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# Does flood protection affect urban expansion in the coastal flood-prone area of China?

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Understanding the characteristics of urbanization under different flood protection levels is vital for sustainable development in coastal flood-prone areas (CFAs). However, little is known about the potential divergences of coastal urbanization across different flood protection levels in the CFAs of China. To fill this research gap, this study investigated the spatio-temporal changes of urban land expansion in Chinese CFAs and explored their relationships with flood protection levels during 2000–2020. It was found that in 2020, the urban lands accounted for 16.35% of the CFAs, 1.81 times that of the non-CFAs (9.04%). The urban lands increased rapidly in the CFAs across all flood protection levels, with an average annual change rate of 6.51%, which was 2.17 times that of non-CFAs (3.00%) and 3.68 times that of the exposed population growth rate (1.77%). Particularly in counties with low flood protection levels (<50 years), the urban lands expanded by 9.40% annually, 1.44 times that of the whole CFAs; moreover, a large portion (39.58%) of the new urban lands were reclaimed from sea waters. These findings suggest that special attention should be paid to coastal landscape changes in the areas of low flood protection levels to reduce flood risk and ensure sustainable cities and communities. Flood adaptation strategies should be applied to include conserving the coastal ecosystem.

KEYWORDS

**flood protection, coastal urbanization, land reclamation, flood exposure, risk reduction**

## Introduction

Coastal flood-prone areas (CFAs) are low-lying areas that are below extreme sea levels and hydrologically connected to the sea (Bilskie et al., 2014; Muis et al., 2016). The CFAs are vulnerable to changing climate, a combined result of sea-level rise, land subsidence, and a potential increase in the probability and intensity of storm surges (Du et al., 2020; Muis et al., 2020). Unfortunately, they are also characterized by a high density of population and land use, which will probably see a further increase during the rapid urbanization process (Jongman et al., 2012; Willner et al., 2018). Therefore, flood risk management in CFAs is critical to achieve the sustainable development goals prompted by United Nations (Reichstein et al., 2021).

Improving flood protection, such as by building levees or dykes, can substantially reduce the probability of flood inundation in CFAs (Ward et al., 2013; Di Baldassarre et al., 2018). Flood protection level (FPL) represents how well a region is protected against flooding, which is generally expressed as the target level of flood return period in designing the flood protection system (Scussolini et al., 2016; Wang et al., 2021). However, high FPLs can cause "levee effect," a false sense of security, that can lead to more rapid development in CFAs, further increasing the proportion of urban lands, population, and assets exposed to extreme floods (Di Baldassarre et al., 2015; Ferdous et al., 2020). Ferdous et al. (2020) found that the higher the level of flood protection, the greater the increase in population and assets exposed to flooding along the Jamuna River, Bangladesh. Accelerated development stemming from flood protection projects has also been documented in California, United States (Hutton et al., 2019).

The CFAs in China are prone to coastal flooding and sea-level rise (Liu et al., 2013). During 2000–2020, a recorded total of 254 storm surges hit China's coastal zones, causing 886 causalities and a cumulative loss of US $31.43 billion (COIN, 2021). Meanwhile, the coastal population has risen by about 90 million, boosting the urbanization rate from 37.44% to 64.87% and expanding urban lands from $6.68 \times 10^4$ km$^2$ to $1.25 \times 10^5$ km$^2$ (NBS, 2019). In the context of climate change, the thriving development is likely to exacerbate coastal flood risk (Wang et al., 2017; Gao et al., 2019; O'Donnell, 2019).

Many studies have examined the urban land increment in China's coastal zones on various scales. On the regional scale, based on Landsat TM images, Weng (2002) found that urban lands in the Pearl River Delta increased by 47.68% during 1989–1997. Han et al. (2020) revealed an urban growth rate in riverine floodplains as high as 125.20% in the middle and lower reaches of the Yangtze River during 1990–2014. Liu and Li (2020) found that urban lands increased by 34.95% along the Bohai Rim during 2000–2015, mainly occupying farmlands and shallow waters. On a national scale, Zheng et al. (2020) found a much faster urbanization process in coastal cities than the national average pace during 2000–2019. However, those studies did not pay attention to the potential divergences of coastal urbanization across different FPLs, which still remains a research gap to be elucidated.

To fill this research gap, our objective was to investigate the urban land expansion in the Chinese CFAs and assess its potential divergence across different FPLs. We first quantified the spatio-temporal dynamics of urban lands in the CFAs during 2000–2020 and their variations across different FPLs. In addition, the interaction among urban land expansion, disaster exposure, and economic loss was discussed. Such an investigation is vital for promoting risk management and achieving sustainable development goals in the coastal region.

