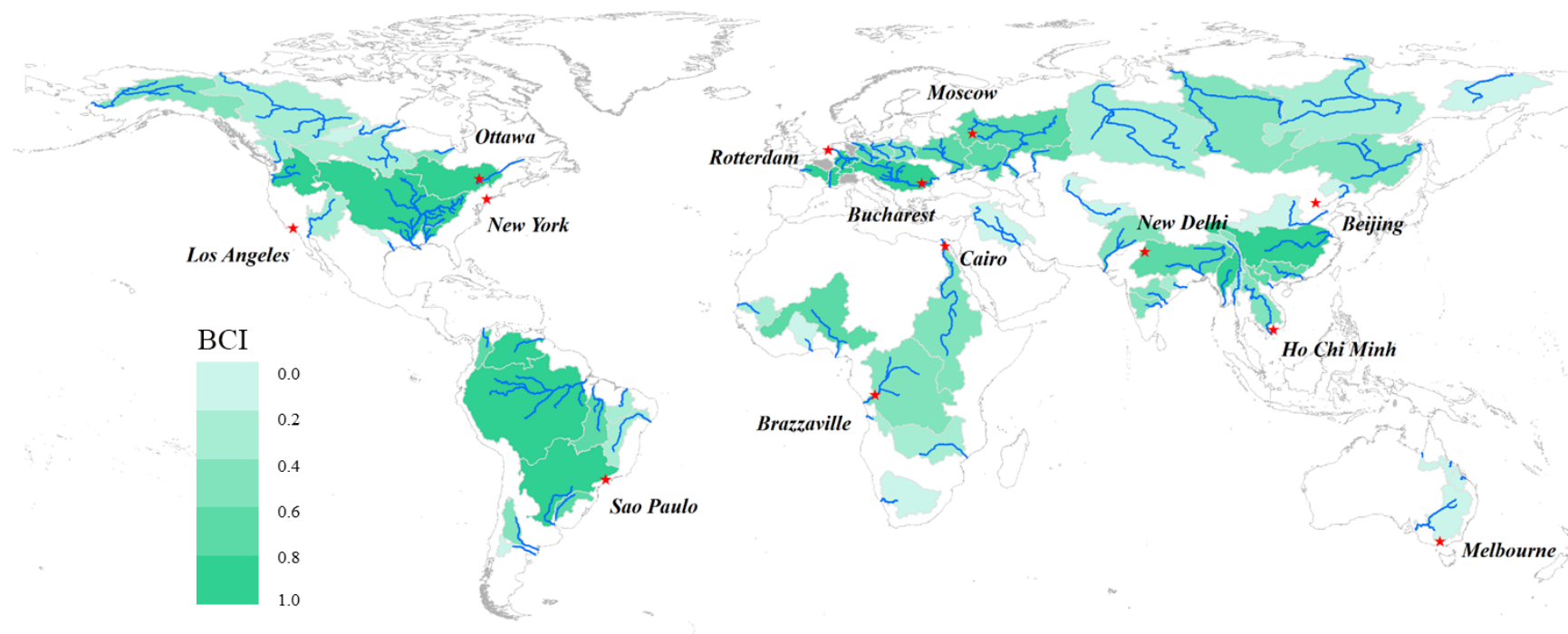


## **Supplementary Information for**

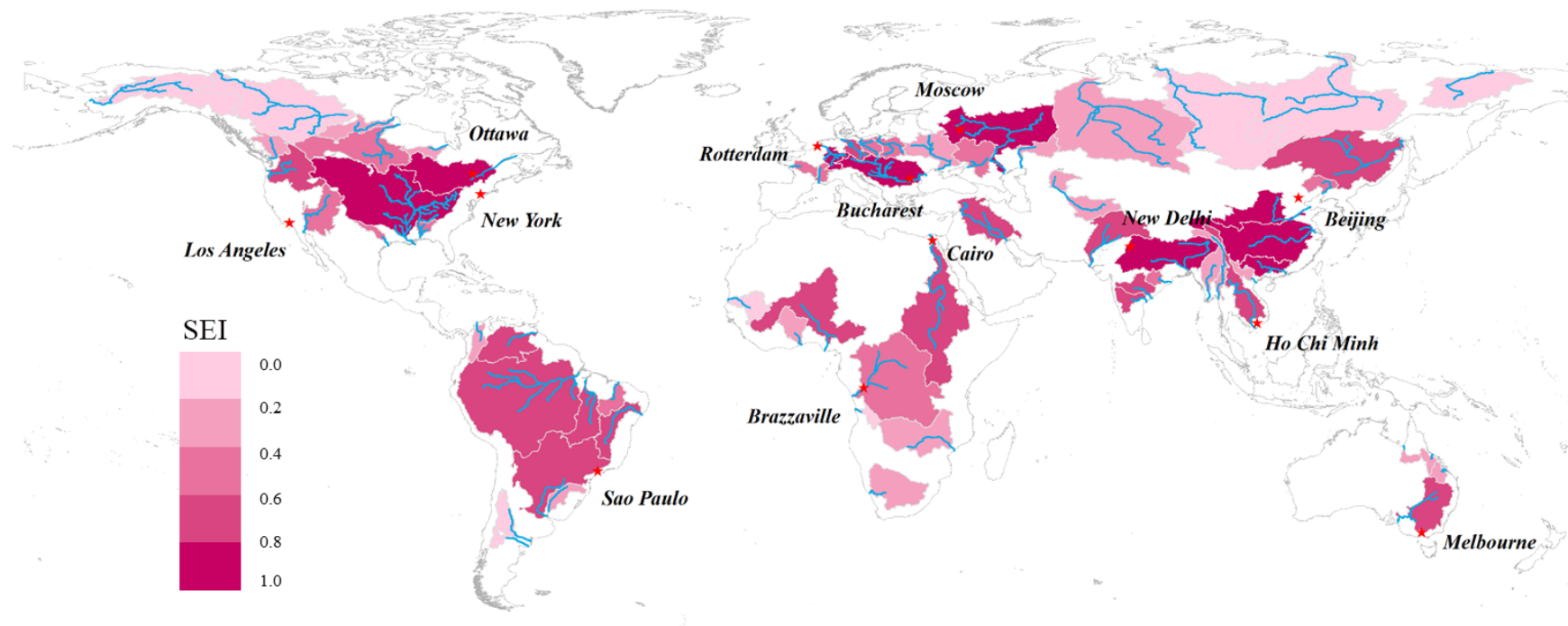
## **Sustainability of Global Golden Inland Waterways**

Wang et al.

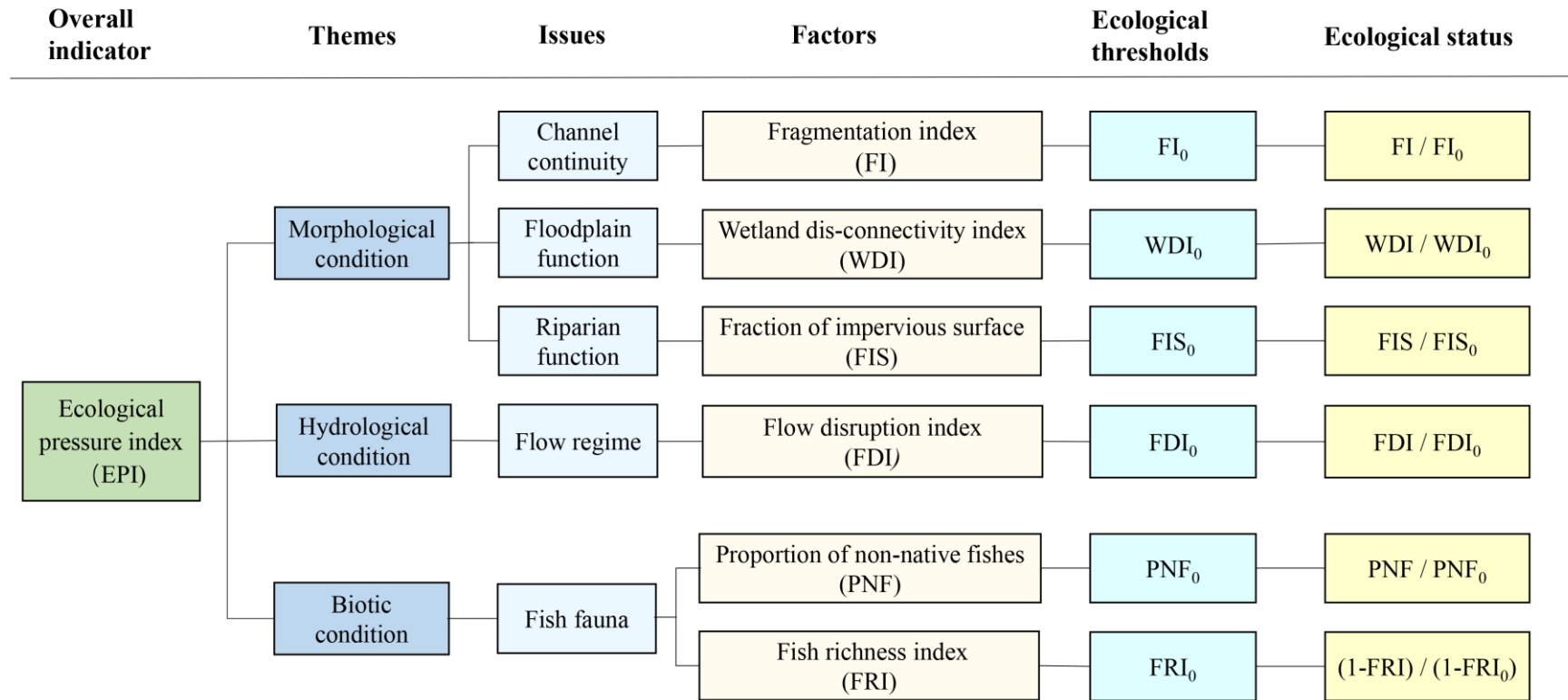
## Supplementary Figures



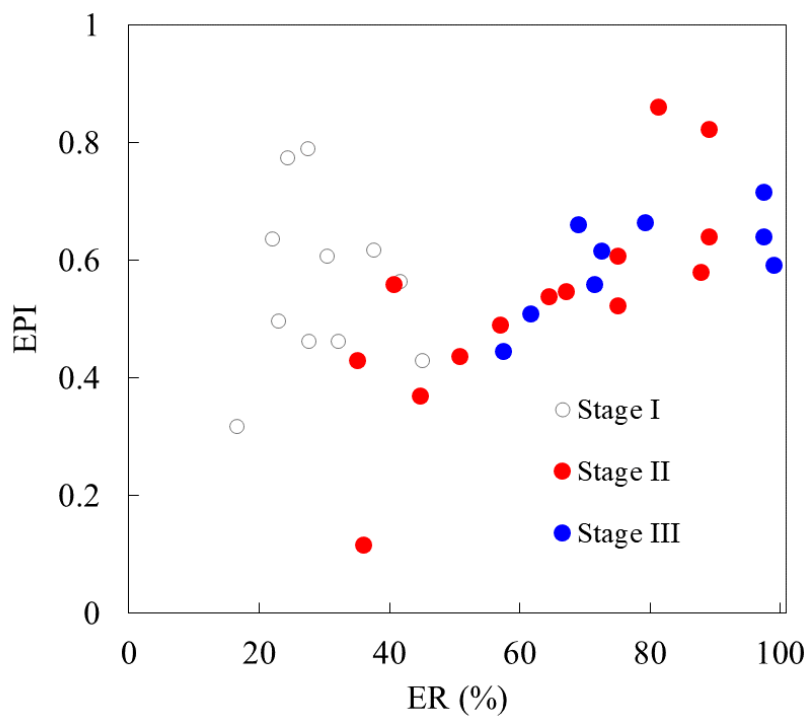
**Supplementary Fig. 1** Global distribution of bearing capacity index (BCI) for large river waterways. Source data are provided as a Source Data file.



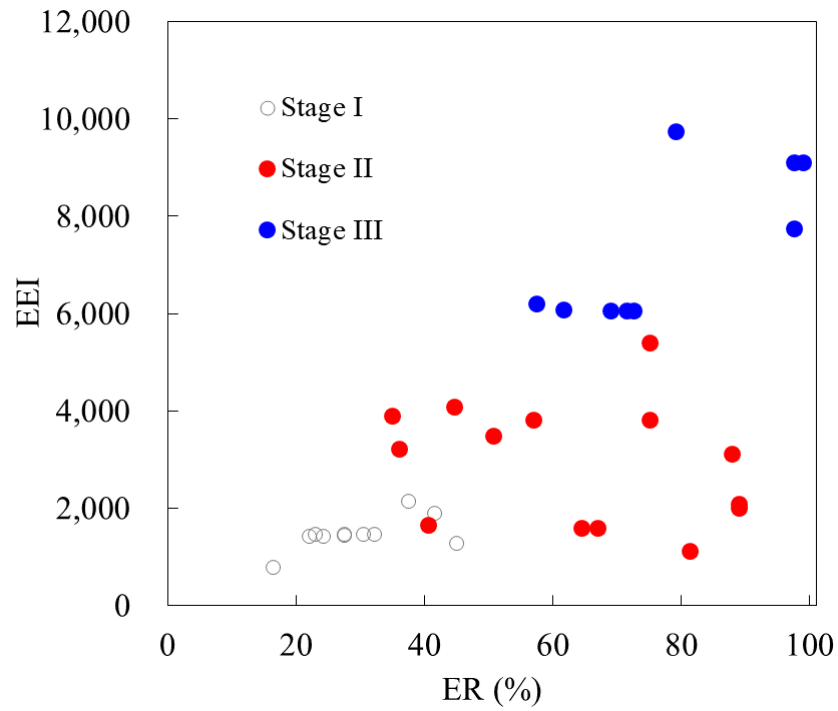
**Supplementary Fig. 2** Global distribution of socio-economic index (SEI) for large river waterways. Source data are provided as a Source Data file.



