



Universitat de Girona

The spread of the Neolithic. General laws in prehistory?

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Workshop on Environmental conditions in prehistory
(c. 10,000 BP - present) - ecology, carrying capacity,
and the landscape: integrating regional models and
developing global datasets.

Kiel University (Germany), December 9th 2022



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These laws have been proposed*

- **First law:** The Neolithic usually spreads inland at a rate of about 1 km/yr, but there is substantial variation (0.4-3.6 km/yr).
- **Second law:** When in addition to demic diffusion there is substantial cultural diffusion, Neolithic spread rates are faster.
- **Third law:** Neolithic spread rates over the sea can take place substantially faster, at about 10 km/yr.
- **Fourth law:** Most Neolithic spreads are mainly demic.
- **Fifth law:** Neolithic spread rates tend to become slower at higher latitudes.
- **Sixth law:** The Neolithic spreads later and more slowly at higher altitudes above sea level.

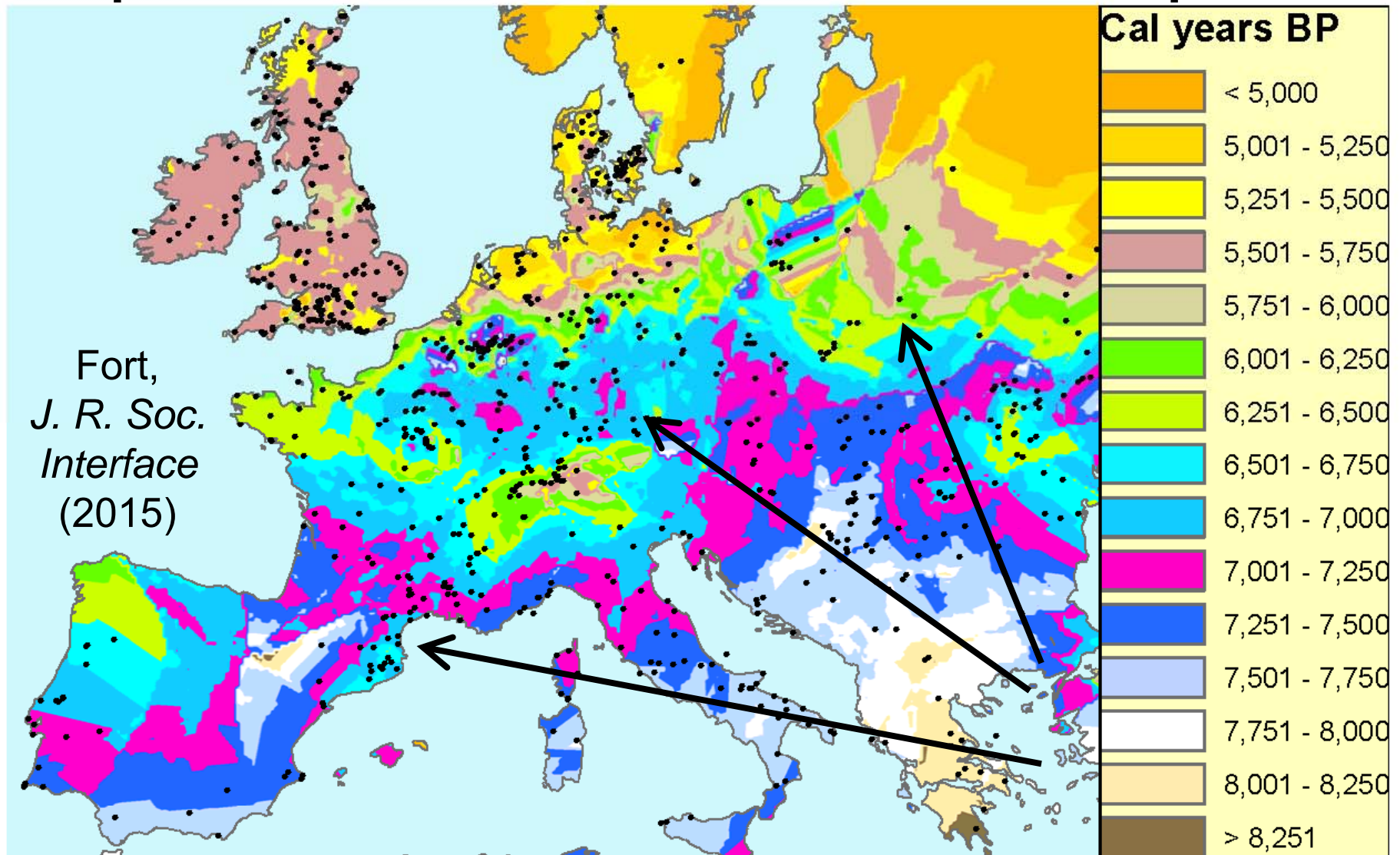
* Fort, book chapters (2021, 2023), *Human Popul. Genet. & Genom.* (2022)

First law

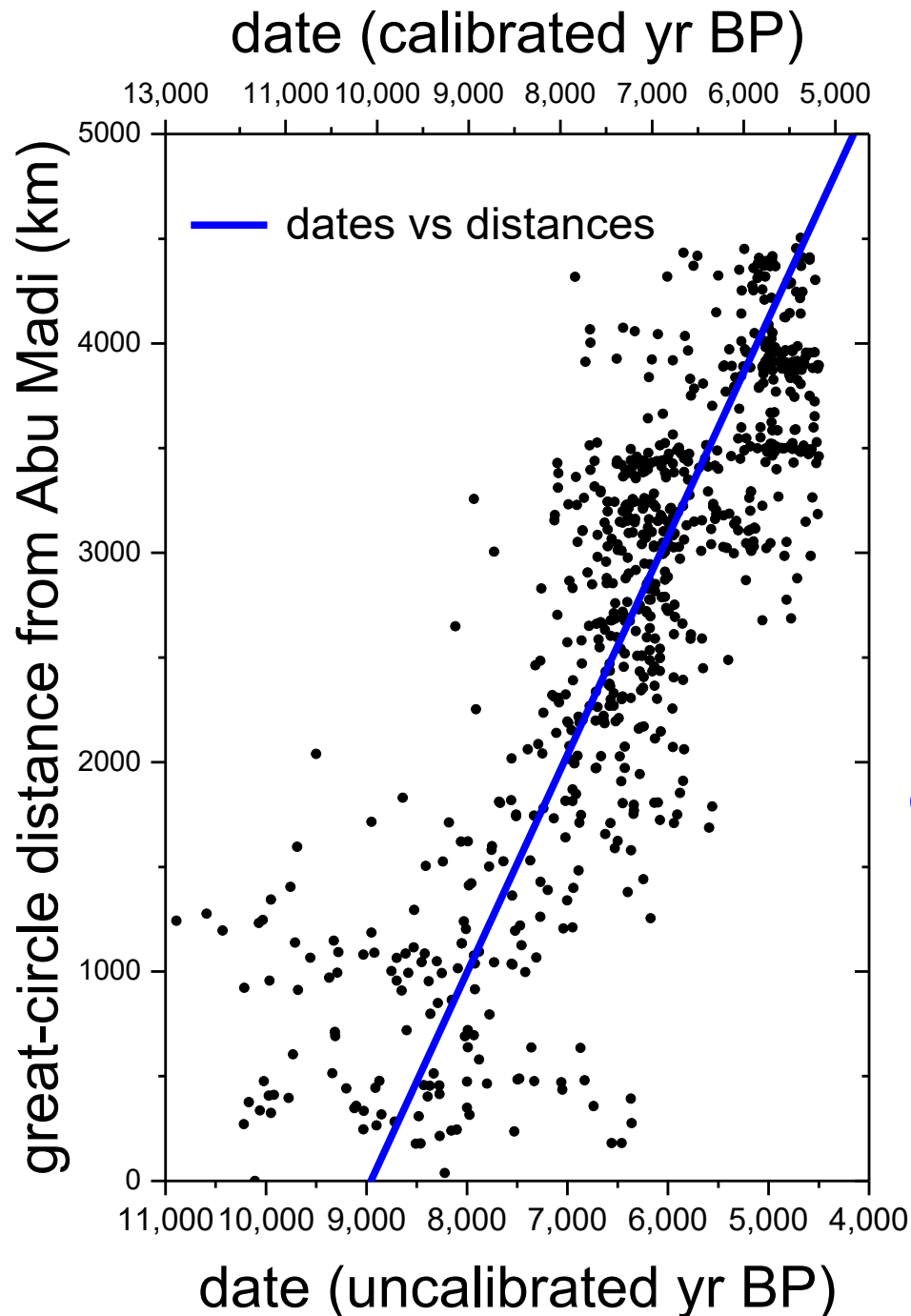
"The Neolithic usually spreads inland at a rate of about 1 km/yr, but there is substantial variation (0.4-3.6 km/yr)."

In the next slides, we analyze the data available.

Spread of the Neolithic in Europe



What is the observed speed?



Observed speed:

0.9-1.3 km/yr

(95% CL)

735 sites in Europe & Near East

$r = 0.83$ (highest- r origin)

range obtained by combining
those obtained using
great circles & shortest paths.

