Electronic supplementary material

1 Functions and aggregate parameters

	Functions and aggregate parameters	Definition	Units
ϕ_i	$\kappa/(1-\alpha_i\eta-\alpha_2(1-\eta))$	Population density on converted land	H
$S(\mathrm{H},\mathrm{q})$	$\left(1-\frac{\mathrm{H}}{\phi(\mathrm{q})}\right)^z$	Long-term species richness	–
γ_2	$(1-\eta)\ T_m\ \alpha_2^{\alpha_2}\left(\frac{1-\alpha_2}{\kappa}\right)^{1-\alpha_2}$	Max. *per capita* industrial consumption	H^{-1}
γ_{1i}	$\eta\ T_m\ \alpha_i^{\alpha_i}\ \left(\frac{1-\alpha_i}{\kappa}\right)^{1-\alpha_i}$	Max. *per capita* agricultural consumption	H^{-1}
y_{1i}	$\gamma_{1i}\ \mathrm{B}^{\Omega}\ \mathrm{T}/T_m$	Mean *per capita* agricultural consumption	H^{-1}
y_2	$\gamma_2\ \mathrm{T}/T_m$	*Per capita* industrial consumption	H^{-1}
U_i	$y_{1i}^{\eta}\ y_2^{1-\eta}$	*Per capita* consumption utility	H^{-1}
Δ	$\epsilon-4\Omega z y_1^{min}\left(\left(\frac{\gamma_{1u}}{y_1^{min}}\right)^{\frac{1}{\Omega z}}-1\right)e^{-b_2\gamma_2}\mu$	Sustainability criterion	t^{-1}

Table S1: **Functions and aggregate parameters expression and definition.** $i=\{u,s\}$; H: units of labor; t: units of time.

2 Parameters definition, units and defaults values

	Parameters	**Default values**	**Units**
	Economic parameters		
η	Agents preference for agricultural goods	0.35	–
α_s	Sustainable agricultural labor elasticity	0.5	–
α_u	Unsustainable agricultural labor elasticity	0.15	–
α_2	Labor elasticity in the industrial sector	0.9	–
	Social parameters		
w_{max}	Maximum ostracism	*varies*	H^{-1}
t	Threshold efficiency	−200	–
r	Rate of social change	−30	–
	Technological parameters		
T_m	Maximum technological efficiency	1.8	$\mathrm{H}^{-\alpha}$
σ	Rate of technological change	0.1	$\mathrm{H}^{-\alpha}.\mathrm{t}^{-1}$
κ	Land operating cost	1	H
	Demographic parameters		
μ	Maximum growth rate	1	$\mathrm{H}.\mathrm{t}^{-1}$
y_1^{min}	Minimum *per capita* agricultural consumption	0.3	H^{-1}
b_2	Sensitivity to industrial goods' consumption	3.5	–
	Ecological parameters		
Ω	Concavity of the BES relationship	0.4	–
z	Concavity of the SAR	0.2	–
ϵ	Ecological relaxation rate	0.1	t^{-1}

Table S2: **Definition, units and default values of the parameters.** H: units of labor; t: units of time.

3 Dynamical system analysis

$$\begin{cases} \dot{\mathrm{H}} = \mu\ \mathrm{H}\ \left(1 - e^{y_1^{min} - \overline{y_1}}\right) e^{-b_2 y_2} \\ \dot{\mathrm{B}} = -\epsilon\ [\mathrm{B} - (1 - \mathrm{H}/\overline{\phi})^z] \\ \dot{\mathrm{q}} = \mathrm{q}(1 - \mathrm{q})(U_s - U_u)(1 - w(\mathrm{q})/U_u) \\ \dot{\mathrm{T}} = \sigma\ \mathrm{T}\ [1 - \mathrm{T}/T_m] \end{cases} \tag{1}$$

Parameters and functions are summarized in Tables S1 and S2, with $\overline{y_1} = \mathrm{q}\ y_{1s} + (1-\mathrm{q})\ y_{1u}$, $\overline{\phi} = \mathrm{q}\ \phi_s + (1-\mathrm{q})\ \phi_u$, the consumption utility $U_i = y_{1i}^{\eta} y_2^{1-\eta}$ $(i = \{u, s\})$, and the ostracism function $w(\mathrm{q}) = w_{max} e^{te^{r\mathrm{q}}}$.

