

# Evaluating and analyzing the comprehensive community disaster reduction capability

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**Abstract:** China currently faces the important task of strengthening its regional disaster reduction capabilities. Communities are basic components of urban areas, and ensuring that they participate in disaster reduction is important for urban safety. The "National Demonstration Community for Comprehensive Disaster Reduction (NDCCDR)" is one of the community comprehensive disaster prevention and reduction work organized nationwide by the National Committee for Disaster Reduction and the Ministry of Civil Affairs in order to carry out the disaster relief work efficiently and orderly and strengthen the capacity building of disaster prevention and reduction. In this paper, in view of the imperfect evaluation criteria in the NDCCDR, and according to the connotation of community comprehensive disaster reduction capability (CCDRC), we construct an index system to evaluate the CCDRC; the system is comprised of six primary evaluation indices that measure the ability to evaluate disaster risk, the ability to provide rescue and support, the presence of engineering defenses, the presence of social and economic base support, the ability to manage disasters, and the level of public cognitive ability. These six primary indices include 31 secondary indices. Because the index system is characterized by a small sample size, sparse information, and large spatial extent, for the index system, we evaluate CCDRC using the entropy-weighted grey target model and geographic information system (GIS) overlay analysis. According to the distribution status of NDCCDR, we take the Suzhou New District (SND) as a case study for the empirical measurements and calculations and use ArcMap 10.2 software to produce a map of the spatial distribution of CCDRC in this region. The results indicate that the area's CCDRC is relatively low. The spatial distribution of CCDRC is uneven. However, the CCDRC in the region has a good foundation and it also has large potential for improvement. The results also show that all of the NDCCDR are in the forefront of the case area, but their CCDRC is unbalanced and their primary evaluation indices of CCDRC are also not balanced. Therefore, we propose that the construction of NDCCDR and CCDRC should be combined, from point to face, and ultimately to improve the overall level of CCDRC in the community.

**Key words:** CCDRC; NDCCDR; entropy weighted grey target model; target center degree; GIS overlay analysis.

## 1. Introduction

Despite the capacity to understand and transform nature, humans remain vulnerable to various natural disasters. Studies on the techniques, methods, and strategies involved in disaster prevention and mitigation remain important. In the past, engineering defenses have constituted the main approach to disaster mitigation. However, studies have suggested that this method is not always a successful means of disaster prevention and reduction (Gall et al., 2011; Deckers et al., 2010). Risk analysis can help decision makers identify high risk areas and thus use their limited capital and resources in the correct places (Hanne Glas et al., 2016; Shi et al., 2012). Therefore, risk analysis can significantly increase the

40 effectiveness of disaster management, and it has become an active focus of research on disaster  
41 prevention and reduction in recent years. As the basic component of urban public disaster prevention  
42 and reduction strategies, communities play an important role in urban safety systems. More attention  
43 should be paid to disaster risk evaluation at the community scale. *The national comprehensive disaster*  
44 *prevention and reduction plan (2016-2020, China)* identified the "conduction of community disaster  
45 risk identification and evaluation, and compilation of community disaster risk maps" as a major  
46 strategy for disaster prevention and reduction over this time period (General Office of the State Council,  
47 2017). Rapid urbanization and the interactions between various natural disasters mean that urban and  
48 rural communities are impacted by many kinds of disasters, sometimes simultaneously. Therefore,  
49 community-level disaster management has increasingly become the focus of global disaster  
50 management (Li, 2012). Currently, the international community follows the concept of  
51 "community-based disaster risk management" (CBDRM) (Bajet et al., 2008). Emphasis is placed on a  
52 complete understanding of disaster risk (in addition to natural disasters, including public health, traffic  
53 security, social safety, and accidents involving water, gas, and electricity) (UNISDR, 2012), a holistic  
54 approach to disaster management (Zhan, 2006) and the universal characteristics of disaster prevention  
55 and preparation (Zhou, 2013).

56 In recent years, China has experienced several major disasters, including the Sichuan (Wenchuan)  
57 earthquake, the Yushu, Qinghai earthquake, and the Zhouqu debris flows in Gansu Province. Therefore,  
58 the concept of comprehensive disaster reduction capability has gained significant traction. It is  
59 generally recognized that comprehensive improvements in the disaster reduction capability will reduce  
60 or mitigate the casualties and property loss caused by disasters (Hu, 2013). Prior to the International  
61 Day for Disaster Reduction in 2006, the State Council of China convened the "Symposium on  
62 enhancing the comprehensive disaster reduction capability", which focused on comprehensively  
63 strengthening China's comprehensive disaster reduction capability. The concept of comprehensive  
64 disaster reduction involves four main aspects: first, preparing for and defending against various kinds  
65 of disasters; second, preparing to respond at different stages during the development of a disaster; third,  
66 integrating various resources; and fourth, applying various disaster reduction approaches (Lyu, 2011).  
67 Many studies have addressed the disaster reduction capability in China and other countries, and their  
68 results have been adopted by the governmental organizations and committee and applied in actual  
69 regional disaster management situations. These studies have mostly focused on single types of disasters  
70 ((Francesco D et al., 2017; Zhang, 2004), single aspects of disaster reduction (Boris F et al., 2016;  
71 Daniel Green et al., 2017), and the comprehensive regional disaster reduction capability (Ma, 2007).  
72 Relatively few studies have addressed disaster reduction at the community scale. Although some  
73 authors have constructed index systems for the ability of communities to prevent and mitigate disasters,  
74 they did not propose an in-depth or specific quantitative method (Smith et al., 2017; Yi, 2012).  
75 **The concrete measures contain the use of community-based early warning systems (Paul J. Smith et al.,**  
76 **2017), community infrastructure exposure risk analysis (S. Fuchs et al., 2015; R. Figueiredo et al., 2016;**  
77 **Saif Shabou et al., 2017), disaster risk reduction education (Avianto Amri et al., 2017) and**  
78 **community-level resilience to disaster (Adriana Keating et al., 2017; Estefania Aroca-Jimenez et al.,**  
79 **2017). However, there is little research on the quantitative evaluation method of CCDRC. In this paper,**  
80 **we aim to address the above situation** by proposing a quantitative method of evaluating CCDRC. We  
81 construct an index system for CCDRC. We quantitatively evaluate CCDRC using grey target modeling  
82 and overlay analysis of GIS, and use **the Suzhou New District (SND)** as a case study to demonstrate  
83 our calculations referring to the distribution status of NDCCDR. We analyze the spatial distribution of

