

“DON’T PUT ALL YOUR EGGS IN ONE BASKET”

modelling cropping strategies and climate change in
the Indus Civilisation

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Alena Giesche, Joanna Walker, M. Cemre Ustunkaya, Nathan Wright,
Ravindra N. Singh and Cameron A. Petrie

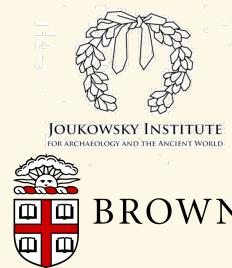
available at <https://andros-spica.github.io/CAA-Angourakis-et-al-2019/>
<https://andros-spica.github.io/CAA-Angourakis-et-al-2019/index.html?print-pdf> (printable version)



McDonald Institute for
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1. *'THOU SHALT BE ...*

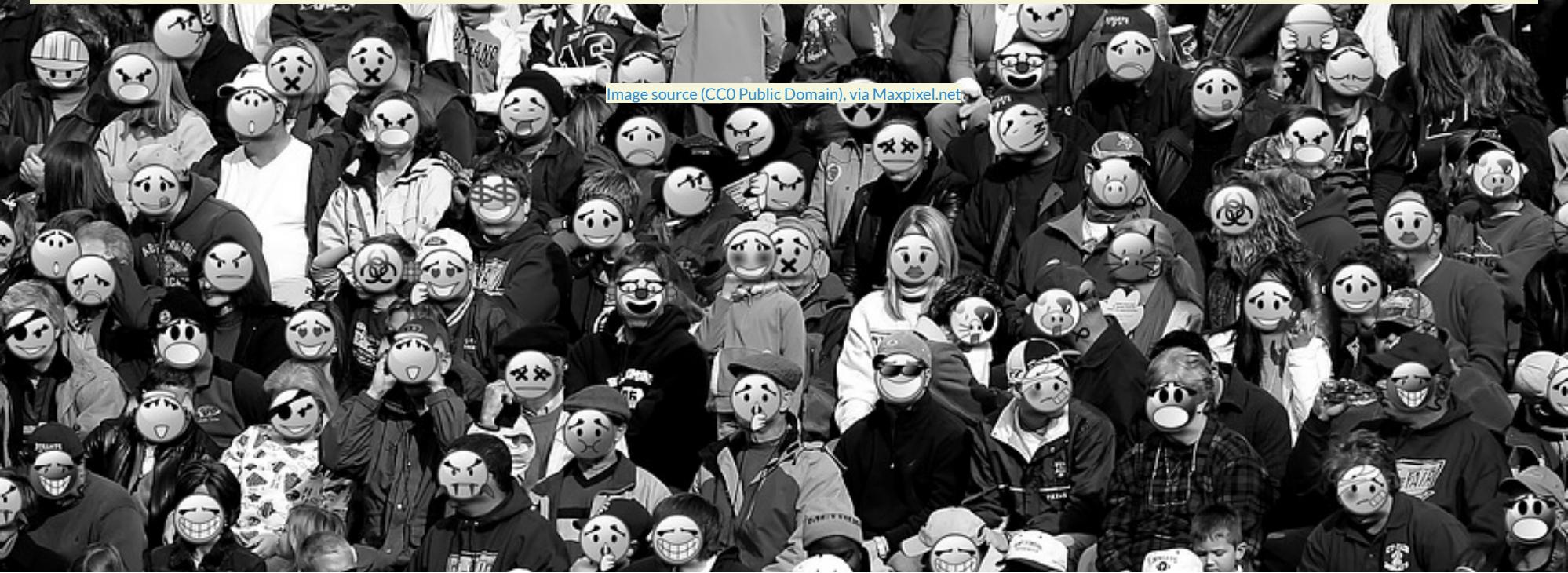
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1. '*THOU SHALT BE ... DIVERSE'*

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TOP DEFINITION



all of your eggs in one basket

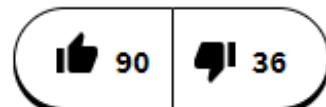
Having all of your resources in one place; putting your money or hopes or future into one thing.

'Eggs' are delicate, and if all of your eggs were in one container, and that container was damaged, you might lose all of your eggs in one quick and painful moment.

1) You don't want to keep all of your eggs in one basket. You might lose everything!

2) Tom had all of his eggs in one basket -- Yoyodyne.com stock -- and when the stock market crashed he was bankrupt.

by **VAK15** May 10, 2005

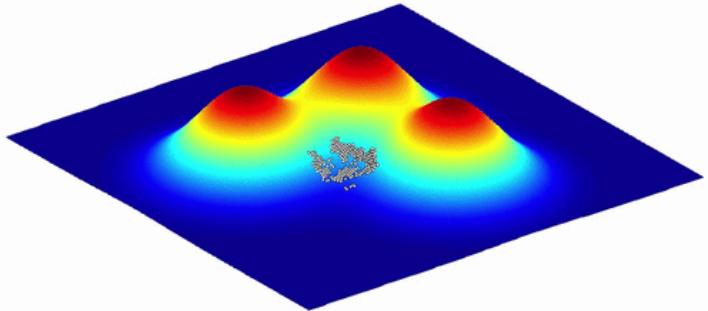


"DIVERSITY FAVOURS ADAPTATION"

- As finance motto: **minimising risk**
- **Fisher's fundamental theorem of natural selection** (as genetic variance)
- Applied at multiple levels:
 - Ecosystem: *populations* are more diverse → *ecosystem* adapts easier/faster
 - Population: *individuals/groups* are more diverse → *population* adapts easier/faster
 - Group: *individuals* are more diverse → *group* adapts easier/faster
 - Individual: *practices* are more diverse → the *individual* adapts easier/faster
- **A principle, not necessarily a fact**

