THEORY STRIKES BACK

A modelling and simulation theory building approach on the origin of agriculture

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Session 6: Subsistence

available at https://andros-spica.github.io/ENE-Angourakis-et-al-2019/
https://andros-spica.github.io/ENE-Angourakis-et-al-2019/index.html?print-pdf (printable version)

PLANT DOMESTICATION AND ORIGIN OF AGRICULTURE

***Origins of agriculture**: transitions from foraging to any modality of agriculture.*

***Agriculture**: a subsistence system in which humans rely on extracting foodstuff from domesticated species.*

***Domestication**: process in which certain human behaviours condition the differential reproduction of phenotypes of another species, eventually modifying its genetic composition (domestication syndrome).*

MODELLING AND THEORY BUILDING

- *Advances in **where/when**, but **how/why** still lacking*
- *Common topics, but still **conflicting** models:*
  push vs pull,
  internal vs external causation,
  communalities vs particularities
- *Converging framework:*
  ***Coevolution** between humans and another species*
  *as **mutualistic** partners*

THE HUMAN-PLANT COEVOLUTION MODEL

THE IDEA

- *Inspiration from*
  D. Rindos (1984) The Origins of Agriculture: An evolutionary Perspective

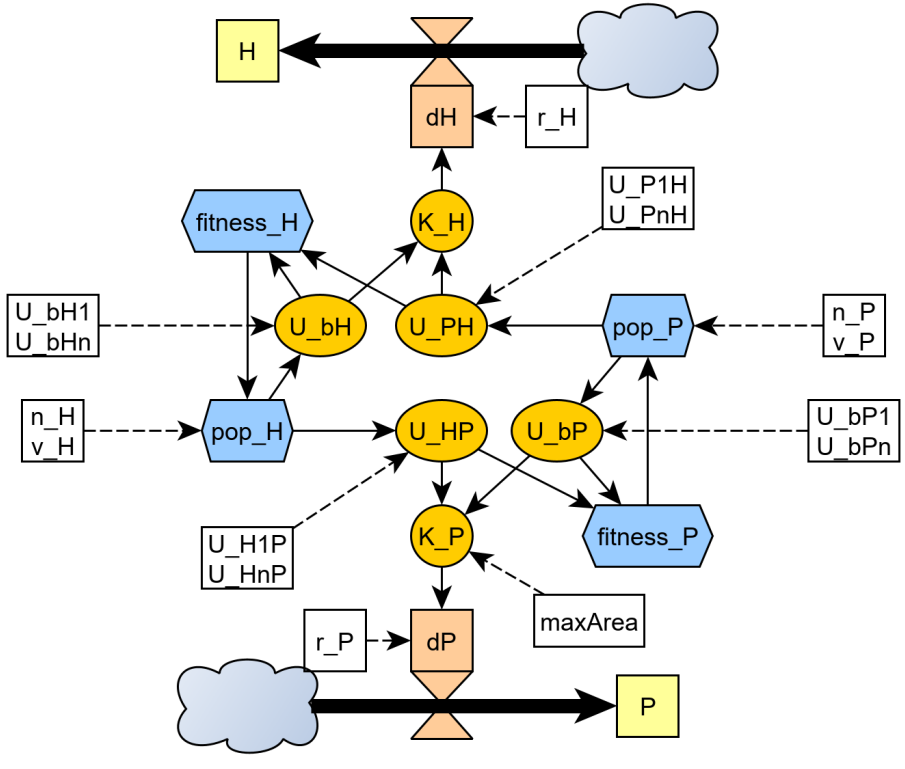
- *Combining models:*
  ***Population ecology** (similar to predator-prey models)*

dynamically reinforced (coevolution), positive feedback loop (mutualism)

- *Humans become more dependent on a plant population as a food source, and invest more time and energy in maintaining the conditions favouring it.*

- *The plant population rely more on a human-modified environment, and some phenotypes thrive the more intense is human action.*

DESIGN



Coevolution coefficient

$$coevo_A[t] = \frac{\sum_{i=1}^{n_A} pop_{A_i}[t] * (types_{A_i} - 1))}{n_A - 1} * 2 - 1$$