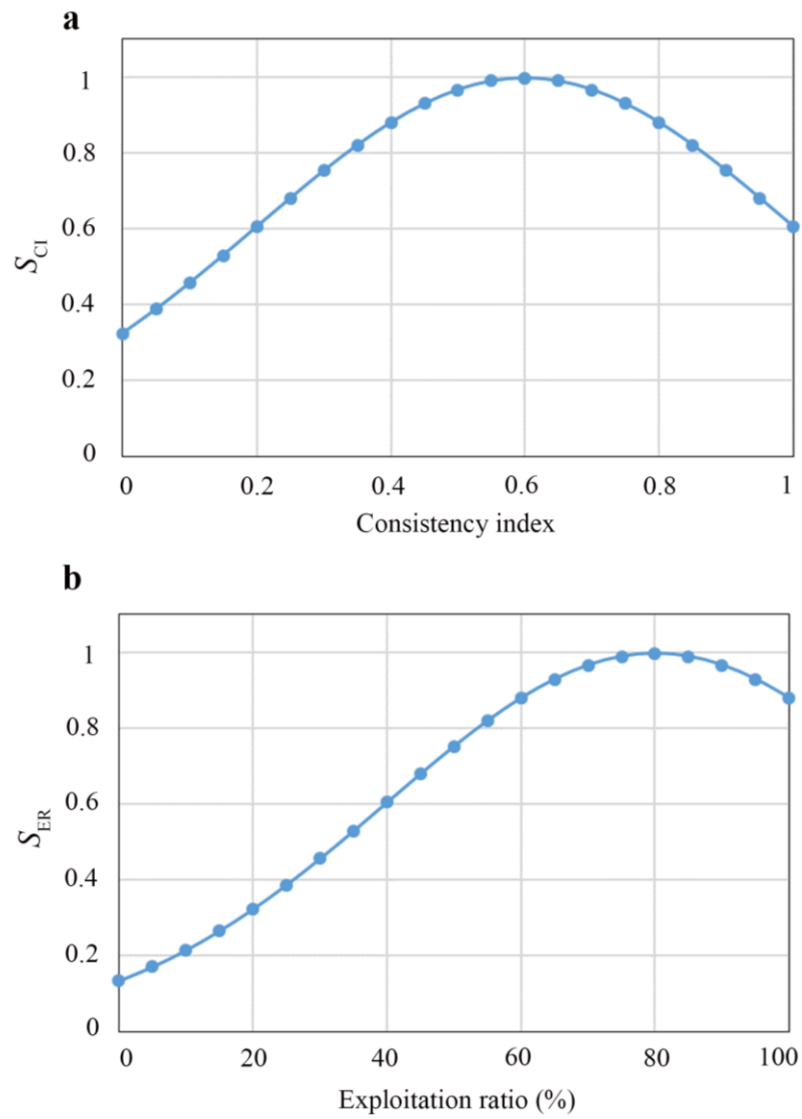
**Supplementary Fig. 3** Hierarchical system for ecological pressure index (EPI) under waterway exploitation.  $FI_0$ ,  $WDI_0$ ,  $FIS_0$ ,  $FDI_0$ ,  $FRI_0$ , and  $PNF_0$  are the critical values of FI, WDI, FIS, FDI, FRI, and PNF when waterway exploitation ratio approaching 80%, respectively.



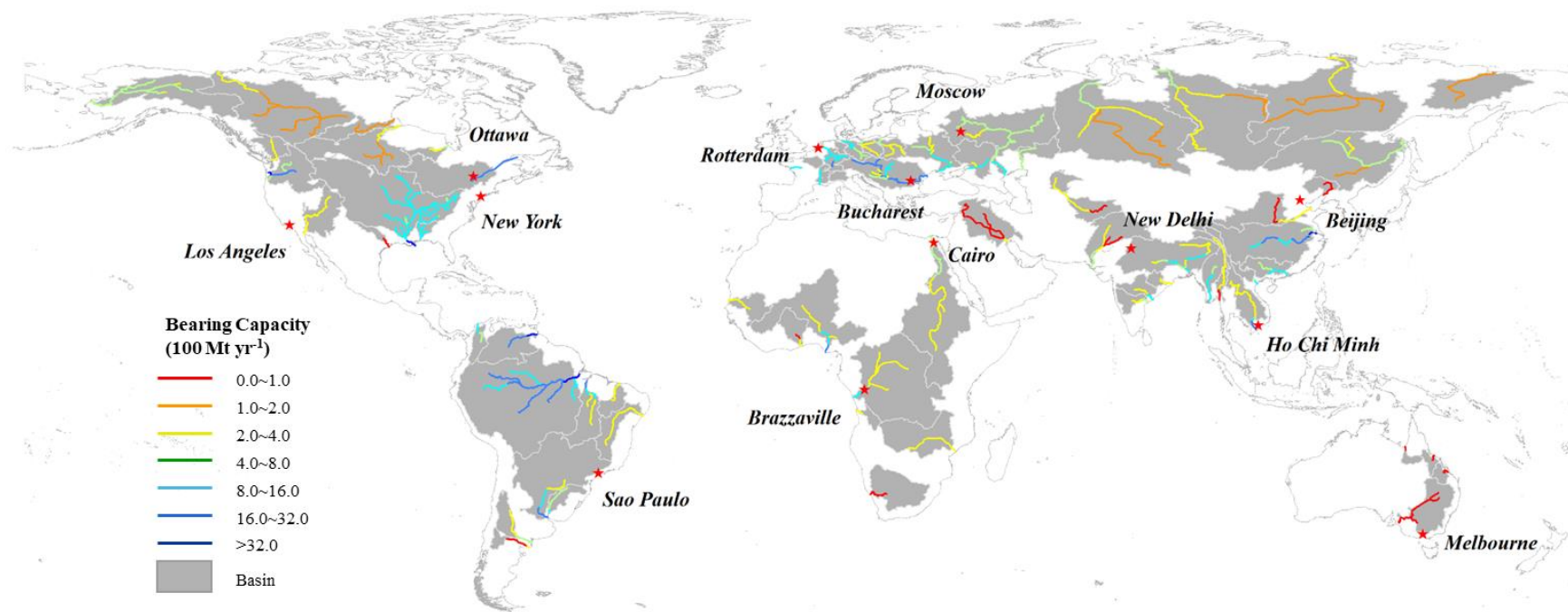
**Supplementary Fig. 4** Relationship between waterway exploitation ratio (ER, %) and ecological pressure index (EPI). Development stage: I, initial; II, developing; III, developed. Source data are provided as a Source Data file.



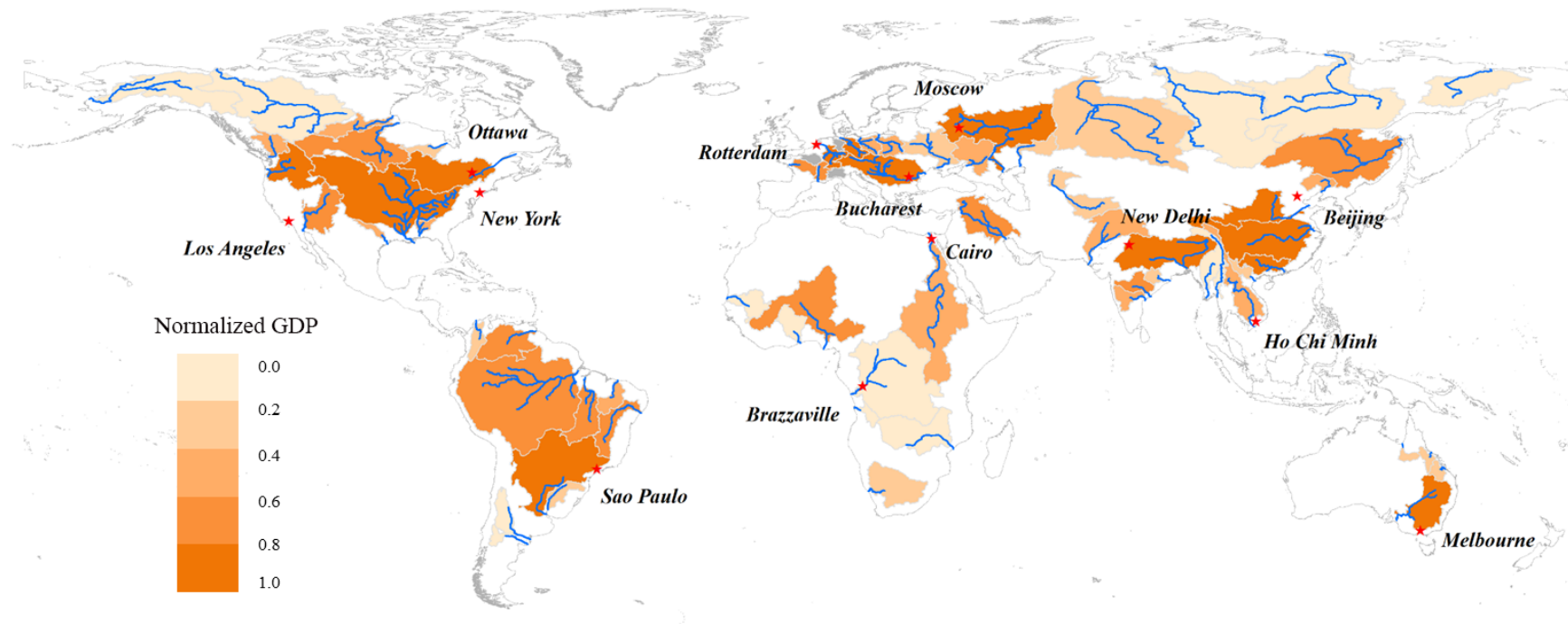
**Supplementary Fig. 5** Relationship between waterway exploitation ratio (ER, %) and eco-efficiency index (EEI) for global GIWs. Development stage: I, initial; II, developing; III, developed. Source data are provided as a Source Data file.



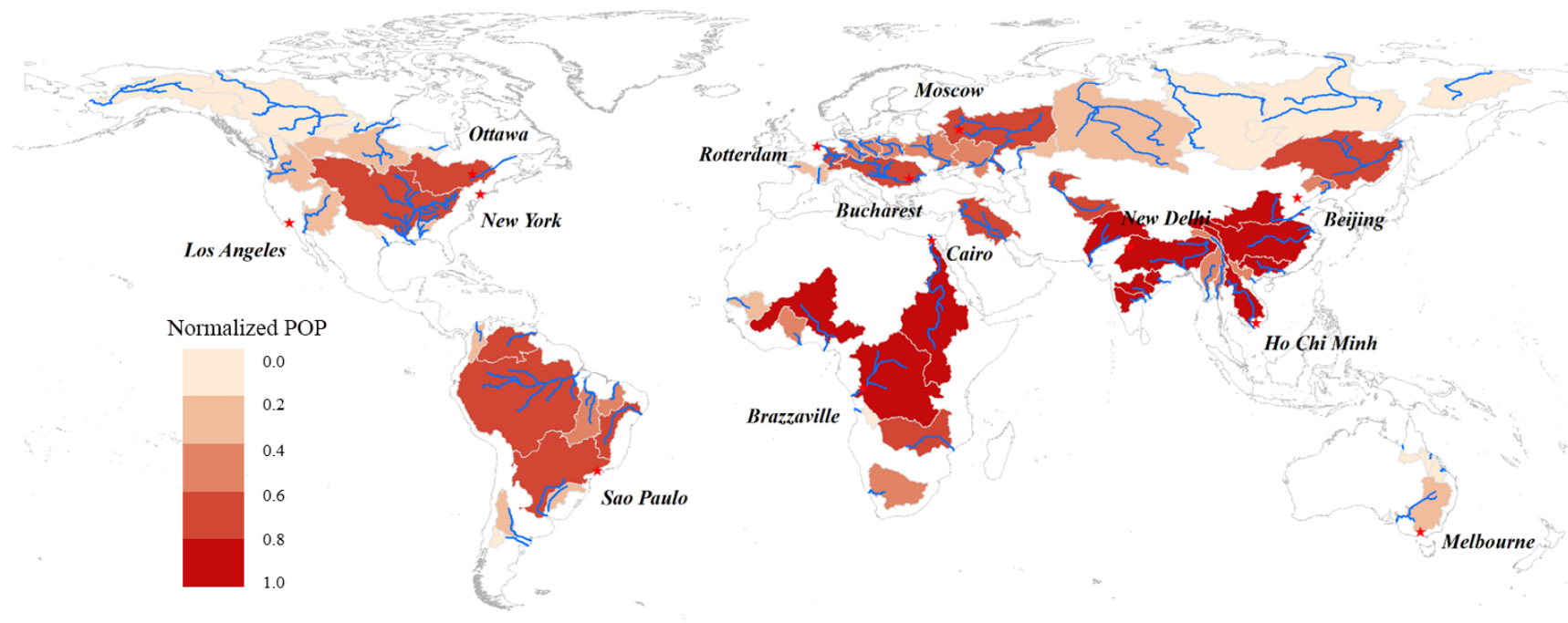
**Supplementary Fig. 6** Score functions of consistency index **(a)** and exploitation ratio **(b)**, used to estimate the sustainability index.  $S_{CI}$  and  $S_{ER}$  denote the scores of a certain consistency index, and an exploitation ratio, respectively.



