Fuzzy-logic based multi-site crop model evaluation

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A Review of Methodologies to Evaluate Agroecosystem Simulation Models

F. MARTORANA and G. BELLOCCHI

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www.agronomy-journal.org

Review article

Validation of biophysical models: issues and methodologies. A review

Gianni BELLOCCHI[1,*,**], Mike RIVINGTON[2], Marcello DONATELLI[1,***], Kees

Environmental Modelling & Software 26 (2011) 328–336

Contents lists available at ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

Technical assessment and evaluation of environmental models and software: Letter to the Editor

Alexandrov[a,*], D. Ames[b], G. Bellocchi[c], M. Bruen[d], N. Crout[e], M. Erechtchoukova[f], A. Hildebrandt[g], Matsunaga[a], S.T. Purucker[k], M. Rivington[l],

Contents lists available at Science

Agricultural Systems

journal homepage: www.elsevier.com/loc

An evaluation of the statistical methods for testing the pe of crop models with observed data

J.M. Yang[a], J.Y. Yang[b,*], S. Liu[b,c], G. Hoogenboom[d]

Deliberative processes for comprehensive evaluation of agroecological models. A review

Assessment equacy of

MACSUR outcome!

Agronomy for Sustainable Development

Ecological Modelling 220 (2009) 1395–1410

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

of the models WARM, CropSyst, and WOFOST for rice

Acutis[b], Gianni Bellocchi[c], Marcello Donatelli[d,1]

Ecological Modelling 221 (2010) 960–964

Contents lists available at ScienceDirect

Ecological Modelling

/locate/ecolmodel

obustness based on the xplored conditions

Journal of Applied Remote Sens

Derivation of biophysical variables Earth observation data: validation statistical measures

