remote sensing

MDPI

Influences of Ecological Restoration Programs on Ecosystem Services in Sandy Areas, Northern China

(Supplementary material for online publication only)

1. Supplementary Information

Table S1. Descriptions of parameters for the Revised Universal Soil Loss Equation (RUSLE).

Parameters	Calculation Methods	Descriptions of Input Parameters
rainfall-runoff erosivity factor (R)	$R = \sum_{i=1}^{12} 1.735 \times 10^{[1.5 \times \log_{10}(p_i^2/p) - 0.08188]}$	Where i represents the month in a year; Pi is the precipitation in month i ; P is the total annual precipitation.
soil erodibility factor (K)	$\mathrm{K} = \left\{0.2 + 0.3\,exp\left[-0.0256 S_a \left(1 - \frac{S_i}{100}\right)\right]\right\} \times \left(\frac{S_i}{C_l + S_i}\right)^{0.3} \times \left[1 - \frac{0.25C}{C + exp(3.72 - 2.95C)}\right] \times \left[1 - \frac{0.7(1 - 0.01S_a)}{S_n + exp(-5.51 + 22.9S_n)}\right]$	Where Sa, Si, Cl and C are the mass percentages of sand (0.02–2 mm), silt (0.002–0.02 mm), clay (<0.002 mm) and organic carbon in the soil, respectively.
Slope length and steepness factor (LS)	$L = (\lambda/22.13)^{[\beta/(\beta+1)]}$ $\beta = (\sin\theta\,/0.0896)/[3 \times (\sin\theta)^{0.8} + 0.56]$ $S = \begin{cases} 10.8 \times \sin\theta + 0.03, \theta < 9° \\ 16.8 \times \sin\theta - 0.5, 9^{\circ} \le \theta < 18° \\ 21.91 \times \sin\theta - 0.96, \theta \ge 18° \end{cases}$	Where λ is the slope length and θ is the inclination angle.
Cover management (C)	$C = \begin{cases} 1, fvc = 0 \\ 0.6508 - 0.3436 \times \log_{10} fvc, 0 \le fvc \le 78.3\% \\ 0, fvc > 78.3\% \end{cases}$	where fvc is the vegetation cover.
Support practice factor (P)	P values were assigned following the approaches proposed by Teng et al. [1], Ma et al. [2].	P is a dimensionless conservation practice factor.

Table S2. Descriptions of parameters for the revised wind erosion equation (RWEQ).

Parameters	Calculation Methods	Descriptions of Input Parameters
Weather factor (*WF*)	$WF = \frac{SW \times SD \times \sum_{i=1}^{N} u_2(u_2 - u_t) \times N_d \times \rho}{Ng}$ $\rho = \frac{1}{T}(1.013 - 0.1183EL + 0.0048EL^2)$ $SW = \frac{PET - (R + I)\left({}^{R_d}/_{N_d}\right)}{PET}$ $SD = 1 - P_{snow}$	Where W_f is the wind factor ($m^3\ s^{-3}$); ρ is air density ($kg\ m^{-3}$); g is acceleration due to gravity ($m\ s^{-2}$); *SW* is the soil wetness factor; *SD* is the snow cover factor; U_2 is the wind speed at a height of 2 m ($m\ s^{-1}$); U_t is the threshold wind speed at a height of 2 m ($m\ s^{-1}$); N_d is the number of days in the period (usually 15 to 16 days); *N* is the number of wind speed observations; *PET* is potential evapotranspiration (mm); *EL* is elevation (km) obtained from DEM; *T* is absolute temperature (degrees Kelvin); *R* + *I* is rainfall plus irrigation (mm); R_d is the number of rainfall and/or irrigation days; P_{snow} is probability of snow depth greater than 25.4 mm.
Erodible fraction (*EF*); Soil crust factor (*SCF*)	$EF = \frac{29.09 + 0.31Sa + 0.17Si + 0.33Sa/Cl - 2.59OM - 0.95CaCO_3}{100}$ $SCF = \frac{1}{1 + 0.0066Cl^2 + 0.021OM^2}$	Where *Sa* is the sand content (%); *Si* is the silt content (%); *Sa*/*Cl* is the ratio of sand to clay; *OM* is the organic matter (%); $CaCO_3$ is the calcium carbonate (%).
Soil roughness factor (*K*)	$K' = e\left(1.86K_{rmod} - 2.41{K_{rmod}}^{0.934} - 0.124C_{rr}\right)$ $K_r = \frac{RH^2}{RS}$ $R_c = 1 - 0.00032A - 0.000349A^2 + 0.0000258A^3$	Where K_{rmod} is a modified roughness factor which is the product of the ridge roughness K_r and the rotation coefficient R_c; where *RH* and *RS* are the height and spacing respectively of ridges in the arable lands (cm); where *A* is the wind angle to the ridges (0° if perpendicular, 90° if parallel).
Combined vegetation factor (*COG*)	$SLR_s = e^{-0.0344SA^{0.6413}}$ $SLR_c = e^{-5.614CC^{0.7366}}$	*SA* is the silhouette area computed by multiplying the number of standing stalks in 1 m^2 times average diameter (cm) times stalk height (cm); *CC* is the growing vegetation cover, calculated by remote sensing data.