Dates vs distances regressions.

Pinhasi, Fort & Ammerman,
PLoS Biol. (2005)

Ammerman & Cavalli-Sforza
(1971) already found ~ 1 km/yr

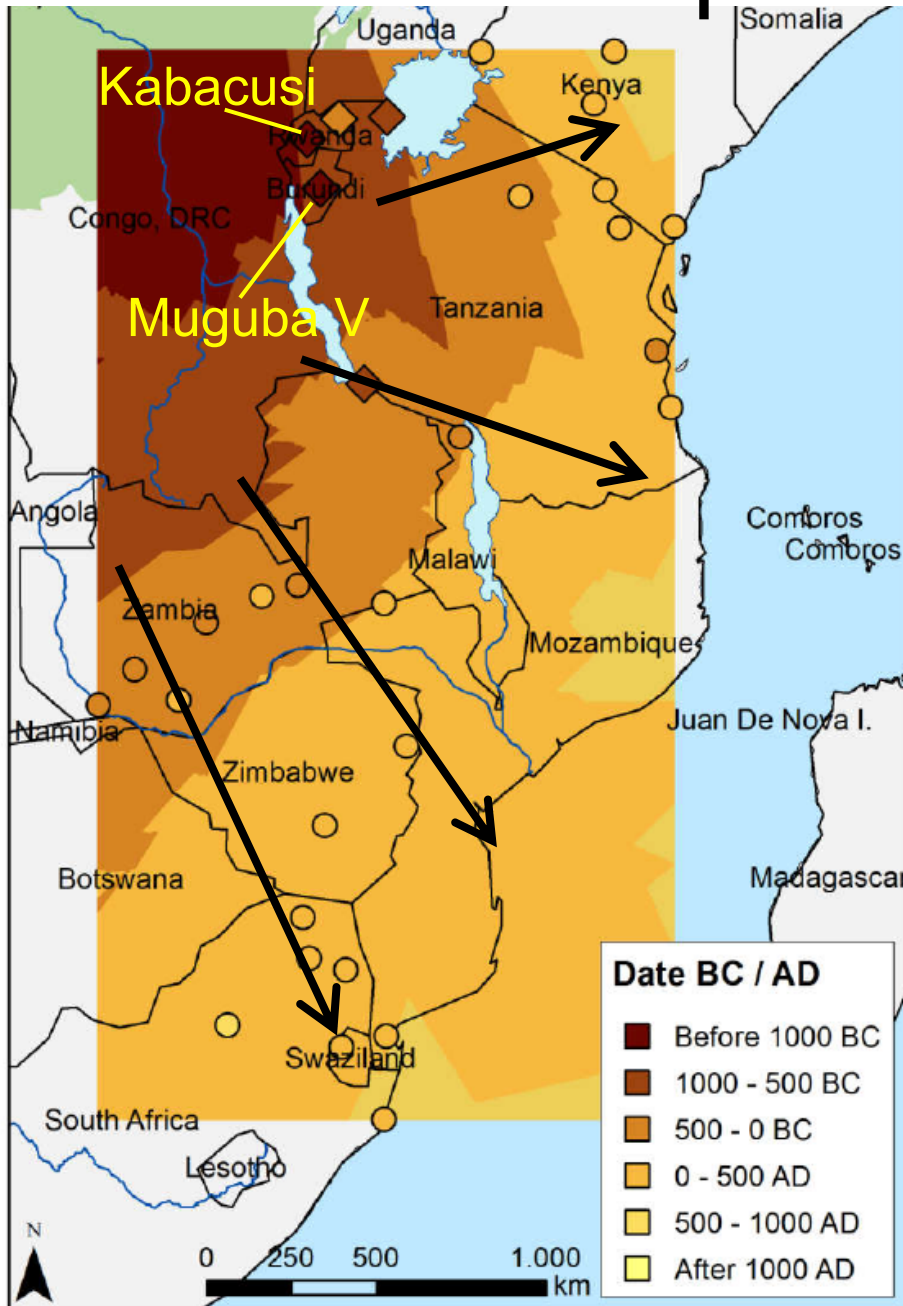
First law

"The Neolithic usually spreads inland at a rate of **about 1 km/yr**, but there is substantial variation (0.4-3.6 km/yr)."

1. Europe: 0.9-1.3 km/yr → OK

(95% CL)

The Bantu expansion in Eastern Africa



Faster southwards than eastwards

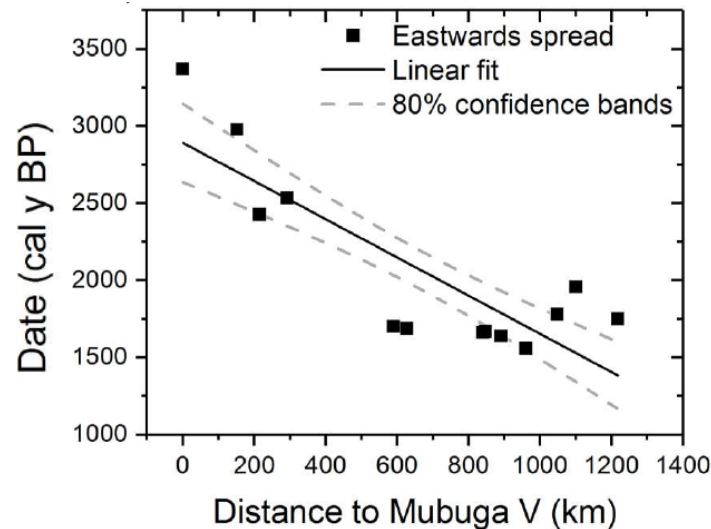
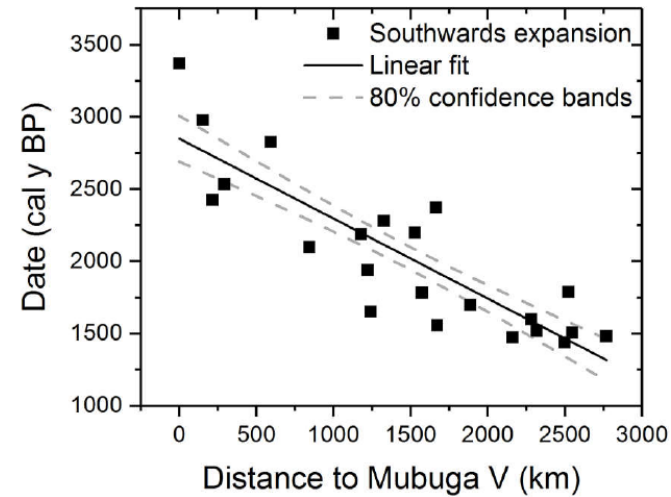
Highest-r origins ($r \geq 0.8$) are the 2 oldest sites: Muguba V and Kabacusi.

Combining both origins:

South:
1.3-2.5
km/yr

East*:
0.5-1.5
km/yr

(95% CL)
*East of lakes
Tanganika
and Malawi



Isern & Fort, *PLoS One* (2019)

