The spread of maize cultivation in America: quantitative analyses

Joaquim Fort, *Univ. Girona & ICREA*
Tim A. Kohler, *Washington State Univ. & Santa Fe Inst.*
Michael Blake, *Univ. British Columbia*

EAA annual meeting
Univ. Barcelona, 7 Sept. 2018
Dedicated to the memory of Luca Cavalli-Sforza

Database: ancient maize map

(http://en.ancientmaize.com)

174 sites, 704 samples. Compiled by M. Blake.

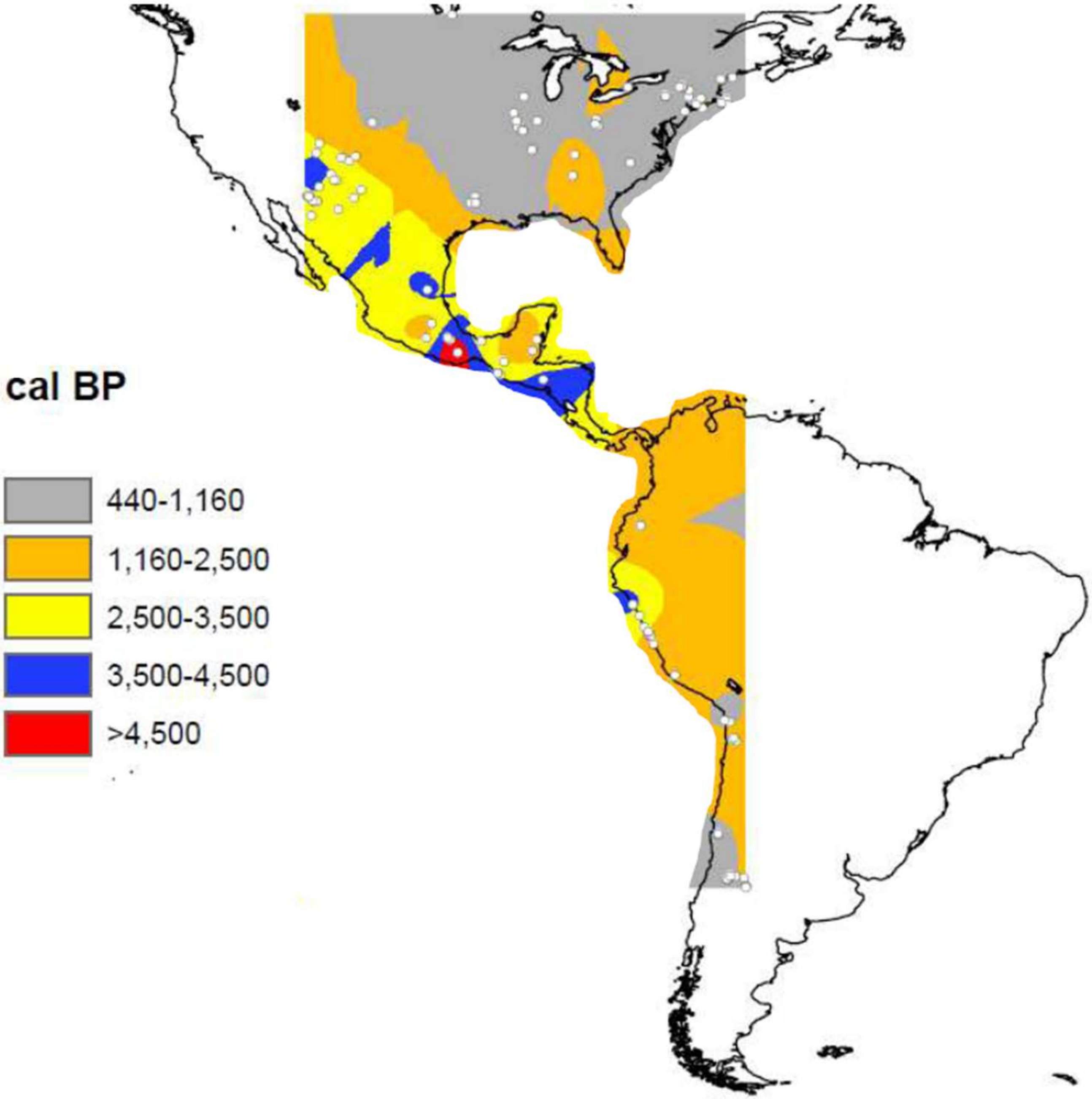
We consider only the oldest maize macro-remains directly dated using AMS or conventional 14C methods.

We exclude:

· all indirectly dated samples→we exclude all microremains.

· all samples with evidence of contamination.