Populations

$$H[t+1] = H[t] + r_H H[t] - r_H \frac{H[t]^2}{K_H[t]}$$

$$P[t+1] = P[t] + r_P P[t] - r_P \frac{P[t]^2}{K_P[t]}$$

Carrying capacities

$$K_H[t] = U_{PH}[t] + U_{bH}[t]$$

$$K_P[t] = \min(U_{HP}[t] + U_{bP}[t],\ MaxArea)$$

Utilities

$$U_{AB}[t] = A[t] \sum_{i=1}^{n_A} pop_{A_i}[t] \cdot \bar{U}_{A_i B}$$

$$U_{bA}[t] = \sum_{i=1}^{n_A} pop_{A_i}[t] \cdot U_{bA_i}$$

Proportion of types

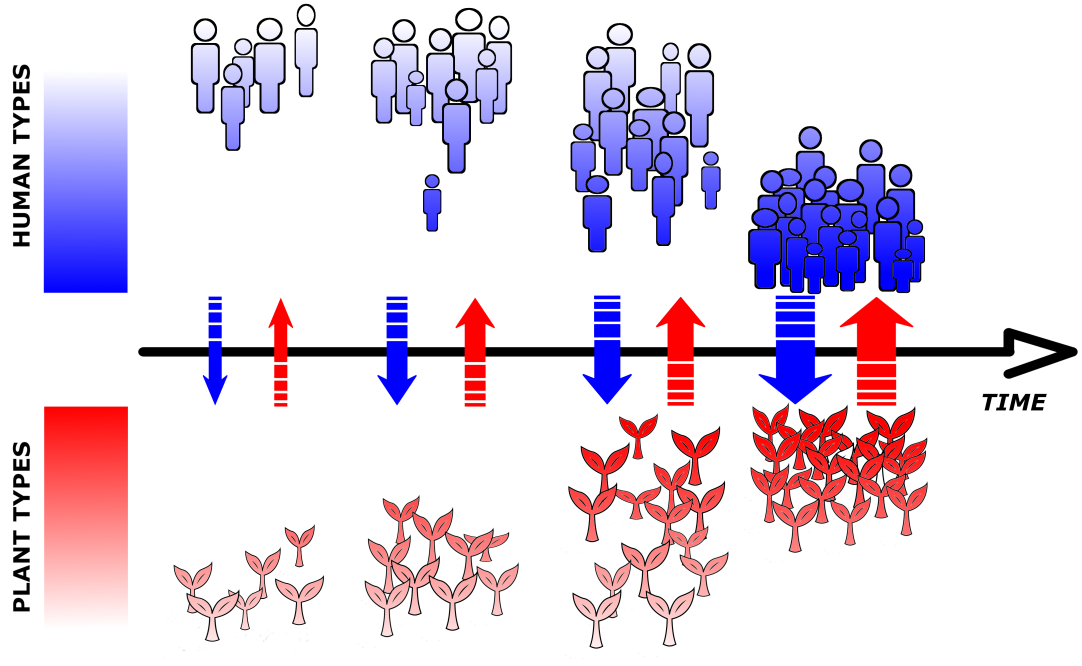
$$pop_A[t]' = pop_A[t] + v_A \left(\frac{1}{n_A} - pop_A[t] \right)$$

$$pop_{A_i}[t+1] = \frac{fitness_{A_i}[t] \cdot pop_{A_i}[t]}{\sum_{j=1}^{n_A} fitness_{A_j}[t] \cdot pop_{A_j}[t]}$$

