Uncertainty in sensitivity analysis

- Sensitivity analysis **methods** have **their own parameters**

  e.g., levels and trajectories for Morris, number of executions for all other methods

Ecological Modelling 221 (2010) 1897–1906

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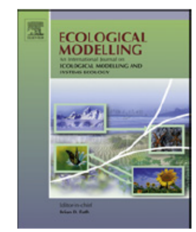


Comparison of sensitivity analysis techniques: A case study with the rice model WARM

R. Confalonieri[a,*], G. Bellocchi[b], S. Bregaglio[a,b], M. Donatelli[b,c], M. Acutis[a]

Uncertainty in sensitivity analysis

- Sensitivity analysis **methods** have **their own parameters**
  - ✓ **Concordance among rankings** (Top-Down Concordance Coefficient, TDCC):

$$TDCC = \frac{\sum_{i=1}^{N}\left[\sum_{j=1}^{nSA} SS(SM_{ij})\right] - nSA^2 \cdot N}{nSA^2 \cdot \left(N - \sum_{i=1}^{N}\frac{1}{i}\right)}$$

where

- nSA is the number of sensitivity analysis results to be compared
- $SS(SM_{ij})$ is the Savage Sore of x_{ij}

Sensitivity analysis

Uncertainty in sensitivity analysis

- Sensitivity analysis **methods** have **their own parameters**
  - ✓ **Concordance** among rankings is considered **NON significant** for ***p*-values > 0.05**.
  - ✓ with ***p*-value** calculated according to the **statistic T**, which **approximates a X^2** distribution with **N-1 degrees of freedom**:

$$T = nSA \cdot (N-1) \cdot TDCC$$

  - ✓ **Null hypothesis** is **absence of concordance**.

Uncertainty in sensitivity analysis

- Sensitivity analysis **methods** have **their own parameters**

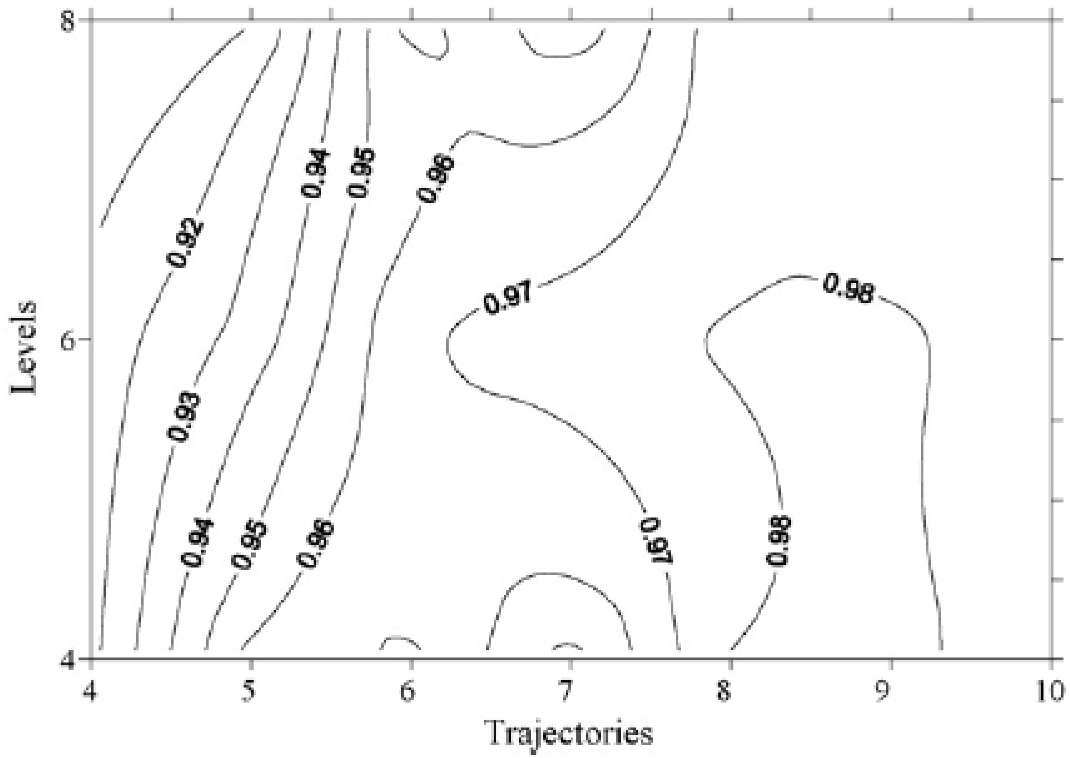


Fig. 1. Morris robustness. Top-down concordance coefficient (TDCC) calculated on rankings obtained, for each combination trajectory × level, with seven different seeds (*p*-values always lower than 10^{-9}).