84 CCDRC in the study area with the goal of providing decision support for efficient disaster response  
85 management by local government. The evaluation of CCDRC will help to defend against various kinds  
86 of disasters in the community as a whole, respond at different stages during the development of a  
87 disaster, integrate various resources, and coordinate various disaster reduction approaches. Through the  
88 evaluation of CCDRC, the overall level of CCDRC and the status of the main evaluation indexes can  
89 be grasps, so as to make it easy to take specific measures to effectively strengthen the weak links. The  
90 evaluation indices in this paper have the completeness, availability and quantifiable characteristics. The  
91 model has the advantages of simple construction, space transferability, simple operation, and multiple  
92 characteristics of evaluation results. Therefore, the method introduced in this paper is universal.

## 93 **2. Construction of an index system for evaluating the CCDRC**

### 94 **2.1 Defining the CCDRC**

95 Based on CBDRM ideas, as well as the general philosophy of regional disaster reduction  
96 capability in China, we define the CCDRC as follows: a community's ability to avoid or reduce natural  
97 disasters and accidents involving public health, traffic security, and major utilities by using engineering  
98 and non-engineering measures to integrate resources from the government, non-governmental  
99 organizations, community residents, and the general public. These measures are taken during the  
100 process of disaster prevention and preparation, emergency response, and post-disaster recovery, with  
101 the aim of protecting the life and property of residents and supporting their normal activities (especially  
102 vulnerable groups), as well as the normal operation of industrial activities in the community. When  
103 evaluating the CCDRC, several aspects are critical: (1) while the disaster reduction capability at the  
104 community scale is an integral component of disaster reduction capability at the regional scale, they  
105 should not be evaluated or measured in the same way; (2) in addition to community organizations, the  
106 government, community, residents, and other organizations all contribute to community disaster  
107 reduction; (3) community disaster reduction is defined by the ability to cope with various kinds of  
108 disasters (both natural and man-made), not any single disaster; and (4) it is important to  
109 comprehensively consider various factors, including the evaluation criteria in the NDCCDR, when  
110 constructing an objective and comprehensive index system for evaluating the CCDRC.

### 111 **2.2 Creating an index system for evaluating CCDRC**

112 The NDCCDR uses demonstration as a means to enhance a community's ability to reduce disaster  
113 risk. The document defines ten aspects of organizational management mechanism, disaster risk  
114 evaluation, infrastructure of disaster prevention and mitigation and so on as the basic elements for  
115 compliance with the disaster reduction demonstration community (Office of National Disaster  
116 Reduction Committee, 2010). The wide-abroad implemented CBDRM attach importance to software  
117 construction but despise hardware environment construction. Compared with these disadvantages, the  
118 NDCCDR not only strengthen the planning and construction of software such as community residents'  
119 awareness and skills for disaster reduction, disaster reduction publicity and training, but also has taken  
120 into account the construction of community disaster reduction hardware such as shelters and material  
121 reserves. However, the above indicators are not enough to fully reflect the CCDRC. Therefore, based  
122 on the meaning of CCDRC, we consider quantitative factors including a community's economic status,  
123 rescue and safeguarding resources, and engineering defenses, as well as qualitative factors including

124 disaster risk evaluation, organizational management, and public awareness of disaster prevention.  
 125 Taking account of the universality, availability and quantifiable characteristics of indicators, we  
 126 construct the evaluation index system of CCDRC. Our index system is made up of six primary indices  
 127 and a total of 31 secondary indices, which mainly includes two types of attribute (spatial attribute and  
 128 non spatial attribute), involve binary, numerical, and categorical data. The indices are listed in Table A1  
 129 of the Appendix A.

### 130 3. Evaluating the CCDRC

131 Our index system has the following characteristics: (1) it is hierarchical, but includes numerical,  
 132 binary, and categorical data; thus, these data cannot be processed in a standard way, and it is difficult to  
 133 determine their weights using traditional methods; (2) the index data do not have empirical values, and  
 134 the quantity of data is small, so quantitative evaluation is difficult; and (3) the same index differs  
 135 spatially, can evolve between communities and can be transformed to an index with consistent  
 136 polarization. Based on the aforementioned characteristics, we use **grey target modeling** to evaluate the  
 137 comprehensive disaster reduction capability of a single community. Next, we use GIS overlay analysis  
 138 to create a map showing the spatial distribution of the CCDRC throughout the region.