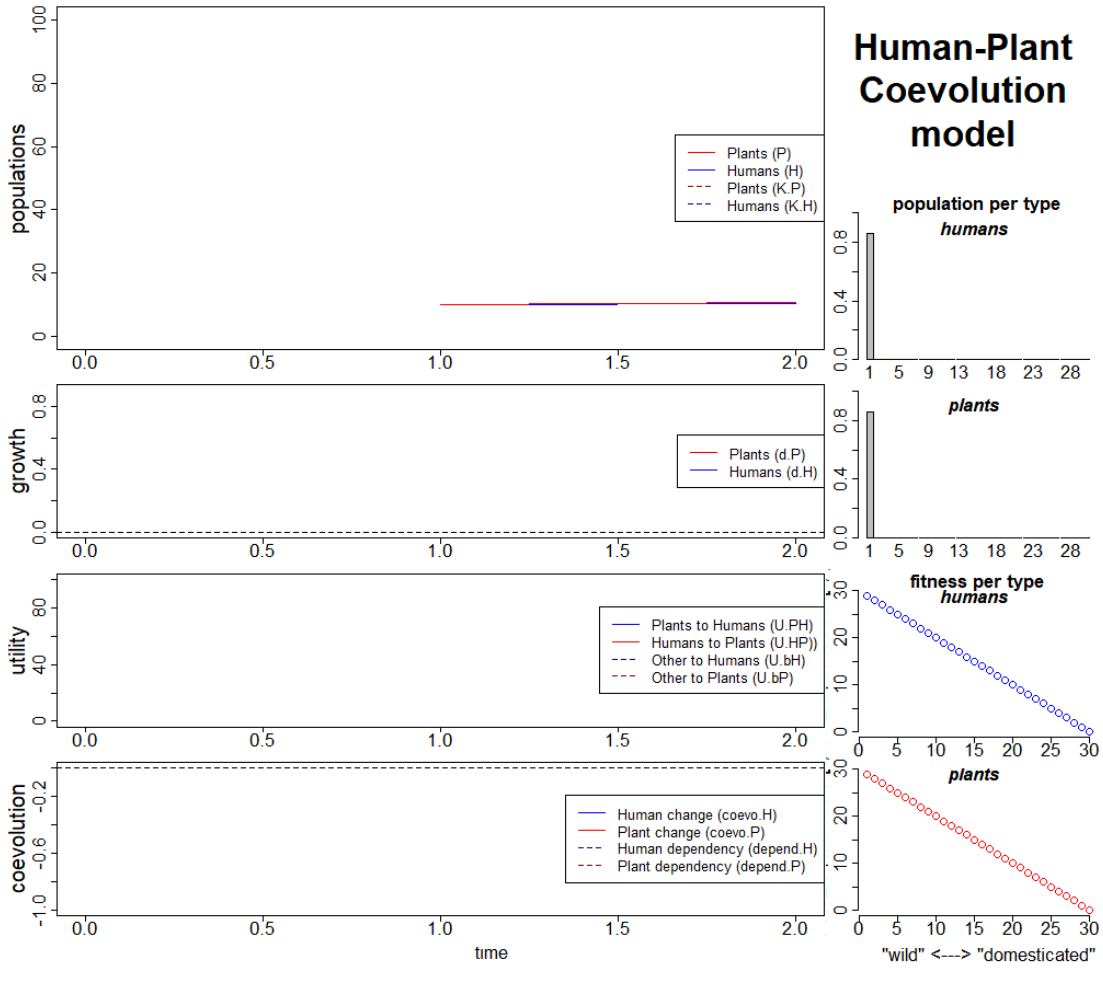
DYNAMICS

Two populations linked by mutualism

Coevolutionary dynamics integrating ***utility exchange*** *and* ***phenotypic fitness***



OUTCOMES: END-STATES



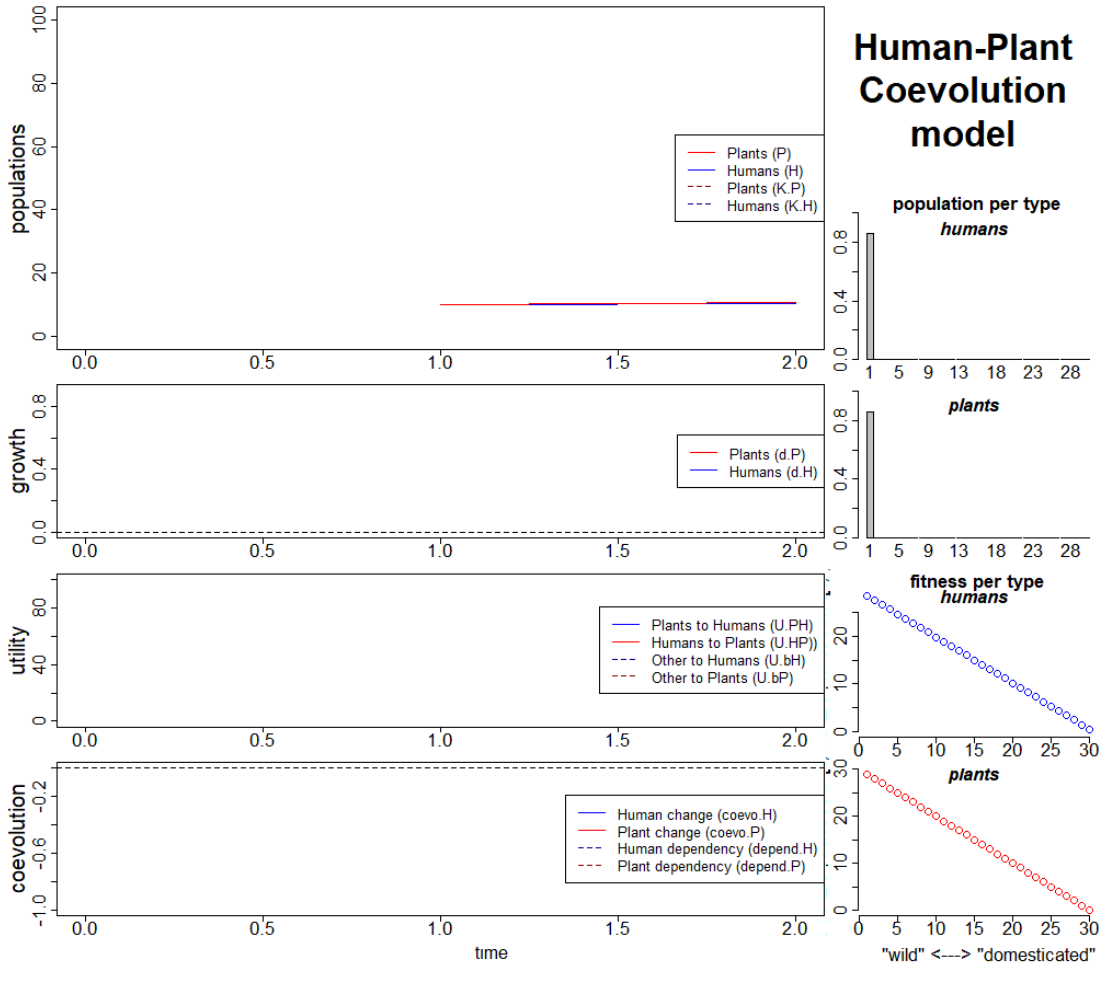
Parameter setting:

iniH = 10, iniP = 10, n.H = 30, n.P = 30, v.H = 0.15, v.P = 0.15, r.H = 0.04, r.P = 0.1, mU.PnH = 1.5, mU.HnP = 1, mU.P1H = 0, mU.H1P = 0, U.bHn = 10, U.bPn = 20, U.bH1 = 80, U.bP1 = 100, MaxArea = 200, maxIt = 5000, tol = 6, timing.threshold = 0.5

