

Process-oriented models of autumn leaf phenology: ways to sound calibration and implications of uncertain projections

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S1 Daily drivers of the senescence rate

The senescence rate in all models that we evaluated either depends on daily minimum temperature [°C] and, except for the CDD model, on day length [h]. Daily minimum temperature was taken directly from the corresponding climate datasets (GLDAS and CRODEX; Rodell et al., 2004; Jacob et al., 2014), while day length (L ; [h]) was approximated from latitude (LAT ; [°]) and the day of year (DOY ; [doy]; e.g. 32 for February 2) according to Brock (1981, p. 4):

$$L = \left(24[h]/180^\circ\right) \times \cos^{-1} \left\{ -\tan(LAT) \times \tan \left[23.45^\circ \times \sin \left(360^\circ \times (284 + DOY)/365 \right) \right] \right\}$$

Eq. S1

S2 Seasonal drivers of the threshold for the senescence rate

The threshold value is either a constant or depends linearly on one or two of the following seasonal drivers: the timing of spring phenology in the current year, the mean temperature or low precipitation index (LPI) of the typical growing season or leafy season, the current growing season index (GSI), or the accumulated net photosynthetic rate ignoring or considering water limitation constraints (A_{net} or A_{net-w}) during the current growing season. These drivers were calculated from the minimum, mean, and maximum air temperature, net short- and longwave radiation, downwelling shortwave radiation, precipitation, and soil moisture as well as plant-available water capacity, atmospheric CO_2 concentration, leaf area index and plant functional type (cf. Supplement S1). We calculated driver values according to Eqs. S2–S42 and either applied directly or as site-specific anomalies (in the SIAM, SIAM_{Za20}, PIA_{GSI}, PIA⁺, and PIA[−] models), depending on the model. Furthermore, all driver values except for the spring phenology depend on the period for which they are calculated. This period was either from observed spring to average autumn phenology per site and species (average temperature, LPI_{Za20} , GSI , A_{net} , and A_{net-w} for the TDM_{Za20}, PDM_{Za20}, TPDM_{Za20}, PIA_{GSI}, PIA⁺, and PIA[−] models) or from observed spring phenology to the first day of the accumulation period (d_1 ; average temperature and LPI for the TDM1, PDM1, TPDM1, TM2, PDM2, TPDM2 models).

S2.1 Low precipitation index and adapted low precipitation index

The models by Liu et al. (2019) base their threshold value on the average temperature (TDM1, TDM2, TPDM1, and TPDM2 model) and/or the low precipitation index (LPI ; PDM1, PDM2, TPDM1, and TPDM2 model) for the leafy

season, i.e. the period from observed spring phenology to the starting day of the accumulation of the senescence rate (d_l ; Supplement S2: Eq. S2). The LPI corresponds to the mean number of low precipitation events [$\in (0, 1)$], defined as ≥ 7 consecutive days without rain, between spring phenology (d_{SP} ; [doy]) and the first day of the accumulation period for the senescence rate (d_l ; [doy]; fitted during model calibration):

$$LPI = \overline{\sum_{l=d_{SP}}^{d_l} LPI_l}$$

Eq. S2

Zani et al. (2020) adapted both, the calculations of the average temperature and of the LPI , for the temperature and/or precipitation dependent models by Zani et al. (2020) (i.e. TDM_{Za20} , PDM_{Za20} , and $TPDM_{Za20}$). The corresponding periods were defined to last from the observed spring phenology to the site-specific average autumn phenology. Moreover, the low precipitation index was altered by Zani et al. (2020) and further adapted for this study, corresponding to the number of days with less than 2 mm of precipitation during the three driest periods of 30 consecutive days, hence denoted LPI_{Za20} . In contrast, Zani et al. (2020) based this index on the precipitation during the three driest months within the month of observed spring phenology to the month of the site-specific average autumn phenology.