Uncertainty in sensitivity analysis

- Sensitivity analysis **methods** have **their own parameters**

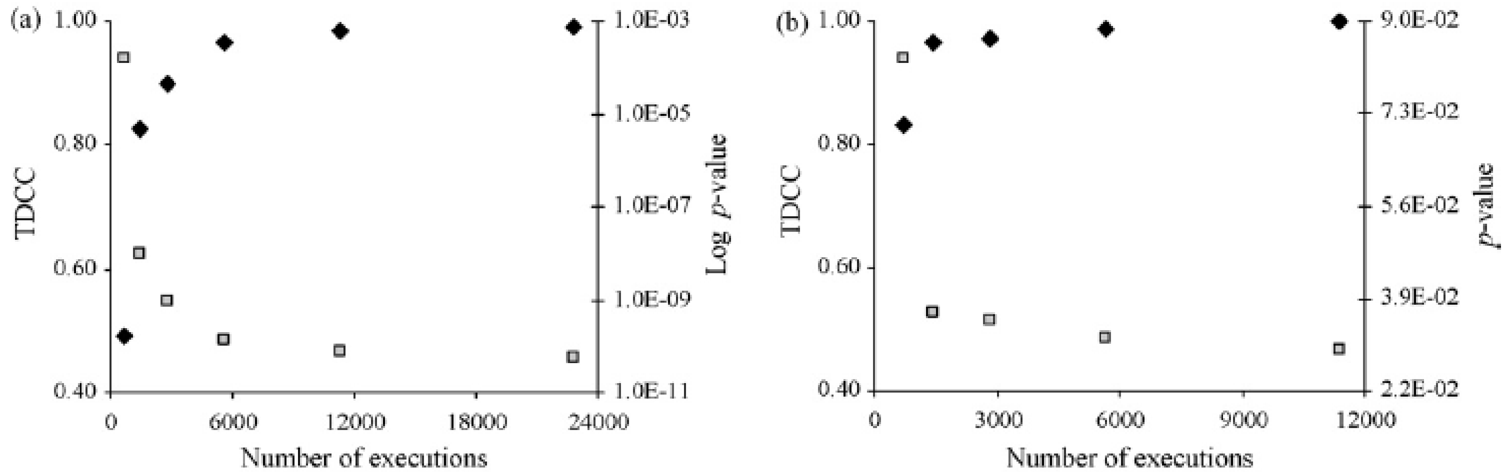


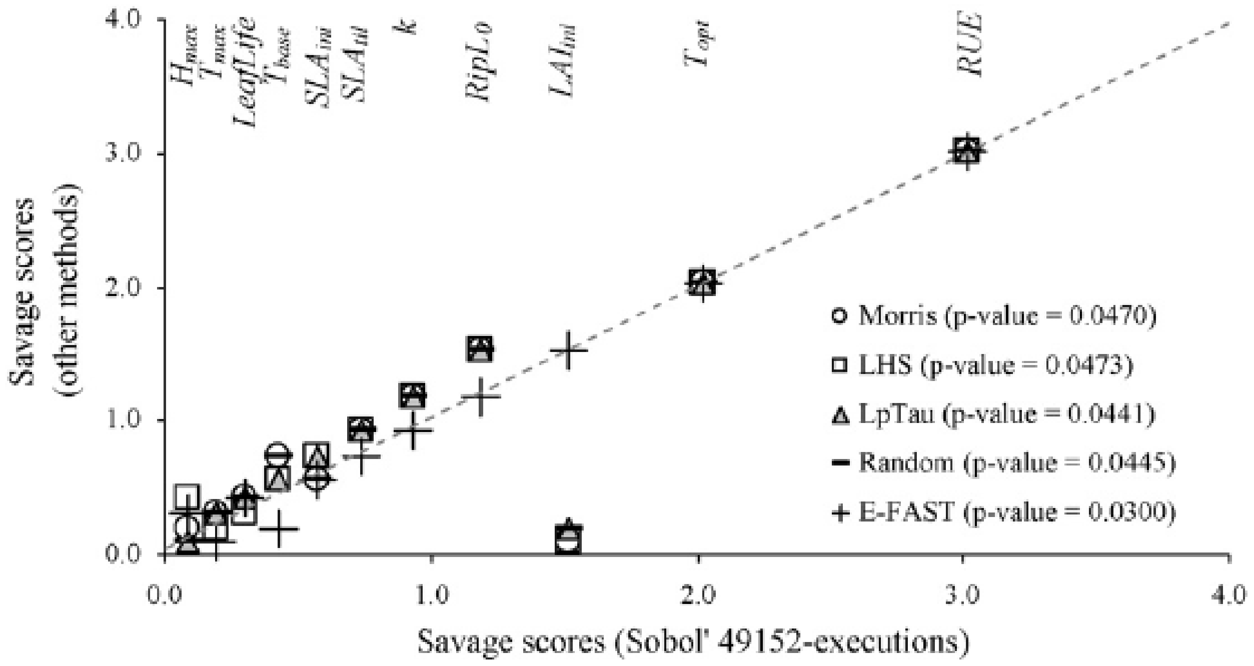
Fig. 5. E-FAST robustness. Top-down concordance coefficient (TDCC; black diamonds) and related *p*-values (grey squares) calculated for different method parameterizations. (a) Effect of seven different seeds in influencing parameters ranking for increasing number of model executions. (b) Comparison between the ranking obtained with 22,803 model executions and those obtained increasing the number of executions.

Sensitivity analysis

Uncertainty in sensitivity analysis

- Sensitivity analysis **methods** have **their own parameters**

R. Confalonieri et al. / Ecological Modelling 221 (2010) 1897–1906



Uncertainty in sensitivity analysis

- Most **methods** are very sensitive to **parameter distributions**

Ecological Modelling 340 (2016) 57–63

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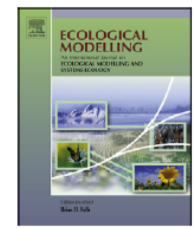


ELSEVIER

Sensitivity analysis of a sensitivity analysis: We are likely overlooking the impact of distributional assumptions