Coevolution does not occur

weaker mutualism

population levels can still be relatively high, depending on parameter conditions



Parameter setting:

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Coevolution occurs

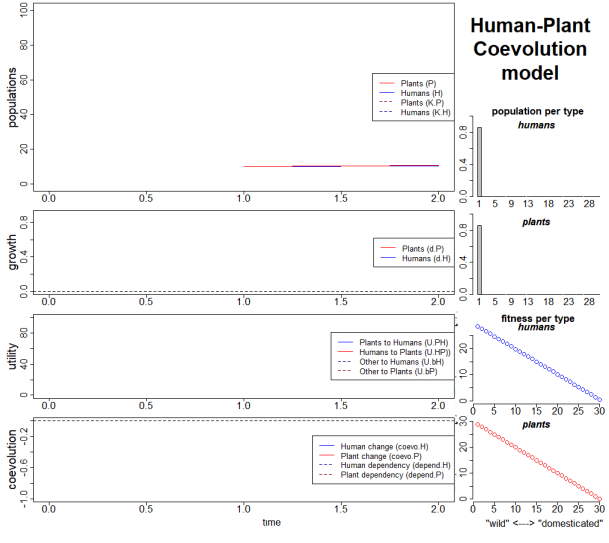
stronger mutualism

both population "booms" and "bleeps" are possible

order and scale of timing of change also vary

Coevolution occurs

boom



Parameter setting:

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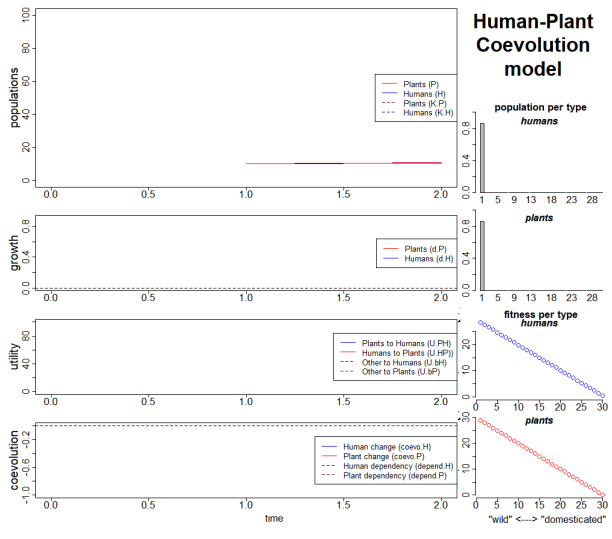
bleep



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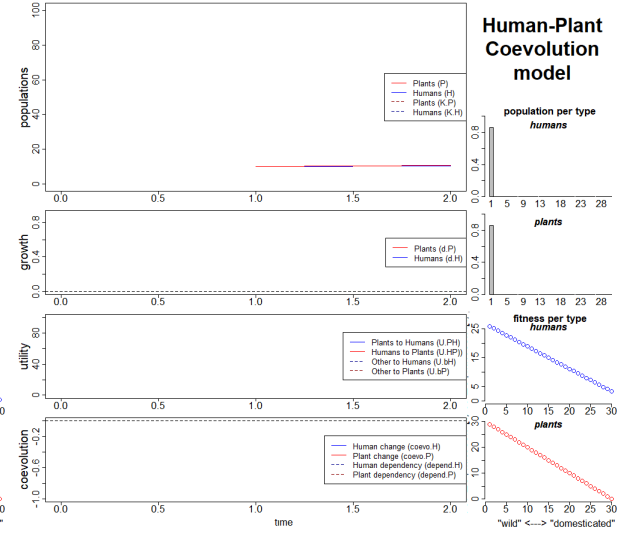
long boom