S2.2 Growing season index

In the PIA_{GSI} model, the threshold value depends on the anomaly of the growing season index (GSI) per site (Jolly et al., 2005, Eq. 3; Zani et al., 2020). Daily GSI values were accumulated between observed spring phenology and the site-specific average autumn phenology. The daily index values are the product of a function of the mean temperature [$^{\circ}C$] $f(T_i)$, the vapor pressure deficit [Pa] $f(VPD_i)$, and the day length [h] $f(L_i)$ of day i . Both, accumulation period as well as $f(T_i)$, $f(VPD_i)$, and $f(L_i)$ were based on Zani et al. (2020, Eqs. S10–S15 and S36–S42) and Zani et al. (2021).

$$GSI = \sum_{i=d_{SP}}^{d_{L_i} < 11h} GSI_i$$

Eq. S3

$$GSI_i = f(T_i) \times f(VPD_i) \times f(L_i)$$

Eq. S4

$$f(T_i) = \frac{1}{1 + e^{k_1(k_2 - T_i)}} \times (1 - 0.01 \times e^{k_3(T_i - x_3)})$$

Eq. S5

$$k_1 = 2 \frac{\log(1/0.99 - 1)}{x_1 - x_2}$$

Eq. S6

$$k_2 = \frac{x_1 + x_2}{2}$$

Eq. S7

$$k_3 = \log\left(\frac{0.99/0.01}{x_4 - x_3}\right)$$

Eq. S8

$$f(VPD_i) = \begin{cases} 0 & , \quad VPD \geq VPD_{max} \\ 1 - \frac{VPD_i - VPD_{min}}{VPD_{max} - VPD_{min}} & , \quad VPD_{max} > VPD > VPD_{min} \\ 1 & , \quad VPD \leq VPD_{min} \end{cases}$$

Eq. S9

$$f(L_i) = \begin{cases} 0 & , \quad L_i \leq L_{min} \\ \frac{L_i - L_{min}}{L_{max} - L_{min}} & , \quad L_{min} < L_i < L_{max} \\ 1 & , \quad L_i \geq L_{max} \end{cases}$$

Eq. S10

Here, $f(T_i)$ ranges from 0 to 1 and the values for x_1 , x_2 , x_3 , and x_4 are 1, 18, 25, and 45 °C, respectively. VPD_{min} and VPD_{max} were set to 900 and 4100 Pa, respectively. L_{min} and L_{max} were set to the maximum day length during the observed growing season per site and year and to 11 h, respectively. Daily mean temperature (T_i) and day length (L_i) were taken directly from the climate data and derived directly from the latitude and day of year (Eq. S1). However, daily vapor pressure deficit (VPD_i ; [Pa]) was derived from daily saturation vapor pressure (e_{si} ; [Pa]) and actual vapor pressure (e_{ai} ; [Pa]), which we approximated by functions of daily minimum and maximum temperature and by substituting dew point temperature by minimum temperature (Sadler and Evans, 1989; Table 1.8; Allen et al., 1998, Eqs. 11, 12, 14, and 48; Jones, 2013, Eqs. 5.15 and 5.16).

$$VPD_i = e_{si} - e_{ai}$$

Eq. S11

$$e_{si} = (e_{Tx_i} + e_{Tn_i})/2$$

Eq. S12

$$e_{ai} = e_{Tn_i}$$

Eq. S13

$$e_{Tj_i} = 611.21 \times e^{[(18.678 - Tj_i/234) \times Tj_i]/(257.14 + Tj_i)}$$

Eq. S14

Here, e_{Tj_i} is the vapor pressure [Pa] at temperature Tj [°C] of day i , with Tj being either daily maximum or minimum temperature (Tx or Tn , respectively).

S2.3 Accumulated net photosynthetic rate

The threshold values of the PIA^+ and PIA^- models are both driven by net photosynthesis, ignoring and considering water limitation constraints, respectively (A_{net} and A_{net-w} ; [mol m⁻²]; Zani et al., 2020). A_{net} and A_{net-w} were accumulated

between observed spring phenology and the site-specific average autumn phenology. They are based on net photosynthesis. This change can be calculated by deducting daytime respiration from gross photosynthesis (A_{gd} ; [mol m⁻²]), which may also be referred to as light respiration and real photosynthesis, respectively (Egle, 1960; Wohlfahrt and Gu, 2015). A_{gd} is limited by photon availability, Rubisco activity, and sink capacity (Farquhar et al., 1980; Kirschbaum and Farquhar, 1984; Collatz et al., 1991). It can be expressed as $\min(J_E, J_C, J_S)$, with J_E , J_C , and J_S being the respective rates depending on light, Rubisco activity, and sink capacity (Collatz et al., 1991, Eq. A.1):

$$A_{gd_i} = L_i \times \frac{J_{P_i} + J_{S_i} - \sqrt{(J_{P_i} + J_{S_i})^2 - 4\beta J_{P_i} J_{S_i}}}{2\beta}$$