#### 139 3.1 Entropy weighted grey target model

140 For evaluating data that involves a small sample and sparse and uncertain information, we first set  
 141 a grey target and take the bull's eye of the grey target as the standard model. The model is divided into  
 142 different grades based on the degree to which the model to be evaluated is close to the target center  
 143 (that is, the target center degree). This method is the traditional grey target model (Deng, 2002). We can  
 144 then consider the degree to which the various evaluation indices influence the target center degree and  
 145 use the entropy weight method to determine the weight of the evaluation indices, which will yield more  
 146 objective and fair evaluation results. This methodology constitutes the improved grey target model, or  
 147 the entropy-weighted grey target model (Li et al., 2012; Li et al., 2013; Li et al., 2016). The target  
 148 center degree of various spatial units  $\Gamma(X_0(j), X_i(j))$  can be calculated by the following Eq.(1):

$$149 \Gamma(X_0(j), X_i(j)) = \sum_{j=1}^n w_j \frac{\min \Delta_{0i}(j) + 0.5 \max \Delta_{0i}(j)}{\Delta_{0i}(j) + 0.5 \max \Delta_{0i}(j)}, \quad (1)$$

150 The fraction on the right side of the equation is the target center coefficient of index  $j$  ( $j=1, 2, \dots, n$ )  
 151 with a spatial unit of  $i$ ;  $\Delta_{0i}(j)$  is the corresponding grey correlation difference; and  $w_j$  is the weight of  
 152 index  $j$ . Equation (2) shows the formula for calculating the **entropy weight**, as follows:

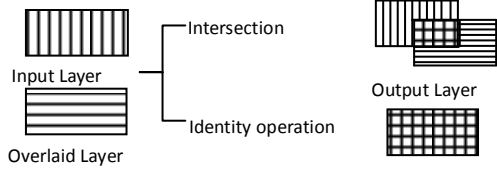
$$153 w_j = (1 - \bar{H}_j) / (n - \sum_{j=1}^n \bar{H}_j), \quad (2)$$

154 where  $\bar{H}_j$  is the conditional entropy of index  $j$  (Jin, 1994; Lian, 2004).

#### 155 3.2 GIS spatial overlay analysis

156 Spatial overlaying is an important spatial analysis method in GIS. The method overlays two or  
 157 more layers on the same scale in the same region to generate a new layer with multiple attributes. The  
 158 new layer synthesizes the attributes of the original layers; this new layer represents a new spatial  
 159 relationship as well as indicating the relationship between the attributes of the original layers based on  
 160 logical operations (Gong et al., 2001; Yang et al., 2016; He et al., 2015). Overlaying a polygon layer  
 161 includes both intersection and **identity** (Fig.1). Both the range and attribute of a spatial unit will change

162 after the intersection operation. This kind of overlay requires logical operations and also includes  
 163 complicated topological operations on spatial objects. After the **identity** operation, the range of the  
 164 spatial units will not change, but the attributes will, mainly because of the logical operations. When  
 165 there many layers are included in the operation, their weights must be considered. In this paper, to  
 166 determine a community's CCDRC, we take the community as the evaluation unit and the layers  
 167 corresponding to various evaluation indices as the objects of operation; we use the **entropy-weighted**  
 168 grey target model for the **identity** operation.



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170 **Figure 1. Schematic diagram of overlay operation.**

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### 172 3.3 Evaluation method and process

173 Setting the community as the unit, we sequentially constructed the impact space of the index  
 174 sequence  $\{U_j\}$  and the standard model  $\{x_0(U_j)\}$  based on grey target modeling from the six primary  
 175 evaluation indices. The standard value of various indices in the impacting space is related to the index  
 176 polarity. The maximum standard value of index polarity is the maximum of the corresponding index in  
 177 the impacting space, and the minimum polarity index is the corresponding minimum. The specific  
 178 procedures of measurement and calculation are described below.

179 (1) Grey target transformation and determination of the grey correlation difference information: to  
 180 avoid the effect of large values (caused by excessively large differences between data values in the  
 181 standard model sequence) on the relatively small values, we conducted grey target transformation on  
 182 the various index sequences. After grey target transformation, the value of the evaluation index  $U_j$  in  
 183 the  $i^{\text{th}}$  research unit,  $Tx_i(U_j)$ , was calculated using the following Eq.(3):

$$184 \quad Tx_i(U_j) = \min(x_i(U_j), x_0(U_j)) / \max(x_i(U_j), x_0(U_j)), \quad (3)$$

185 Next, we obtained the grey correlation difference for index  $U_j$  for unit  $i$  in equation (1),  $\Delta_{0i}(j)$ , as  
 186 follows:

$$187 \quad \Delta_{0i}(j) = |1 - Tx_i(U_j)|, \quad (4)$$

188 (2) Calculation of conditional entropy  $\bar{H}_j$  for index  $U_j$ : the relative distance between the index  
 189  $U_j$  in unit  $i$  and the standard value  $x_0(U_j)$  can be expressed with the closeness degree  $d_{ij}$ , as follows:

$$190 \quad d_{ij} = 1 - \left[ \max(x_i(U_j), x_0(U_j)) - \min(x_i(U_j), x_0(U_j)) \right] / \delta X_j, \quad (5)$$

191 where  $\delta X_j$  is the difference between the maximum and minimum of index  $j$  for all the spatial units of  
 192 the study area. The normalized value of the uncertainty measurement (that is, the conditional entropy)  
 193 for the relative significance of this index can be expressed as follows:

$$194 \quad \bar{H}_j = \frac{1}{\ln m} \sum_{i=1}^m (d_{ij}/d_j) \ln(d_{ij}/d_j), \quad (6)$$

195 where  $d_j = \sum_{i=1}^m d_{ij}$ . If  $d_{ij}=0$ , we prescribed  $(d_{ij}/d_j) \ln(d_{ij}/d_j) = 0$ .

196 (3) Calculation of the target center degree and grades for the various spatial units: first, we

197 calculated the **entropy weight**  $w_j$  of the various indices  $j$  using Eq.(2). Next, using Eq.(1), we calculated  
198 the target center degree of the corresponding primary index of the different spatial units and the target  
199 center degree of the corresponding CCDRC.

200 (4) Production of the CCDRC spatial distribution map: we import the above calculation results  
201 into ArcGIS10.2, and the target layer of each level index of the study area will be set up. Then we carry  
202 out the GIS overlay calculation according to the calculation method of the total target center degree,  
203 and the CCDRC spatial distribution map of the study area can be obtained.