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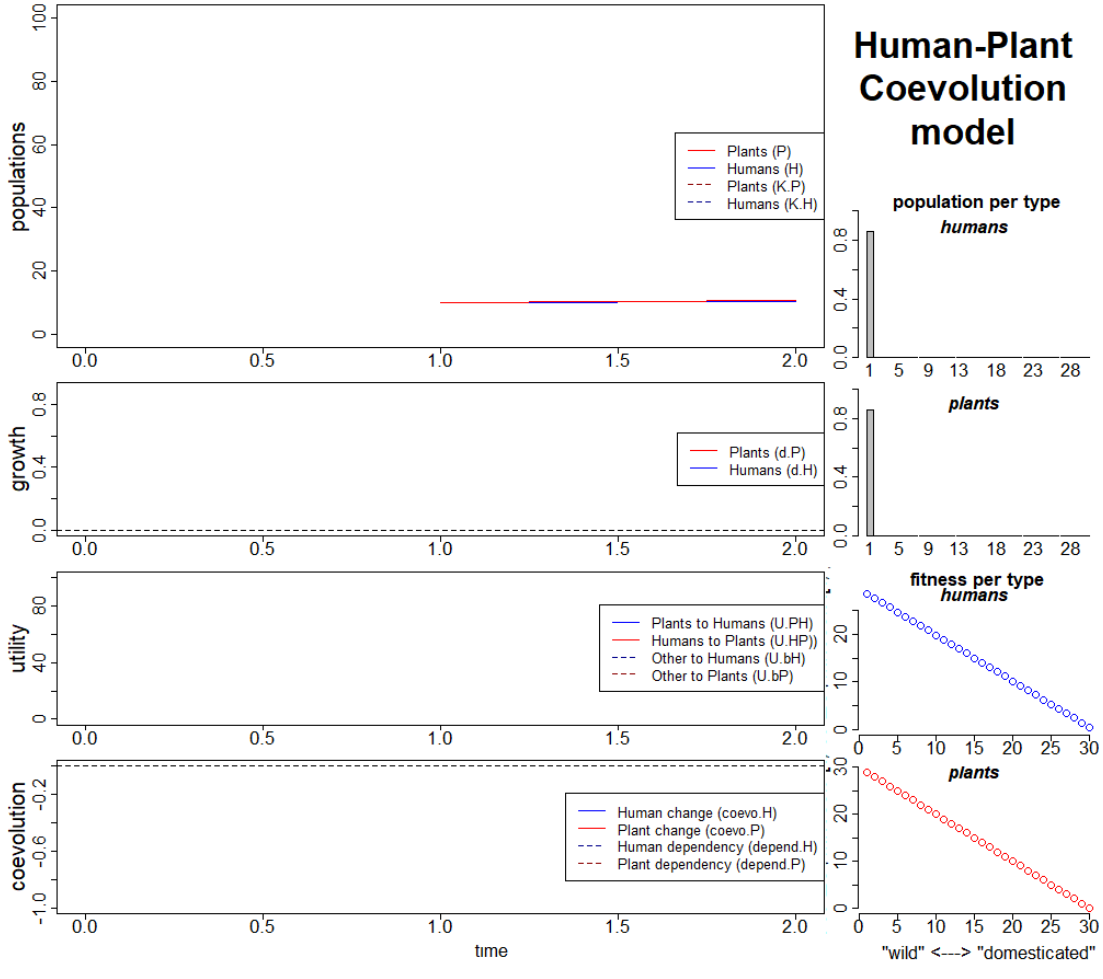

Parameter setting:

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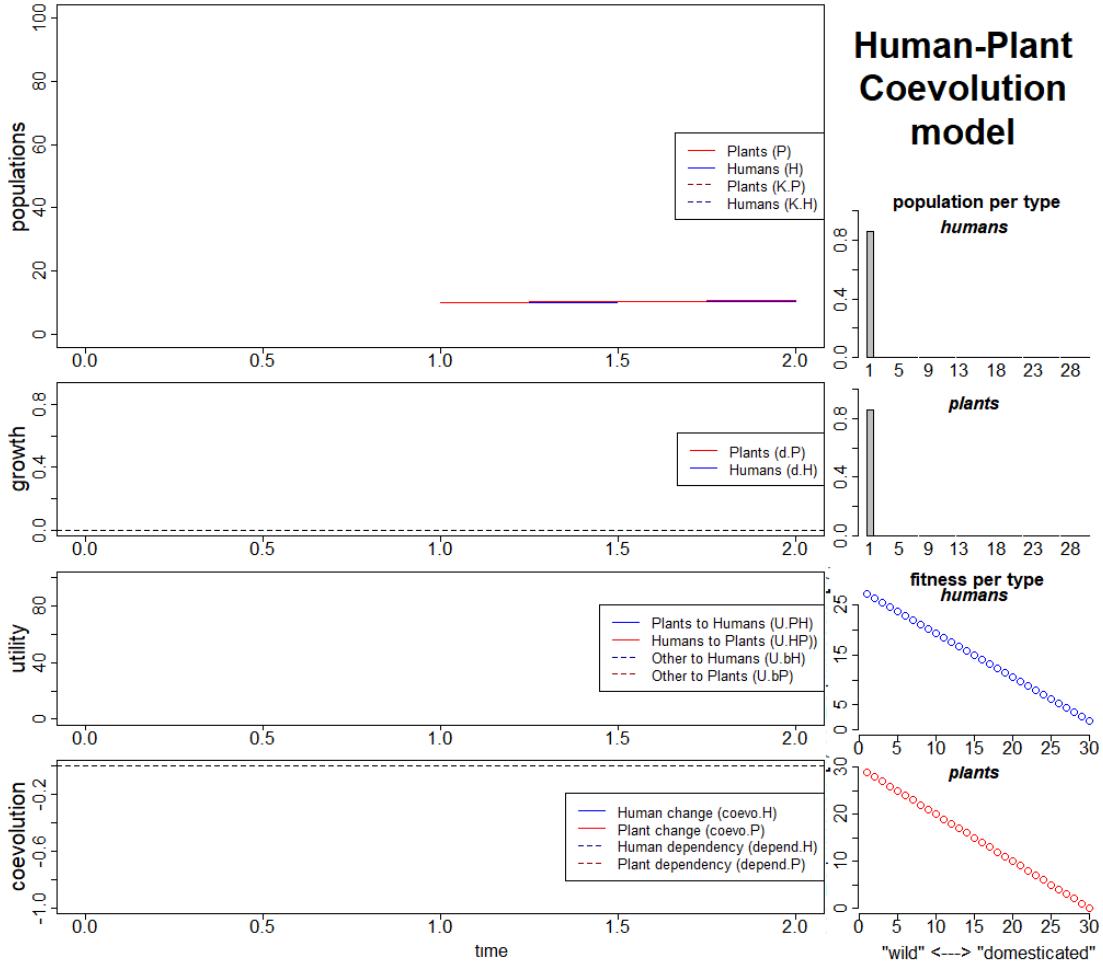
Coevolution occurs partially

