Fuzzy-logic based multi-site crop model evaluation

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Ital. J. Agron., 3, 1, 19-39

A Review of Methodologies to Evaluate Agroecosystem Simulation Models

F. MARTORANA and G. BELLOCCHI

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Agronomy for Sustainable Development

Review article

Validation of biophysical models: issues and methodologies. A review

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

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: ...etter to the Editor

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

Contents lists available at ScienceDirect
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

Agronomy for Sustainable Development

MACSUR outcome!

Ecological Modelling 220 (2009) 1395–1410
Contents lists available at ScienceDirect
Ecological Modelling
...l 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
...n/locate/ecolmodel

...obustness based on the ...xplored conditions

Assessment ...dequacy of

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

...lli

Elaboration of new metrics

Setting of thresholds

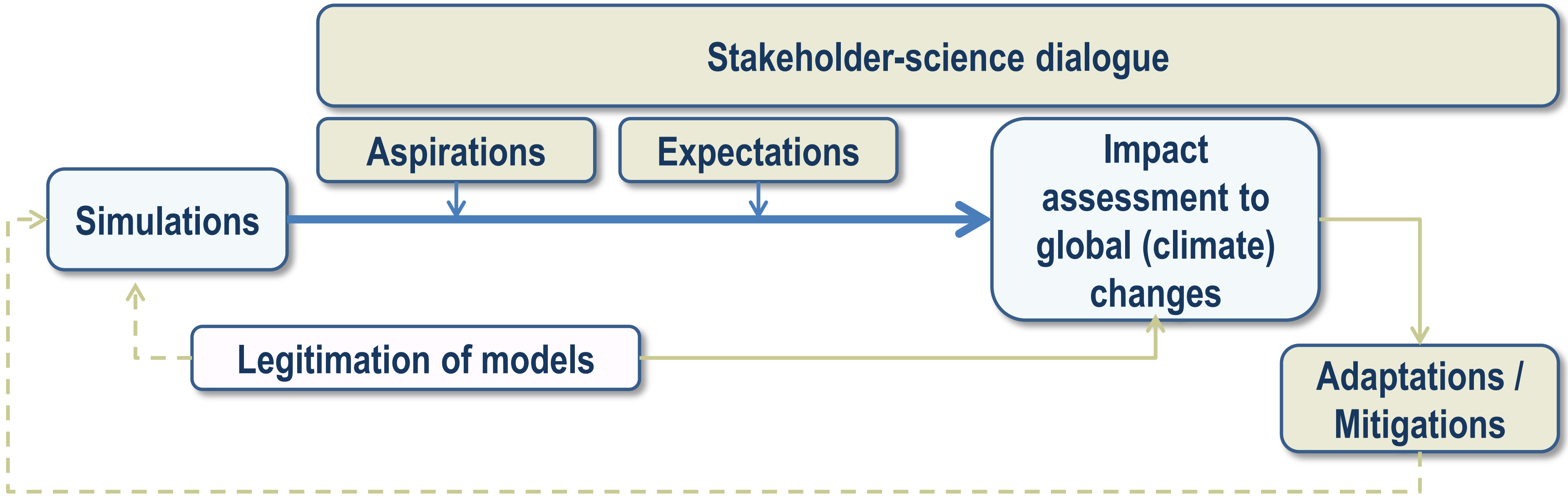
Meaning and limitations

Intercorrelation

Disaggregation

Aggregation

Deliberative process in model-based climate change studies

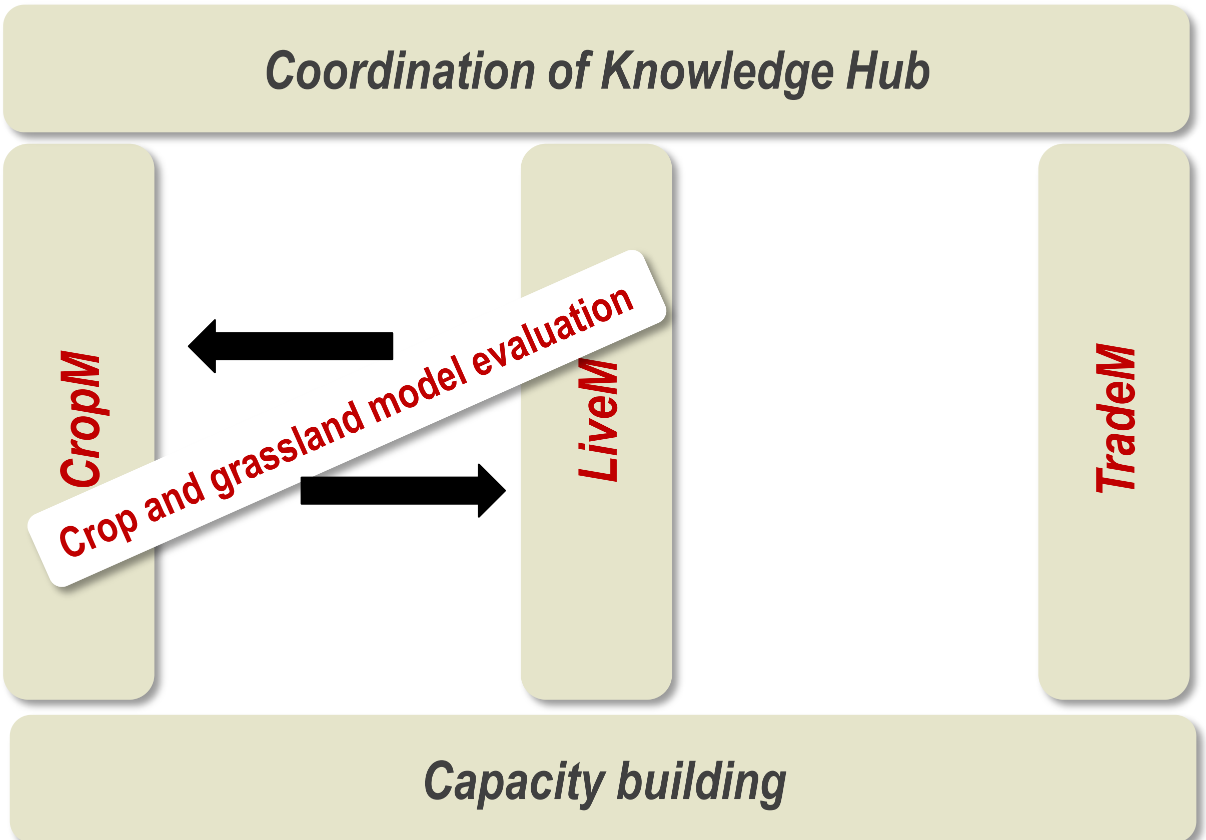


Bellocchi et al., 2006, Ital. J. Agrometeorol.

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

difference-based metrics

simple:

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

absolute:

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

squared:

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

non-parametric:

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

association-based metrics

$$r = \frac{\sum_{i=1}^{n} (P_i - \bar{P}) \cdot (O - \bar{O})}{\sqrt{\sum_{i=1}^{n} (P_i - \bar{P})^2 \cdot \sum_{i=1}^{n} (O_i - \bar{O})^2}}$$

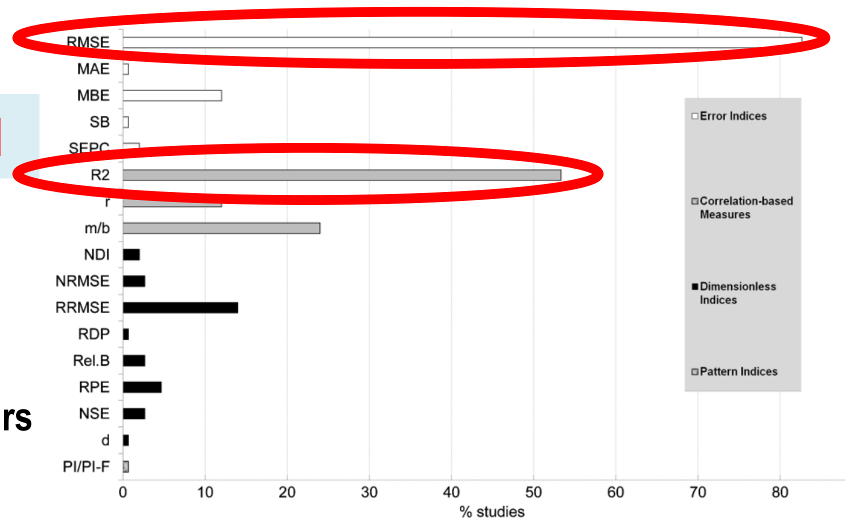
$r^2, slope, intercept$

combined

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

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

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 (**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