This yields <u>116 sites</u>


cal BP
440-1,160
1,160-2,500
2,500-3,500
3,500-4,500
>4,500

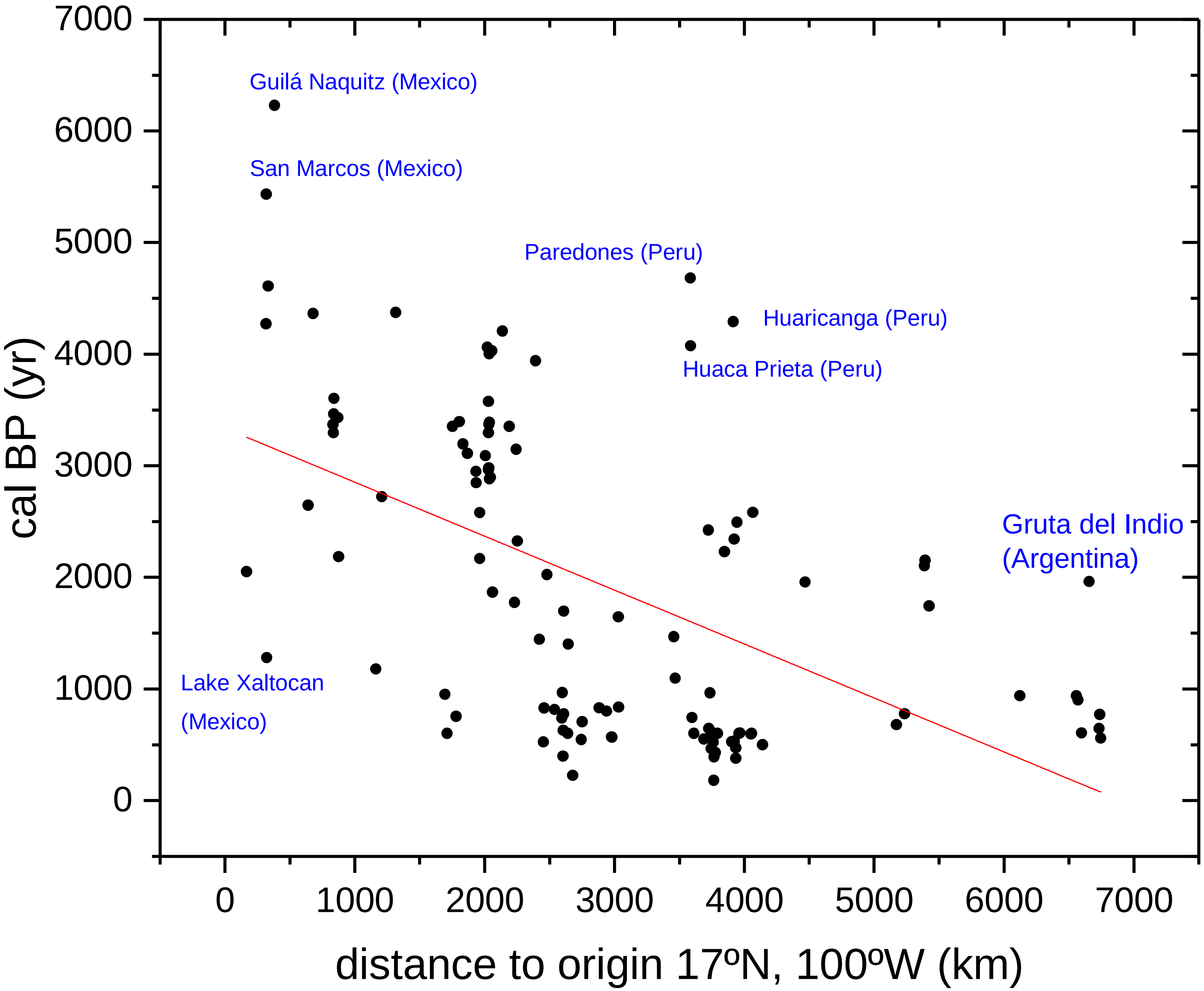
Demic or cultural diffusion?

- Demic diffusion refers to the spread of populations of maize cultivators.
- Cultural diffusion refers to the incorporation of other people into the populations of maize cultivators, via acculturation or interbreeding.
- A demic-cultural mathematical model (Fort, *PNAS* 2012) makes it possible to estimate the % of demic diffusion and the % of cultural diffusion, if we know the spread rate.
- To estimate the spread rate, first we tried using an origin at 17ºN, 100ºW (in the Río Balsas area).

