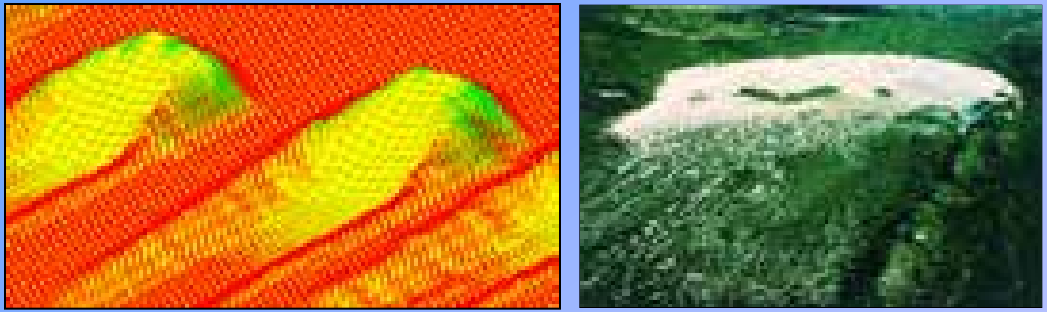
Innovation of Models across Agro-Environmental Scales:

Modelling Aeolian Agro-Environmental Landscape Dynamics



Andreas Baas

Department of Geography
King's College London

thanks to:

Aeolian Agro-Environmental Landscapes

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Agro-Environmental Modelling

- Models are tools for understanding agro-environmental processes
  (e.g. plant production, plant-soil interactions, soil degradation and soil erosion)

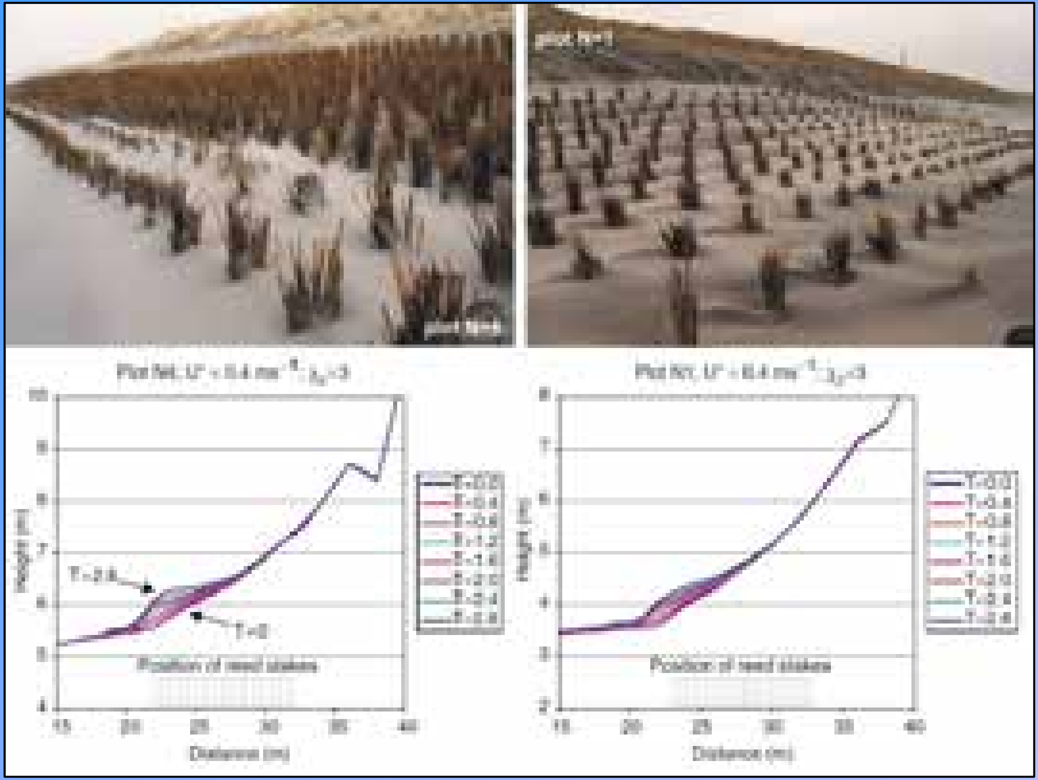
- Progressively used in land use planning and assessment

- Need to reflect different spatio-temporal scales and complex interactions
  (e.g. socio-economic driving-forces, soil management practices and geo-ecological processes)

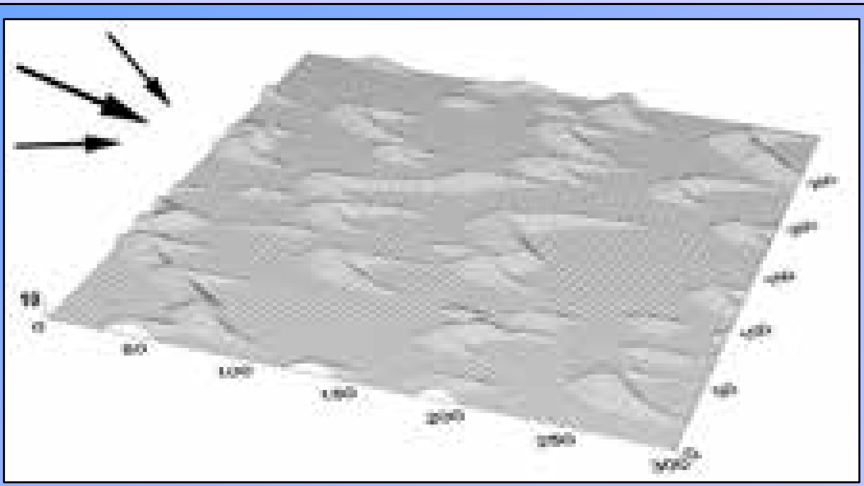
- Challenges to:
  1) cover processes across spatio-temporal scales
  2) linking processes of different kind

Personal Modelling Background

SAFE

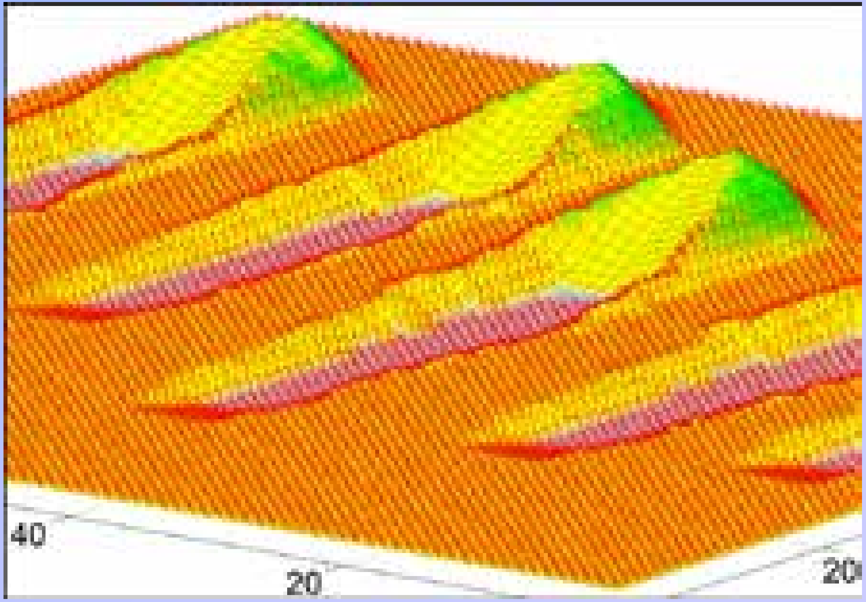


Arens *et al.* (2001)



Baas (2002)

DECAL



Baas and Nield (2007)

Outline

Goal: to review challenges and innovations

- Historical context and types of models
  1D, 2D, 3D

- Challenges & opportunities
  scaling and vegetation

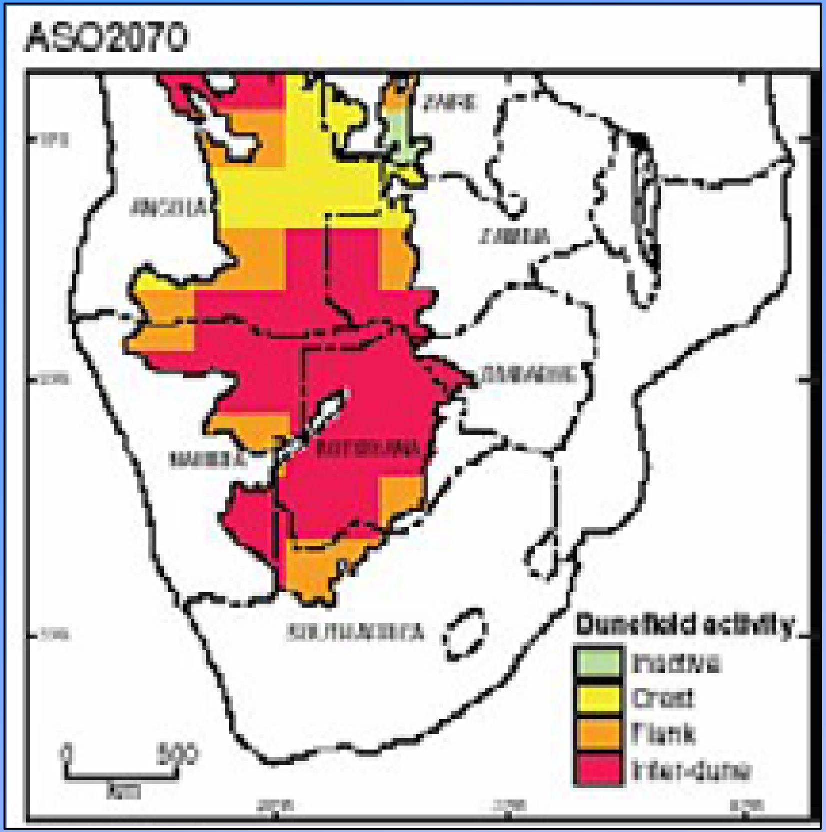
- Recent innovations
  combination and versatility

- Good modelling practices
  implications

Historical Context & Model Types

Dune Mobility

____



Thomas *et al.* (2005)

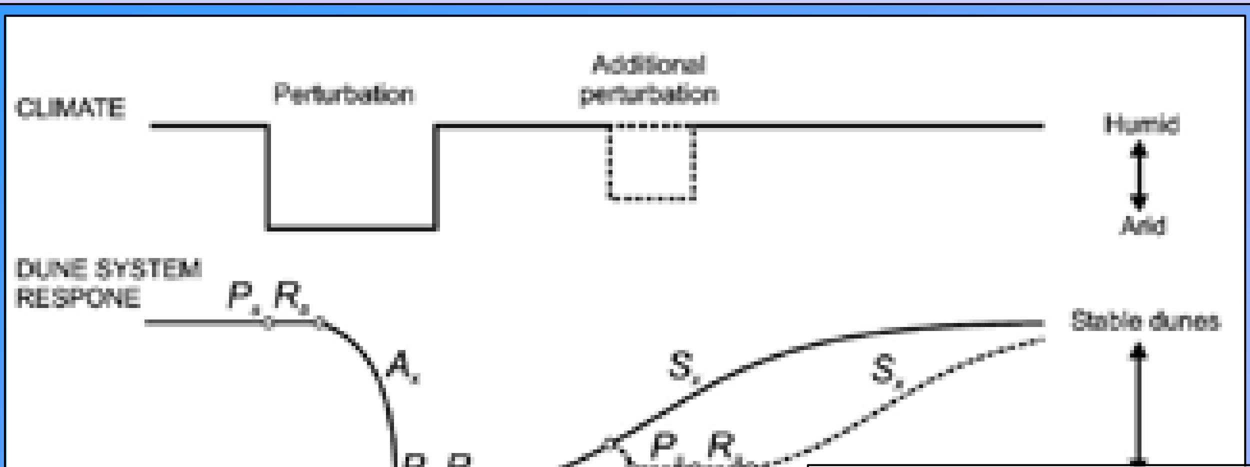
Chepil-Siddoway-Armbrust (1962):

____

Lancaster (1988):

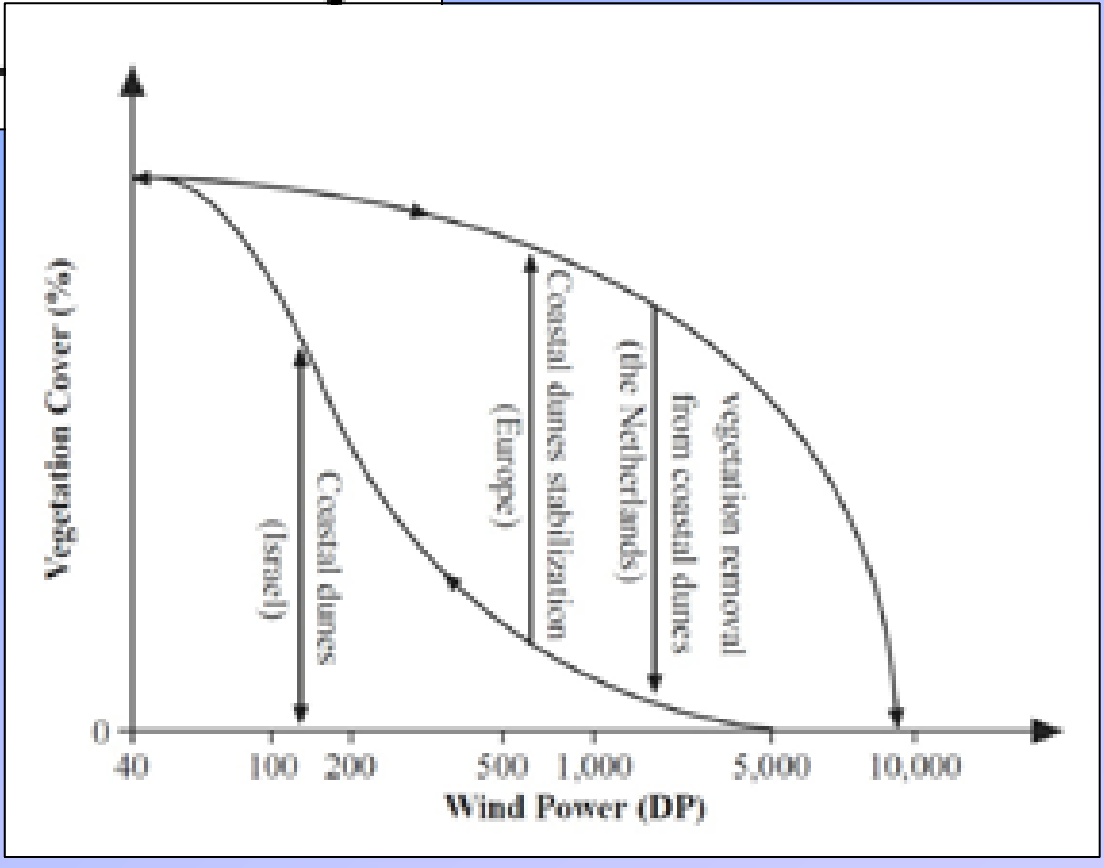
_____

Dune Mobility



Hugenholtz and Wolf (2005)

Yizhaq-Ashkenazy-Tsoar (2009)



Agricultural Wind Erosion

Wind Erosion Equation, WEQ

Woodruff and Siddoway (1965):

E = ¦ (I’, K’, C’, L’, V)

I’ = soil erodibility
K’ = soil ridge roughness
C’ = climate
L’ = field length
V = vegetation

