6 Integrated Environmental Risks

Xingcai Liu, Yuanyuan Yin, Xinchuang Xu, Qiuhong Tang and Huijuan Cui

6.1 Introduction

Most environmental risks have been recognized as top global risks in terms of their likelihood and impact (WEF 2015, 2016). In recent years, environmental risks facing society are apparently systematic in nature and greatly impaired ecosystem and resulted in huge losses to socioeconomic domain (Briggs 2008). Thus, integrated assessment of environmental risks is necessary for risk management. Several integrated risk indices have been developed to describe global risk patterns or trends (Dilley 2005; Shi 2009; Joern et al. 2014). For example, the United Nations Development Programme (UNDP 2004) has developed a disaster risk index (DRI) to assess the global integrated risk by combining the exposure of human to the hazards such as flood, drought, and cyclone. The United Nations University (Joern et al. 2014) has promulgated a world risk index (WRI) for the assessment and estimation of disaster risk for a country. WRI takes into consideration both external and internal factors, i.e., threats by natural hazards, climate change, and societal conditions. WRI was calculated for 171 countries by combining the exposure of individual countries to natural hazards, and the socioeconomic and ecological conditions of these countries. Shi and Kasperson (2014) used a total risk index (TRI) and a multi-hazard risk index (MRhI) to estimate the world risk with respect to annual mortality and affected population.

Many assessments have reported that China is being or will be under relatively high environmental risks (Dilley 2005). In this chapter, an integrated assessment of environmental risks focuses on the risks estimation for human, society, and natural system under changing climate was presented. To achieve this, the climate change risks in multiple sectors were assessed using multiple climate impact models (Warszawski et al. 2014; Tang and Oki 2016). The risk assessments of heat wave, agricultural production, and ecosystem shift were then combined into one integrated assessment. It is expected to present a more comprehensive and advanced assessment of China's environmental risks based on the climate impact assessments across sectors under new climate and socioeconomic scenarios developed for the Intergovernmental Panel on Climate Change (IPCC).

6.2 Methodology

In this study, we adopted a variation of the integrated environmental risk index (IERI) similar to the TRI after Shi and Kasperson (2014). First, three disaster hazards, i.e., the heat wave hazard, agricultural hazard in terms of crop yield, and ecosystem shift hazard, were estimated under various climate scenarios in the future. The corresponding risks were then estimated and normalized to the consistent risk levels (from 1 to 10 as risks increase) and finally, the IERI was calculated as the weighted sum of the three disaster risks using the following equation:

$$IERI = \sum_{i=1}^{n=3} r_i \times w_i \quad (6.1)$$

where r_i is the risk level of a disaster, w_i is the weight of the disaster. In this study, equal weights were used for IERI calculation.

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Climate data from five general circulation models (GCMs) under four representative concentration pathways (RCPs) were used to drive the impact models to estimate the risks in China in the twenty-first century. The uncertainties cross GCMs and impact models were also addressed in terms of standard deviations of risk levels for each single RCP scenario. The estimations of the risks were described in Chaps. 3–5 in this atlas. The integrated environmental risk zones (IERZ) were then delineated based on the IERI estimates.

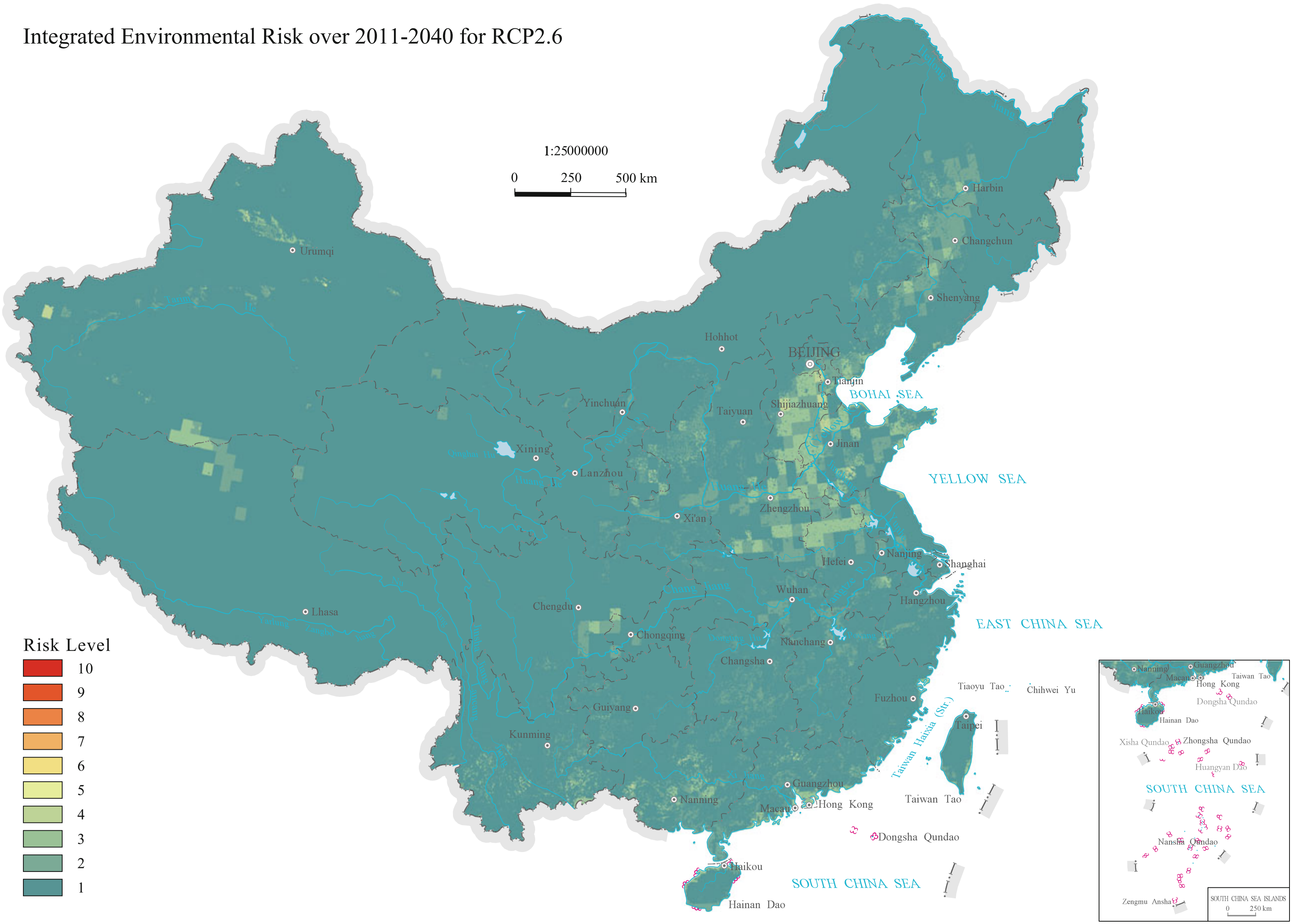
6.3 Results

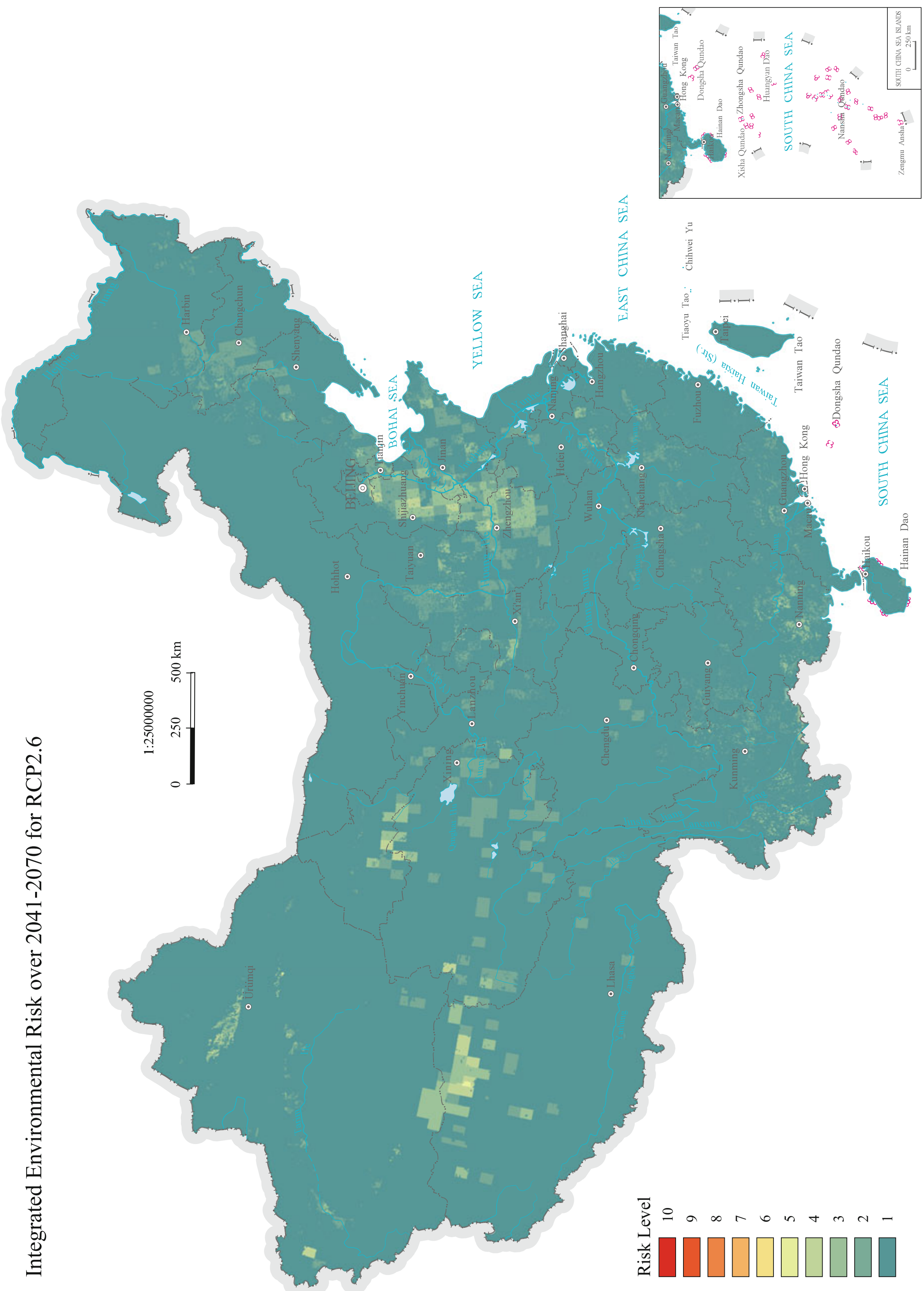
The integrated environmental risks were estimated for the four RCPs, i.e. RCP2.6, RCP4.5, RCP6.0, and RCP8.5, respectively. The IERI values were also generalized to ten levels denoted as 1–10 from low to high risk. In general, there were relatively low risks in China under RCP2.6, and relatively high risks under RCP8.5. Both the maps of IERI and the associated uncertainty will be shown in the Maps section.

