The Effect of the TseTse Fly on African Development

Marcella Alsan

Overview

- This paper explores how an endowment affects agricultural productivity and long-run development
- TseTse is an insect that is unique to Africa and causes disease in livestock and humans
- This paper provides support for the hypothesis that the TseTse hindered the ability of precolonial Africans to adopt agricultural technologies, leading to low population density and weak/extractive institutions
- There is also evidence that TseTse continues to affect modern African development through its effect on historical institutions

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    - Institutions$\longrightarrow$ labor coercion (Hopkins) and weakened state development (Herbst)

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  - Technology (Goody)
  - Land Abundance (Austin, Iliffe, Fenske)
    - Institutions$\longrightarrow$ labor coercion (Hopkins) and weakened state development (Herbst)
- The role of TseTse has not been empirically investigated

TseTse: Hypothesized Role

- "It seems reasonable to suppose that for hundreds of years, the tsetse dictated that the economy of the African be based on the hoe and the headload, a dictatorship which he is now being freed by the petrol engine and the railway locomotive." *T.A.M. Nash (1969)*

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- "though the argument about the tsetse fly is obviously relevant, it can only be a very partial solution to the puzzle" *Chaves Engerman & Robinson (2010)*

Contribution

- First empirical examination of the effect of the TseTse fly on historical African development
- How did the TseTse affect precolonial (circa 19th century) Africa?
  - Agricultural Technologies (domesticated animals, plow use)
  - Subsistence Patterns (hunting and gathering, animal husbandry, extensive vs. intensive farming)
  - Urbanization (population density, cities)
  - Institutions (political centralization, coerced labor)
- Does the TseTse fly still affect economic outcomes today?

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  - Identification (Insect Physiology$\longrightarrow$ *TSI*)

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  - Robustness tests
  - Placebo test
  - Simulation

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  - Placebo test
  - Simulation
- Data and Empirics for Modern Africa

TseTse Fly

- Blood-sucking insect vector
  - **Only in Africa**
- Manifestations of *Trypanosomiasis*
  - Untreated, fatal to domesticated animals (*nagana*) and humans (sleeping sickness)
  - Livestock more affected than humans ▸ Ox Bait
  - Habitat is in fertile areas ▸ Habitat

Identification Strategy

- Develop a TseTse suitability index (TSI)
  - based on laboratory experiments on the fly
  - specific relationships between TseTse survival and temp/humidity
  - standard exponential population growth model with density dependent mortality$\longrightarrow$steady state fly population at ethnic group level
  - historical climate data
  - reanalysis of the National Oceanic and Atmospheric Administration's climate research lab available worldwide at 2 deg resolution beginning in 1871

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- TSI is therefore interaction of specific nonlinearities in climate
- Placebo test to show TSI is not correlated with same outcomes in the Tropics outside of Africa

Model of TseTse Fly Population Growth

▸ Insect Physiology

- Λ : constant exponential growth in the absence of competition

$$\Lambda = B - M$$

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- N^* : steady state fly population $(\Lambda = \Delta)$

$$N^* = \left(\frac{\Lambda}{\phi}\right)^{\frac{1}{\psi}}$$

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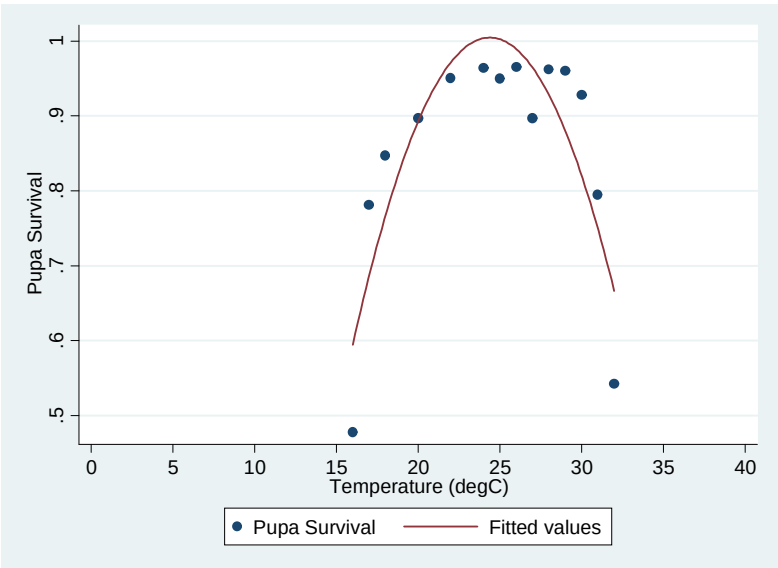
$$N^* = \left(\frac{\Lambda}{\phi}\right)^{\frac{1}{\psi}}$$

