Supplementary data

Text S1. The formula of emergy accounting method.

Provisioning Services

Considering that the alpine wetland of Maqu can provide human with livestock products such as yak, sheep, milk and wool products, while the unique hydrological conditions and environment of the wetland can provide a large amount of pasture as feed for yak and sheep, in this way, the livestock product production and raw material production is selected as provisioning services.

(1) Livestock product production: The Maqu wetland ecosystem can provide various livestock products for human beings. In this paper, the quantity of yak and sheep and the output of milk and wool in Maqu County were selected as the ESV accounting of livestock products. The calculation formula is as follows:

$$E_{map} = \sum_{n=1}^{n} (B_i \times UEV_{mapj}) \hspace{3cm} S1$$

Where E_{map} represents the emergy value (sej) corresponding to livestock production services in the wetland ecosystem; B_i represents the production of the ith livestock product, UEV_{mapj} represents the transformity corresponding to the i-th livestock product $(sej/unit)$.

(2) Raw material production: The grazing production in Maqu County is selected to account for the value of raw material production services, calculated as follows:

$$E_{mgp} = G \times S \times UEV_{grass} \hspace{3cm} S2$$

Where E_{mgp} represents the emergy value corresponding to the raw material production service of wetland ecosystem (sej); G represents the grass yield per unit area of wetland (kg), S represents the area of wetland (m^2), UEV_{grass} represents the per unit emergy of grass (sej/kg).

Regulating Services

The special hydrological cycle of wetlands can make the wetland ecosystem have good water-saving ability. It can not only be used as a water source for agriculture, industry and urban life, but also can supply groundwater and surface water. Wetland plants have the function of carbon fixation and water purification. In this paper, water conservation, climate regulation, carbon sequestration and water purification were selected as the final regulating

services.

(1) Water conservation: The sum of groundwater and surface water recharge of wetland ecosystem is selected to calculate the service value of water conservation, and the calculation formula is as follows:

$$E_{mwc} = \sum (R \times \rho \times S \times k \times UEV_{mgw})(H \times \rho \times UEV_w) \qquad S3$$

Among them, E_{mwc} represents the emergy value (sej) corresponding to water conservation service. ρ represents the density of water (kg/m^3); UEV_w represents the per unit emergy of wetland water supply (sej/kg); R represents annual precipitation in the study area(m); S represents the wetland area of the study area (m^2); K represents the groundwater infiltration coefficient of the wetland ecosystem; UEV_{mgw} represents the emergy transformity of groundwater (sej/g); H represents the runoff difference of the Yellow River between Maqu's entry and exit (m^3).

(2) Climate regulation: There is a large amount of evaporation of water in wetland ecosystem every year, which can reduce temperature and increase humidity. The specific calculation formula is as follows:

$$E_{me} = E \times S \times \rho \times UEV_{wv} \qquad S4$$

Where E_{me} represents the emergy value (sej) of the function of the climate regulating service. E represents the average annual evaporation of wetlands in the research area (m); S represents the wetland area of the study area (m^2); ρ represents the density of water (kg/m^3); UEV_{wv} represents the per unit emergy of water vapor (sej/g).

(3) Water purification: considering that wetland vegetation can absorb pollutants in water and has a certain purification effect on water, the absorption effect of typical wetland vegetation on water pollutants is used to calculate the water purification. The formula is as follows:

$$E_{mwp} = \sum_{n=1}^{n} (A_{ij} \times Z_i \times S_i \times UEV_{mwpj}) \qquad S5$$

Where E_{mwp} represents the emergy value (sej) corresponding to the water purification. A_{ij} represents the absorption capacity of the i-th wetland vegetation to the j-th water pollutant (g/kg); Z_i stands for fresh weight (kg/m^2) per square meter of

wetland vegetation of type i; S_i represents the area covered by the vegetation of the i-th wetland (m^2); UEV_{mwpj} represents the per unit emergy of the j-th pollutant (sej/g).