Six level-I IERZs, i.e., the Northwest-Low-Risk region, Northeast-Relatively-Low-Risk region, Tibet-Moderate-Risk region, Jin-Shaan-Moderate-Risk region, South-China-High-Risk region, and Huang-Huai-Hai-High-Risk region, were delineated using the top-down approach for China under RCP8.5 and RCP6.0 scenarios. Level-II IERZs were delineated from bottom to top by combining local counties that have similar environmental risks. According to the characteristics of local environmental risks, total 42 and 54 level-II IERZs were further identified under RCP8.5 and RCP6.0 scenarios, respectively.

6.4 Maps

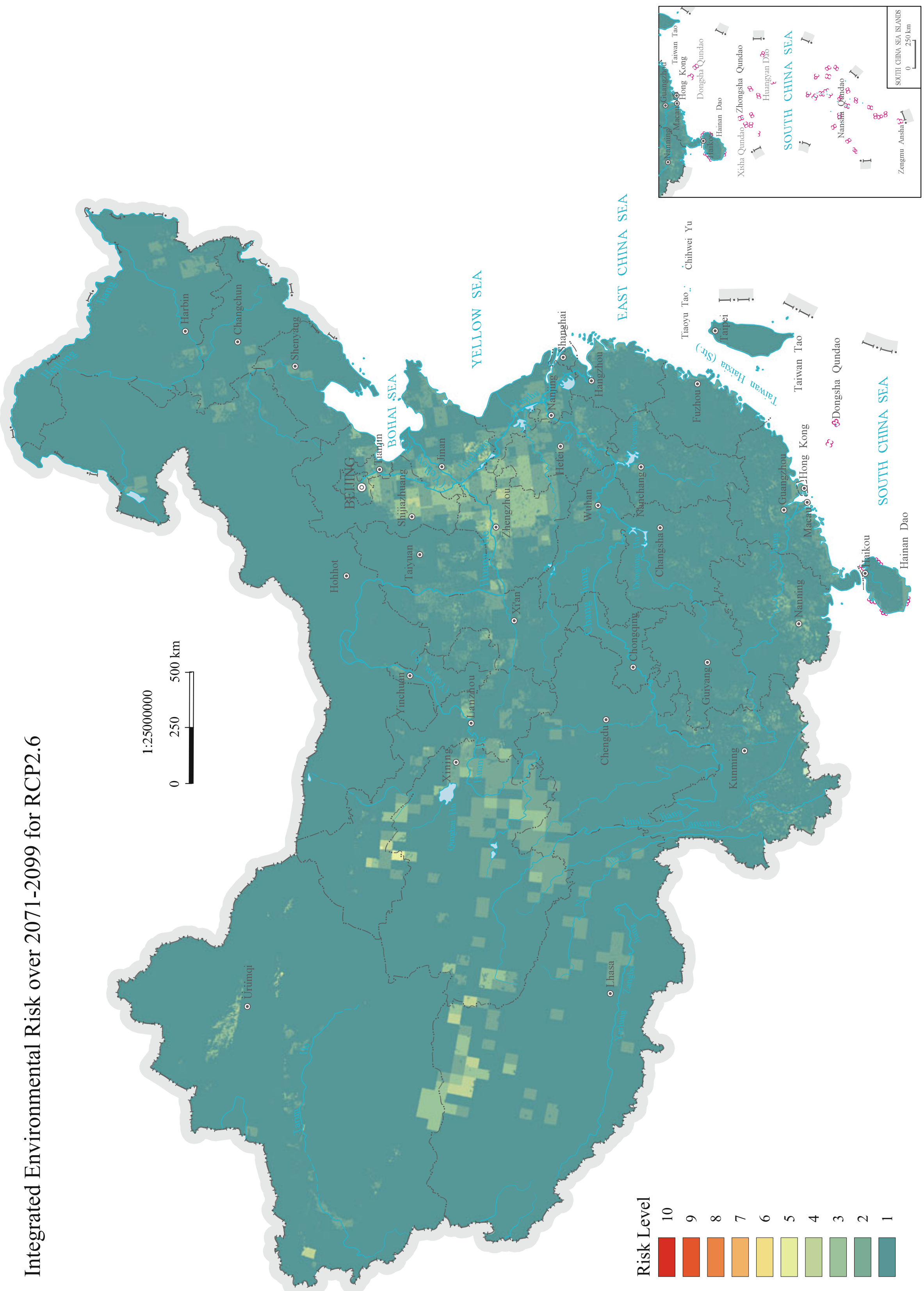
Integrated Environmental Risk over 2011-2040 for RCP2.6