- Parameter values from May et al., (1974): $(0 < \psi < 2)$

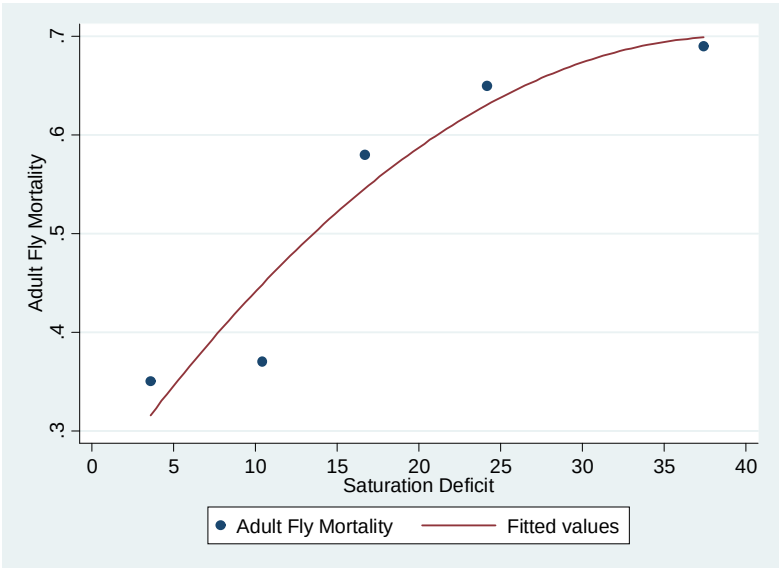
TseTse Physiology

growth

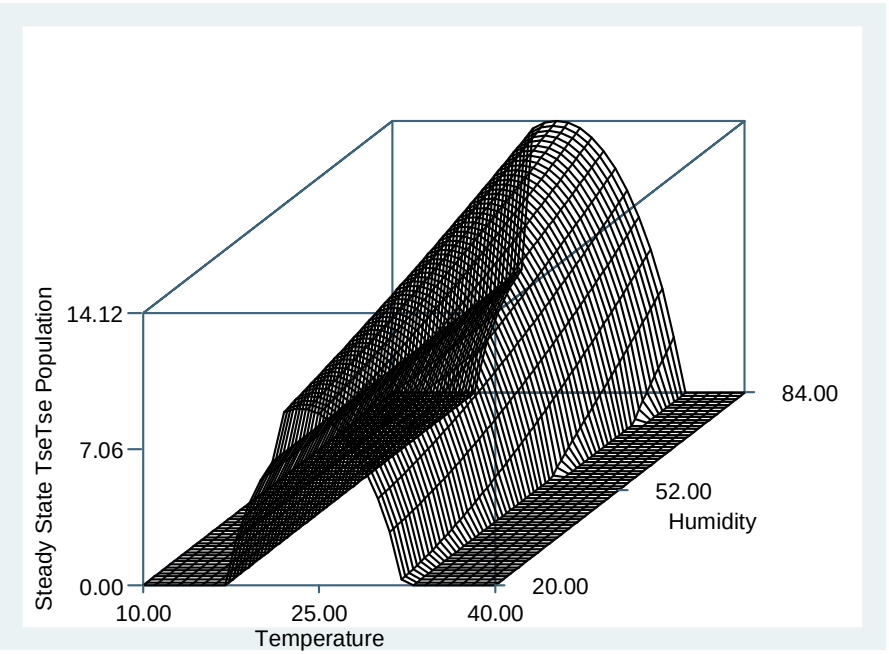
A. Pupa Survival and Temperature



B. Adult Fly Survival and Humidity



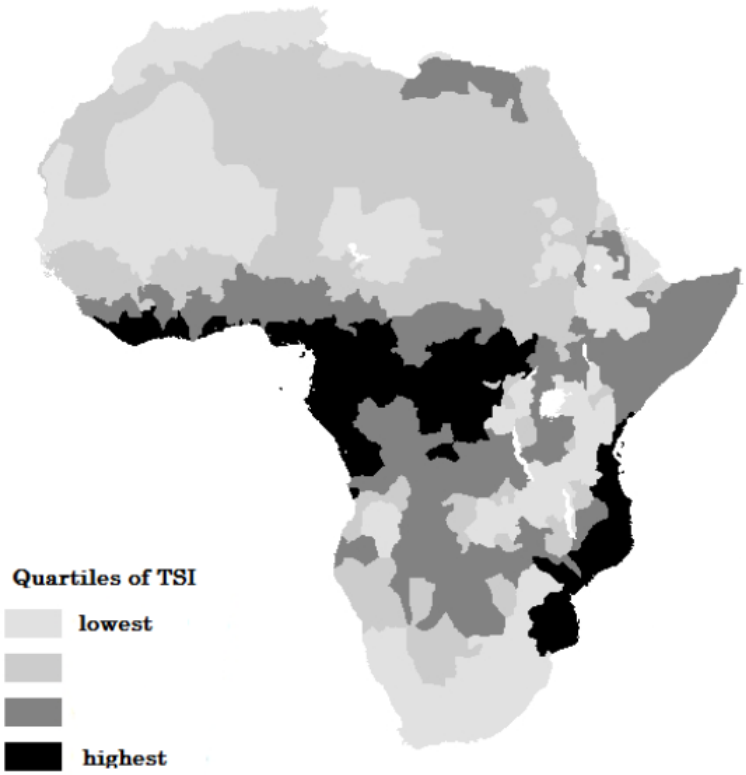
TseTse Steady State Population



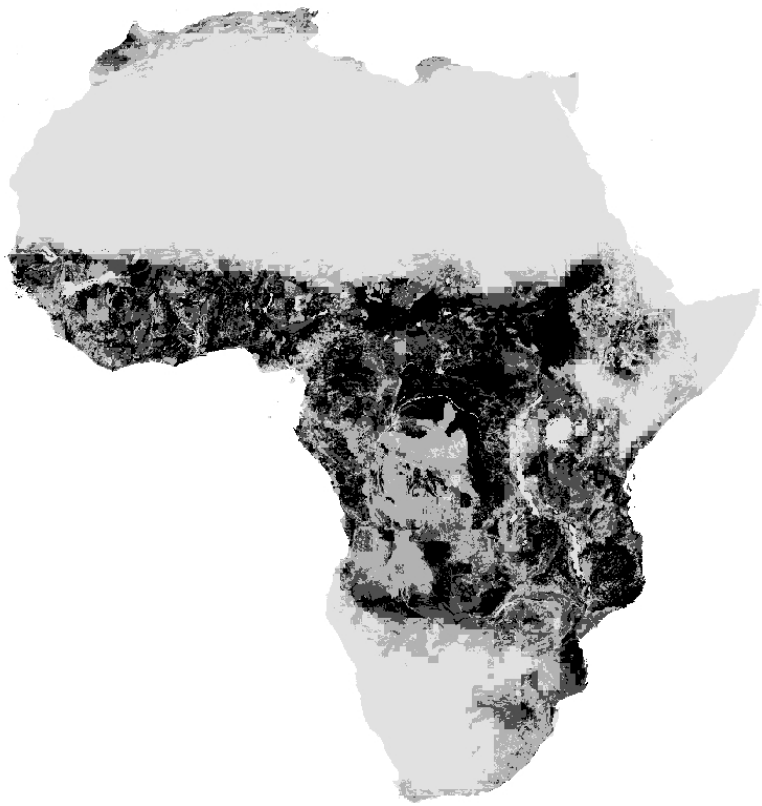
- TSI (TseTse Suitability Index)=Z-score of the fly population

Historical TSI

Historical TSI (1871)



Agricultural Suitability (FAO)



Channels

1. influence subsistence patterns
    - population density, settlement structure, occupational specialization
2. $\uparrow$ transport/trade costs
3. $\downarrow$ labor productivity

Main Historical Data Source

- Precolonial Africa, few written records (indigenous writing systems)
- *Ethnographic Atlas*
  - 533 groups in Africa
  - Meant to capture indigenous characteristics of ethnic groups
  - Join with *Murdock's Map* of Africa (843 ethnic groups)
  - Observations mostly from 19th or early 20th century
  - Outcomes mainly binary
  - Population density estimates
- Chandler *Four Thousand Years of Urban Growth : An Historical Census*
  - Location of urban centers in 1800 with >=20,000 inhabitants

Empirical Framework: Historical Analysis

$$y_j = \alpha_0 + \delta TSI_j + \mathbf{X}_j'\Omega + \varepsilon_j$$

- Unit of analysis is ethnic group (j)
- Focus on reduced form
  - comparability with outside of Africa (placebo)
  - lack of historical TseTse map
- $\mathbf{X}_j'$ vector of plausibly exogenous control variables that may explain African agricultural productivity
  - tropical climate: absolute latitude, proportion of land area in the Tropics
  - climate variables: rel hum, temp, first-order interaction
    ▸ Steady State
  - access to waterways: river & coast
  - altitude: free from insects, slave raiders and more rainfall
  - malaria: Sach's malaria ecology index
  - soil constraints: FAO ag suitability index ▸ Correlation
    ▸ Sample and Clusters