Eq. S15

and

$$J_{P_i} = \frac{J_{E_i} + J_{C_i} - \sqrt{(J_{E_i} + J_{C_i})^2 - 4\theta_{Co} J_{E_i} J_{C_i}}}{2\theta_{Co}}$$

Eq. S16

Here, J_P , which is an intermediate variable for the minimum of J_E and J_C . J_E , J_C , and J_S are in [mol m⁻² h⁻¹], L_i is the length of day i [h] (Eq. S1), and β and θ_{Co} are two shaping parameters (Table S1; Collatz et al., 1991, Eqs. A.8 and A.9).

The daily photosynthetic rate depending on light (J_E) was defined as

$$J_{E_i} = CI_i \times APAR_i / L_i$$

Eq. S17

with CI being the daily available fraction of the absorbed photosynthetically active radiation ($APAR$; [mol m⁻²]) accumulated during day i (Haxeltine and Prentice, 1996, Eqs. 3 & 4; Sitch et al., 2000, Eq. 14). Daily $APAR$ was derived from downward shortwave radiation as follows:

$$APAR_i = c_q \times \alpha_a \times f_{apar} \times PAR_i \times (24 \times 3600)[s] \quad \text{Eq. S18}$$

$$f_{apar} = 1 - e^{-0.5 \times LAI} \quad \text{Eq. S19}$$

$$PAR_i = 0.5R_{dsi} \quad \text{Eq. S20}$$

Here, PAR is the photosynthetically active radiation ($[W\ m^{-2}]$), f_{apar} is the intercepted fraction of incoming PAR at ecosystem level, which was calculated from the corresponding leaf area index (LAI; Haxeltine and Prentice, 1996, Eq. 1; Sitch et al., 2000, Eq. 7), α_a is the fraction of assimilated PAR from ecosystem to leaf level (Table S1), and c_q is the conversion factor for solar radiation at 550 nm $[E\ J^{-1}]$ (i.e. $[mol\ J^{-1}]$; Table S1; Sitch et al., 2000, Eq. 14; Smith, 2007, p. 9). PAR was estimated from the downwelling shortwave radiation ($R_{ds}\ [W\ m^{-2}]$; Prentice et al., 1993, Eq. 12; Sitch et al., 2000, Eq. A.1) accumulated during day i .

The fraction $C1$ depends on the daily internal partial pressure of CO_2 (p_lCO_2 ; [Pa]), CO_2 condensation point (Γ^* ; [Pa]) and mean temperature (T ; $[^\circ C]$), as well as on a parameter accounting for the decreasing maximum photosynthetic rate of conifer needles with age (Φ_C) and for the quantum efficiency of C_3 plants (α_{C3} ; Table S.C1; Haxeltine and Prentice, 1996, Eq. 4; Sitch et al., 2000, Eq. 15):

$$C1_i = \Phi_C \times \alpha_{C3} \times f(T_i) \times (p_lCO_{2i} - \Gamma_{*i}) / (p_lCO_{2i} + 2\Gamma_{*i}) \quad \text{Eq. S21}$$

We applied the same function of daily mean temperature $f(T_i)$ as for the calculation of the GSI (Eq. S5). Further, the daily internal partial pressure of CO_2 (p_lCO_2) and the daily CO_2 condensation point (Γ^*) were derived according to

$$p_lCO_{2i} = \lambda_{C3} \times [CO_{2,A}]_i \times P_0 \quad \text{Eq. S22}$$

$$\Gamma_{*i} = p_A O_2 / 2\tau \times Q_{10,\tau}^{((T_i - 25)/10)} \quad \text{Eq. S23}$$

with λ_{C3} being the optimal ratio of internal to ambient $[CO_2]$ of C_3 plants (Table S1), $[CO_{2,A}]$ being the ambient (i.e. atmospheric) $[CO_2]$ of day i , and P_0 being the atmospheric standard pressure [Pa] (Table S1; Collatz et al., 1991, Eqs. A3 & A12; Haxeltine and Prentice, 1996, Eq. 8). In addition, $p_A O_2$ is the ambient partial pressure of O_2 [Pa] (Table S1), τ is the CO_2 to O_2 specificity ratio (Table 1), $Q_{10,\tau}$ is the corresponding change for a temperature change of 10 K (Table S1), and T is the mean temperature $[^\circ C]$ of day i (Haxeltine and Prentice, 1996, Eq. 7; Sitch et al., 2000, Eq. 18).