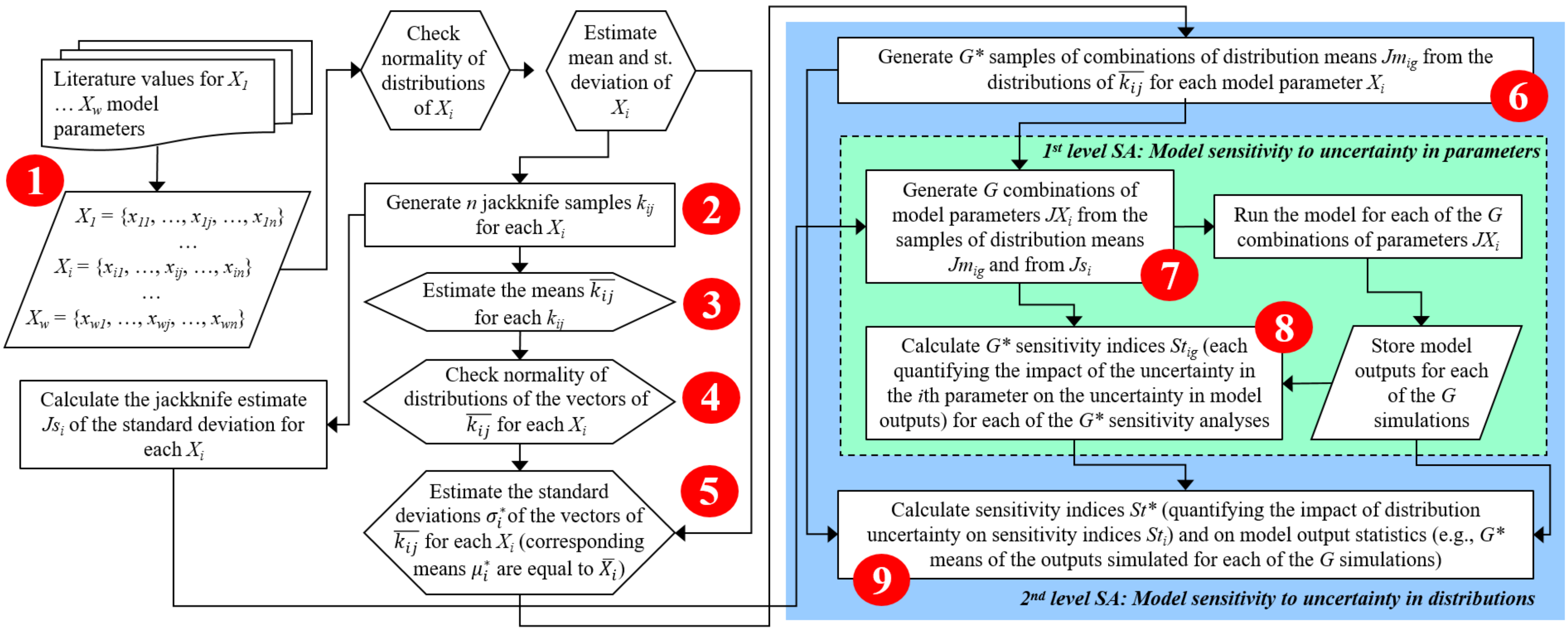
CrossMark

Livia Paleari[a], Roberto Confalonieri[b,*]

Sensitivity analysis

Uncertainty in sensitivity analysis

- Most **methods** are very sensitive to **parameter distributions**



Uncertainty in sensitivity analysis