FITNESS LANDSCAPES

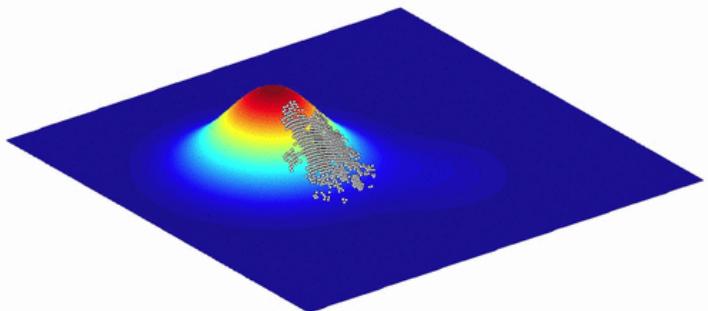
Static fitness landscape



Population size, $N = 2,304$
Mutation rate, $\mu = 0.05$ per trait

© Randy Olson and Bjørn Østman

Dynamic fitness landscape



Population size, $N = 2,304$
Mutation rate, $\mu = 0.5$ per trait

© Randy Olson and Bjørn Østman

- Used in eco-evo theory
- fitness x multiple dimensions
- Metaphoric/operational applications
- Caveats, e.g., *Do populations move through low fitness "valleys"?*
- "Seascapes": dynamic fitness landscapes

SCALES OF DIVERSITY

Local/momentum:

'hill climbing'

→ **fitness maximiser**

Regional/period:

'boat stabilising'

→ **risk minimiser**

Integration of multiple instances creates an average fitness landscape that buffers the diversity of conditions

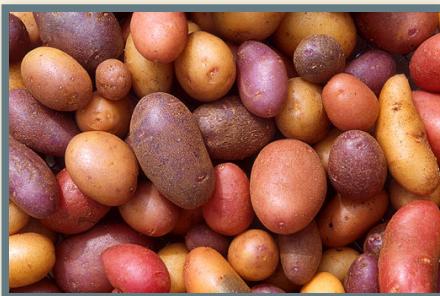


2. *DIVERSITY IN FOOD PRODUCTION*



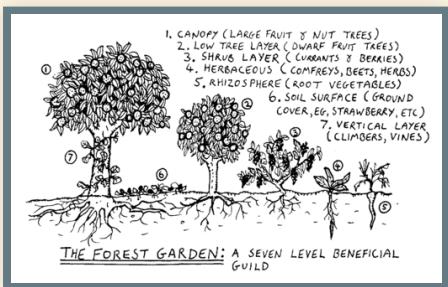
[See page for author \[Public domain\], via Wikimedia Commons](#)

DIVERSITY IN FOOD PRODUCTION



- factor of *food security*
- Increasing demand
versus sustainability
- International trade
versus food sovereignty
- Commercial crops,
genetic engineering,
landraces
- Climate change, plagues

MULTI-CROPPING



- Two forms (Andrews and Kassam 1976, cited in Petrie & Bates 2017):
 - Sequential cropping
 - Intercropping
- 'Traditional' practices (e.g., *permeaculture*)
- Undermined by commercial crops but not lost

MULTI-CROPPING

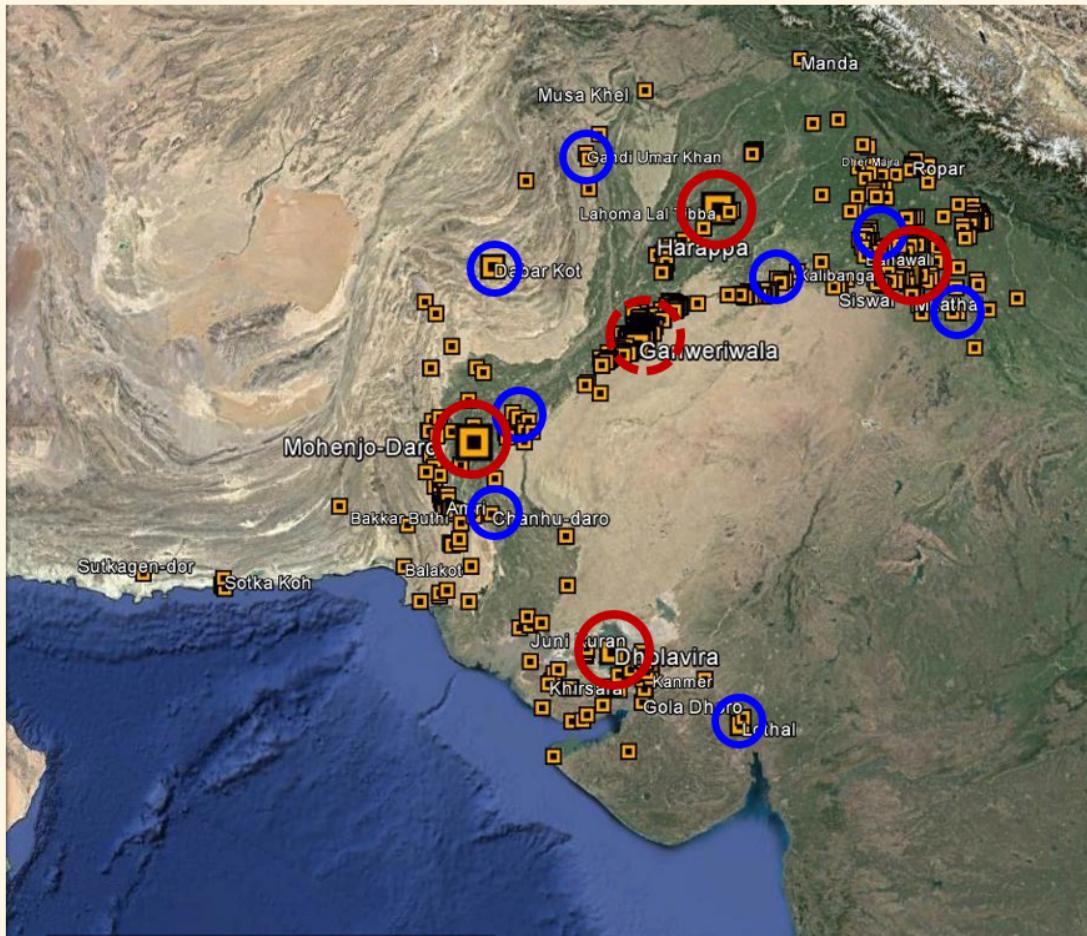
What impact does it have for resilience?