Model Quality Indicator (MQI_s) → MQI_s

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

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

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	
F	F	0.00
F	U	0.75
U	F	0.25
U	U	1.00

Multi-site, Model Quality Indicator (MQI_m)

MQI_m

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

Agreement

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

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

Complexity

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

	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

Robustness

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

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

	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

Synthetic indicators

Aggregation rules:
fuzzy-logic based weighing system

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

Non-dimensionality

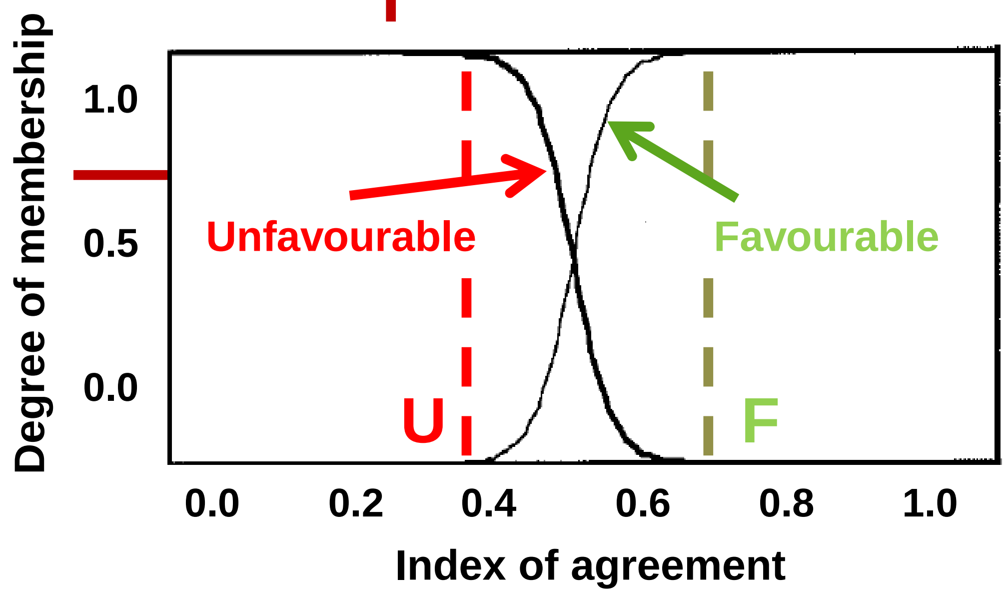
Lower and upper bounding

(best) 0 – 1 (worst)