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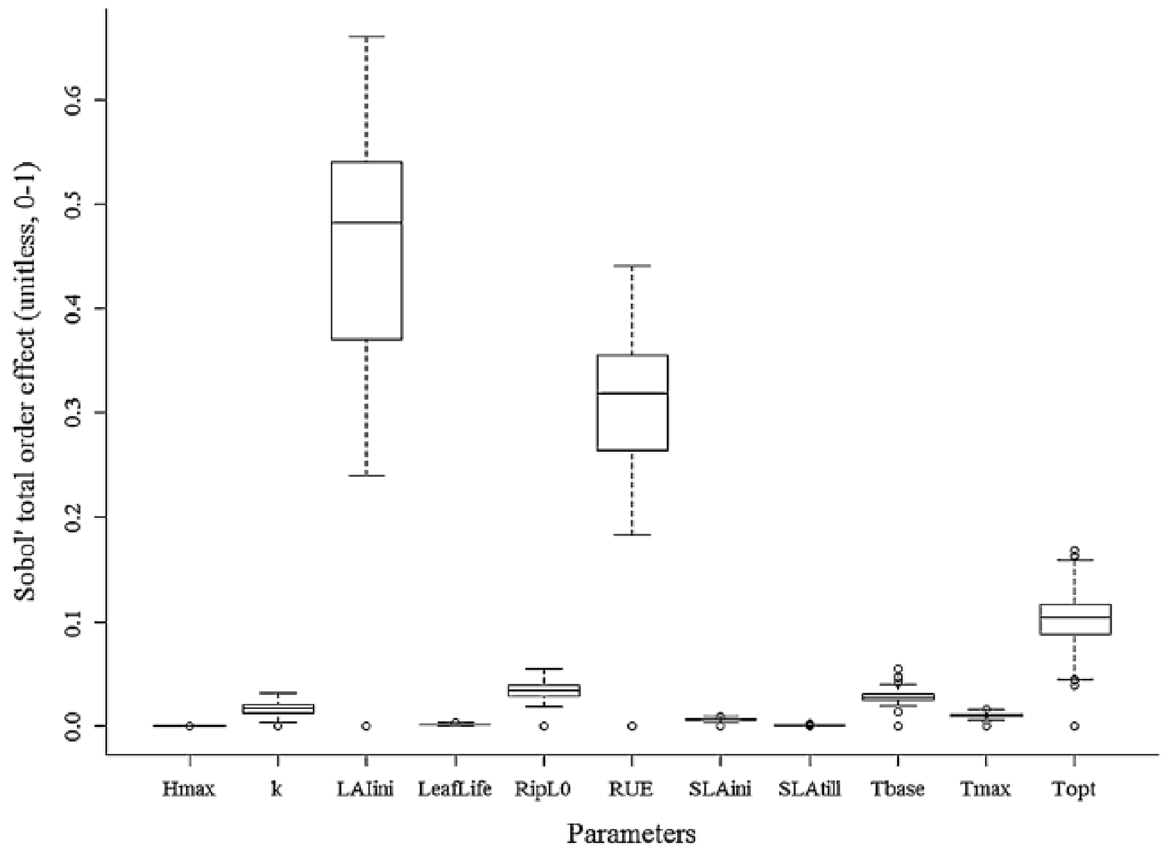

Fig. 2. Box plots of the Sobol' total order effects (St) for model parameters obtained for the 6144 1st level sensitivity analyses. Variability results from the use of different distributions (generated) for model parameters.