The daily photosynthetic rate depending on Rubisco activity (J_C) was defined as

$$J_{Ci} = C2_i \times V_{max_i} / 24[\text{h}]$$

Eq. S24

with $C2$ being the daily available fraction of the maximum photosynthetic rate (V_{max} ; [mol m^{-2}]) accumulated during day i , divided by 24 hours (Haxeltine and Prentice, 1996, Eq. 5; Sitch et al., 2000, Eq. 20).

The daily fraction $C2$ depended on the internal partial pressure of CO_2 ($p_i\text{CO}_2$), the CO_2 condensation point (Γ^*), the ambient partial pressure of O_2 ($p_A\text{O}_2$), the kinetic coefficients for CO_2 (K_C) and O_2 (K_O), and the daily mean temperature (T [$^\circ\text{C}$]; Table S1; Collatz et al., 1991, Eq. A12; Haxeltine and Prentice, 1996, Eq. 6; Sitch et al., 2000, Eq. 21):

$$C2_i = \frac{p_i\text{CO}_{2i} - \Gamma^*_{*i}}{p_i\text{CO}_{2i} + K_{Ci} \left(1 + p_A\text{O}_{2i} / K_{Oi} \right)}$$

Eq. S25

$$K_{Ci} = k_C \times Q_{10,k_C}^{((T_i-25)/10)}$$

Eq. S26

$$K_{Oi} = k_O \times Q_{10,k_O}^{((T_i-25)/10)}$$

Eq. S27

The maximum photosynthetic rate (V_{max}) was calculated according to

$$V_{max_i} = \beta_{C_3}^{-1} \times (C1_i / C2_i) \times [(2\theta_{HP} - 1)s_i - (2\theta_{HP}s_i - C2_i)\sigma_i] \times APAR_i$$

Eq. S28

with β_{C_3} being the ratio of dark respiration to V_{max} of C_3 plants and θ_{HP} being a shaping parameter (Table S1; Haxeltine and Prentice, 1996, Eq. 11; Sitch et al., 2000, Eq. 25), whereas s and σ were derived from day length (L) and the fractions $C1$ and $C2$ as follows (Haxeltine and Prentice, 1996, Eqs. 12 & 13; Sitch et al., 2000, Eq. 25):

$$s_i = \beta_{C_3} \times 24[\text{h}] / L_i$$

Eq. S29

$$\sigma_i = \sqrt{1 - C2_i - s_i / C2_i - \theta_{HP}s_i}$$

Eq. S30

The daily photosynthetic rate depending on sink capacity (J_s) was defined as

$$J_{ci} = C2_i \times V_{max_i} / 24[\text{h}]$$

Eq. S31

From A_{gd} , we derived the daily daytime net photosynthetic rate unconstrained by water limitation (A_{net} ; [mol m^{-2}]) by subtracting the daytime respiration (R_d ; [mol m^{-2}]) from A_{gd} (Haxeltine and Prentice, 1996, Eq. 19; Sitch et al., 2000, Eq. 26):

$$A_{net_i} = A_{gd_i} - R_{d_i} \times L_i / 24[\text{h}]$$

Eq. S32

$$R_{d_i} = \beta_{C3} \times V_{max_i}$$

Eq. S33

While A_{net} depended on the daytime fraction of daily respiration (R_d ; [mol m^{-2}]) and thus on day length (L ; [h]), R_d was derived from the maximum photosynthetic rate (V_{max} ; [mol m^{-2}]) and the fraction of leaf respiration per maximum Rubisco capacity for C3 plants (β_{C3} ; Table S1; Haxeltine and Prentice, 1996, Eq. 10; Sitch et al., 2000, Eq. 24):

From A_{net} , we derived the daily daytime net photosynthetic rate constrained by water limitation (A_{net-w} ; [mol m^{-2}]) by multiplying A_{net} with a factor for daily water stress ($0 \leq w_d \leq 1$; Zani et al., 2020, Eq. S.34):

$$A_{net-w_i} = A_{net_i} \times w_{d_i}$$

Eq. S34

$$w_{d_i} = E_{S_i} / E_{D_i}$$

Eq. S35

Here, E_S is the abiotic, atmosphere and soil-controlled moisture supply [mm d^{-1}] and E_D is the biotic, plant-controlled moisture demand [mm d^{-1}] for day i (Prentice et al., 1993; Gerten et al., 2004; Zani et al., 2020, Eq. S.23).