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

Model Quality Indicator

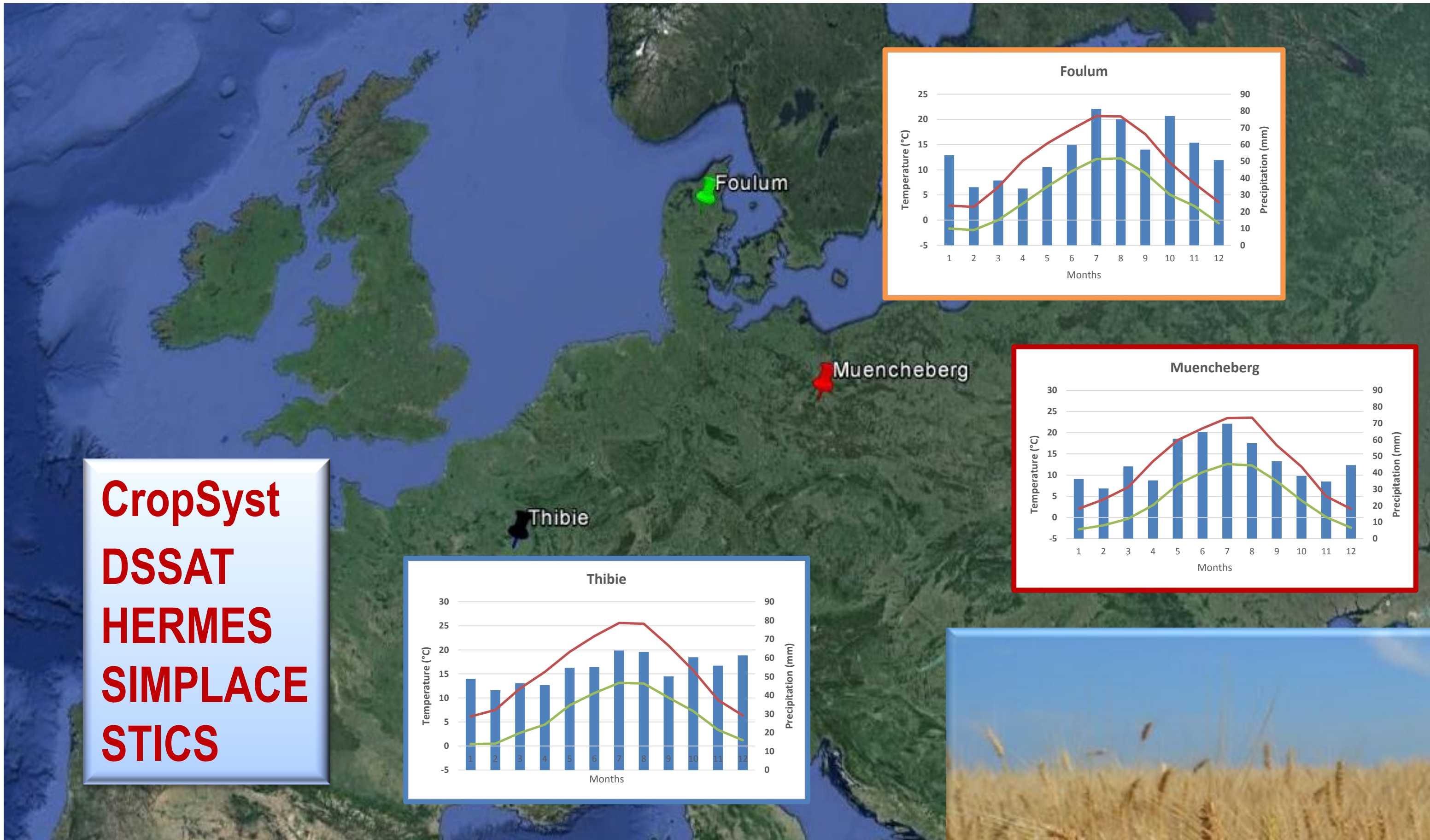
III. Stability (robustness)
- Index of robustness