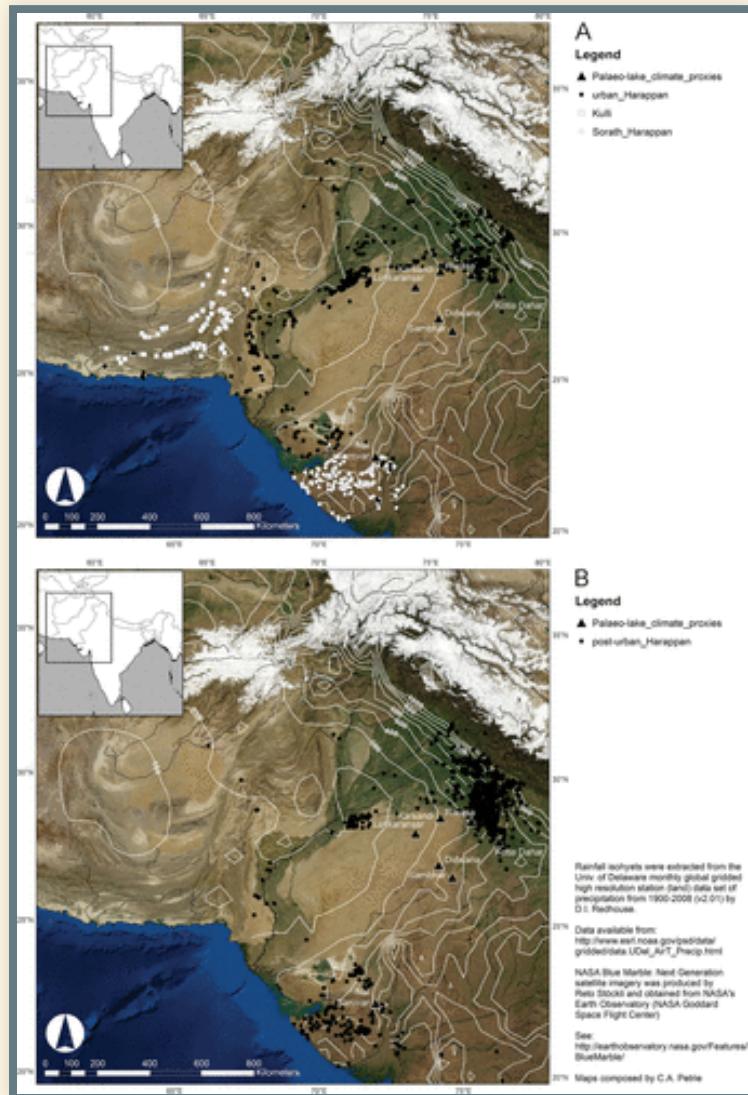
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3. CASE STUDY: THE INDUS CIVILISATION

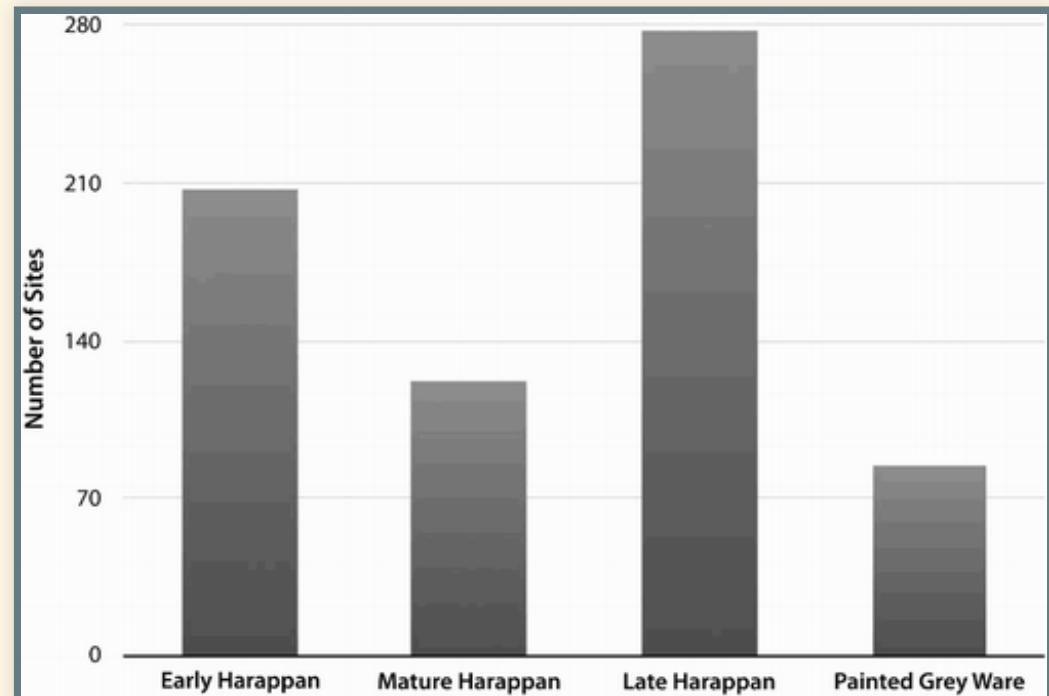


- One of the great 'Old World' Bronze Age civilisations
- First cities in South Asia ('Mature Harappan', c.2500-1900 BC)
- Five (or four) known major urban centres