Katja Richter
Clement Atzberger
Tobias B. Hank
Wolfram Mauser

Spanish Journal of Agricultural Research 2009 7(3), 680-686
ISSN: 1695-971-X

strategies for rice modelling

M. Boschetti[3] and M. Acutis[4]

An Indi

y Expert System

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Elaboration of new metrics

Setting of thresholds

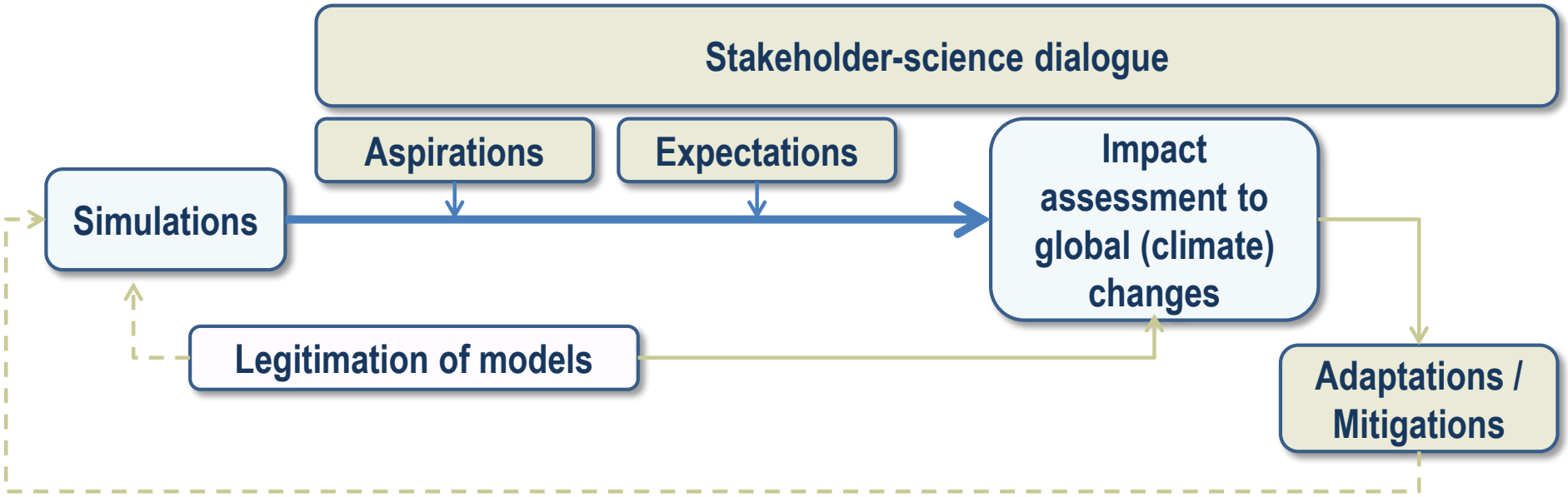
Meaning and limitations

Intercorrelation

Disaggregation

Aggregation

Deliberative process in model-based climate change studies

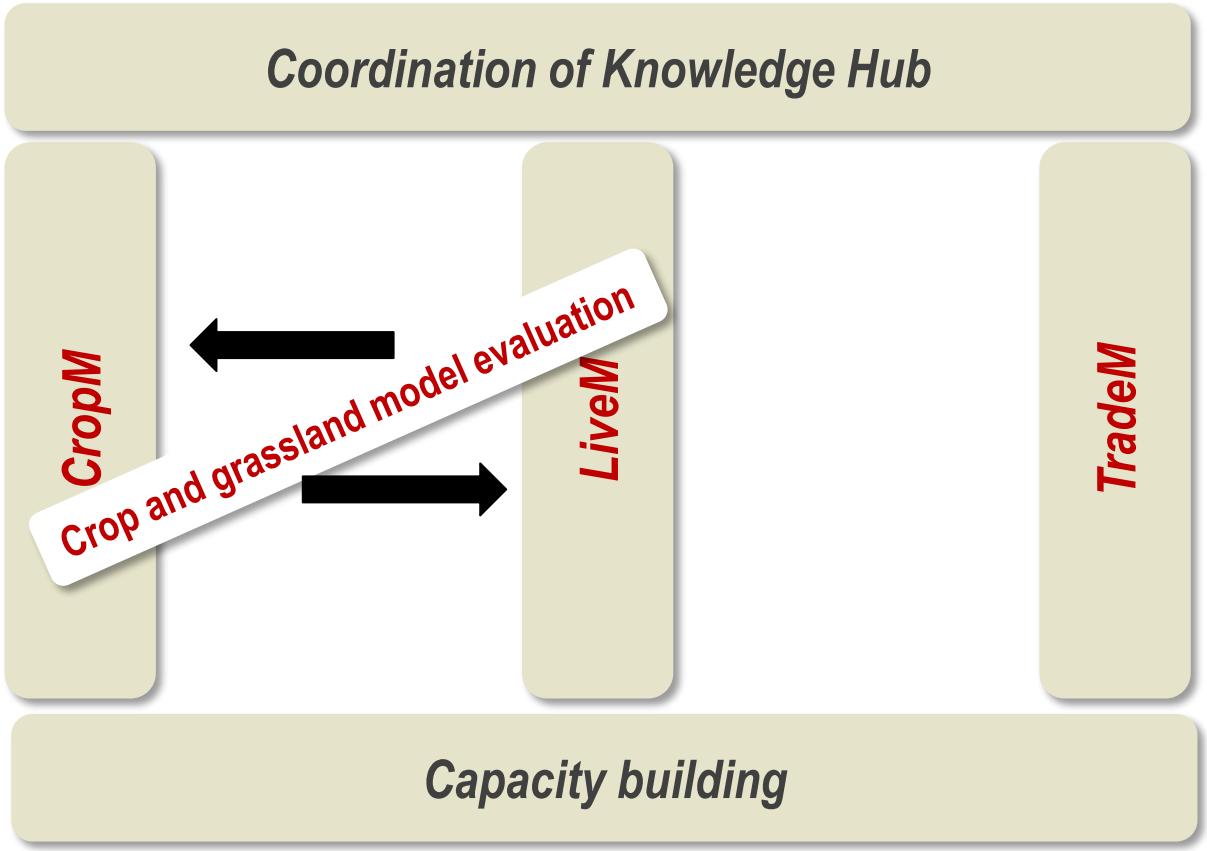


Bellocchi et al., 2006, Ital. J. Agrometeorol.

Rivington et al., 2007, Environ. Modell. Softw.

Bellocchi et al., 2015, Agron. Sustain. Dev.

MACSUR cross-cutting activities



CropM-LiveM

- Definition of model performance indicators
- Elaboration of model evaluation protocols

Some metrics

$$CRM = \frac{\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} O_i}$$

$$MAE = \frac{\sum_{i=1}^{n} |P_i - O_i|}{n}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (P_i - O_i)^2}{n}}$$