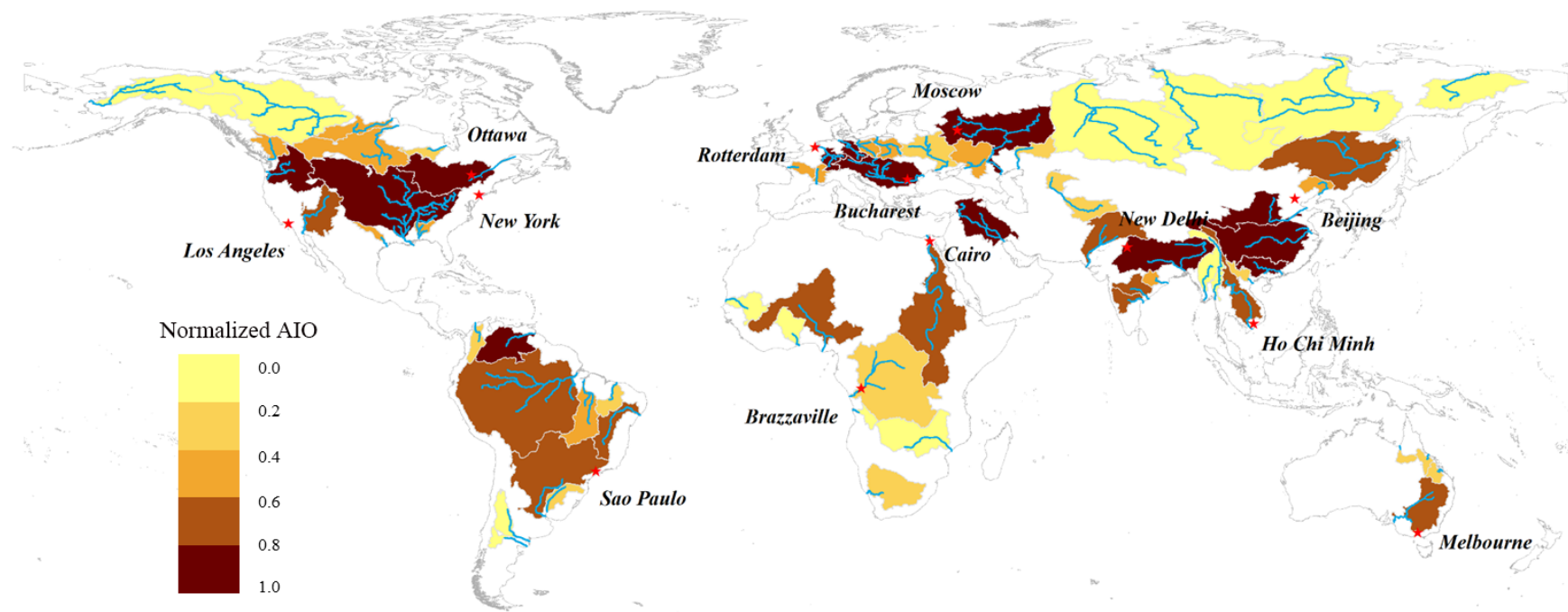
**Supplementary Fig. 7** Global distribution of reach-scale bearing capacity of large river waterways. Source data are provided as a Source Data file.



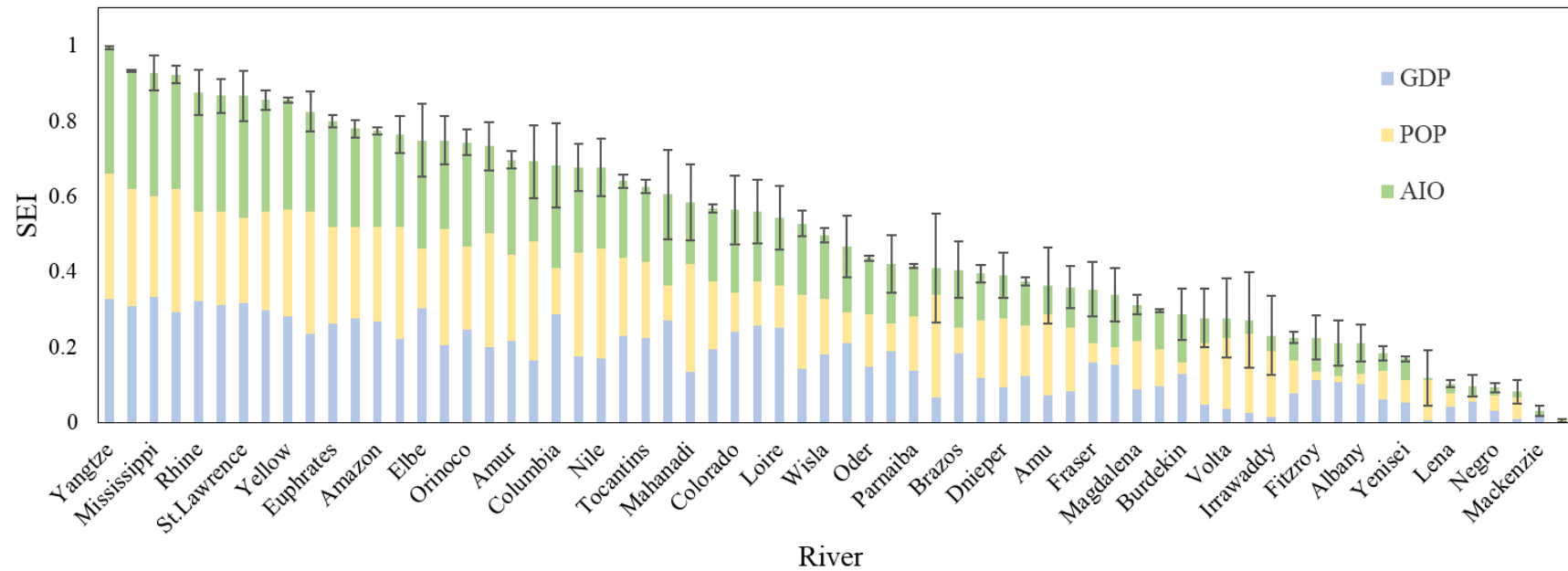
**Supplementary Fig. 8** Global distribution of the normalized gross domestic product (GDP) for large river waterways. Source data are provided as a Source Data file.



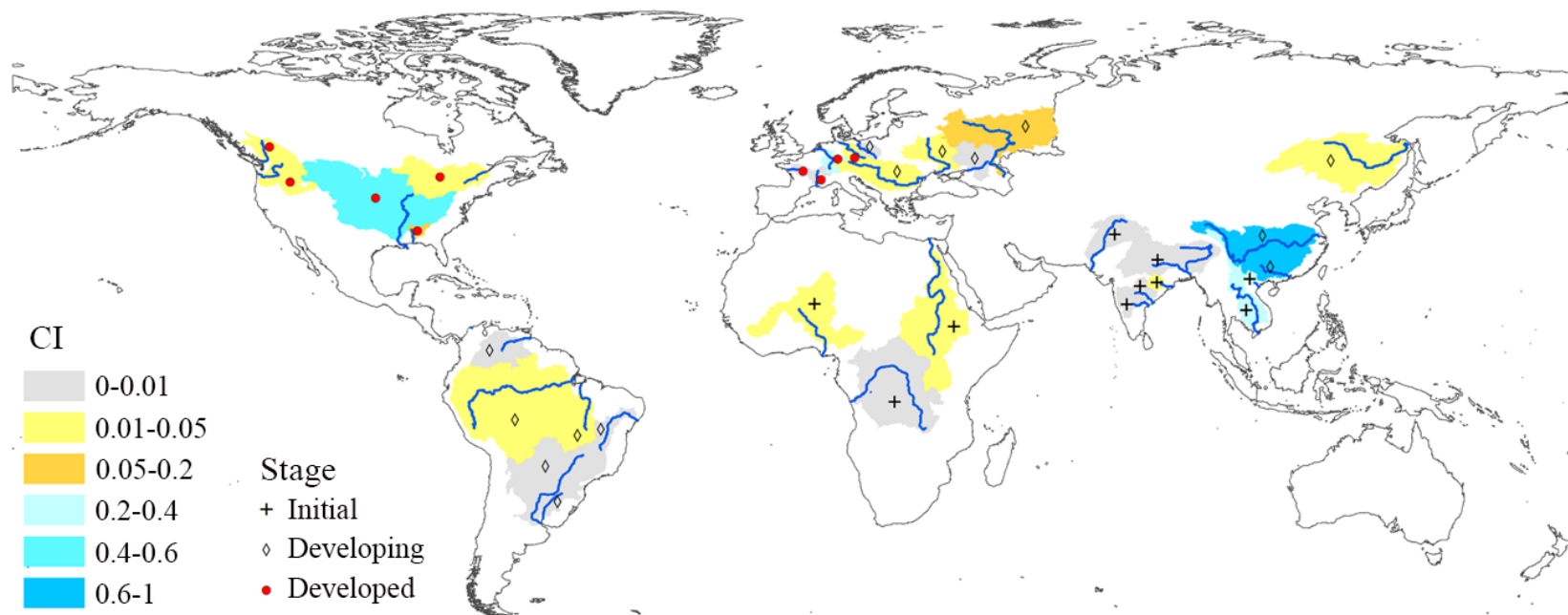
**Supplementary Fig. 9** Global distribution of the normalized population (POP) for large river waterways. Source data are provided as a Source Data file.



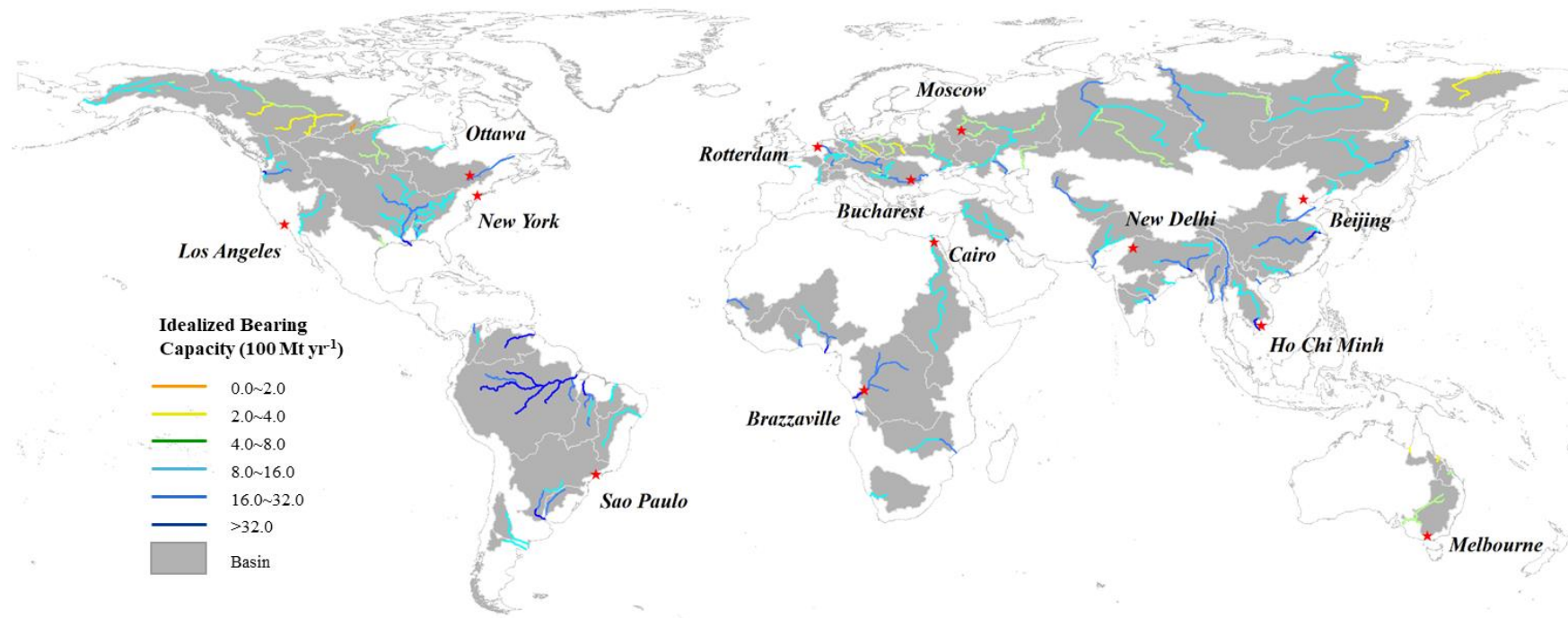
**Supplementary Fig. 10** Global distribution of the normalized agriculture and industrial output (AIO) of large river waterways. Source data are provided as a Source Data file.