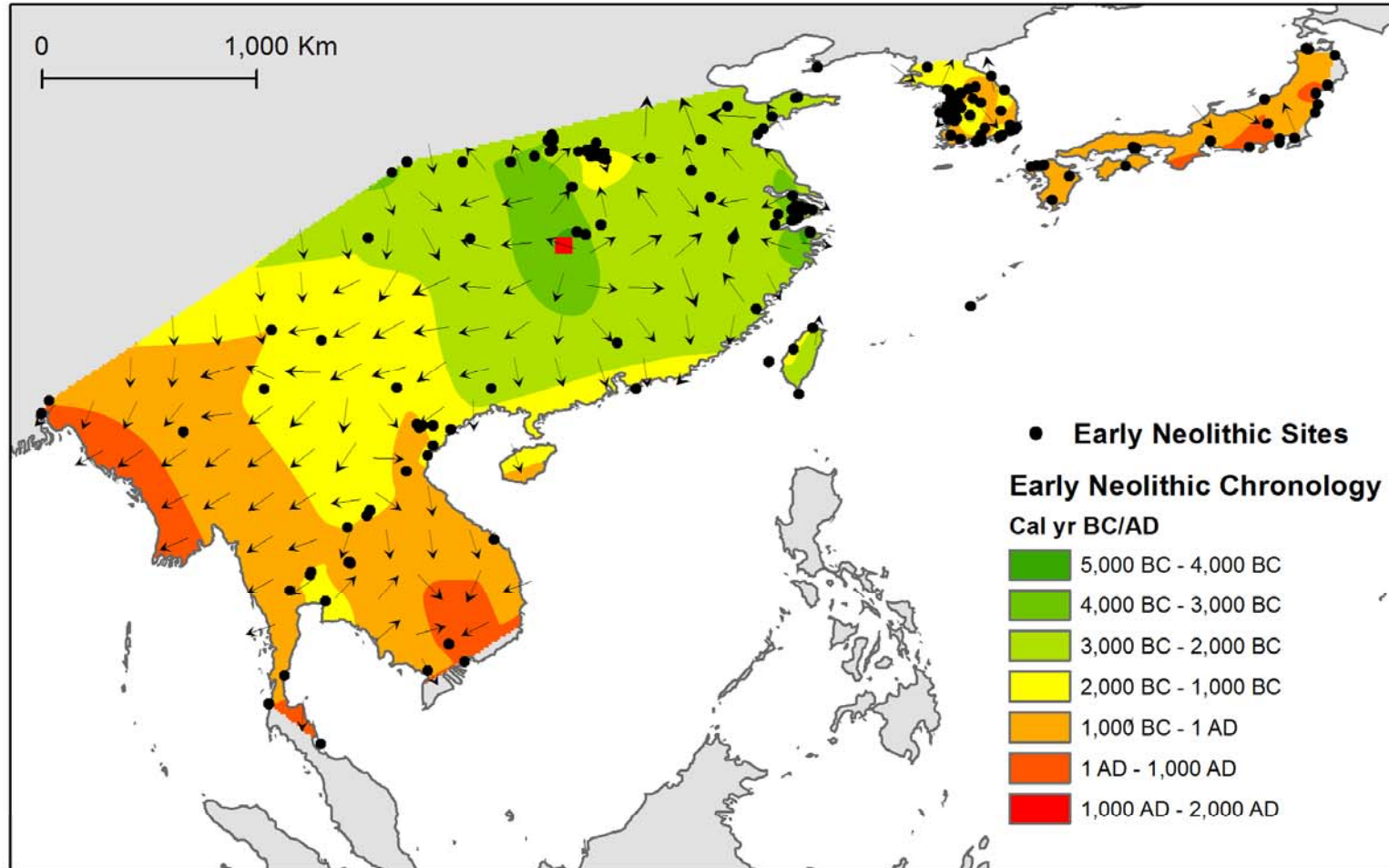
First law

"The Neolithic usually spreads inland at a rate of **about 1 km/yr**, but there is substantial variation (**0.4-3.6 km/yr**)."

1. Europe: 0.9-1.3 km/yr → OK
2. Bantu - South: 1.3-2.5 km/yr → OK
3. Bantu - East: 0.5-1.5 km/yr → OK

(all ranges with 95% CL)

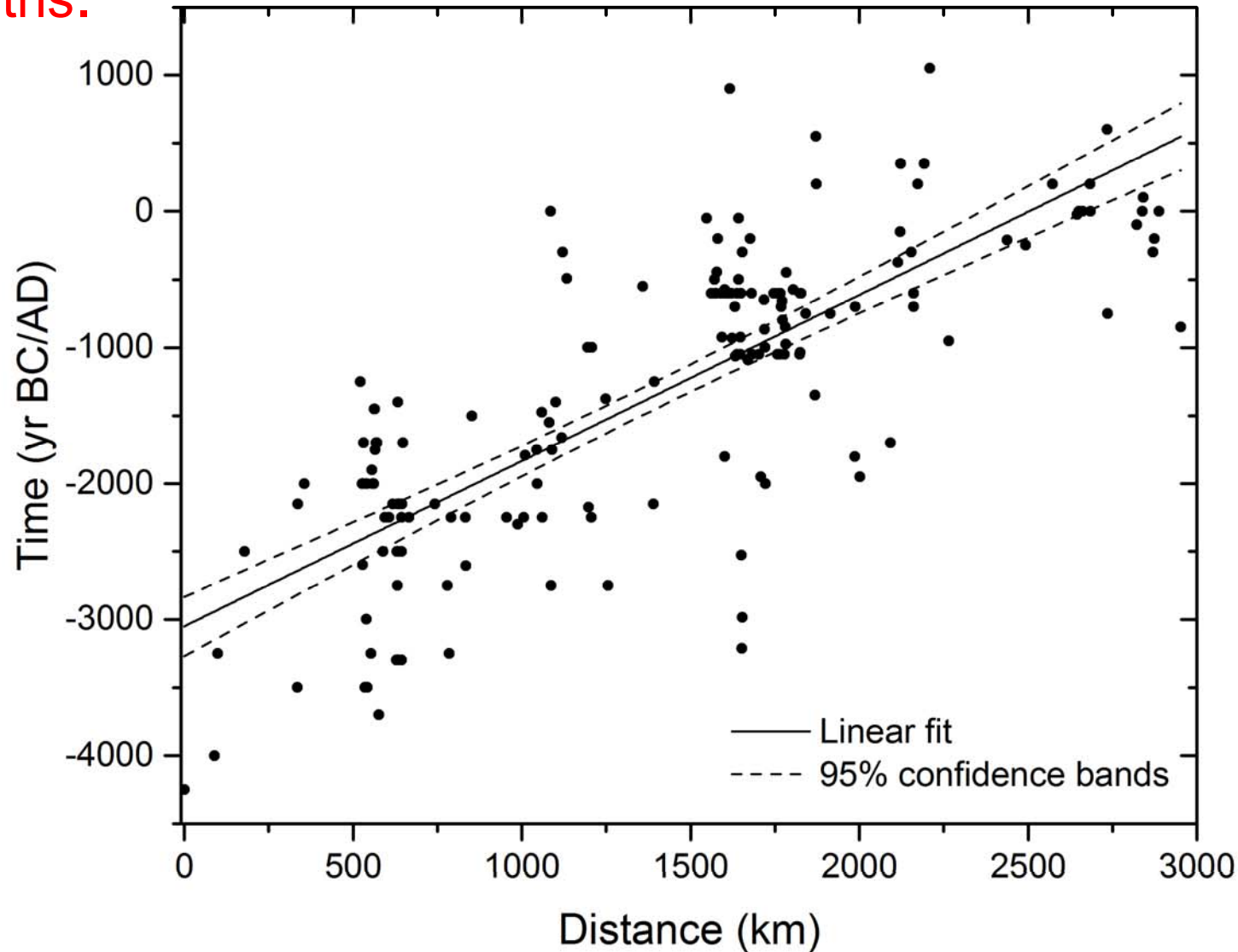
Spread of domesticated rice in China and southeastern Asia



Cobo, Fort & Isern, *J. Arch. Sci.* (2019)

Data from Silva et al., *PLoS One* (2015) [updated database of Fuller et al., *The Holocene* (2011)]

speed=0.72-1.28 km/yr (95% CL), $r=0.76$. Dates vs distances.
Range obtained by combining great circles (this plot) & shortest paths.



Great circle distance from Chegtoushan (China), which is the highest-r site.

Hemudu and nearby sites neglected (it is possibly an independent domestication center)

Cobo, Fort & Isern, *J. Arch. Sci.* (2019)

First law

"The Neolithic usually spreads inland at a rate of **about 1 km/yr**, but there is substantial variation (**0.4-3.6 km/yr**)."

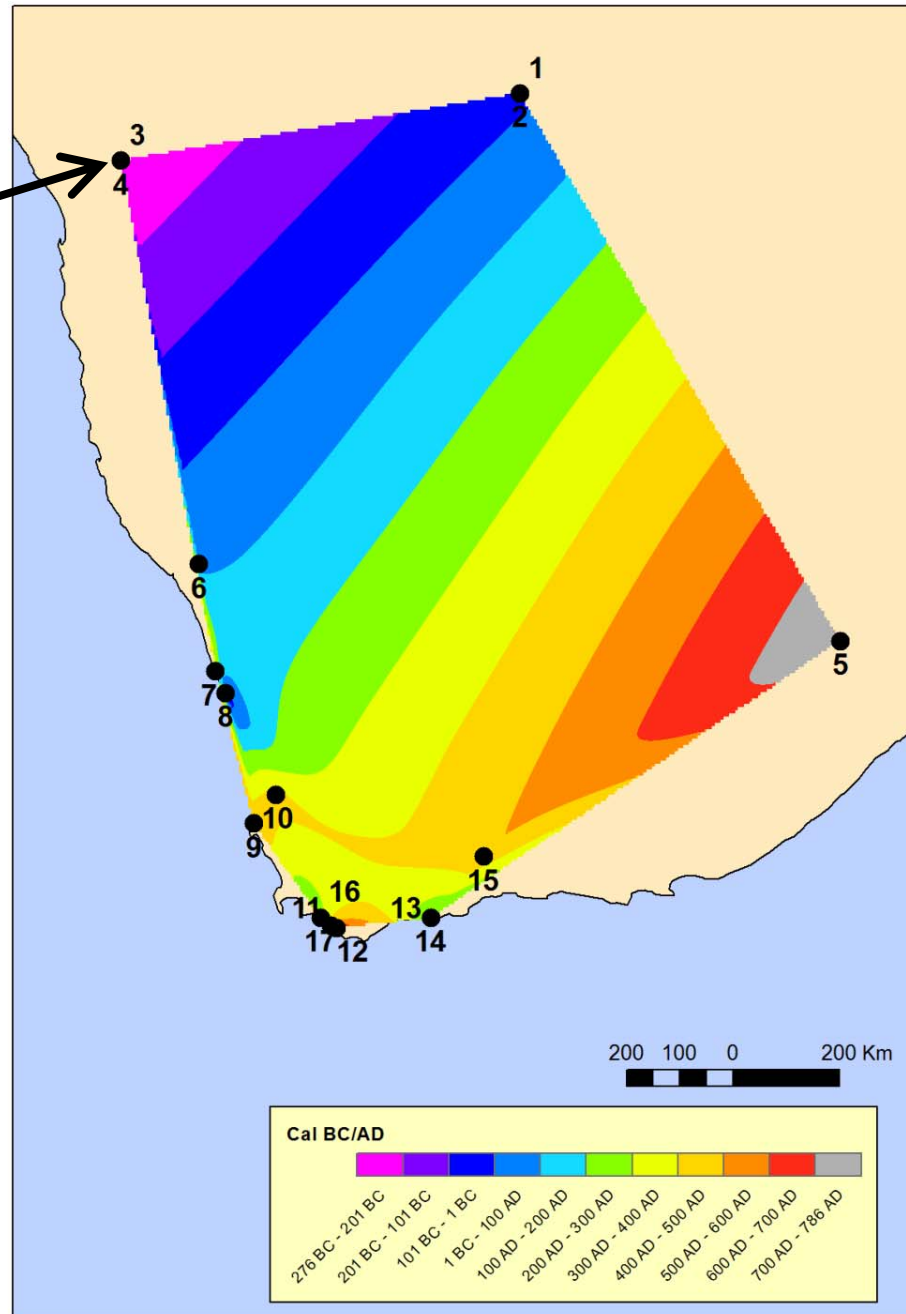
1. Europe: 0.9-1.3 km/yr → OK
2. Bantu - South: 1.3-2.5 km/yr → OK
3. Bantu-East: 0.5-1.5 km/yr → OK
4. Rice - China, etc.: 0.7-1.3 km/yr → OK