# Materials and methods

## Study area and data

We used multiple scales (CFA, province, and county scales) to analyze the urban lands in the CFA of China (Figure 1). The study area contained 11 provincial units, such as Jiangsu, Zhejiang, Guangdong, and Shanghai, and involved 182 county-level units. As a consequence of limited data availability, Hong Kong, Macao, and Taiwan were not included in this research. The administrative boundaries were obtained from the Resource and Environment Science and Data Center (https://www.resdc.cn/).

The urban lands in 2000, 2010, and 2020 were mapped based on the artificial surface dataset in GlobeLand30 (http://www.globallandcover.com/). The initial resolution, 30 × 30 m, was aggregated to 100 × 100 m in our study in accordance with other data resolutions. The accuracy of GlobeLand30 in the CFAs of China was evaluated using high-precision images from Google Earth. Based on a sample of 3,000 points, the evaluated accuracy was 91.3%, 93.7%, and 92.6% for the 3 years, respectively. The urban land refers to the surfaces formed by man-built activities, including human settlements, industrial and mining area, and transportation facilities (Yu et al., 2014).

The FPLs were originally taken from the Flood Protection Level Database (Wang et al., 2021) and were updated using flood policy documents and plans (Wang, 2022). The FPLs were expressed in flood return period (years). They were applicable to coastal floods caused by a joint effect of tides, storm surges, and mean sea level, but did not consider pluvial floods, for example, urban waterlogging and compound flood scenarios, which referred to a co-occurrence of coastal floods, riverine floods, and pluvial floods.

The economic losses due to the storm surge were derived from Marine Disaster Bulletin (COIN, 2021), which were converted into US dollars by the 2020 price. The population grids in 2000, 2010, and 2020 were derived from WorldPop (https://www.worldpop.org/). The data had a resolution of 100 m.

## Defining coastal flood-prone areas of China

The CFAs were defined as the maximum extent of the 100-year return period coastal flood (Du et al., 2018). They comprised continental and island areas hydrologically connected to the sea and lower than the 100-year sea levels. The coastal elevation dataset (Kulp and Strauss, 2019) and sea-level extremes dataset (Muis et al., 2020) were employed to derive the CFAs. The latter was simulated by Global Tide and Surge Model version 3.0, which considered the joint effects of tides, storm surges, and mean sea level on extreme sea levels (Muis et al., 2020). From the multiple return periods contained in the dataset, the 100-year

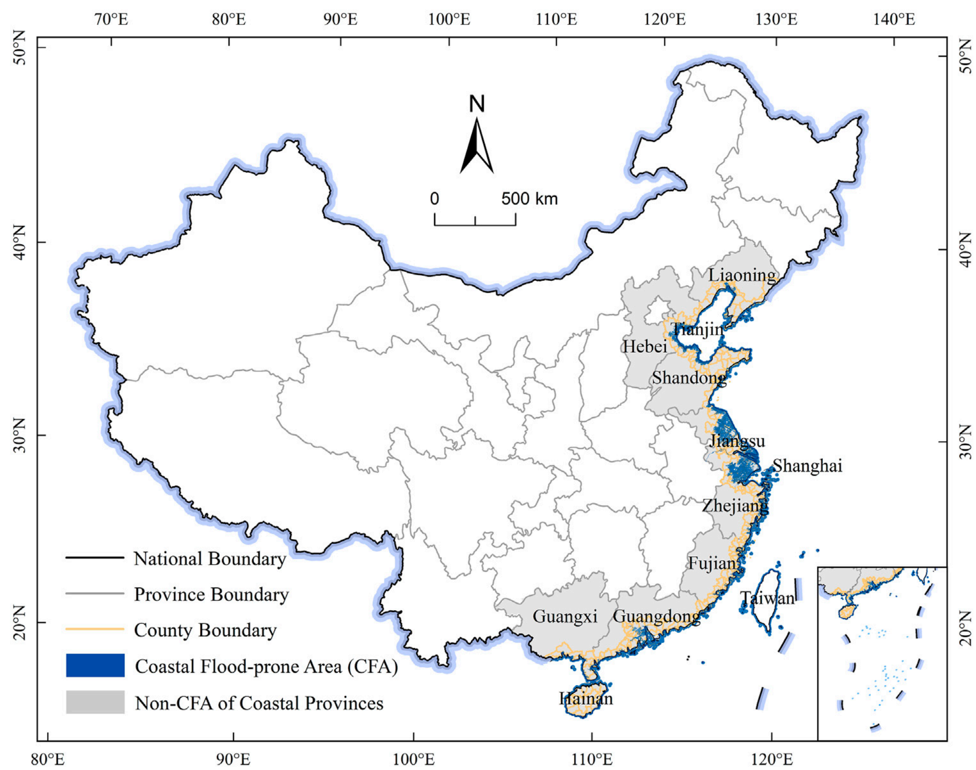


FIGURE 1
The coastal flood-prone areas (CFAs) in China.

sea-level extremes were employed to produce the CFAs by using a bath-tub model, about which more details are available in Gao et al. (2019).