simple

absolute

squared

difference-based metrics

non-parametric

$$MdAE = \text{median}_{i=1,\ldots,n} |P_i - O_i|$$

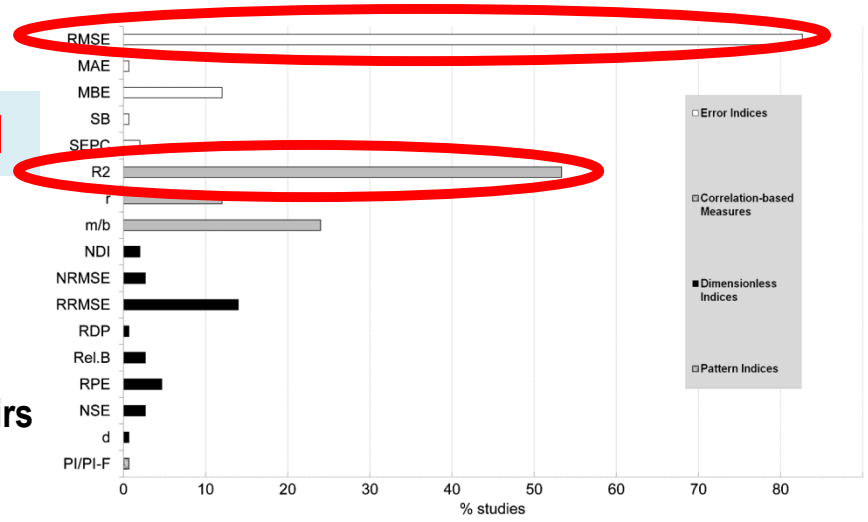
association-based metrics

$$r = \frac{\sum_{i=1}^{n} (P_i - \overline{P}) \cdot (O - \overline{O})}{\sqrt{\sum_{i=1}^{n} (P_i - \overline{P})^2 \cdot \sum_{i=1}^{n} (O_i - \overline{O})^2}} \qquad r^2, slope, intercept$$

combined

$$EF = 1 - \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} (O_i - \overline{O})^2}$$

$$d = 1 - \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} (|P_i - \overline{O}| + |O_i - \overline{O}|)^2}$$



P = predicted; O = observed; i = i^{th} O/P pair; n = number of O/P pairs

Richter et al., 2012, J. Appl. Remote Sens.

Setting of thresholds

Performance measure	Unit	Value range and purpose	Reliability criteria
Coefficient of determination ($\mathbf{R^2}$) of the linear regression estimates versus measurements	dimensionless	0 (absence of fit) to 1 (perfect fit): the closer values are to 1, the better the model	> 0.8
Willmott (1982) index of agreement (**d**)	dimensionless	0 (absence of agreement) to 1 (perfect agreement): the closer values are to 1, the better the model	> 0.8
Mean absolute error over the mean of the measured values (**MAE(%)**)	%	0 (optimum) to positive infinity: the smaller MAE(%), the better the model performance	< 20