URBANISATION AND *DE*-URBANISATION

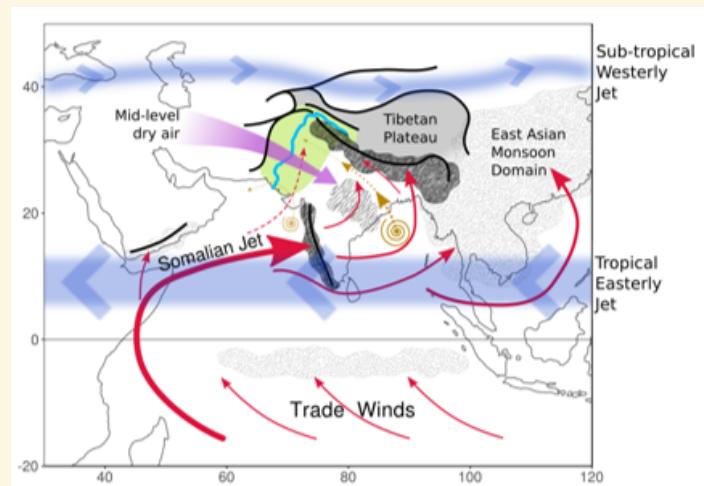
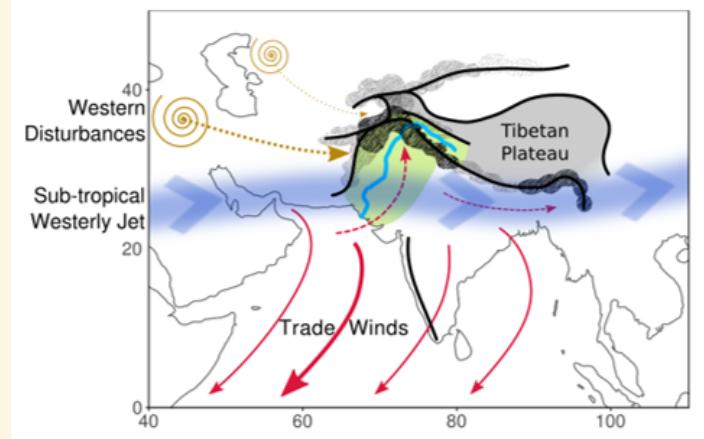
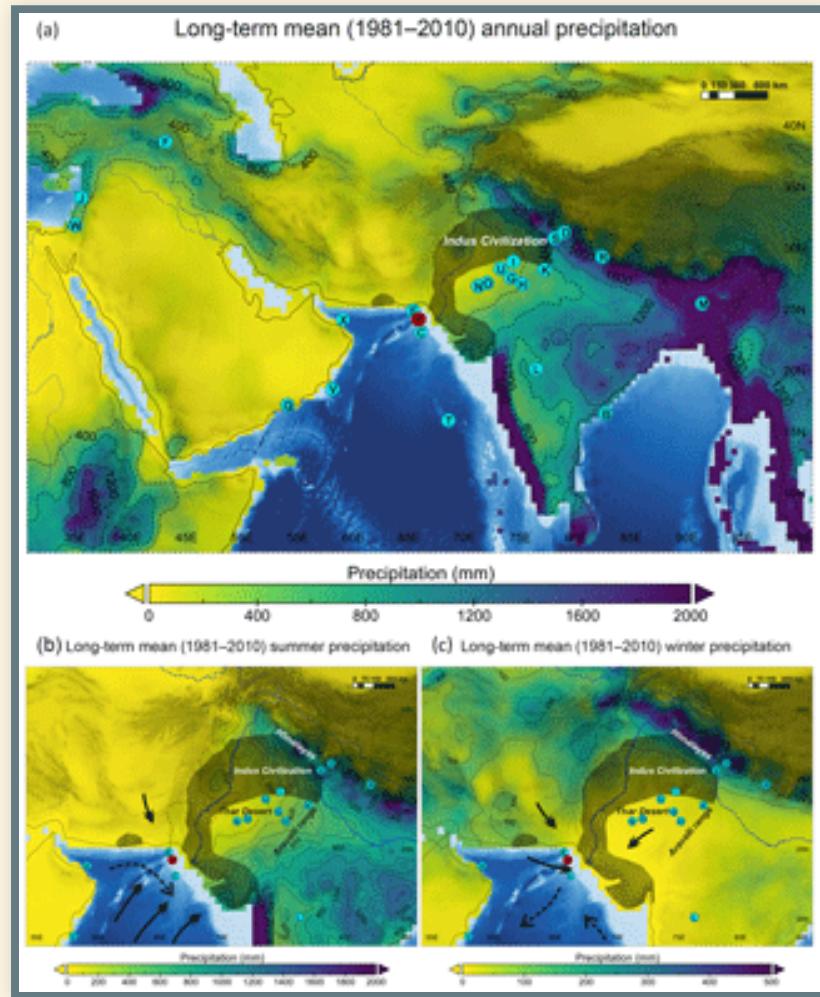
Green & Petrie 2018, Journal of Field Archaeology



SUMMER RAIN, WINTER RAIN

Giesche et al. 2019, *Clim. Past*

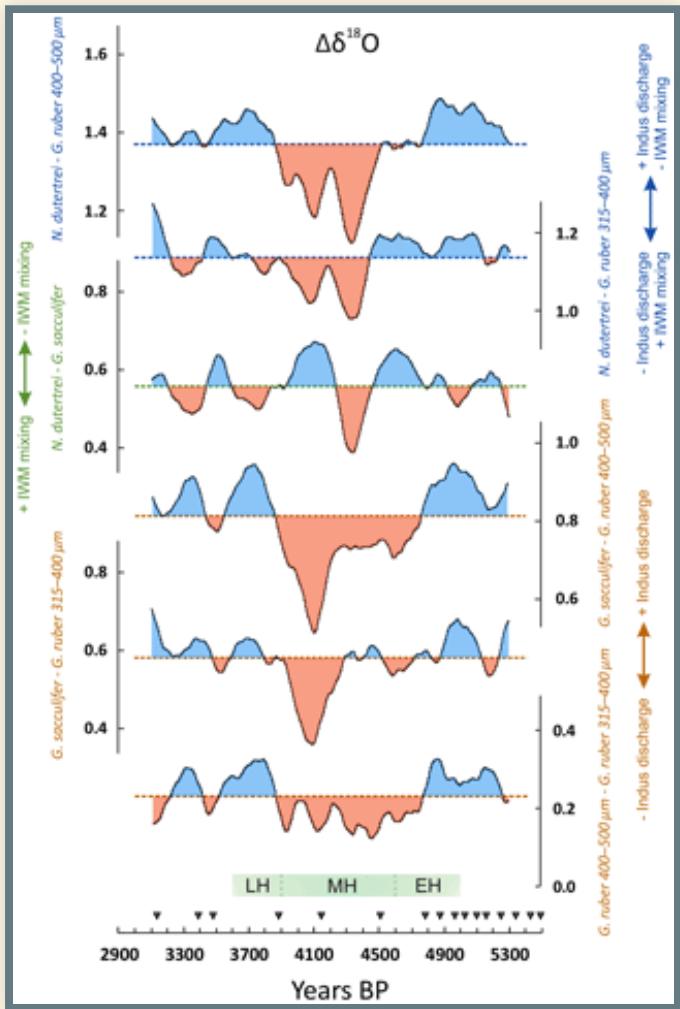
J.-P. Baudouin (in preparation)