Baseline Historical Results: Overview

Table I

REDUCED FORM ESTIMATES OF THE RELATIONSHIP BETWEEN HISTORICAL AFRICAN DEVELOPMENT AND TSETSE SUITABILITY

Dependent Variable	(1)	(2)	(3)	(4)	No. Obs	No. Clusters	Sample mean
Agriculture							
Large Domesticated Animals	–0.214***	–0.219***	–0.208***	–0.227***	484	44	0.626
	(0.043)	(0.045)	(0.045)	(0.041)			
Intensive Agriculture	–0.091***	–0.078**	–0.082***	–0.081***	485	44	0.320
	(0.027)	(0.031)	(0.029)	(0.027)			
Plow Use	–0.052**	–0.050**	–0.052**	–0.058**	484	44	0.076
	(0.021)	(0.023)	(0.022)	(0.023)			
Female Participation in Agriculture	0.253***	0.224***	0.213***	0.193***	315	43	0.489
	(0.052)	(0.052)	(0.052)	(0.062)			
Urbanization							
Log Population Density (Murdock)	–0.875***	–0.823***	–0.797***	–0.699***	398	43	1.700
	(0.270)	(0.254)	(0.242)	(0.230)			
Institutions							
Indigenous Slavery	0.094**	0.109**	0.104**	0.101**	446	44	0.848
	(0.039)	(0.043)	(0.043)	(0.040)			
Centralization	–0.058*	–0.076**	–0.075**	–0.082**	467	44	0.334
	(0.035)	(0.035)	(0.035)	(0.035)			
Climate Controls	Y	Y	Y	Y			
Malaria Controls	N	Y	Y	Y			
Waterway Controls	N	N	Y	Y			
Geography Controls	N	N	N	Y			

Notes: OLS estimates of Equation (4). Each cell in columns (1)–(4) represents a separate regression and the coefficient on the TSI is reported. The dependent variable is listed in the leftmost column of the upper panel. The mean of the dependent variables is located in the rightmost column. With the exception of the urbanization category, the data for the dependent variable are from the Ethnographic Atlas, and are based on anthropological observations from the late 19th and early 20th century. The climate variables are from the 20th century reanalysis for the year 1871. Climate controls refer to temperature, relative humidity and the first–order interaction between temperature and humidity as well as the proportion of land that is in the Tropics. Malaria refers to the malaria ecology index developed by Kiszewski et al., (2004). Waterway controls include whether a river was located within the ethnic group boundaries and whether the boundaries included a coast. Geography controls include log mean altitude, the FAO's agricultural suitability index, longitude and absolute latitude. Robust standard errors clustered at the level of cultural province in parentheses. * ** *** Significant at 10, 5 and 1 percent levels.

Baseline Historical Results

Preferred Specification: Agriculture

Dependent Variable	*(4)*	*Sample mean*
Agriculture		
Large Domesticated Animals	*–0.227****	*0.626*
	(0.041)	
Intensive Agriculture	*–0.081****	*0.320*
	(0.027)	
Plow Use	*–0.058***	*0.076*
	(0.023)	
Female Participation in Agriculture	*0.193****	*0.489*

Baseline Historical Results

Preferred Specification: Urbanization and Institutions

Dependent Variable	*(4)*	*Sample mean*
Urbanization		
Log Population Density (Murdock)	*–0.699****	*1.700*
	(0.230)	
Institutions		
Indigenous Slavery	*0.101***	*0.848*
	(0.040)	
Centralization	*–0.082***	*0.334*
	(0.035)	

Subsistence Agriculture and TseTse Fly

Table II

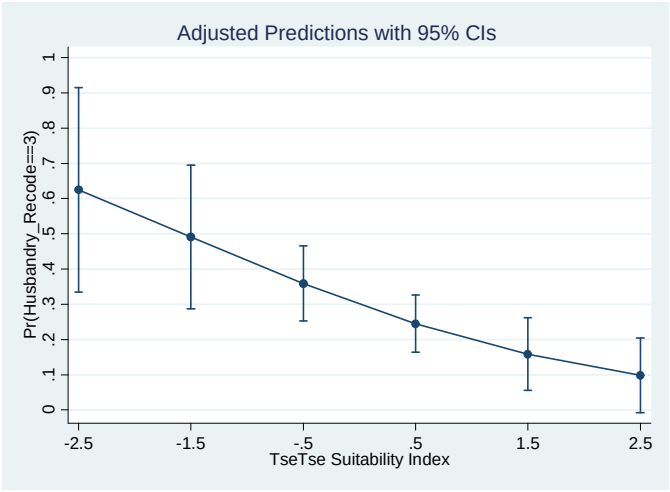
REDUCED FORM ESTIMATES OF THE RELATIONSHIP BETWEEN TSETSE SUITABILITY AND SUBSISTENCE PATTERNS WITHIN HISTORICAL AFRICA

	(1)	(2)	(3)	(4)	(5)
	Husbandry	Hunting	Gathering	Agriculture	Fishing
TSI	–0.223***	0.201***	0.160*	0.074	–0.036
	(0.073)	(0.071)	(0.085)	(0.189)	(0.082)
Malaria Ecology Index	0.013	–0.007	0.011	0.007	–0.003
	(0.007)	(0.005)	(0.009)	(0.018)	(0.014)
No. Obs	522	522	522	522	522
No. Clusters	44	44	44	44	44
Partial R2	0.439	0.129	0.095	0.267	0.175

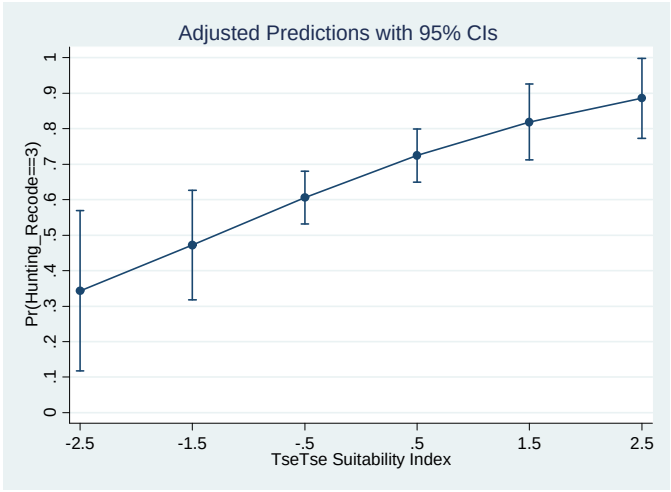
Notes: OLS estimates of Equation (4). Each column is a separate regression. The coefficient on the TSI and the malaria ecology index are reported. Other covariates (not reported) include temperature, relative humidity the first-order interaction between temperature and humidity as well as the proportion of land that is in the Tropics, river, coast, log mean altitude, agricultural suitability, longitude and absolute latitude. The malaria ecology index was developed by Kiszewski et al., (2004). Robust standard errors clustered at the level of cultural province in parentheses. * ** *** Significant at 10, 5 and 1 percent levels.