(all ranges with 95% CL)

Spread of the Neolithic in southern Africa

Oldest site
(Leopard
cave,
Namibia)

*Some sites
have two
dates (e.g.,
1-2, 3-4,
etc.) In
these cases
we use the
oldest one.*

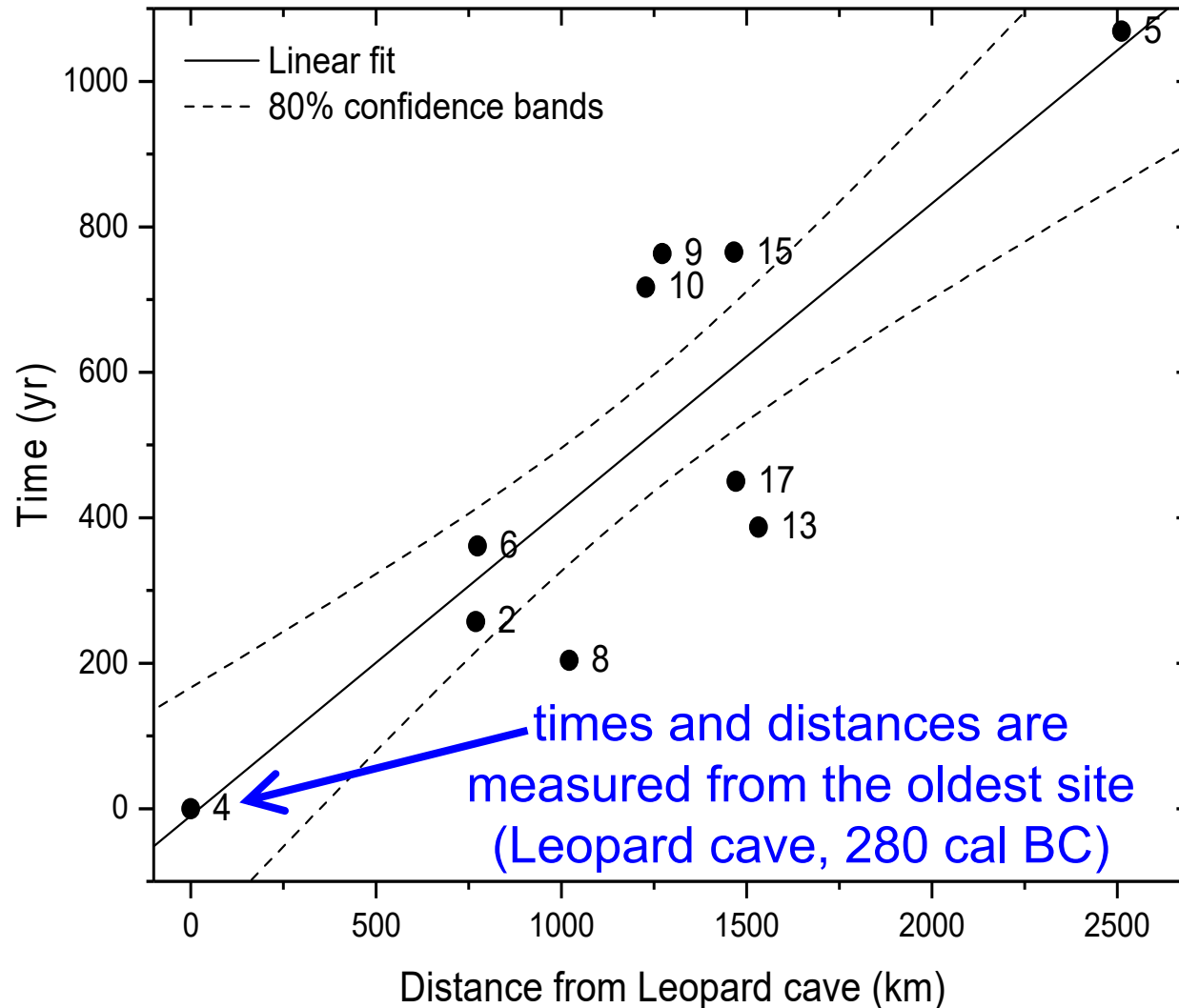


Spread of
Khoi-khoi
herders

Jerardino,
Fort,
Isern, Rondelli,
PLoS One (2014)

Spread of the Neolithic in southern Africa

speed= 1.2-3.6 km/yr (95% CL), $r = 0.85$



Great-circle distances except for site 5 (shortest path through site 17)

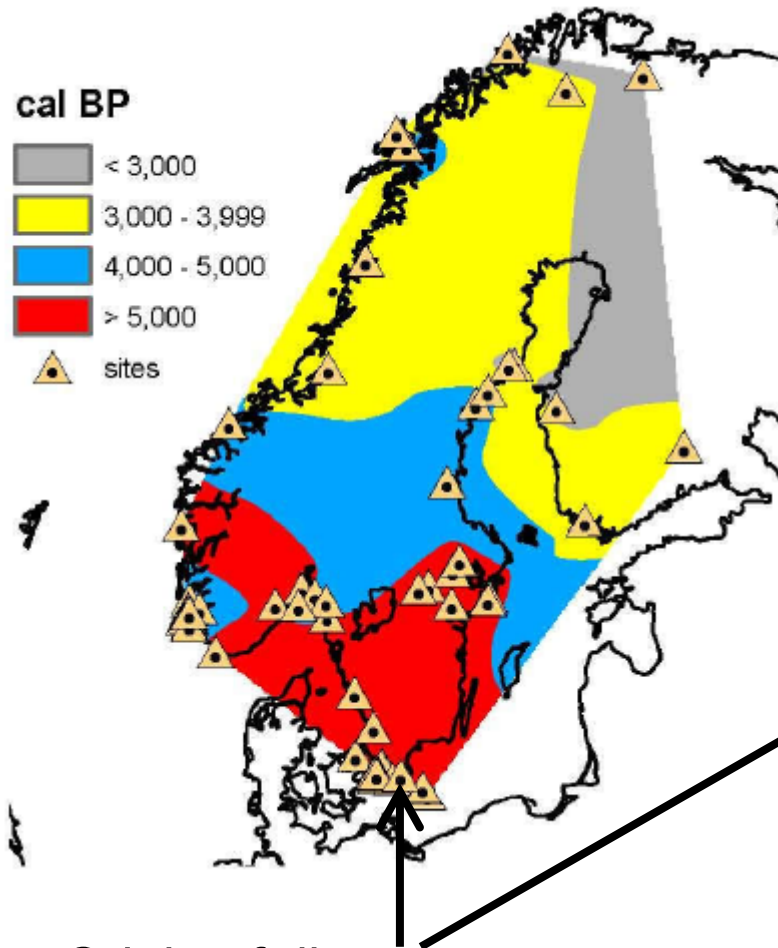
First law

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5. Khoi-khoi: 1.2-3.6 km/yr → OK