## Calculating indices of urban land

We used the average annual change rate to reflect the intensity of urban land change during 2000–2020 (Du et al., 2018), which was calculated as follows:

$$AACR = \left( \sqrt[(t2-t1)]{\frac{X_{t2}}{X_{t1}}} - 1 \right) \times 100\% \quad (1)$$

where $AACR$ was the average annual change rate; $X_{t1}$ and $X_{t2}$ referred to the area of urban lands in CFAs in years $t1$ and $t2$, respectively.

## Analyzing the relationship between flood protection and urban land expansion

The Pearson correlation coefficient (Schober et al., 2018) was used to explore the relationship between the average annual change rate of urban lands in CFAs and FPLs, which was calculated by Eq. 2:

$$r = \frac{\sum_{i=1}^{n} (A_i - \bar{A})(B_i - \bar{B})}{\sqrt{\sum_{i=1}^{n} (A_i - \bar{A})^2} \sqrt{\sum_{i=1}^{n} (B_i - \bar{B})^2}} \quad (2)$$

where $r$ referred to the correlation coefficient; $A_i$ and $\bar{A}$ referred to the average annual change rate of urban lands in CFAs for zone $i$ and its average across the entire study area, respectively; and $B_i$ and $\bar{B}$ referred to the FPL for zone $i$ and its average FPL.

The Kruskal–Wallis test is a non-parametric statistical tool that evaluated whether two or more samples were drawn from the same distribution (Guo et al., 2013). We used Eq. 3 to explore whether there were significant differences in the average annual change rate of urban lands under different FPLs.

$$KW = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1) \quad (3)$$

where $N$ was the total number of all samples, $n_i$ was the number of values contained in the $i$th sample, and $R_i$ was the sum of ranks in $i$th sample.

We calculated the transformation matrix of land use changes to reveal the transfer characteristics of land use types (Xu et al.,