(4) Carbon sequestration: as a terrestrial carbon sink, wetland ecosystem can play a role in carbon sequestration. The calculation formula is as follows:

$$E_{mcs} = C \times S \times UEV_{Bio} \qquad\qquad S6$$

Where E_{mcs} represents the emergy value (sej) corresponding to the carbon sequestration. C represents the annual carbon sequestration per unit area of wetland $(g/m^2/yr)$; S stands for wetland ecosystem area (m^2); UEV_{Bio} represents the emergy transformity of carbon sequestration (sej/g).

(5) Oxygen release: Wetland vegetation can release oxygen through photosynthesis. In this paper, oxygen release of wetland vegetation is used to calculate the value of oxygen release service. The calculation formula is as follows:

$$E_{mor} = O \times S \times L \times UEV_{Bio} \qquad\qquad S7$$

Where E_{mor} represents the emergy value (sej) corresponding to the oxygen release service function of wetland ecosystem. O represents annual dry matter yield per unit area of wetland ecosystem in the study area (kg/m^2); S represents the area of wetland ecosystem (m^2); L represents the amount of oxygen released by photosynthesis per kilogram of dry matter (kg); UEV_{Bio} represents the emergy conversion rate corresponding to the release of oxygen by wetland vegetation.

Culture Services

Considering that wetland ecosystem can provide wetland landscape, attracting tourists and scientific research, we select scientific research and recreation as cultural services.

(1) Recreation: The calculation formula is as follows:

$$E_{mt} = I_t \times S \times E_m R \qquad\qquad S8$$

Where E_{mt} represents the emergy (sej) corresponding to the leisure and entertainment value of the wetland ecosystem. I_t represents the tourism income of wetland ecosystem per unit area $(dollar/m^2)$; S stands for wetland ecosystem area (m^2); $E_m R$ represents the local emergy currency ratio $(sej/dollar)$ for the current year.

(2) Scientific research: Due to the availability of data, this paper calculated the value of scientific research culture service by referring to the average scientific research value of

ecosystem per unit area in China. The calculation formula is as follows:

$$E_{ms} = Y_s \times S \times E_mR \qquad\qquad S9$$

Where E_{ms} represents the emergy (sej) corresponding to the scientific research and cultural service value of wetland ecosystem. Y_s represents the average scientific research value of wetlands per unit area in China (dollar/m^2); S stands for wetland ecosystem area (m^2); E_mR represents the local emergy currency ratio of the year (sej/dollar).

Table S1. The data sources of this article.

Data Types	Data Sources
(1) Remote sensing images of Maqu County	Geospatial Data Cloud （https://www.gscloud.cn/）
(2) Physical quantity data	
①Renewable resources: sunshine hours, wind speed, precipitation, etc.	Statistical Yearbook of Gannan Prefecture 1990-2020
②Renewable resource factors: eddy diffusion coefficients, wind speed gradients, etc.	Odum [1], Lan et al. [2], Zhu [3]
③Yak and sheep slaughter, wool and milk production	1990-2004 Maqu County Annals; Statistical Yearbook of Gannan Prefecture 1990-2020
④Surface runoff, exit and entry runoff	Gansu Yearbook 2000 and 2005; 2006; Gansu Water Resources Bulletin 2000-2010
⑤Water purification	Li [4], Zhao et al [5]
⑦Annual evaporation	Maqu County Meteorological Bureau
⑧Wetland carbon sequestration per unit area	Piao et al [6]
⑨Tourism income per unit area of wetland and scientific research value	Xie et al [7]

Table S2. The emergy analysis table of valuation on wetland ecosystem services in 1990 in Maqu County.