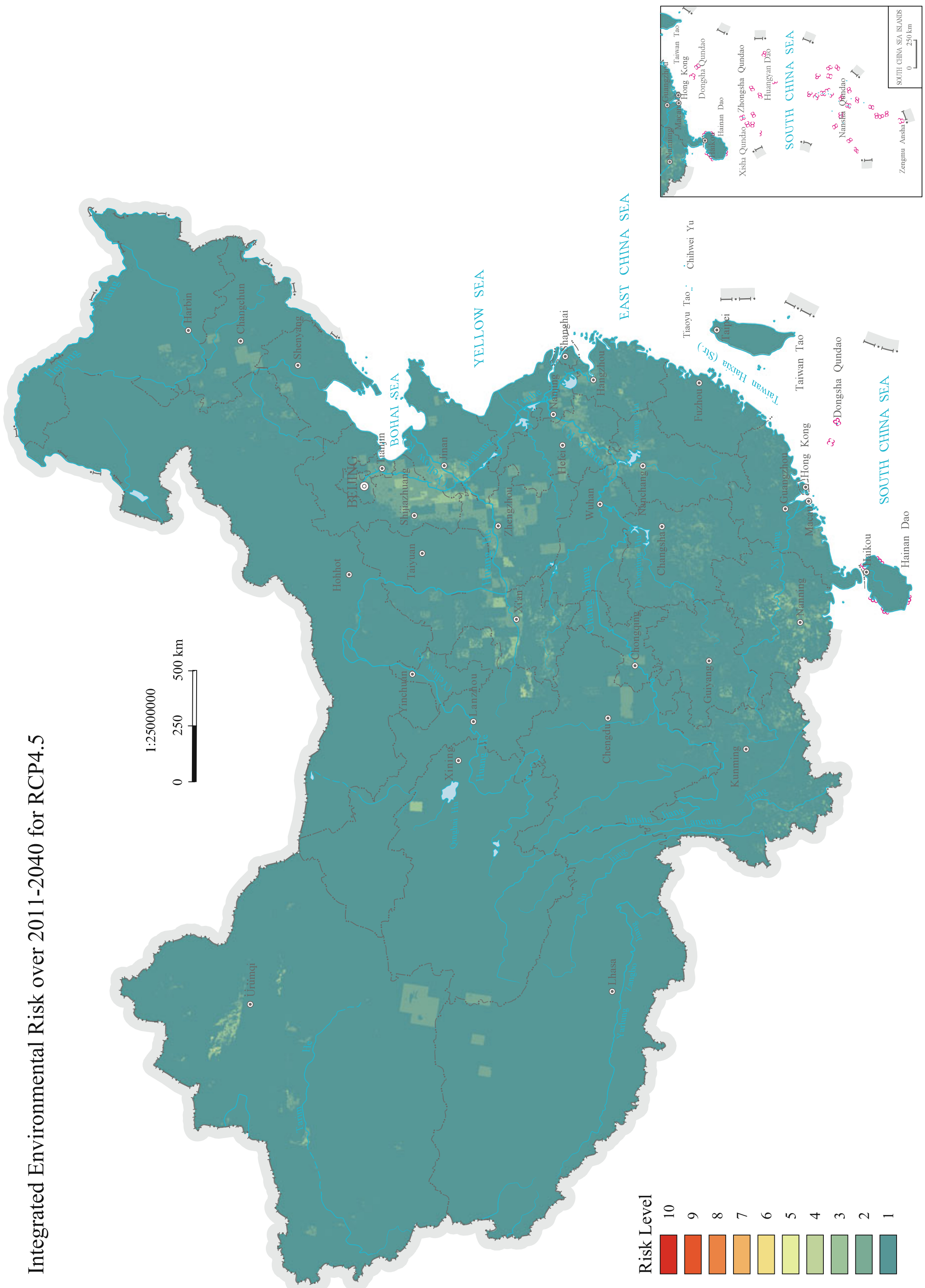




Integrated Environmental Risk over 2041-2070 for RCP2.6

Integrated Environmental Risk over 2071-2099 for RCP2.6




Integrated Environmental Risk over 2011-2040 for RCP4.5
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0 250 500 km
Risk Level
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BEIJING
Harbin
Changchun
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Shijiazhuang
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Nanchang
Wuhan
Hefei
Nanjing
Shanghai
Hangzhou
Fuzhou
Taipei
BOHAI SEA
YELLOW SEA
EAST CHINA SEA
SOUTH CHINA SEA
Taiwan Haixia (Str.)
Taiwan Tao
Diaoyu Tao
Chihwei Yu
Dongsha Qundao
Hainan Dao
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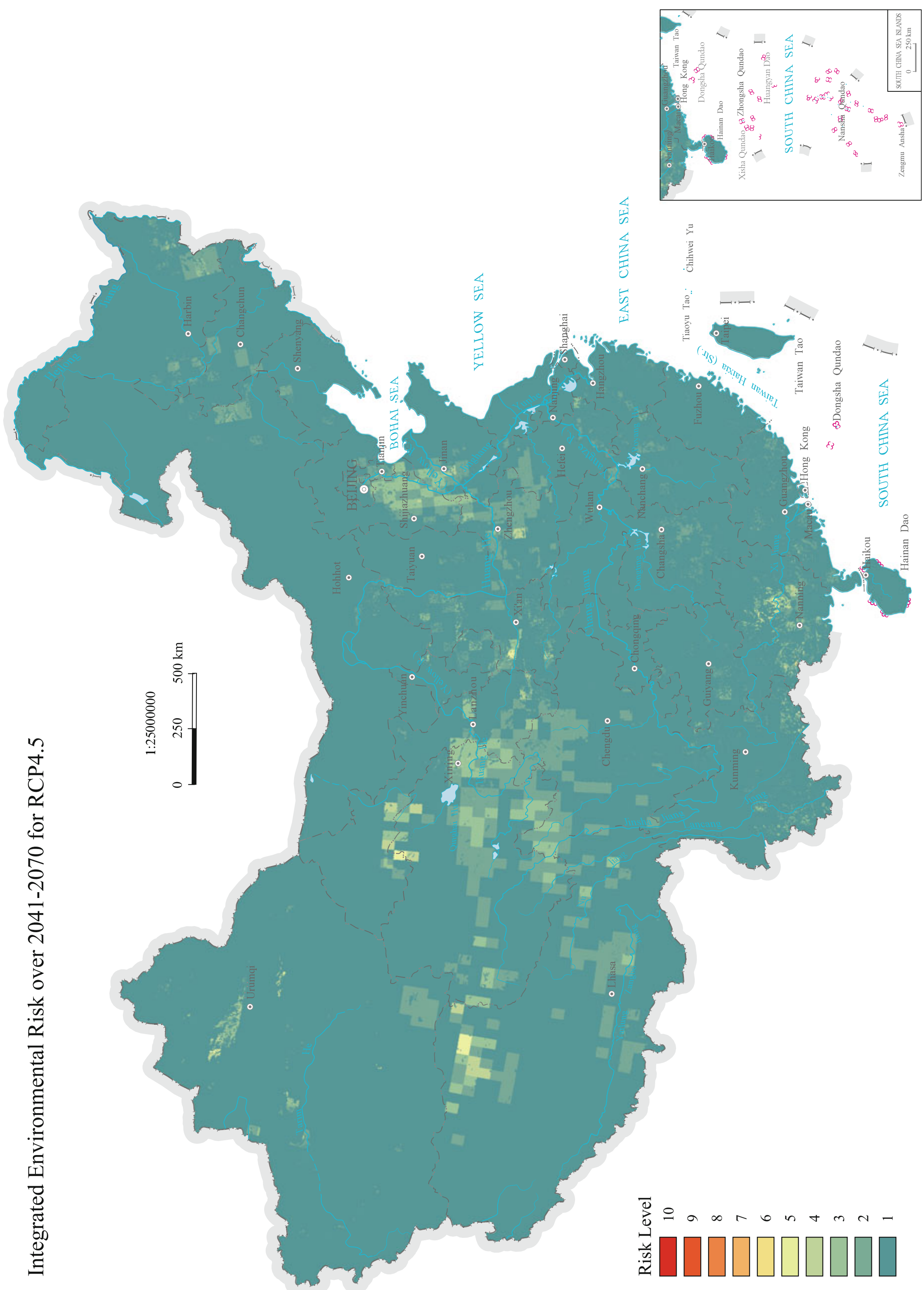
Zhongsha Qundao
Huangyan Dao
Nansha Qundao
Zengmu Ansha
SOUTH CHINA SEA ISLANDS
0 250 km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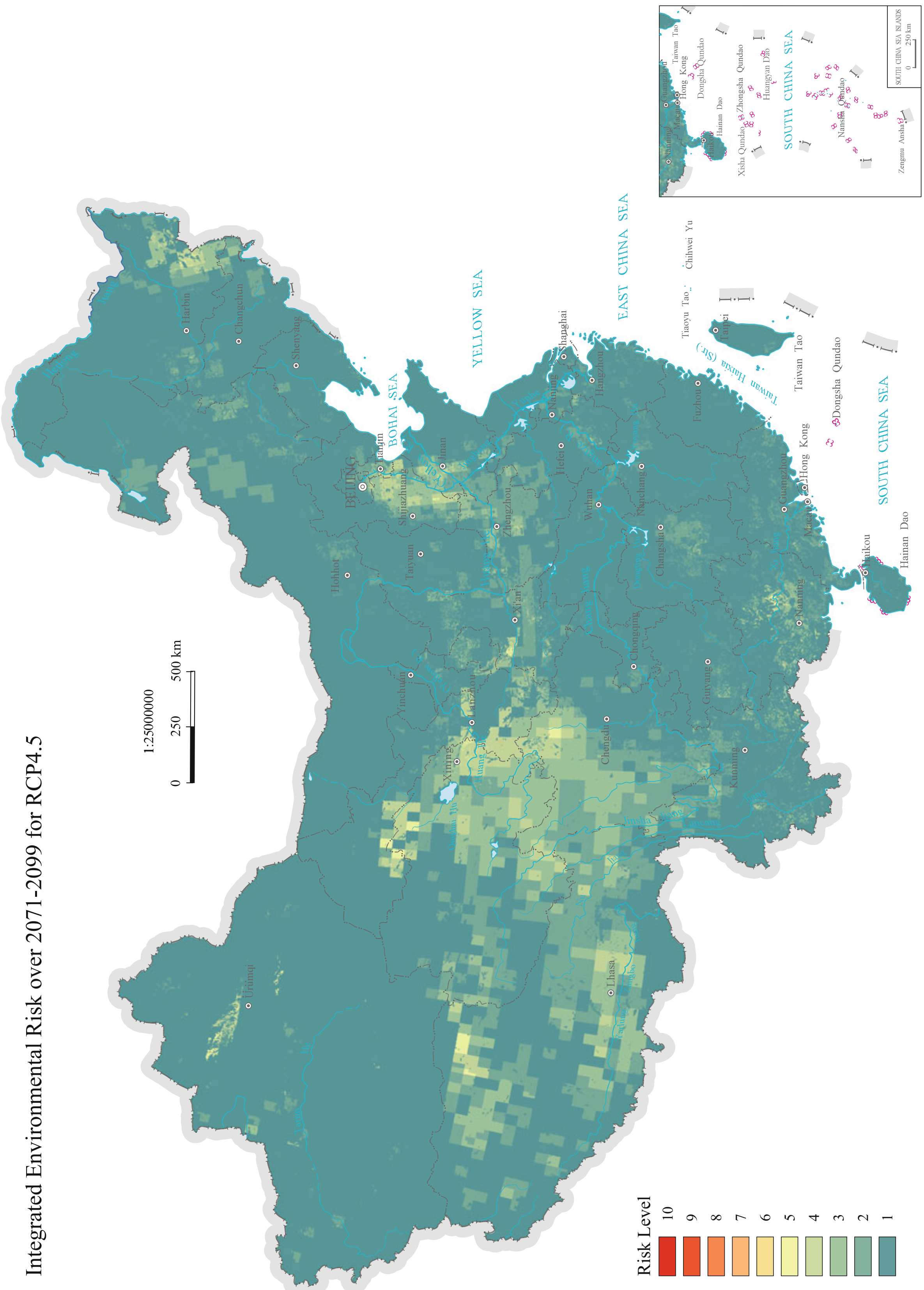
SOUTH CHINA SEA ISLANDS