While past climate data were available for four different soil layers, climate projection data were only available for the entire soil in one layer. Hence, we derived daily moisture supply (E_S) by adapting the two-layer approach of Haxeltine and Prentice (1996, Eqs. 24 & 30) and Gerten et al. (2004, Eqs. 4 & 6) to one soil layer depth of 2 m:

$$E_{S_i} = \begin{cases} E_{max} \times (w_i / w_{max}) & ; \quad w_i < w_{max} \\ E_{max} & ; \quad w_i \geq w_{max} \end{cases}$$

Eq. S36

$$w_{max} = 2 \times 1000[\text{mm m}^{-1}] \times PAWC$$

Eq. S37

Here, E_{max} is the maximum transpiration rate ($[\text{mm d}^{-1}]$; Table S1), w is the soil moisture content ($[\text{mm}]$; for the soil layer depth of 0–2 m) of day i , and w_{max} is the corresponding plant-available water capacity $[\text{mm}]$ according to site-specific volumetric plant-available water capacity ($PAWC$, $[\%]$).

Daily moisture demand (E_D) was derived according to Gerten et al. (2004, Eq. 7), neglecting the fraction of daytime during which the canopy is wet, by

$$E_{D_i} = E_{q_i} \times \alpha_m / \left(1 + g_m / g_{pot_i}\right)$$

Eq. S38

with E_q being the daily equilibrium evapotranspiration rate $[\text{mm d}^{-1}]$, α_m being a maximum Priestley-Taylor coefficient (Table S1), g_m being a scaling conductance coefficient ($[\text{mm s}^{-1}]$; Table S1), and g_{pot} being the potential canopy conductance $[\text{mm s}^{-1}]$ for day i .

The daily equilibrium evapotranspiration rate (E_q) depends on mean air temperature (T ; $[\text{°C}]$) and net radiation (i.e. sum of net short- and longwave radiation with positive inward and negative outward fluxes; R_S and R_L , respectively; $[\text{W m}^{-2}]$; Prentice et al., 1993, Eq. 5; Gerten et al., 2004, Eq. 1):

$$E_{q_i} = \frac{\Delta_i}{\Delta_i + \gamma} \times \frac{R_{S_i} + R_{L_i}}{L} \times (24 \times 3600)[\text{s d}^{-1}]$$

Eq. S39

$$\Delta_i = 2.503 \times 10^6 \times \frac{e^{17.269 \times T_i / (237.3 + T_i)}}{(237.3 + T_i)^2}$$

Eq. S40

Here, Δ is the temperature depending rate of increase of the saturation vapor pressure ($[\text{Pa K}^{-1}]$; Prentice et al., 1993, Eq. 6) of day i , γ is a psychrometric constant ($[\text{Pa K}^{-1}]$; Table S1), R_S and R_L are the net short- and longwave radiation $[\text{W m}^{-2}]$, respectively, and L is the latent heat of vaporization of water ($[\text{J kg}^{-1}]$; Table S1).

The potential canopy conductance (g_{pot}) of day i was derived from the daytime net photosynthetic product (A_{DT} ; $[\text{kg C m}^{-2} \text{s}^{-1}]$, Gerten et al., 2004, Eq. 8).

$$g_{pot_i} = g_{min} + \frac{1.6 A_{DT_i}}{[CO_{2,A}]_i \times (1 - \lambda_{c3})}$$

Eq. S41

$$A_{DT_i} = \frac{C_{mol}}{1000[\text{kg g}^{-1}]} \times A_{net_i}[\text{d}^{-1}]$$

Eq. S42

Here, g_{min} is the plant functional type specific minimum canopy conductance ($[\text{mm s}^{-1}]$; Table S1), $[CO_{2,A}]$ is the ambient $[CO_2]$, λ_{C3} is the optimal ratio of internal to ambient $[CO_2]$ of C_3 plants (Table S1), C_{mol} is the molecular mass of carbon (i.e. 12 g mol^{-1}), and A_{net} is the daytime net photosynthetic rate unconstrained by water limitation $[\text{mol m}^{-2}]$.