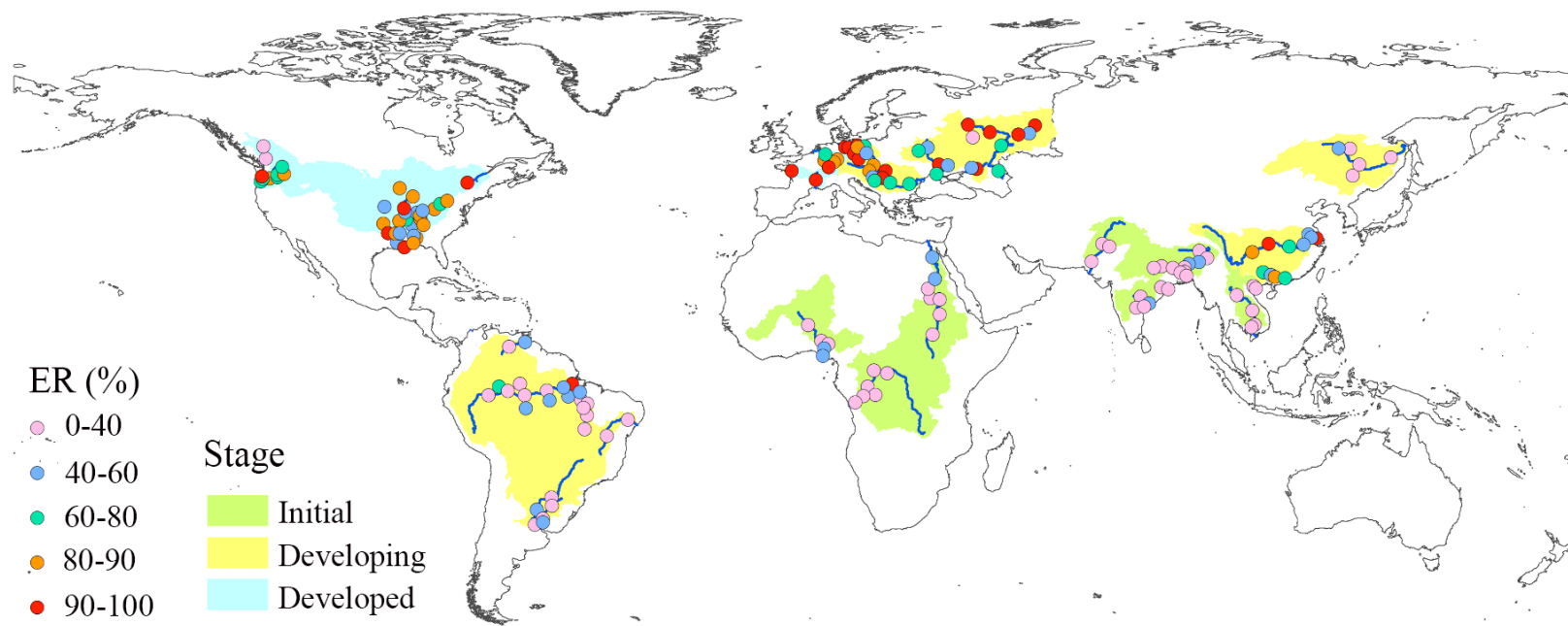
**Supplementary Fig. 11** Socio-economic index (SEI) for the 66 large river inland waterways worldwide, SEI is the combination of 3 indicators with equal weightings assumed. GDP, POP, and AIO represent gross domestic product, population, and agriculture and industrial output, respectively. The error bars show the standard deviation (SD) in SEI obtained after applying the Monte Carlo approach to generate 10,000 random weights (uniformly distributed). Source data are provided as a Source Data file.



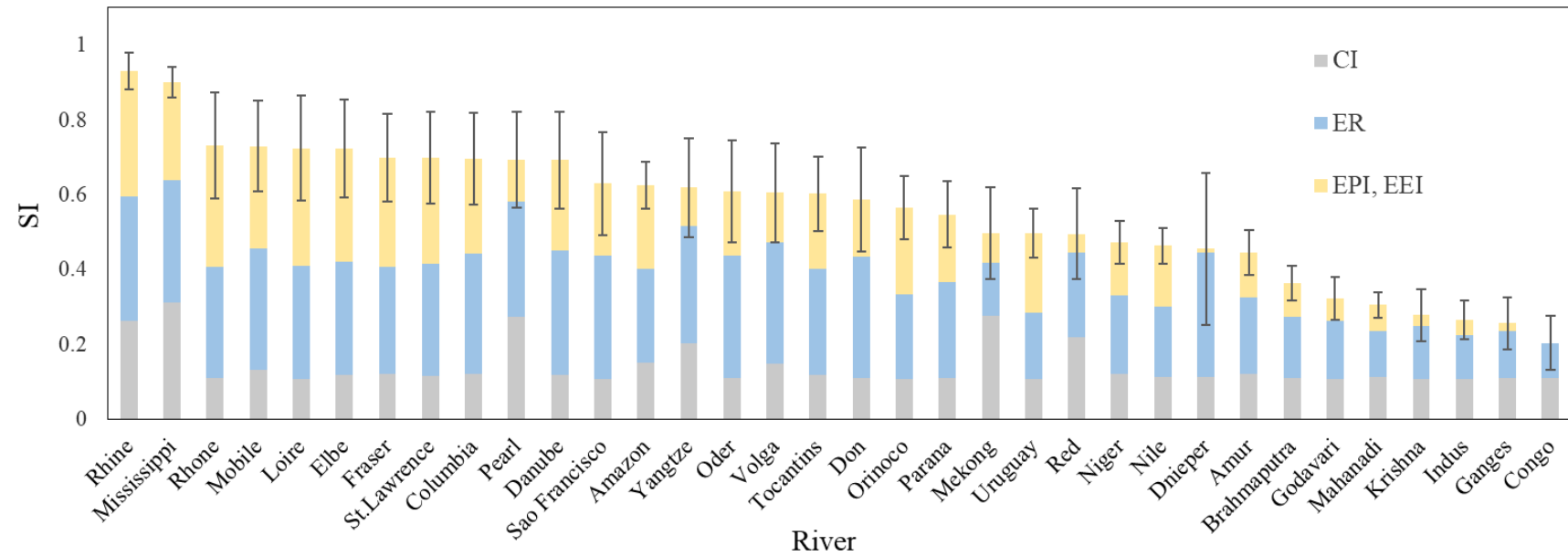
**Supplementary Fig. 12** Global distribution of consistency index (CI) and corresponding development stage of golden inland waterways in 2015. Source data are provided as a Source Data file.



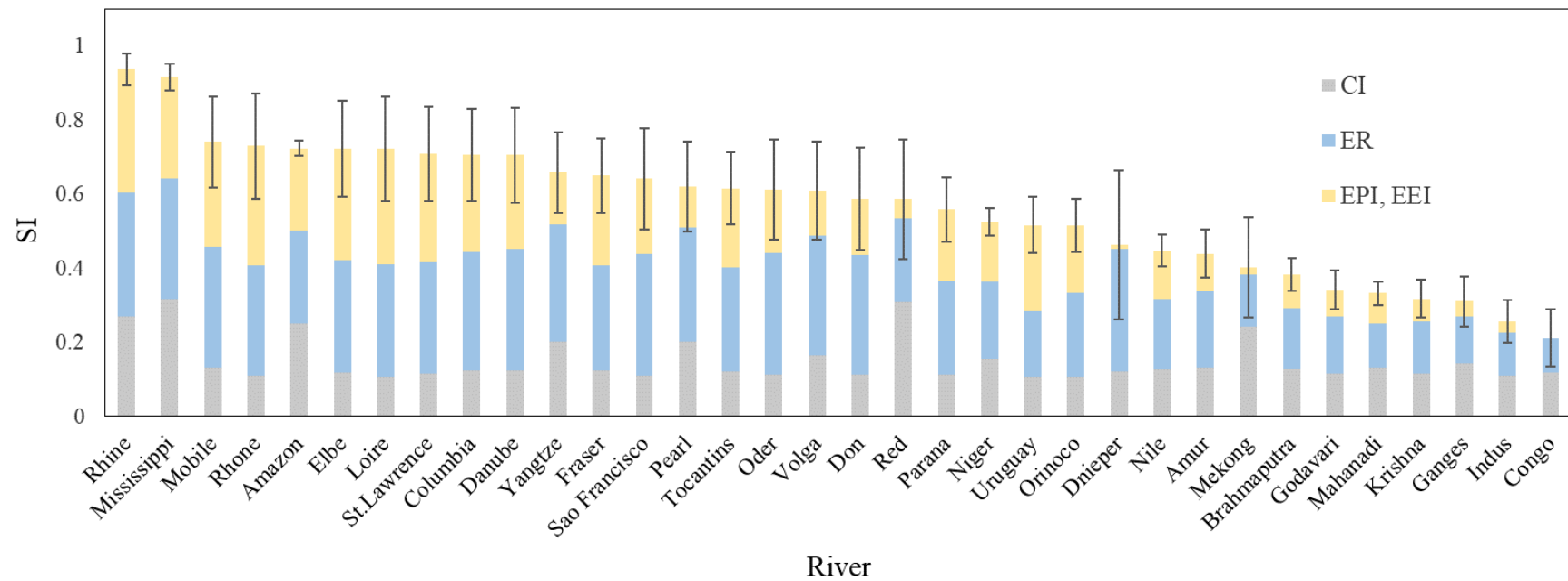
**Supplementary Fig. 13** Global distribution of reach-scale idealized bearing capacity of large river waterways. Source data are provided as a Source Data file.



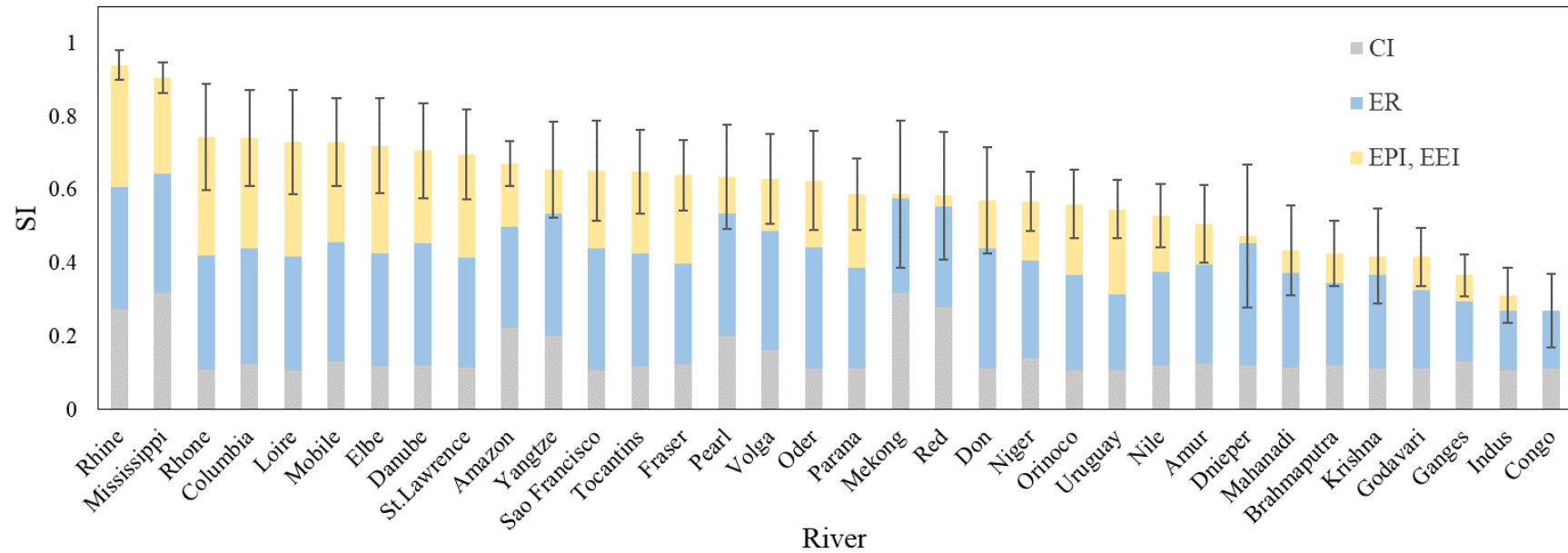
**Supplementary Fig. 14** Global distribution of reach-scale exploitation ratio (ER, %) and corresponding development stage of golden inland waterways in 2015. Source data are provided as a Source Data file.



**Supplementary Fig. 15** Sustainability index (SI), for 34 golden inland waterways by 2015. The error bars show the standard deviation (SD) in SI obtained after applying the Monte Carlo approach to generate 10,000 random weights (uniformly distributed). CI, ER, EPI, and EEI represent consistency index, exploitation ratio, ecological pressure index, and eco-efficiency index, respectively. Source data are provided as a Source Data file.



**Supplementary Fig. 16** Sustainability index, SI, for 34 golden inland waterways by 2050 under the ER invariant scenario (the first scenario). The error bars show the standard deviation (SD) in SI obtained after applying the Monte Carlo approach to generate 10,000 random weights (uniformly distributed). CI, ER, EPI, and EEI represent consistency index, exploitation ratio, ecological pressure index, and eco-efficiency index, respectively. Source data are provided as a Source Data file.



**Supplementary Fig. 17** Sustainability index, SI, for 34 golden inland waterways by 2050 under the idealized scenario (the second scenario). The error bars show the standard deviation (SD) in SI obtained after applying the Monte Carlo approach to generate 10,000 random weights (uniformly distributed). CI, ER, EPI, and EEI represent consistency index, exploitation ratio, ecological pressure index, and eco-efficiency index, respectively. Source data are provided as a Source Data file.