204 Using the CCDRC primary indices spatial distribution map and CCDRC spatial distribution map  
205 generated in the case study area based on the above model, we can seek the following target: (1) the  
206 overall level of CCDRC in case area, (2) the spatial distribution of CCDRC in the region, (3) the  
207 potential analysis and improvement measures of CCDRC, (4) the CCDRC level of NDCCDR.

208 We can obtain the spatial attribute data of the index system from a regional geographic database.  
209 The non spatial attribute data can be obtained by means of community disaster monitoring logs, reports  
210 and other historical archives, resident visits and field surveys with the help of local civil affairs  
211 department. Therefore, the process of CCDRC calculation and analysis based on entropy weight - grey  
212 target model and GIS overlay method in this paper, is generally applicable to most of the provinces in  
213 mainland China. If the model is used to evaluate the foreign CCDRC, the benefits will offer to  
214 communities that are vulnerable to various kinds of disasters, as well as some challenges, such as  
215 different national conditions, unbalanced economic development among countries, great differences in  
216 the system of disaster prevention and reduction, and great differences in the organization level of the  
217 project. To address these challenges, features that make this approach worth considering in the context  
218 of other countries or regions include,

219 - Besides from the open network GIS platform such as Google earth, many open databases for  
220 disaster prevention and mitigation have been put into use within many countries, and the spatial  
221 information needed for the evaluation of CCDRC can be online obtained. It is convenient to obtain  
222 community attribute information through residents' visit, field investigation and non-governmental  
223 organization's disaster prevention and reduction report under the model of CBDRM.

224 - The model used in this paper has comparability between spatial units, and has transferability  
225 between regions; using entropy method to determine index weights can avoid the arbitrariness and  
226 unilateralism of subjective weight determination.

227 - This method is not focused on the index itself, and does not need to establish a function  
228 relationship between the indexes, but rather to model the order relation represented by the index  
229 value, so it is very easy to operate, and the results of evaluation are diversified.

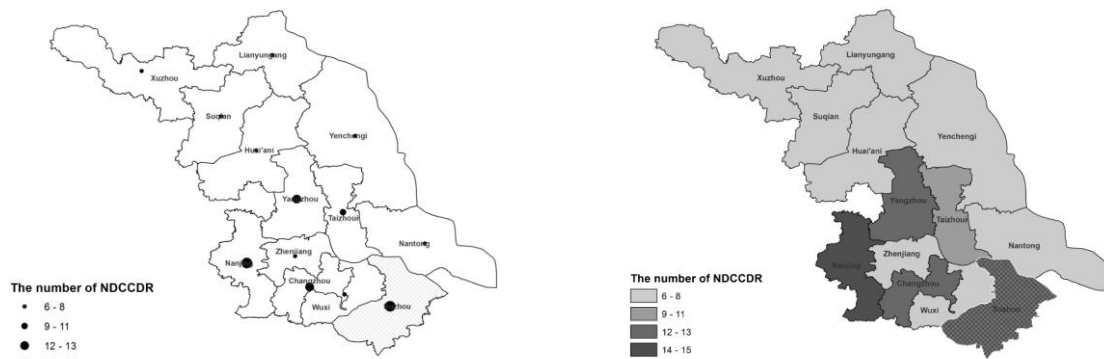
230 On the whole, it is world widely feasible to apply the methods introduced in this paper to evaluate  
231 the CCDRC.

## 232 4. Example calculations

### 233 4.1 The distribution status of NDCCDR

234 Since the selection of NDCCDR was organized in 2008, nearly three thousand community have  
235 been selected (or once been selected) in succession. Figure 2 (a) is the nationwide distribution map of  
236 NDCCDR in 2017. The map shows that the selected communities are mainly distributed in the  
237 relatively developed capital region (Beijing, Tianjin and Hebei, 117), the Yangtze River Delta (Jiangsu,

238 Zhejiang, Shanghai, 241), the Pearl River Delta (Guangdong, 126) and Shandong Province (92),  
 239 accounting for 38.9% of the total number. Figure 2 (b) shows that there are respectively 15  
 240 communities in Nanjing and Suzhou cities, which are cities with the largest number of NDCCDR in  
 241 Jiangsu province (115). The distribution status shows that the NDCCDR construction of Suzhou is in  
 242 the forefront of China; nevertheless, the construction of NDCCDR is a demonstration project of  
 243 comprehensive disaster reduction work in China, and it is also a component part of strengthening the  
 244 comprehensive disaster reduction ability across our country. Taking SND as an example, with 8  
 245 communities currently selected as the NDCCDR, the NDCCDR construction work is obviously among  
 246 the highest in China. However, the region has jurisdiction over 82 communities, and the number of  
 247 NDCCDR accounts for only 10% of the total community. In addition, the evaluating index system of  
 248 NDCCDR is imperfect compared with that of CCDRC, and the NDCCDR is not necessarily consistent  
 249 with the CCDRC. According to above two aspects, we select SND as the research area to calculate and  
 250 analyze the CCDRC. The characteristics and distribution of the regional CCDRC can partially reflect  
 251 the current situation and construction direction of CCDRC in China.