Using all 116 dates

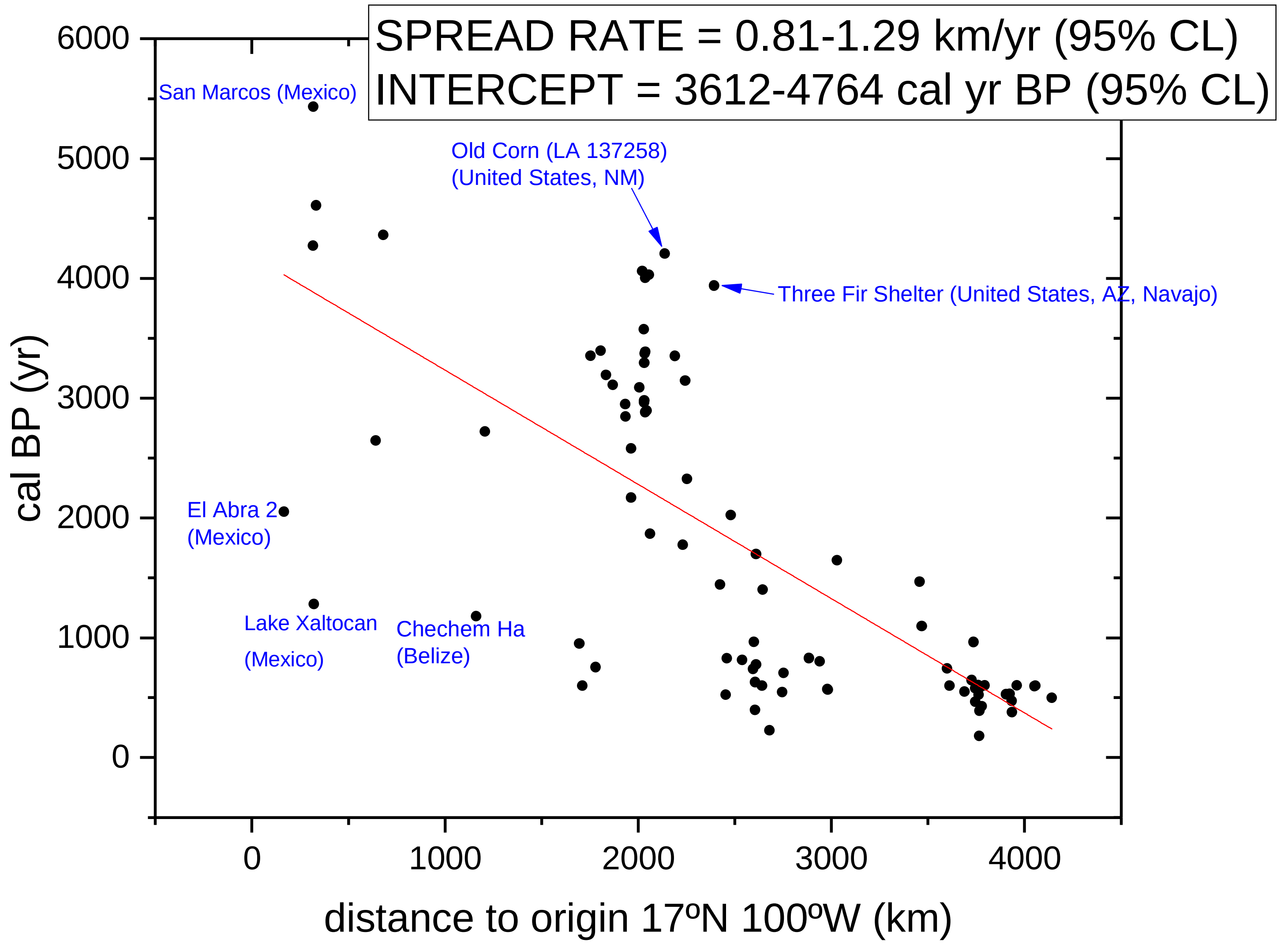
R=0.54

116 dates (all of them on macrosamples)