one population achieve the full potential of change

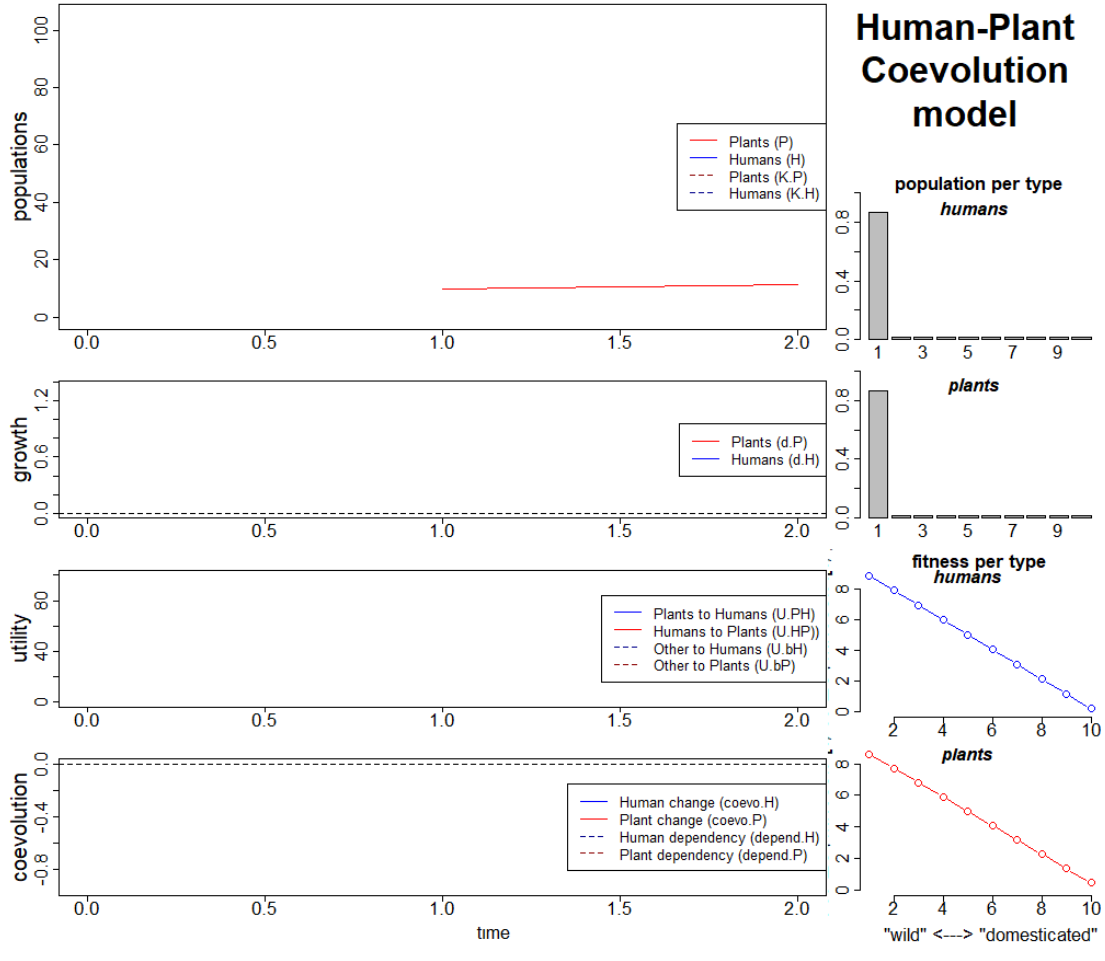


Parameter setting:

iniH = 10, iniP = 10, n.H = 30, n.P = 30, v.H = 0.15, v.P = 0.15, r.H = 0.04, r.P = 0.1, mU.PnH = 0.5, mU.HnP = 1, mU.P1H = 0.5, mU.H1P = 0, U.bHn = 10, U.bPn = 20, U.bH1 = 80, U.bP1 = 100, MaxArea = 200, maxIt = 5000, tol = 6, timing.threshold = 0.5

Coevolution occurs partially (II)

One or both populations undergo a significant, but partial change, remaining relatively well distributed among types.