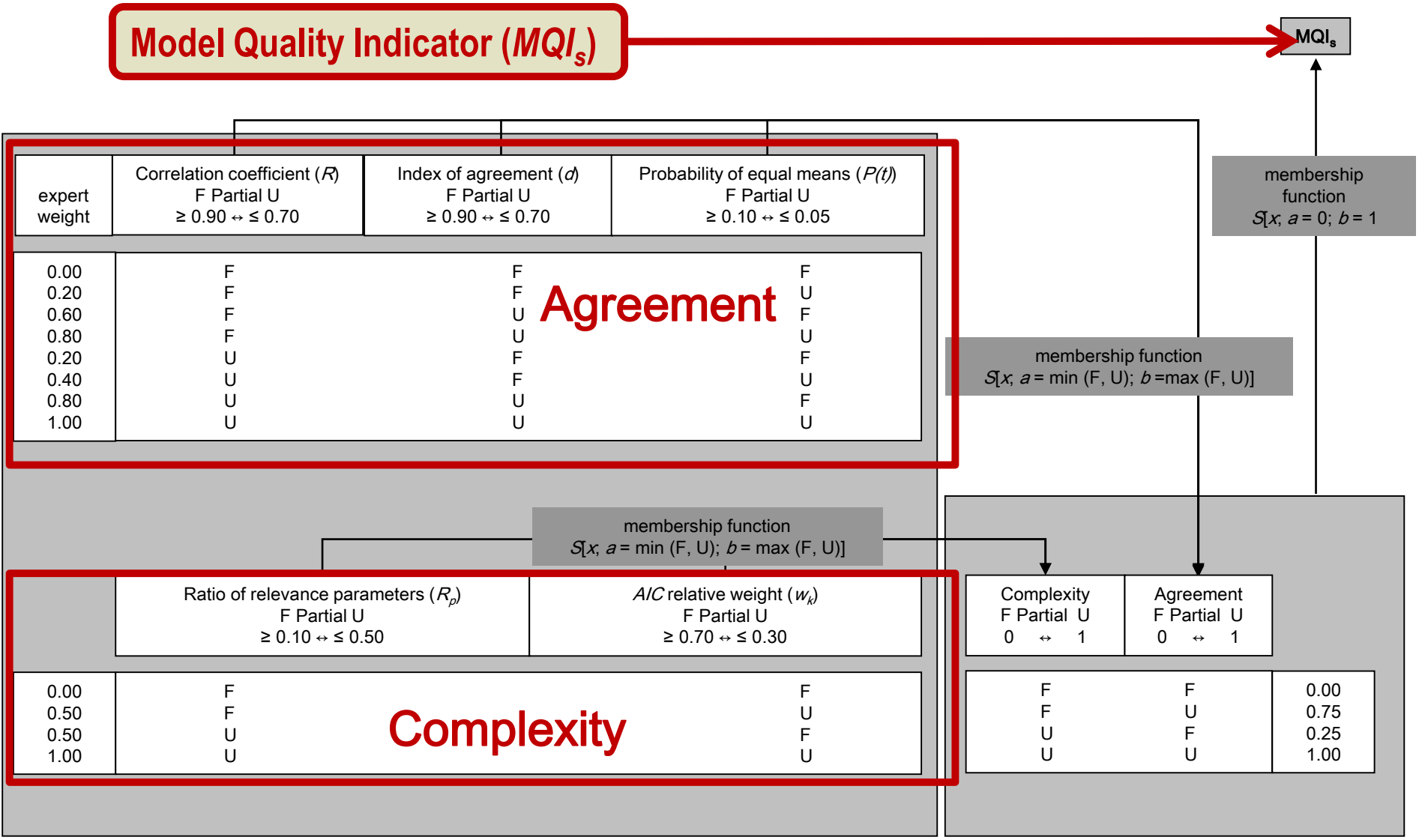
De Jager, 1994, Water SA

Key issues and factors

Key validation issues	Major factors to investigate				
	Modelling objective	Model inputs	Model outputs	Model structure	Modelling conditions
Validation purpose	X		X		X
Robustness of results			X		X
Interpretation of phenomena		X	X	X	
Model comparison				X	
Model predictions	X		X		X
Model complexity		X	X	X	
Data accuracy		X	X		
Time histories			X		

Bellocchi et al., 2010, Agron. Sustain. Dev.

Fuzzy-logic based indicators



Multi-site, Model Quality Indicator (MQI_m)

MQI_m

membership function
$S[x; a = \min(F, U); b = \max(F, U)]$

membership function
$S[x; a = 0; b = 1$

Agreement

expert weight	Correlation coefficient (R) F Partial U ≥ 0.90 ↔ ≤ 0.70	Index of agreement (d) F Partial U ≥ 0.90 ↔ ≤ 0.70	Probability of equal means ($P(t)$) F Partial U ≥ 0.10 ↔ ≤ 0.05
0.00	F	F	F
0.20	F	F	U
0.60	F	U	F
0.80	F	U	U
0.20	U	F	F
0.40	U	F	U
0.80	U	U	F
1.00	U	U	U

membership function
$S[x; a = \min(F, U); b = \max(F, U)]$

Complexity

	Ratio of relevance parameters (R_p) F Partial U ≥ 0.10 ↔ ≤ 0.50	AIC relative weight (w_k) F Partial U ≥ 0.70 ↔ ≤ 0.30
0.00	F	F
0.50	F	U
0.50	U	F
1.00	U	U

Complexity F Partial U 0 ↔ 1	Agreement F Partial U 0 ↔ 1	Robustness F Partial U 0 ↔ 1
0.00	F	F	F
0.25	F	F	U
0.50	F	U	F
0.75	F	U	U
0.25	U	F	F
0.50	U	F	U
0.75	U	U	F
1.00	U	U	U