Integrated Environmental Risk over 2071-2099 for RCP4.5
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Risk Level
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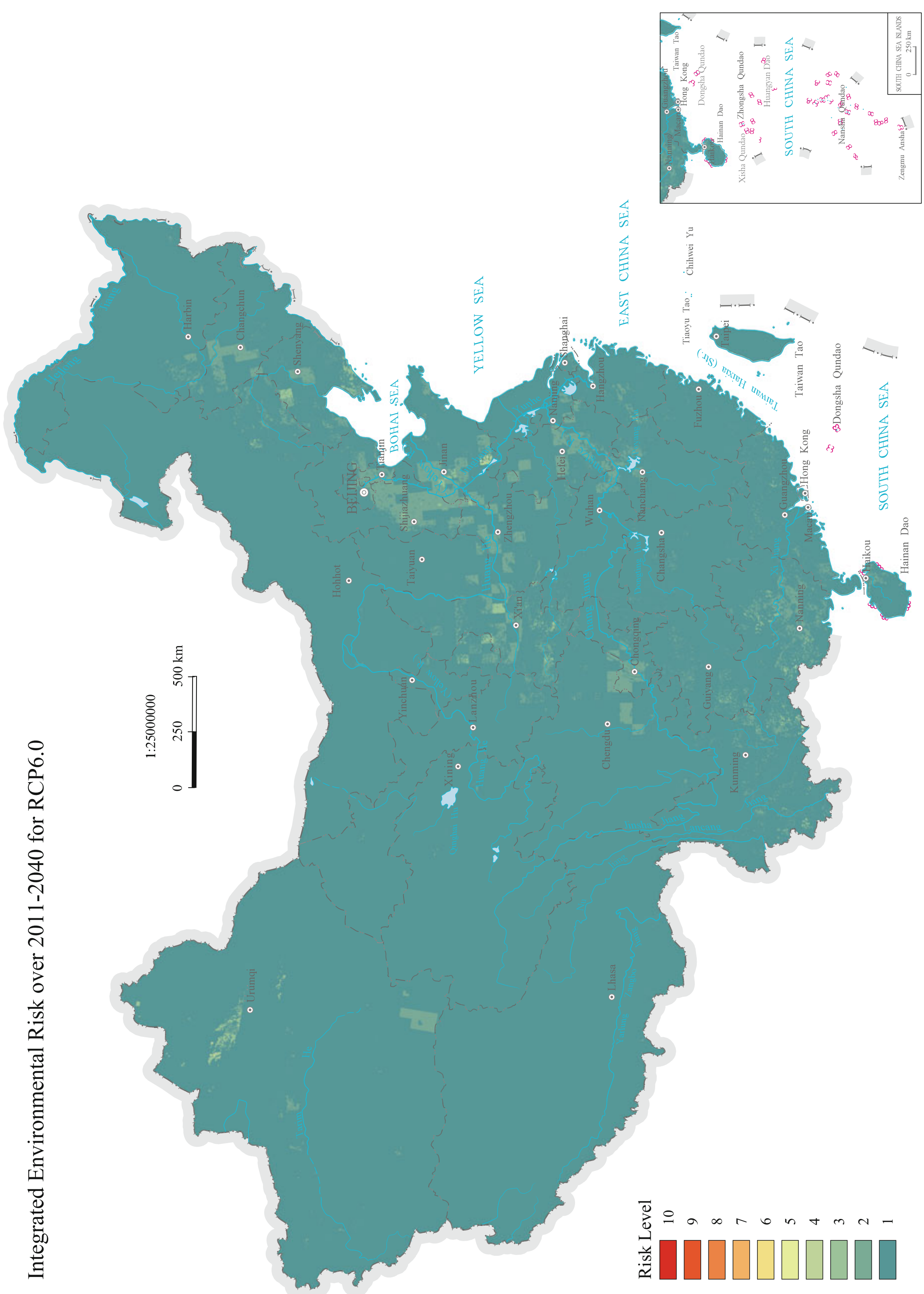
Integrated Environmental Risk over 2011-2040 for RCP6.0
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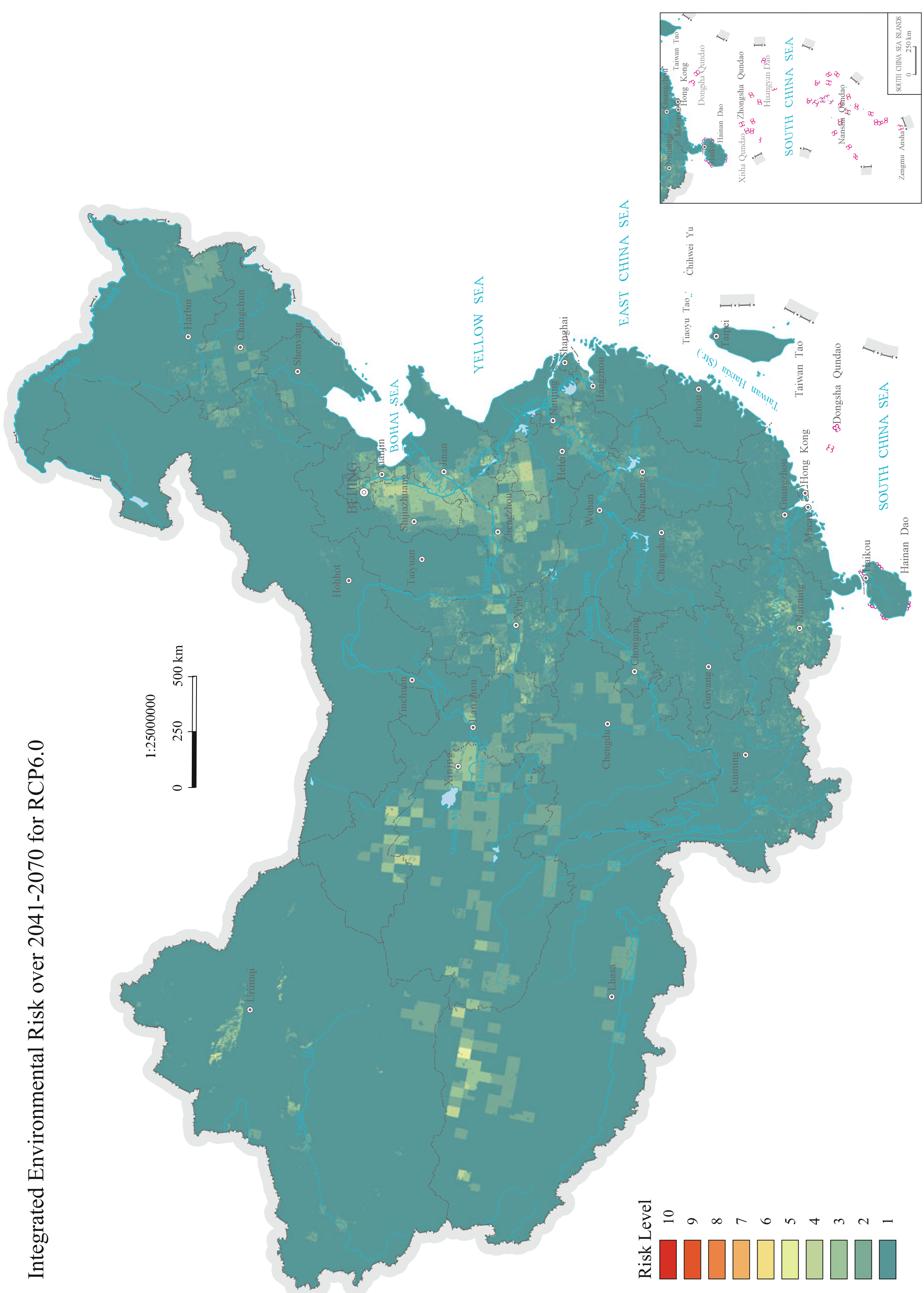
Tiaoyu Tao
Chihwei Yu
SOUTH CHINA SEA ISLANDS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Risk Level
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Tiaoyu Tao
Chihwei Yu
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Huangyan Dao
Nansha Qundao
Zengmu Ansha
SOUTH CHINA SEA ISLANDS
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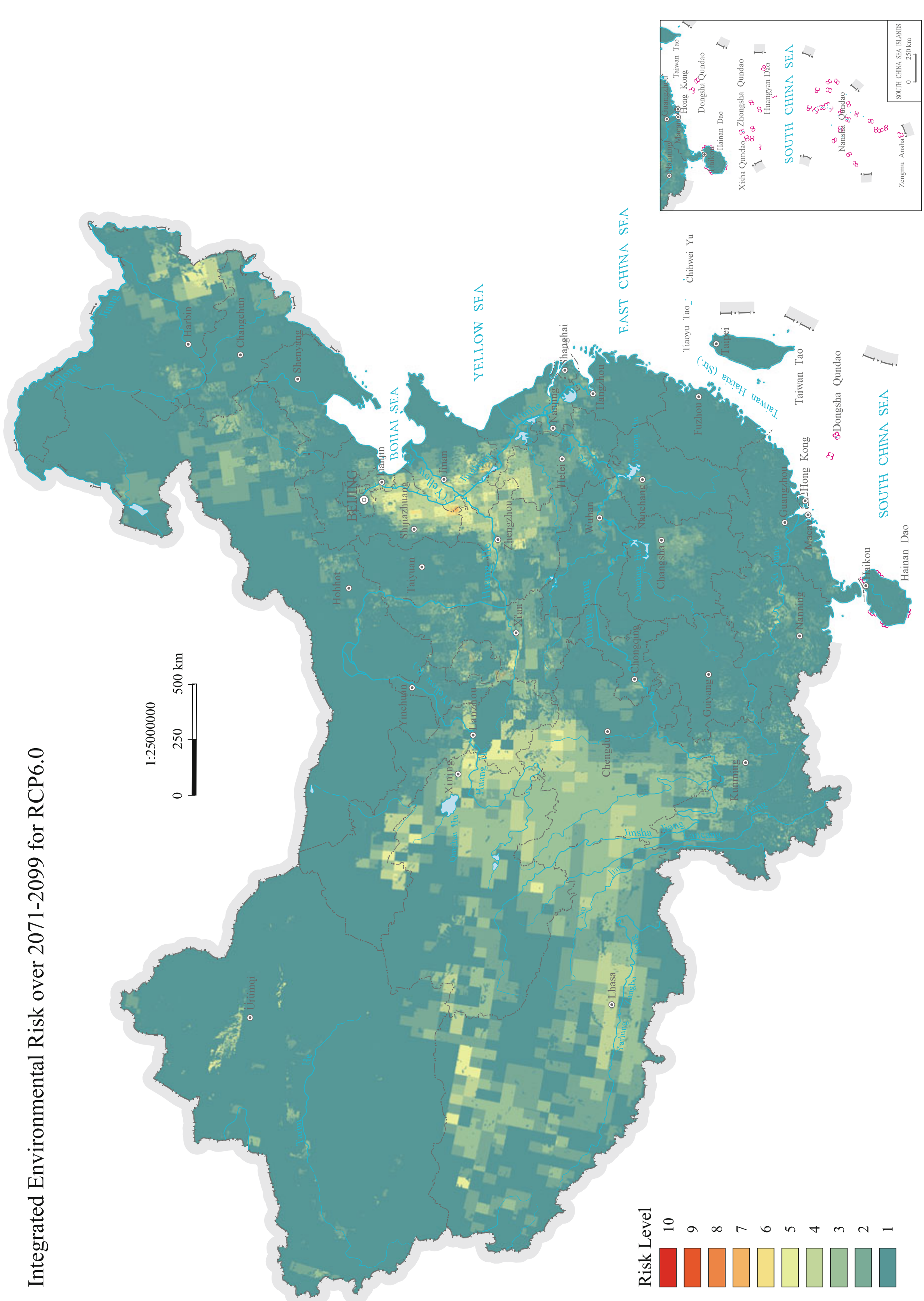
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Hong Kong