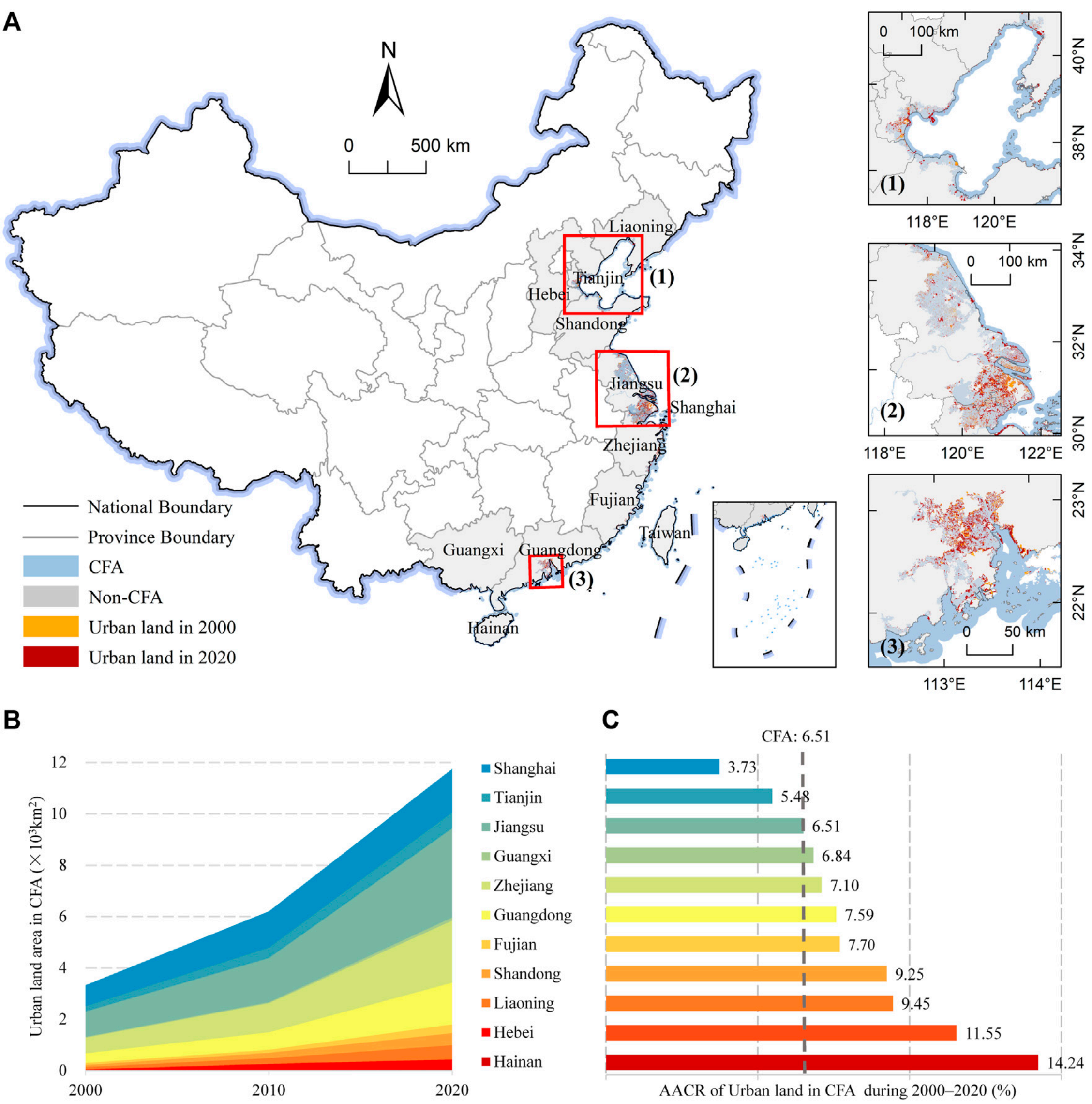


FIGURE 2
Changes of urban lands in CFAs of China during 2000–2020: the pattern **(A)**, growth amount **(B)**, and average annual change rates **(C)**.

2013), and then we made a Sankey diagram based on Python to visually display the transformation matrix (Soundararajan et al., 2014).

# Results

## Urban land patterns of CFAs in 2020

In 2020, the total area of CFAs in China was $7.19 \times 10^4$ km², accounting for 5.60% of the total area of China's coastal provinces. These areas are mainly distributed in Jiangsu ($2.88 \times 10^4$ km²), Zhejiang ($1.01 \times 10^4$ km²), Guangdong ($7.33 \times 10^3$ km²), and Shanghai ($6.07 \times 10^3$ km²), with obvious spatial agglomeration characteristics (Figure 1).

In 2020, the urban lands in CFAs encompassed a total area of $1.18 \times 10^4$ km². It accounted for 16.35% of the CFAs in China, which was 1.81 times the ratio of urban lands to the non-CFAs in China's coastal provinces. A large proportion of the urban lands in CFAs (78.31%, $9.20 \times 10^3$ km²) was located in Jiangsu, Zhejiang, Shanghai, and Guangdong. Jiangsu featured the largest urban lands in CFAs (29.54%, $3.47 \times 10^3$ km²), followed by Zhejiang, Shanghai, and Guangdong, whose urban lands in CFAs were about 1,500–2,500 km². The urban lands in CFAs in other coastal provinces, such as Tianjin, Liaoning, and Shandong, were less than 1,000 km².

TABLE 1 The urban lands in CFAs and its changes under different FPLs during 2000–2020 in China and the results of the Kruskal–Wallis test.

| FPL (return period, years) | Urban land area ($km^2$) | | Changes in 2000–2020 | | Kruskal–Wallis test (mean rank) |
|---|---|---|---|---|---|
| | 2000 | 2020 | Increases ($km^2$) | AACR (%) | |
| 10–20 | 59 (1.77%) | 413 (3.52%) | 354 (4.22%) | 10.22 | 96.85 |
| 20–30 | 70 (2.10%) | 319 (2.72%) | 249 (2.97%) | 7.87 | 73.81 |
| 30–50 | 10 (0.30%) | 108 (0.92%) | 98 (1.17%) | 12.48 | 120.50 |
| 50–100 | 600 (18.04%) | 2,042 (17.42%) | 1,442 (17.18%) | 6.32 | 86.53 |
| 100–200 | 877 (26.37%) | 4,043 (34.50%) | 3,167 (37.73%) | 7.94 | 100.85 |
| ≥200 | 1,710 (51.41%) | 4,794 (40.91%) | 3,084 (36.74%) | 5.29 | 62.43 |
| Total | 3,326 (100%) | 11,719 (100%) | 8,394 (100%) | 6.51 | KW=14.63* |

*$p$<0.01. AACR is the abbreviation of average annual change rate. The percentages in the brackets are the proportion of urban lands (increases) with a specific FPL to the total in CFAs.

## Urban land expansion in CFAs during 2000–2020

Urban lands in CFAs expanded rapidly during 2000–2020 (Figure 2A). It multiplied from $3.33 \times 10^3$ $km^2$ to $1.18 \times 10^4$ $km^2$, with a total growth of $8.42 \times 10^3$ $km^2$. The average annual change rate of urban lands in CFAs was 6.51%, much higher than that in non-CFAs (3.00%).