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 263 (a) Distribution of NDCCDR in China (b) Distribution of NDCCDR in Jiangsu Province

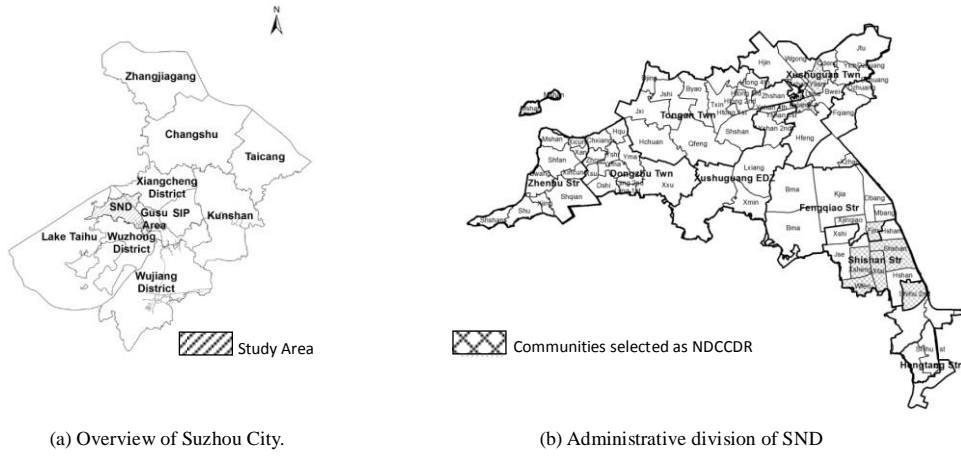
264 **Figure 2. Distribution status of the NDCCDR in China.**

265 **4.2 Overview of the study area and data sources**

266 The city of Suzhou is located in the southeastern part of Jiangsu Province in China's Yangtze  
 267 Delta. It is a major part of the Yangtze River economic zone in Jiangsu. The area has a subtropical  
 268 monsoon oceanic climate, with four seasons and abundant rainfall. In recent years, although large  
 269 natural disasters have not occurred, various climate disasters have affected the day to day life of  
 270 residents. Figure 3(a) shows a map of Suzhou. The study area is the SND, which is located west of the  
 271 main urban area of Suzhou and shown as hashed parts in Fig. 3(a); it includes one major zone of  
 272 economic development, three town level administrative districts, and four street administrative areas,  
 273 totaling 83 communities. Figure 3(b) shows the administrative map. Since the 1990s, the SND has  
 274 suffered from hailstorms, typhoons, freezing, and floods, which together have caused significant  
 275 economic losses. In recent years, rapid economic development in Suzhou has resulted in a population  
 276 boom and increased the frequency of man-made disasters. Thus, the local government has begun to  
 277 focus more attention on enhancing the CCDRC in the area. Thus, eight communities, including Ylian,  
 278 Hxiang, and Shshan, have been designated as NDCCDR (see shaded areas in Fig.3 (b)). These  
 279 communities are mainly located in Xushuguan Town in the northeastern part of the study area and  
 280 along Shishan Street in the southeastern study area. Thus, these communities have relatively strong

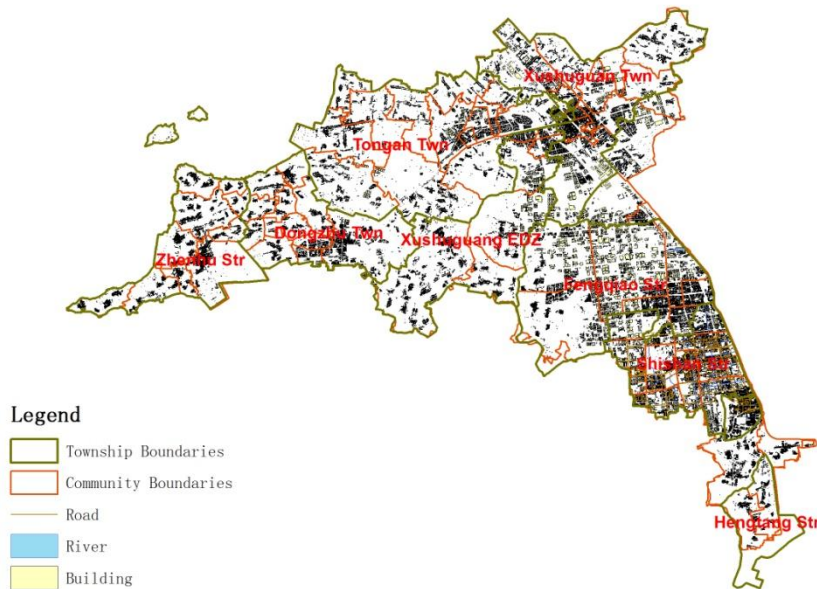
281 organizations for responding to disasters and management capabilities, and they have focused on  
 282 improving their ability to address disasters. However, CCDRC should also consider other aspects such  
 283 as the community's rescue and support capability and engineering defenses. The model we present in  
 284 this paper addresses the measurement and analysis of these aspects so that they can be strengthened.

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297 **Figure 3. Overview of research area and administrative district.**

298 In this research, the employed data used for empirical calculation and analysis are provided by  
 299 Ministry of Civil Affairs of Suzhou and were collected in 2015. The spatial size of SND is 22.65 km<sup>2</sup>  
 300 and the average size of a community is 0.33 km<sup>2</sup>. There are totally five vector layers: administrative  
 301 boundaries for towns and communities, and roads, water system, and building footprints (Fig. 4). The  
 302 data were updated and examined before use. Table A1 of the Appendix A shows the indices of the open  
 303 space area ratio, the fortified area ratio of buildings, and the community road density, which were  
 304 obtained using the statistical computation function of ArcGIS 10.2 software.



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306 **Figure 4. Image layer of spatial data in the study area.**



308 **4.3 Calculation of CCDRC in the region**

309 We surveyed and conducted statistical analyses on all 83 communities in the study area; we  
 310 obtained effective sample data for 72 communities, which we used as the basic data. According to the  
 311 grey target theory, we built the community-based influence space of the index sequence from six  
 312 aspects, namely, disaster risk evaluation capability, rescue and support capability. In the light of  
 313 formula (1) - (6), we calculated the entropy weight, constructed the grey correlation difference  
 314 information, and then obtained the target center degree. During the calculation, we need to pay  
 315 attention to the index polarity. Except for number of group event disasters, number of fire disasters and  
 316 the disaster risk intensity, all other secondary indices are maximum polarity indices.