## Supplementary Tables

**Supplementary Table 1** Inland waterway patterns of 66 large rivers in terms of bearing capacity index (BCI) and socio-economic index (SEI)

| River         | BCI  | SEI  | Pattern | River          | BCI  | SEI  | Pattern |
|---------------|------|------|---------|----------------|------|------|---------|
| Rhine         | 0.86 | 0.88 | L-L     | Congo          | 0.57 | 0.41 | M-M     |
| Danube        | 0.92 | 0.87 | L-L     | Irrawaddy      | 0.77 | 0.23 | L-S     |
| Elbe          | 0.71 | 0.75 | L-L     | Magdalena      | 0.74 | 0.31 | L-S     |
| Volga         | 0.68 | 0.86 | L-L     | Ural           | 0.62 | 0.30 | M-S     |
| Yangtze       | 0.97 | 0.99 | L-L     | Ob             | 0.37 | 0.23 | M-S     |
| Pearl         | 0.75 | 0.93 | L-L     | Yenisei        | 0.45 | 0.17 | M-S     |
| Mississippi   | 0.88 | 0.93 | L-L     | Yukon          | 0.55 | 0.10 | M-S     |
| Columbia      | 0.94 | 0.68 | L-L     | Albany         | 0.43 | 0.21 | M-S     |
| St. Lawrence  | 0.95 | 0.87 | L-L     | Zambezi        | 0.46 | 0.27 | M-S     |
| Amazon        | 0.98 | 0.77 | L-L     | Volta          | 0.42 | 0.28 | M-S     |
| Orinoco       | 1.00 | 0.74 | L-L     | Yellow         | 0.15 | 0.86 | S-L     |
| Parana        | 0.91 | 0.78 | L-L     | Euphrates      | 0.12 | 0.80 | S-L     |
| Niger         | 0.69 | 0.76 | L-L     | Wisla          | 0.26 | 0.50 | S-M     |
| Rhone         | 0.89 | 0.56 | L-M     | Liao           | 0.09 | 0.53 | S-M     |
| Loire         | 0.78 | 0.54 | L-M     | Amu            | 0.18 | 0.36 | S-M     |
| Don           | 0.83 | 0.57 | L-M     | Murray-Darling | 0.05 | 0.61 | S-M     |
| Red           | 0.72 | 0.36 | L-M     | Brazos         | 0.03 | 0.41 | S-M     |
| Mobile        | 0.85 | 0.42 | L-M     | Churchill      | 0.17 | 0.34 | S-M     |
| Sao Francisco | 0.80 | 0.64 | L-M     | Colorado       | 0.34 | 0.56 | S-M     |
| Tocantins     | 0.82 | 0.63 | L-M     | Nelson         | 0.22 | 0.47 | S-M     |
| Amur          | 0.54 | 0.70 | M-L     | Parnaiba       | 0.32 | 0.42 | S-M     |
| Mekong        | 0.51 | 0.68 | M-L     | Orange         | 0.02 | 0.39 | S-M     |
| Ganges        | 0.63 | 0.92 | M-L     | Salween        | 0.23 | 0.28 | S-S     |
| Brahmaputra   | 0.58 | 0.83 | M-L     | Lena           | 0.25 | 0.10 | S-S     |
| Godavari      | 0.52 | 0.75 | M-L     | Kolyma         | 0.20 | 0.01 | S-S     |
| Krishna       | 0.48 | 0.73 | M-L     | Burdekin       | 0.00 | 0.29 | S-S     |
| Indus         | 0.40 | 0.69 | M-L     | Fitzroy        | 0.08 | 0.23 | S-S     |
| Nile          | 0.49 | 0.68 | M-L     | Flinders       | 0.06 | 0.21 | S-S     |
| Oder          | 0.35 | 0.44 | M-M     | Mackenzie      | 0.28 | 0.03 | S-S     |
| Dnieper       | 0.60 | 0.39 | M-M     | Rio Colorado   | 0.11 | 0.18 | S-S     |
| Mahanadi      | 0.38 | 0.58 | M-M     | Negro          | 0.14 | 0.09 | S-S     |
| Fraser        | 0.66 | 0.35 | M-M     | Senegal        | 0.31 | 0.12 | S-S     |
| Uruguay       | 0.65 | 0.37 | M-M     | Cuanza         | 0.29 | 0.08 | S-S     |

**Supplementary Table 2** Golden inland waterways (GIWs) development stages and corresponding industrialization processes and manufacturing characteristics

| GIWs development stage | Economic development stage | Industrial characteristics                                                | Added value structure (%)    | GDP per capita (2010 US\$) | Goods characteristics                                           | Growth rate for IWT |
|------------------------|----------------------------|---------------------------------------------------------------------------|------------------------------|----------------------------|-----------------------------------------------------------------|---------------------|
| initial                | agricultural society       | dominated by agricultural and handicraft industries                       | $A > I$                      | 819-1638                   | crops                                                           | low                 |
|                        | early industrialization    | manufacturing begins to develop, especially light industry                | $A > 20\%$ , $A < I$         | 1638-3277                  | textiles, coals, ores, etc.                                     | low to middle       |
| developing             | mid-industrialization      | dominated by heavy and chemical industries                                | $10\% < A < 20\%$<br>$A < I$ | 3277-6553                  | mineral building materials, oil, chemical products, steel, etc. | middle to high      |
|                        | late industrialization     | capital and technology-intensive industries rise up                       | $A < 10\%$ , $I < S < 50\%$  | 6553-12287                 | raw materials, containers, cars and other industrial products   | high                |
|                        | post-industrial society    | capital and technology-intensive industries                               | $A < 10\%$ , $S > 50\%$      | $> 12287$                  | bulk commodities (coals, ores, etc.)                            | middle              |
| developed              | modernized society         | Biotechnology, information and other high-tech industries develop rapidly | $A < 10\%$ , $S > 70\%$      | $> 25000$                  | container transportation increase                               | low                 |

A, I, and S denote agricultural, industrial, and service industries, respectively

**Supplementary Table 3** Inland waterway investment and maintenance costs incurred by European countries in the period from 1995 to 2015

| Year | Netherlands |        | France  |       | Belgium |        | Serbia |       | Hungary |       | Bulgaria |        | Romania |       |
|------|-------------|--------|---------|-------|---------|--------|--------|-------|---------|-------|----------|--------|---------|-------|
|      | A           | B      | A       | B     | A       | B      | A      | B     | A       | B     | A        | B      | A       | B     |
| 1995 | -           | -      | 144.00  | 24.00 | 151.00  | 25.00  | 3.33   | 0.35  | 0.81    | -     | -        | -      | 240.92  | -     |
| 1996 | -           | -      | 79.00   | 26.00 | 125.00  | 27.00  | 3.86   | 1.05  | 0.72    | -     | -        | -      | 148.28  | -     |
| 1997 | 203.00      | 414.00 | 93.00   | 33.00 | 181.00  | 35.00  | 4.38   | 1.45  | 0.28    | -     | -        | -      | 110.03  | -     |
| 1998 | 261.00      | 357.00 | 114.00  | 33.00 | 129.00  | 30.00  | 5.92   | 1.75  | 0.33    | -     | -        | -      | 107.94  | -     |
| 1999 | 319.00      | 222.00 | 139.00  | 37.00 | 139.00  | 31.00  | 3.73   | 1.10  | 0.29    | -     | -        | -      | 97.00   | -     |
| 2000 | 402.00      | 362.00 | 783.17  | 46.00 | 152.00  | 48.00  | 4.98   | 1.29  | 0.33    | -     | -        | -      | 104.84  | -     |
| 2001 | 379.00      | 334.00 | 820.94  | 40.00 | 153.00  | 51.00  | 5.52   | 1.96  | 7.40    | -     | -        | -      | 168.78  | 6.54  |
| 2002 | 512.00      | 441.00 | 950.66  | 41.00 | 153.00  | 51.00  | 13.95  | 4.07  | 5.76    | -     | 463.27   | 470.45 | 103.69  | 6.08  |
| 2003 | 479.00      | 410.00 | 836.65  | 48.00 | 153.00  | 61.00  | 12.31  | 4.29  | 7.34    | -     | 38.48    | 544.38 | 163.79  | 13.32 |
| 2004 | 486.00      | 289.00 | 837.60  | 43.00 | 153.00  | 61.00  | 18.66  | 6.13  | 0.75    | 1.01  | 25.60    | 292.85 | 190.50  | 7.65  |
| 2005 | 284.00      | 604.00 | 860.20  | 55.00 | 156.00  | 66.00  | 14.72  | 6.00  | 1.57    | 1.27  | 85.39    | 507.21 | 139.69  | 6.07  |
| 2006 | 312.00      | 377.00 | 978.00  | 61.00 | 162.00  | 67.00  | 29.51  | 7.20  | 3.88    | 24.53 | 196.85   | 619.18 | 213.09  | 17.31 |
| 2007 | 263.00      | 492.00 | 1052.43 | 58.00 | 178.00  | 76.00  | 23.58  | 11.28 | 4.14    | 33.11 | 405.46   | 787.91 | 358.61  | 28.46 |
| 2008 | 270.00      | 583.00 | 795.29  | 60.00 | 188.00  | 87.00  | 36.32  | 13.46 | 0.39    | 1.60  | -        | -      | 489.96  | -     |
| 2009 | 361.00      | 693.00 | 693.35  | 61.00 | 188.00  | 131.00 | 19.30  | 10.54 | 3.05    | 0.92  | -        | -      | 536.14  | -     |
| 2010 | 252.00      | 544.00 | 758.64  | 60.00 | 154.00  | 65.00  | 21.12  | 13.24 | 0.75    | 3.18  | -        | -      | 423.46  | -     |
| 2011 | 263.00      | 343.00 | 948.95  | 61.00 | 152.00  | 58.00  | 25.76  | 23.03 | 0.21    | 1.57  | -        | -      | 519.04  | -     |
| 2012 | -           | -      | 938.56  | 61.00 | 152.00  | 71.00  | 24.69  | 17.64 | 0.01    | 0.81  | -        | -      | 279.49  | -     |
| 2013 | -           | -      | 744.46  | 61.00 | 167.00  | 66.00  | 15.48  | 16.52 | 0.12    | 0.86  | -        | -      | 268.14  | -     |
| 2014 | -           | -      | 702.41  | 61.00 | 103.00  | -      | 17.73  | 17.29 | 0.02    | 1.30  | -        | -      | 314.11  | -     |
| 2015 | -           | -      | 700.60  | 59.76 | 291.00  | -      | 22.32  | 29.82 | ...     | 1.42  | -        | -      | 505.94  | -     |

A: inland waterway investment cost; B: inland waterway maintenance cost. Data source: <https://data.oecd.org/>. No data (-).

**Supplementary Table 4** Development stage, bearing capacity (BC), freight transport volume (TN) of global golden inland waterways (GIWs) in 2015 and 2050

| No. | GIW         | 2015              |                           |                           | 2050 (scenario 1) |                           |                           | 2050 (scenario 2) |                           |                           |
|-----|-------------|-------------------|---------------------------|---------------------------|-------------------|---------------------------|---------------------------|-------------------|---------------------------|---------------------------|
|     |             | Development stage | BC (Mt yr <sup>-1</sup> ) | TN (Mt yr <sup>-1</sup> ) | Development stage | BC (Mt yr <sup>-1</sup> ) | TN (Mt yr <sup>-1</sup> ) | Development stage | BC (Mt yr <sup>-1</sup> ) | TN (Mt yr <sup>-1</sup> ) |
| 1   | Rhine       | III               | 1051.78                   | 345.82                    | III               | 1051.78                   | 362.78                    | III               | 1022.56                   | 362.78                    |
| 2   | Danube      | II                | 1318.38                   | 38.34                     | III               | 1318.38                   | 47.75                     | III               | 1410.36                   | 47.75                     |
| 3   | Elbe        | III               | 756.6                     | 18.96                     | III               | 756.6                     | 19.66                     | III               | 741.08                    | 19.66                     |
| 4   | Rhone       | III               | 1093.95                   | 6.36                      | III               | 1093.95                   | 6.71                      | III               | 1049.75                   | 6.71                      |
| 5   | Loire       | III               | 862.88                    | 1.29                      | III               | 862.88                    | 1.36                      | III               | 845.18                    | 1.36                      |
| 6   | Oder        | II                | 230.04                    | 2.26                      | III               | 230.04                    | 3.63                      | III               | 224.01                    | 3.63                      |
| 7   | Dnieper     | II                | 539.02                    | 6.5                       | II                | 539.02                    | 17.43                     | II                | 533.7                     | 17.43                     |
| 8   | Don         | II                | 962.09                    | 8.98                      | II                | 962.09                    | 11.03                     | II                | 940.47                    | 11.03                     |
| 9   | Volga       | II                | 732.47                    | 95.88                     | II                | 732.47                    | 130.43                    | II                | 732.47                    | 130.43                    |
| 10  | Yangtze     | II                | 1735.3                    | 2229.37                   | III               | 1735.3                    | 4565.34                   | III               | 2046.1                    | 4565.34                   |
| 11  | Pearl       | II                | 868.82                    | 737.48                    | III               | 868.82                    | 1653.67                   | III               | 1061.44                   | 1653.67                   |
| 12  | Amur        | II                | 452.69                    | 13.73                     | III               | 452.69                    | 27.22                     | III               | 602.1                     | 27.22                     |
| 13  | Red         | I                 | 774.02                    | 198.54                    | II                | 774.02                    | 348.6                     | II                | 1341.6                    | 348.6                     |
| 14  | Mekong      | I                 | 372.876                   | 133.37                    | II                | 372.876                   | 342.8                     | II                | 689.01                    | 342.8                     |
| 15  | Ganges      | I                 | 638.36                    | 3.93                      | II                | 638.36                    | 52.57                     | II                | 840.64                    | 52.57                     |
| 16  | Brahmaputra | I                 | 465.29                    | 3.21                      | II                | 465.29                    | 22.96                     | II                | 635.8                     | 22.96                     |
| 17  | Godavari    | I                 | 431.58                    | 0.52                      | II                | 431.58                    | 8.9                       | II                | 594.3                     | 8.9                       |
| 18  | Krishna     | I                 | 303.8                     | 0.39                      | II                | 303.8                     | 6.77                      | II                | 563.55                    | 6.77                      |
| 19  | Mahanadi    | I                 | 254.15                    | 4                         | II                | 254.15                    | 13.92                     | II                | 563.55                    | 13.92                     |

Development stage: I, initial; II, developing; III, developed. Column No. was ranked by continents, which coincide with GIW number in Figure 2c.