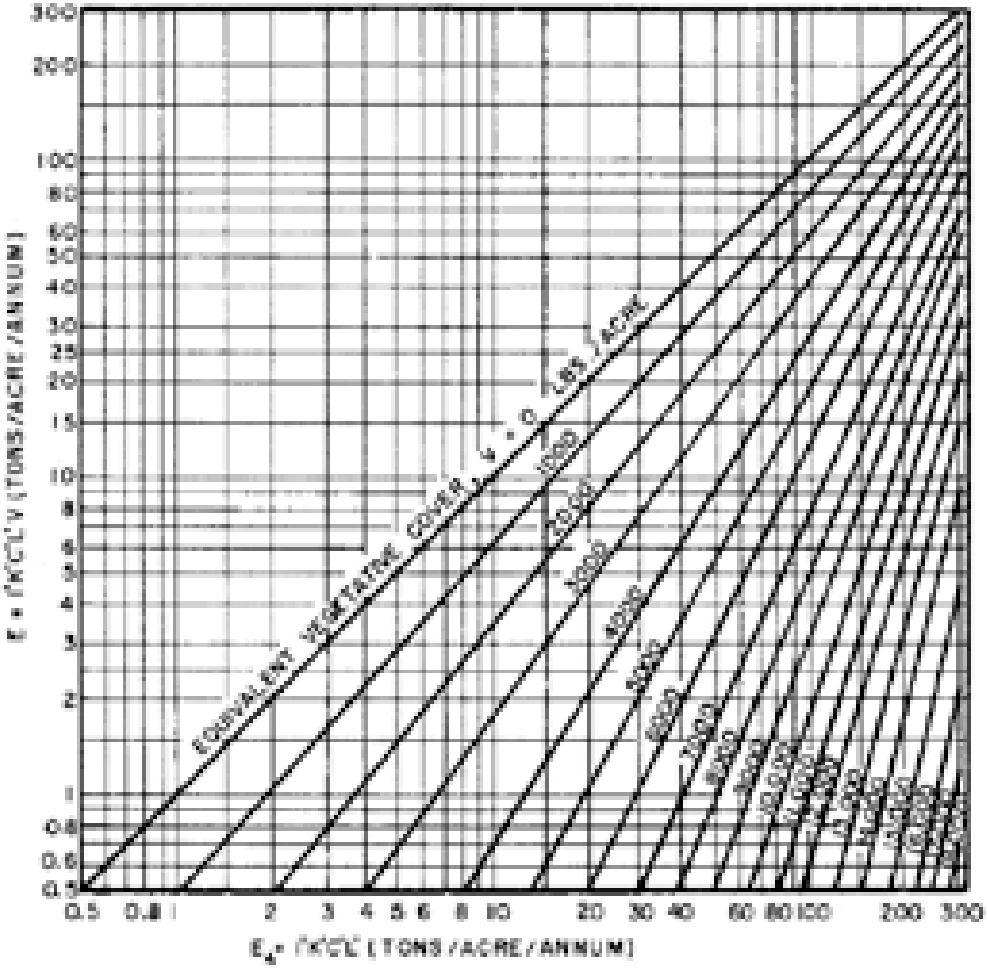
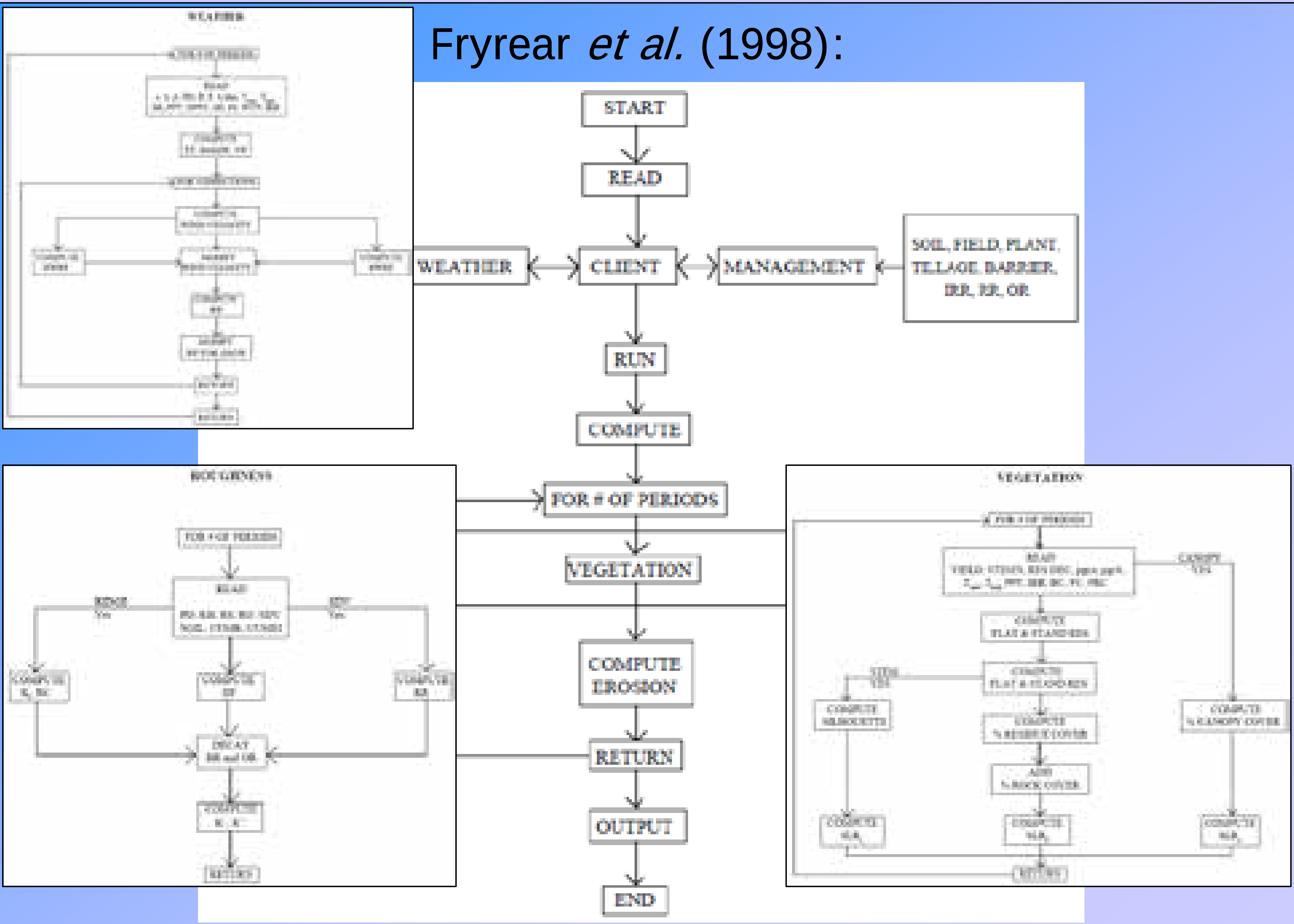


Fig. 10—Chart to determine soil loss E = I'K'C'L'V from soil loss E_2 = I'K'C'L' and from the vegetative cover factor, V. The chart can be used in reverse to determine V needed to reduce soil loss to any degree.

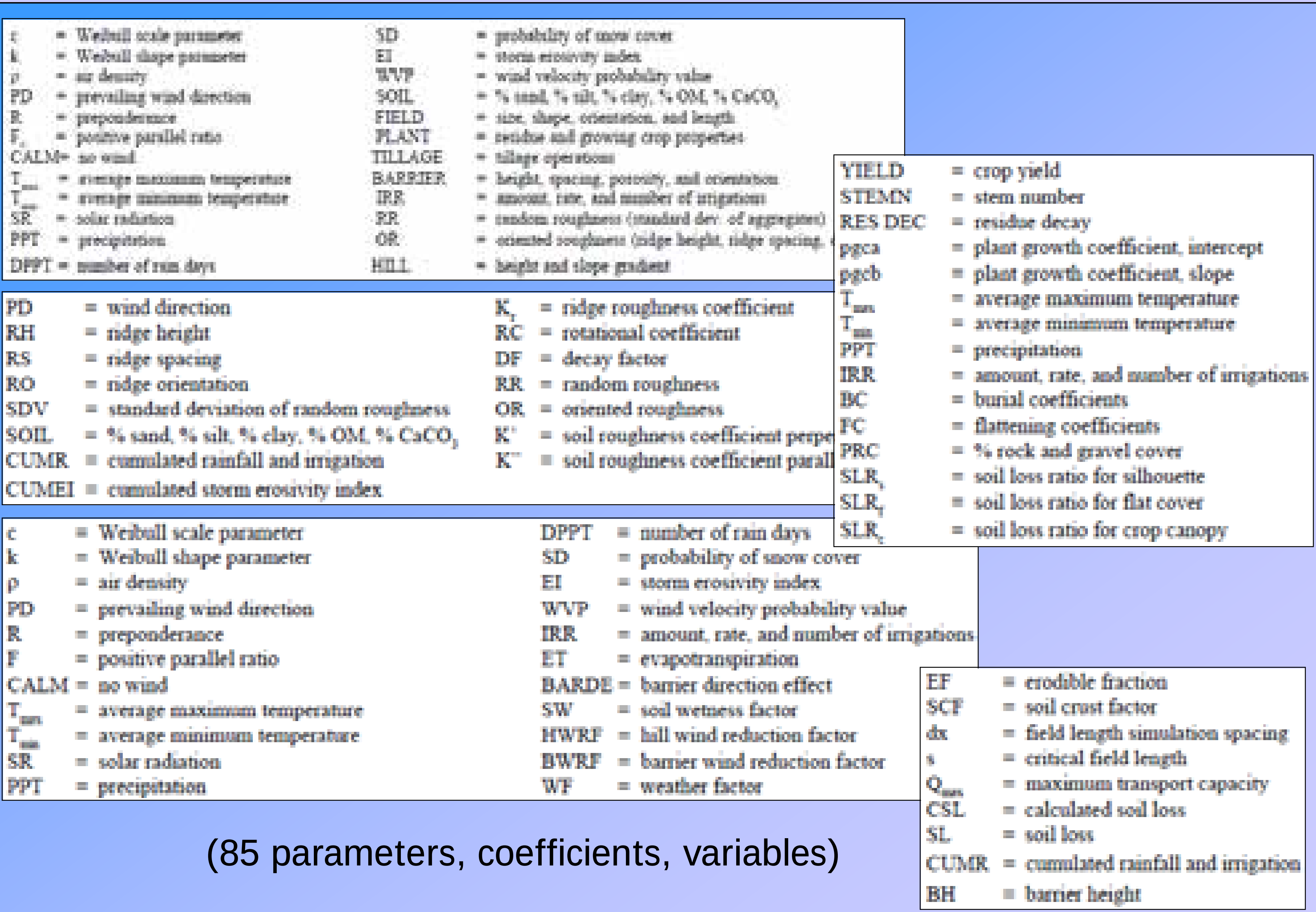
Nomograms:
(graphical
calculators)

Revised Wind Erosion Equation, RWEQ

Fryrear *et al.* (1998):



Revised Wind Erosion Equation, RWEQ



c = Weibull scale parameter
k = Weibull shape parameter
ρ = air density
PD = prevailing wind direction
R = preponderance
F_s = positive parallel ratio
CALM= no wind
T_{max} = average maximum temperature
T_{min} = average minimum temperature
SR = solar radiation
PPT = precipitation
DPPT = number of rain days

SD = probability of snow cover
EI = storm erosivity index
WVP = wind velocity probability value
SOIL = % sand, % silt, % clay, % OM, % $CaCO_3$
FIELD = size, shape, orientation, and length
PLANT = residue and growing crop properties
TILLAGE = tillage operations
BARRIER = height, spacing, porosity, and orientation
IRR = amount, rate, and number of irrigations
RR = random roughness (standard dev. of aggregates)
OR = oriented roughness (ridge height, ridge spacing,
HILL = height and slope gradient

PD = wind direction
RH = ridge height
RS = ridge spacing
RO = ridge orientation
SDV = standard deviation of random roughness
SOIL = % sand, % silt, % clay, % OM, % $CaCO_3$
CUMR = cumulated rainfall and irrigation
CUMEI = cumulated storm erosivity index

K_r = ridge roughness coefficient
RC = rotational coefficient
DF = decay factor
RR = random roughness
OR = oriented roughness
K' = soil roughness coefficient perpe
K'' = soil roughness coefficient parall

YIELD = crop yield
STEMN = stem number
RES DEC = residue decay
pgca = plant growth coefficient, intercept
pgcb = plant growth coefficient, slope
T_{max} = average maximum temperature
T_{min} = average minimum temperature
PPT = precipitation
IRR = amount, rate, and number of irrigations
BC = burial coefficients
FC = flattening coefficients
PRC = % rock and gravel cover
SLR_s = soil loss ratio for silhouette
SLR_f = soil loss ratio for flat cover
SLR_c = soil loss ratio for crop canopy

c = Weibull scale parameter
k = Weibull shape parameter
ρ = air density
PD = prevailing wind direction
R = preponderance
F = positive parallel ratio
CALM = no wind
T_{max} = average maximum temperature
T_{min} = average minimum temperature
SR = solar radiation
PPT = precipitation

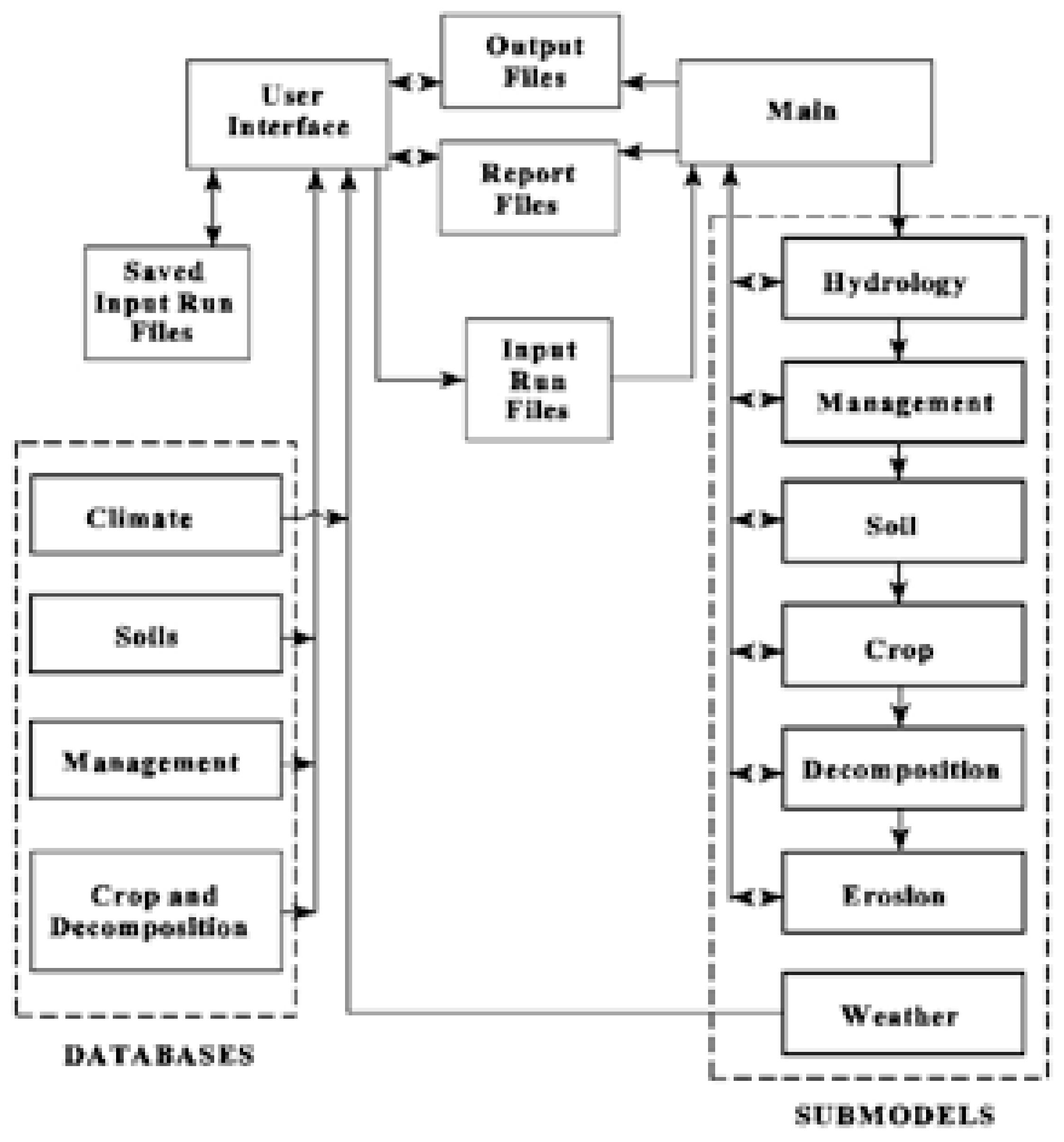
DPPT = number of rain days
SD = probability of snow cover
EI = storm erosivity index
WVP = wind velocity probability value
IRR = amount, rate, and number of irrigations
ET = evapotranspiration
BARDE = barrier direction effect
SW = soil wetness factor
HWRF = hill wind reduction factor
BWRF = barrier wind reduction factor
WF = weather factor