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Haikou
Nanning
Guiyang
Chongqing
Chengdu
Kunming
Xi'an
Yinchuan
Lanzhou
Xining
Lhasa
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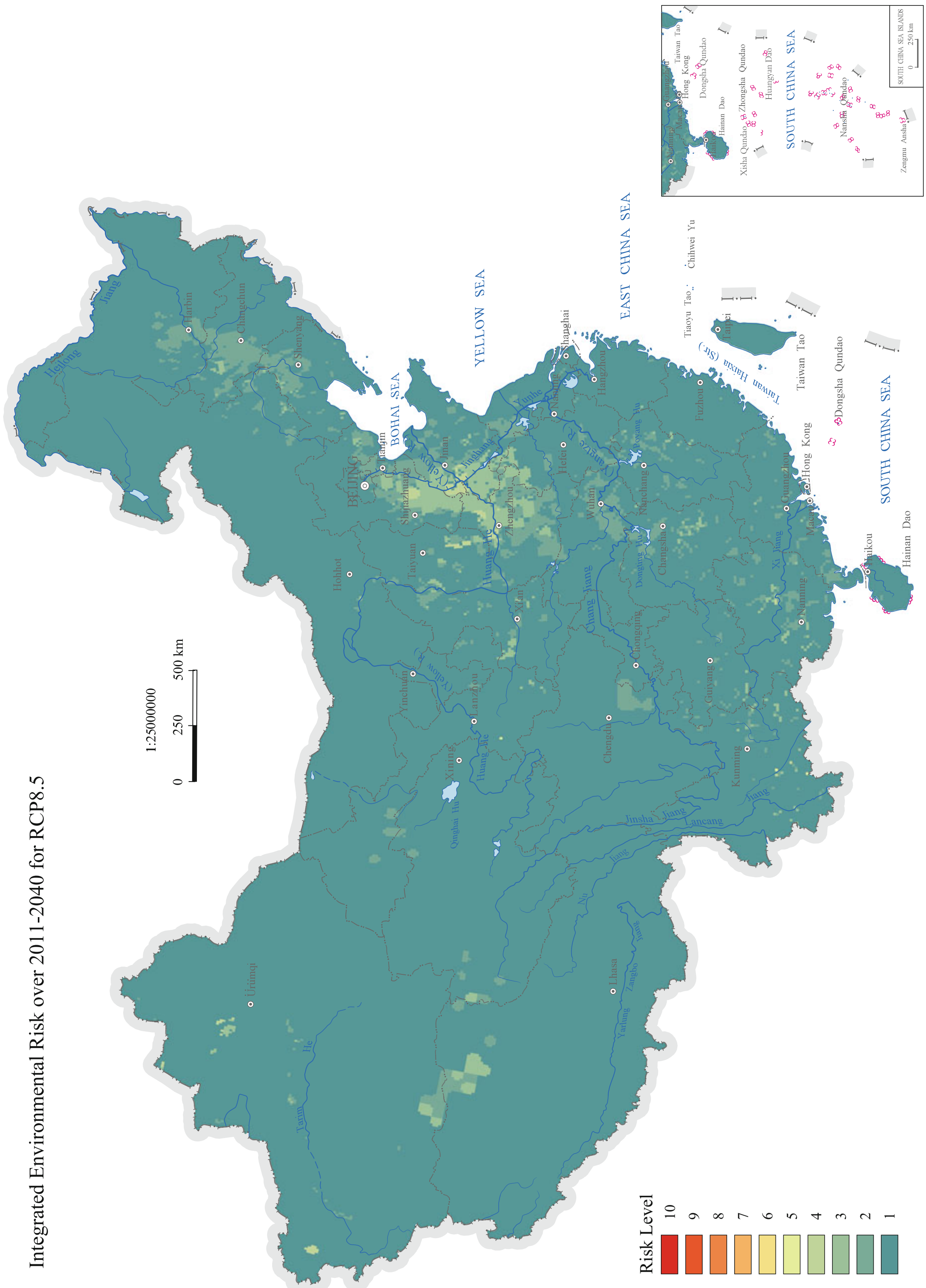
Zengmu Ansha
SOUTH CHINA SEA ISLANDS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Risk Level
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YELLOW SEA
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Jinan
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Guiyang
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Hainan Dao
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Nanchang
Wuhan
Hefei
Nanjing
Shanghai
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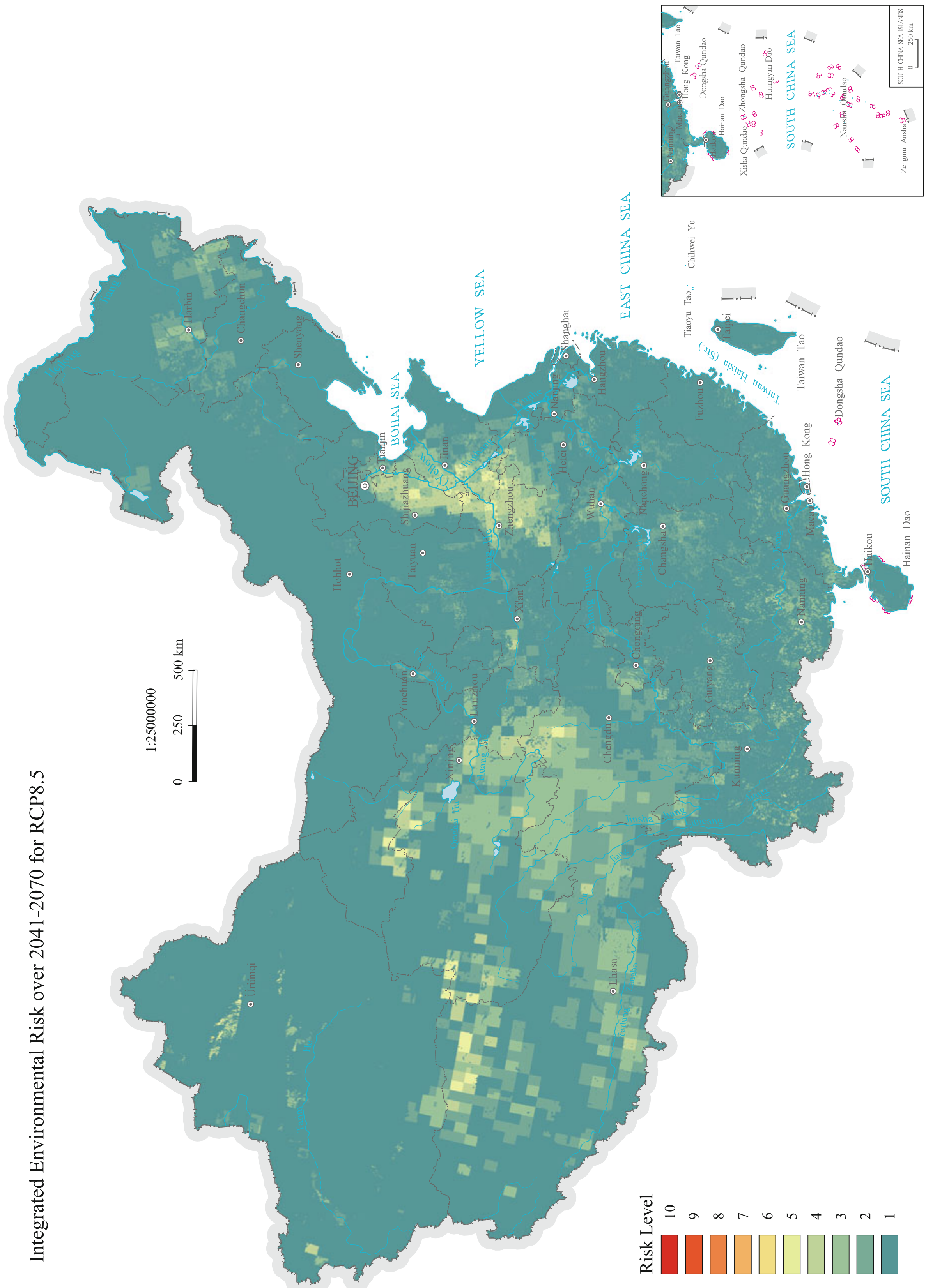
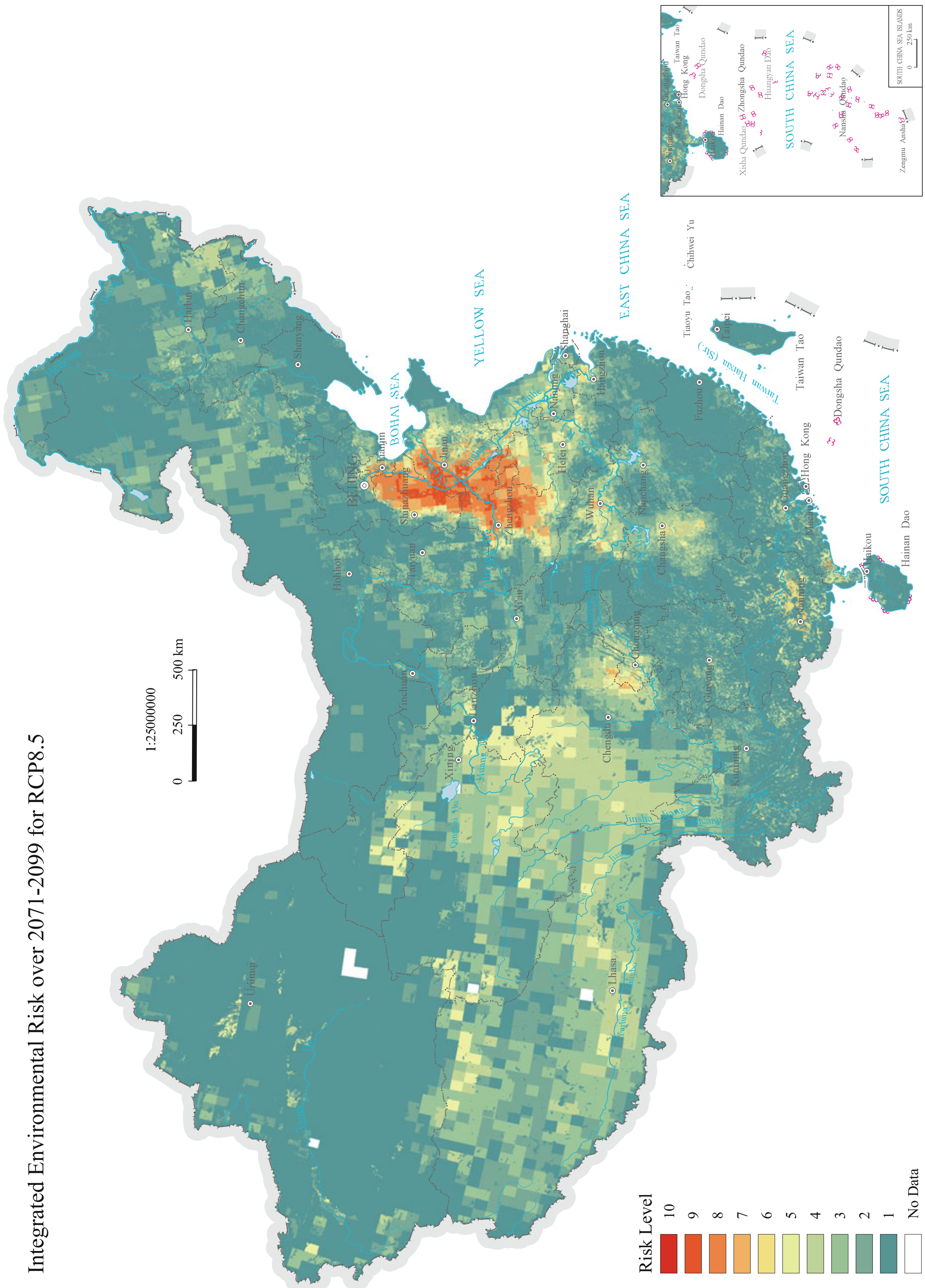
Fuzhou
Taipei
Taiwan Tao
Dongsha Qundao
SOUTH CHINA SEA ISLANDS