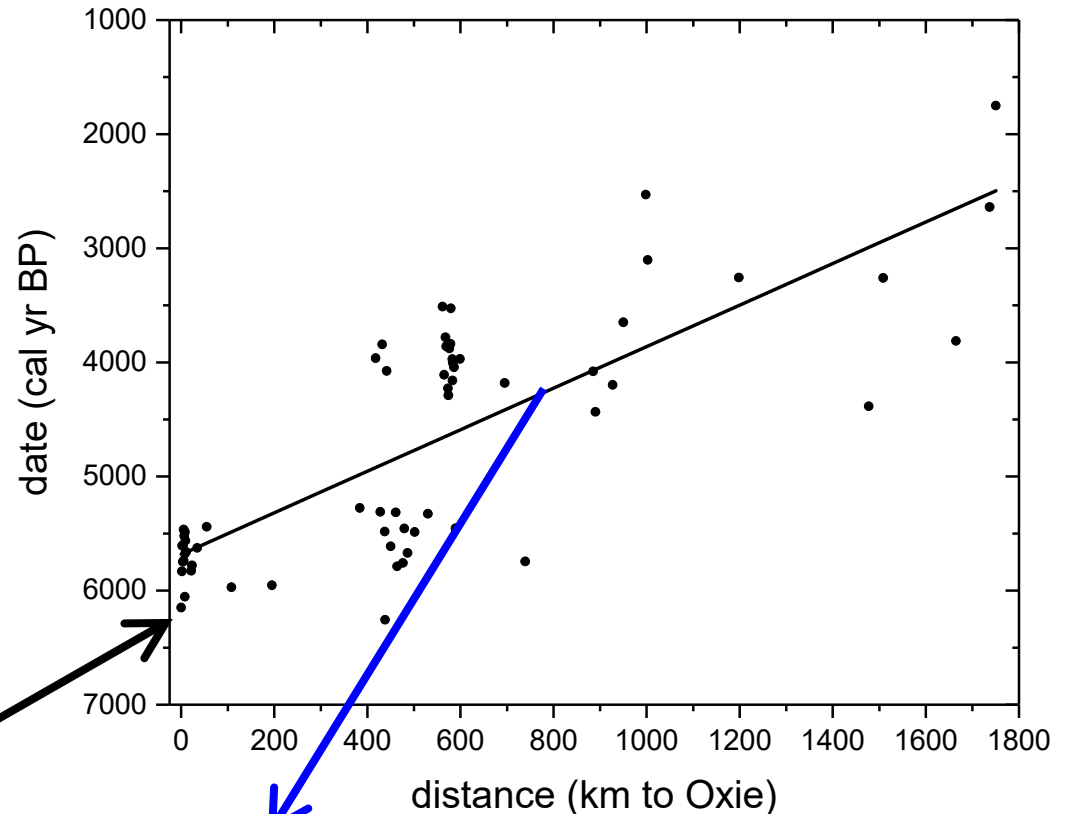
(all ranges with 95% CL)

Spread of the Neolithic in Scandinavia



Origin of distances:
Oxie (oldest site in
southern Sweden)

Fort, Pareta & Sørensen,
J. R. Soc. Interface (2018)



0.44-0.84 km/yr (95% CL)

combing great circles (this plot,
0.44-0.66 km/yr, $r=0.77$) and shortest
paths (due to landscape and
vegetation: google maps, path by foot,
0.56-0.84 km/yr, $r=0.78$)

First law

"The Neolithic usually spreads inland at a rate of **about 1 km/yr**, but there is substantial variation (0.4-3.6 km/yr)."

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3. Bantu-East: 0.5-1.5 km/yr → OK
4. Rice - China, etc.: 0.7-1.3 km/yr → OK
5. Khoi-khoi: 1.2-3.6 km/yr → OK
6. Scandinavia: 0.4-0.8 km/yr → OK

(all ranges with 95% CL)

First law

Other authors have reported spread rates for additional case studies that also agree with this law:

7. Near-Eastern Neolithic across southern Asia [1, 2]

8. Balkans [3]

9. LBK (Linearbandkeramik) [4, 5]

10. TRBK (Trichterbeckerkultur) [4, 5]

11. Painted Pottery [4, 5]

12. Saladoid-Barrancoid expansion (tropical South America) [6]

13. Incised-punctuate expansion (tropical South America) [6]

14. Dispersal of rice farming in Japan [7]

[1] Galal *et al.*, *PLoS One* (2014); [2] de Souza *et al.*, *PLoS One* (2022); [3] Porcic *et al.*, *J. Arch. Sci. Rep.* (2020); [4] Bocquet-Appel *et al.*, *J. Arch. Sci.* (2012); [5] Fort & Pareta, *J. Arch. Sci.* 2020; [6] de Souza *et al.*, *PLoS One* (2020); [7] Crema *et al.*, *Sci. Adv.* (2022).

Second law

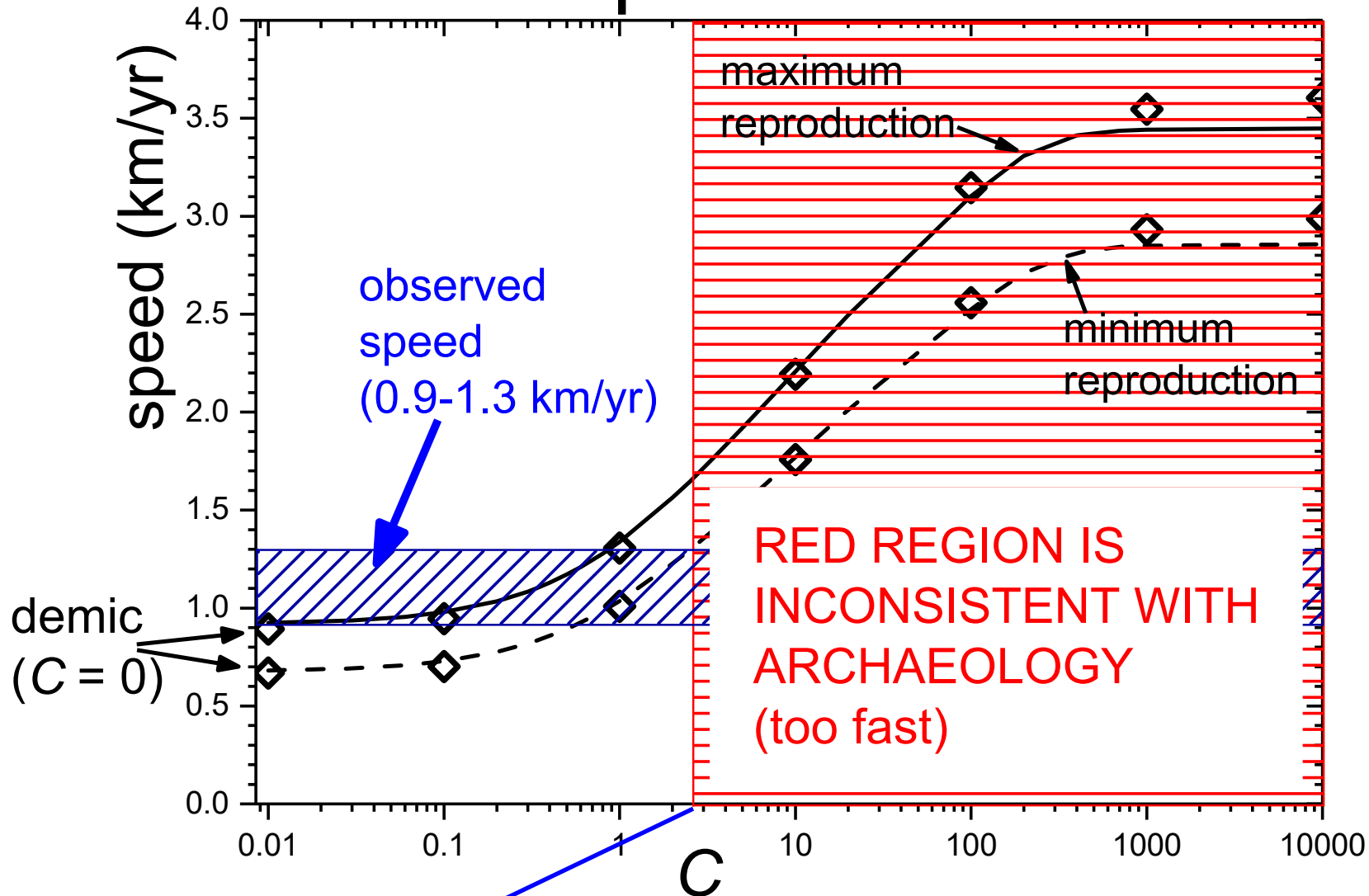
"When in addition to demic diffusion there is substantial cultural diffusion, Neolithic spread rates are faster."