Robustness

	Index of robustness (I_R) F Partial U 1 ↔ 10
0.00	F
1.00	U

membership function
$S[x; a = \min(F, U); b = \max(F, U)]$

Synthetic indicators

Aggregation rules: *fuzzy-logic based weighing system*

I. Agreement
- Correlation coefficient
- Index of agreement
- Probability of equal means

Non-dimensionality

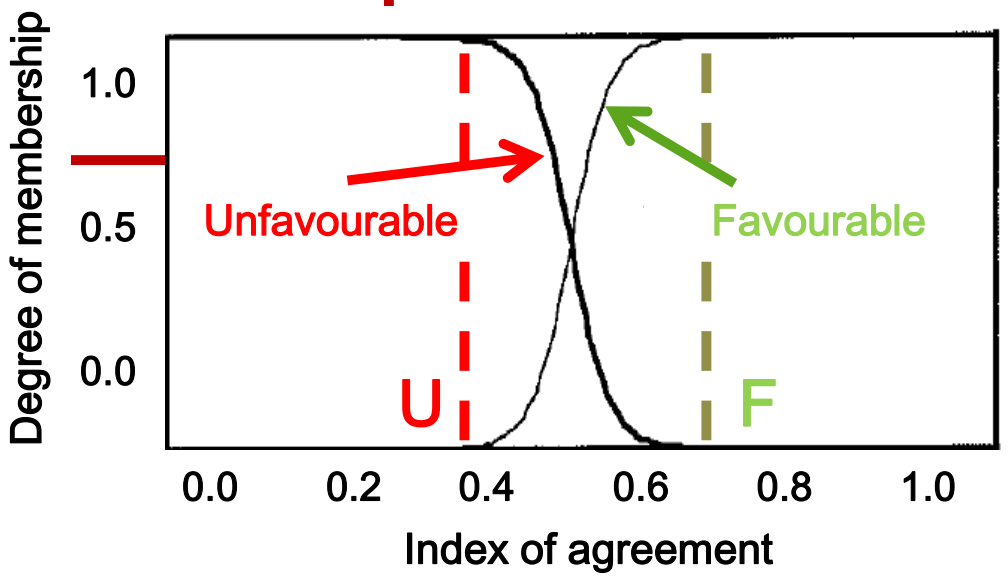
Lower and upper bounding

(best) 0 – 1 (worst)