Integrated Environmental Risk over 2041-2070 for RCP8.5




Integrated Environmental Risk over 2071-2099 for RCP8.5
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Risk Level
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Shijiazhuang
Zhengzhou
Taiyuan
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Harbin
Changchun
Shenyang
Nanjing
Shanghai
Hangzhou
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Wuhan
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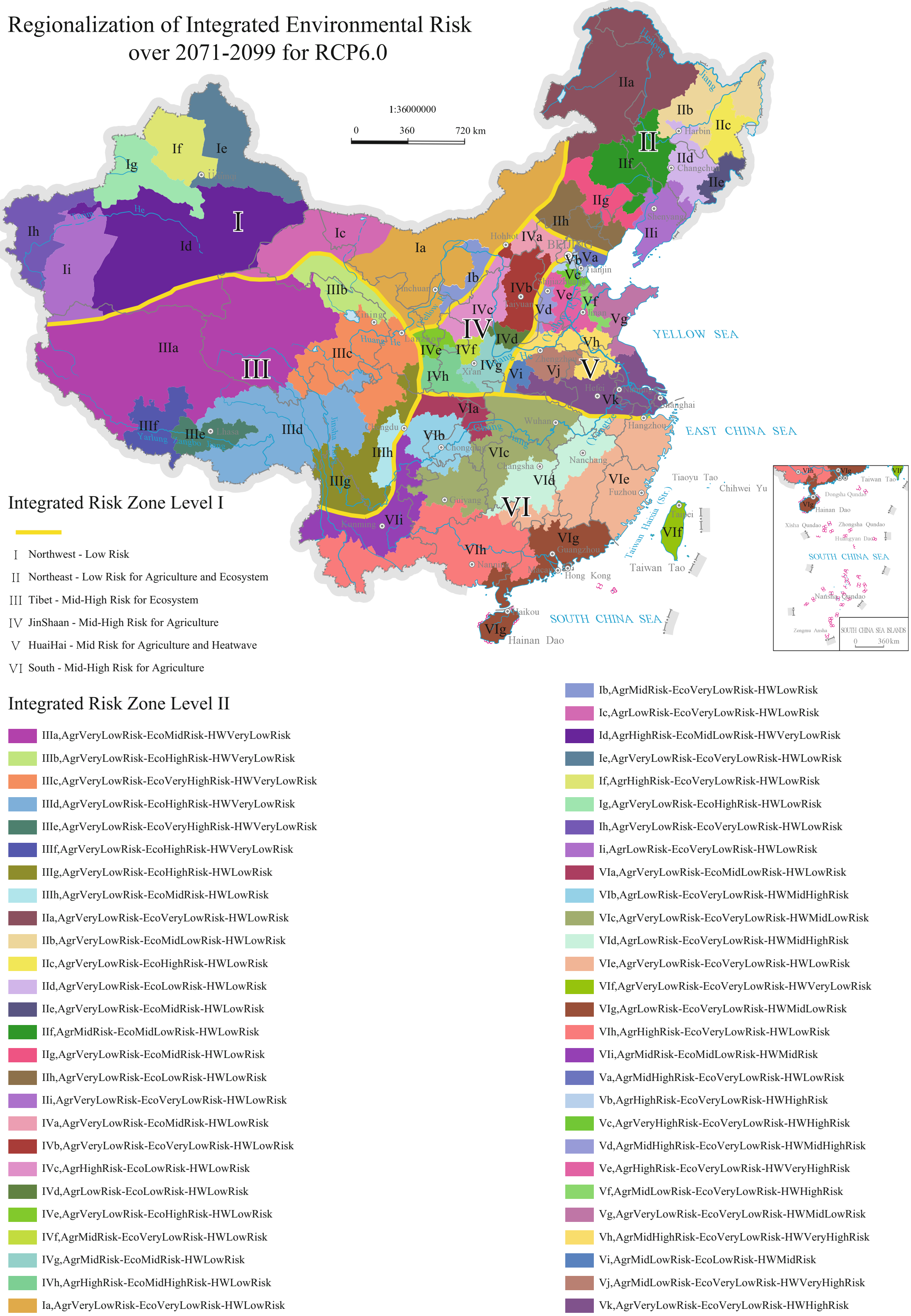
Zengmu Ansha
SOUTH CHINA SEA ISLANDS
0 250 km