This law has support from mathematical models (the next slide shows an example)

Neolithic in Europe

— equations

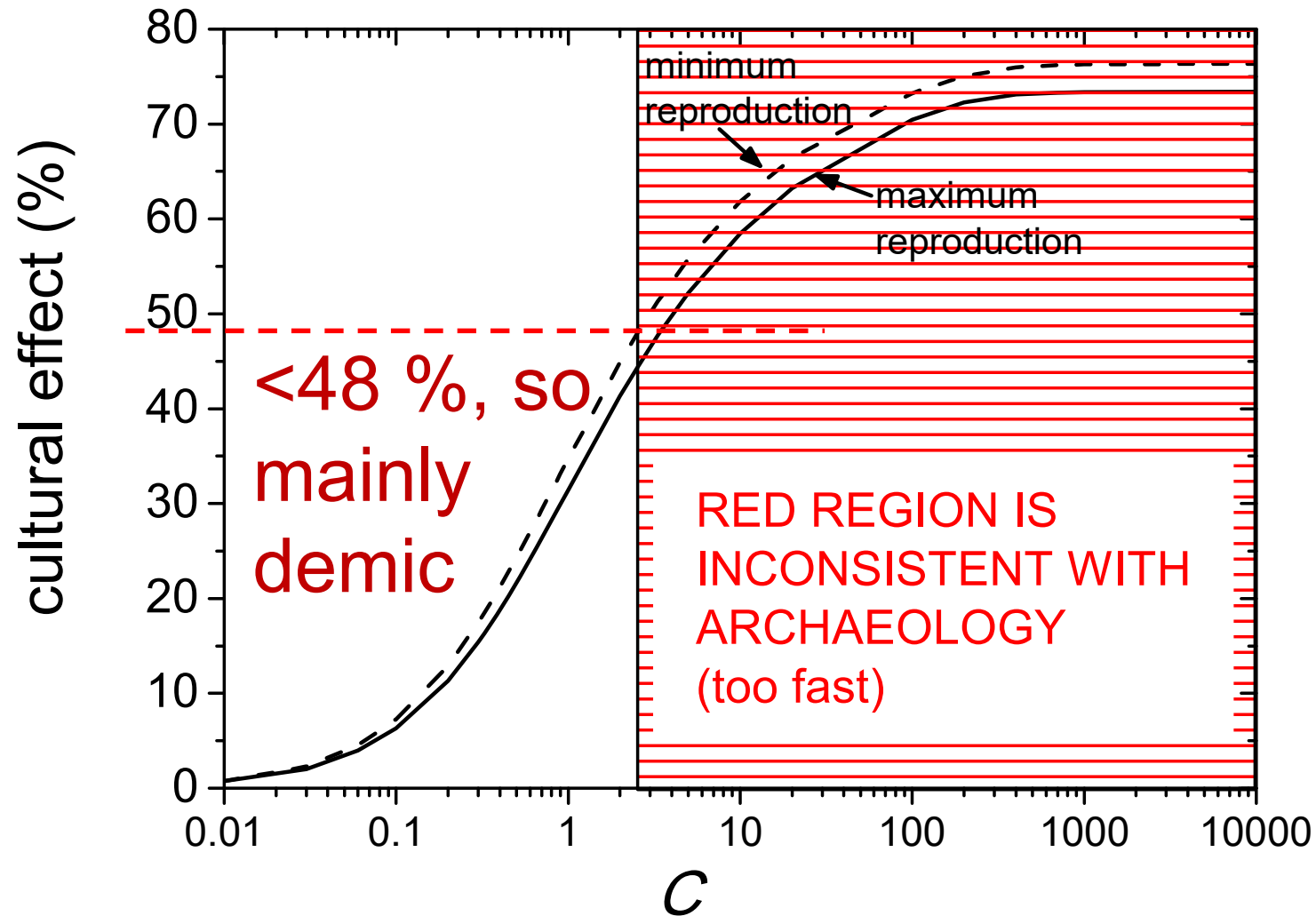
◇ simulations



Fort,
PNAS
(2012)

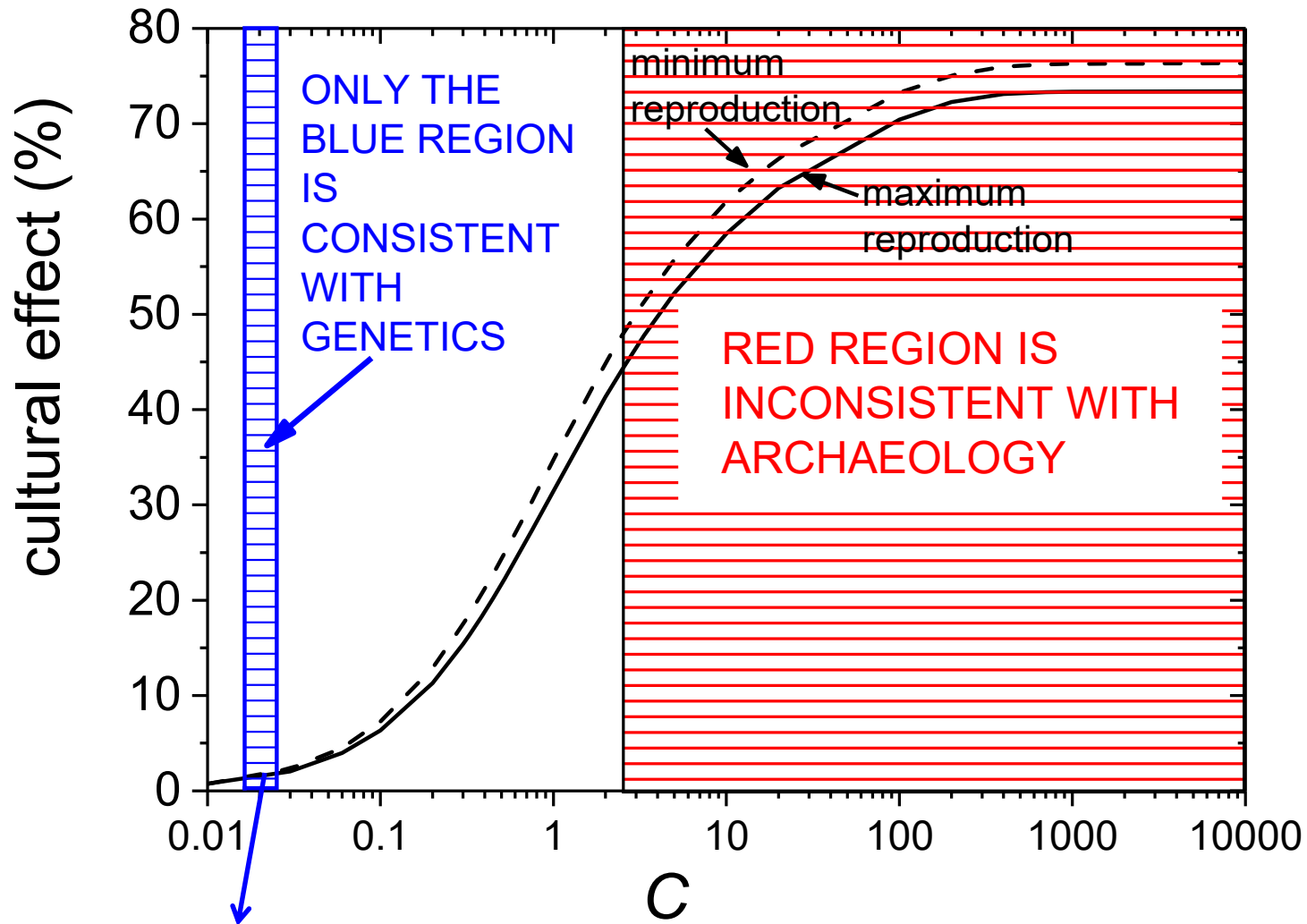
$C < 3$, so less than 3 HGs were converted per F per generation

Cultural effect (%) = (speed – demic speed) / speed · 100



Fort,
PNAS
(2012)

$$\text{Effect (\%)} = (\text{speed} - \text{demic speed}) / \text{speed} \cdot 100$$



Fort,
PNAS
(2012);

Fort,
Human Popul. Genet. Genom
(2022)

cultural effect of only 2%, so demic >> cultural

Second law

"When in addition to demic diffusion there is substantial cultural diffusion, Neolithic spread rates are faster."

The two fastest expansions (in red) are precisely those for which some authors* have proposed that cultural diffusion was important.

1. Europe: 0.9-1.3 km/yr
- 2. Bantu - South: 1.3-2.5 km/yr**
3. Bantu-East: 0.5-1.5 km/yr
4. Rice - China, etc.: 0.7-1.3 km/yr
- 5. Khoi-khoi: 1.2-3.6 km/yr**
6. Scandinavia: 0.4-0.8 km/yr

Are their claims valid? Ancient DNA will tell !!