Parameter setting:

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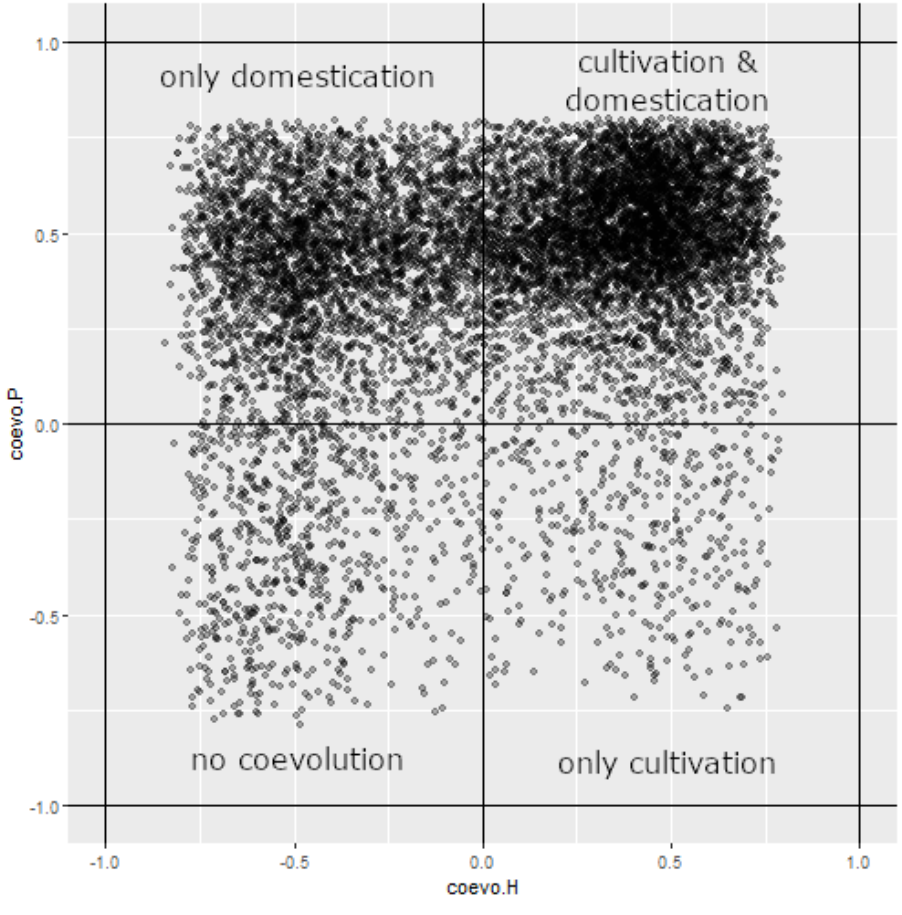
Coevolution occurs partially (III)

Both populations become trapped in an endless cycle alternating stronger and weaker mutualism

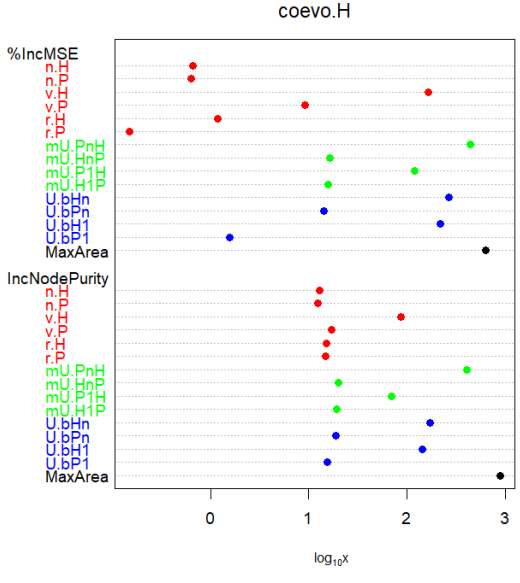
SENSITIVITY ANALYSIS

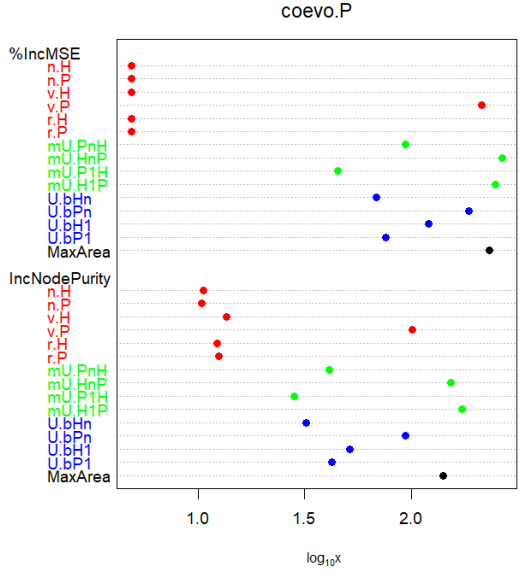


EXTENSIVE EXPLORATION OF PARAMETER SPACE

Change in plants (domestication) is more likely to happen than change in humans (cultivation) (assuming all conditions explored are equally probable)