Uncertainty in sensitivity analysis

- **Sensitivity** analysis is **situational**!

Ecological Modelling 225 (2012) 159–166

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Ecological Modelling

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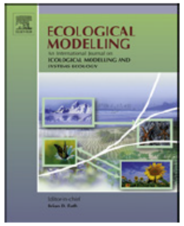


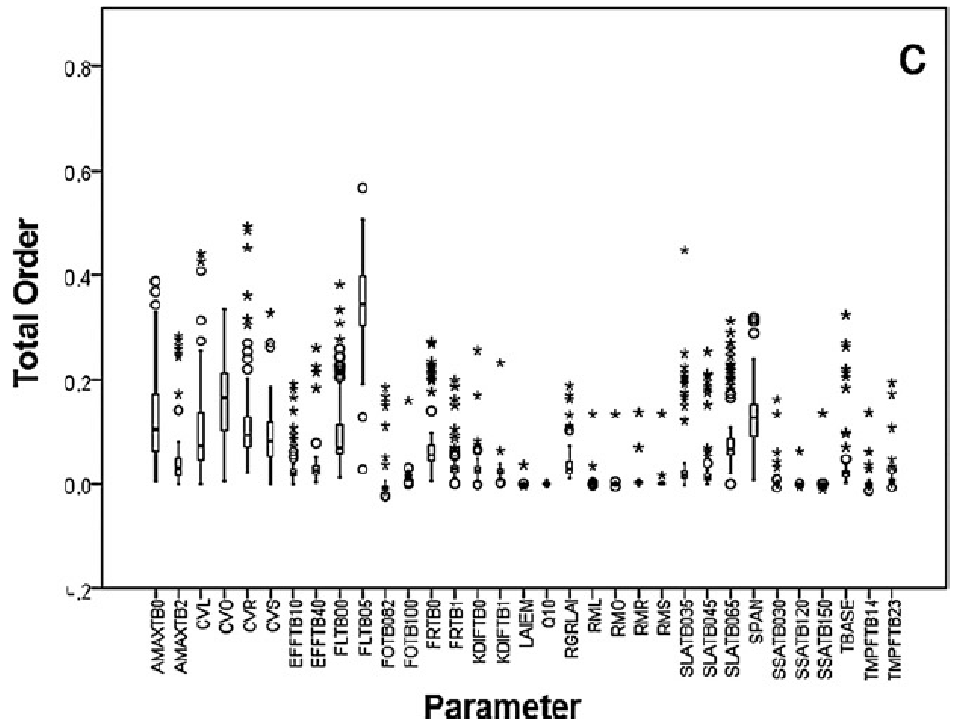
Quantifying plasticity in simulation models

R. Confalonieri[a,*], S. Bregaglio[a,b], M. Acutis[a]

Sensitivity analysis

Uncertainty in sensitivity analysis

- **Sensitivity** analysis is **situational**!
  - ✓ WOFOST model, rice
  - ✓ 10 locations, three diverging seasons per location
  - ✓ Output: aboveground biomass



- **Crucial for ideotyping**

- **District-specific ideotypes**

In silico ideotyping

1. Define **ranges/statistical distributions** for **trait** values

2. Identify **most relevant traits**

   ✓ Global **sensitivity analysis**

3. Define "**optimal**" **values** for those traits (targeting specific ***objective functions***)

   ✓ Trial and error/grid search

Europ. J. Agronomy 82 (2017) 144–162

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European Journal of Agronomy

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

Designing future barley ideotypes using a crop model ensemble

CrossMark

Fulu Tao[a,*], Reimund P. Rötter[a,b], Taru Palosuo[a], C.G.H. Díaz-Ambrona[c], M. Inés Mínguez[c], Mikhail A. Semenov[d], Kurt Christian Kersebaum[e], Claas Nendel[e], Davide Cammarano[f], Holger Hoffmann[g], Frank Ewert[g], Anaelle Dambreville[h], Pierre Martre[h], Lucía Rodríguez[c], Margarita Ruiz-Ramos[c], Thomas Gaiser[g], Jukka G. Höhn[a], Tapio Salo[a], Roberto Ferrise[i], Marco Bindi[i], Alan H. Schulman[a,j]