EF = erodible fraction
SCF = soil crust factor
dx = field length simulation spacing
s = critical field length
Q_{max} = maximum transport capacity
CSL = calculated soil loss
SL = soil loss
CUMR = cumulated rainfall and irrigation
BH = barrier height

(85 parameters, coefficients, variables)

Wind Erosion Prediction System, WEPS

Hagen (1991); Hagen-Wagner-Tatarko (1996)



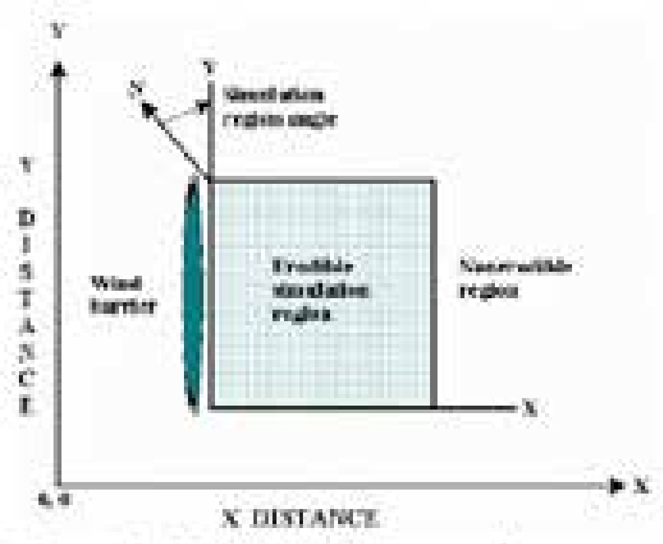
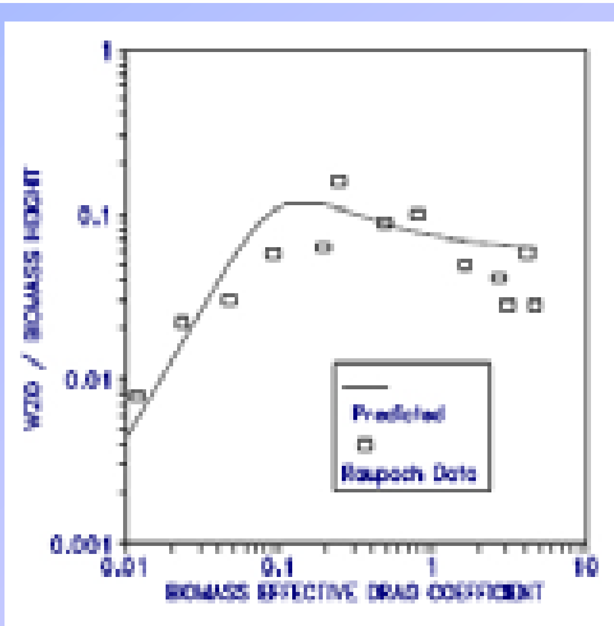
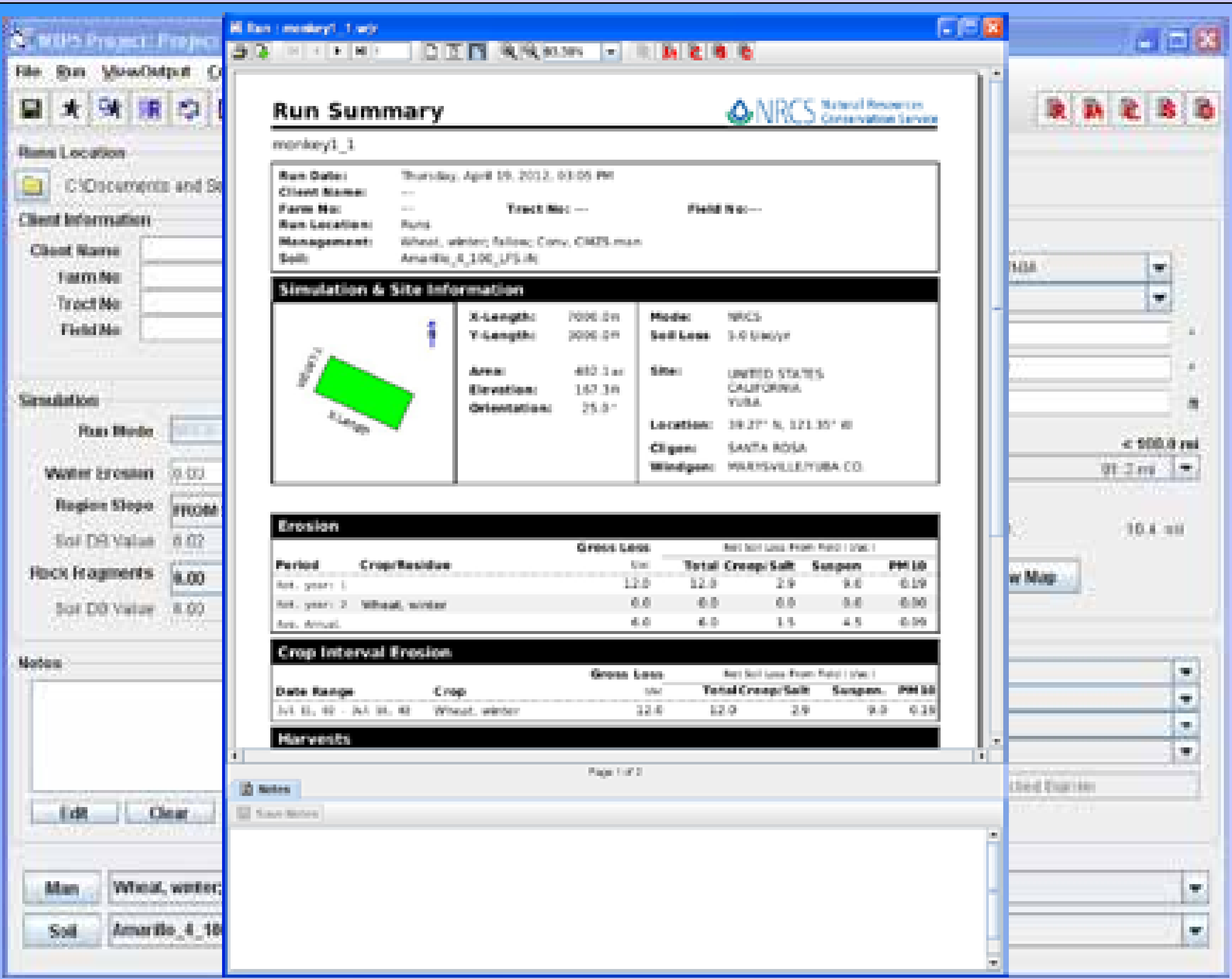


Figure 1.2. WEPS simulation geometries.



Wind Erosion Prediction System, WEPS



Run Summary

NRCS Natural Resources Conservation Service

monkey1_1

Run Date: Thursday, April 19, 2012, 03:05 PM
Client Name: ---
Farm No: --- **Tract No:** --- **Field No:** ---
Run Location: Runs
Management: Wheat, winter; fallow; Conv, [illegible]
Soil: Amarillo_4_100_[illegible]

Simulation & Site Information

Mode: NRCS
Site: UNITED STATES
CALIFORNIA
YUBA
Location: 39.27° N, 121.35° W
Cligen: SANTA ROSA
Windgen: MARYSVILLE/YUBA CO

Erosion

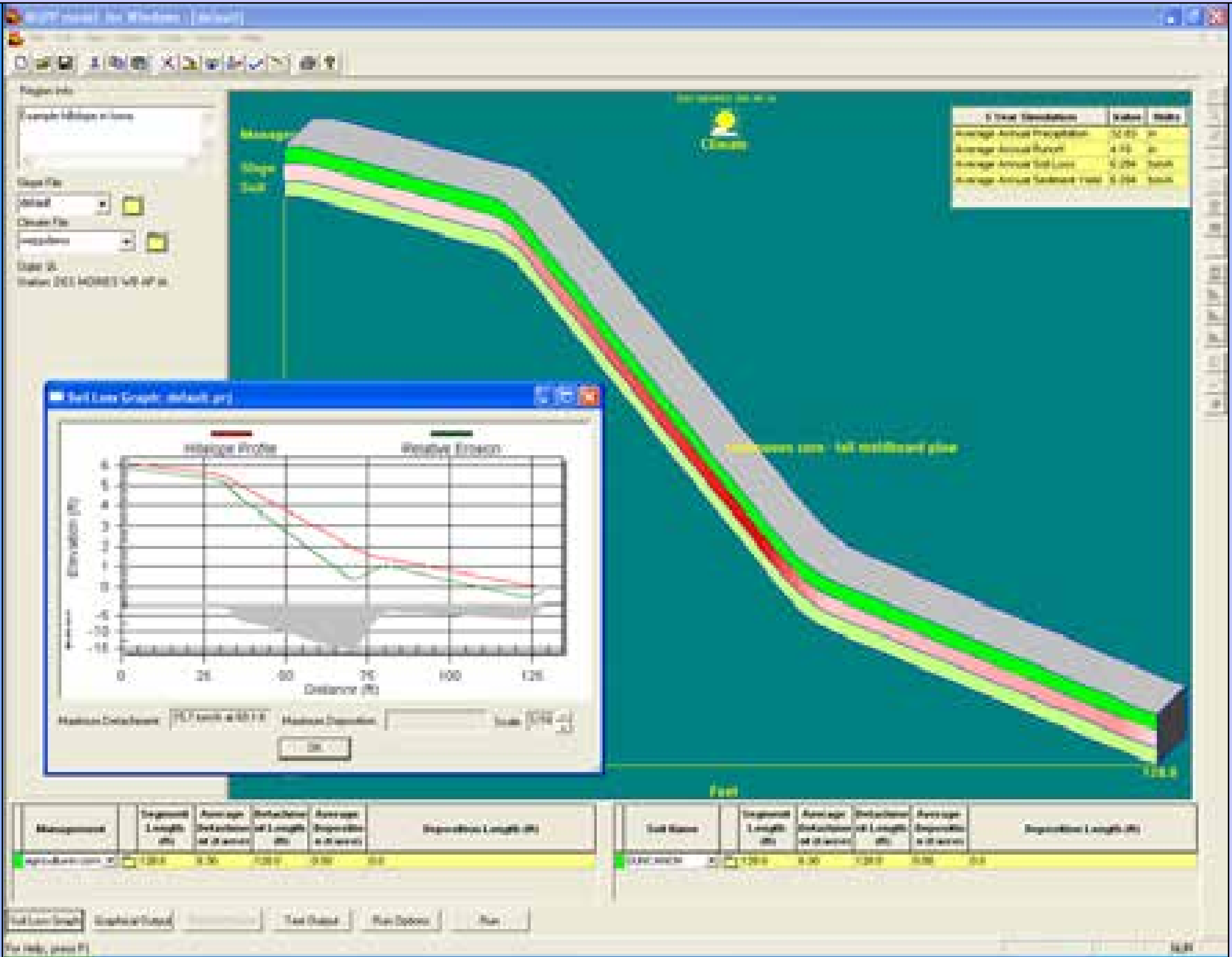
Period	Crop/Residue	Gross Loss t/ac	Net Soil Loss From Field (t/ac) Total	Creep/Salt	Suspen	PM10
Rot. year: 1		12.0	12.0	2.9	9.0	0.19
Rot. year: 2	Wheat, winter	0.0	0.0	0.0	0.0	0.00
Avg. Annual		6.0	6.0	1.5	4.5	0.09

Crop Interval Erosion

Date Range	Crop	Gross Loss t/ac	Net Soil Loss From Field (t/ac) Total	Creep/Salt	Suspen.	PM10
[illegible]	Wheat, winter	12.0	12.0	2.9	9.0	0.19

Harvests

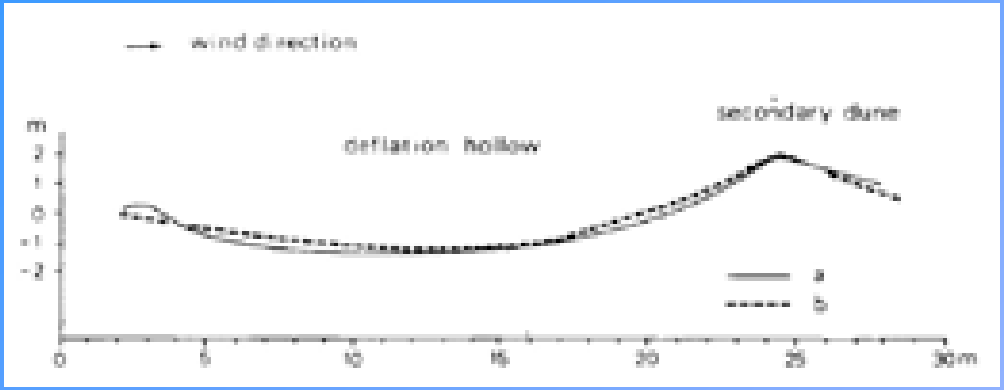
Water Erosion Prediction Project, WEPP



Transect Models

Transect Models

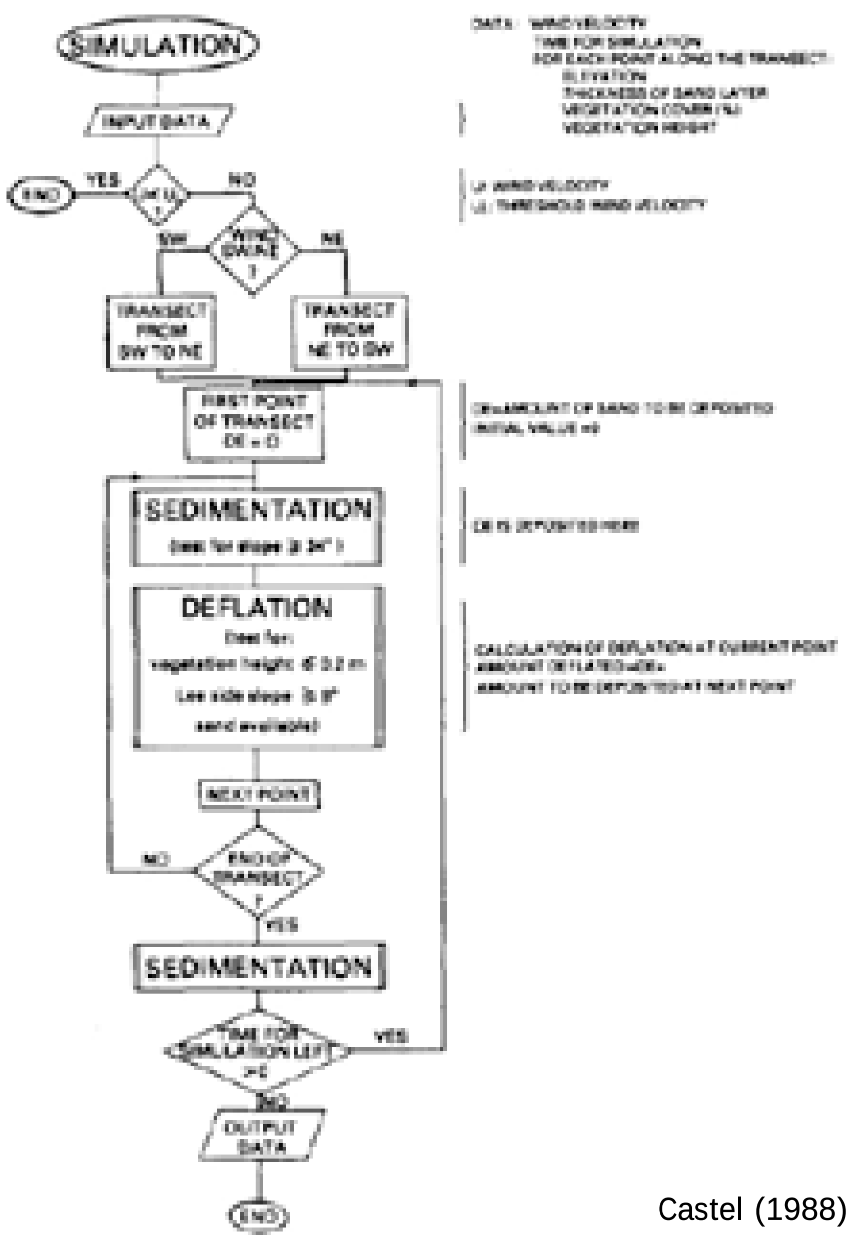
Blow-outs



Jungerius (1984)