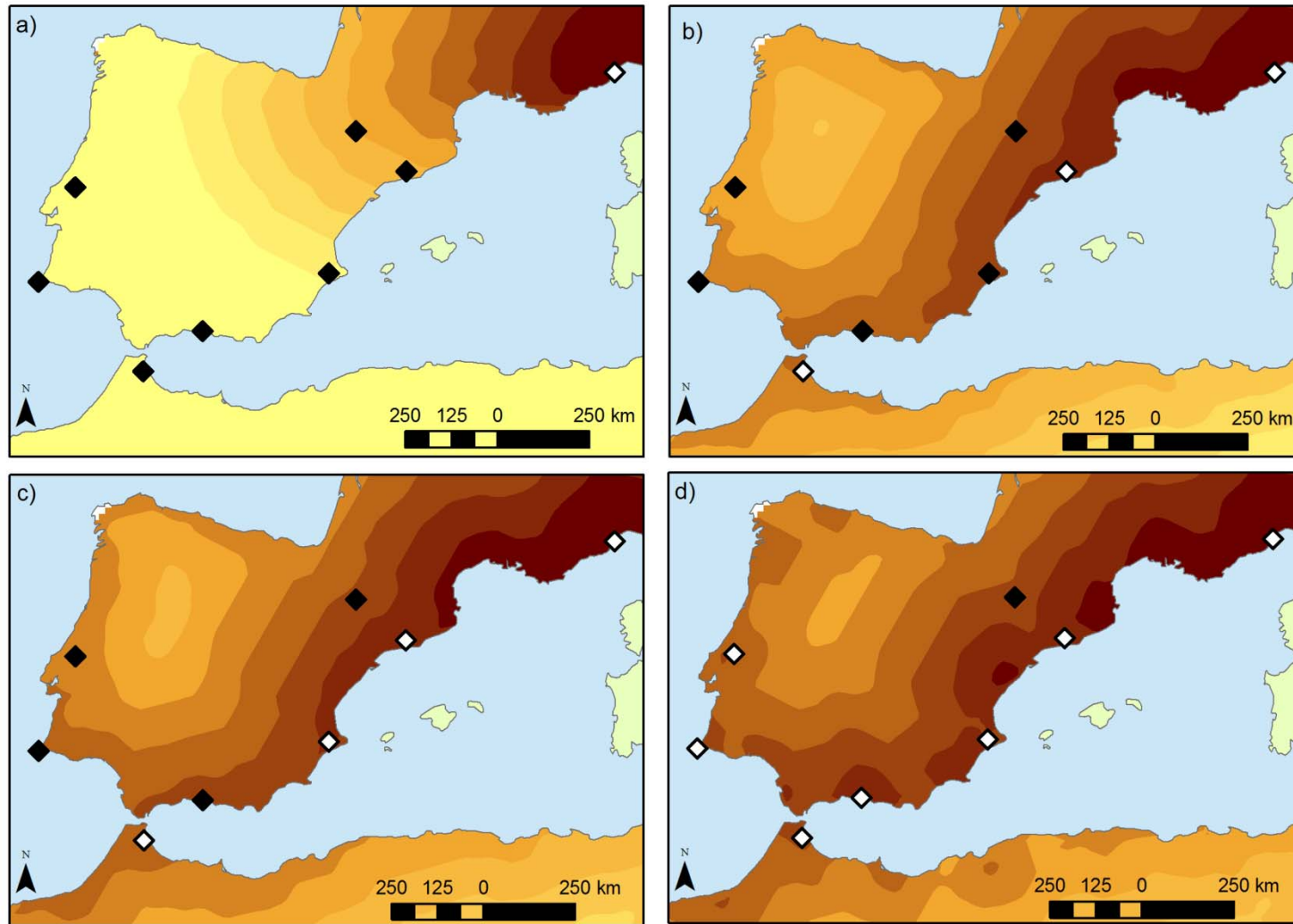
* Ehret, *An African classical age* (1998); Diamond & Bellwood, *Science* (2003).

Third law

"Neolithic spread rates over the sea can take place substantially faster, at about 10 km/yr."

- In the next slides, we analyze the data available for the western Mediterranean.
- The data for Austronesia also support this law, but there are few data and only the lower bound of 8 km/yr is known [Fort, *Antiquity* (2003)].

The western Mediterranean



a) inland travel only.

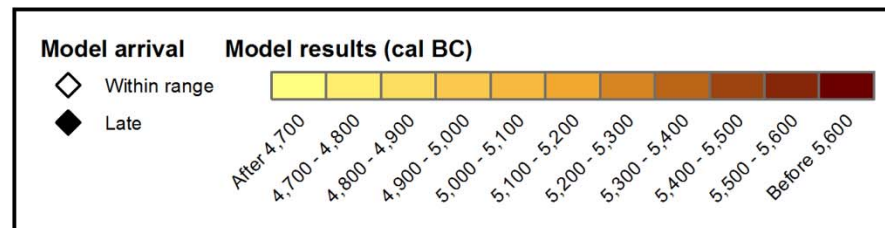
b)-d) also coast travel **up to 350 km** per generation.

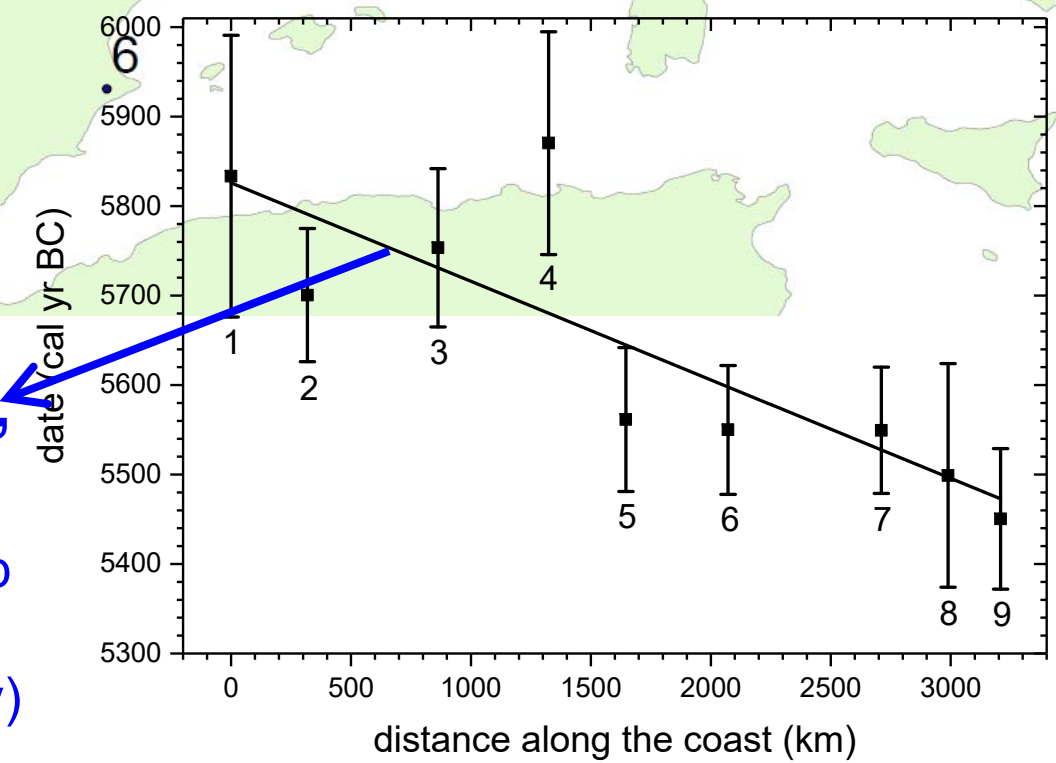
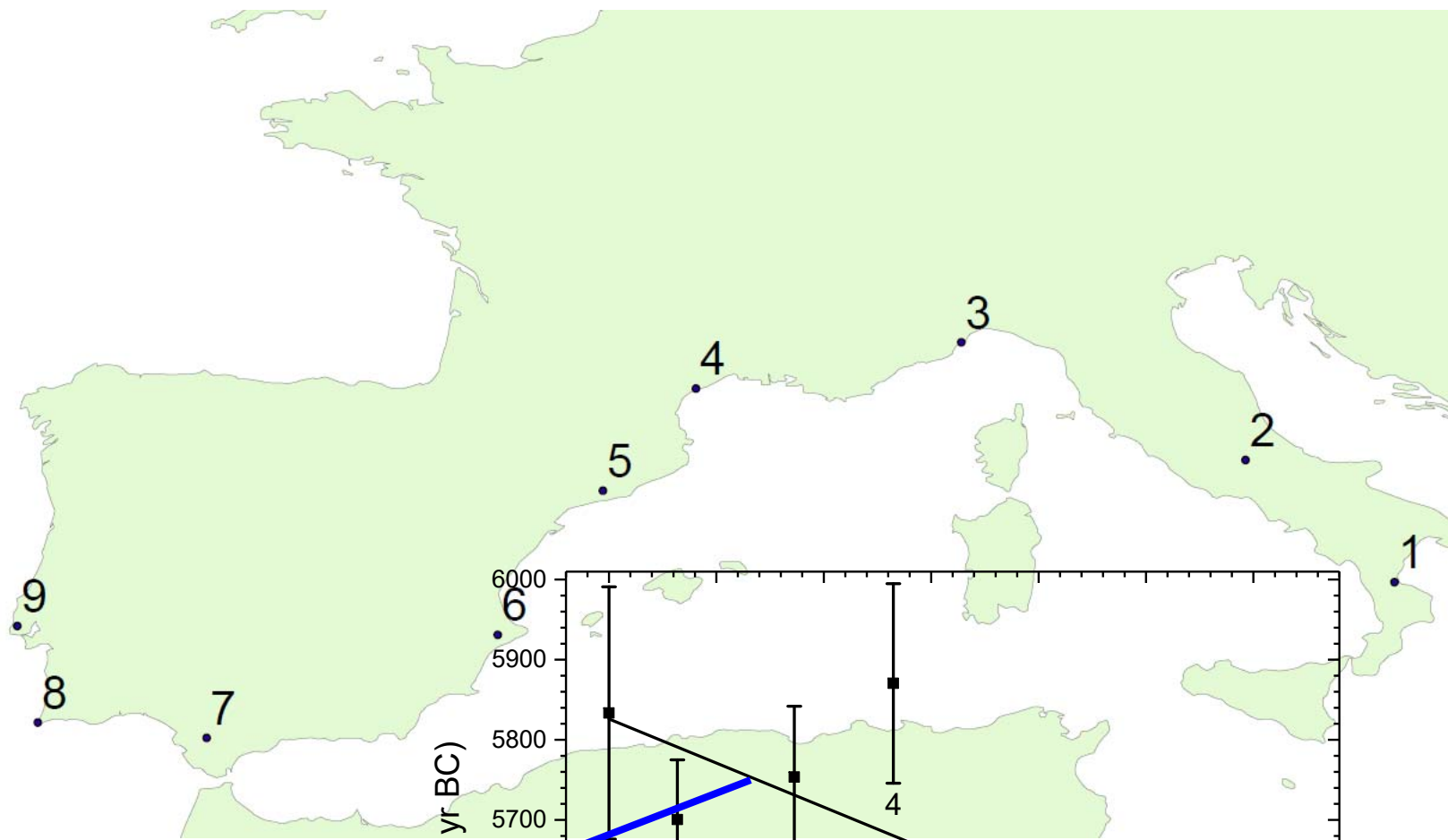
b) nearer distances more probable

c) all distances equally probable

d) **all coast travels of 350 km**

Isern, Zilhao,
Fort & Ammerman,
PNAS (2017)