“Predictable unpredictability”

CLIMATE CHANGE

Giesche et al. 2019, Clim. Past

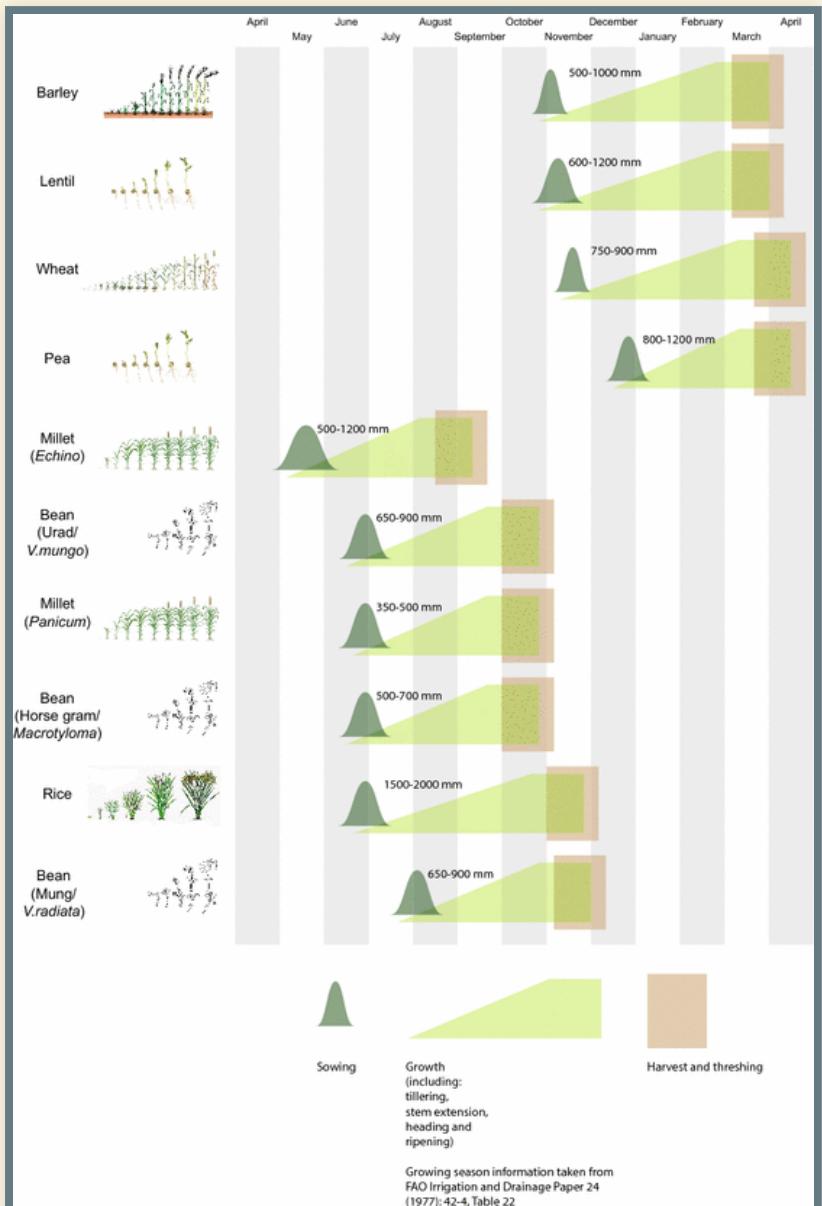


- Urban phase
(MH, 4.5 and 4.3 ka)
→ stronger winter precipitation
- End of urban phase
(MH-LH, 4.1 ka)
→ decrease in both the summer and winter precipitation

FOOD PRODUCTION

- Main crops:
 - barley/wheat (winter)
 - millet/rice (summer)
- Pulses
- Other

Bates, Petrie & Singh 2018, Archaeol Anthropol Sci



FOOD PRODUCTION



- Animal husbandry: zebu, water buffalo, sheep, goat, pigs (?)



- Fishing, hunting
- Role of herding?