Regionalization of Integrated Environmental Risk
over 2071-2099 for RCP6.0
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0 360 720 km
YELLOW SEA
EAST CHINA SEA
SOUTH CHINA SEA
Hainan Dao
Taiwan Tao
SOUTH CHINA SEA ISLANDS
Integrated Risk Zone Level I
I Northwest - Low Risk
II Northeast - Low Risk for Agriculture and Ecosystem
III Tibet - Mid-High Risk for Ecosystem
IV JinShaan - Mid-High Risk for Agriculture
V HuaiHai - Mid Risk for Agriculture and Heatwave
VI South - Mid-High Risk for Agriculture
Integrated Risk Zone Level II
IIIa,AgrVeryLowRisk-EcoMidRisk-HWVeryLowRisk
IIIb,AgrVeryLowRisk-EcoHighRisk-HWVeryLowRisk
IIIc,AgrVeryLowRisk-EcoVeryHighRisk-HWVeryLowRisk
IIId,AgrVeryLowRisk-EcoHighRisk-HWVeryLowRisk
IIIe,AgrVeryLowRisk-EcoVeryHighRisk-HWVeryLowRisk
IIIf,AgrVeryLowRisk-EcoHighRisk-HWVeryLowRisk
IIIg,AgrVeryLowRisk-EcoHighRisk-HWLowRisk
IIIh,AgrVeryLowRisk-EcoMidRisk-HWLowRisk
IIa,AgrVeryLowRisk-EcoVeryLowRisk-HWLowRisk
IIb,AgrVeryLowRisk-EcoMidLowRisk-HWLowRisk
IIc,AgrVeryLowRisk-EcoHighRisk-HWLowRisk
IId,AgrVeryLowRisk-EcoLowRisk-HWLowRisk
IIe,AgrVeryLowRisk-EcoMidRisk-HWLowRisk
IIf,AgrMidRisk-EcoMidLowRisk-HWLowRisk
IIg,AgrVeryLowRisk-EcoMidRisk-HWLowRisk
IIh,AgrVeryLowRisk-EcoLowRisk-HWLowRisk
IIi,AgrVeryLowRisk-EcoVeryLowRisk-HWLowRisk
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IVb,AgrVeryLowRisk-EcoVeryLowRisk-HWLowRisk
IVc,AgrHighRisk-EcoLowRisk-HWLowRisk
IVd,AgrLowRisk-EcoLowRisk-HWLowRisk
IVe,AgrVeryLowRisk-EcoHighRisk-HWLowRisk
IVf,AgrMidRisk-EcoVeryLowRisk-HWLowRisk
IVg,AgrMidRisk-EcoMidRisk-HWLowRisk
IVh,AgrHighRisk-EcoMidHighRisk-HWLowRisk
Ia,AgrVeryLowRisk-EcoVeryLowRisk-HWLowRisk
Ib,AgrMidRisk-EcoVeryLowRisk-HWLowRisk
Ic,AgrLowRisk-EcoVeryLowRisk-HWLowRisk
Id,AgrHighRisk-EcoMidLowRisk-HWVeryLowRisk
Ie,AgrVeryLowRisk-EcoVeryLowRisk-HWLowRisk
If,AgrHighRisk-EcoVeryLowRisk-HWLowRisk
Ig,AgrVeryLowRisk-EcoHighRisk-HWLowRisk
Ih,AgrVeryLowRisk-EcoVeryLowRisk-HWLowRisk
Ii,AgrLowRisk-EcoVeryLowRisk-HWLowRisk
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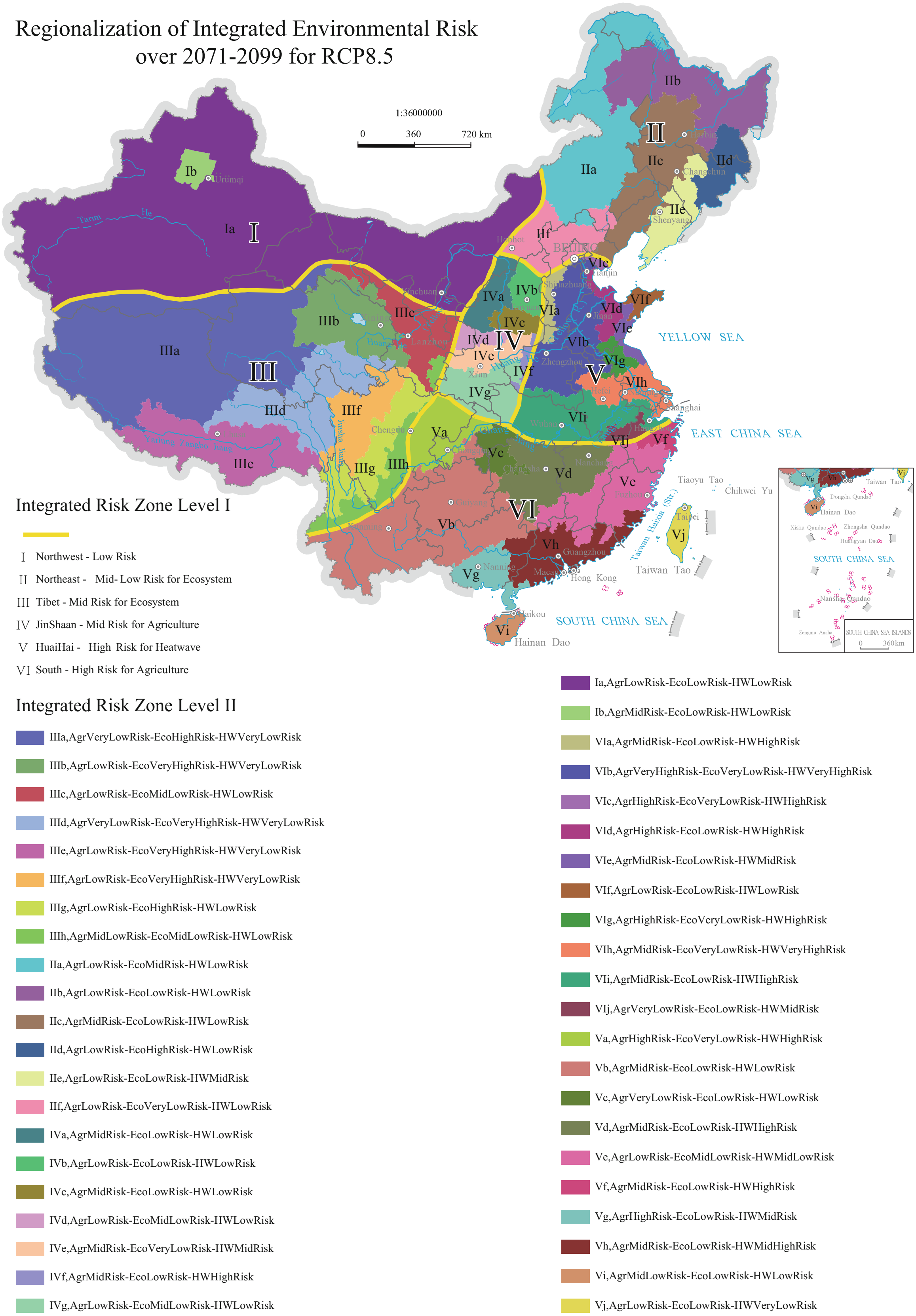
Regionalization of Integrated Environmental Risk
over 2071-2099 for RCP8.5
1:36000000
0 360 720 km
YELLOW SEA
EAST CHINA SEA
SOUTH CHINA SEA
Integrated Risk Zone Level I
I Northwest - Low Risk
II Northeast - Mid- Low Risk for Ecosystem
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IIIg,AgrLowRisk-EcoHighRisk-HWLowRisk
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IIc,AgrMidRisk-EcoLowRisk-HWLowRisk
IId,AgrLowRisk-EcoHighRisk-HWLowRisk
IIe,AgrLowRisk-EcoLowRisk-HWMidRisk
IIf,AgrLowRisk-EcoVeryLowRisk-HWLowRisk
IVa,AgrMidRisk-EcoLowRisk-HWLowRisk
IVb,AgrLowRisk-EcoLowRisk-HWLowRisk
IVc,AgrMidRisk-EcoLowRisk-HWLowRisk
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IVe,AgrMidRisk-EcoVeryLowRisk-HWMidRisk
IVf,AgrMidRisk-EcoLowRisk-HWHighRisk
IVg,AgrLowRisk-EcoMidLowRisk-HWLowRisk
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Ib,AgrMidRisk-EcoLowRisk-HWLowRisk
VIa,AgrMidRisk-EcoLowRisk-HWHighRisk
VIb,AgrVeryHighRisk-EcoVeryLowRisk-HWVeryHighRisk
VIc,AgrHighRisk-EcoVeryLowRisk-HWHighRisk
VId,AgrHighRisk-EcoLowRisk-HWHighRisk
VIe,AgrMidRisk-EcoLowRisk-HWMidRisk
VIf,AgrLowRisk-EcoLowRisk-HWLowRisk
VIg,AgrHighRisk-EcoVeryLowRisk-HWHighRisk
VIh,AgrMidRisk-EcoVeryLowRisk-HWVeryHighRisk
VIi,AgrMidRisk-EcoLowRisk-HWHighRisk
VIj,AgrVeryLowRisk-EcoLowRisk-HWMidRisk
Va,AgrHighRisk-EcoVeryLowRisk-HWHighRisk
Vb,AgrMidRisk-EcoLowRisk-HWLowRisk
Vc,AgrVeryLowRisk-EcoLowRisk-HWLowRisk
Vd,AgrMidRisk-EcoLowRisk-HWHighRisk
Ve,AgrLowRisk-EcoMidLowRisk-HWMidLowRisk
Vf,AgrMidRisk-EcoLowRisk-HWHighRisk
Vg,AgrHighRisk-EcoLowRisk-HWMidRisk
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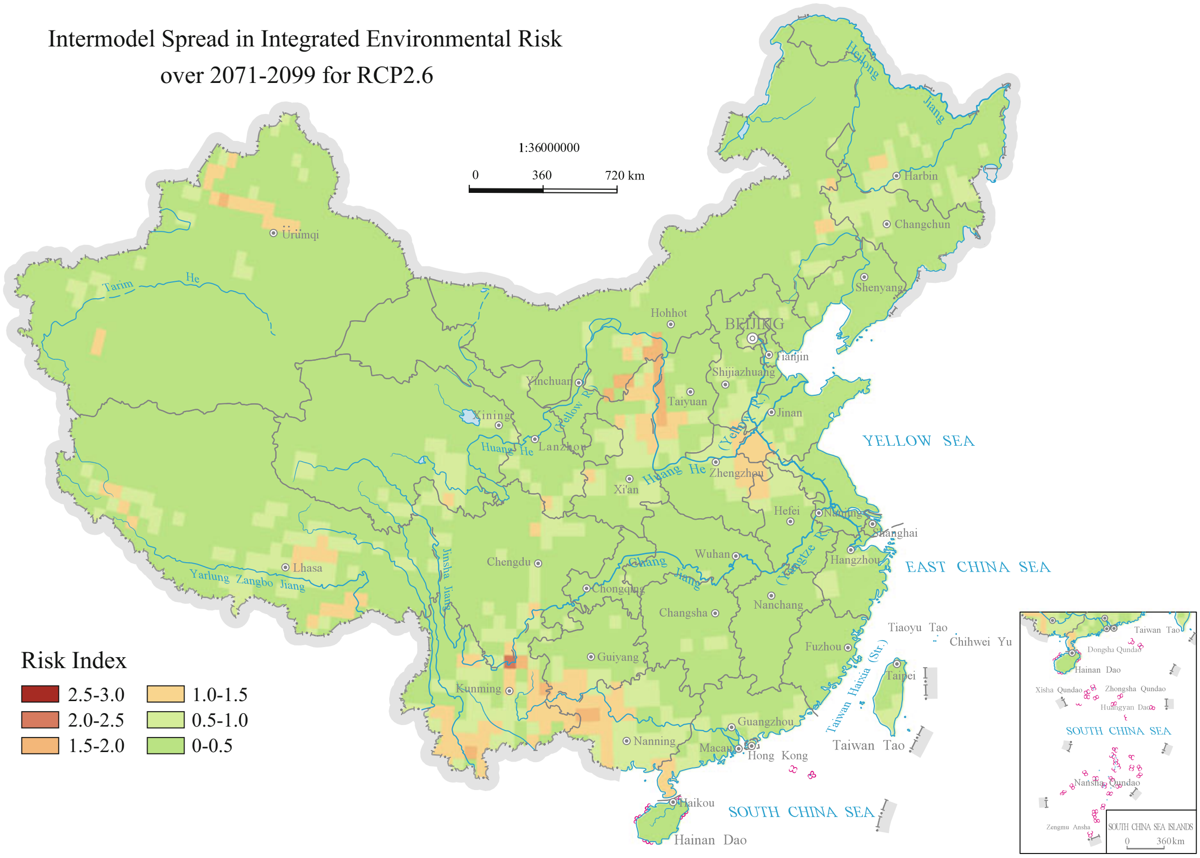
Vi,AgrMidLowRisk-EcoLowRisk-HWLowRisk
Vj,AgrLowRisk-EcoLowRisk-HWVeryLowRisk


Intermodel Spread in Integrated Environmental Risk
over 2071-2099 for RCP2.6
1:36000000
0 360 720 km
Risk Index
2.5-3.0
2.0-2.5
1.5-2.0
1.0-1.5
0.5-1.0
0-0.5
Ürümqi
Tarim He
Lhasa
Yarlung Zangbo Jiang
Harbin
Changchun
Shenyang
Hohhot
BEIJING
Tianjin
Shijiazhuang
Yinchuan
Taiyuan
Jinan
Xining
Lanzhou
Huang He
Xi'an
Zhengzhou
YELLOW SEA
Hefei
Nanjing
Shanghai
Chengdu
Wuhan
Hangzhou
EAST CHINA SEA
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Taipei
Kunming
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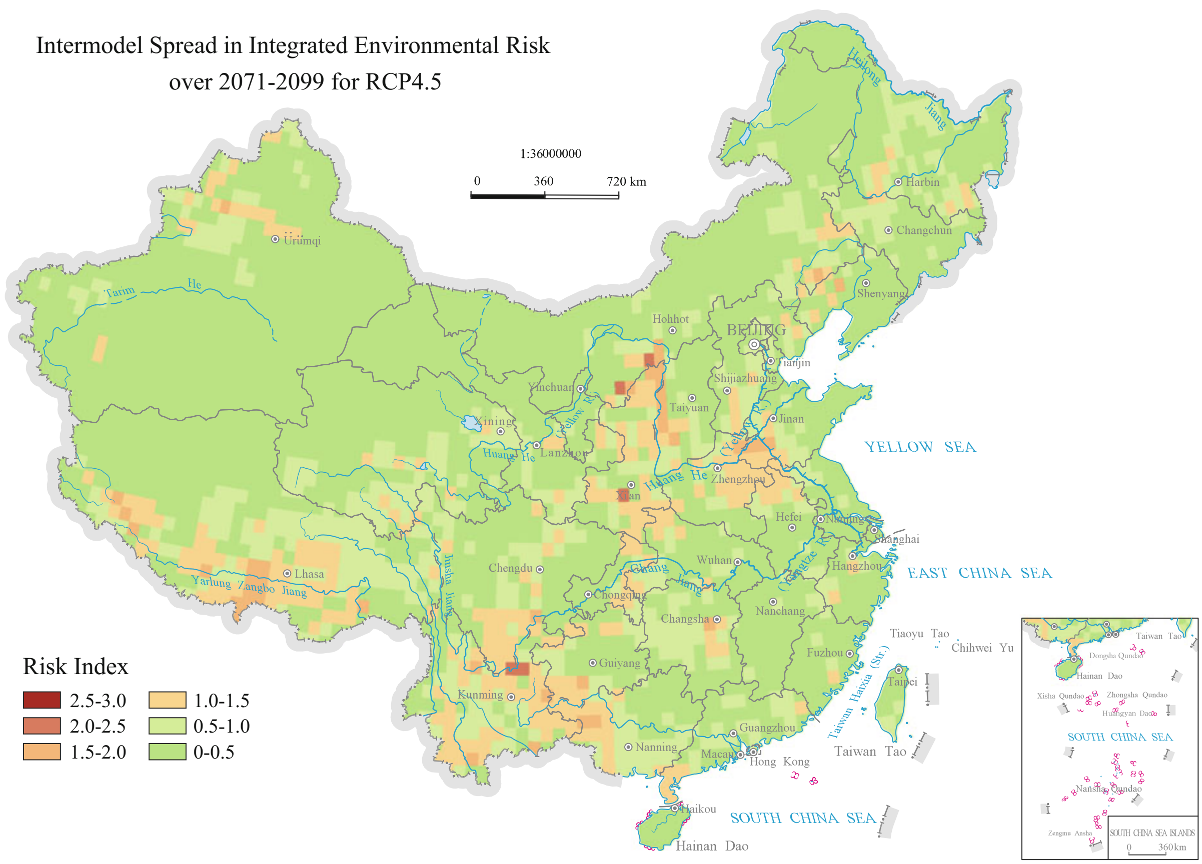
Macau
Hong Kong
Taiwan Tao
Haikou
SOUTH CHINA SEA
Hainan Dao
SOUTH CHINA SEA ISLANDS