Over the past 2 decades, Jiangsu experienced the greatest increase in urban lands in CFAs of $2.49 \times 10^3$ $km^2$, followed by Zhejiang ($1.80 \times 10^3$ $km^2$) and Guangdong ($1.25 \times 10^3$ $km^2$) (Figure 2B). The average annual change rate of urban lands in CFAs in Hainan and Hebei were the highest, 14.24% and 11.55%, respectively (Figure 2C), which were 2.19 and 1.77 times that of the average rate in CFAs (6.51%), respectively. Both the expanded area and the change rate of urban lands in CFAs were higher during 2010–2020 than those during 2000–2010 in coastal provinces, except Shanghai, Hebei, Shandong, and Tianjin.

## Urban land expansion under different flood protection levels

An overwhelming majority of urban lands in CFAs (92.83%, $1.09 \times 10^4$ $km^2$) were located in areas with FPLs ≥50 years (Table 1). In 2020, there were $4.79 \times 10^3$ $km^2$ (40.91%) of urban lands in CFAs in the areas with the highest FPLs (≥200 years), followed by the areas with FPLs of 100–200 years ($4.04 \times 10^3$ $km^2$, or 34.50%) and 50–100 years ($2.04 \times 10^3$ $km^2$, or 17.42%). The urban lands in CFAs were less than 500 $km^2$ in those areas with FPLs less than 50 years.

During 2000–2020, a significant negative correlation was between FPLs (the FPLs of each province was the mode of the FPLs of its coastal counties) and the growth rate of urban lands at the provincial level ($r = -0.68$, Sig. <0.05), that is, the expansion speed of urban lands in CFAs with low FPLs was relatively high, and vice versa. Meanwhile, at the county level, a significant divergence was also observed in the expanding speed of urban lands in CFAs under different FPLs (Table 1; Figure 3). The average annual change rate of urban lands in CFAs in the 17 counties with FPLs of 10–20 years was 10.22%, 1.57 times of that across all the FPLs (6.51%). For the 12 counties with FPLs of 30–50 years, the average annual change rate of urban lands was the highest (12.48%), which is 1.92 times of that across all the FPLs (6.51%). The average annual change rate of urban lands in CFAs was lowest in the 22 counties with FPLs ≥200 years (5.29%). As a result, for the 42 counties with <50-year flood protection level, the average annual change rate of urban lands in the CFAs was 9.40%, which is 1.44 times of that across all the FPLs (6.51%) and 1.48 times of the remaining counties with a higher flood protection level (≥50 years, 6.33%).

## Land use conversion under different flood protection levels

During 2000–2020, the main sources of enlarged urban lands in CFAs in China were farmlands, water bodies, and newly reclaimed lands (Figure 4). Among the expanded urban lands in CFAs, 61.69% ($5.19 \times 10^3$ $km^2$) came from farmlands, 20.73% ($1.75 \times 10^3$ $km^2$) from water bodies, and 16.42% ($1.38 \times 10^3$ $km^2$) from newly reclaimed lands.

In the areas with lower FPLs, the gained urban lands in CFAs were mainly from newly reclaimed lands, while in the areas with higher FPLs, they were mostly from farmlands (Figure 5). In CFAs where the FPLs were less than 50 years, 39.58% (287 $km^2$) of the enlarged urban lands came from the newly reclaimed lands, 30.61% (222 $km^2$) from farmlands, and 22.69% (165 $km^2$) from water bodies. In the areas with FPLs ≥50 years, more than 50% ($4.95 \times 10^3$ $km^2$) of the new urban lands in CFAs were from farmlands (Figure 5).

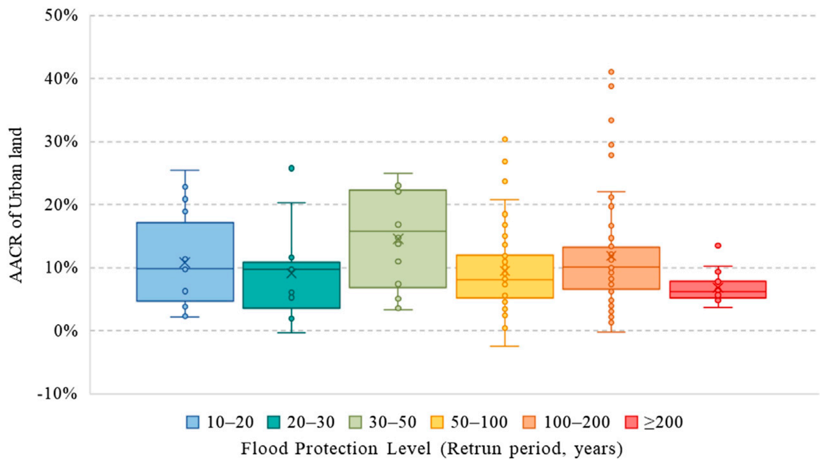


FIGURE 3
The average annual change rates (AACR) of urban lands in CFAs under different FPLs during 2000–2020 in China.