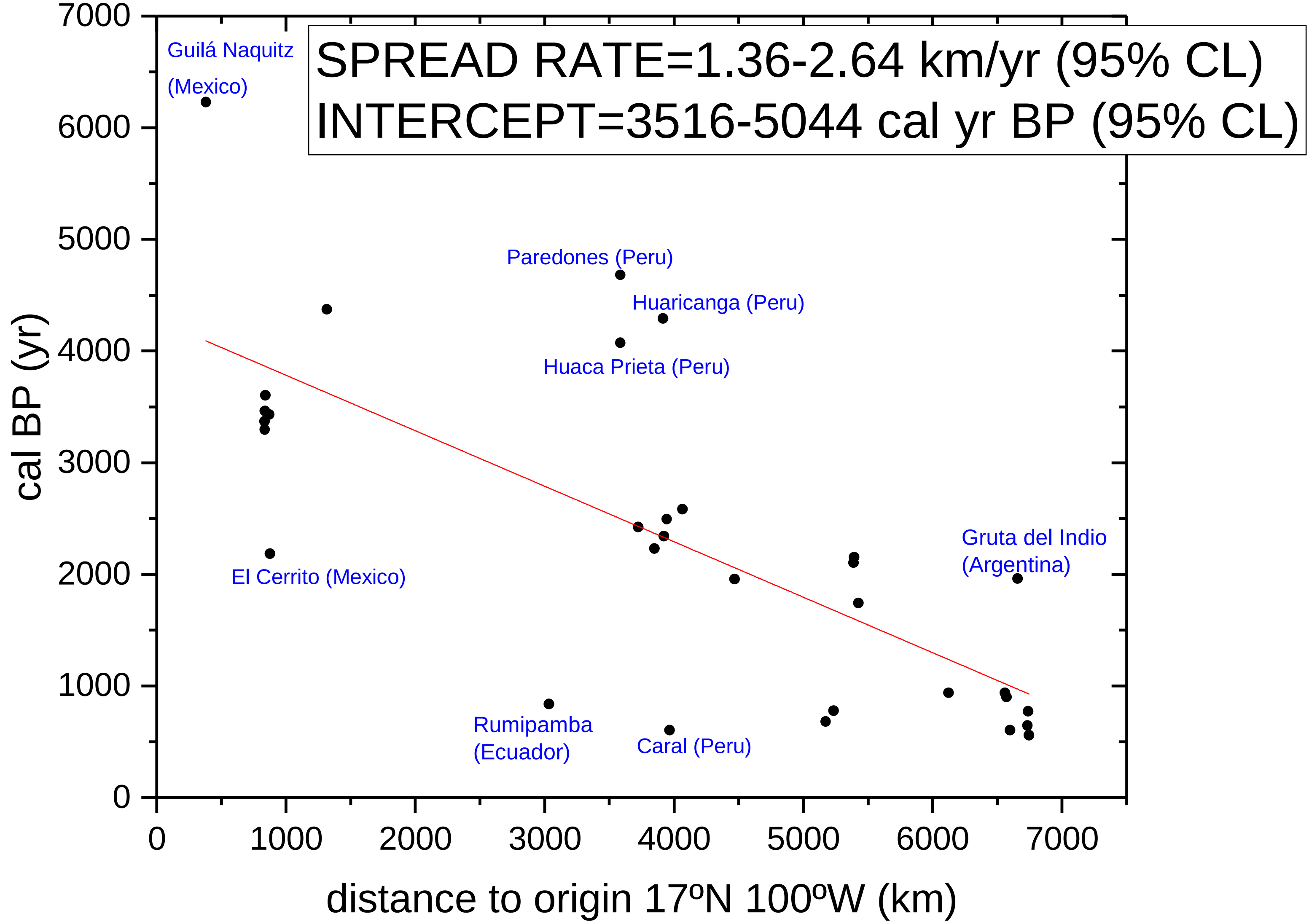
84 dates to the North

spread to the North R=0.71 84 dates (all on macrosamples)


SPREAD RATE = 0.81-1.29 km/yr (95% CL)
INTERCEPT = 3612-4764 cal yr BP (95% CL)

There are only 32 dates to the South

spread to the South R=0.73 32 dates (all on macrosamples)



Intercepts (95% CL)

- spread to the North: 3612- 4764 cal yr BP
- spread to the South: 3516 - 5044 cal yr BP

Both ranges overlap widely→the intercepts are essentially the same.

This suggests a common origin for the spreads to the North and South, both in space and time.

- These results are for an origin at 17°N, 100°W.
- The intercepts strongly suggest a common origin→we look for the origin that maximizes the average of the R values to the North and South.
- Next we consider possible origins only in the state of Oaxaca (Mexico) for 3 reasons:

  (1) If we include other regions, the maximum r is at the US border. This makes no sense, since sites there are much later than in Oaxaca. Presumably this is a geographical effect, due to the presence of the Oceans.

  (2) Oaxaca contains the oldest maize site (Guilá Naquitz cave, dated 6229 cal BP); and

  (3) the closest wild relative of maize (*Zea mays* ssp. *parviglumis*) grows in Oaxaca today.

- Best origin: 17°N, 98°W: r=0.67 North, r=0.73 South.