Trial and error

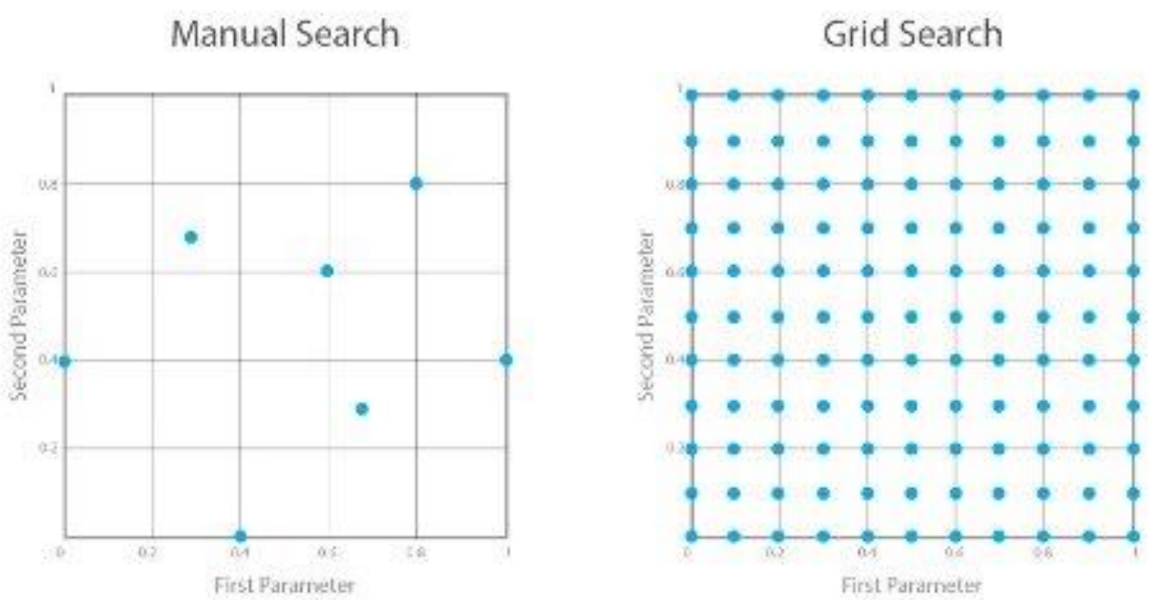
- Once most relevant parameters have been identified

⇩

- Calibration of model parameters

Grid search

- Once most relevant parameters have been identified



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   - ✓ Global **sensitivity analysis**
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   - ✓ Trial and error/grid search
   - ✓ Automatic calibration algorithms

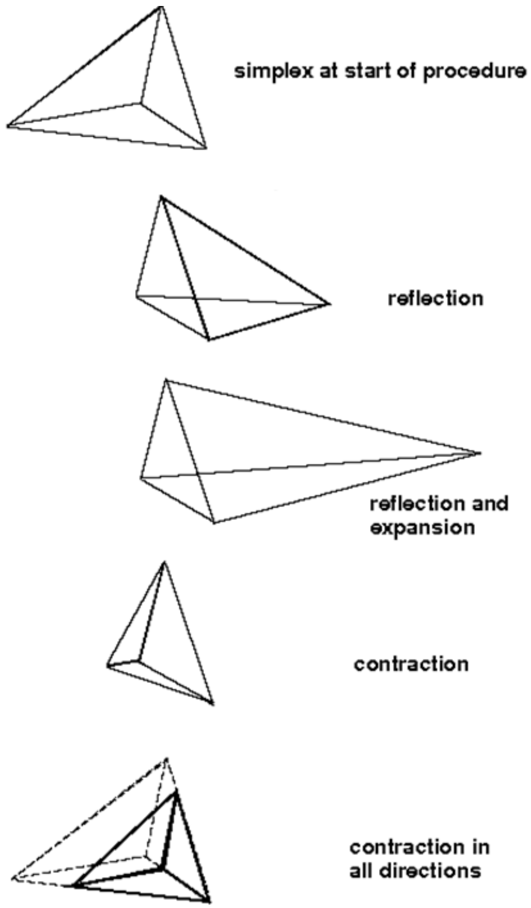
Global Change Biology
celebrating 20 years
Global Change Biology (2014), doi: 10.1111/gcb.12567