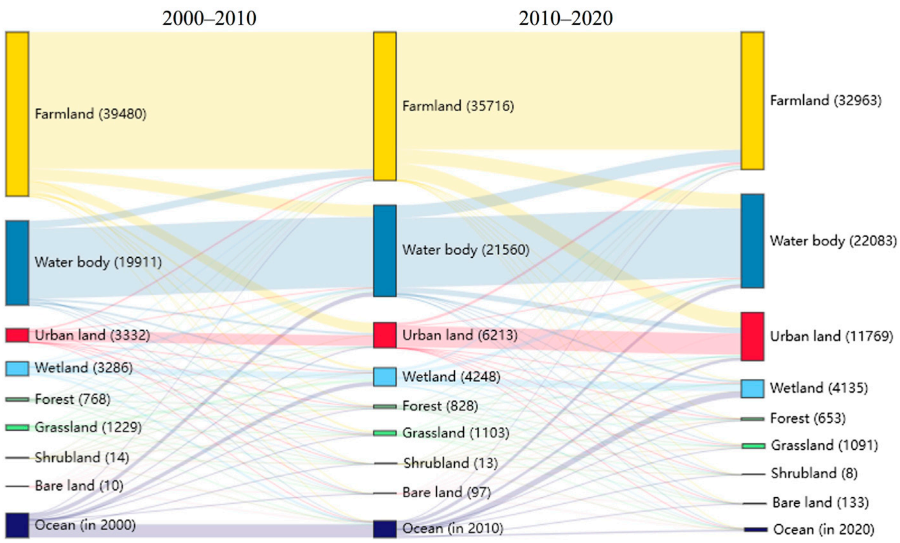


FIGURE 4
The land use conversions in CFAs during 2000–2020. Note: the height of each column represents the total area of a specific land use type, which is presented in brackets ($km^2$); the width of each branch corresponds to the transferred land area.

# Discussion

## The growth rates of urban lands and population are incompatible

The growth rate of urban lands in CFAs in China was much faster than that of the population during 2000–2020 (Figure 6), and their ratio was higher than those of the national and global levels. The average annual change rate (6.51%) of the urban lands in CFAs was about 3.68 times that of the exposed population (1.77%). For 47 counties with FPLs of 50–100 years, the ratio of two was as high as 15.14, and 22 counties with the highest FPLs (≥200 years) had the lowest ratio of 1.86. Chen et al. (2019) found that the ratio of the average annual change rate of urban lands (3.41%) to the exposed population (1.17%) was about 2.91 in high-frequency flood areas in China during 1995–2015. Ehrlich et al. (2018) pointed out that the ratio of two in floodplains in the world during 2000–2015 was about 1.22. The growth rate of

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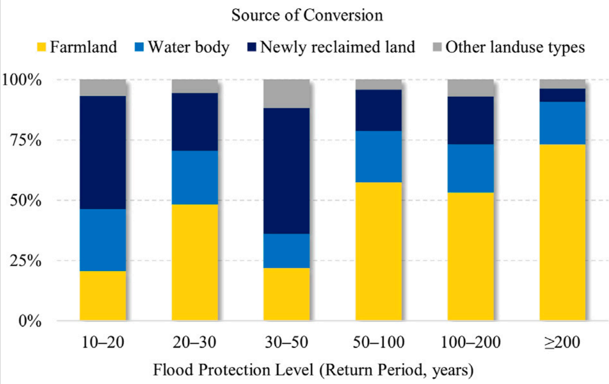


FIGURE 5
Proportion of main sources of urban lands in CFAs of China under different FPLs during 2000–2020.

urban lands in CFAs of China was relatively higher, especially in areas with FPLs of 50–100 years.

The CFAs have historically been a natural place for human settlements as they typically offer ready access to water and fertile soil; recently, these areas are seeing rapid urbanization, much faster than that in non-CFAs (UNU-IHDP, 2015). Reclaiming lands for urban development and a growing population is a good example for the CFAs as a favorite place over the non-CFAs. In the context of climate change, the continuous increment of urban lands and population concentration in CFAs of China would exacerbate the flood risk in coastal zones (Du et al., 2018; Gao et al., 2019), thus stepping up the challenges faced by risk management. Therefore, China should pay much more attention to the adjustment of the growth rate of urban lands in CFAs and its optimization of spatial layout.

## Reinforced seawalls cannot protect against all coastal flooding

Higher FPLs do not mean absolute safety (Figure 7). The mode of FPLs in Guangdong, Fujian, and Zhejiang was 100–200 years, while the cumulated direct economic losses of storm surges in these three provinces accounted for about 75.47% (US $23.72 billion) of the national total during 2000–2020. Among them, the loss ratio of storm surge to GDP in Fujian was the highest (3.65‰), followed by Zhejiang (1.01‰) and Guangdong (0.98‰).