Intermodel Spread in Integrated Environmental Risk
over 2071-2099 for RCP4.5
1:36000000
0 360 720 km
Risk Index
2.5-3.0
2.0-2.5
1.5-2.0
1.0-1.5
0.5-1.0
0-0.5
Ürümqi
Tarim He
Lhasa
Yarlung Zangbo Jiang
Harbin
Changchun
Shenyang
Hohhot
BEIJING
Tianjin
Shijiazhuang
Yinchuan
Taiyuan
Jinan
Xining
Lanzhou
Huang He
Zhengzhou
YELLOW SEA
Hefei
Nanjing
Shanghai
Chengdu
Wuhan
Hangzhou
EAST CHINA SEA
Chongqing
Changsha
Nanchang
Jinsha Jiang
Guiyang
Fuzhou
Tiaoyu Tao
Chihwei Yu
Taipei
Kunming
Guangzhou
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Macau
Hong Kong
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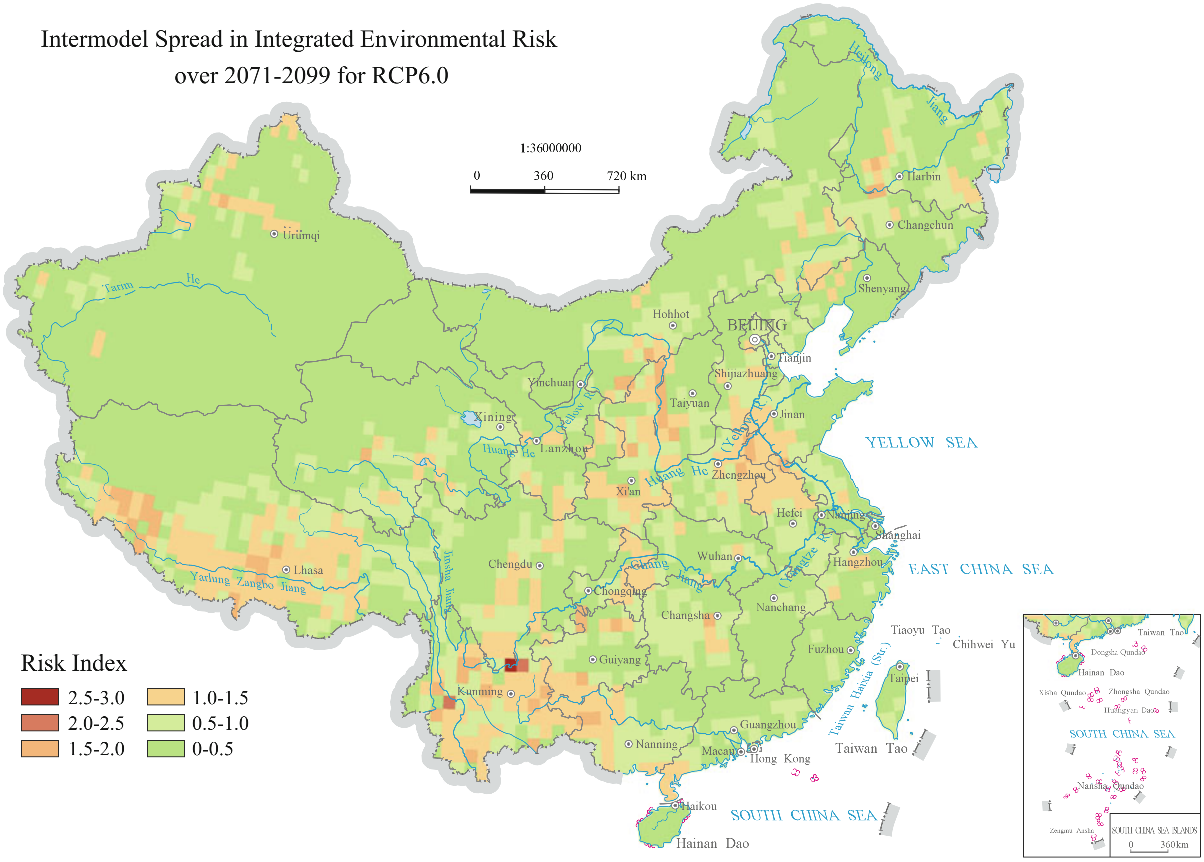
Haikou
SOUTH CHINA SEA
Hainan Dao
SOUTH CHINA SEA ISLANDS


Intermodel Spread in Integrated Environmental Risk
over 2071-2099 for RCP6.0
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0 360 720 km
Risk Index
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2.0-2.5
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1.0-1.5
0.5-1.0
0-0.5
Harbin
Changchun
Shenyang
Ürümqi
Tarim He
Hohhot
BEIJING
Tianjin
Shijiazhuang
Yinchuan
Taiyuan
Jinan
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Hefei
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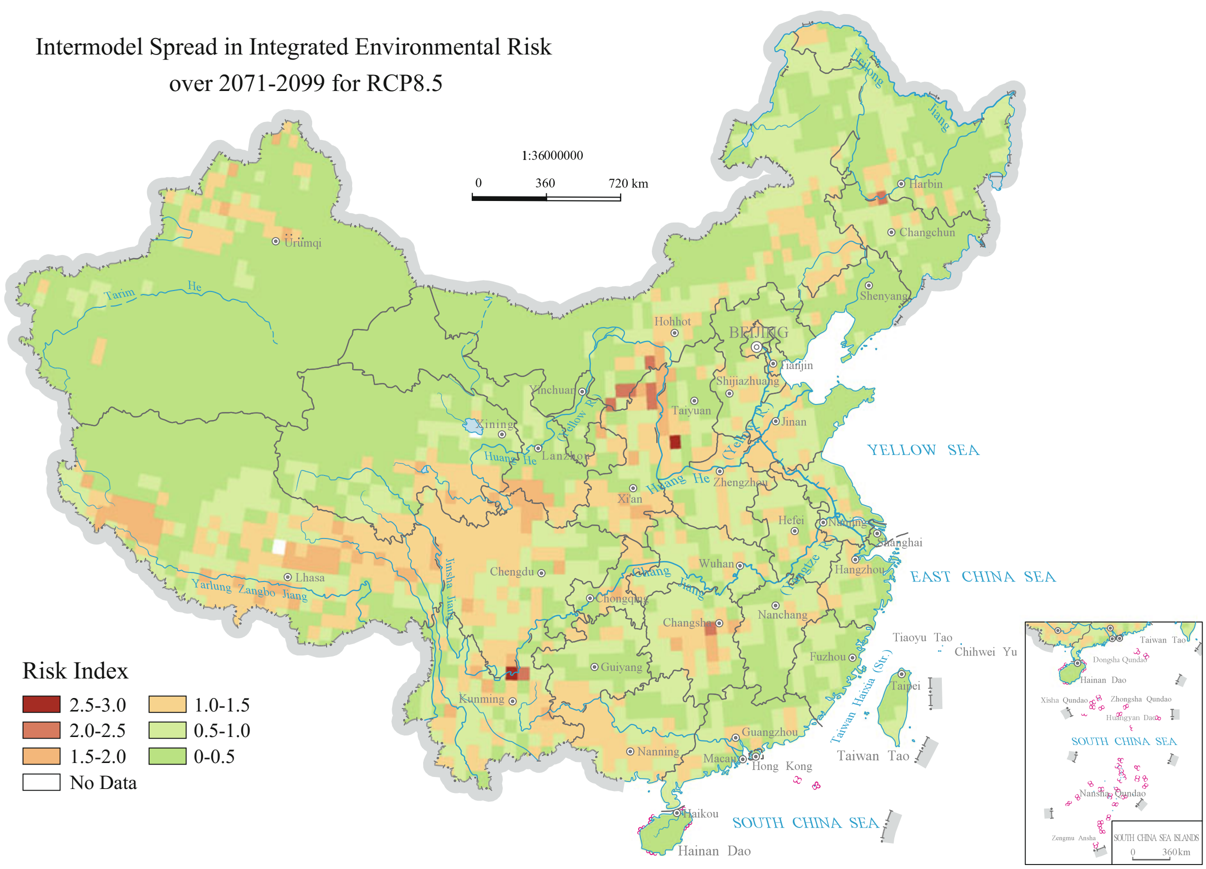
SOUTH CHINA SEA ISLANDS


Intermodel Spread in Integrated Environmental Risk
over 2071-2099 for RCP8.5
1:36000000
0 360 720 km
Risk Index
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2.0-2.5
1.5-2.0
1.0-1.5
0.5-1.0
0-0.5
No Data
Harbin
Changchun
Shenyang
Ürümqi
Tarim He
Hohhot
BEIJING
Tianjin
Shijiazhuang
Yinchuan
Taiyuan
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