II. Complexity
- Ratio of relevant parameters
- Parameters-agreement criterion

III. Stability (robustness)
- Index of robustness

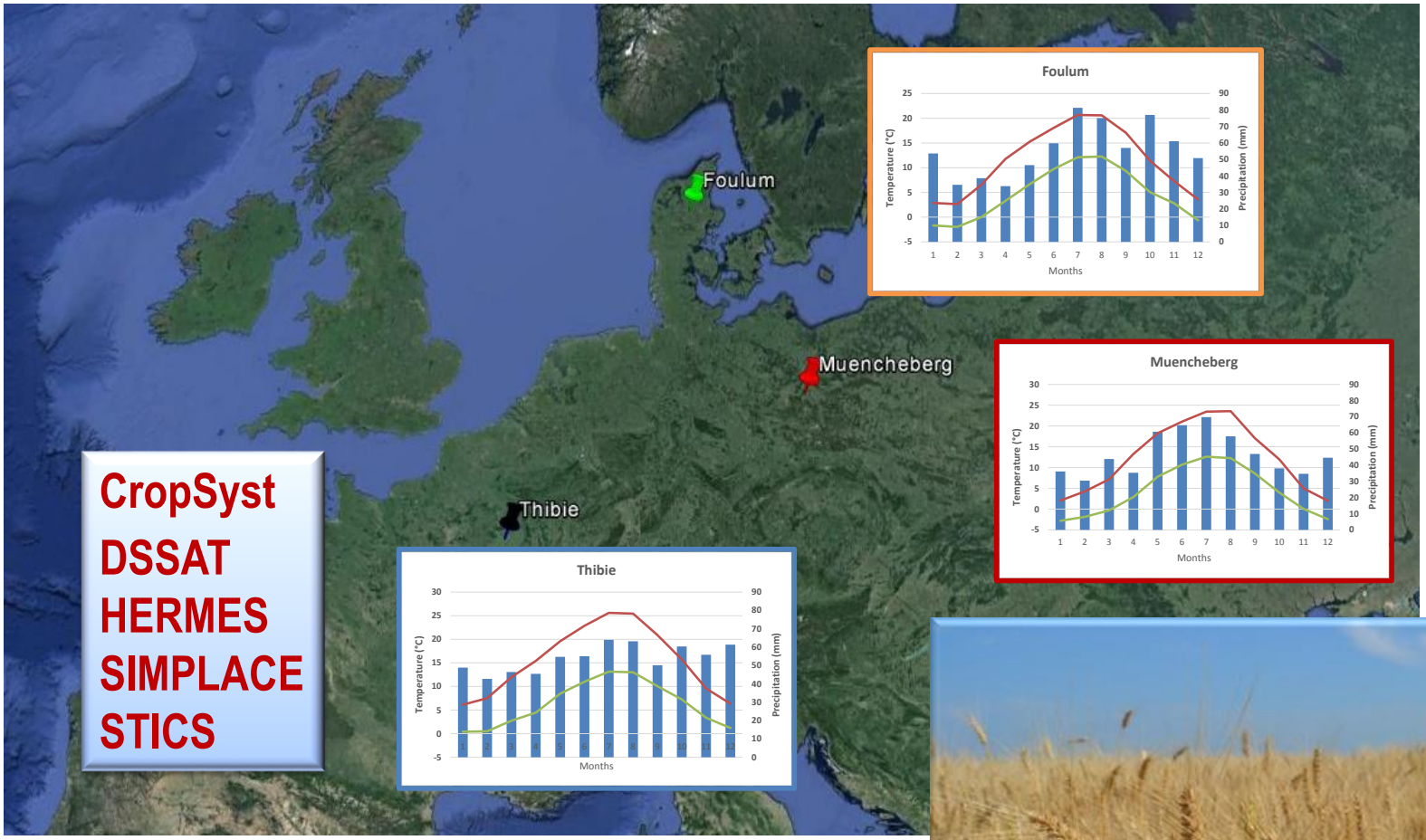
Model Quality Indicator

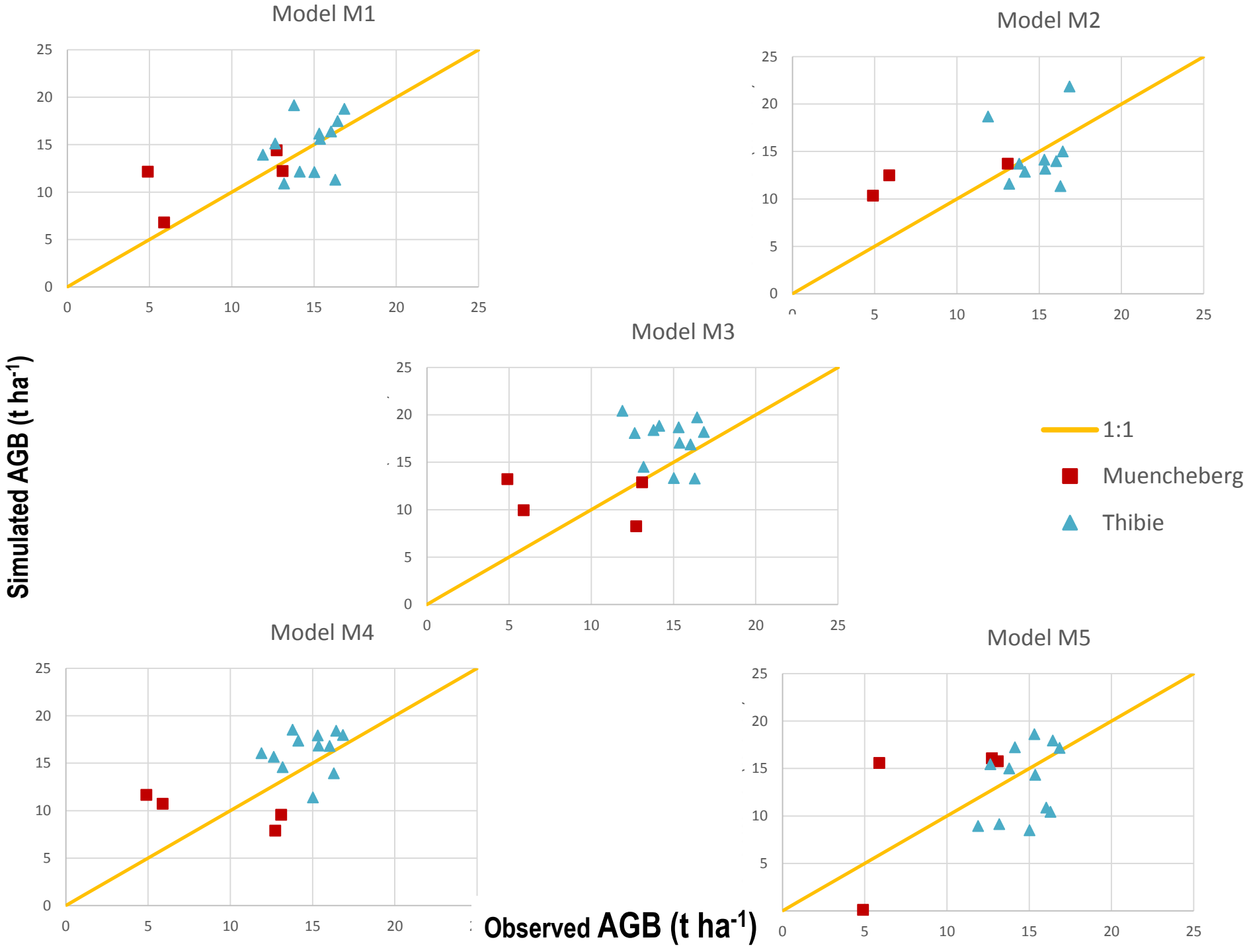


Hindrances to overcome: *thresholds and weights*

CropM wheat simulations:

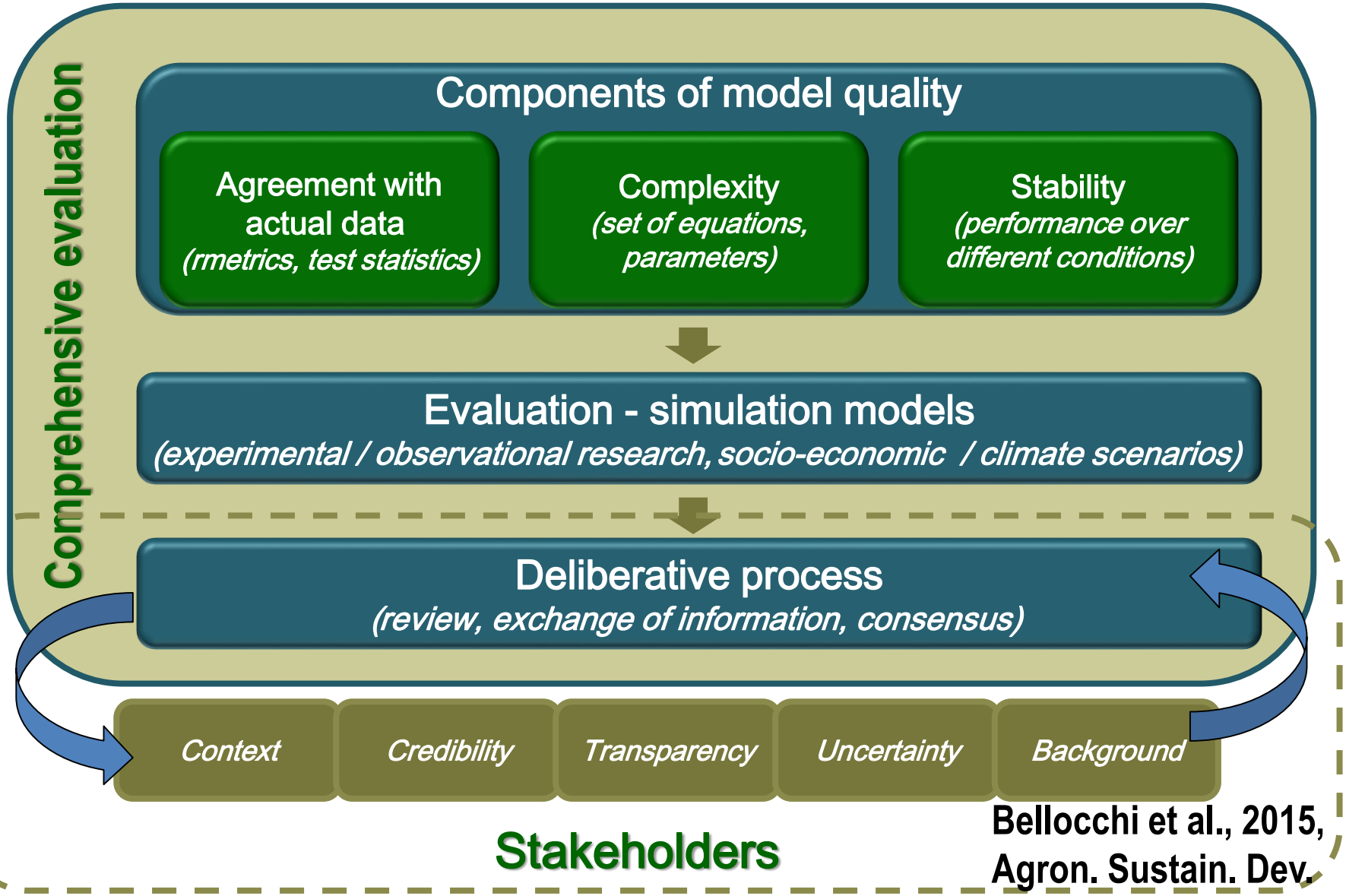
yield, above-ground biomass at maturity




Model M1
Model M2
Model M3
Model M4
Model M5
Simulated AGB (t ha-1)
Observed AGB (t ha-1)
1:1
Muencheberg
Thibie

Model	Aboveground biomass at maturity: performance metrics, modules and indicator					
	$\overline{P(t)}$	$\bar{r}$	$\bar{d}$	$\overline{R_p}$	$\overline{w_k}$	I_R
M1	0.23	0.46	0.64	0.32	1.99E-13	65.4
M2	0.20	0.46	0.60	0.28	2.66E-11	6.0
M3	0.01	-0.25	0.70	0.53	0.12	149.5
M4	0.08	-0.36	0.25	0.50	0.88	344.6
M5	0.08	0.49	0.60	0.37	1.34E-08	377.6
	Agreement			Complexity		Robustness
M1	0.8000			0.7975		1.0000
M2	0.8000			0.7975		0.6049
M3	1.0000			1.0000		1.0000
M4	0.8640			0.5000		1.0000
M5	0.8640			0.8944		1.0000
	MQI_m					
M1	0.8976					
M2	0.7471					
M3	1.0000					
M4	0.8428					
M5	0.9640					