Simultaneous improvement in productivity, water use, and albedo through crop structural modification

DARREN T. DREWRY[1,2], PRAVEEN KUMAR[3,4] and STEPHEN P. LONG[5,6]
[1]*Climate Physics Group, Jet Propulsion Laboratory, California Institute of Technology, m/s 233-300, Pasadena, CA 91109-8099, USA,* [2]*Joint Institute for Regional Earth System Science & Engineering, University of California Los Angeles, 607 Charles E Young Drive East, Young Hall, Room 4242, Los Angeles, CA 90095-7228, USA,* [3]*Department of Civil and Environmental Engineering, University of Illinois, 2527B Hydrosystems Laboratory, 301 North Mathews Avenue, Urbana, IL 61801-2352, USA,* [4]*Department of Atmospheric Sciences, University of Illinois, 150 South Gregory Street, Urbana, IL 61801-3070, USA,* [5]*Department of Crop Sciences, University of Illinois, AW-101 Turner Hall, 1102 South Goodwin Avenue, Urbana, IL 61801, USA,* [6]*Department of Plant Biology, University of Illinois, 265 Morrill Hall, 505 South Goodwin Avenue, Urbana, IL 61801, USA*

Optimization

- There are **different optimization algorithms**
  - ✓ The **downhill simplex** is often considered as one of those with the best "value for money"
  - ✓ Parameters with a biophysical meaning →use a **bounded simplex**
  - ✓ **Evolutionary shuffled simplex**, developed to reduce the risk to fall in local minima
  - ✓ **Easy** to implement
  - ✓ **Fast**



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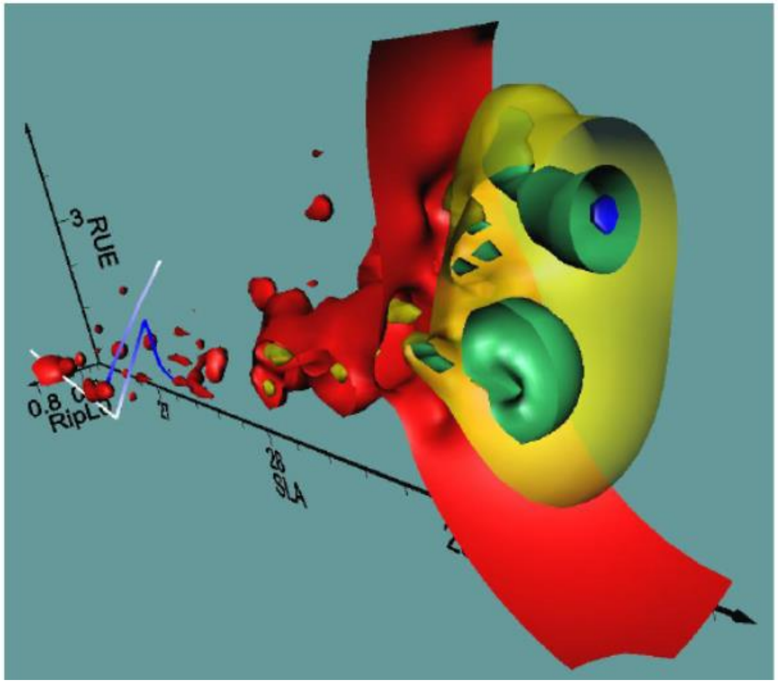

In silico ideotyping

1. Define **ranges/statistical distributions** for **trait** values
2. Identify **most relevant traits**
   - ✓ Global **sensitivity analysis**
3. Define "**optimal**" **values** for those traits (targeting specific ***objective functions***)
   - ✓ Trial and error/grid search
   - ✓ Automatic calibration algorithms
   - ✓ From sensitivity analysis results

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ELSEVIER

Sensitivity analysis of a sensitivity analysis: We are likely overlooking the impact of distributional assumptions

Livia Paleari[a], Roberto Confalonieri[b,*]