**Supplementary Table 4** Development stage, bearing capacity (BC), freight transport volume (TN) of global golden inland waterways (GIWs) in 2015 and 2050 (*continued*)

| No. | GIW           | 2015              |                           |                           | 2050 (scenario 1) |                           |                           | 2050 (scenario 2) |                           |                           |
|-----|---------------|-------------------|---------------------------|---------------------------|-------------------|---------------------------|---------------------------|-------------------|---------------------------|---------------------------|
|     |               | Development stage | BC (Mt yr <sup>-1</sup> ) | TN (Mt yr <sup>-1</sup> ) | Development stage | BC (Mt yr <sup>-1</sup> ) | TN (Mt yr <sup>-1</sup> ) | Development stage | BC (Mt yr <sup>-1</sup> ) | TN (Mt yr <sup>-1</sup> ) |
| 20  | Indus         | I                 | 269.06                    | 0.5                       | II                | 269.06                    | 1.38                      | II                | 391.36                    | 1.38                      |
| 21  | Mississippi   | II                | 1093.3                    | 497.28                    | III               | 1093.3                    | 523.51                    | III               | 1063.14                   | 523.51                    |
| 22  | Columbia      | III               | 1395.18                   | 49.48                     | III               | 1395.18                   | 52.13                     | III               | 1354.74                   | 52.13                     |
| 23  | Mobile        | III               | 982.41                    | 55.68                     | III               | 982.41                    | 58.66                     | III               | 968.67                    | 58.66                     |
| 24  | St. Lawrence  | III               | 1719.87                   | 36.25                     | III               | 1719.87                   | 38.21                     | III               | 1703.12                   | 38.21                     |
| 25  | Fraser        | III               | 733.13                    | 26.15                     | III               | 733.13                    | 27.61                     | III               | 701.25                    | 27.61                     |
| 26  | Amazon        | II                | 2039.04                   | 51.92                     | II                | 2039.04                   | 111.07                    | II                | 2152.32                   | 111.07                    |
| 27  | Orinoco       | II                | 2624.78                   | 3.69                      | II                | 2624.78                   | 5.11                      | II                | 3053.44                   | 5.11                      |
| 28  | Parana        | II                | 1187.9                    | 10.38                     | II                | 1187.9                    | 15.06                     | II                | 1288.65                   | 15.06                     |
| 29  | Sao Francisco | II                | 933.75                    | 0.08                      | II                | 933.75                    | 3.92                      | II                | 964.88                    | 3.92                      |
| 30  | Tocantins     | II                | 934.23                    | 25.26                     | II                | 934.23                    | 32.08                     | II                | 1048.96                   | 32.08                     |
| 31  | Uruguay       | II                | 663.95                    | 0.44                      | II                | 663.95                    | 0.7                       | II                | 777.77                    | 0.7                       |
| 32  | Congo         | I                 | 470.25                    | 1.67                      | I                 | 470.25                    | 12.16                     | I                 | 883.5                     | 12.16                     |
| 33  | Nile          | I                 | 358.7                     | 3.71                      | II                | 358.7                     | 15.91                     | II                | 486.54                    | 15.91                     |
| 34  | Niger         | I                 | 751.71                    | 24.26                     | II                | 751.71                    | 77.24                     | II                | 957.71                    | 77.24                     |

Development stage: I, initial; II, developing; III, developed. Column No. was ranked by continents, which coincide with GIW number in Figure 2c.

**Supplementary Table 5** Consistency index (CI), exploitation ratio (ER), ecological pressure index (EPI), and eco-efficiency index (EEI) of global golden inland waterways (GIWs) in 2015 and two scenarios in 2050

| No. | GIW         | 2015 |      |      |         | 2050 (scenario 1) |      |      |          | 2050 (scenario 2) |      |      |          |
|-----|-------------|------|------|------|---------|-------------------|------|------|----------|-------------------|------|------|----------|
|     |             | CI   | ER   | EPI  | EEI     | CI                | ER   | EPI  | EEI      | CI                | ER   | EPI  | EEI      |
| 1   | Rhine       | 0.33 | 0.79 | 0.66 | 9755.51 | 0.34              | 0.79 | 0.66 | 14320.34 | 0.35              | 0.77 | 0.60 | 14320.34 |
| 2   | Danube      | 0.03 | 0.75 | 0.60 | 5399.23 | 0.04              | 0.75 | 0.60 | 10154.84 | 0.03              | 0.79 | 0.61 | 10154.84 |
| 3   | Elbe        | 0.03 | 0.98 | 0.64 | 7758.53 | 0.03              | 0.98 | 0.64 | 11661.64 | 0.03              | 0.96 | 0.70 | 11661.64 |
| 4   | Rhone       | 0.01 | 0.99 | 0.59 | 9117.38 | 0.01              | 0.99 | 0.59 | 13129.87 | 0.01              | 0.95 | 0.70 | 13129.87 |
| 5   | Loire       | 0.00 | 0.98 | 0.71 | 9117.38 | 0.00              | 0.98 | 0.71 | 13129.87 | 0.00              | 0.96 | 0.70 | 13129.87 |
| 6   | Oder        | 0.01 | 0.88 | 0.57 | 3121.74 | 0.02              | 0.88 | 0.57 | 6125.25  | 0.02              | 0.86 | 0.65 | 6125.25  |
| 7   | Dnieper     | 0.01 | 0.81 | 0.83 | 1121.80 | 0.03              | 0.81 | 0.83 | 2456.84  | 0.03              | 0.81 | 0.62 | 2456.84  |
| 8   | Don         | 0.01 | 0.89 | 0.63 | 2018.18 | 0.01              | 0.89 | 0.63 | 3975.41  | 0.01              | 0.87 | 0.66 | 3975.41  |
| 9   | Volga       | 0.09 | 0.89 | 0.79 | 2102.62 | 0.13              | 0.89 | 0.79 | 4096.02  | 0.13              | 0.89 | 0.67 | 4096.02  |
| 10  | Yangtze     | 1.00 | 0.67 | 0.55 | 1595.50 | 1.00              | 0.67 | 0.55 | 3668.57  | 1.00              | 0.79 | 0.61 | 3668.57  |
| 11  | Pearl       | 0.85 | 0.65 | 0.53 | 1595.50 | 1.00              | 0.65 | 0.53 | 3436.51  | 1.00              | 0.79 | 0.61 | 3436.51  |
| 12  | Amur        | 0.03 | 0.41 | 0.56 | 1653.08 | 0.06              | 0.41 | 0.56 | 3262.04  | 0.05              | 0.54 | 0.47 | 3262.04  |
| 13  | Red         | 0.23 | 0.45 | 0.43 | 1271.44 | 0.45              | 0.45 | 0.43 | 2313.62  | 0.37              | 0.55 | 0.47 | 2313.62  |
| 14  | Mekong      | 0.36 | 0.28 | 0.46 | 1446.55 | 0.92              | 0.28 | 0.46 | 2154.40  | 0.50              | 0.51 | 0.45 | 2154.40  |
| 15  | Ganges      | 0.01 | 0.24 | 0.77 | 1423.25 | 0.08              | 0.24 | 0.77 | 2756.32  | 0.06              | 0.32 | 0.34 | 2756.32  |
| 16  | Brahmaputra | 0.01 | 0.32 | 0.46 | 1466.76 | 0.05              | 0.32 | 0.46 | 2910.42  | 0.04              | 0.44 | 0.41 | 2910.42  |
| 17  | Godavari    | 0.00 | 0.31 | 0.61 | 1463.30 | 0.02              | 0.31 | 0.61 | 2900.58  | 0.01              | 0.42 | 0.40 | 2900.58  |
| 18  | Krishna     | 0.00 | 0.28 | 0.79 | 1463.30 | 0.02              | 0.28 | 0.79 | 2900.58  | 0.01              | 0.51 | 0.45 | 2900.58  |
| 19  | Mahanadi    | 0.02 | 0.23 | 0.50 | 1463.30 | 0.05              | 0.23 | 0.50 | 2900.58  | 0.02              | 0.51 | 0.45 | 2900.58  |
| 20  | Indus       | 0.00 | 0.22 | 0.64 | 1417.91 | 0.01              | 0.22 | 0.64 | 2499.39  | 0.00              | 0.32 | 0.34 | 2499.39  |

Development stage: I, initial; II, developing; III, developed. Column GIW No. was ranked by continents, which coincide with GIW number in Figure 2c.

**Supplementary Table 5** Consistency index (CI), exploitation ratio (ER), ecological pressure index (EPI), and eco-efficiency index (EEI) of global golden inland waterways (GIWs) in 2015 and two scenarios in 2050 (*continued*)

| No. | GIW           | 2015 |      |      |         | 2050 (scenario 1) |      |      |          | 2050 (scenario 2) |      |      |          |
|-----|---------------|------|------|------|---------|-------------------|------|------|----------|-------------------|------|------|----------|
|     |               | CI   | ER   | EPI  | EEI     | CI                | ER   | EPI  | EEI      | CI                | ER   | EPI  | EEI      |
| 21  | Mississippi   | 0.45 | 0.73 | 0.61 | 6064.99 | 0.48              | 0.73 | 0.61 | 10774.22 | 0.49              | 0.71 | 0.56 | 10774.22 |
| 22  | Columbia      | 0.04 | 0.69 | 0.66 | 6064.99 | 0.04              | 0.69 | 0.66 | 10774.22 | 0.04              | 0.67 | 0.54 | 10774.22 |
| 23  | Mobile        | 0.06 | 0.72 | 0.55 | 6064.99 | 0.06              | 0.72 | 0.55 | 10774.22 | 0.06              | 0.71 | 0.56 | 10774.22 |
| 24  | St. Lawrence  | 0.02 | 0.62 | 0.51 | 6079.25 | 0.02              | 0.62 | 0.51 | 10576.07 | 0.02              | 0.61 | 0.51 | 10576.07 |
| 25  | Fraser        | 0.04 | 0.58 | 0.45 | 6212.19 | 0.04              | 0.58 | 0.45 | 8429.14  | 0.04              | 0.55 | 0.47 | 8429.14  |
| 26  | Amazon        | 0.03 | 0.36 | 0.12 | 3215.17 | 0.05              | 0.36 | 0.12 | 5325.00  | 0.05              | 0.40 | 0.39 | 5325.00  |
| 27  | Orinoco       | 0.00 | 0.45 | 0.37 | 4098.61 | 0.00              | 0.45 | 0.37 | 5622.28  | 0.00              | 0.52 | 0.46 | 5622.28  |
| 28  | Parana        | 0.01 | 0.51 | 0.43 | 3486.01 | 0.01              | 0.51 | 0.43 | 6103.49  | 0.01              | 0.55 | 0.47 | 6103.49  |
| 29  | Sao Francisco | 0.00 | 0.75 | 0.52 | 3820.66 | 0.00              | 0.75 | 0.52 | 6596.82  | 0.00              | 0.78 | 0.60 | 6596.82  |
| 30  | Tocantins     | 0.03 | 0.57 | 0.49 | 3820.66 | 0.03              | 0.57 | 0.49 | 6596.82  | 0.03              | 0.64 | 0.53 | 6596.82  |
| 31  | Uruguay       | 0.00 | 0.35 | 0.43 | 3899.08 | 0.00              | 0.35 | 0.43 | 7537.73  | 0.00              | 0.41 | 0.40 | 7537.73  |
| 32  | Congo         | 0.00 | 0.17 | 0.32 | 781.50  | 0.03              | 0.17 | 0.32 | 1499.69  | 0.01              | 0.31 | 0.34 | 1499.69  |
| 33  | Nile          | 0.01 | 0.38 | 0.61 | 2146.01 | 0.04              | 0.38 | 0.61 | 3765.50  | 0.03              | 0.51 | 0.45 | 3765.50  |
| 34  | Niger         | 0.03 | 0.42 | 0.56 | 1897.65 | 0.10              | 0.42 | 0.56 | 4004.21  | 0.08              | 0.53 | 0.46 | 4004.21  |

Development stage: I, initial; II, developing; III, developed. Column No. was ranked by continents, which coincide with GIW number in Figure 2c.