Subsistence Agriculture and TseTse Fly

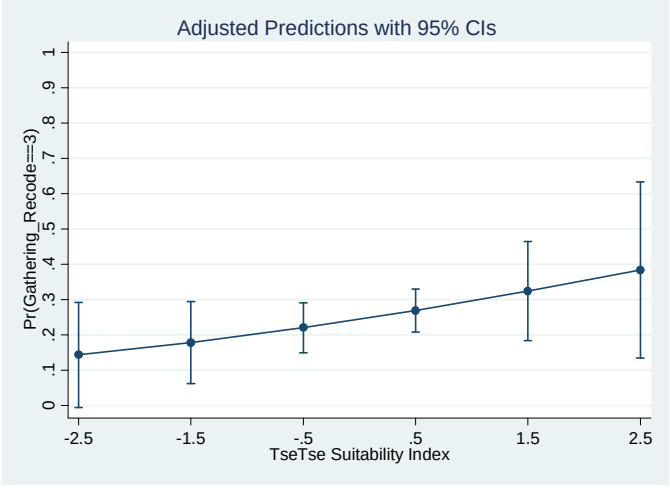
A. Husbandry



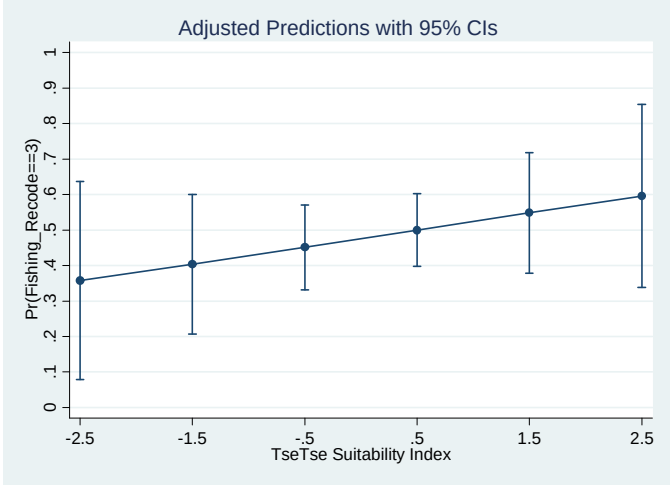
B. Hunting



C. Gathering



D. Fishing



Baseline Historical Estimates: Robustness Tests

1. Perturbations to the TSI formula ▸ perturbations

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4. Parameters in TSI - (sensitivity analysis)

Baseline Historical Estimates: Robustness Tests

1. Perturbations to the TSI formula ▸ perturbations
2. Different TseTse measure (Oxford Zoologists)
3. Growth Rate/Box-Plot
4. Parameters in TSI - (sensitivity analysis)
5. Different Modes of Statistical Inference (Conley 10 lat/lon, cluster country, Multiway clustering)

Robustness Tests

▸ robust3 ▸ IV ▸ intensive ▸ sutva1

ROBUSTNESS TESTS OF THE RELATIONSHIP BETWEEN THE REDUCED FORM ESTIMATES OF TSETSE SUITABILITY AND HISTORICAL AFRICAN DEVELOPMENT

Dependent Variable	Alternative TseTse Indices					Alternative Clustering		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Placebo TSI Shift Left	Placebo TSI Shift Right	Intrinsic Rate of Growth	Box-Plot	Optimal TseTse Conditions	Conley S.E.	S.E. Clustered by Country	Multi-way Clustering
Agriculture								
Large Domesticated Animals	0.003	–0.012	–1.39***	–0.009***	–0.359***	–0.227***	–0.227***	–0.227***
	(0.067)	(0.082)	(0.249)	(0.002)	(0.075)	(0.040)	(0.040)	(0.036)
Intensive Agriculture	0.023	0.011	–0.538***	–0.003***	–0.119*	–0.081***	–0.081***	–0.081***
	(0.039)	(0.048)	(0.168)	(0.001)	(0.061)	(0.030)	(0.030)	(0.022)
Plow Use	–0.028	0.007	–0.418***	–0.002**	–0.044**	–0.058*	–0.058*	–0.058**
	(0.015)	(0.039)	(0.138)	(0.0009)	(0.021)	(0.031)	(0.031)	(0.031)
Female Participation in Agriculture	–0.068	–0.023	1.21***	0.008***	0.254***	0.193***	0.193***	0.193***
	(0.059)	(0.071)	(0.383)	(0.002)	(0.063)	(0.043)	(0.049)	(0.060)
Urbanization								
Log Population Density (Murdock)	–0.369	–0.366	–4.32***	–0.028***	–0.635**	–0.699***	–0.699***	–0.699***
	(0.238)	(0.302)	(1.39)	(0.009)	(0.280)	(0.195)	(0.198)	(0.236)
Institutions								
Indigenous Slavery	0.027	0.046	0.545**	0.004**	0.097*	0.101	0.101**	0.101**
	(0.044)	(0.058)	(0.230)	(0.0016)	(0.054)	(0.039)	(0.041)	(0.040)
Centralization	0.021	–0.001	–0.479**	–0.003**	–0.002	–0.082**	–0.082**	–0.082**
	(0.063)	(0.084)	(0.205)	(0.001)	(0.058)	(0.042)	(0.037)	(0.036)

Baseline Historical Estimates: Export Slavery

- Clearly trade between Europeans and Africans would have been a source of influence
- Export slave trade could have led to depopulation and war, decentralization
- Possible OVB can be corrected by including estimates of number of slaves exported as a control

Dependent Variable	*Export Slave Trade*
Urbanization	
Log Population Density	*–0.709****
	(0.225)
Institutions	
Indigenous Slavery	*0.099***
	(0.041)
Centralization	*–0.084***
	(0.036)