4. MODELLING CROPPING STRATEGIES

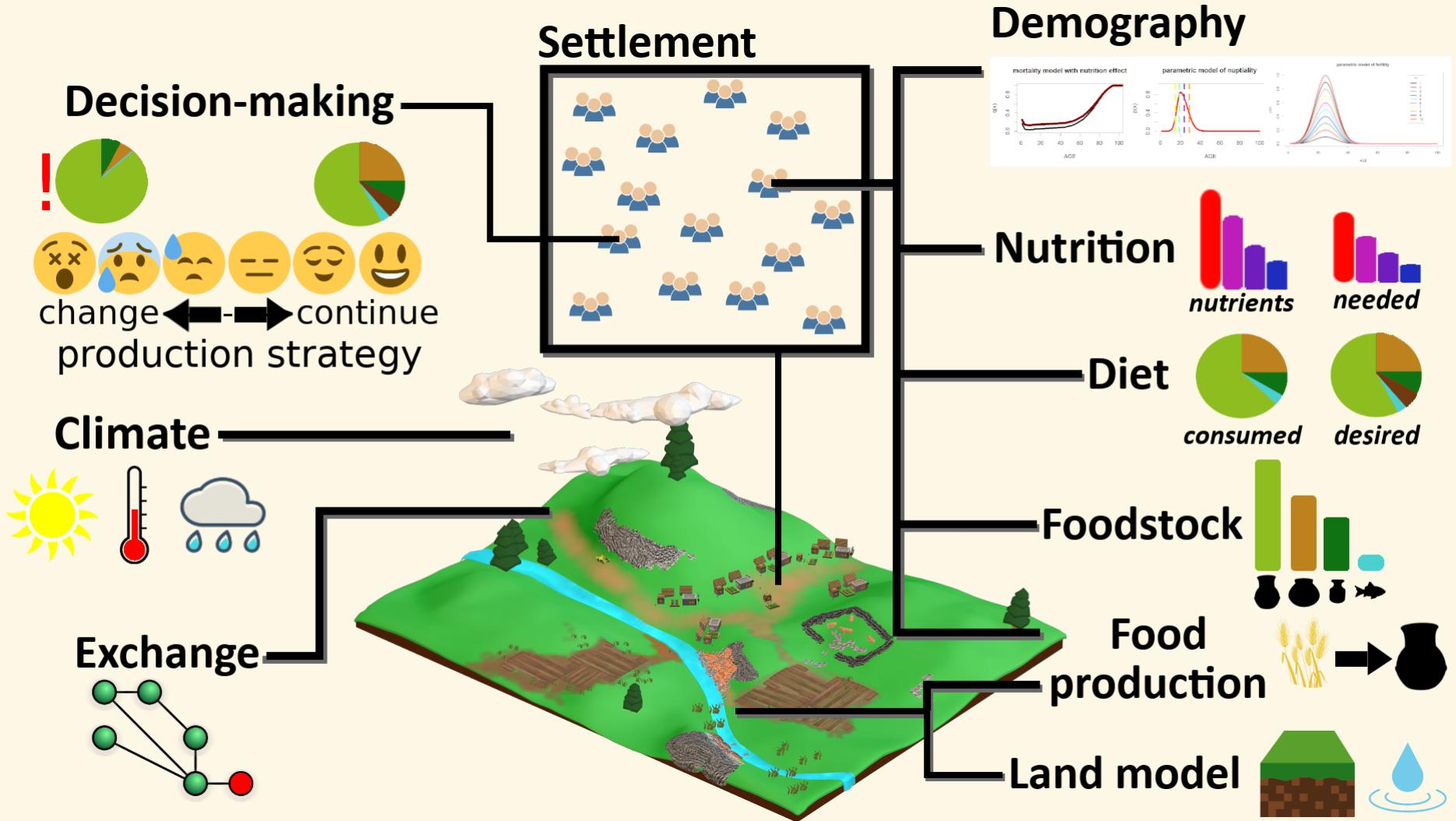


GOAL

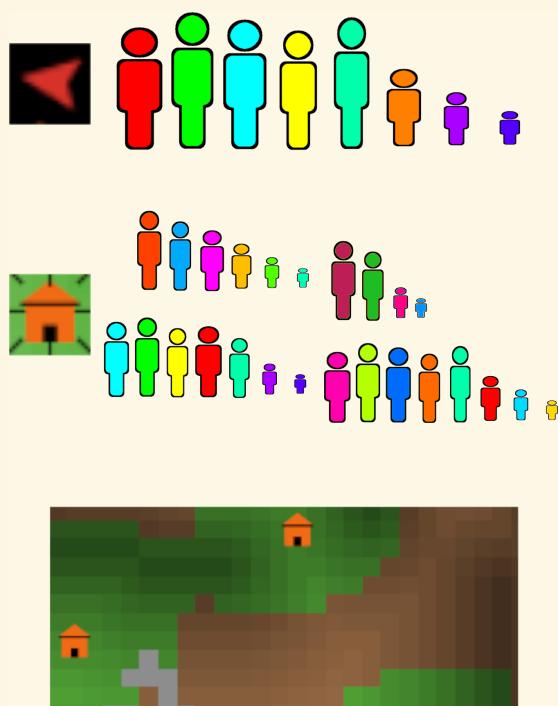
to explore human *adaptation to the diverse landscapes* of NW India and expose the *sustainability* of different types of *food production regimes*, mainly in terms of *cropping strategies*, in front of *abrupt climate change*

RATIONALE

- rural settlement(s)
- local scale
- food production/consumption
- Explore parameters/scenarios
- Questions:
 - Does diversity favours adaptation?
 - Is it detrimental to generating surplus?

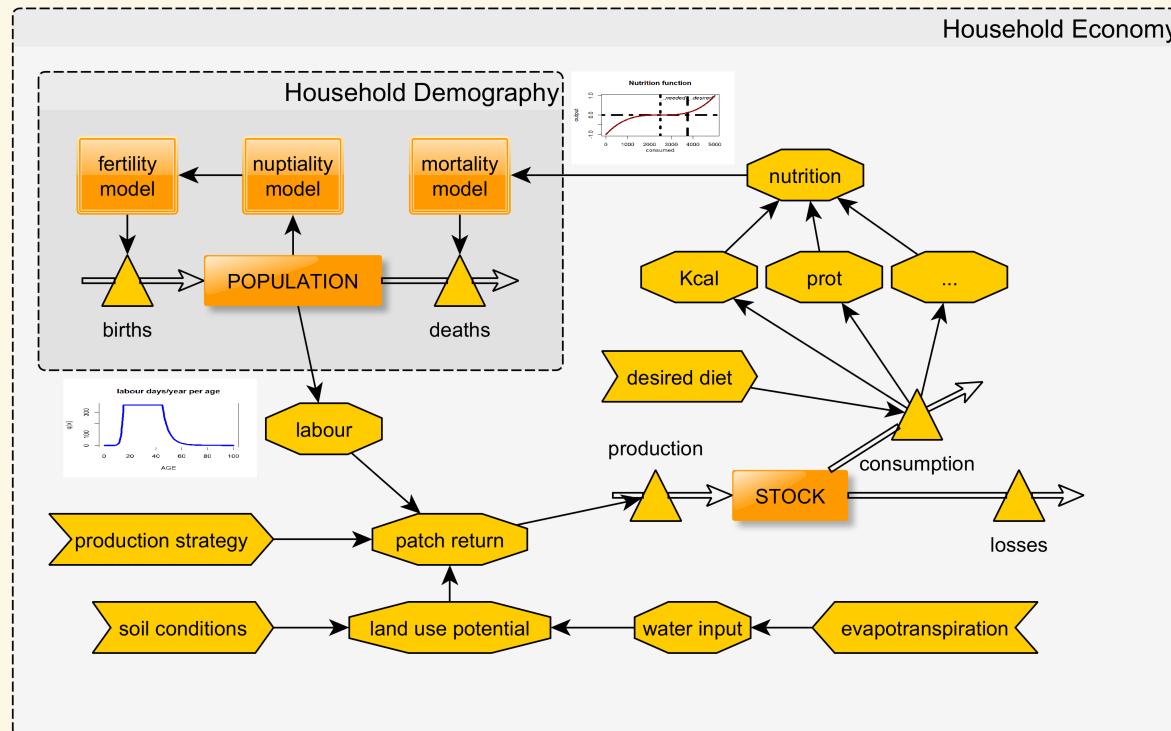


ELEMENTS



- Household: *propinquity* and *co-residence*, rather than *kinship*
- Group: set of households, united by *kinship* or *coexistence*; may form a 'settlement'
- Patches: 1 hectare, vary in *soil*, *water balance*, and *land use*