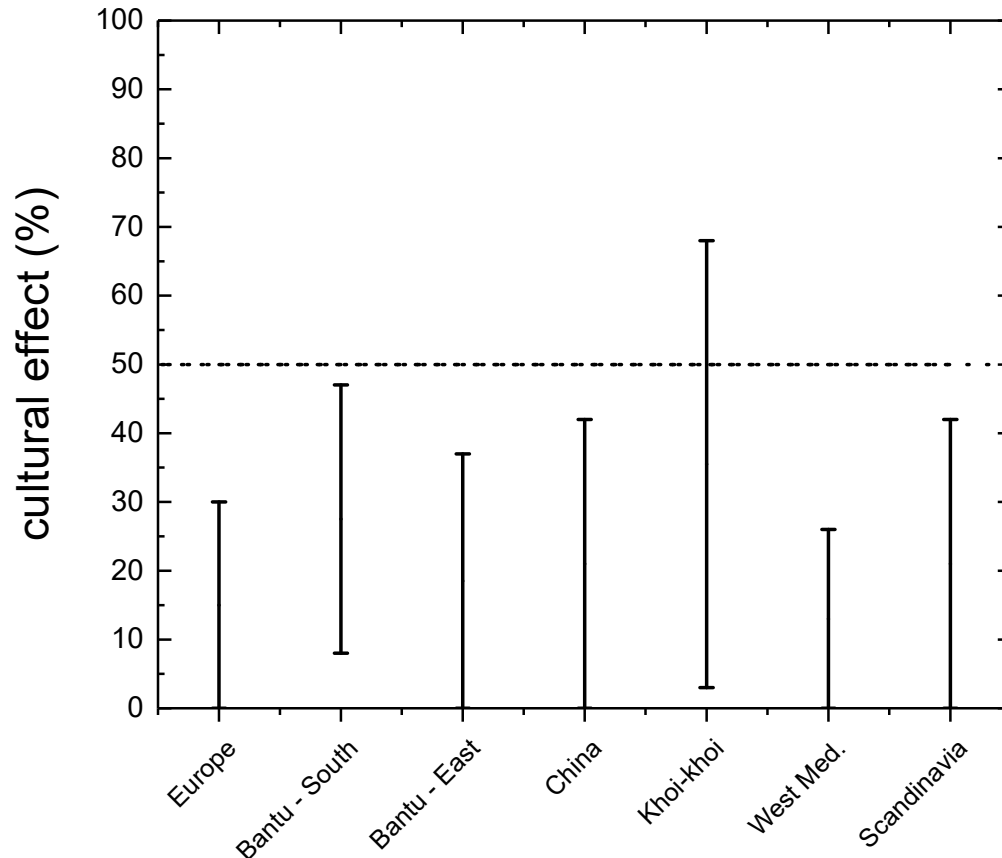


7.5-10.6 km/yr,
 $r = 0.84$
 (80% CL by bootstrap
 using the calibrated
 distribution probability)

*Fort, Arch.
 Anthropol.
 Sci. (2022)*

Fourth law

" Most inland and coastal Neolithic spreads are mainly demic."



This figure includes 7 case studies [1] but this law is consistent with 15 case studies: 14 listed above (first law) + the western Mediterranean.

Note that the Khoi-khoi expansion might have been mainly cultural. Another possible exception may be the spread of maize in America [2].

[1] J. Fort, The spread of agriculture: general laws in prehistory? *in Simulating transitions to agriculture in prehistory*, eds. S. Pardo-Gordó & S. Bergin (Springer, Cham, 2021), p. 17-28.

[2] Fort, Kohler & Blake, in preparation.

Fifth law

"Neolithic spread rates tend to become slower at higher latitudes"

1. Europe: 0.9-**1.3** km/yr
2. Bantu - South: 1.3-**2.5** km/yr
3. Bantu-East: 0.5-**1.5** km/yr
4. Rice - China, etc.: 0.7-**1.3** km/yr
5. Khoi-khoi: 1.2-**3.6** km/yr
- 6. Scandinavia: 0.4-0.8** km/yr

Another result supports this law:

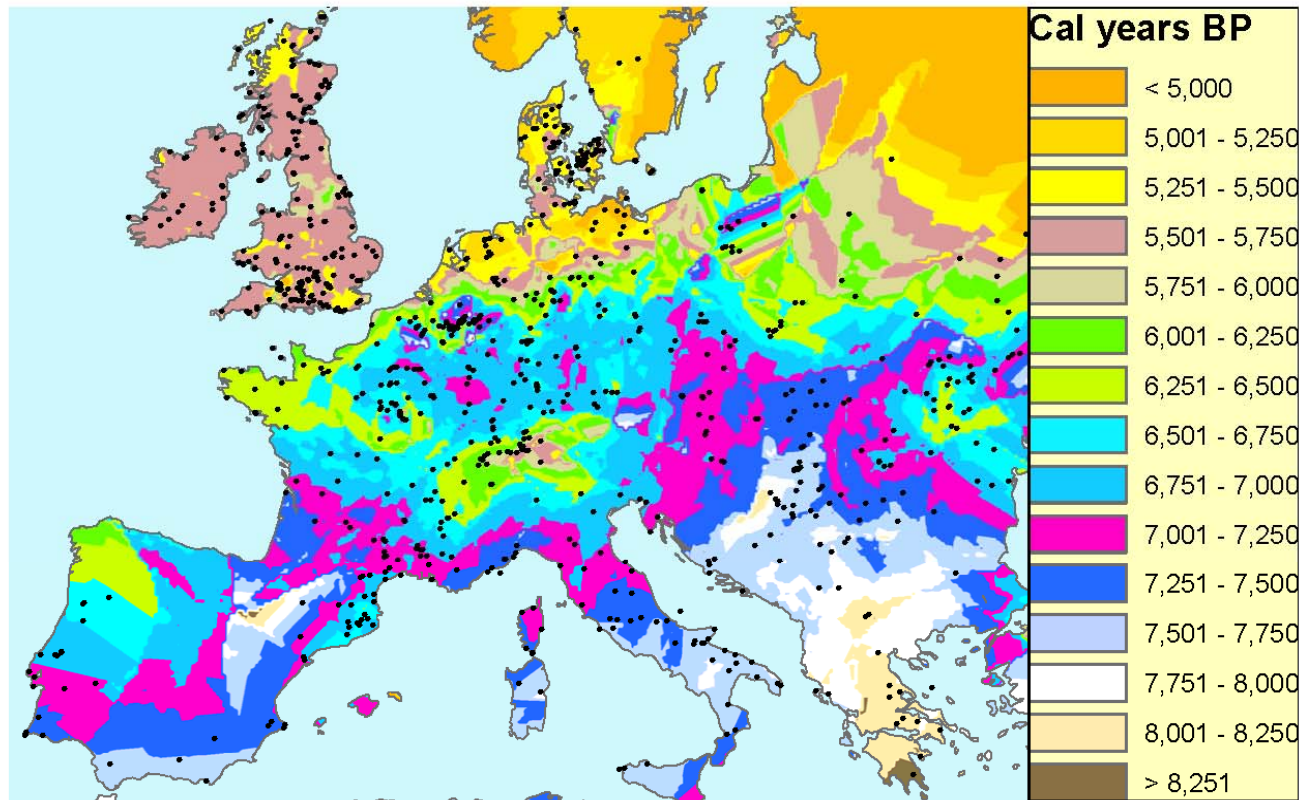
Northern Europe*: 0.2-0.5 km/yr

More case studies are needed!

*Austria, Czech Rep., Germany & Netherlands, see Isern, Fort & vander Linden, *PLoS One* (2012)

Sixth law

"The Neolithic spreads later and more slowly at higher altitudes above sea level."



Fort,
*J. R. Soc.
Interface*
(2015)

More case studies are needed!

Questions?