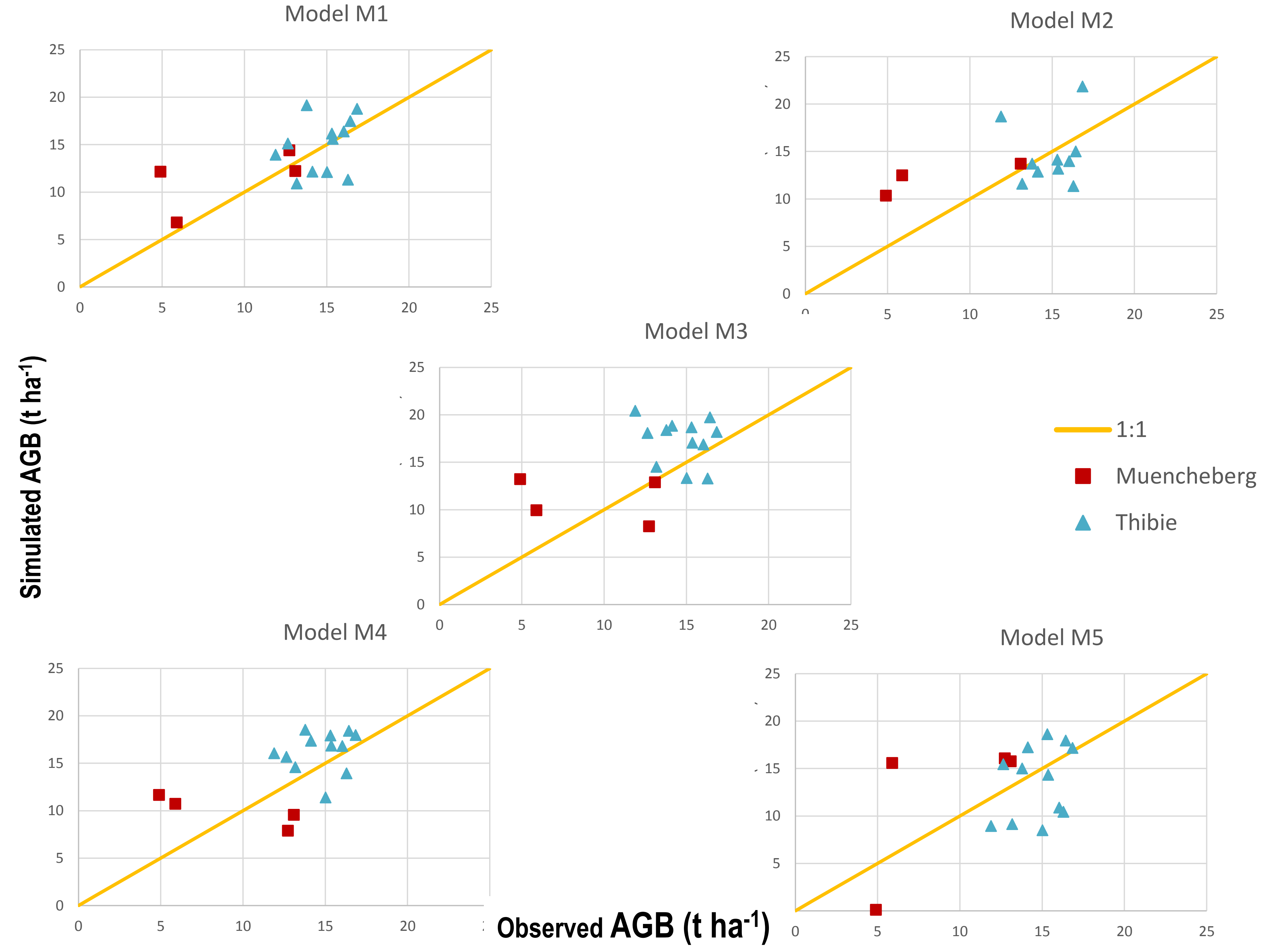


Hindrances to overcome:
thresholds and weights

CropM wheat simulations:

yield, above-ground biomass at maturity

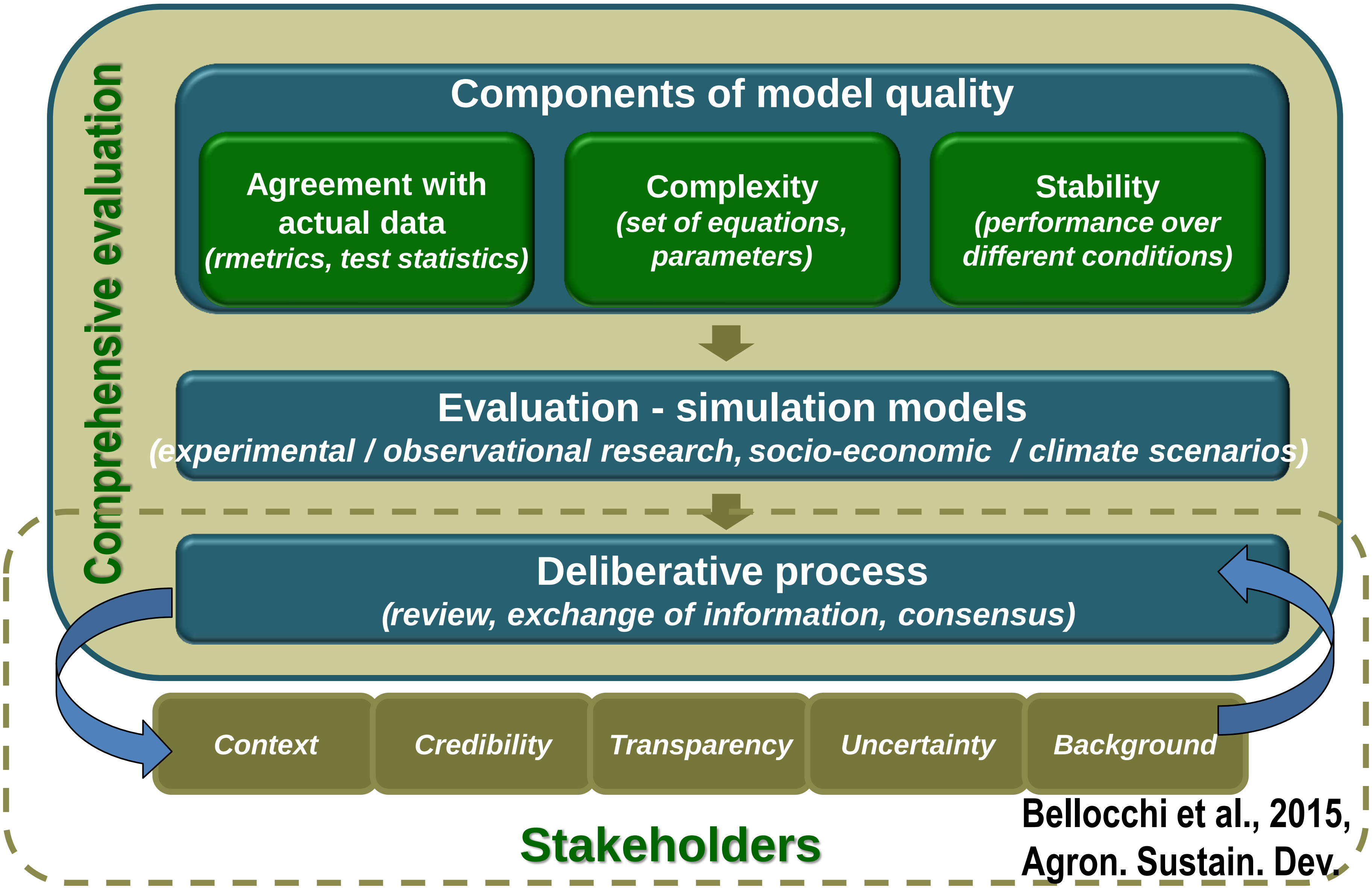




Model M1
Model M2
Model M3
Model M4
Model M5
Simulated AGB (t ha-1)
Observed AGB (t ha-1)
1:1
Muencheberg
Thibie

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					

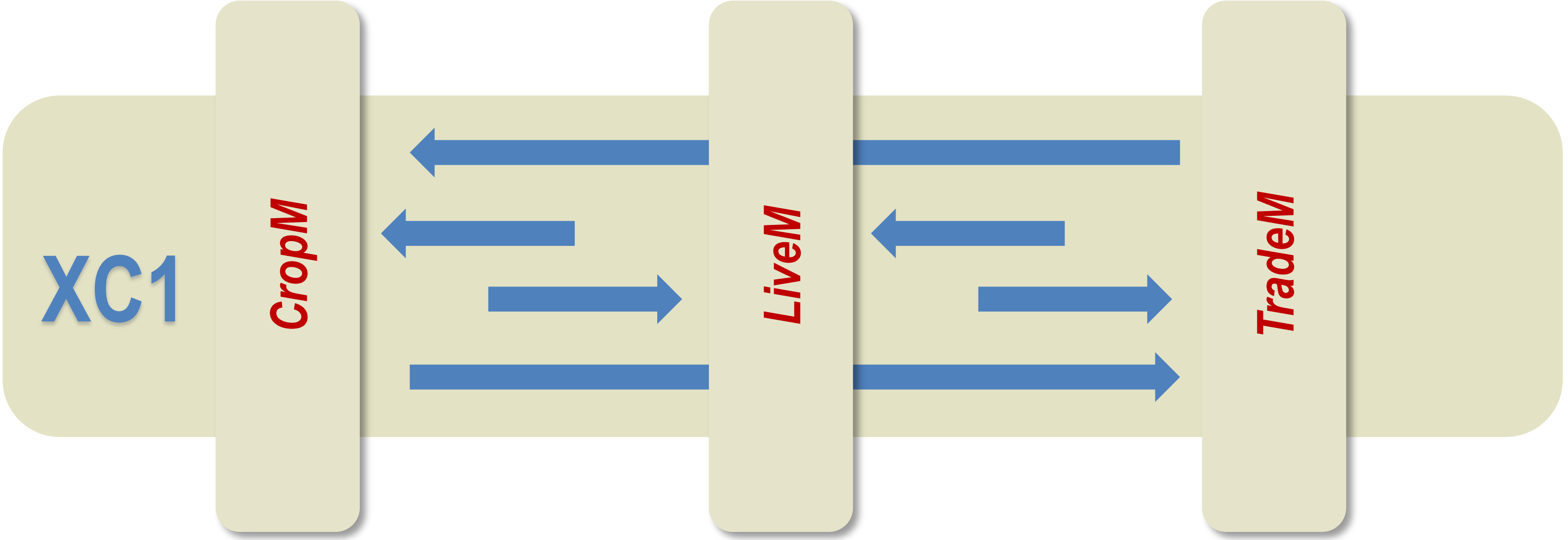
Model evaluation / deliberative process



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



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FACCEJPI Agriculture Food Security and Climate Change

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Acronym	CN-MIP

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agriculture facing extreme climatic events

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