Origin at 17ºN, 98ºW

Intercepts (95% CL)

spread to the North: 3491- 4727 cal yr BP

spread to the South: 3439 - 4907 cal yr BP

Again they overlap widely→common origin.

Spread rates (95% CL)

spread to the North: 0.82-1.32 km/yr

spread to the South: 1.35-2.75 km/yr

Almost same as for the former origin → same conclusions (in the following slides).

Demic or cultural diffusion?

Now that we have found the spread rate from archaeological data, we can compare to the demic-cultural wave-of-advance model (Fort, *PNAS* 2012).

For completeness, we summarize the eqs. in the following slide, but they are not necessary (simulations on a grid give the same results).

$F(x,y,t) =$ population density of farmers.

$$F(x,y,t+T) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \tilde{F}(x+\Delta_x, y+\Delta_y, t)\,\phi_F\left(\Delta_x,\Delta_y\right)d\Delta_x\,d\Delta_y$$

where $\phi_F\left(\Delta_x,\Delta_y\right)$ is the probability to disperse distances $\left(\Delta_x,\Delta_y\right)$ and

$$\tilde{F}(x,y,t) \equiv R_T[F(x,y,t)] + f\,\frac{R_T[F(x,y,t)]R_T[H(x,y,t)]}{R_T[F(x,y,t)] + \gamma\,R_T[H(x,y,t)]}$$

where the last term corresponds to cultural transmission,

and R_T stands for logistic reproduction, i.e.:

$$R_T[F(x,y,t)] = \frac{e^{a_F T}\,K_F\,F(x,y,t)}{K_F + (e^{a_F T}-1)\,F(x,y,t)}$$

Similar equations hold for the hunter-gatherers $H\,(x,y,t)$.

Fort, *PNAS* 2012

In this model the spread rate is

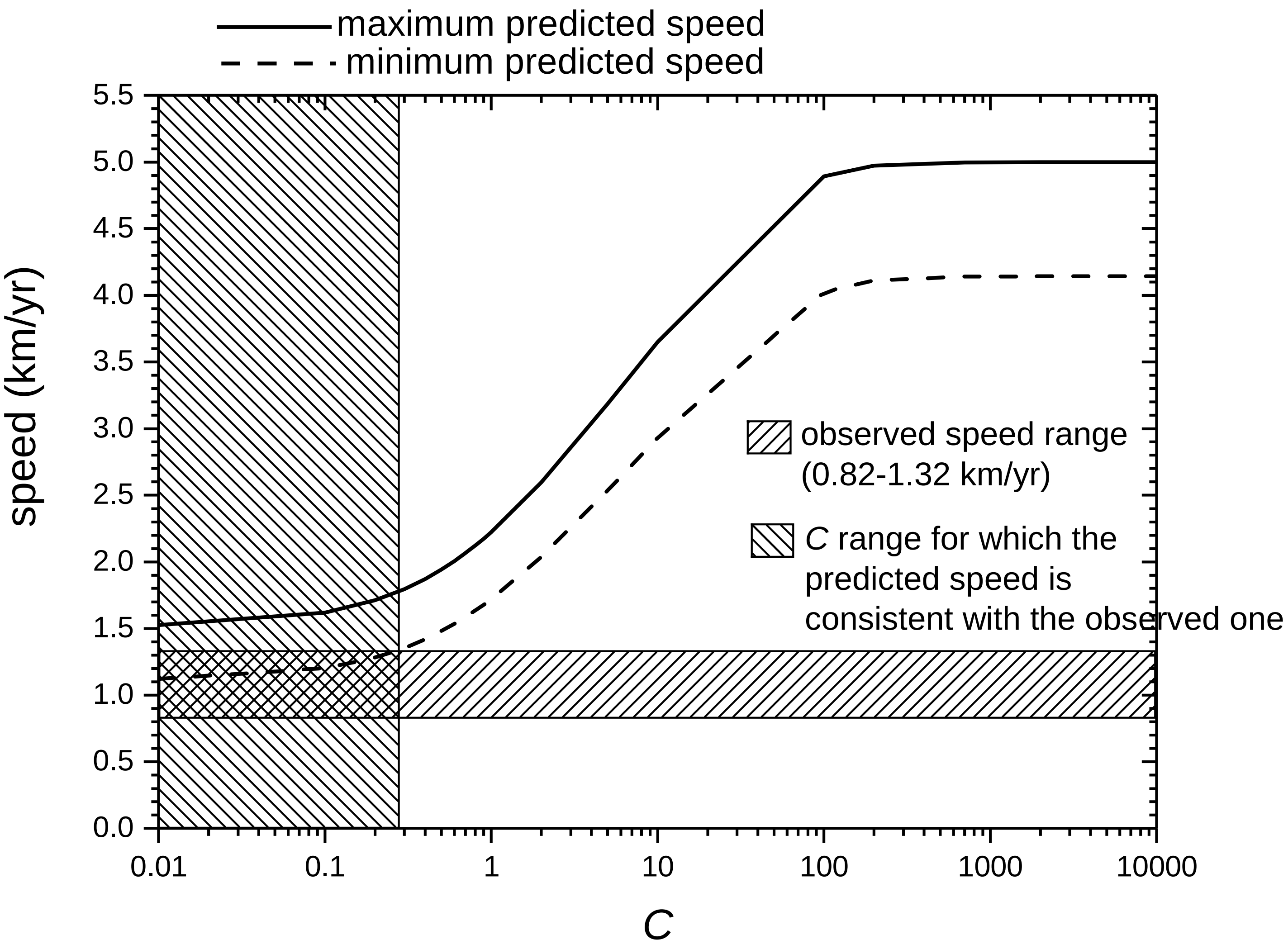
$$\text{spread rate} = \min_{\lambda > 0} \frac{a_F\, T + \ln\left[(1 + C)\left(\sum_{j=1}^{M} p_j\, I_0(\lambda r_j)\right)\right]}{T\lambda}$$