Table S1. Values and sources of constants applied to the calculation of accumulated apparent daily photosynthetic rates.

Parameter	Value	Unit	Description	Source
β	0.95	fraction	co-limitation (shape) parameter	Co&.91, Eq. A9
θ_{Co}	0.98	fraction	co-limitation (shape) parameter	Co&.91, Eq. A8
α_a	0.5	fraction	ratio of assimilated PAR from ecosystem to leaf level	Si&.00, Table 4
c_q	4.6×10^{-6}	$[\text{E J}^{-1}]$ (i.e. $[\text{mol J}^{-1}]$)	conversion factor for solar radiation at 550 nm	Si&.00, Table 4
Φ_C	1.0 (TBL) 0.8 (TNL)	fraction	parameter accounting for the decreasing maximum photosynthetic rate of leaves with age	H&P.96, Table 4
α_{C3}	0.08	fraction	intrinsic quantum efficiency of CO_2 uptake in C_3 plants	Co&.91, Table A1 H&P.96, Table 2
λ_{C3}	0.8	fraction	optimal ratio of internal to ambient $[CO_2]$ for C_3 plants	Ge&.04, Eq. 8, p. 254
P_0	1.013×10^5	$[\text{Pa}]$	atmospheric standard pressure	
p_{AO_2}	$0.209 \times P_0$	$[\text{Pa}]$	partial ambient pressure of O_2	Co&.91, Table A1 H&P.96, Table 2
τ	2600	fraction	kinetic parameter for the CO_2 to O_2 specificity ratio at 25 °C	Co&.91, Table A1 H&P.96, Table 2
$Q_{10,\tau}$	0.57	fraction	relative change in τ for a 10 K change in temperature	Co&.91, Table A1 H&P.96, Table 2
k_C	30	$[\text{Pa}]$	Michaelis constant for CO_2 at 25 °C	Co&.91, Table A1 H&P.96, Table 2
Q_{10,k_C}	2.1	fraction	relative change in k_C for a 10 K change in temperature	Co&.91, Table A1 H&P.96, Table 2
k_O	3×10^4	$[\text{Pa}]$	Michaelis constant for O_2 at 25 °C	Co&.91, Table A1 H&P.96, Table 2

Table S1. Continued.

$Q_{10,kO}$	1.2	fraction	relative change in k_O for a 10 K change in temperature	Co&.91, Table A1 H&P.96, Table 2
θ_{HP}	0.7	fraction	co-limitation (shape) parameter	M&W.93, Table 1 H&P.96, Table 2
β_{C3}	0.015	fraction	ratio of dark respiration to V_{max} for C_3 plants	Fa&.80, Table A1 H&P.96, Table 2
E_{max}	5	[mm d ⁻¹]	maximum evapotranspiration rate	Si&.03, Table 3 Ge&.04, Table 1
α_m	1.391	fraction	a maximum Priestley-Taylor coefficient	Ge&.04, Eq. 7, p. 253
g_m	3.26	[mm s ⁻¹]	scaling conductance coefficient	Ge&.04, Eq. 7, p. 253
γ	65	[Pa K ⁻¹]	psychrometric constant	Pr&.93, Eq. 5, p. 55 Ge&.04, Eq. 1, p. 253
L	2.5×10^6	[J kg ⁻¹]	latent heat of vaporization of water	Pr&.93, Eq. 5, p. 55 Ge&.04, Eq. 1, p. 253
g_{min}	0.5 (TBL) 0.3 (TNL)	[mm s ⁻¹]	plant functional type specific minimum canopy conductance	Ge&.04, Table 1

Note: Where indicated, constants are plant functional type specific and hence differ between temperate broad-leaved trees (TBL) and temperate needle-leaved trees (TNL). The abbreviations of the sources are Collatz et al. (1991; Co&.91), Farquhar et al. (1980; Fa&.80), Gerten et al. (2004; Ge&.04), Haxeltine and Prentice (1996; H&P.96), Mcmurtrie and Wang (1993; M&W.93), Prentice et al. (1993; Pr&.93), Sitch et al. (2000; Si&.00), Sitch et al. (2003; Si&.03), and Wong et al. (1979; Wo&.79).

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