317 We calculate the rescue and support capability for eight communities on Shishan Street as an  
 318 example. Following the procedures above, we sequentially conducted grey target transformation,  
 319 spatially determined the grey correlation difference information and conditional entropy, and calculated  
 320 the entropy weight of each evaluation index (the calculated entropy weights for all the primary and  
 321 secondary indices are shown in Table A1 of the Appendix A). Finally, we obtained the target center  
 322 degree of the various primary evaluation indices. The results are shown in Table 1.

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**Table 1.** Target center coefficients, entropy weights, and primary target center degrees for the rescue and support capability of communities on Shishan Street.

Name of community	Hshan	Jse	Shshan	Wfeng	Xsheng	Xtai	Hshan	Xshi	Entropy weight
Compilation of comprehensive asylum map	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	<b>0.045</b>
Disaster reduction capital investment (10,000 RMB/year)	0.34	0.35	0.50	0.38	0.36	0.80	0.33	0.34	<b>0.065</b>
Number of emergency rescue teams	0.52	0.45	0.57	0.52	0.42	0.42	0.35	0.48	<b>0.023</b>
Disaster information personnel (persons)	0.34	0.34	0.34	0.34	0.34	0.35	0.34	0.34	<b>0.059</b>
Reserve of rescue materials (10,000 RMB)	0.34	0.35	0.37	0.36	0.34	0.36	0.35	0.37	<b>0.036</b>
Per capita medical resources (/10,000 persons)	0.33	0.33	0.33	1.00	1.00	0.35	0.33	0.34	<b>0.061</b>
Target center degree	<b>0.454</b>	<b>0.451</b>	<b>0.495</b>	<b>0.602</b>	<b>0.588</b>	<b>0.554</b>	<b>0.440</b>	<b>0.454</b>	

326 Note: the entropy weight corresponding to the various evaluation indices is the normalized weight determined with the 72 spatial units  
 327 (communities) in the research area used as the reference.

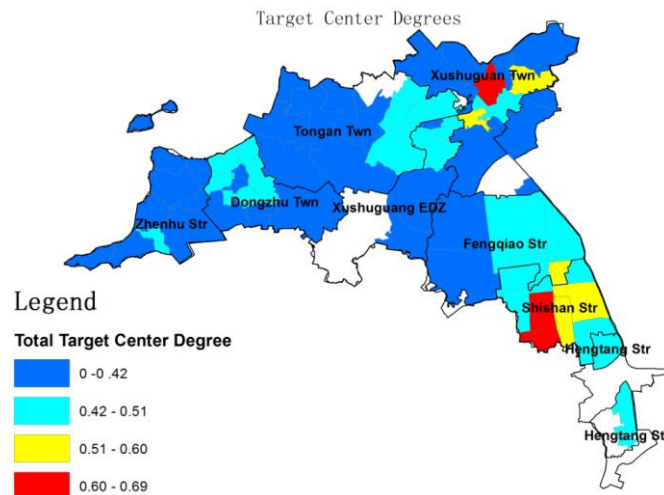
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329 The target center degree indicates the strength of the rescue and support capability. Table 1 shows  
 330 that, of the eight Shishan Street communities, the rescue and support capability is strongest in the four  
 331 NDCCDR, Wanfeng, Xinsheng, Xintai, and Shishan (Fig.3 (b)); it is relatively weak in the other  
 332 communities.

333 **4.4 Grading the CCDRC**

334 After inputting the data from Table 1 into ArcGIS 10.2, we conducted the GIS overlay operation  
 335 using the entropy-weighted gray target model described above, resulting in a map of the distribution of  
 336 the rescue and support capability in the Shishan Street communities. We repeated this operation for all  
 337 the communities in the study area and then graded their capabilities based on the target center degree.

338 We used anomalies to create four capability grades, excellent, good, moderate, and poor. Next, we  
 339 created a map of the distribution of the rescue and support capability grades for the communities in the  
 340 study area. We repeated the same operation for the disaster risk evaluation, engineering defense, social  
 341 and economic base support, disaster management and public cognitive capabilities of all the  
 342 communities, yielding the individual grade distribution maps for each capability. Finally, based on the  
 343 entropy weight of the primary evaluation indices (Table A1 of the Appendix), we used GIS overlay  
 344 analysis to determine the total target center degree of the CCDRC for all the communities in the study  
 345 area. Once divided into grades, based on the minimum information principle, the target center degree  
 346 should not be smaller than  $1/(1+\zeta)$  (where  $\zeta$  is the resolution coefficient, and its value in Eq. (1) is 0.5).  
 347 Therefore, the minimum of the total target center degree should be 0.3333. The results show that the  
 348 maximum total target center degree was 0.6941 for the Wanfeng community of Shishan Street.  
 349 Therefore, we created four grades in the interval [0.3333, 0.6941] and used these grades to create a map  
 350 of the spatial distribution of grades of CCDRC (Fig.5). The blank regions in the figure show  
 351 communities where we could not obtain qualified sample data.