Solving system (1) for $\dot{\mathrm{H}} = 0$, $\dot{\mathrm{B}} = 0$, $\dot{\mathrm{T}} = 0$ and $\dot{\mathrm{q}} = 0$ gives five equilibria: (1) a sustainable equilibrium, $(H_s^*, B_s^*, T_m, 1)$, (2) an unsustainable equilibrium, $(H_u^*, B_u^*, T_m, 0)$, (3) a mixed equilibrium, $(H_c^*, B_c^*, T_m, q_c^*)$, and (4) two unviable equilibria, $(0, 1, T_m, 0)$ and $(0, 1, T_m, 1)$.

We first evaluate the Jacobian matrix at the viable equilibria, $(\mathrm{H}^*, \mathrm{B}^*, \mathrm{q}^*, \mathrm{T_m})$ where $q^* = 1$ or $q^* = 0$. After simplification, we obtain:

$$J(\mathrm{H}^*, \mathrm{B}^*, \mathrm{q}^*, \mathrm{T_m}) = \begin{pmatrix} 0 & \frac{J_1^* \Omega \gamma_1^*}{\mathrm{B}^*} & J_1^*(\gamma_{1s} - \gamma_{1u}) & \frac{\gamma_1^* J_1^*}{T_m} \\ -\frac{J_2^*}{\phi^*} & -\epsilon & J_2^* \frac{\phi_s - \phi_u}{\phi^{*2}} & 0 \\ 0 & 0 & J_3^* & 0 \\ 0 & 0 & 0 & -\sigma \end{pmatrix}$$

where $J_1^* = \mu e^{-b_2 \gamma_2} \mathrm{H}^* \mathrm{B}^{*\Omega}$, $J_2^* = \epsilon z \left(1 - \frac{\mathrm{H}^*}{\phi^*}\right)^{z-1}$, and $J_3^* = (U_s(B^*) - U_u(B^*))(1 - 2\mathrm{q}^*)(1 - \frac{w(\mathrm{q}^*)}{U_u^*})$.

The determinant D of this Jacobian matrix is the product of the four eigenvalues of the system. An equilibrium is locally stable if all its eigenvalues are negative, i.e. $D > 0$. In order to assess the local stability of the viable equilibria, lets first derive the determinant of $J(\mathrm{H}^*, \mathrm{B}^*, \mathrm{q}^*, \mathrm{T_m})$:

$$D = -\epsilon \sigma z \Omega \mu y_1^{min} e^{-b_2 \gamma_2} (B^{*-\frac{1}{z}} - 1)(1 - 2\mathrm{q}^*)[\delta_u^* w(\mathrm{q}^*) + U_s(B^*) - U_u(B^*)] \tag{2}$$

where $\delta_u = \frac{U_u(B^*) - U_s(B^*)}{U_u(B^*)}$.

We obtain the determinant D_s of the Jacobian evaluated at the sustainable equilibrium by taking $B^* = B_s^*$ and $q^* = 1$, so that:

$$D_s = \epsilon \sigma z \Omega \mu y_1^{min} e^{-b_2 \gamma_2} (B_s^{*-\frac{1}{z}} - 1)\ \delta^* [1 - w(1)/U_u(B_s^*)] \tag{3}$$

where $\delta^* = (U_s(B_s^*) - U_u(B_s^*)) = y_1^{min\eta} \gamma_2^{1-\eta} (1 - (\gamma_{1u}/\gamma_{1s})^\eta)$. Since $\gamma_{1u} > \gamma_{1s}$ and $B_s^* \in [0, 1]$, we deduce that $\delta^* < 0$ and $B_s^{*-\frac{1}{z}} - 1 > 0$, so that the sign of D_s depends on the last term of eq. (3). The sustainable equilibrium $(H_s^*, B_s^*, 1, T_m)$ is thus locally stable $(D_s > 0)$ if

$$w(1) > U_u(B_s^*)$$

where $U_u(B_s^*) = \gamma_2^{1-\eta} y_1^{min\ \eta} (\gamma_{1u}/\gamma_{1s})^\eta$.