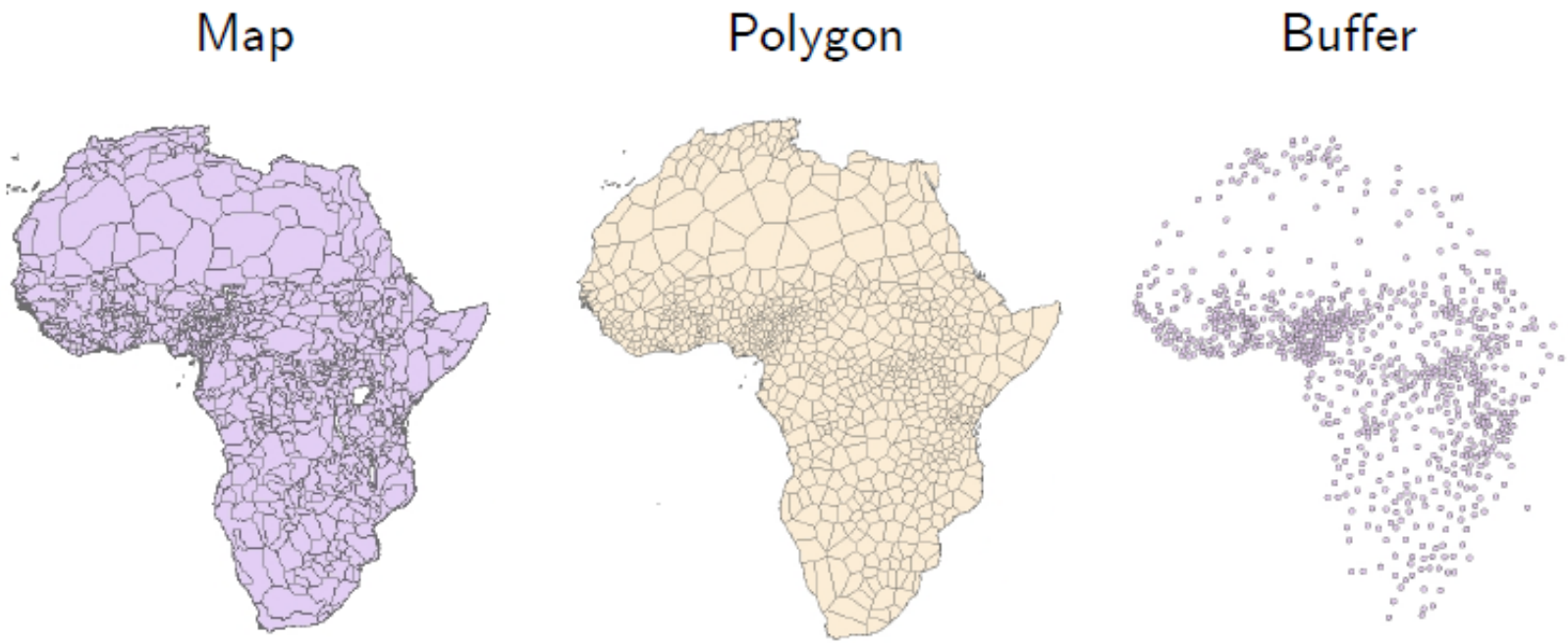
Placebo

- TseTse only in Africa; so TSI, conditional on same variables, should not make similar predictions in the Tropics outside of Africa
- Challenge is that map with ethnic group boundaries only exists for Africa

Ethnographic Atlas Centroids



Thiessen Polygons



Map vs. Polygon Coefficient

Table IV

COMPARISION OF MURDOCK MAP AND THIESSEN POLYGON COEFFICIENTS TROPICS ONLY

Dependent Variable	(1) Map	(2) Polygon	(3) Difference
Agriculture			
Large Domesticated Animals	–0.261***	–0.179***	–1.69*
	(0.042)	(0.024)	
Intensive Agriculture	–0.099***	–0.094***	–0.069
	(0.039)	(0.023)	
Plow Use	–0.034*	–0.010	–0.94
	(0.018)	(0.018)	
Female Participation in Agriculture	0.218***	0.224***	–0.079
	(0.052)	(0.056)	
Urbanization			
Log Population Density (Murdock)	–0.486***	–0.504***	0.070
	(0.172)	(0.192)	
Institutions			
Indigenous Slavery	0.091**	0.095***	–0.091
	(0.038)	(0.022)	
Centralization	–0.090**	–0.097***	0.128
	(0.045)	(0.031)	

Placebo Test: Specification

$$y_j = \beta\ TSI_j + \delta\ \overbrace{TSI_j \cdot I_j^{Africa}} + \mathbf{X}_j'\Omega + I_j^{Africa}\mathbf{X}_j'\Gamma + \eta_j$$

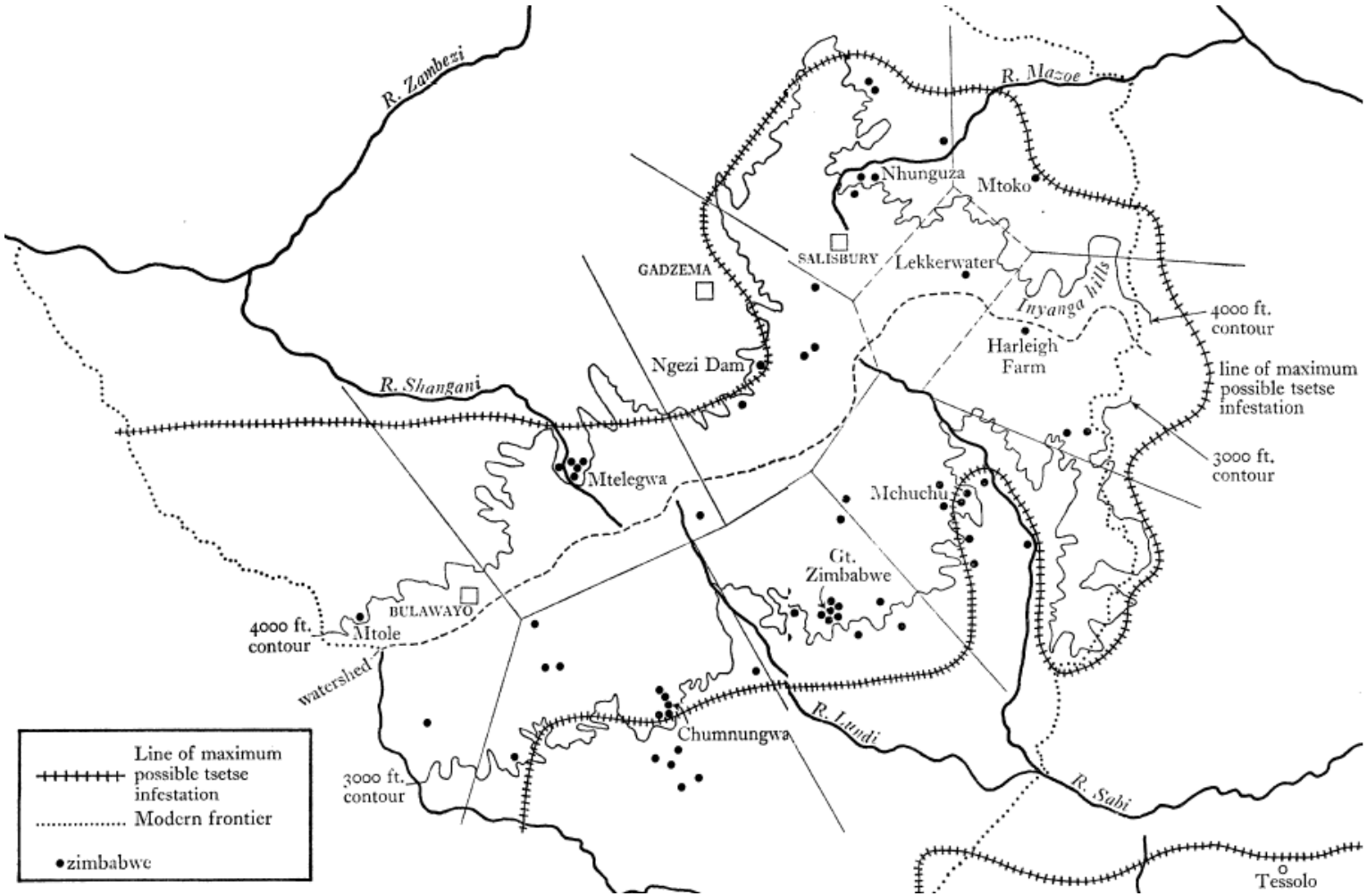
- TSI : main effect
- $TSI \cdot I_j^{Africa}$: interaction, represents the differential effect of the TSI in Africa
- $I_j^{Africa}\mathbf{X}_j'$: Africa allowed to differ from the rest of the Tropics, not just the TSI

Placebo Test: Results

	PLACEBO TEST		
	(1)	(2)	(3)
Dependent Variable	Main Effect TSI (β)	Africa Interaction TSI (δ)	Africa Total TSI (β+δ)
Agriculture			
Large Domesticated Animals	0.005	–0.184***	–0.179***
	(0.296)	(0.032)	(0.016)
Intensive Agriculture	–0.022	–0.072*	–0.094***
	(0.037)	(0.050)	(0.019)
Plow Use	0.059	–0.063*	–0.010
	(0.031)	(0.036)	(0.017)
Female Participation in Agriculture	0.021	0.204***	0.224***
	(0.059)	(0.070)	(0.046)
Institutions			
Indigenous Slavery	–0.010	0.105**	0.095***
	(0.037)	(0.042)	(0.018)
Centralization	–0.023	–0.075*	–0.098**
	(0.029)	(0.040)	(0.038)

Africa without the TseTse?