Items	Raw data	unit	UEV (sej·unit·1) [1]	Sources	Total emergy (sej·a·1)
Renewable Resource					
Sunlight	1.05E+19	J	1	Brown and Ulgiati [8]	1.05E+19
Deep heat	1.10E+15	J	4.90E+03	Brown and Ulgiati [8]	5.41E+18
Wind	7.24E+10	J	8.00E+02	Brown and Ulgiati [8]	5.79E+13
Rain (geo potential)	1.75E+16	J	1.05E+04	Brown and Ulgiati [8]	1.84E+20
Rain (chemical)	2.52E+15	J	7.00E+03	Brown and Ulgiati [8]	1.76E+19
Runoff (geo potential)	6.15E+16	J	1.28E+04	Brown and Ulgiati [8]	7.87E+20
Runoff (chemical)	1.30E+15	J	2.13E+04	Brown and Ulgiati [8]	2.77E+19
Provisioning Services					

Livestock production	4.95E+10	g	Calculated by Eq	Zhu [3]	1.56E+14
Raw material production	7.65E+11	g	2.70E+04	Dong et al [9]	2.07E+16
Regulating Services					
Water conservation [2]	2.24E+15	g	Calculated by Eq	Zhu [3]	1.57E+19
Water purification [3]	3.76E+07	g	Calculated by Eq	Dong [9]	3.69E+17
Climate regulation	1.33E+12	g	5.15E+05	Odum [1]	6.85E+17
Carbon sequestration	3.09E+09	g	4.58E+03	Brown and Ulgiati [10]	1.41E+13
Oxygen release	5.59E+13	g	4.58E+03	Brown and Ulgiati [10]	2.56E+17
Culture Services					
Recreation	Calculated by Eq	Yuan	Calculated by Eq	This article	2.69E+18
Scientific research	Calculated by Eq	Yuan	Calculated by Eq	This article	1.95E+18

[1]The value of livestock production services consists of four components: yak, sheep, milk and wool, and the transformity is 4.00E+06 (sej/unit),2.00E+06 (sej/unit), 2.00E+06 (sej/unit) and 4.40E+06 (sej/unit), respectively.

[2] The service value of water conservation is composed of groundwater recharge and surface water recharge of wetland ecosystem, and the transformity is 2.23E+03 (sej/unit) and 7.01E+03 (sej/unit), respectively.

[3] The value of wetland water purification is calculated by formula, Considering the availability of data, only the absorption data of three common heavy metal pollutants, Cu, Zn and Pb, were selected to account for the value of water purification. The transformity of Cu, Zn and Pb were 6.80E+09 (sej/unit), 1.25E+10 (sej/unit) and 1.25E+10 (sej/unit).

Table S3. The emergy analysis table of valuation on wetland ecosystem services in 2000 in Maqu County.

Items	Raw data	unit	UEV (sej·unit·1) [1]	Sources	Total emergy (sej·a·1)
Renewable Resource					
Sunlight	1.09E+19	J	1	Brown and Ulgiati [8]	1.09E+19
Deep heat	1.09E+15	J	4.90E+03	Brown and Ulgiati [8]	5.33E+18
Wind	7.14E+10	J	8.00E+02	Brown and Ulgiati [8]	5.71E+13
Rain (geo potential)	1.95E+16	J	1.05E+04	Brown and Ulgiati [8]	2.04E+20
Rain (chemical)	2.81E+15	J	7.00E+03	Brown and Ulgiati [8]	1.96E+19
Runoff (geo potential)	3.32E+16	J	1.28E+04	Brown and Ulgiati [8]	4.24E+20
Runoff (chemical)	7.02E+14	J	2.13E+04	Brown and Ulgiati [8]	1.50E+19
Provisioning Services					
Livestock production	1.24E+07	g	Calculated by Eq①	Zhu [3]	1.90E+14
Raw material production	7.54E+11	g	2.70E+04	Dong et al [9]	2.04E+16
Regulating Services					
Water conservation [2]	1.42E+15	g	Calculated by Eq③	Zhu [3]	9.97E+18
Water purification [3]	3.71E+07	g	Calculated by Eq⑤	Dong et al [9]	3.64E+17