where $C = \frac{f}{\gamma}$ is the intensity of cultural transmission, i.e. the number of hunter-gatherers that become farmers per pioneering farmer and generation.

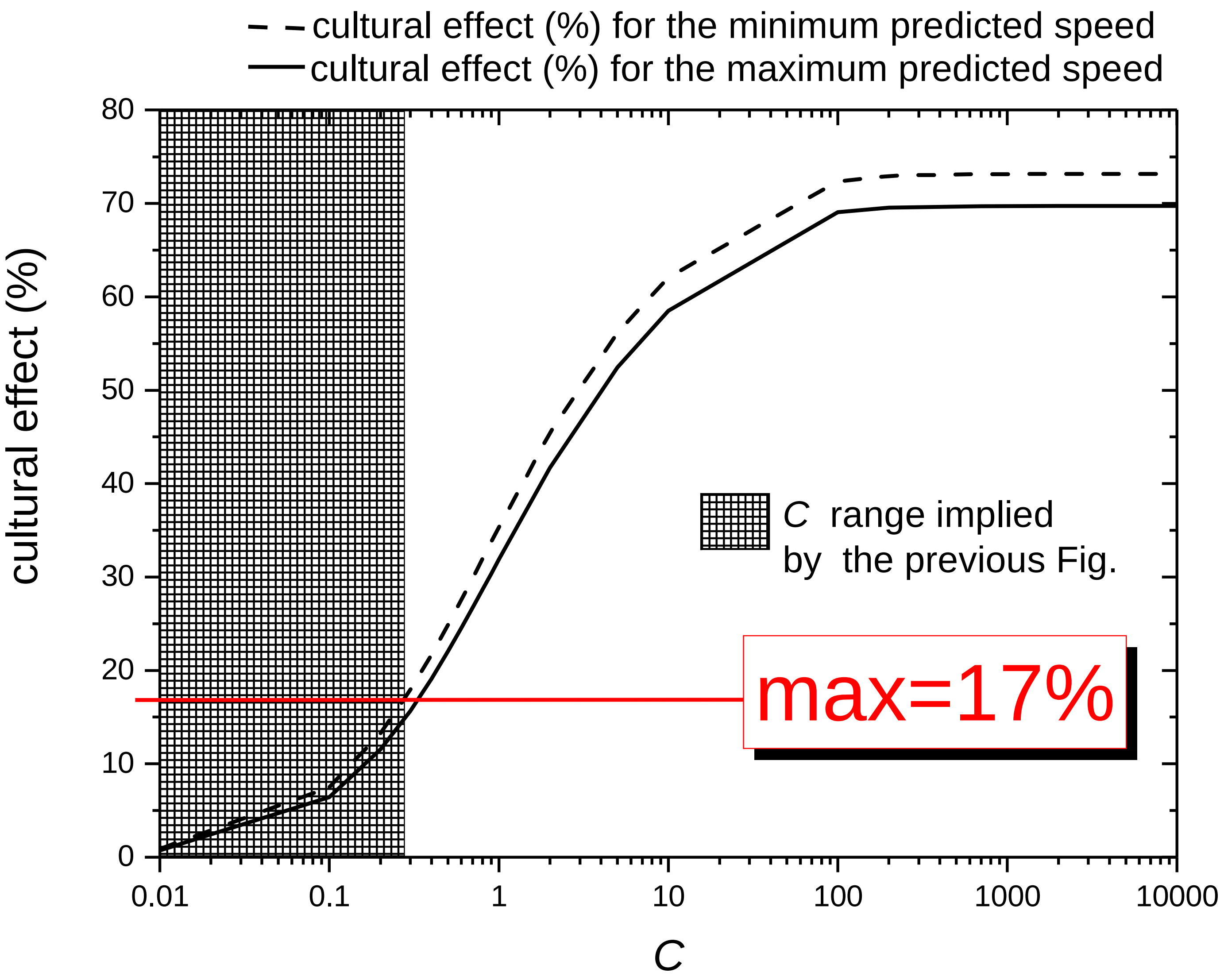
Using this equation, we obtain the curves in the following slides (predicted spread rates).