Great Zimbabwe *"peninsula in a sea of TseTse"* Garlake (1978)



Simulation Setup

$$y_j = \beta\ TSI_j + \delta\ \overbrace{TSI_j \cdot I_j^{Africa}} + \mathbf{X}_j'\Omega + I_j^{Africa}\mathbf{X}_j'\Gamma + \eta_j$$

- There is a differential effect of the TSI in Africa
- Reduce TSI in $TSI_j \cdot I_j^{Africa}$ to world mean
- Caveat- does not account for endogenous response to TseTse removal

Simulation Results

	SIMULATION		
	(1)	(2)	(3)
	Africa	Africa	
Dependent Variable	Baseline TseTse	Reduced TseTse	Eurasia
Agriculture			
Large Domesticated Animals	0.60	0.80	0.83
Intensive Agriculture	0.28	0.36	0.72
Plow Use	0.03	0.10	0.72
Female Participation in Agriculture	0.47	0.25	0.13
Institutions			
Indigenous Slavery	0.86	0.74	0.23
Centralization	0.30	0.39	0.63

TseTse and Current Development

- Approach
  - is there a correlation between TSI and current economic performance
  - if so, is this relationship robust to adding controls for historical institutions affected by the fly
- Outcomes
  - Satellite Light Density (2008)
  - Cattle Density (2005)

Modern TseTse: Empirical Framework

- Construct a district-level measure of the fraction of population whose ancestors practiced slavery or lived in a centralized ethnic group

$$\begin{aligned} Institution_c^i &= \frac{\sum_j L_{j,d,c} \cdot \mathbf{I}_j^i}{L_{d,c}} \\ i &\in \{centralization, slavery\} \end{aligned}$$

  - $\mathbf{I}_j^i$ is an indicator variable equal to one if ethnicity j was historically characterized by institution i and zero otherwise
  - $L_{j,d,c}$ is the number of inhabitants of country c in district d that are of ethnicity j
    - mapped groups to their current location using the *Ethnologue*

Economic Development and the TseTse

REDUCED FORM ESTIMATES OF THE RELATIONSHIP BETWEEN MODERN ECONOMIC DEVELOPMENT AND TSETSE SUITABILITY

	(1)	(2)	(3)	(4)	(5)
Panel A: Dependent Variable is the Log Mean Luminosity					
TSI	–0.703**	–0.592***	–0.461*	–0.270	–0.281
	(0.318)	(0.267)	(0.255)	(0.190)	(0.237)
Malaria Index		0.043	–0.005	–0.003	–0.003
		(0.029)	(0.030)	(0.017)	(0.026)
Historical Centralization				1.36***	1.28***
				(0.219)	(0.304)
Historical Slavery					0.244
					(0.362)
Panel B: Dependent Variable is the Log Number of Cattle					
TSI	–1.37**	–1.24***	–0.664*	–0.657*	–0.689*
	(0.509)	(0.432)	(0.364)	(0.370)	(0.368)
Malaria Index		0.041	0.041	0.041	0.042
		(0.042)	(0.028)	(0.028)	(0.028)
Historical Centralization				0.052	–0.184
				(0.352)	(0.422)
Historical Slavery					0.709
					(0.442)
Climate Controls	Y	Y	Y	Y	Y
Malaria, Water and Other Geo Controls	N	N	Y	Y	Y
Country Fixed Effects	N	N	Y	Y	Y
No. Obs	642	642	642	642	642
No. clusters	47	47	47	47	47

Conclusion

- Investigated the effect of the TseTse on historical African development
- Created a TSI using insect physiology and fly population growth model
- TSI correlated with "backward" agricultural technologies, low population density and extractive/weak institutions within but not outside of Africa
- Simulation and archaeological record suggests Africa would have been more similar to rest of Old World without the fly
- Economic development appears to be affected by the fly through the channel of precolonial centralization