MODEL DESIGN, INSO FAR



HOUSEHOLD *DEMOGRAPHY*

STRUCTURE

HOUSEHOLD								
index	[0	1	2	3	4	5	6	7]
SEX (is female?)	true	true	false	true	false	true	true	false]
AGE	65	36	41	22	19	7	2	0
COUPLE index	-1	0	0	1	1	-1	-1	-1]

Green is a 36 years-old woman.
She is married to Cyan, a 41 years-old man.
Upon their union, Cyan moved into Green's household ("matrilocal").

HOUSEHOLD *DEMOGRAPHY* DYNAMICS

- Age/sex-specific submodels: *mortality* (Coale-Demeny, from `demogR` package), *nuptiality* and *fertility* (Peristeva & Kostaki 2007, 2015)
- Open population
- Couples: residence rule and kinship tabu
- Sensitivity to population size
- Local instability, stability, and exponential growth

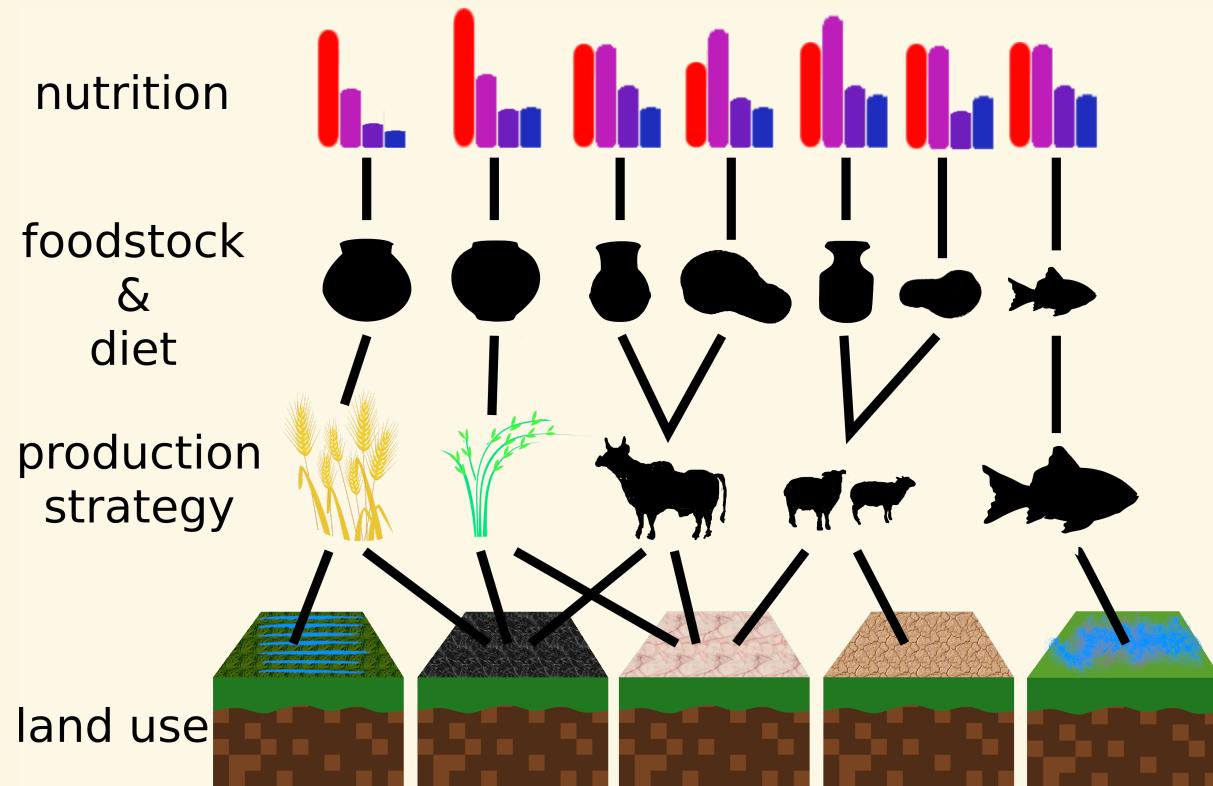
HOUSEHOLD *ECONOMY*

FROM LAND USE TO DIET

- *Food production* at household-level
- *Diet* and *nutrition*
- Specific *strategies* applied to patches with specific (changing) *conditions*
- Sharing/exchange to be realised at group-level