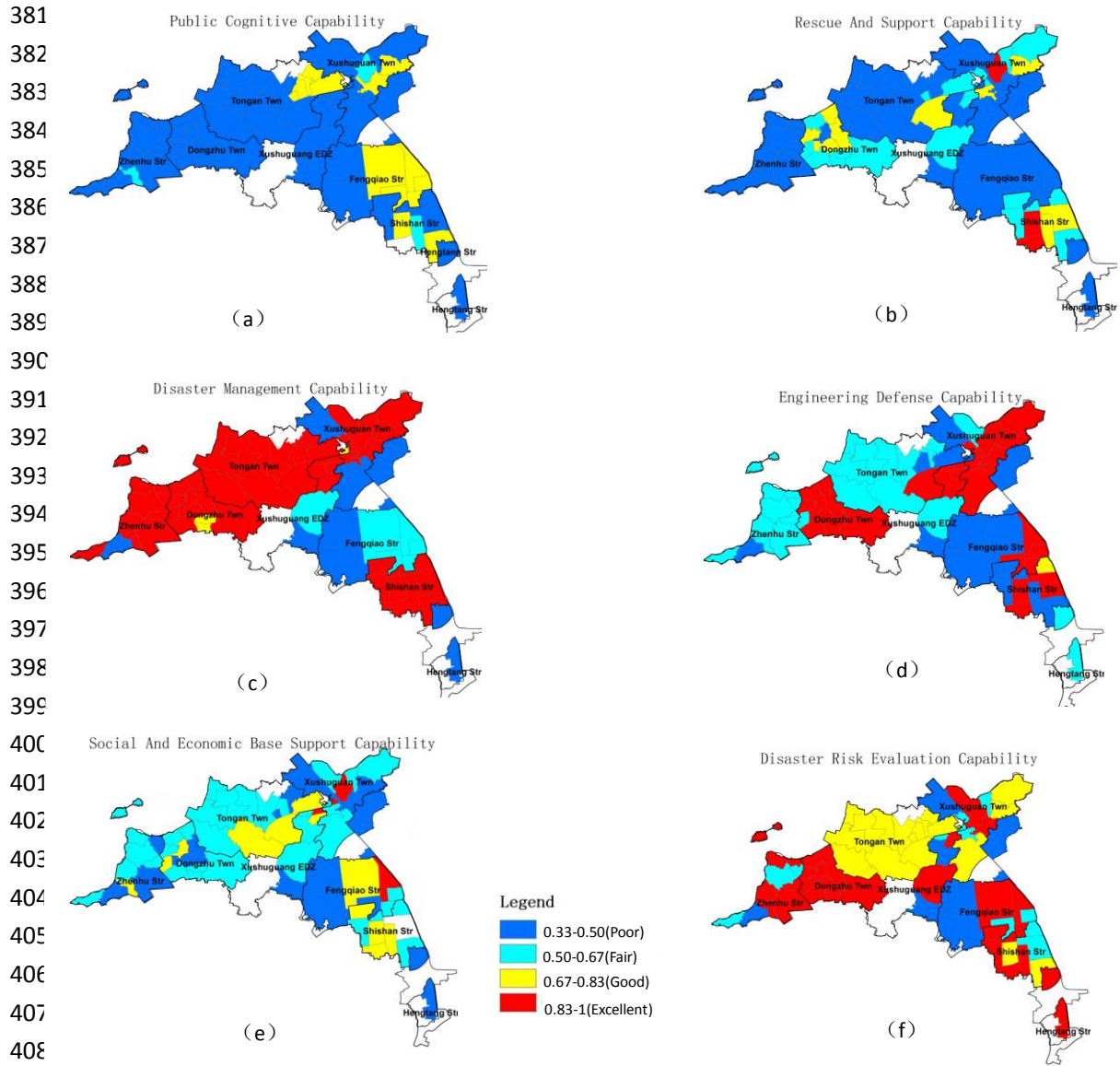


364 **Figure 5.** Spatial grade distribution map of CCDRC.

#### 365 4.5 Result analysis and suggestion

366 Comparing the spatial distribution of the grades of CCDRC in Fig.5 to the administrative  
 367 divisions shown in Fig. 3 (b), we observe the following characteristics:

368 (1) The CCDRC in the study area is generally weak. Communities with a poor CCDRC account  
 369 for 63.1% of the study area, and communities with a moderate grade account for 28.6%; communities  
 370 with an excellent grade only account for 8.3%. The distribution of these grades is not accidental but is  
 371 derived from the spatial distribution of the primary evaluation indices. For convenience of comparison,  
 372 we set the interval of the target center degree for all the primary evaluation indices to [0.3333, 1]. We  
 373 then divided the grades based on anomaly values to obtain the spatial grade distribution maps for the  
 374 primary indices (Fig.6). The figure is descending ordered from the upper left to the lower right based  
 375 on the entropy weight of the primary evaluation indices. It can be seen that the public cognitive  
 376 capability (Fig. 6 (a)) and the rescue and support capability (Fig.6 (b)), despite their maximum weight  
 377 values(0.381 and 0.288,respectively, visible from Table A1 of the Appendix ), show a general poor  
 378 feature, which is the main reason for the generally weak CCDRC in the study area.



**Figure 6. Spatial grade distribution map of various primary evaluation indexes in the community**

(2) The spatial distribution of the CCDRC is uneven. The eastern communities have relatively greater CCDRC than the western communities adjacent to Lake Taihu. Communities in the southeastern part of the research area generally have the strongest capabilities, and the CCDRC on Shishan Street are the strongest. The communities of Xsheng and Wfeng have the best capabilities; the community of Ylian, located in Xushuguan Town (in the northern part of the study area) has a grade of excellent, and Hxiang and Yxin have grades of good. In contrast, the CCDRC is poor for most communities on Zhenhu Street and in the towns of Dongzhu and Tongan, in the western research area adjacent Lake Taihu. As mentioned in Sect. 4.2, all eight communities of NDCCDR in the research area are located in Xushuguan Town and Shishan Street, and these communities selected as the 10 aspects of organization management and disaster risk evaluation. Figures 6 (c) and (f) show that most of them have excellent grades for disaster management capability and disaster risk evaluation; on the other hand, their engineering defense capabilities (Fig.6 (d)) and social and economic base capabilities (Fig.6 (e)) are also in the overall advantage. Other communities, including Zhenhu Street (in the western

425 study area) and the town of Tongan (in the central part of the study area) have an excellent disaster  
 426 management capability, but their other primary evaluation indices are weaker. The uneven spatial  
 427 distribution of the disaster reduction capability is also related to the location. Shishan Street is  
 428 comprised of new urban villages constructed at the end of the twentieth century; it is bordered to the  
 429 east by the urban area of Suzhou (in the Gusu District), which has well-developed community facilities  
 430 and a high population. The Hxiang and Ylian communities are located in the central part of the town of  
 431 Xushuguan, which has a similar setting as Shishan Street. The towns of Tongan, Dongzhu, and Zhenhu,  
 432 in the western study area, are located on the edge of the Suzhou urban area. Most structures are houses  
 433 built by individual farmers or as part of settlement communities; living expenses are relatively low, and  
 434 there is a large transient population. The CCDRC in these communities is thus relatively weak.