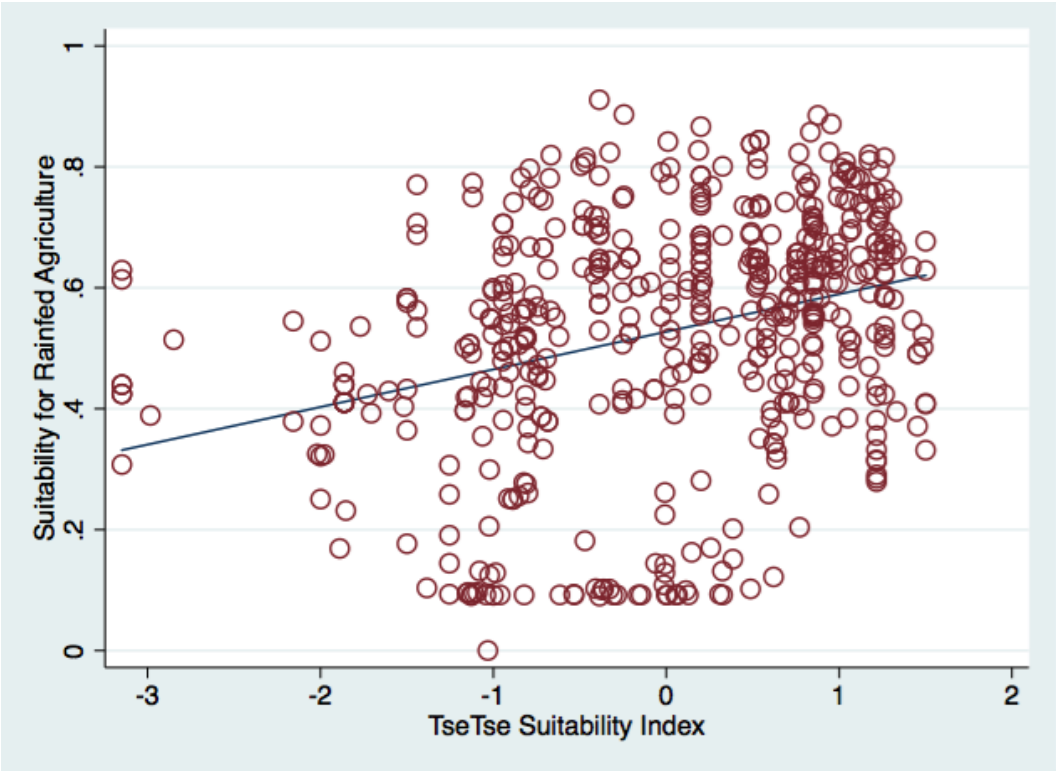
Ox Bait

▸ fly



TseTse Suitability and Agricultural Suitability

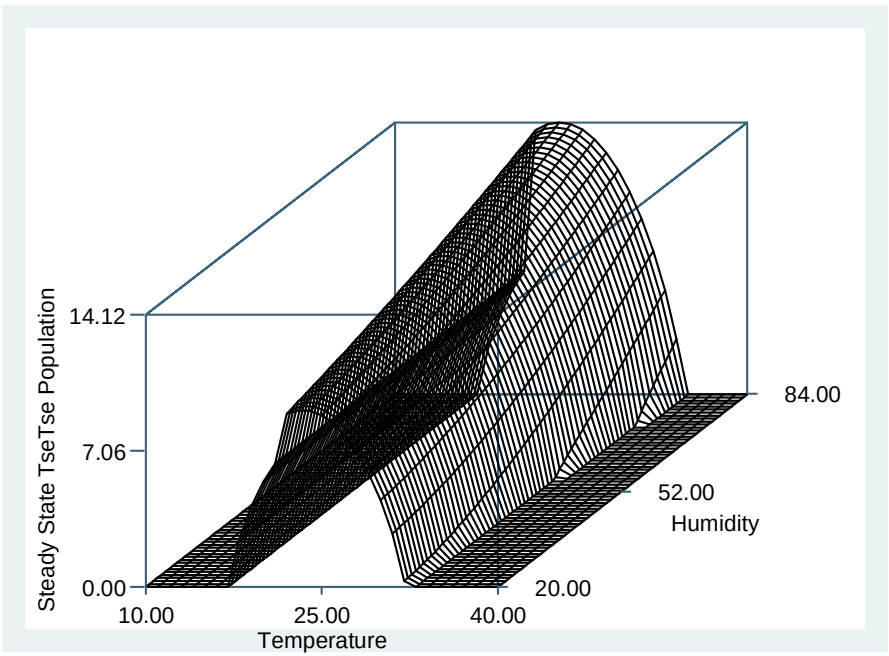
▸ fly



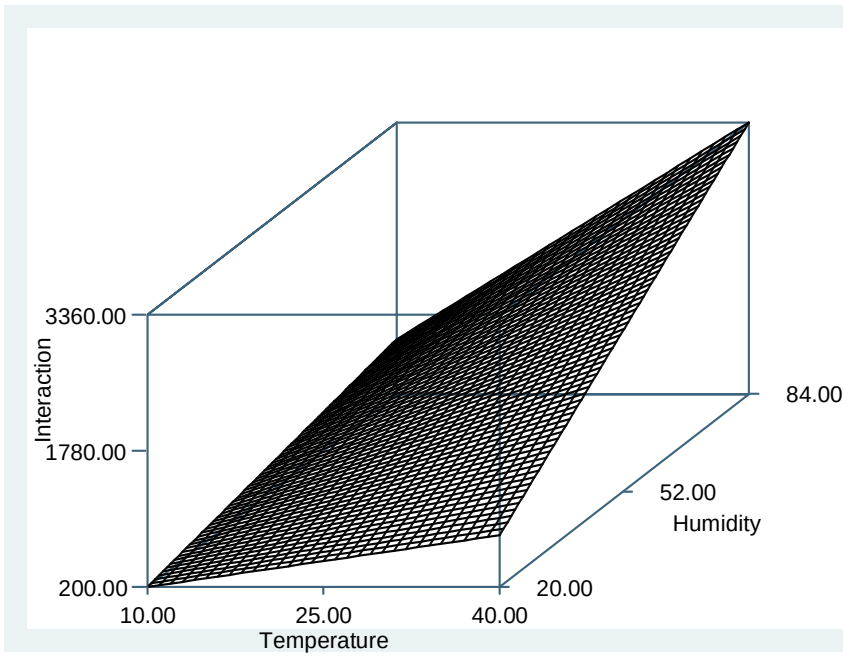
Steady State Fly Population

empirics

C.Steady State Fly Population



D. Itx of Temp & Rel Hum



Sample and (44) Clusters

▸ empirics



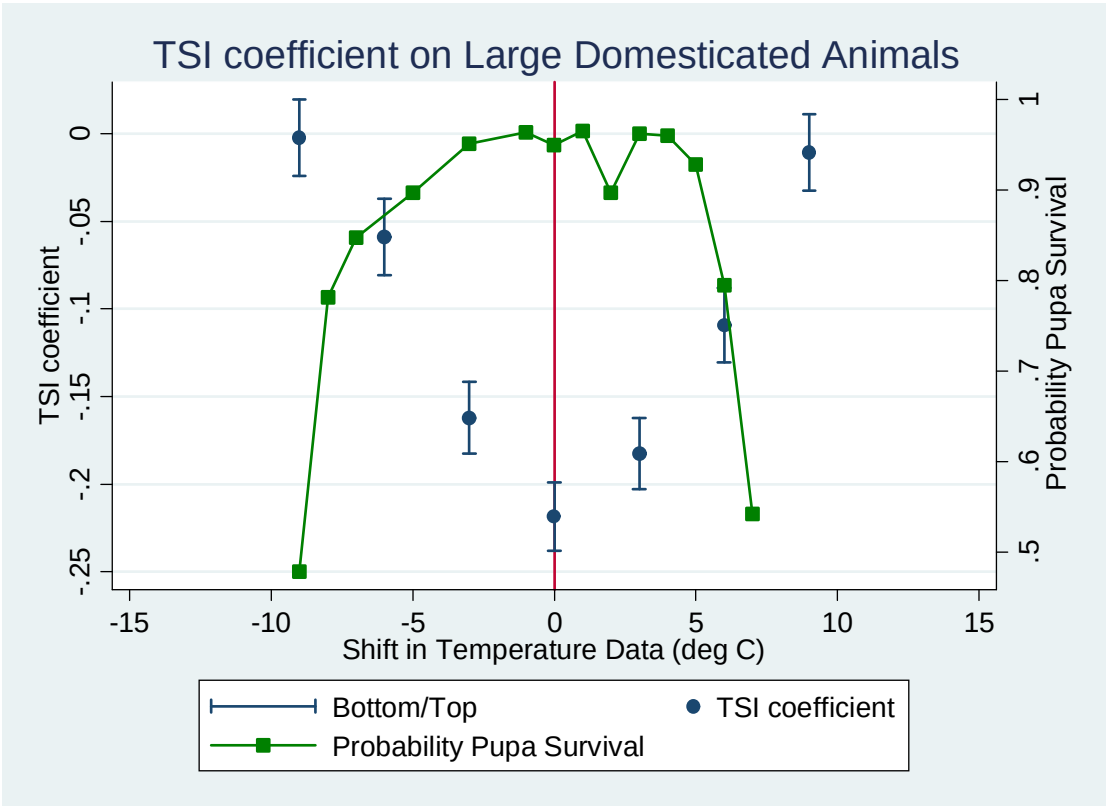
Correlation

empirics

	TSI	Temp	RH	Itx	Mal 1900	Mal Ecology	Abs Lat	Longitude	River	Coast	Log Alt	Ag Suit
Historical TSI	1.00											
Historical Temperature	0.38	1.00										
Historical RH	0.36	–0.45	1.00									
Interaction	0.66	0.04	0.87	1.00								
Malaria 1900	0.42	0.25	0.41	0.59	1.00							
Malaria Ecology Index	0.38	0.70	–0.01	0.37	0.46	1.00						
Absolute Latitude	–0.39	–0.08	–0.52	–0.60	–0.52	–0.25	1.00					
Longitude	–0.21	–0.46	0.15	–0.10	–0.21	–0.39	–0.22	1.00				
River	0.10	–0.05	0.19	0.19	0.18	0.12	–0.10	0.02	1.00			
Coast	0.04	0.01	0.06	0.07	–0.11	–0.16	0.29	–0.20	–0.03	1.00		
Log Mean Altitude (meters)	–0.23	–0.40	–0.05	–0.27	–0.21	–0.33	0.05	0.41	0.15	–0.33	1.00	
Agricultural SI	0.32	0.16	0.38	0.52	0.57	0.50	–0.43	–0.08	0.18	–0.15	–0.26	1.00