Table S3. Descriptions of parameters for the Carnegie-Ames-Stanford approach (CASA) model.

Parameters	Calculation Methods	Descriptions of Input Parameters
APAR	$APAR(x,t) = SOL(x,t) \times FPAR(x,t) \times 0.5$ $FPAR(x,t) = \frac{SR - SR_{i,min}}{SR_{i,max} - SR_{i,min}} \times (FPAR_{max} - FPAR_{min}) + FPAR_{min}$ $SR = \frac{1 + NDVI}{1 - NDVI}$	*SOL* is total solar radiation, *FPAR* is the proportion of absorbed solar radiation.
ε	$\varepsilon = T_{\varepsilon 1} \times T_{\varepsilon 2} \times \omega_{\varepsilon} \times \varepsilon_{max}$	where ε_{max} is the maximal LUE, and the default set of ε_{max} in the CASA model is assigned to a constant value of 0.389 gC·MJ^{-1}, $T_{\varepsilon 1}$ and $T_{\varepsilon 2}$ represent the stress effects of temperature upon the LUE, and W_{ε} is the water stress influence coefficient.

Table S4. Descriptions of parameters for the Water yield model.

Parameters	Calculation Methods	Descriptions of Input Parameters
$\frac{AET(x)}{P(x)}$	$\frac{AET(x)}{P(x)} = 1 + \frac{PET(x)}{P(x)} - \left[1 + (\frac{PET(x)}{P(x)})^{\omega}\right]^{\frac{1}{\omega}}$	where P is the annual precipitation, AET is the actual evapotranspiration, PET is the potential evapotranspiration (mm), and ω is a nonphysical parameter that characterizes the natural climate–soil properties.
$PET(x)$	$PET(x) = K_c(\iota_x) \times ET_0(x)$	where k is the evapotranspiration coefficient for each vegetation type, where ET_0 is the reference evapotranspiration.
$\omega(x)$	$\omega(x) = Z \times \frac{AWC(x)}{P(x)} + 1.25$	where Z is an empirical factor.

Table S5. Comparison of simulated.

Variables	Source	Region	Value	Source	Region	Value
Carbon sequestration	MOD17A3	TNR	192.5 (gC m^{-2} yr^{-1})	This study	TNR	167.6 (gC m^{-2} yr^{-1})
Wind erosion	Zhang et al. [3]	Inner Mongolia	3800 (t km^{-2} yr^{-1})	This study	Inner Mongolia	4279 (t km^{-2} yr^{-1})
Soil conservation	Li et al. [4]	TNR	5656 (t km^{-2} yr^{-1})	This study	TNR	4800 (t km^{-2} yr^{-1})
Water yield	Li et al. [5]	YERB	200 (mm yr^{-1})	This study	TERB	239 (mm yr^{-1})

TNR, Three Northern Protected Forests Program; YERB, Yellow River Basin.

References

1. Teng, H.; Liang, Z.; Chen, S.; Liu, Y.; Rossel, R.A.V.; Chappell, A.; Yu, W.; Shi, Z. Current and future assessments of soil erosion by water on the Tibetan Plateau based on RUSLE and CMIP5 climate models. *Sci. Total Environ.* **2018**, *635*, 673–686.
2. Ma, X.; Zhu, J.; Yan, W.; Zhao, C. Assessment of soil conservation services of four river basins in Central Asia under global warming scenarios. *Geoderma* **2020**, *375*, 114533.
3. Zhang, H.; Fan, J.; Cao, W.; Harris, W.; Li, Y.; Chi, W.; Wang, S. Response of wind erosion dynamics to climate change and human activity in Inner Mongolia, China during 1990 to 2015. *Sci. Total Environ.* **2018**, *639*, 1038–1050.
4. Li, J.; He, H.; Zeng, Q.; Chen, L.; Sun, R. A Chinese soil conservation dataset preventing soil water erosion from 1992 to 2019. *Sci. Data* **2023**, *10*, 319.
5. Li, Y.; Chen, P.; Niu, Y.; Liang, Y.; Wei, T. Dynamics and attributions of ecosystem water yields in China from 2001 to 2020. *Ecol. Indic.* **2022**, *143*, 109373.