies from 42-100.47 in different studies (Fan et al., 2015;Meijide et al., 2017;Teh Boon Sung and See Siang, 2018)
LAI_{max}	LAI_MAX	maximum leaf area index	/	7	CFT 1: 1.5 CFT 2: 2.5 CFT 3: 3.5 CFT 4: 4.5 CFT 5: 5.5 CFT 6: 5.0	Increased with age (Corley et al., 1971;Corley and Lee, 1992;Kallarackal, 1996;Kotowska et al., 2015;Legros et al., 2009;Noor et al., 2002;Noor and Harun, 2004;Tan et al., 2014;Wahid et al., 2004)

Respiration parameter						
f_{GR}	FRAC_GROWTHRESP	Fraction of GPP which is lost as growth respiration	/	0.35	CFT 1: 0.5 CFT 2: 0.425 CFT 3: 0.4 CFT 4: 0.375 CFT 5: 0.35 CFT 6: 0.3	calibration using the ratio between growth respiration/maintainance respiration from previous studies. AR consists of 60-75% GPP (Breure, 1988;Henson and Dolmat, 2003;Henson and Harun, 2005)
S_1	MAINT_RESP_SLOPE_C	constant define the slope of maintenance respiration coefficient	/	0.12	CFT 1: 0.4 CFT 2: 0.5 CFT 3: 0.6 CFT 4: 0.7 CFT 5: 0.8 CFT 6: 0.9	
Carbon allocation parameter						
θ	DEMI_ALLOC	constant parameter for the function of partitioning allocation between above and belowground sapwood biomass	/	5	CFT 1: 0.2 CFT 2: 0.2 CFT 3: 0.5 CFT 4: 1.0 CFT 5: 2.0 CFT 6: 2.0	calibration
$f_{sapab,min}$ / $f_{sapab,max}$	ALLOC_MIN/ALLOC_MAX	minimum/maximum value of allocation coefficient between above and belowground sapwood biomass	/	0.2/0.8	CFT 1: 0.2/0.3 CFT 2: 0.65/0.85 CFT 3: 0.7/0.9	calibration

					CFT 4: 0.75/0.94 CFT 5: 0.8/0.99 CFT 6: 0.750.95	
f_{seed}	F_SEED	standard seed allocation coefficient	/	0.1	0.0001	calibration
R_1	RS_COEFF	empirical coefficient for the root allocation	/	/	0.95	calibration
L_1/L_2 / L_3	LSR_COEFF	empirical coefficient for the function of leaf allocation	/	/	0.45 100 6	calibration
$f_{leaf,max}$	MAX_LTOLSR	maximum leaf allocation fraction	/	0.5	0.35	(Fan et al., 2015;Kotowska et al., 2015)
$f_{leaf,min}$	MIN_LTOLSR	minimum leaf allocation fraction	/	0.2	0.25	(Fan et al., 2015;Kotowska et al., 2015)
$f_{root,max}$	MAX_RTOLSR	maximum root allocation fraction	/	/	0.35	(Kotowska et al., 2015)
$f_{root,min}$	MIN_RTOLSR	minimum root allocation fraction	/	/	0.25	(Fan et al., 2015;Kotowska et al., 2015)
$f_{br+fr,min}$ $f_{br+fr,max}$	PHYALLOC_MIN PHYALLOC_MAX	prescribed minimum and maximum value of aboveground sapwood allocation fraction to branch and fruit	/	/	0.001 1	this paper
P_1/P_2 / P_3	PHY_COEFF	empirical coefficient for the phytomer allocaion	/	/	0.265 2 0.8	calibration
$f_{fr,min}$/	FTOPHY_MIN/ FTOPHY_MAX		/	/	CFT 1: 0.0/0.0 CFT 2: 0.3/0.8	calibration

$f_{fr,max}$		minimum/maximum fresh fruit bunch allocation fraction in phytomers			CFT 3: 0.4/0.82 CFT 4: 0.5/0.84 CFT 5: 0.6/0.9 CFT 6: 0.7/0.82	
F_1	FFB_COEFF	empirical coefficient for the fresh fruit bunch allocaion	/	/	0.02	calibration
Other parameter						
$Age_{leafcrit}$	LEAFAGECRIT	critical leaf age, leaf longevity	day	730	640	Ranges from 600-700 (Corley and Tinker, 2015;Fan et al., 2015;Van Kraalingen et al., 1989)
$Age_{phycrit}$	PHYTOMERAGECRIT	critical phytomer age	day	/	640	(Fan et al., 2015)
$Age_{ffbcrit}$	FFBHARVESTAGECRIT	critical fruit harvest age	day	/	600	(Fan et al., 2015)
τ	RESIDENCE_TIME	residence time of trees	year	30	1000	
L_1	LOSS_COEFF	empirical coefficient for the leaf loss with the pruning of phytomer	/	/	2	this paper
ρ	PIPE_DENSITY	wood density	m^{-2}	2.00E-05	1.30E-05	(Ibrahim et al., 2010;Sunaryathy et al., 2015)
$nphs$	NPHS	Maximum number of phytomer		/	40	(Combres et al., 2013;Corley and Tinker, 2015)

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