Perturbations

robust2



Baseline Historical Estimates: TSLS

robust2

Subsample of Countries with Surveillance after Independence

OLS AND IV ESTIMATES OF THE RELATIONSHIP BETWEEN OBSERVED TSETSE AND HISTORICAL AFRICAN DEVELOPMENT

Dependent Variable	Large Domesticated Animals	Intensive Agriculture	Plow Use	Female Participation in Agriculture	Indigenous Slavery	Centralization	Log Population Density (Murdock)
Panel A: Two-Stage Least Squares with TSI as the Instrument							
Observed TseTse	–0.967***	–0.557***	–0.260*	1.15***	0.860***	–0.387*	–3.66**
	(0.241)	(0.199)	(0.140)	(0.384)	(0.306)	(0.219)	(1.54)
Panel B: First Stage							
TseTse Suitability Index (1871)	0.161***	0.161***	0.161***	0.171***	0.152***	0.159***	0.152***
	(0.024)	(0.024)	(0.024)	(0.032)	(0.026)	(0.024)	(0.027)
F-statistic	38.66	38.4	38.7	42.6	26.4	38.4	18.9
Panel C: Ordinary Least Squares							
Observed TseTse (1973)	–0.444***	–0.172	–0.056	0.216**	0.155	–0.072	–0.744***
	(0.119)	(0.162)	(0.035)	(0.900)	(0.106)	(0.110)	(0.261)
No. obs.	407	408	407	264	369	393	336
Clusters	42	42	42	41	42	42	40

Robustness Tests

▸ robust2

ADDITIONAL ROBUSTNESS TESTS OF THE RELATIONSHIP BETWEEN THE REDUCED FORM ESTIMATES OF TSETSE SUITABILITY AND HISTORICAL AFRICAN DEVELOPMENT

Dependent Variable	(1) Cultural Province F.E.	(2) Linguistic F.E.	(3) Region F.E.	(4) Probit	(5) Alternative Malaria Index	(6) TSI squared	(7) Plow Positive Crops	(8) Export Slave Trade	(9) Ethnic Group Land Area	(10) Higher Order Terms
Agriculture										
Large Domesticated Animals	–0.121***	–0.133***	–0.202***	–0.188***	–0.256***	–0.228***	–0.226***	–0.227***	–0.223***	–0.235***
	(0.044)	(0.036)	(0.040)	(0.040)	(0.046)	(0.043)	(0.050)	(0.041)	(0.045)	(0.052)
Intensive Agriculture	–0.052*	–0.079**	–0.071*	–0.082***	–0.097***	–0.086***	–0.101***	–0.080***	–0.073**	–0.099*
	(0.029)	(0.033)	(0.037)	(0.026)	(0.026)	(0.030)	(0.033)	(0.028)	(0.030)	(0.053)
Plow Use	–0.037	–0.042*	–0.038*	–0.025	–0.064***	–0.053**	–0.084***	–0.058**	–0.052**	0.011
	(0.023)	(0.023)	(0.020)	(0.015)	(0.024)	(0.022)	(0.029)	(0.023)	(0.023)	(0.035)
Female Participation in Agriculture	0.109*	0.168**	0.156***	0.169***	0.243***	0.194***	0.195***	0.192***	0.178**	0.136*
	(0.064)	(0.065)	(0.055)	(0.056)	(0.062)	(0.062)	(0.058)	(0.063)	(0.066)	(0.074)
Urbanization										
Log Population Density	–0.625**	–0.641**	–0.698***	N.A.	–0.645***	–0.712***	–0.362*	–0.709***	–0.576***	–0.363
	(0.293)	(0.267)	(0.213)		(0.236)	(0.239)	(0.205)	(0.225)	(0.192)	(0.222)
Institutions										
Indigenous Slavery	0.086*	0.068*	0.132***	0.069**	0.096**	0.104**	0.072	0.099**	0.099**	0.067
	(0.049)	(0.040)	(0.036)	(0.034)	(0.038)	(0.040)	(0.043)	(0.041)	(0.040)	(0.063)
Centralization	–0.099*	–0.084**	–0.059	–0.079**	–0.063	–0.084**	–0.083*	–0.084**	–0.109***	–0.137**
	(0.053)	(0.040)	(0.043)	(0.034)	(0.037)	(0.036)	(0.042)	(0.036)	(0.038)	(0.058)

Intensive Margin and Crop Choice

robust2

- Results so far only on the extensive margin
- Even if ethnic groups had livestock may not have been able to use them for milking

REDUCED FORM ESTIMATES OF THE RELATIONSHIP BETWEEN CEREAL CULTIVATION, MILKING, CITIES AND TSETSE SUITABILITY

Dependent Variable	(1)	(2)	(3)	(4)
Cereal	–0.103***	–0.081**	–0.082**	–0.069***
	(0.035)	(0.033)	(0.033)	(0.030)
Milking	–0.120***	–0.142**	–0.140**	–0.176***
	(0.040)	(0.040)	(0.039)	(0.030)
Presence of an Urban	–0.035*	–0.031*	–0.028*	–0.028*
Center (1800)	(0.018)	(0.017)	(0.015)	(0.015)
Climate controls	Y	Y	Y	Y
Malaria control	N	Y	Y	Y
Waterway controls	N	N	Y	Y
Geography controls	N	N	N	Y

Baseline Historical Estimates : SUTVA

▸ export slavery

- Spillover effects: biased estimates because ethnic groups near to fly are being affected by it
  - May be nearby groups are doing worse because affected by slave-raiding, or technologies that did not diffuse etc.
  - May be nearby groups are doing better because have weaker states nearby they can extract from

$$y_i = \alpha_1 + \delta TSI_i + \gamma \sum_j w_{ij} TSI_j + \mathbf{X}_i' \Omega + \varepsilon_i$$

Baseline Historical Estimates: SUTVA

▸ export slavery

- Approach: include as a control the TSI of the nearest ethnic group

INCLUDING SPATIAL LAGS OF TSETSE SUITABILITY

Dependent Variable	(1)	(2)
Agriculture	Own TSI	Spatial Lag TSI
Large Domesticated Animals	–0.223***	–0.054**
	(0.041)	(0.020)
Intensive Agriculture	–0.081***	–0.046***
	(0.027)	(0.019)
Plow Use	–0.054**	–0.010*
	(0.023)	(0.004)
Females in Agriculture	0.188***	0.061***
	(0.061)	(0.011)
Urbanization		
Log Population Density (Murdock)	–0.641***	0.118**
	(0.221)	(0.049)
Institutions		
Indigenous Slavery	0.087**	0.131
	(0.037)	(0.199)
Centralization	–0.083**	–0.033
	(0.034)	(0.021)