Climate regulation	1.50E+12	g	5.15E+05	Odum [1]	7.70E+17
Carbon sequestration	3.05E+09	g	4.58E+03	Brown and Ulgiati [10]	1.40E+13
Oxygen release	5.51E+13	g	4.58E+03	Brown and Ulgiati [10]	2.52E+17
Culture Services					
Recreation	Calculated by Eq	Yuan	Calculated by Eq⑧	This article	6.81E+17
Scientific research	Calculated by Eq	Yuan	Calculated by Eq⑨	This article	4.93E+17

[1]The value of livestock production services consists of four components: yak, sheep, milk and wool, and the transformity is 4.00E+06 (sej/unit),2.00E+06 (sej/unit), 2.00E+06 (sej/unit) and 4.40E+06 (sej/unit), respectively.

[2] The service value of water conservation is composed of groundwater recharge and surface water recharge of wetland ecosystem, and the transformity is 2.23E+03 (sej/unit) and 7.01E+03 (sej/unit), respectively.

[3] The value of wetland water purification is calculated by formula, Considering the availability of data, only the absorption data of three common heavy metal pollutants, Cu, Zn and Pb, were selected to account for the value of water purification. The transformity of Cu, Zn and Pb were 6.80E+09 (sej/unit), 1.25E+10 (sej/unit) and 1.25E+10 (sej/unit).

Table S4. The emergy analysis table of valuation on wetland ecosystem services in 2010 in Maqu County.

Items	Raw data	unit	UEV (sej·unit·1) [1]	Sources	Total emergy (sej·a·1)
Renewable Resource					
Sunlight	9.07E+18	J	1	Brown and Ulgiati [8]	9.07E+18
Deep heat	1.07E+15	J	4.90E+03	Brown and Ulgiati [8]	5.26E+18
Wind	7.05E+10	J	8.00E+02	Brown and Ulgiati [8]	5.64E+13
Rain (geo potential)	2.07E+16	J	1.05E+04	Brown and Ulgiati [8]	2.17E+20
Rain (chemical)	2.98E+15	J	7.00E+03	Brown and Ulgiati [8]	2.09E+19
Runoff (geo potential)	5.08E+16	J	1.28E+04	Brown and Ulgiati [8]	6.50E+20
Runoff (chemical)	1.08E+15	J	2.13E+04	Brown and Ulgiati [8]	2.29E+19
Provisioning Services					
Livestock production	1.24E+07	g	Calculated by Eq①	Zhu [3]	3.26E+14
Raw material production	7.53E+11	g	2.70E+04	Dong et al [9]	2.03E+16
Regulating Services					
Water conservation [2]	2.17E+15	g	Calculated by Eq③	Zhu [3]	1.52E+19
Water purification [3]	3.65E+07	g	Calculated by Eq⑤	Dong et al [9]	3.58E+17
Climate regulation	1.43E+12	g	5.15E+05	Odum [1]	7.35E+17
Carbon sequestration	2.99E+09	g	4.58E+03	Brown and Ulgiati [10]	1.37E+13
Oxygen release	5.71E+13	g	4.58E+03	Brown and Ulgiati [10]	2.62E+17
Culture Services					
Recreation	Calculated by Eq	Yuan	Calculated by Eq⑧	This article	5.13E+17

[1]The value of livestock production services consists of four components: yak, sheep, milk and wool, and the transformity is 4.00E+06 (sej/unit),2.00E+06 (sej/unit), 2.00E+06 (sej/unit) and 4.40E+06 (sej/unit), respectively.

[2] The service value of water conservation is composed of groundwater recharge and surface water recharge of wetland ecosystem, and the transformity is 2.23E+03 (sej/unit) and 7.01E+03 (sej/unit), respectively.

[3] The value of wetland water purification is calculated by formula, Considering the availability of data, only the absorption data of three common heavy metal pollutants, Cu, Zn and Pb, were selected to account for the value of water purification. The transformity of Cu, Zn and Pb were 6.80E+09 (sej/unit), 1.25E+10 (sej/unit) and 1.25E+10 (sej/unit).

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