Drift sands

Kootwijkerzand

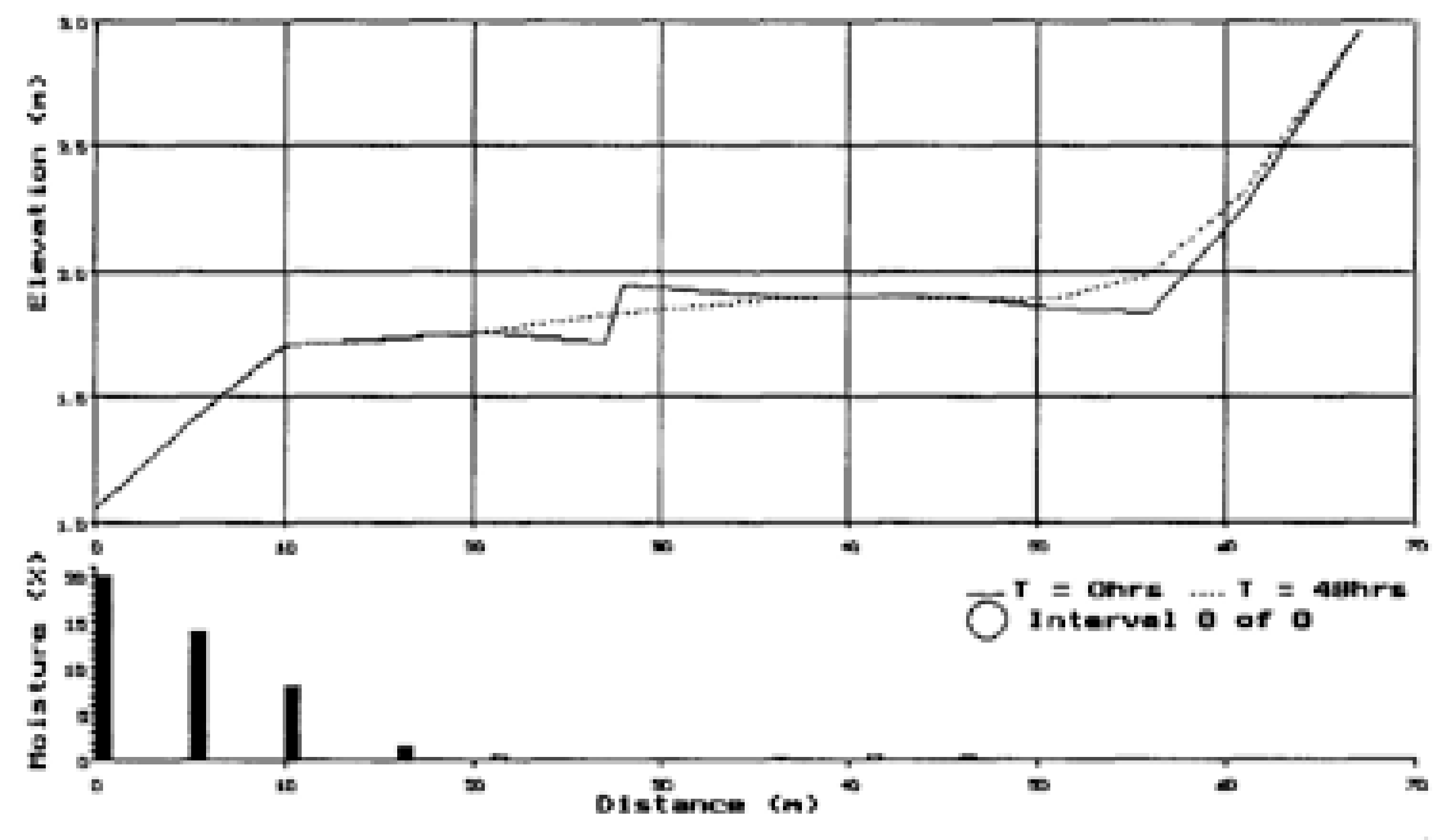


Castel (1988)

Transect Models

Exner (1920), sediment continuity:

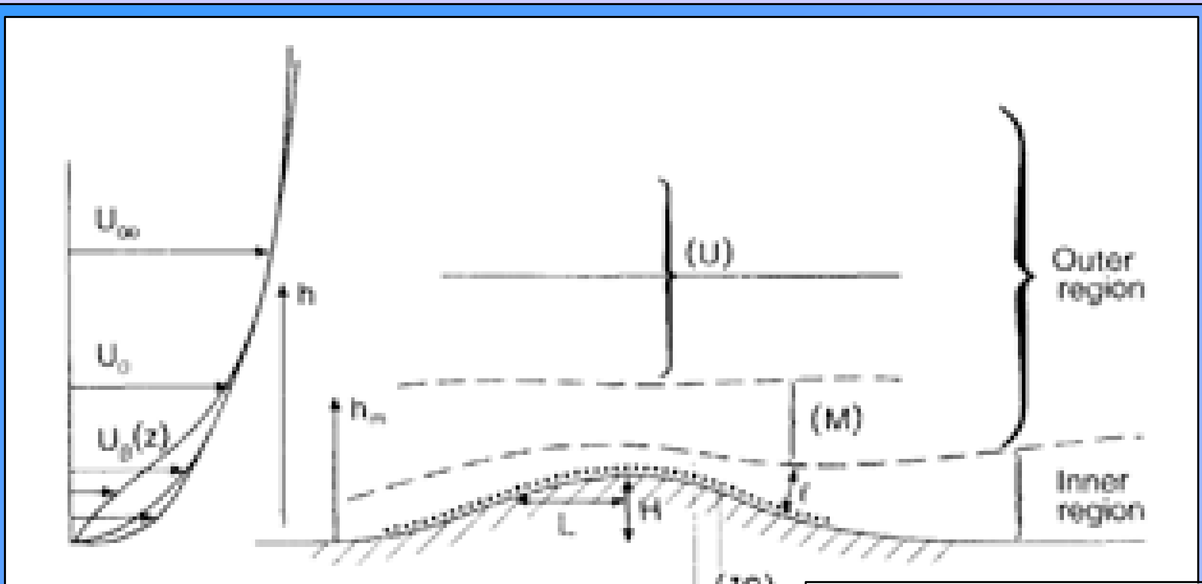
transport gradients à surface evolution



Namikas and Sherman (1998)

Coupled Airflow – Sand Transport Models

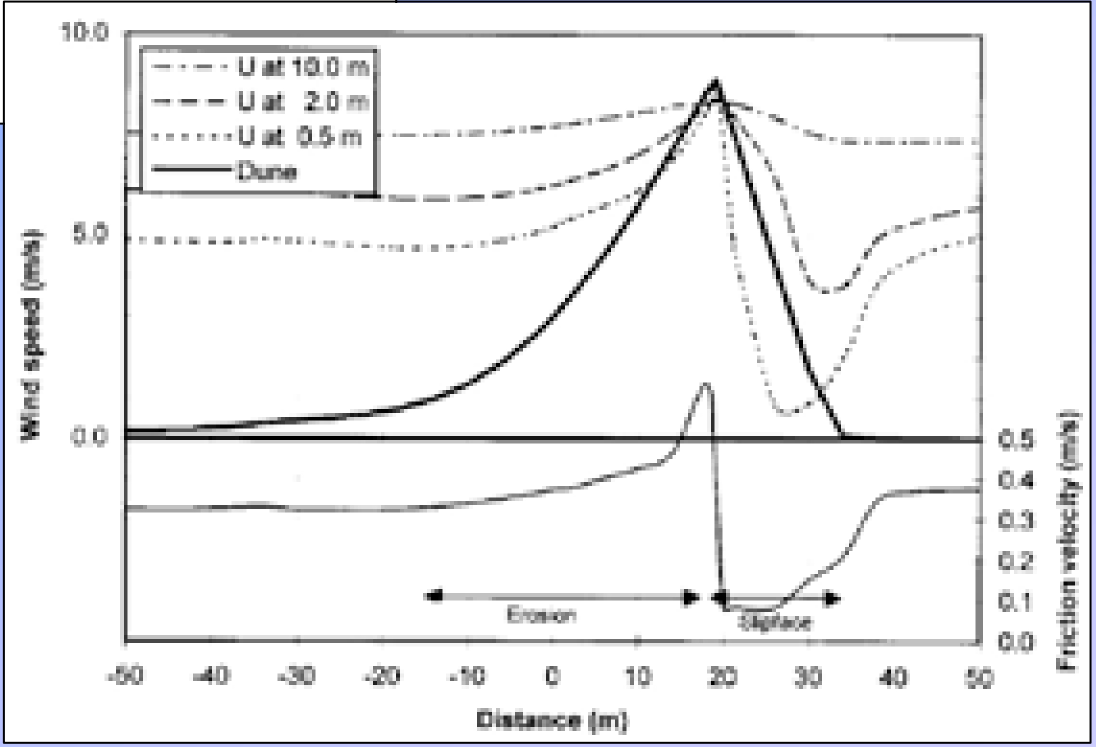
Airflow Modelling



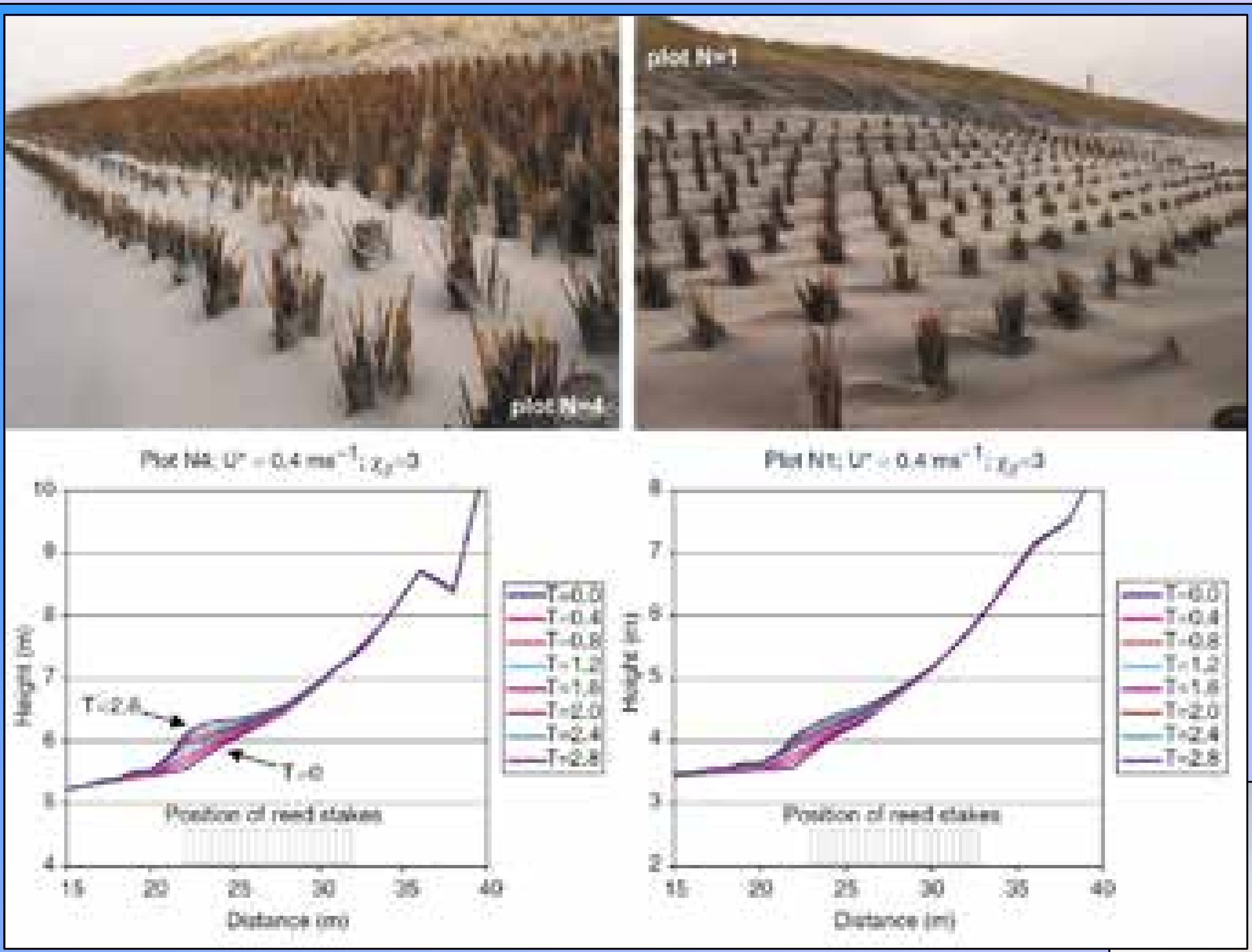
Jackson and Hunt (1975)

HILL/SAFE:

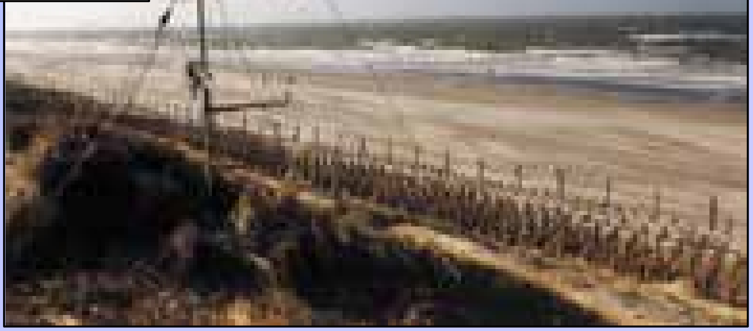
Van Boxel *et al.* (1999)



Simulating Aeolian Foredune Evolution, SAFE



Arens *et al.* (2001)



Three dimensional

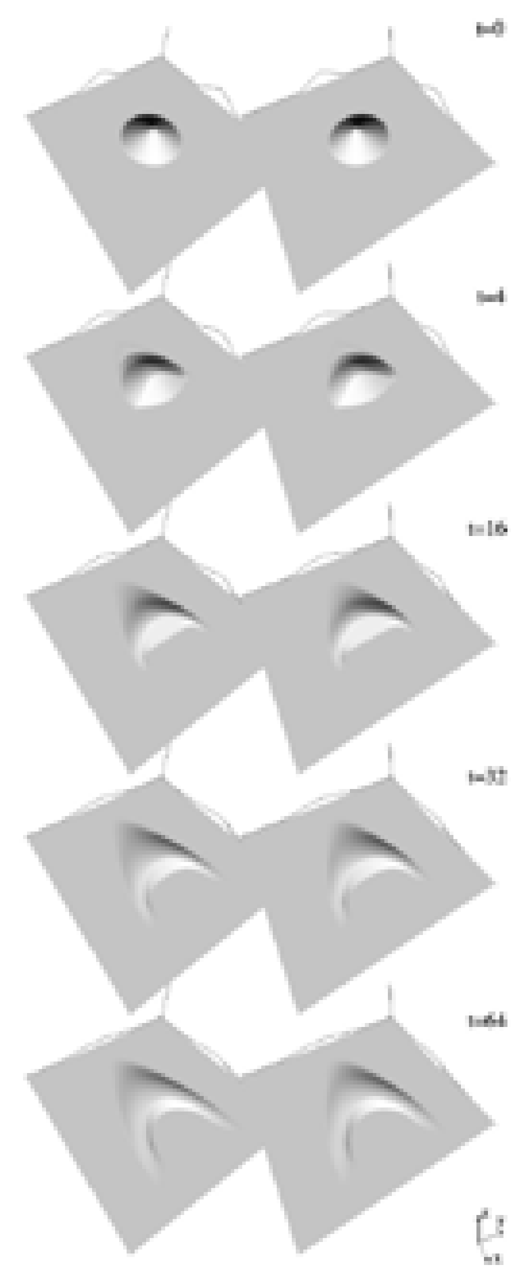
Three dimensional

Two approaches:

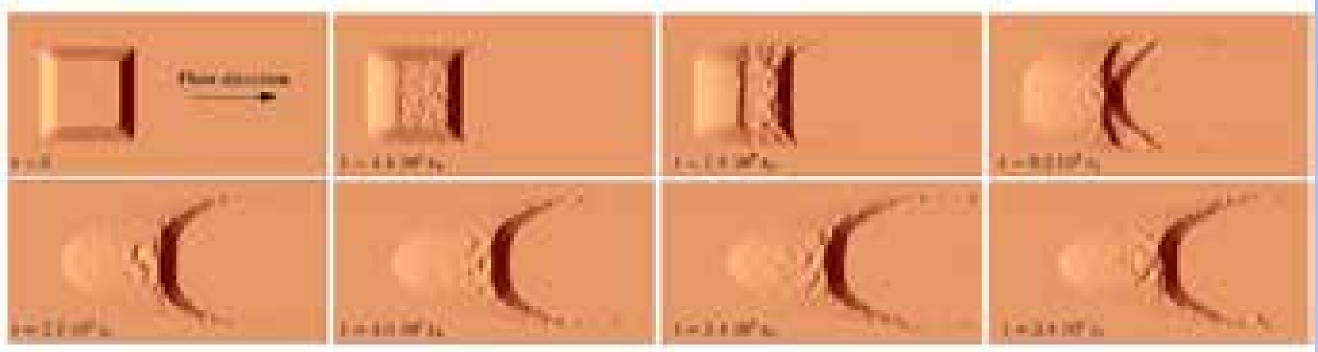
Reductionist physically-based
coupled airflow-sand transport dynamics
and resulting surface evolution

Self-organising systems
Non-linear dynamics, emergent
behaviour, cellular automata (CA)

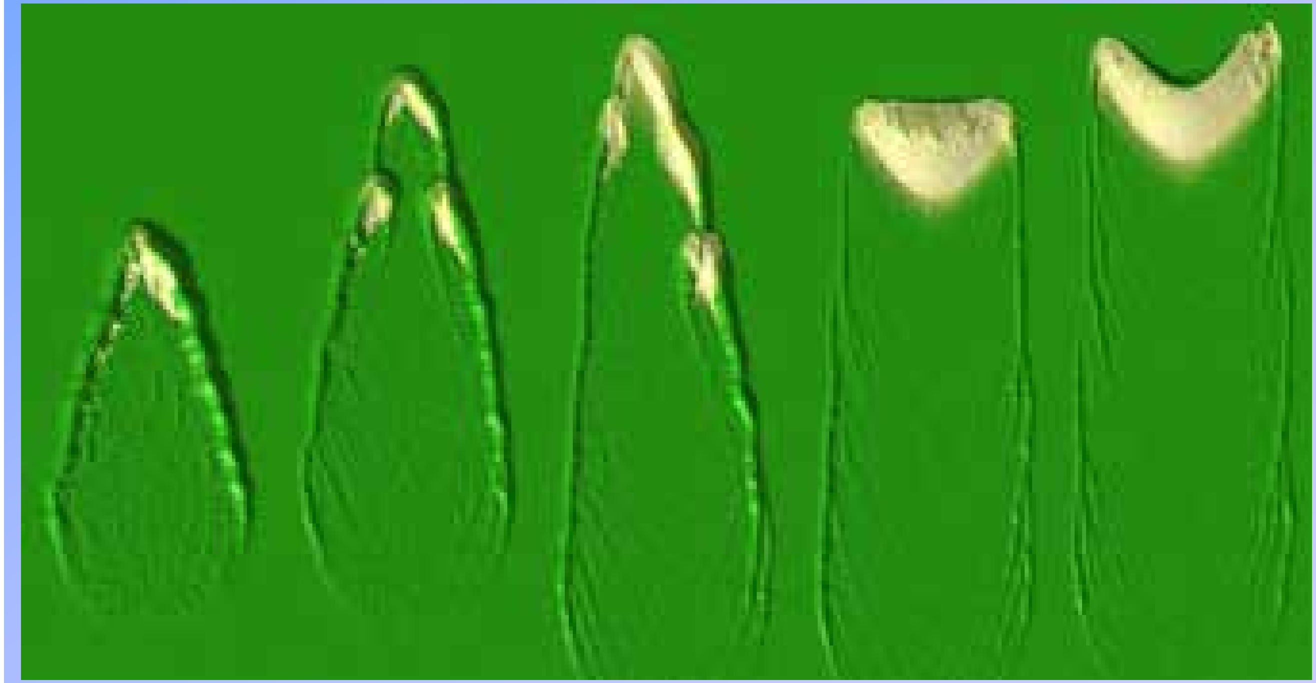
3D-Reductionist



Hersen *et al.* (2004)



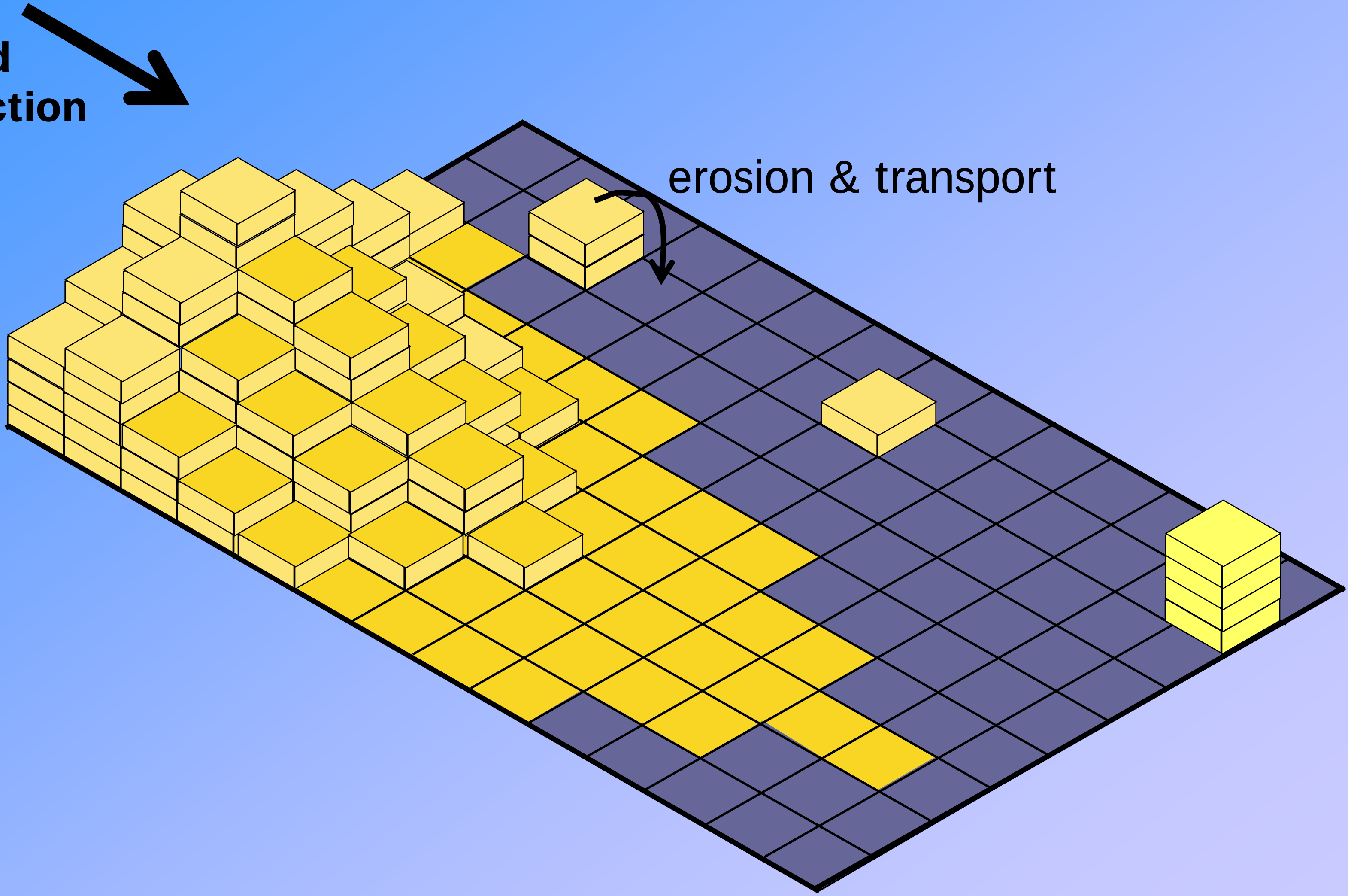
Narteau *et al.* (2009)



Duran and Herrmann (2006)

3D-Self-Organising

Werner (1995) CA algorithm

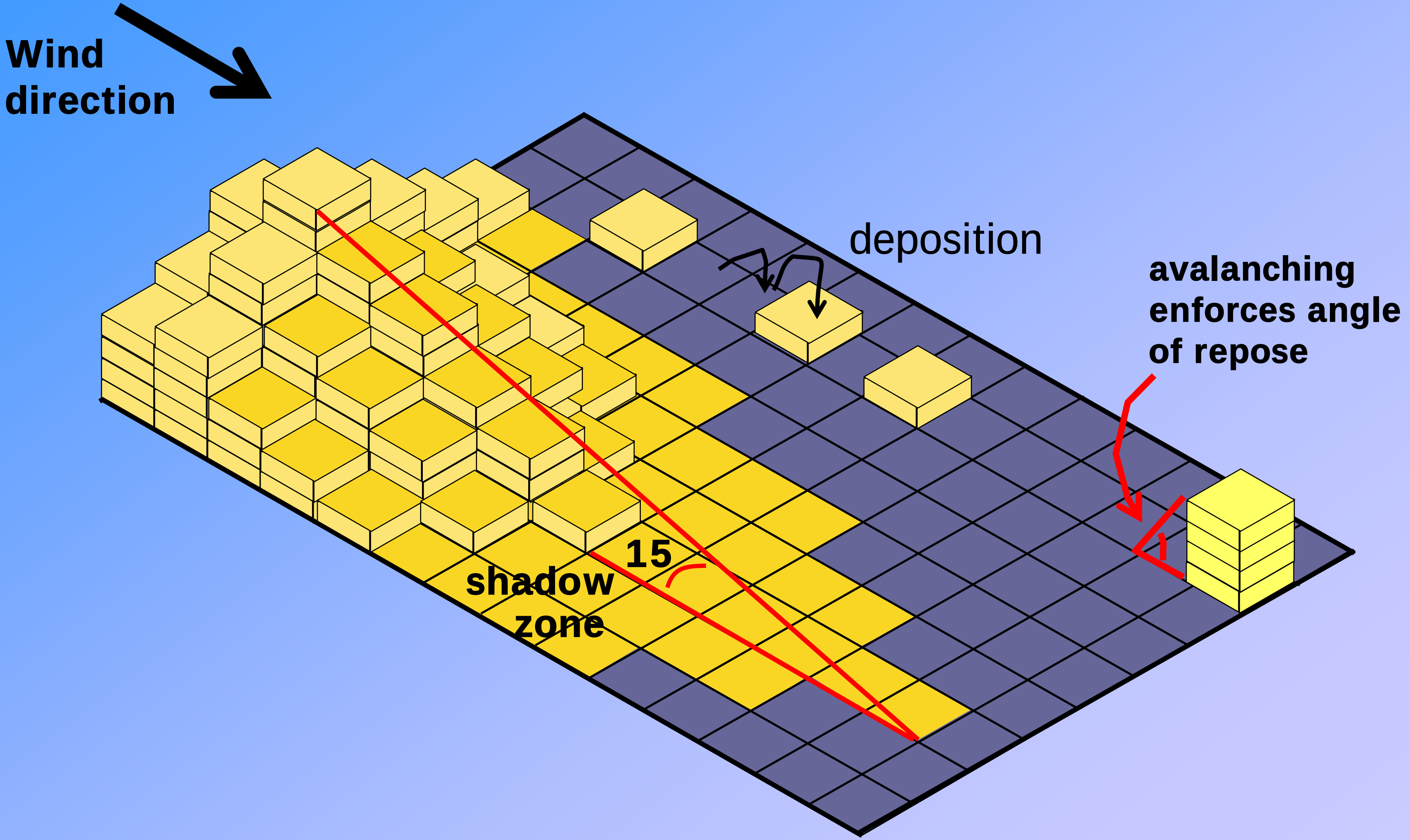


Wind direction

erosion & transport

3D-Self-Organising

Werner (1995) CA algorithm



Werner Dune Model

Bare sand dune landscape simulations

Whole fields instead of single dunes

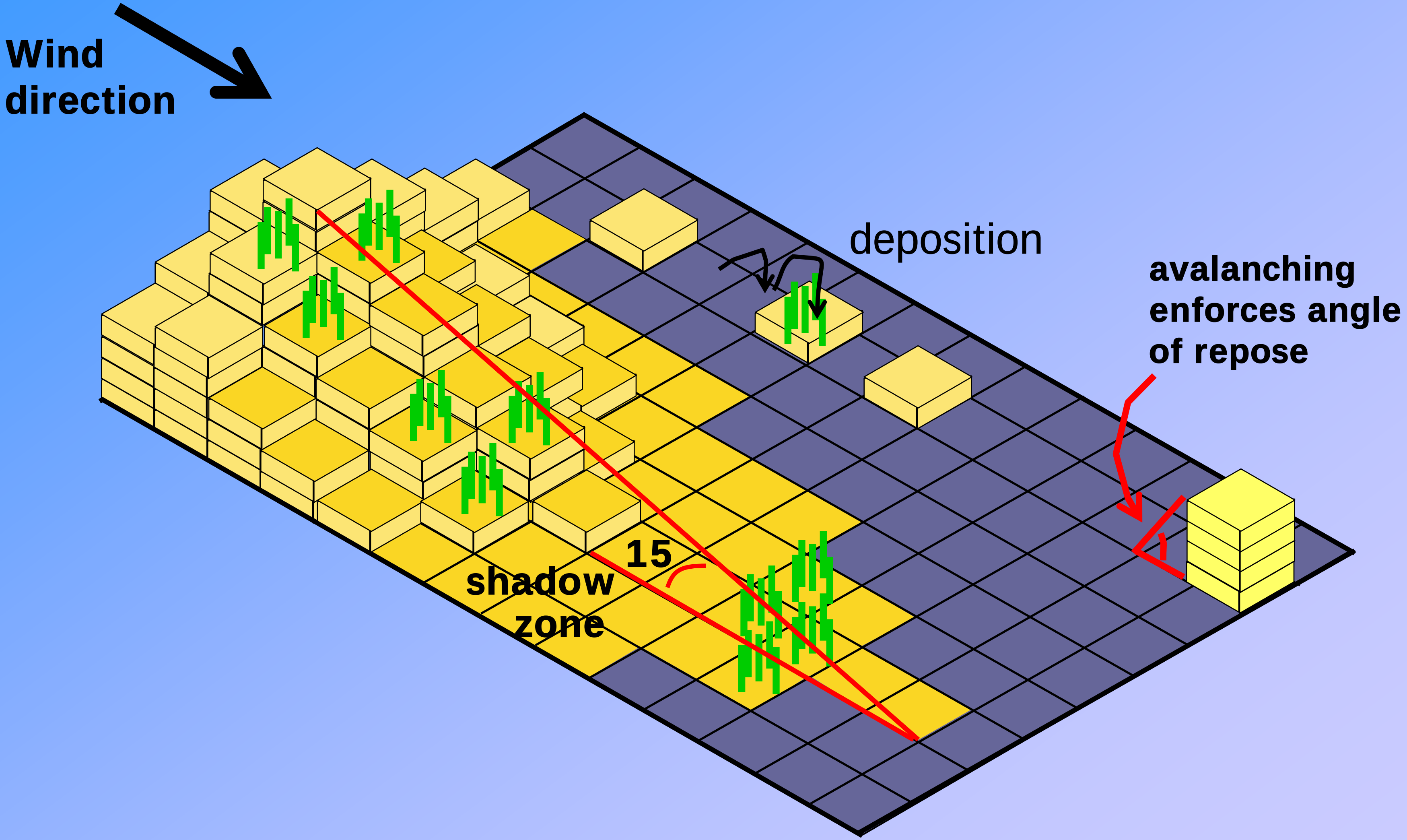
Werner Dune Model

Bare sand simulations: barchan field evolution

Baas and Nield (2005)