**Supplementary Table 6** Navigation standard of inland waterways grade of China<sup>1</sup>, and the corresponding average tonnage ( $M$ ), minimum waterway maintenance depth, the longitudinal domain lengths of upstream ( $l_u$ ) and downstream ships ( $l_d$ ), and bearing capacity (BC)<sup>2,3</sup>

| Waterway grade | $M$ (t) | Minimum waterway maintenance depth (m) | $l_u$ | $l_d$ | BC ( $10^8$ t yr <sup>-1</sup> ) |
|----------------|---------|----------------------------------------|-------|-------|----------------------------------|
| I-1            | 50000   | 12.5                                   | 2.6   | 4.5   | 86.85                            |
| I-2            | 20000   | 9.0-12.5                               | 3.3   | 5.2   | 45.35                            |
| I-3            | 10000   | 6.0-9.0                                | 2.7   | 4.3   | 26.45                            |
| I-4            | 7000    | 4.5-6.0                                | -     | -     | 20.95                            |
| I-5            | 5000    | 4.0-4.5                                | 2.8   | 4.8   | 17.20                            |
| I-6            | 3000    | 3.5-4.0                                | 3.5   | 5.2   | 11.05                            |
| II             | 2000    | 2.6-3.5                                | 2.9   | 4.5   | 8.85                             |
| III            | 1000    | 2.0-2.6                                | 3.7   | 5.0   | 5.65                             |
| IV             | 500     | 1.6-2.0                                | 3.2   | 4.6   | 3.03                             |
| V              | 300     | 1.4-1.6                                | -     | -     | 2.24                             |
| VI             | 100     | 1.0-1.4                                | -     | -     | 0.86                             |
| VII            | 50      | 0.7-1.0                                | -     | -     | 0.58                             |

**Supplementary Table 7** Minimum maintenance depth of inland waterways

| River       | Minimum maintenance depth<br>(m) | River          | Minimum maintenance depth<br>(m) |
|-------------|----------------------------------|----------------|----------------------------------|
| Rhine       | 2.6-3.5                          | Fitzroy        | 1.1                              |
| Danube      | 1.4-4.5                          | Flinders       | 1.0                              |
| Elbe        | 2.6-3.0                          | Murray-Darling | 1.3                              |
| Rhone       | 3.5-3.5                          | Mississippi    | 2.1-13.7                         |
| Loire       | 2.6-2.6                          | Columbia       | 2.1-13.4                         |
| Oder        | 1.6-2.5                          | Mobile         | 2.7-12.2                         |
| Wisla       | 1.4-3.5                          | St. Lawrence   | 2.4-9.1                          |
| Dnieper     | 1.6-4.5                          | Yukon          | 2.1-3.7                          |
| Don         | 2.0-4.0                          | Albany         | 1.4-1.8                          |
| Volga       | 1.6-4.5                          | Brazos         | 1.2                              |
| Ural        | 3.0-3.0                          | Churchill      | 1.4-1.6                          |
| Yangtze     | 2.0-12.6                         | Colorado       | 1.4                              |
| Pearl       | 2.0-4.5                          | Fraser         | 2.0-2.6                          |
| Amur        | 1.8-3.5                          | Nelson         | 1.5-2.0                          |
| Liao        | 1.2                              | Mackenzie      | 1.8-3.7                          |
| Yellow      | 1.2-1.4                          | Amazon         | 3.6-18.0                         |
| Red         | 2.4-3.4                          | Rio Colorado   | 1.1-1.2                          |
| Mekong      | 1.4-4.5                          | Magdalena      | 2.2-3.5                          |
| Salween     | 1.1-1.4                          | Negro          | 1.2-1.4                          |
| Irrawaddy   | 2.6-2.9                          | Orinoco        | 4.0-10.5                         |
| Ganges      | 1.4-3.8                          | Parana         | 1.6-6.0                          |
| Brahmaputra | 1.6-2.6                          | Parnaiba       | 1.5                              |
| Godavari    | 1.4-2.6                          | Sao Francisco  | 1.8-4.0                          |
| Krishna     | 1.6-1.8                          | Tocantins      | 1.8-4.5                          |
| Mahanadi    | 1.4-1.6                          | Uruguay        | 2.0-3.5                          |
| Indus       | 1.2-2.0                          | Congo          | 1.6-3.5                          |
| Amu         | 1.1-1.5                          | Nile           | 1.4-2.3                          |
| Euphrates   | 0.8-1.6                          | Niger          | 1.4-6.0                          |
| Ob          | 1.6-3.6                          | Orange         | 1.2                              |
| Yenisei     | 1.8-3.7                          | Zambezi        | 1.6                              |
| Lena        | 1.8-2.6                          | Senegal        | 1.4                              |
| Kolyma      | 2.0                              | Cuanza         | 1.5                              |
| Burdekin    | 1.1                              | Volta          | 1.5-1.7                          |

**Supplementary Table 8** Government agencies managing 66 large inland waterways worldwide

| River          | Data source                                                                                                                             |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Rhine          | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Danube         | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Elbe           | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Rhone          | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Loire          | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Oder           | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Wisla          | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Dnieper        | <a href="http://www.unece.org/trans/resources/publications/">http://www.unece.org/trans/resources/publications/</a>                     |
| Don            | <a href="http://www.morflot.ru/deyatelnost/vvt.html">http://www.morflot.ru/deyatelnost/vvt.html</a>                                     |
| Volga          | <a href="http://www.morflot.ru/deyatelnost/vvt.html">http://www.morflot.ru/deyatelnost/vvt.html</a>                                     |
| Ural           | <a href="http://www.morflot.ru/deyatelnost/vvt.html">http://www.morflot.ru/deyatelnost/vvt.html</a>                                     |
| Yangtze        | <a href="http://www.cjhdj.com.cn/">http://www.cjhdj.com.cn/</a>                                                                         |
| Pearl          | <a href="http://www.zjhw.gov.cn/">http://www.zjhw.gov.cn/</a>                                                                           |
| Amur           | <a href="http://www.mot.gov.cn/">http://www.mot.gov.cn/</a>                                                                             |
| Liao           | <a href="http://www.mot.gov.cn/">http://www.mot.gov.cn/</a>                                                                             |
| Yellow         | <a href="http://www.mot.gov.cn/">http://www.mot.gov.cn/</a>                                                                             |
| Red            | <a href="http://en.viwa.gov.vn/home">http://en.viwa.gov.vn/home</a>                                                                     |
| Mekong         | <a href="http://en.viwa.gov.vn/home">http://en.viwa.gov.vn/home</a>                                                                     |
| Salween        | <a href="http://www.iwt.gov.mm/en">http://www.iwt.gov.mm/en</a>                                                                         |
| Irrawaddy      | <a href="http://www.iwt.gov.mm/en">http://www.iwt.gov.mm/en</a>                                                                         |
| Ganges         | <a href="http://www.iwai.nic.in/">http://www.iwai.nic.in/</a>                                                                           |
| Brahmaputra    | <a href="http://www.iwai.nic.in/">http://www.iwai.nic.in/</a>                                                                           |
| Godavari       | <a href="http://www.iwai.nic.in/">http://www.iwai.nic.in/</a>                                                                           |
| Krishna        | <a href="http://www.iwai.nic.in/">http://www.iwai.nic.in/</a>                                                                           |
| Mahanadi       | <a href="http://www.iwai.nic.in/">http://www.iwai.nic.in/</a>                                                                           |
| Indus          | <a href="http://pakirsa.gov.pk/">http://pakirsa.gov.pk/</a>                                                                             |
| Amu            | <a href="http://www.cawater-info.net/bd/index_e.htm">http://www.cawater-info.net/bd/index_e.htm</a>                                     |
| Euphrates      | <a href="http://www.fao.org/nr/water/aquastat/basins/euphrates-tigris">http://www.fao.org/nr/water/aquastat/basins/euphrates-tigris</a> |
| Ob             | <a href="http://www.morflot.ru/deyatelnost/vvt.html">http://www.morflot.ru/deyatelnost/vvt.html</a>                                     |
| Yenisei        | <a href="http://www.morflot.ru/deyatelnost/vvt.html">http://www.morflot.ru/deyatelnost/vvt.html</a>                                     |
| Lena           | <a href="http://www.morflot.ru/deyatelnost/vvt.html">http://www.morflot.ru/deyatelnost/vvt.html</a>                                     |
| Kolyma         | <a href="http://www.morflot.ru/deyatelnost/vvt.html">http://www.morflot.ru/deyatelnost/vvt.html</a>                                     |
| Burdekin       | <a href="http://www.bom.gov.au/">http://www.bom.gov.au/</a>                                                                             |
| Fitzroy        | <a href="http://www.bom.gov.au/">http://www.bom.gov.au/</a>                                                                             |
| Flinders       | <a href="http://www.bom.gov.au/">http://www.bom.gov.au/</a>                                                                             |
| Murray-Darling | <a href="https://www.mdba.gov.au/">https://www.mdba.gov.au/</a>                                                                         |

**Supplementary Table 8** Government agencies managing 66 large inland waterways worldwide (*continued*)

| River         | Data source                                                                                         |
|---------------|-----------------------------------------------------------------------------------------------------|
| Mississippi   | <a href="http://www.navigationdatacenter.us">http://www.navigationdatacenter.us</a>                 |
| Columbia      | <a href="http://www.navigationdatacenter.us">http://www.navigationdatacenter.us</a>                 |
| Mobile        | <a href="http://www.navigationdatacenter.us">http://www.navigationdatacenter.us</a>                 |
| St. Lawrence  | <a href="http://www.greatlakes-seaway.com">http://www.greatlakes-seaway.com</a>                     |
| Yukon         | <a href="http://www.navigationdatacenter.us">http://www.navigationdatacenter.us</a>                 |
| Albany        | <a href="https://open.canada.ca/en">https://open.canada.ca/en</a>                                   |
| Brazos        | <a href="https://open.canada.ca/en">https://open.canada.ca/en</a>                                   |
| Churchill     | <a href="https://open.canada.ca/en">https://open.canada.ca/en</a>                                   |
| Colorado      | <a href="https://open.canada.ca/en">https://open.canada.ca/en</a>                                   |
| Fraser        | <a href="https://open.canada.ca/en">https://open.canada.ca/en</a>                                   |
| Nelson        | <a href="https://open.canada.ca/en">https://open.canada.ca/en</a>                                   |
| Mackenzie     | <a href="https://open.canada.ca/en">https://open.canada.ca/en</a>                                   |
| Amazon        | <a href="http://infraestrutura.gov.br/index.php">http://infraestrutura.gov.br/index.php</a>         |
| Rio Colorado  | <a href="https://www.argentina.gob.ar">https://www.argentina.gob.ar</a>                             |
| Magdalena     | <a href="https://colaboracion.dnp.gov.co">https://colaboracion.dnp.gov.co</a>                       |
| Negro         | <a href="https://www.argentina.gob.ar">https://www.argentina.gob.ar</a>                             |
| Orinoco       | <a href="http://www.mtc.gob.ve">http://www.mtc.gob.ve</a>                                           |
| Parana        | <a href="https://www.argentina.gob.ar">https://www.argentina.gob.ar</a>                             |
| Parnaiba      | <a href="http://infraestrutura.gov.br/index.php">http://infraestrutura.gov.br/index.php</a>         |
| Sao Francisco | <a href="http://infraestrutura.gov.br/index.php">http://infraestrutura.gov.br/index.php</a>         |
| Tocantins     | <a href="http://infraestrutura.gov.br/index.php">http://infraestrutura.gov.br/index.php</a>         |
| Uruguay       | <a href="http://www.mtop.gub.uy/">http://www.mtop.gub.uy/</a>                                       |
| Congo         | <a href="http://www.cicos.info/siteweb/">http://www.cicos.info/siteweb/</a>                         |
| Nile          | <a href="http://mot.gov.eg/">http://mot.gov.eg/</a>                                                 |
| Niger         | <a href="http://www.abn.ne/">http://www.abn.ne/</a>                                                 |
| Orange        | <a href="https://www.dwa.gov.za/orange/default.aspx">https://www.dwa.gov.za/orange/default.aspx</a> |
| Zambezi       | <a href="http://www.zambezira.org/">http://www.zambezira.org/</a>                                   |
| Senegal       | <a href="https://www.nap.edu/read/10546/chapter/3">https://www.nap.edu/read/10546/chapter/3</a>     |
| Cuanza        | <a href="http://www.mintrans.gov.ao/">http://www.mintrans.gov.ao/</a>                               |
| Volta         | <a href="https://www.ghanamaritime.org/index.php">https://www.ghanamaritime.org/index.php</a>       |

**Supplementary Table 9** Freeze duration of large rivers

| River        | Freeze duration (day) |
|--------------|-----------------------|
| Lena         | 240                   |
| Kolyma       | 240                   |
| Mackenzie    | 240                   |
| Ob           | 210                   |
| Yenisei      | 210                   |
| Yukon        | 210                   |
| Wisla        | 150                   |
| Amur         | 150                   |
| Churchill    | 150                   |
| Nelson       | 150                   |
| St. Lawrence | 140                   |
| Oder         | 120                   |
| Volga        | 120                   |
| Ural         | 120                   |
| Dnieper      | 90                    |
| Don          | 90                    |
| Elbe         | 45                    |
| Fraser       | 30                    |

**Supplementary Table 10** Number of golden inland waterways (GIWs) identified by varying the threshold values

| BCI <sub>T</sub> | SEI <sub>T</sub> | Number of GIWs | Relative percentage to baseline case |
|------------------|------------------|----------------|--------------------------------------|
| 0.50             | 0.33             | 28             | -18%                                 |
| 0.17             | 0.33             | 38             | 12%                                  |
| 0.33             | 0.55             | 27             | -21%                                 |
| 0.33             | 0.17             | 41             | 21%                                  |

BCI<sub>T</sub> and SEI<sub>T</sub> are threshold values of bearing capacity index (BCI) and socio-economic index (SEI) to identify the GIWs.