Ideotype definition

- From sensitivity analysis results
  - ✓ Deriving putative ideotypes **considering both performance and extent** of the **improvement** required
  - ✓ **Avoiding local minima**

$$I_{\text{ideo}} = \left[\sum_{i=1}^{n} \left(\left(\frac{|x_i - m_i|}{m_i} \cdot 100 \right) \cdot \frac{1}{\sqrt{St_i}} \right) \cdot \frac{1}{n} \right] \cdot \left(1 - \frac{Y_v}{Y_{vmax}} \right)$$

- n: number of parameters defining the ideotype;
- x_i : value of the *i*th parameter
- m_i : distribution mean of the *i*th parameter
- St_i: Sobol' total order for the *i*th parameter
- Yv: **economical yield** from the ideotype (e.g., grain quality)
- $Yv/Yv\ max$: yield of the ideotype (€ ha^{-1}) normalized to the maximum of all ideotypes under evaluation

- **Ideotype profile:** average values of the **best 1%**

In silico ideotyping

- **Sample results**
  - ✓ WARM rice model
  - ✓ Traits involved with different processes
    - growth
    - sterility due to cold/heat shocks around flowering
    - plant-pathogen interactions
    - grain quality
  - ✓ 5 sites

In silico ideotyping

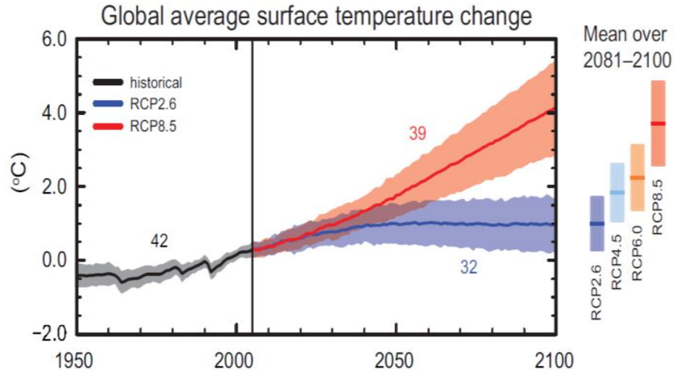
	Los Baños	Ludhiana	Nanjing	Shizukuishi	Milan
Country	**Philippines**	**India**	**China**	**Japan**	**Italy**
Coordinates	121°9'E, 14°6'N	75°48'E, 30°54'N	118°59'E, 32°56'N	140°57'E, 39°41'N	8°41'E, 45°4'N
Climate type	Tropical, humid	Subtropical, semiarid	Subtropical, semihumid	Cool temperate, humid	Temperate, semiarid
Mean T max (°C)	30.2	29.3	20.3	13.7	18.2
Mean T min (°C)	23.2	16.8	12.0	5.1	8.6
Mean rad (MJ m^{-2})	15.9	18.7	14.1	12.1	14.6
Rainfall (mm)	2060	703	1076	1557	698
Emberger continentality (Tmax warmest month – Tmin coldest month)	11.0 (oceanic insular)	31.8 (semi-continental)	32.3 (semi-continental)	33.1 (semi-continental)	31.1 (semi-continental)
SAM Aridity index (ET0-Rain)/(ED0+Rain)	0.13	-0.39	-0.20	-0.01	-0.36

In silico ideotyping

- **Sample results**
  - ✓ WARM rice model
  - ✓ Traits involved with different processes
    - growth
    - sterility due to cold/heat shocks around flowering
    - plant-pathogen interactions
    - grain quality
  - ✓ 5 sites
  - ✓ Different climate scenarios
    - supporting the development of new varieties suitable in the mid-term

In silico ideotyping

- **Climate scenarios**
  - ✓ **4** 20-year **time frames**: 1986-2005 (baseline), 2030, 2050, 2070
  - ✓ **2** IPCC **AR5**: RCP2.6, RCP8.5
  - ✓ **2 GCMs**: HadGEM2, GISS-ModelE2
  - ✓ **WG**: CLIMAK



- **Ideotyping**
  - ✓ Sensitivity analysis method: Sobol' – total order effect
- **Variable analyzed**: Value ha^{-1} → YL · V - YL · [(1-HR)+C] ·V/2
  - ✓ YL (t ha^{-1}): yield limited by biotic/abiotic factors
  - ✓ V (euros t^{-1}): value of entire and non chalky grains
  - ✓ HR (-, 0-1): head rice yield
  - ✓ C (-, 0-1): chalkiness

More than 6.6 million simulations