We apply dispersal probabilities (p_j, r_j) for rice cultivators, growth rates a_F and generation times T from ethnographic data.

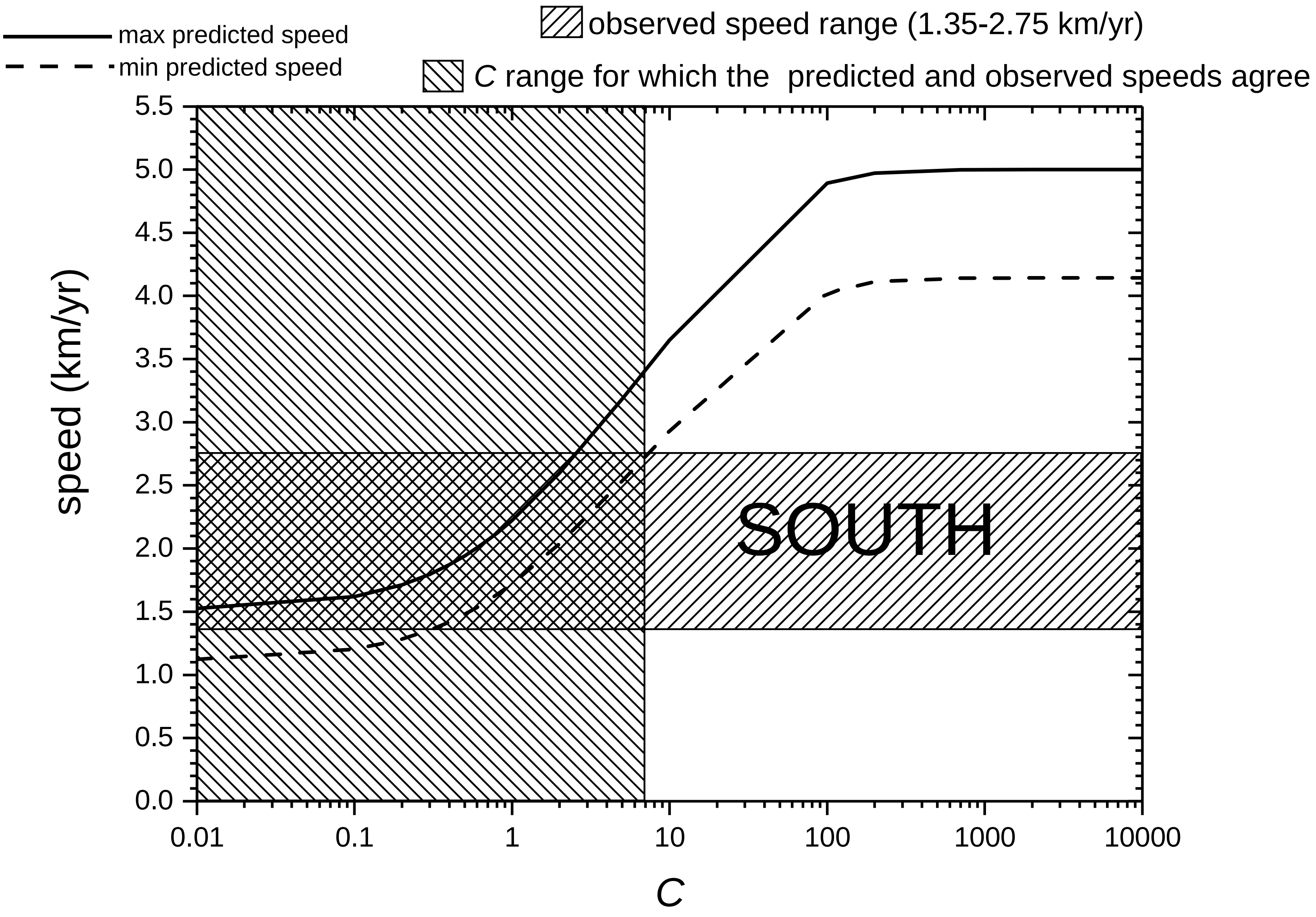
Spread to the North (84 sites)