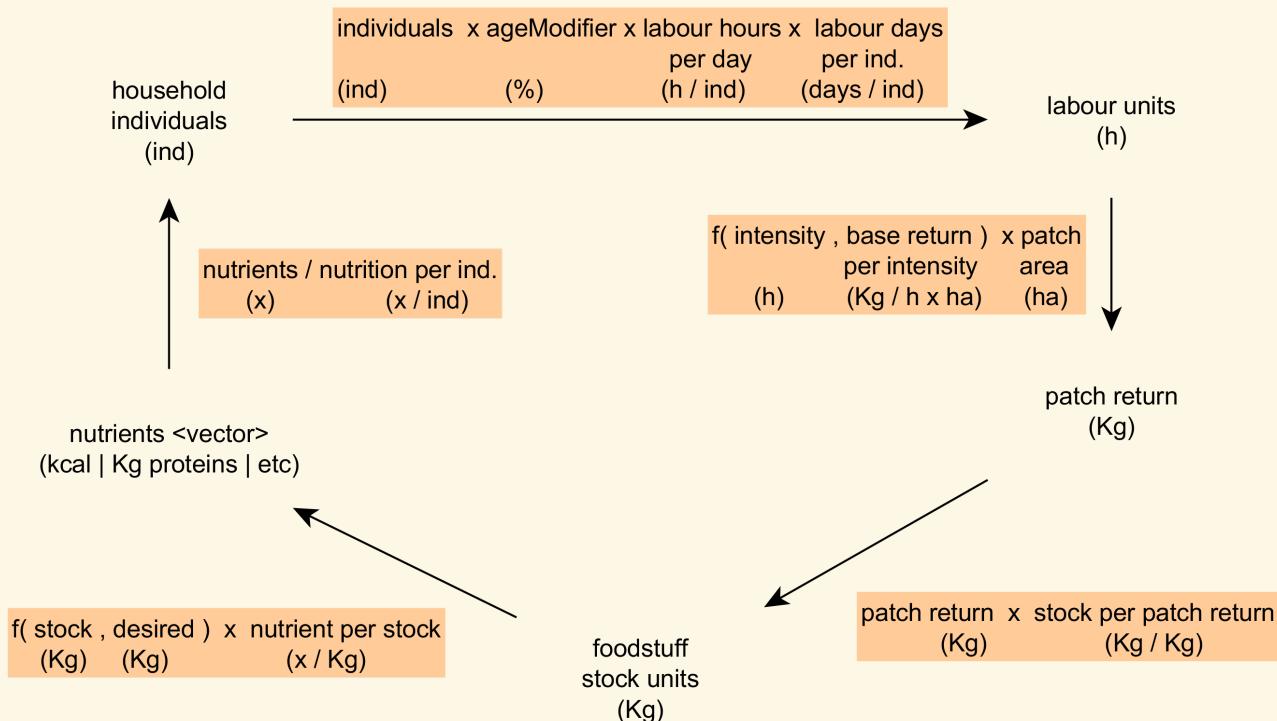
HOUSEHOLD *ECONOMY*

STRUCTURE



HOUSEHOLD *ECONOMY*

DYNAMICS



DATA INPUT

SOILS AND CROP CONDITIONS

FAO SOILS PORTAL

[Home](#) [Survey](#) [Assessment](#) [Biodiversity](#) [Management](#) [Degradation/Restoration](#) [Policies/Governance](#) [Publications](#)

[Soil properties](#)

[Soil classification](#)

[Sampling and laboratory techniques](#)

[Soil Maps and Databases](#)

[FAO/UNESCO Soil Map of the World](#)

Harmonized world soil database v1.2

 This is the result of a collaboration between the FAO with IIASA, ISRIC-World Soil Information, Institute of Soil Science, Chinese Academy of Sciences (ISSCAS), and the Joint Research Centre of the European Commission (JRC). The Harmonized World Soil Database is a 30 arc-second raster database with over 15 000 different soil mapping units that combines existing regional and national updates of soil information worldwide (SOTER, ESD, Soil Map of China, WISE) with the information contained within the 1:5 000 000 scale FAO-UNESCO Soil Map of the World (FAO, 1971-1981).

The resulting raster database consists of 21600 rows and 43200 columns, which are linked to harmonized soil property data. The use of a standardized structure allows for the **linkage of the attribute data with the raster map** to display or query the composition in terms of soil units and the **characterization of selected soil parameters** (organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry).

[Download : Download viewer & data](#) | [Download data](#)

[Publications : Harmonized World Soil Database](#)

A selection of the data is downloadable and available here :

[Terrain](#) [Terrain desc.](#) [Land Cover](#) [Land Cover desc.](#) [Soil Quality](#) [Soil Quality desc.](#)

Soil Qualities for Crop Production

On the basis of soil parameters provided by HWSD seven key soil qualities important for crop production have been derived, namely: nutrient availability, nutrient retention capacity, rooting conditions, oxygen availability to roots, excess salts, toxicities, and workability. Soil qualities are related to the agricultural use of the soil and more specifically to specific crop requirements and tolerances. For the illustration of soil

Challenge: model animal
husbandry

Ecocrop



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FOODSTUFF NUTRITION VALUES

USDA United States Department of Agriculture
Agricultural Research Service
National Nutrient Database for Standard Reference Legacy Release

Home Food Search Nutrient Search Ground Beef Calculator Documentation and Help Downloads Contact Us

Basic Report: 20005, Barley, pearled, raw
[« Return to Search Results](#) [Full Report \(All Nutrients\)](#) [Statistics Report](#) [Download \(CSV\)](#) [Print \(PDF\)](#)

Nutrient values and weights are for edible portion.

Search nutrient table:

Nutrient	Unit	Value per 100 g	Value per 1 cup 200 g
Proximates			
Water	g	10.09	20.18
Energy	kcal	352	704
Protein	g	9.91	19.82
Total lipid (fat)	g	1.16	2.32
Carbohydrate, by difference	g	77.72	155.44
Fiber, total dietary	g	15.6	31.2
Sugars, total	g	0.80	1.60
Minerals			
Calcium, Ca	mg	29	58

Showing 32 nutrients

Challenge: raw or cooked?

Archaeol Anthropol Sci (2018) 10:1703–1716
DOI 10.1007/s12520-017-0489-2



ORIGINAL PAPER

Cereals, calories and change: exploring approaches to quantification in Indus archaeobotany

J. Bates^{1,2} · C.A. Petrie^{1,3} · R.N. Singh⁴

CONCLUSIONS I

- The effects of *diversity in food production* can vary with the time and spatial scale
- Case studies in archaeology can offer insight on the '*long durée*'...
- But modelling (particularly, ABM) can *connect* small/short with large/long scales

CONCLUSIONS II

- Connections made with ABM can be built on *meaningful mechanisms*
- Accounting for:
 - Variability of *environmental conditions*
 - *Social dynamics* of various complexity
 - Sets of *assumptions* that can be flexible and testable (alternative designs, scenarios)
- *Challenge*: still lack a shared, coherent, reproducible *framework* for modelling food production across cultures and for many generations

'TWORAINS' PROJECT

ERC, 2015-2020

Follow our updates!

- Institutional Web page
- Project blog

ACKNOWLEDGEMENTS

Thanks to the **Land, Water and Settlement** and **TwoRains** teams:

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THANK YOU!

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