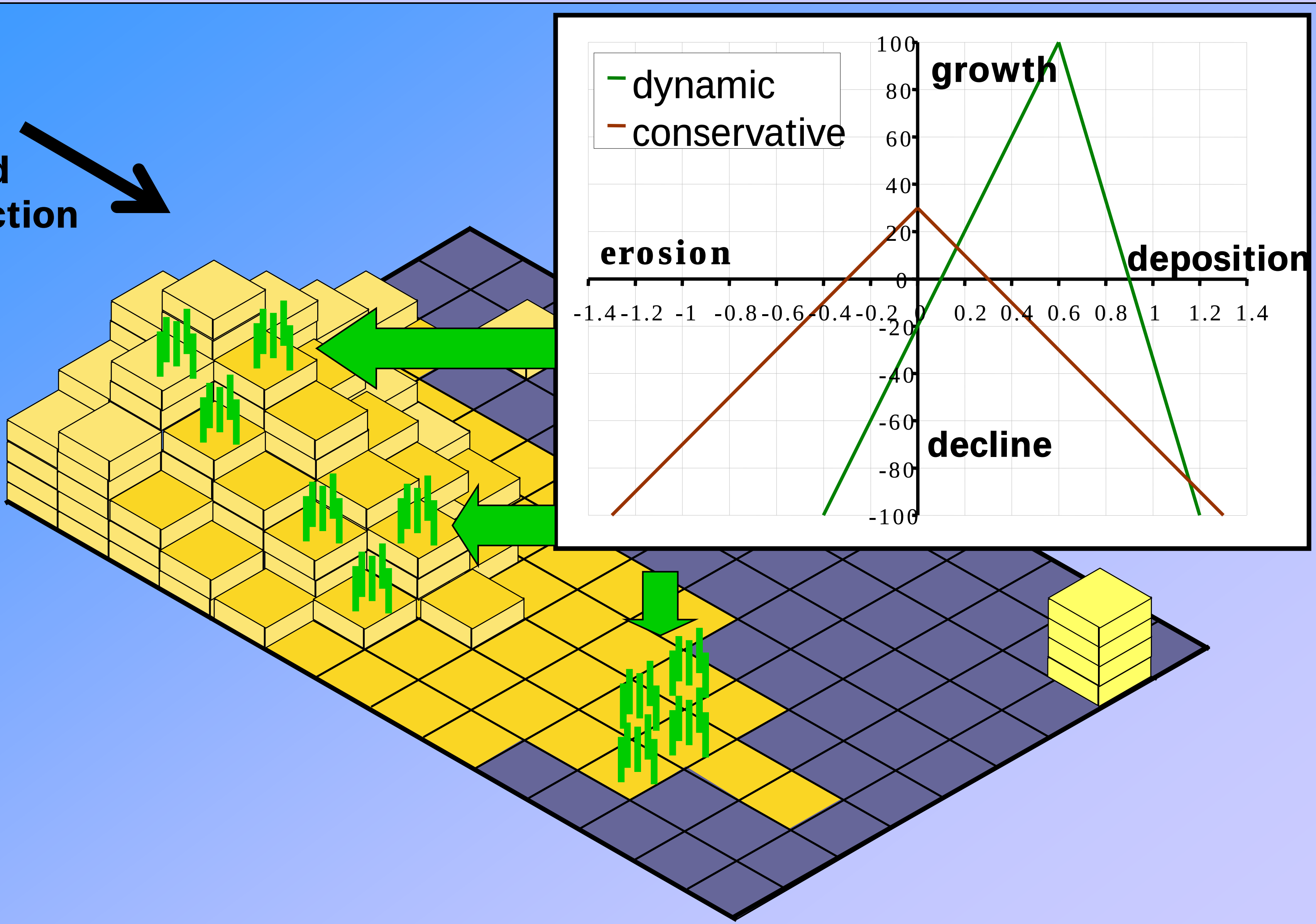
DECAL

(Discrete Ecogeomorphic Aeolian Landscape Model)

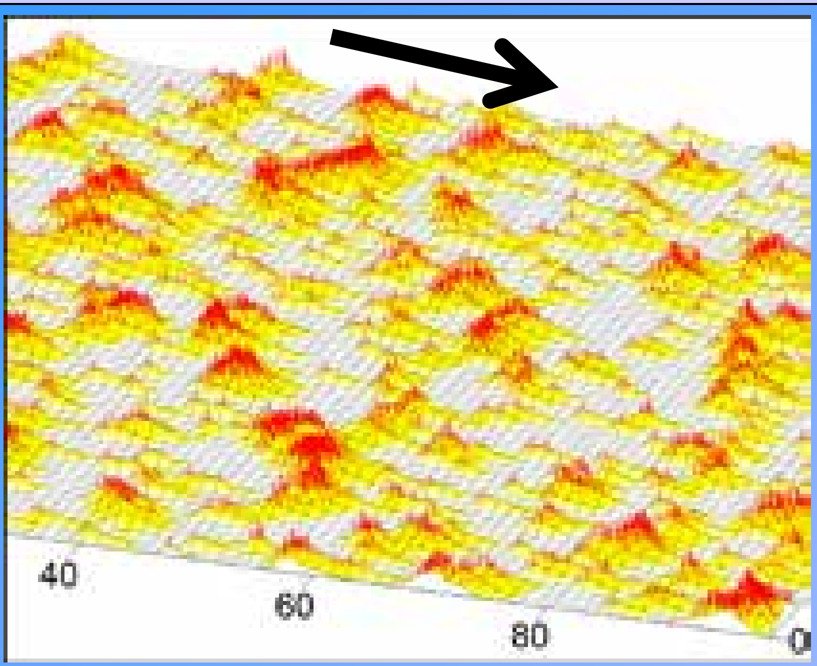


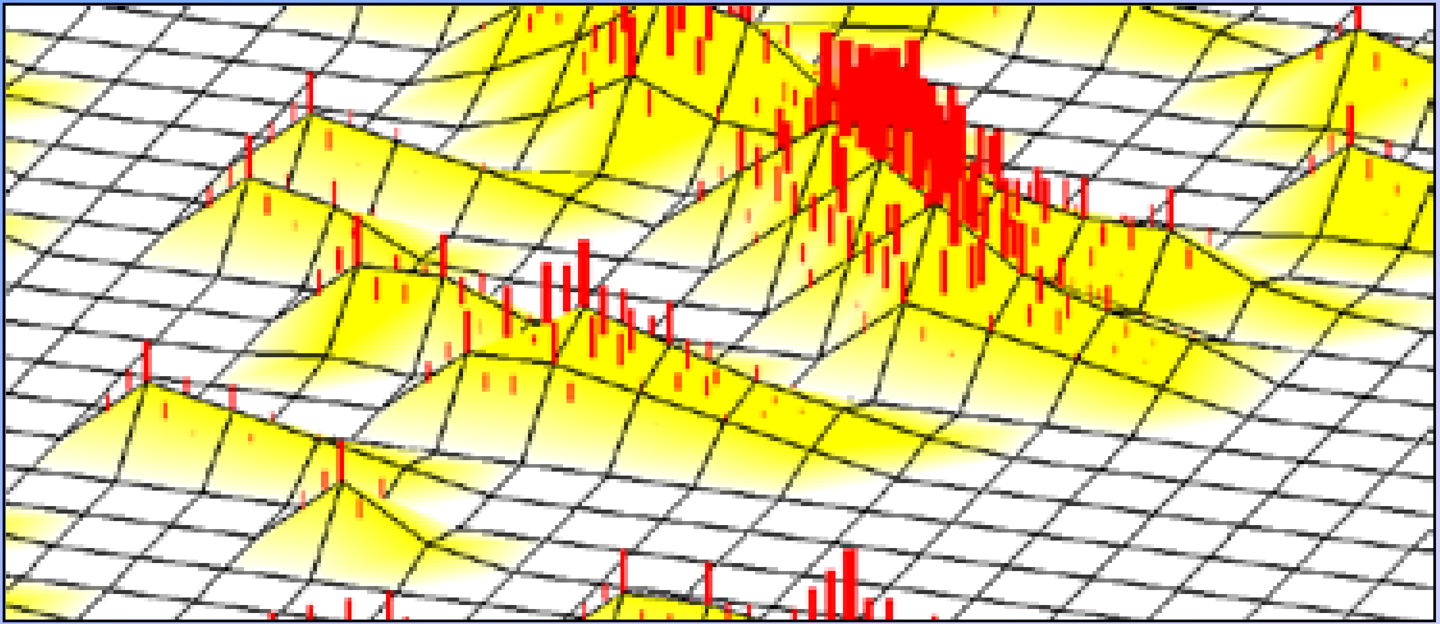
DECAL

Wind direction

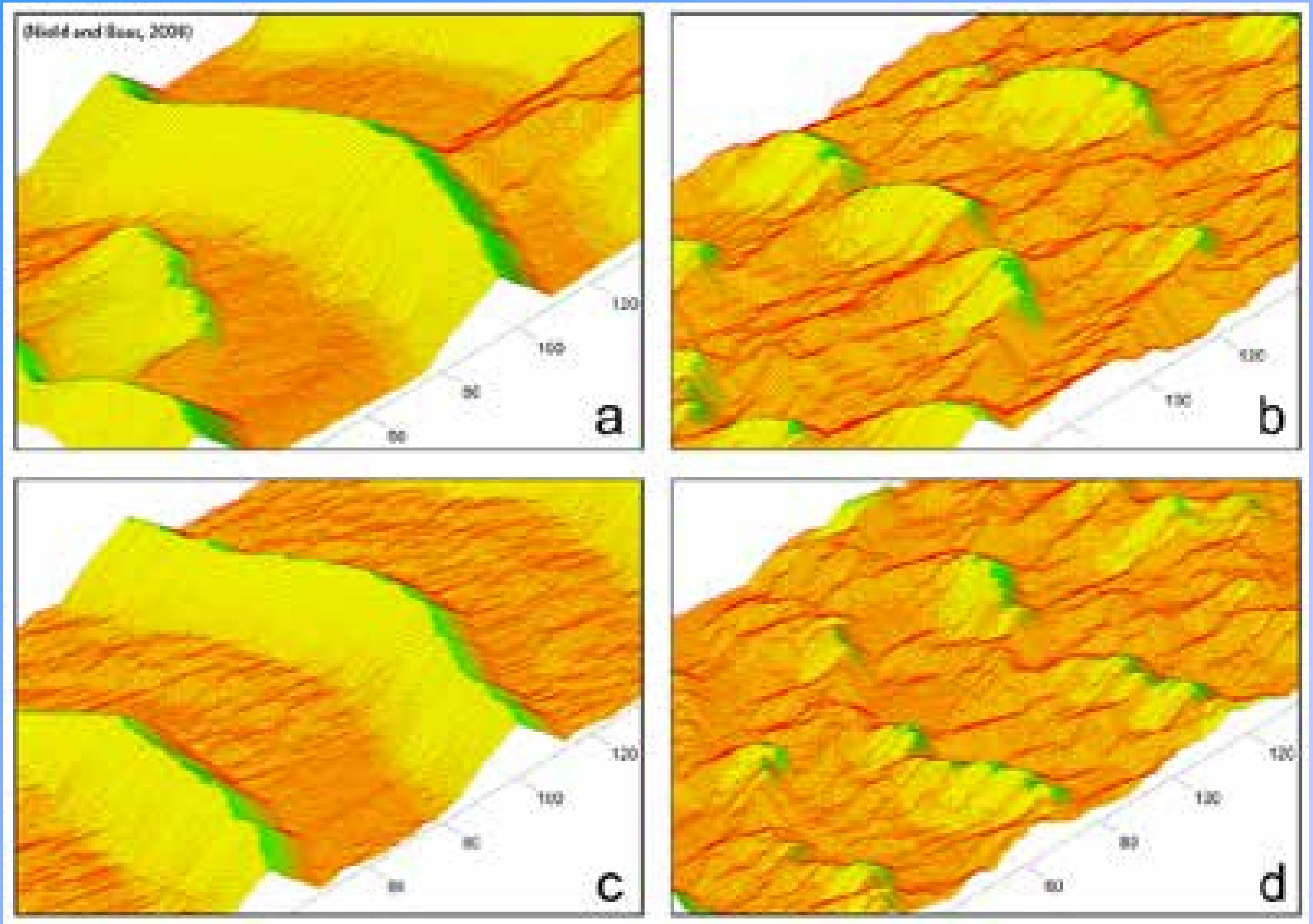


DECAL





DECAL



Nield and Baas (2008)

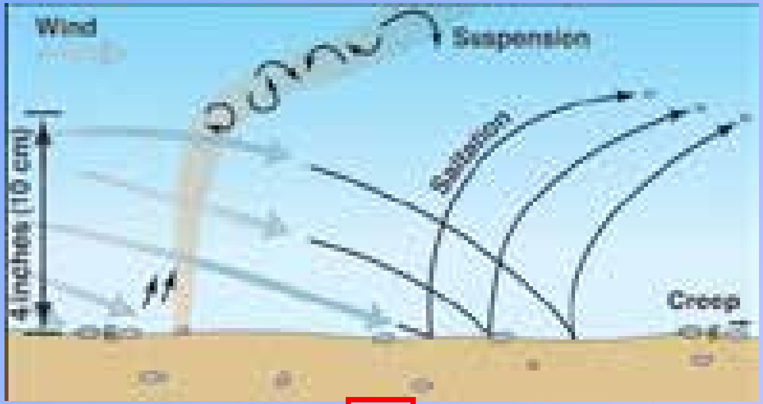
Applications to Agro-Environmental Systems

1D – mobility	regional scale & climate
1D – WEPS	agriculture, field unit soil erosion
2D – SAFE	coastal dunes
3D – reductionist	physical principles (fundamental scales)
3D – CA	organising principles, larger scales

Challenges & Innovations

Challenges & Opportunities

Two challenges:

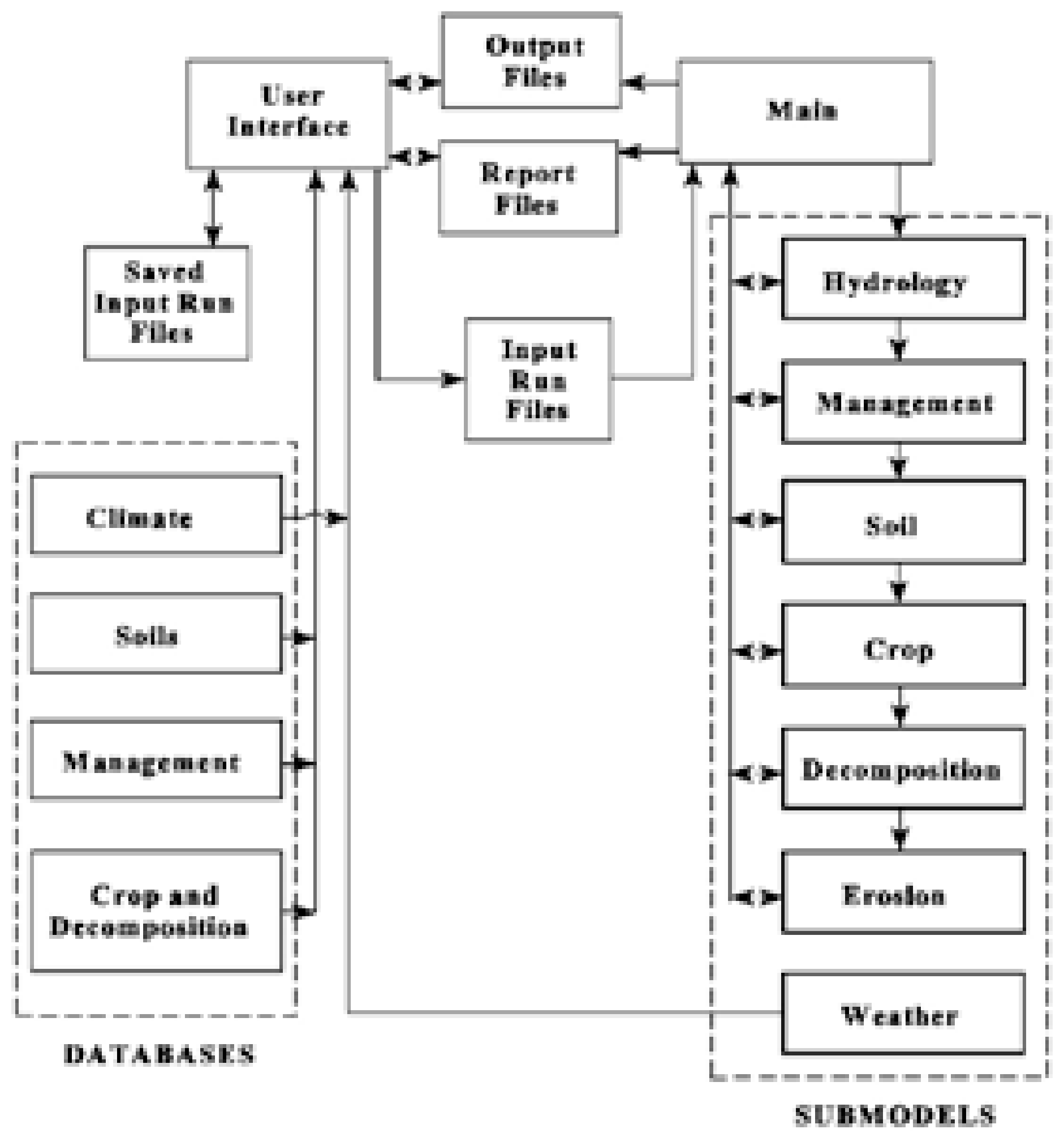


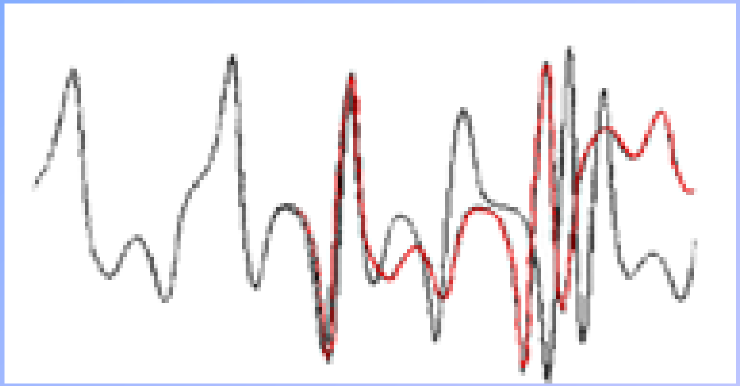
Scaling
Transcending and integrating across spatio-temporal scales

Biological systems
Incorporating and balancing flora and fauna (and humans)

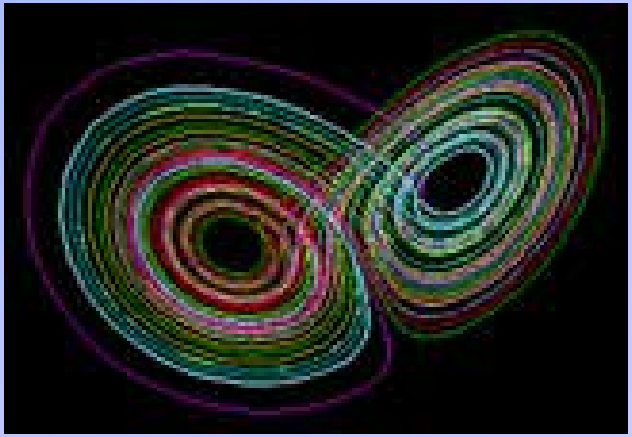
Challenges & Opportunities

Detail reductionist physically-based?





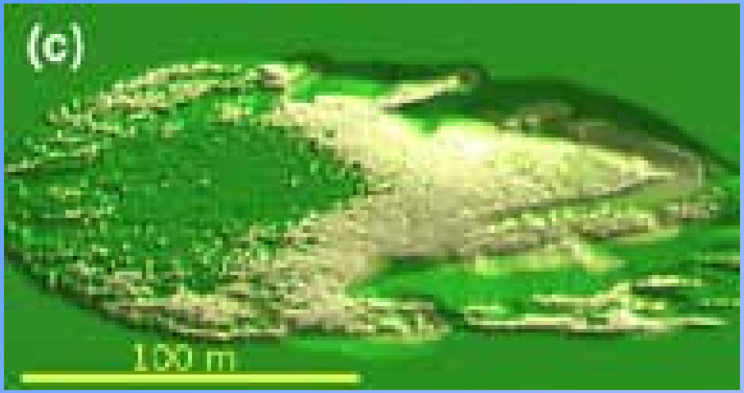
Chaos...



Challenges & Opportunities

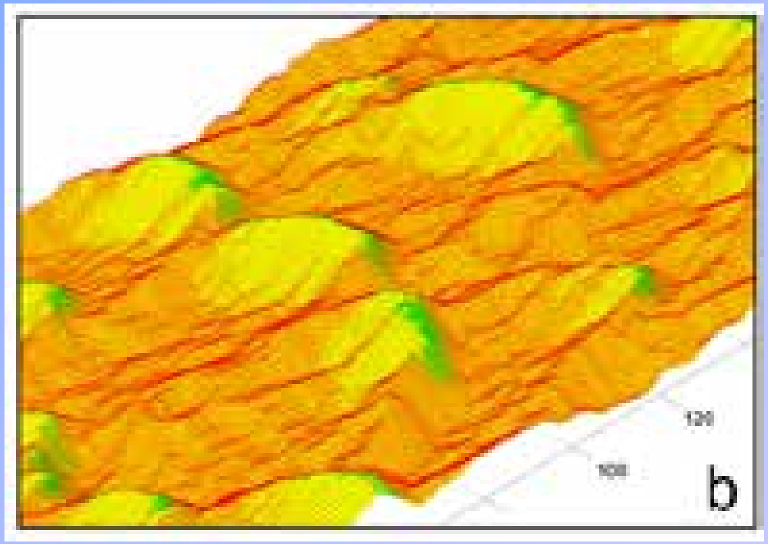
Detail reductionist physically-based?

Single dune



Duran *et al.* (2008)

Dune field



Nield and Baas (2008)

Computation ‘cost’ ↔ resolution & size

Challenges & Opportunities

Flora and fauna?

© M Salmon

- What to measure?
- How to quantify?
- Feedback?

Challenges & Opportunities

Measurement & calibration problems

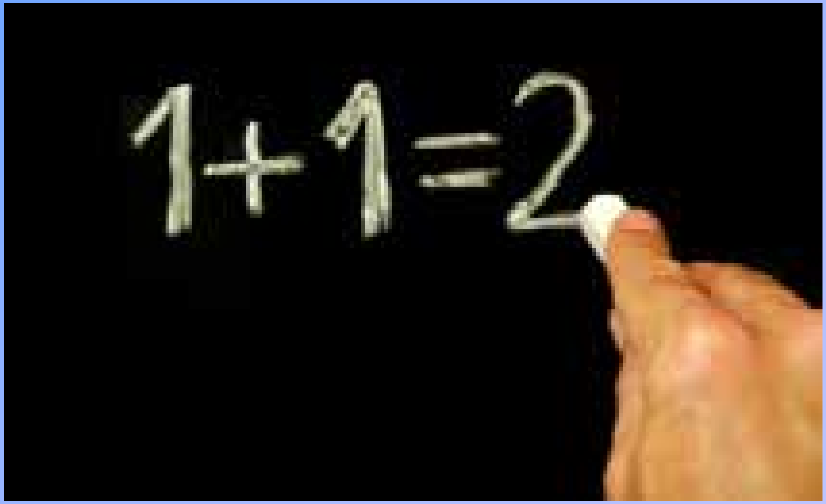
Prof. dr ir. Leo Stroosnijder

“Feeding **more detailed** process knowledge into models with **limited measuring** opportunities will not help to mitigate land degradation.”

Challenges & Opportunities

Answer?

Keep It Simple

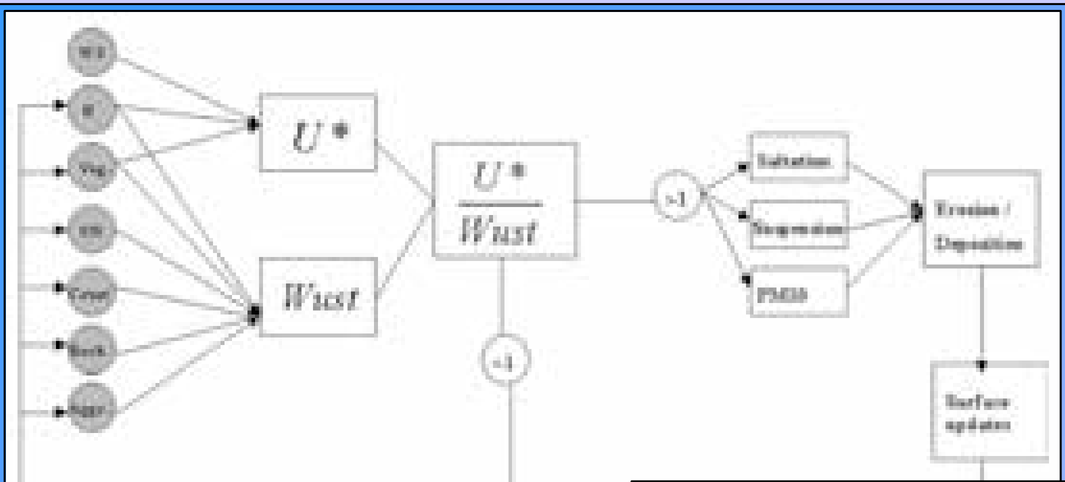


Innovations

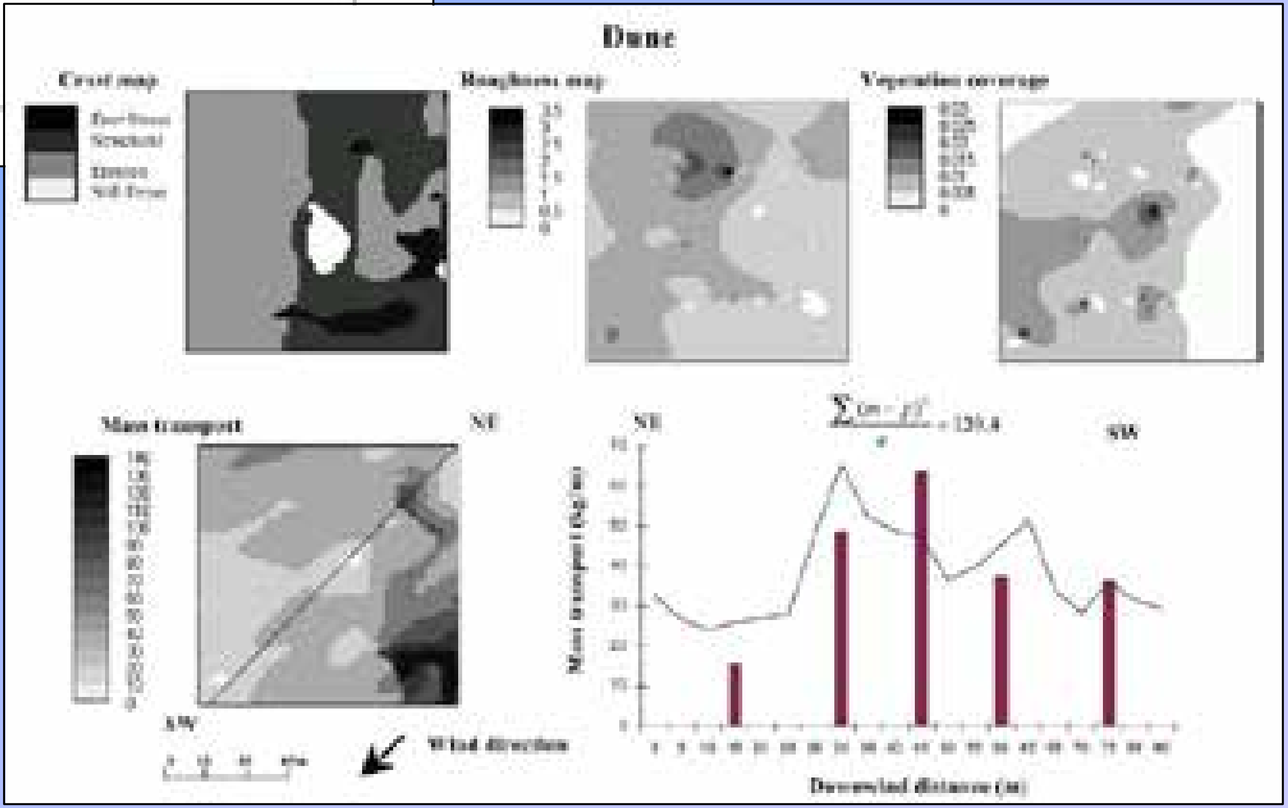
à Gradient of model types
- 1D ↔ 2D ↔ 3D
- reductionist ↔ CA
- discrete ↔ continuous
- local ↔ global

à Innovations by moving along gradient or combining models

Map-Based WEPS



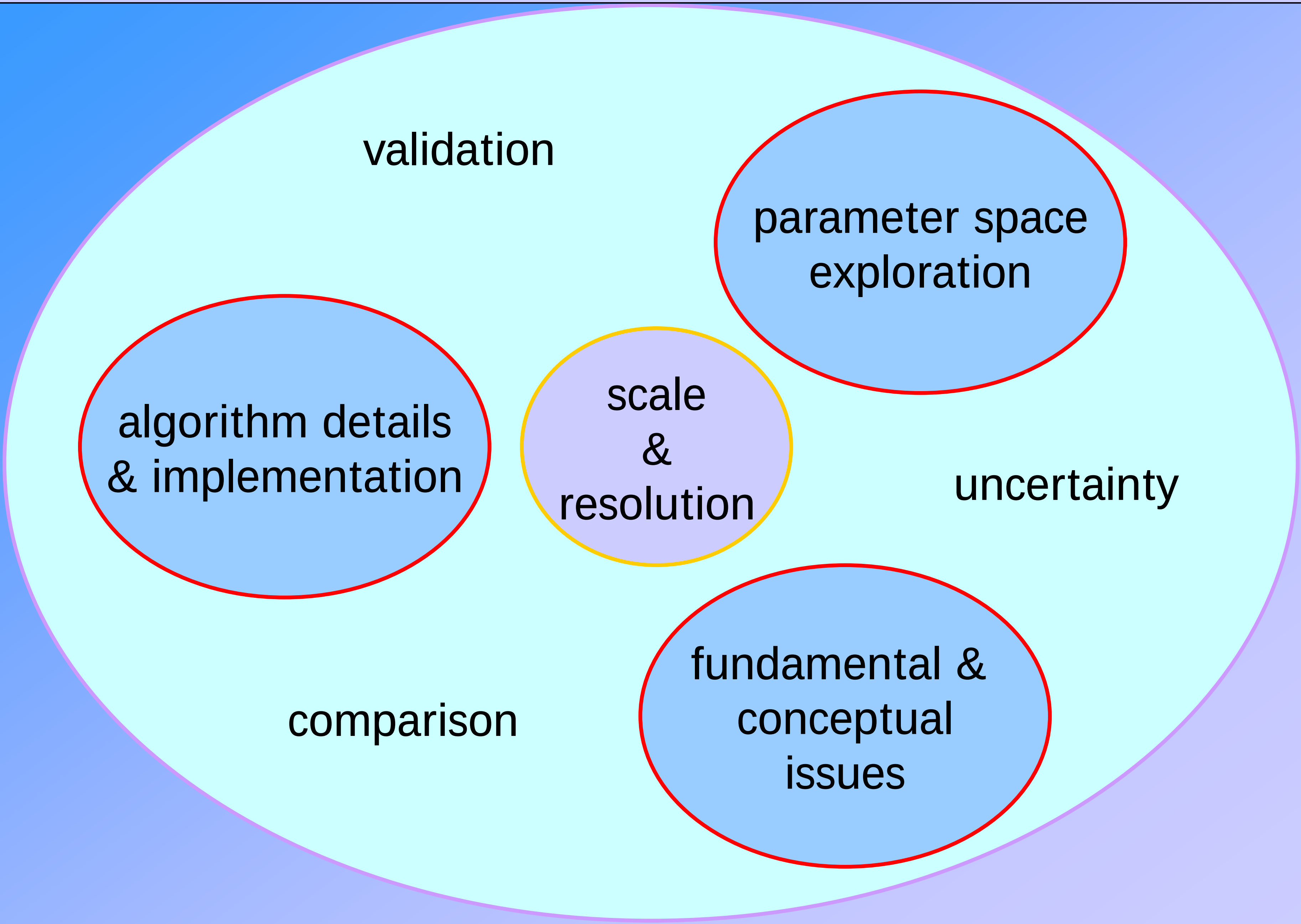
Visser *et al.* (2005)



Visser *et al.* (2005)

Good Modelling Practices

Good Modelling Practices



validation

parameter space exploration

algorithm details & implementation

scale & resolution

uncertainty

comparison

fundamental & conceptual issues

Good Modelling Practices

Nine Good Practices (Malamud and Baas, 2012):

Model construction:
1) select appropriate model type/strategy
2) parsimony (‘Occam’s Razor’)
3) dimensional analysis
4) benchmark testing*

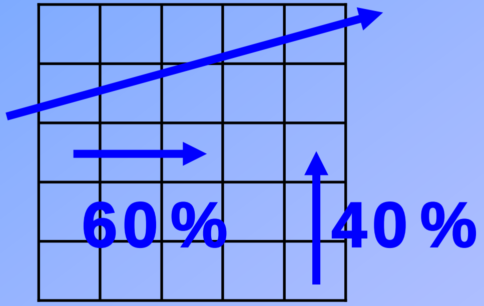
Model running:
5) sensitivity analysis*
6) calibration
7) data exploration
8) uncertainty assessment
9) consider alternatives

Each of these steps can lead to new insights!