In the past 20 years, these three provinces had placed great emphasis on the construction of storm-surge barriers or seawalls. At the end of 2000, Zhejiang invested nearly US $600 million to build and strengthen the seawalls to protect against coastal flooding, and other coastal provinces also built and strengthened the coastal flood protection system in the following years (Fang et al., 2017). In 2017, the National Development and Reform Commission and the Ministry of Water Resources issued the national seawall construction plan, which planned to further improve the flood-control and disaster-reduction engineering system in coastal zones in about 10 years.

Although the repair and reinforcement of seawalls could improve the FPLs and protect people from frequent floods, it would further accelerate the urbanization of CFAs and aggravate flood exposure. Thus, China should explore additional adaptation solutions to settle the contradiction between urban

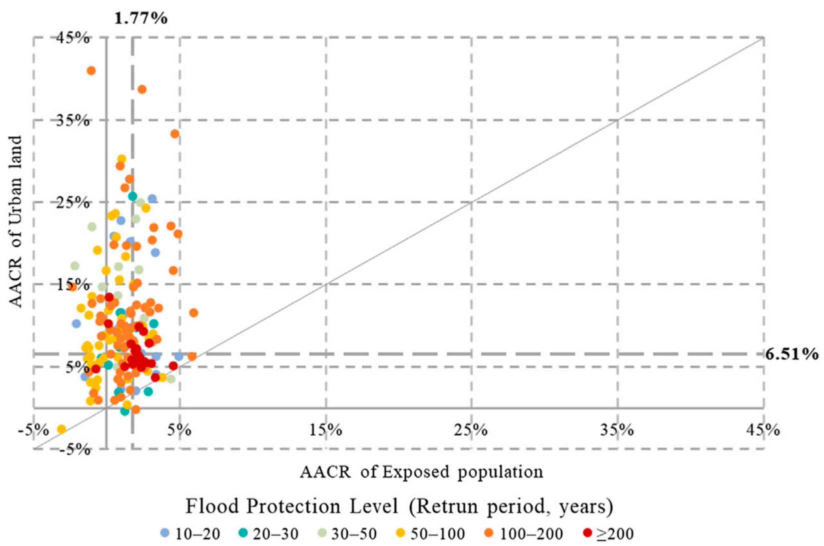


FIGURE 6
The scatter diagram of average annual change rate of urban lands in CFAs and exposed population under different FPLs during 2000–2020.

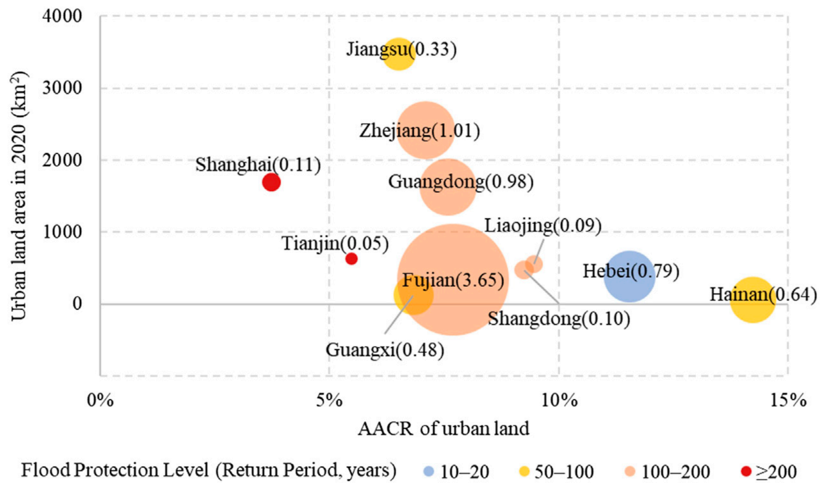


FIGURE 7
The province-level relationship between storm surge losses, urban lands in CFAs in 2020, and its average annual change rates (AACR) during 2000–2020. Note: the circle size represents the rate of storm surge losses to the GDP, which are shown in brackets (‰).

development and structural protection, and prevent the disorderly spread of flood exposure while improving the FPLs (Du et al., 2019).

Moreover, the seawalls could be greatly lowered by land subsidence (Wu et al., 2007; Bagheri-Gavkosh et al., 2021; Herrera-Garcia et al., 2021). Low-lying coastal cities are increasingly in danger of inundation due to land subsidence, particularly associated with a combined influence of sea-level rise (Bagheri-Gavkosh et al., 2021). In Shanghai, for instance, 87% of the seawalls experienced subsidence during 2009–2015 (Chen et al., 2016). In the future, land subsidence could further aggravate flood risk in Shanghai (Du et al., 2020). Land subsidence should be systematically included in flood risk analyses and adaptation strategy design.