The determinant D_u of the Jacobian evaluated at the unsustainable equilibrium ($B^* = B_u^*$ and $q^* = 0$) is:

$$D_u = -\epsilon \sigma z \Omega \mu y_1^{min} e^{-b_2 \gamma_2} (B_u^{*-\frac{1}{z}} - 1)\ \delta^* [1 - w(0)/U_u(B_u^*)] \tag{4}$$

where $\delta^* = (U_s(B_u^*) - U_u(B_u^*)) = y_1^{min\eta} \gamma_2^{1-\eta} ((\gamma_{1s}/\gamma_{1u})^\eta - 1)$. Since $\gamma_{1u} > \gamma_{1s}$ and $B_u^* \in [0, 1]$, we deduce that $\delta^* < 0$ and $B_u^{*-\frac{1}{z}} - 1 > 0$, so that the sign of D_u depends on the last term of eq. (3). The unsustainable equilibrium $(H_u^*, B_u^*, 0, T_m)$ is thus locally stable $(D_u > 0)$ if

$$w(0) < U_u(B_u^*)$$

where $U_u(B_u^*) = \gamma_2^{1-\eta} y_1^{min\ \eta}$.

Let us now evaluate the Jacobian matrix at the unviable equilibria, $(0, 1, \mathrm{q}^*, \mathrm{T_m})$ where $q^* = 1$ or $q^* = 0$. After simplification, we obtain:

$$J(0,1,\mathrm{q}^*,\mathrm{T_m}) = \begin{pmatrix} J_0^* & 0 & 0 & 0 \\ -\epsilon z/\phi^* & -\epsilon & \epsilon z \frac{\phi_s-\phi_u}{\phi^{*2}} & 0 \\ 0 & 0 & J_3^* & 0 \\ 0 & 0 & 0 & -\sigma \end{pmatrix}$$

where $J_0^* = \mu e^{-b_2 y_2}(1 - e^{y_1^{min} - \gamma_1^*})$.

The determinant $D(0,1,q^*,T_m)$ writes:

$$D(0,1,q^*,T_m) = \epsilon\sigma\mu e^{-b_2\gamma_2}(1 - e^{y_1^{min}-\gamma_1^*})(1-2q^*)(U_s(1) - U_u(1))[1 - w(q^*)/U_u(1)] \quad (5)$$

where $U_s(1) = \gamma_{1s}^{\eta}\gamma_2^{1-\eta}$ and $U_u(1) = \gamma_{1u}^{\eta}\gamma_2^{1-\eta}$, so that $U_s(1) < U_u(1)$.

Therefore, the determinant $D(0,1,0,T_m)$ is:

$$D(0,1,0,T_m) = \epsilon\sigma\mu e^{-b_2\gamma_2}(1 - e^{y_1^{min}-\gamma_{1u}})(U_s(1) - U_u(1))[1 - w(0)/U_u(1)] \quad (6)$$

Thus, when the viable equilibria are feasible, i.e. when $y_1^{min} < \gamma_{1u} < \gamma_{1s}$, the unviable equilibrium $(0,1,0,T_m)$ is stable if $w(0) > U_u(1)$. However, since $U_u(1) > U^*$, the unviable equilibrium $(0,1,0,T_m)$ is only stable when the corresponding viable equilibrium $(H_u^*, B_u^*, 0, T_m)$ is unstable.

Similarly, the determinant $D(0,1,1,T_m)$ is:

$$D(0,1,1,T_m) = -\epsilon\sigma\mu e^{-b_2\gamma_2}(1 - e^{y_1^{min}-\gamma_{1s}})(U_s(1) - U_u(1))[1 - w(1)/U_u(1)] \quad (7)$$

When the viable equilibria are feasible, the unviable equilibrium $(0,1,1,T_m)$ is stable if $w(1) < U_u(1)$. In this case, both viable $(H_s^*, B_s^*, 1, T_m)$ and unviable $(0,1,1,T_m)$ equilibria can be stable at the same time, if $U_u(B_s^*) < w(1) < U_u(1)$.