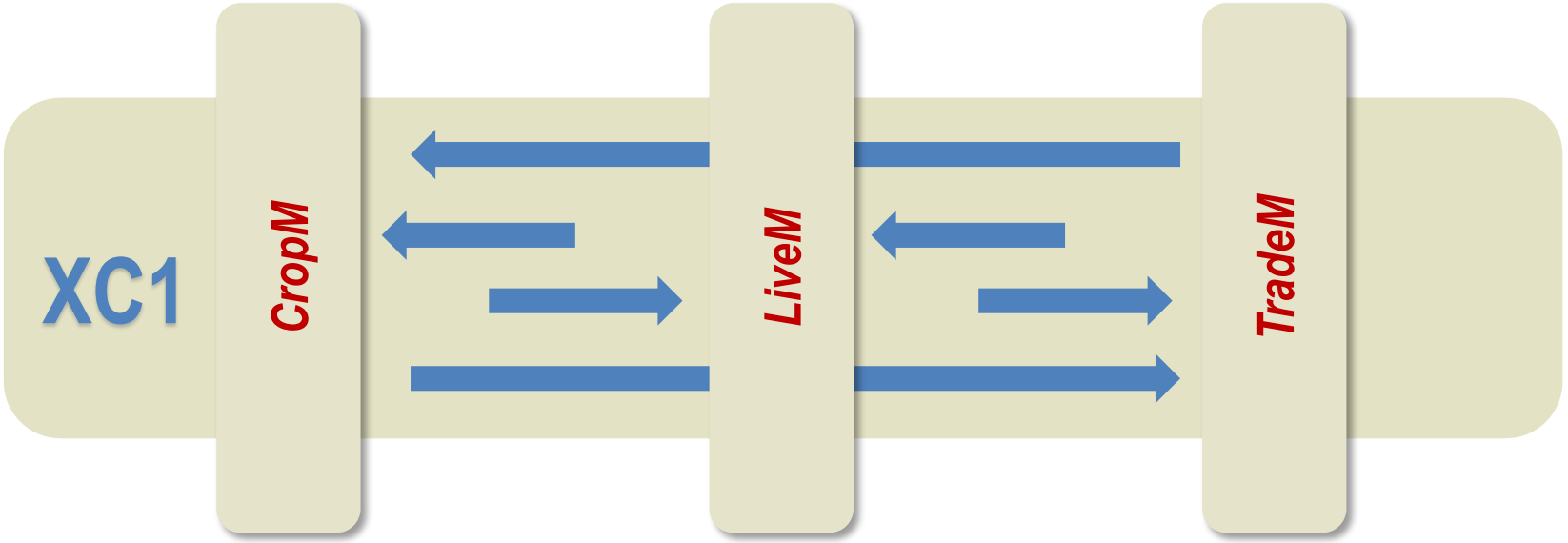
Model evaluation / deliberative process



Bellocchi et al., 2015, Agron. Sustain. Dev.

Towards a consolidated, internationally-agreed protocol to evaluate models: what does go forth?

- Review of settings
  - Selection of metrics
  - Attribution of thresholds and weights
- Extension to multiple outputs



Literature sources

Bellocchi G, Confalonieri R, Donatelli M (2006) Crop modelling and validation: integration of IRENE_DLL in the WARM environment. Italian Journal of Agrometeorology 11:35-39

Bellocchi G, Rivington M, Matthews K, Acutis M (2015) Deliberative processes for comprehensive evaluation of agroecological models. A review. Agronomy for Sustainable Development 35:589-605

Bellocchi G, Rivington M, Donatelli M, Matthews KB (2010) Validation of biophysical models: issues and methodologies. A review. Agronomy for Sustainable Development 30:109-130

De Jager JM (1994) Accuracy of vegetation evaporation formulae for estimating final wheat yield. Water SA 20:307-314

Richter K, Atzberger C, Hank TB, Mauser W (2012) Derivation of biophysical variables from Earth observation data: validation and statistical measures. Journal of Applied Remote Sensing 6:063557

Rivington M, Matthews KB, Bellocchi G, Buchan K, Stöckle CO, Donatelli M (2007) An integrated assessment approach to conduct analyses of climate change impacts on whole-farm systems. Environmental Modelling & Software 22:202-210

Title	**C and N Models Intercomparison and Improvement to assess management options for GHG mitigation in agrosystems worldwide**
Acronym	**CN-MIP**

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