## Policy implications

The expansion of urban lands in CFAs directly intensified the exposure and risk of coastal flooding (Sajjad et al., 2018; Willner et al., 2018). Particularly, we found that the urban lands in CFAs with relatively low FPLs were stepping up with great speed, which may further exacerbate flood risk. Moreover, in this process, the land use change, such as the encroachment of farmlands and the newly reclaimed lands, also changed the hydrological process, damaged the flood regulation service of the ecosystem, and aggravated the flood hazards (Shen et al., 2019; Shen et al., 2021; Li et al., 2022).

Therefore, attention should be paid to effectively control the spread of urban lands and limiting the increment of urban lands in areas at high risk. The average annual change rate of China's urban lands in CFAs (6.51%) was about 3.54 times that of urban lands in global floodplains (1.84%) (Ehrlich et al., 2018), and far exceeded the population growth. It indicated that although China had incorporated flood-control measures into urban planning (Du et al., 2018), it had not limited the enlargement of urban lands in CFAs. Consequently, a large amount of wetlands had been reclaimed for urban expansion.

The ecosystem should be reserved to enhance the resilience of coastal cities. Particularly, coastal wetlands could play a role in "soft adaptation" and nature-based solutions as they can essentially reduce storm surges and water levels (Du et al., 2020). One study indicated that if the wetland rose by 1 $km^2$, the average losses caused by specific storms would be cut by US $12.16 million (in 2020 price) (Liu et al., 2019). However, the wetlands were encroached on Chinese CFAs. In areas where the FPLs were less than 50 years, 39.58% (287 $km^2$) of the enlarged urban lands in CFAs came from newly reclaimed lands, which would further augment the exposure to floods and threaten the coastal ecosystem. Authorities should launch an evaluation of ecosystem services in formulating coastal development plans (Bai et al., 2018) to maximize the flood regulation services of coastal wetlands (Choi et al., 2018) and minimize the protection costs (Van Zelst et al., 2021).

In addition, flood risk information should be made available to facilitate risk-based urban planning (Du et al., 2018). Now, China implements the first National Comprehensive Survey of Natural Disaster Risk (GOSC, 2020), which will provide critical information about flood exposure, vulnerability, protection levels, flood reduction resources, and the risk. Such information should lay a sound basis for urban planning to reasonably avoid high-risk areas or take the way of upgrading the fortification level and enhancing resilience to reduce risks. The choice could be made using a cost and benefit analysis (Du et al., 2020).

## Future perspectives

This study has several limitations. First, there is a lack of storm surge economic loss data on a fine scale, so it is unworkable to explore the possible relations between urban land expansion and economic losses in CFAs. Second, when discussing the relationship between FPLs and urban lands in CFAs, the method used is relatively single. Third, we only quantified land use change from the perspective of statistics and policy, and did not take stakeholders' views or desires into consideration (Huang et al., 2022). Finally, the possible changes in flood risk and the CFAs inundation under the influence of climate change are not considered. In future studies, we plan to extract urban land information based on multi-temporal satellite images and incorporate future climate change scenarios into the study to discuss the enlargement of urban lands in CFAs under different FPLs and adaptation schemes (Chen et al., 2020).

# Conclusion

The urban land is disproportionally distributed in the CFAs of China, and it has a divergent pattern across different flood protection levels. In 2020, urban lands in China's CFAs were about $1.18 \times 10^4$ km$^2$, accounting for 16.35% of the total area of the CFAs, which was 1.81 times of that in the non-CFAs (9.04%). An overwhelming majority of the urban lands in CFAs (92.83%, $1.09 \times 10^4$ km$^2$) were located in the areas of high flood protection levels (≥50 years). During 2000–2020, the urban lands in the CFAs increased rapidly, with an average annual change rates of 6.51%, which was 2.17 times that in non-CFAs (3.00%). The gained urban lands in CFAs mainly came from farmlands ($5.19 \times 10^3$ km$^2$, 61.69%) and newly reclaimed lands ($1.38 \times 10^3$ km$^2$, 16.42%). Particularly, the urban lands in the CFAs with low flood protection levels (<50 years) increased sharply, where the average annual change rate was 1.44 times of that across all the FPLs (6.51%). Moreover, these low flood protection counties saw a considerable portion (39.58%, 287 km$^2$) of the new urban lands reclaimed from the sea waters, which would dampen the coastal ecosystem services and further aggravate the flood risk. Hence, attention should be paid to the expanding urban lands in Chinese CFAs, particularly in areas of low flood protection levels. Flood adaptation strategies need to be implemented to reduce the flood risk and promote sustainable coastal landscape and human society.

# Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding authors.

# Author contributions

YW: formal analysis; investigation; methodology; software; visualization; and writing—original draft, review, and editing. JL: conceptualization; methodology; and writing—original draft, review, and editing. DW, LL, and WS: data curation, formal analysis, and methodology. SD: conceptualization; methodology; and writing—original draft, review, and editing.

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# Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

# Publisher's note



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