**Supplementary Table 11** Data sources for freight transport volume of golden inland waterways (GIWs)

| No. | River       | Data source                                                                                                                                                                                                                                                         |
|-----|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Rhine       | <a href="https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007">https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007</a>                                                                                                                         |
| 2   | Danube      | <a href="https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007">https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007</a>                                                                                                                         |
| 3   | Elbe        | <a href="https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007">https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007</a>                                                                                                                         |
| 4   | Rhone       | <a href="https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007">https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007</a>                                                                                                                         |
| 5   | Loire       | <a href="https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007">https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007</a>                                                                                                                         |
| 6   | Oder        | <a href="https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007">https://ec.europa.eu/eurostat/web/products-datasets/-/ttr00007</a>                                                                                                                         |
| 7   | Dnieper     | <a href="https://mtu.gov.ua/files/USACEreport.pdf">https://mtu.gov.ua/files/USACEreport.pdf</a>                                                                                                                                                                     |
| 8   | Don         | <a href="https://www.fedstat.ru/">https://www.fedstat.ru/</a>                                                                                                                                                                                                       |
| 9   | Volga       | <a href="https://www.fedstat.ru/">https://www.fedstat.ru/</a>                                                                                                                                                                                                       |
| 10  | Yangtze     | <a href="http://www.cjhdj.com.cn">www.cjhdj.com.cn</a>                                                                                                                                                                                                              |
| 11  | Pearl       | <a href="https://zjhy.mot.gov.cn/">https://zjhy.mot.gov.cn/</a>                                                                                                                                                                                                     |
| 12  | Amur        | <a href="http://www.mot.gov.cn/tongjishuju/shuiyun/">http://www.mot.gov.cn/tongjishuju/shuiyun/</a>                                                                                                                                                                 |
| 13  | Red         | <a href="https://openknowledge.worldbank.org/bitstream/handle/10986/16321/9781464801051.pdf?sequence=1&amp;isAllowed=y">https://openknowledge.worldbank.org/bitstream/handle/10986/16321/9781464801051.pdf?sequence=1&amp;isAllowed=y</a>                           |
| 14  | Mekong      | <a href="https://openknowledge.worldbank.org/bitstream/handle/10986/16321/9781464801051.pdf?sequence=1&amp;isAllowed=y">https://openknowledge.worldbank.org/bitstream/handle/10986/16321/9781464801051.pdf?sequence=1&amp;isAllowed=y</a>                           |
| 15  | Ganges      | <a href="http://www.manthan-india.org/wp-content/uploads/2018/04/Strategic-Status-Report-on-Inland-Waterways-V5-26-Apr-17-FINAL.pdf">http://www.manthan-india.org/wp-content/uploads/2018/04/Strategic-Status-Report-on-Inland-Waterways-V5-26-Apr-17-FINAL.pdf</a> |
| 16  | Brahmaputra | <a href="http://www.manthan-india.org/wp-content/uploads/2018/04/Strategic-Status-Report-on-Inland-Waterways-V5-26-Apr-17-FINAL.pdf">http://www.manthan-india.org/wp-content/uploads/2018/04/Strategic-Status-Report-on-Inland-Waterways-V5-26-Apr-17-FINAL.pdf</a> |
| 17  | Godavari    | <a href="http://iwai.nic.in/WriteReadData/1892s/file112-54022272.pdf">http://iwai.nic.in/WriteReadData/1892s/file112-54022272.pdf</a>                                                                                                                               |

Column No. was ranked by continents, which coincide with GIW number in Figure 2c.

**Supplementary Table 11** Data sources for freight transport volume of golden inland waterways (GIWs) (*continued*)

| No. | River         | Data sources                                                                                                                                                                                                        |
|-----|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 18  | Krishna       | <a href="http://iwai.nic.in/WriteReadData/l892s/file112-54022272.pdf">http://iwai.nic.in/WriteReadData/l892s/file112-54022272.pdf</a>                                                                               |
| 19  | Mahanadi      | <a href="http://iwai.nic.in/showfile.php?lid=939">http://iwai.nic.in/showfile.php?lid=939</a>                                                                                                                       |
| 20  | Indus         | <a href="https://iwt.punjab.gov.pk/">https://iwt.punjab.gov.pk/</a>                                                                                                                                                 |
| 21  | Mississippi   | <a href="https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center/">https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center/</a> |
| 22  | Columbia      | <a href="https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center/">https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center/</a> |
| 23  | Mobile        | <a href="https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center/">https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center/</a> |
| 24  | St. Lawrence  | <a href="http://www.greatlakes-seaway.com/en/seaway/index.html">http://www.greatlakes-seaway.com/en/seaway/index.html</a>                                                                                           |
| 25  | Fraser        | <a href="http://faculty.bcitbusiness.org/kevinw/documents/Fraser_River_SSS_Final.pdf">http://faculty.bcitbusiness.org/kevinw/documents/Fraser_River_SSS_Final.pdf</a>                                               |
| 26  | Amazon        | <a href="http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf">http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf</a>                                         |
| 27  | Orinoco       | <a href="http://www.mtc.gob.ve">www.mtc.gob.ve</a>                                                                                                                                                                  |
| 28  | Parana        | <a href="http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf">http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf</a>                                         |
| 29  | Sao Francisco | <a href="http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf">http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf</a>                                         |
| 30  | Tocantins     | <a href="http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf">http://www.transportes.gov.br/images/TRANSPORTE_HIDROVIARIO/PHE/PlanReport.pdf</a>                                         |
| 31  | Uruguay       | <a href="http://www.mtop.gub.uy/">http://www.mtop.gub.uy/</a>                                                                                                                                                       |
| 32  | Congo         | <a href="http://www.cicos.info/siteweb/">http://www.cicos.info/siteweb/</a>                                                                                                                                         |
| 33  | Nile          | <a href="https://www.wwinn.org/nile">https://www.wwinn.org/nile</a>                                                                                                                                                 |
| 34  | Niger         | <a href="https://nigerianports.gov.ng/ports-statistics/">https://nigerianports.gov.ng/ports-statistics/</a>                                                                                                         |

Column No. was ranked by continents, which coincide with GIW number in Figure 2c.

**Supplementary Table 12** Elastic coefficient estimated for golden inland waterways at different development stages and gross domestic product (GDP) per capita

| Development stage | GDP per capita (US\$) | Elastic coefficient |
|-------------------|-----------------------|---------------------|
| developed         | 1000-4000             | 0.4-0.6             |
|                   | 4000-7000             | 0.6-0.9             |
|                   | 7000-11000            | 0.9-1.3             |
|                   | 11000-20000           | 0.7-0.9             |
|                   | 20000-25000           | 0.4-0.7             |
|                   | > 25000               | 0.4-1               |
| developing        | 1000-2000             | 1.3-2.0             |
|                   | 2000-7000             | 0.7-1.3             |
|                   | > 7000                | < 0.5               |

**Supplementary Table 13** Interpretation and data source for metrics in the Methods

| Metric                | Interpretation                                                                                                                                           | Method and Data source                                                                                                                                            |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BC                    | Bearing capacity of inland waterways which is approximated by the theoretical annual freight volume that can pass through a given waterway cross-section | Equation (1)                                                                                                                                                      |
| $M$                   | Average tonnage of inland vessels estimated based on waterway grade determined by minimum waterway maintenance depth                                     | Supplementary Table 6                                                                                                                                             |
| $T$                   | Number of navigable days per year estimated using data on freeze-up duration                                                                             | Supplementary Table 9                                                                                                                                             |
| $q_h$                 | Hourly basic inland waterway traffic capacity                                                                                                            | Equation (2)                                                                                                                                                      |
| $l_u$                 | Longitudinal domain lengths of upstream ships                                                                                                            | Supplementary Table 6                                                                                                                                             |
| $l_d$                 | Longitudinal domain lengths of downstream ships                                                                                                          | Supplementary Table 6                                                                                                                                             |
| BCI                   | Bearing capacity index, representing the navigational capacity of a given waterway                                                                       | Equation (3)                                                                                                                                                      |
| $\widehat{BC}_w$      | Ascending rank order over all waterways of bearing capacity at waterway $w$                                                                              | -                                                                                                                                                                 |
| SEI                   | Socio-economic index, representing transport need driven by socio-economic development                                                                   | Equation (4)                                                                                                                                                      |
| GDP                   | Gross domestic product                                                                                                                                   | <a href="http://data.un.org/">http://data.un.org/</a>                                                                                                             |
| AIO                   | Agriculture and industry outputs                                                                                                                         | <a href="http://data.un.org/">http://data.un.org/</a>                                                                                                             |
| POP                   | Population                                                                                                                                               | <a href="http://data.un.org/">http://data.un.org/</a>                                                                                                             |
| $\widehat{GDP}_w$     | Ascending rank orders over all waterways of GDP at waterway $w$                                                                                          | -                                                                                                                                                                 |
| $\widehat{AIO}_w$     | Ascending rank orders over all waterways of AIO at waterway $w$                                                                                          | -                                                                                                                                                                 |
| $\widehat{POP}_{i,w}$ | Ascending rank orders over all waterways of POP at waterway $w$                                                                                          | -                                                                                                                                                                 |
| HDI                   | Human development index, a metric quantifies life expectancy, educational attainment, and income as a standardized number                                | <a href="http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf">http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf</a> |

**Supplementary Table 13** Interpretation and data source for metrics in the Methods (*continued*)

| Metric                  | Interpretation                                                                                                        | Method and Data source                                                                                                                                                                                                                                                     |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CI                      | Consistency index, defined as the ratio of transport need to bearing capacity                                         | Equation (5)                                                                                                                                                                                                                                                               |
| TN                      | Transport need expressed as freight transport volume                                                                  | Supplementary Table 11                                                                                                                                                                                                                                                     |
| CAGR <sub>freight</sub> | Compound annual growth rate of freight volume                                                                         | Equation (6)                                                                                                                                                                                                                                                               |
| EC                      | Elastic coefficient                                                                                                   | Supplementary Table 12                                                                                                                                                                                                                                                     |
| CAGR <sub>GDP</sub>     | Compound annual growth rate of GDP                                                                                    | <a href="https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2018">https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2018</a><br><a href="https://pardee.du.edu/">https://pardee.du.edu/</a> |
| ER                      | Inland waterway exploitation ratio defined as the ratio of the actual to idealized bearing capacity                   | Equation (7)                                                                                                                                                                                                                                                               |
| IBC                     | Idealized bearing capacity of waterway, representing the maximum potential of bearing capacity for an inland waterway | Equation (1)                                                                                                                                                                                                                                                               |
| $d_w$                   | Minimum waterway maintenance depth for IBC                                                                            | Equation (8)                                                                                                                                                                                                                                                               |
| $d_{dry}$               | Average water depth in the dry season                                                                                 | <a href="http://gaia.geosci.unc.edu/rivers/">http://gaia.geosci.unc.edu/rivers/</a>                                                                                                                                                                                        |
| EPI                     | Ecological pressure index, measuring the health of a river ecosystem affected by human activities                     | Equation (9)                                                                                                                                                                                                                                                               |
| FI                      | Fragmentation index of dams used for navigational purpose                                                             | Equation (10)                                                                                                                                                                                                                                                              |
| FI'                     | Fragmentation index of all kinds of dams                                                                              |                                                                                                                                                                                                                                                                            |
| WDI                     | Wetland dis-connectivity index                                                                                        | <a href="http://www.riverthreat.net/data.html">http://www.riverthreat.net/data.html</a>                                                                                                                                                                                    |
| FIS                     | Fraction of impervious surfaces                                                                                       |                                                                                                                                                                                                                                                                            |
| FDI                     | Flow disruption index                                                                                                 |                                                                                                                                                                                                                                                                            |

**Supplementary Table 13** Interpretation and data source for each metric in the Methods (*continued*)

| Metric               | Interpretation                                                                                         | Method and Data source                                                                                                                                                                                                                                    |
|----------------------|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FRI                  | Fish richness index                                                                                    | <a href="https://static-content.springer.com/esm/art%3A10.1007%2Fs10750-012-1242-6/MediaObjects/10750_2012_1242_MOESM2_ESM.txt">https://static-content.springer.com/esm/art%3A10.1007%2Fs10750-012-1242-6/MediaObjects/10750_2012_1242_MOESM2_ESM.txt</a> |
| PNF                  | Proportion of non-native fish                                                                          |                                                                                                                                                                                                                                                           |
| FI <sub>0</sub>      | Threshold value of FI corresponding to                                                                 |                                                                                                                                                                                                                                                           |
| WDI <sub>0</sub>     | Threshold value of WDI when ER approaching 80%                                                         | Fig. 5                                                                                                                                                                                                                                                    |
| FIS <sub>0</sub>     | Threshold value of FIS when ER approaching 80%                                                         |                                                                                                                                                                                                                                                           |
| FDI <sub>0</sub>     | Threshold value of FDI when ER approaching 80%                                                         |                                                                                                                                                                                                                                                           |
| FRI <sub>0</sub>     | Threshold value of FRI when ER approaching 80%                                                         |                                                                                                                                                                                                                                                           |
| PNF <sub>0</sub>     | Threshold value of PNF when ER approaching 80%                                                         |                                                                                                                                                                                                                                                           |
| $\alpha$             | Proportional factor, proportion of dams built for navigability purposes                                | Equation (11)                                                                                                                                                                                                                                             |
| $N_{\text{navi}}$    | Number of dams used for navigation in a basin                                                          | <a href="http://globaldamwatch.org/grand/">http://globaldamwatch.org/grand/</a>                                                                                                                                                                           |
| $N_{\text{total}}$   | Total number of dams in a basin                                                                        |                                                                                                                                                                                                                                                           |
| EEI                  | Eco-efficiency index, defined as the ratio of GDP to ecological footprint                              | Equation (12)                                                                                                                                                                                                                                             |
| EF                   | ecological footprint                                                                                   | <a href="https://www.footprintnetwork.org/">https://www.footprintnetwork.org/</a>                                                                                                                                                                         |
| SI                   | Sustainability index, equal to average of $S_{\text{CI}}$ , $S_{\text{ER}}$ , and $S_{\text{EEI,EPI}}$ | -                                                                                                                                                                                                                                                         |
| $S_{\text{CI}}$      | Score of CI                                                                                            | Equation (13)                                                                                                                                                                                                                                             |
| $S_{\text{ER}}$      | Score of ER                                                                                            | Equation (14)                                                                                                                                                                                                                                             |
| $S_{\text{EEI,EPI}}$ | Score of EEI and EPI                                                                                   | Equation (4)                                                                                                                                                                                                                                              |

## Supplementary References

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