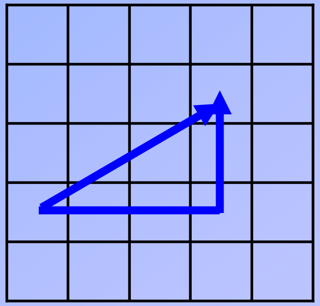
Testing Algorithm: Directional Variability

Testing Algorithm: Directional Variability

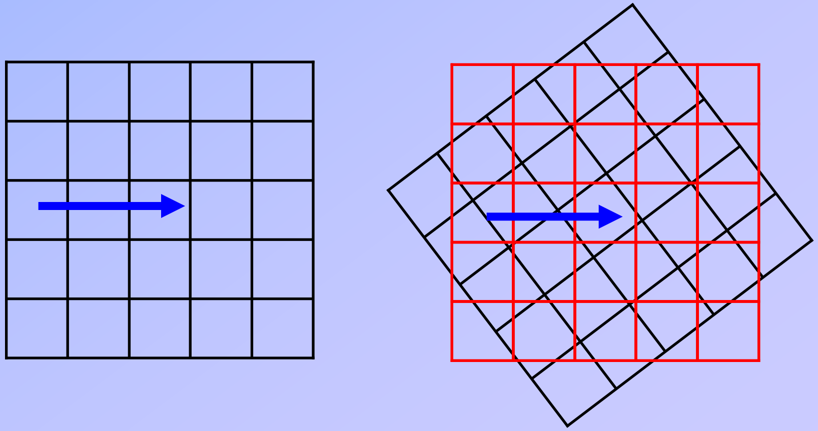
Probabilistic:
horizontal/vertical as % of ‘time’
to achieve an oblique x,y direction



2D transport paths:
Displacement vectors with
x and y components

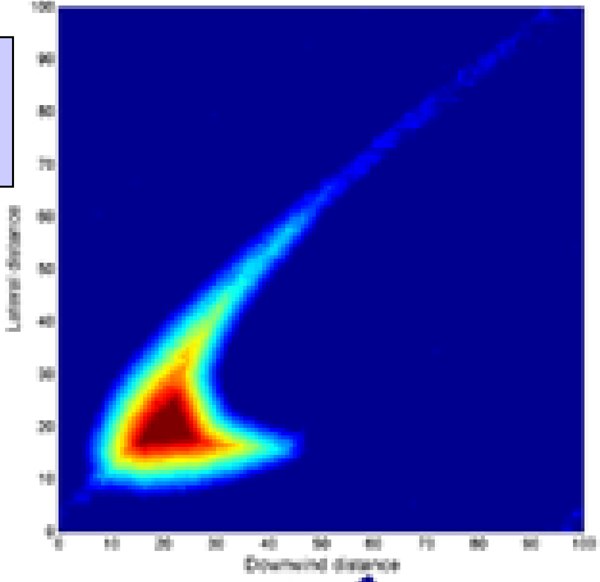


Rotation:
Rotate domain and resample

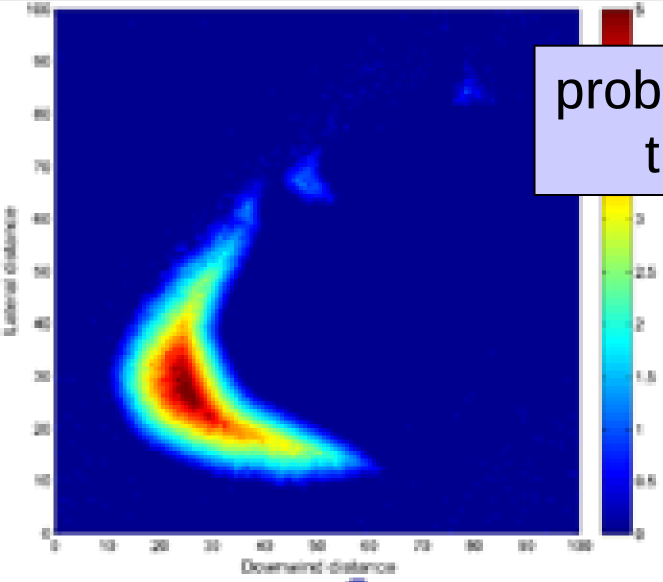


Testing Algorithm: Directional Variability

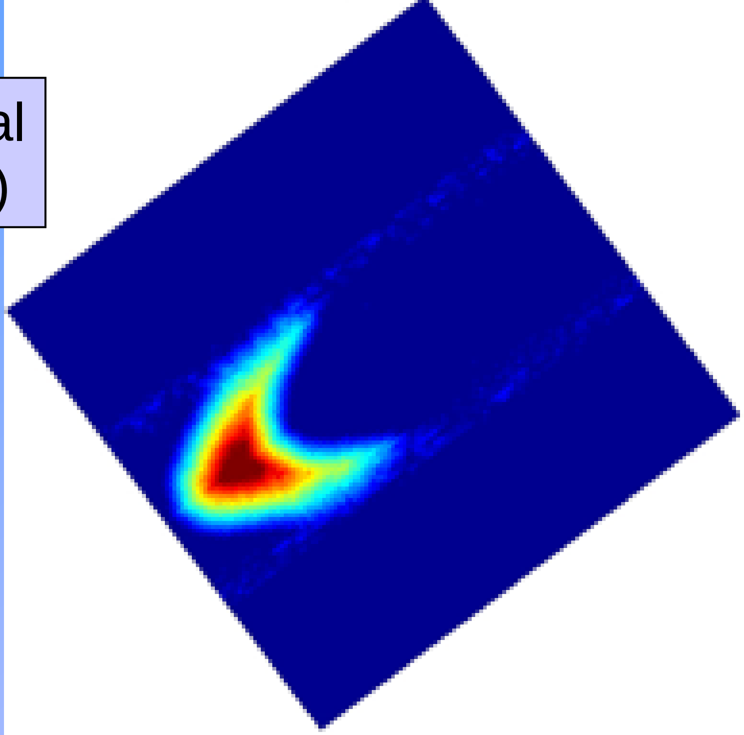
2D path
(chess)



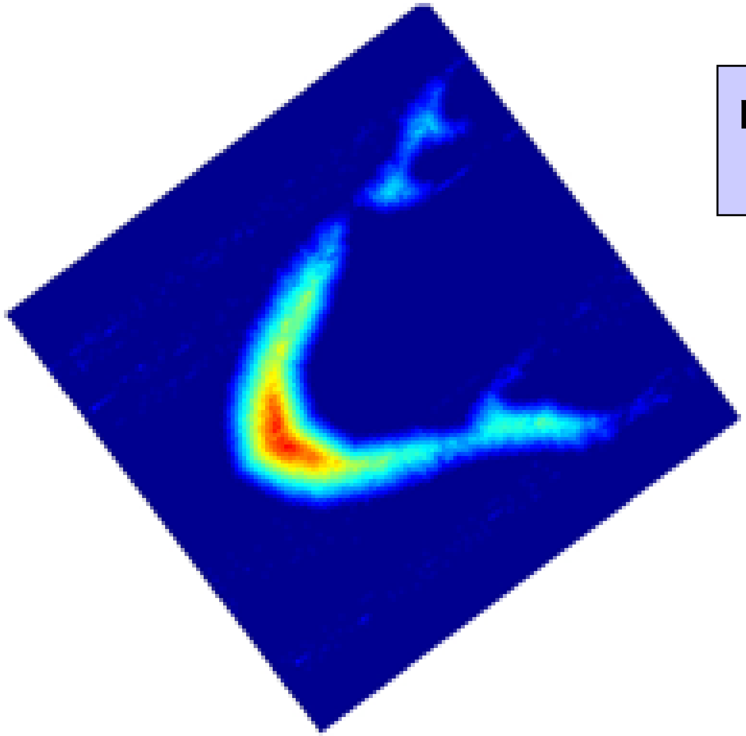
probabilistic
time



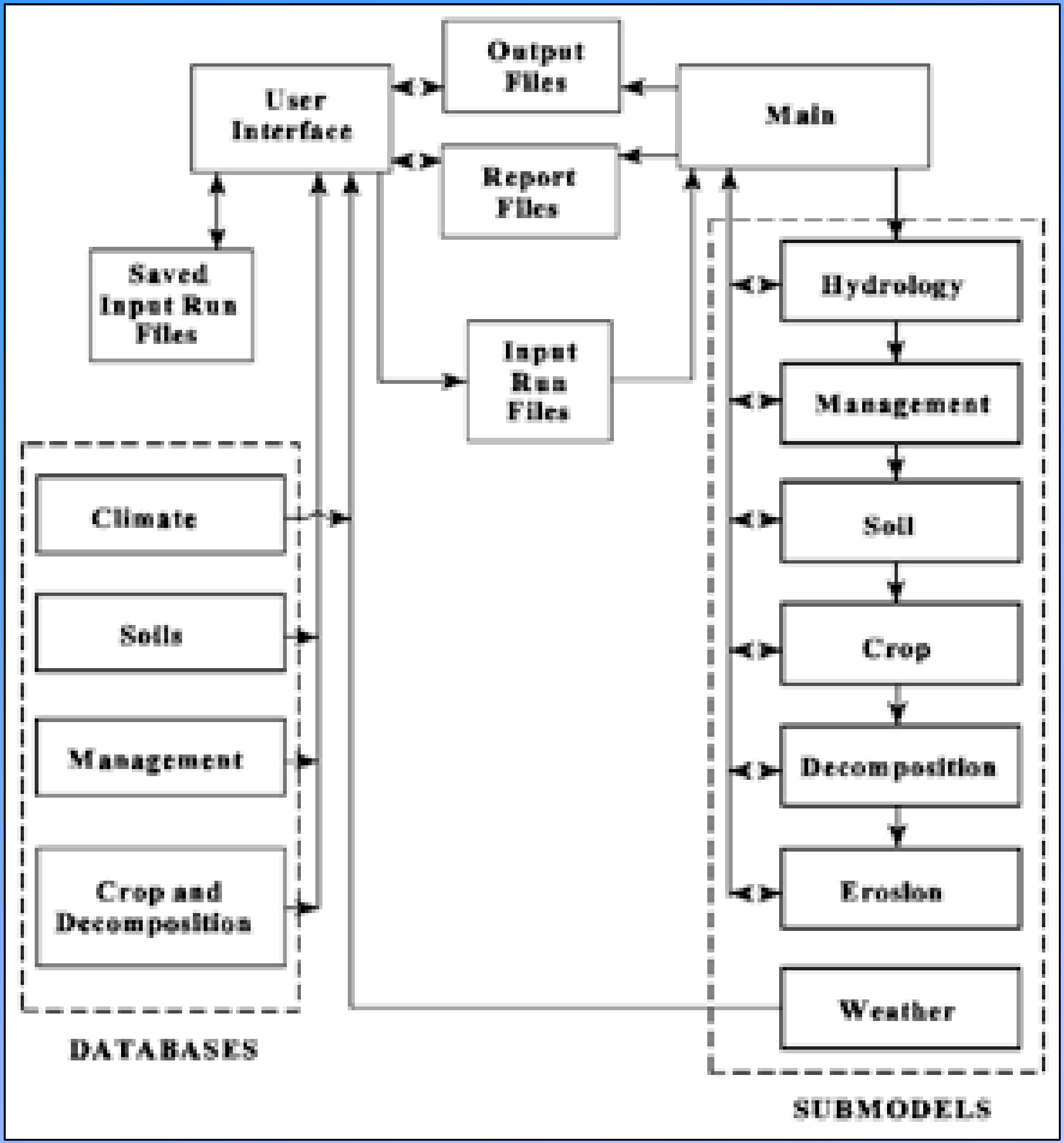
normal
(L=5)

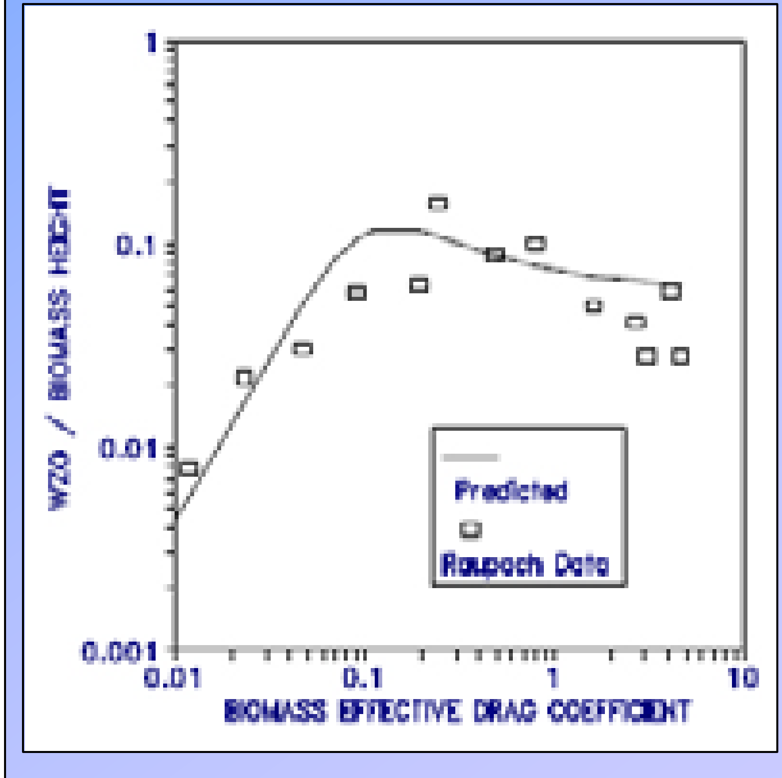


normal
(L=1)



Sensitivity Analysis / Calibration





Biggest Challenge

Final Thoughts

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à Parameters and algorithm details
need to be investigated thoroughly,

à These inquiries can lead to fundamental questions
and insights,

à Many interesting science and application questions
arise during model development,

à The journey is often more fruitful than the destination!

Final Thoughts