MULTICAUSALITY

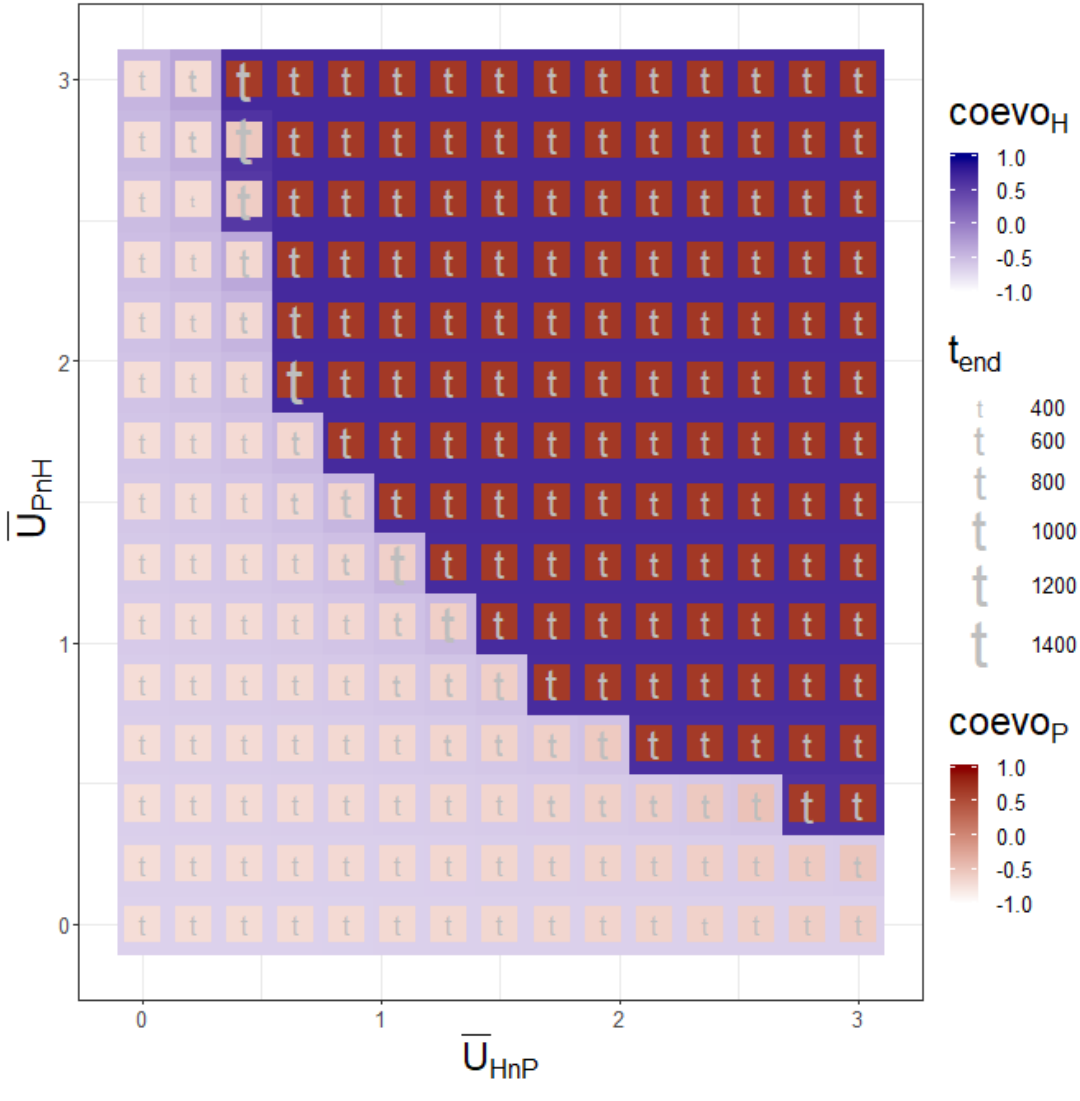




multiple requirements/triggers for coevolution to happen

but there are differences in importance (parameters more likely to be requirements/triggers than others)

ROLES OF PARAMETERS



- *facilitators*
- *obstructors*
- *scalers*

Example:
utility of the most mutualistic human and plant types
→ facilitators and scalers

PUBLICATION & DOCUMENTATION

- *publication in preparation*
- *R package (HPCoevo) to be release*
- *repository of this presentation:*
  https://github.com/Andros-Spica/ENE-Angourakis-et-al-2019

FUNDING

Modelling plant cultivation in prehistory/Modelado del cultivo en la prehistoria (HAR2016-77672-P; PI: Débora Zurro, IMF-CSIC)

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THANK YOU!

address any questions to A. Angourakis: andros.spica@gmail.com

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