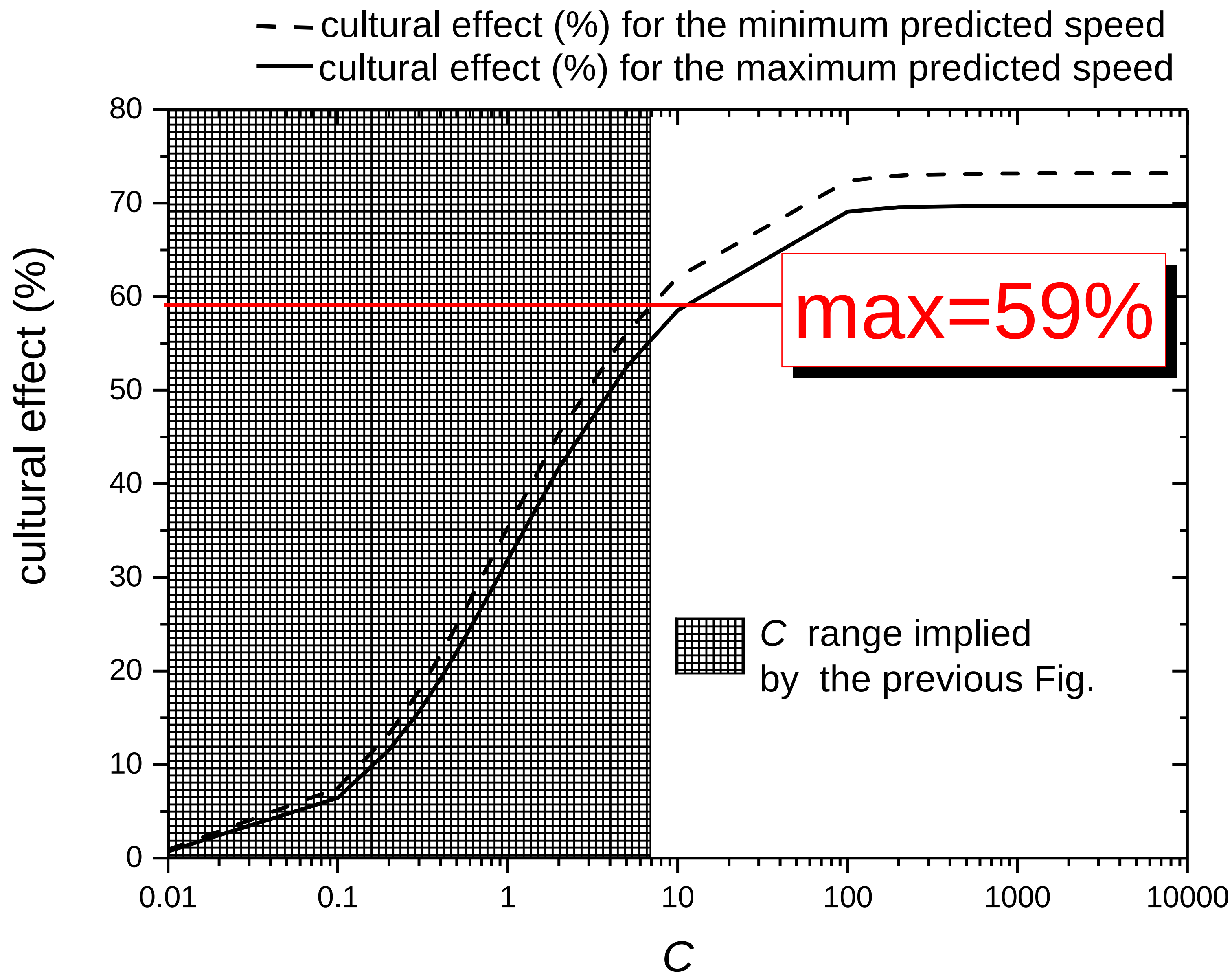
Cultural effect (%) = (speed – demic speed) /speed · 100



Spread to the South (only 32 sites)



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



Conclusions

- **Spread to the North:** mainly demic. Error in the spread rate = ±0.5 km/yr (84 sites).
- **Spread to the South:** probably mainly demic also. But for the upper bound for the observed spread rate is consistent with mainly cultural diffusion. Possible reason: only 32 sites→substantial error in the spread rate (±1.4 km/yr). When more sites are dated, the spread range error will be probably smaller and the results more conclusive. The mean rate yields mainly demic diffusion.