435 (3) There is great potential to improve the CCDRC. The area ratio for the different grades of the  
 436 primary evaluation indices and CCDRC in the study area can be obtained from Fig. 5 and Fig. 6 (see  
 437 Table 2).

438

439 Table 2. Area ratio for the different grades of the primary evaluation indices and CCDRC in the study area  
 440 (unit: %).

Grade	Public cognition	Rescue and support capability	Disaster management capability	Engineering defense capability	Economic base support	Disaster risk evaluation	CCDRC
Excellent	1.2	3.1	63.0	33.8	4.7	39.3	3.1
Good	13.2	10.2	0.9	0.7	19.1	32.5	5.2
Moderate	3.2	21.5	12.3	35.5	46.0	8.9	28.6
Poor	82.4	65.2	23.9	30.0	30.1	19.3	63.1

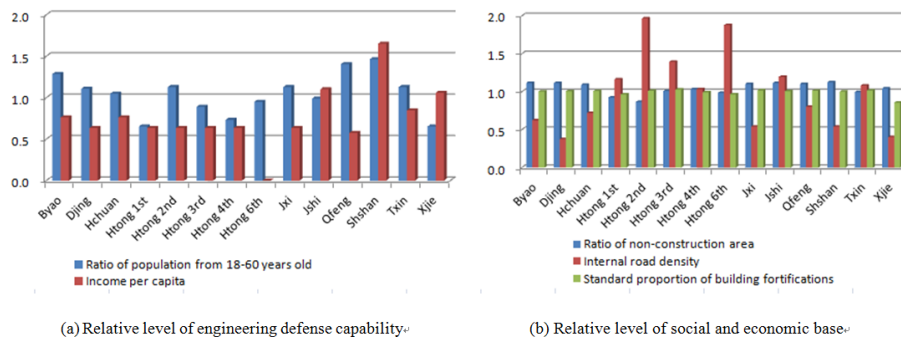
441 Note: the primary evaluation indices in the table are shown in descending order from left to right based on their entropy weights.

442 The results show that communities with moderate or higher CCDRC account for 36.9% of the  
 443 study area; with the exception of the public cognitive capability and the rescue and support capability  
 444 (with the largest weights), communities with a grade of moderate or higher for other indices account  
 445 for over 76.1% of the study area, and communities with an excellent disaster management capability  
 446 (with the third highest entropy weight) account for 63%. To further analyze the potential for  
 447 improvements in the CCDRC, we use Tongan, which has a moderate CCDRC, as an example. Most  
 448 secondary evaluation indices of its engineering defense and community social and economic base  
 449 support capabilities are close to or better than the average level of the study area (as shown in Fig. 7,  
 450 where the vertical axis is the ratio between an evaluation index and the index's average value in the  
 451 study area). The analysis above indicates that there is a relatively large potential for improving the  
 452 CCDRC in the research area.

453 Above analyses suggest that we should focus on the following several aspects to enhance the  
 454 CCDRC in the study area:

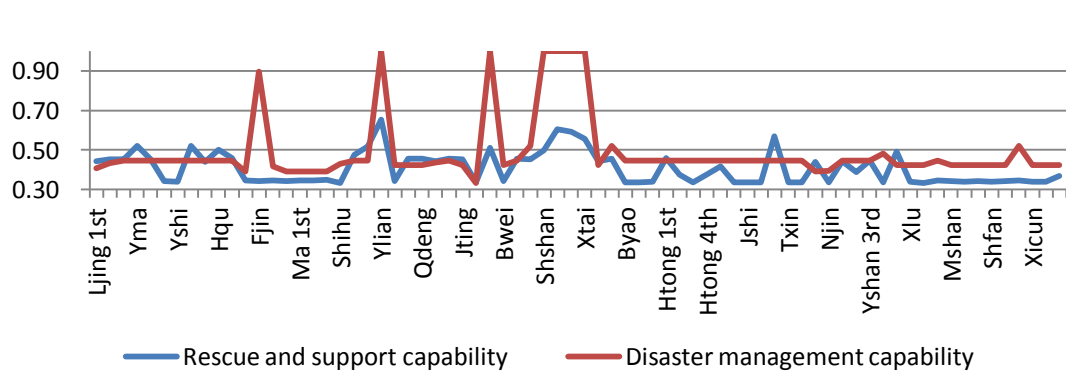
455 (1) Several measures should be taken to improve the cognitive level in the communities. Because  
 456 its weight is largest, the public cognitive capability significantly affects the CCDRC. Figure 6(a) and  
 457 Table 2 both demonstrate that the public cognitive capability in the research area is insufficient,  
 458 communities with a poor grade account for 82.4% of the study area. In modern communities with  
 459 highly developed means of communication, many measures can be used to improve the public  
 460 cognitive capability. For example, some measures include creating official ways to disseminate disaster  
 461 reduction information, developing publicity material, setting up disaster early-warning display screens,  
 462 and increasing the amount of publicity material to increase residents' knowledge of disaster prevention  
 463 and reduction. Better publicizing disaster reduction activities will help residents understand the dangers  
 464 of disasters and instill a common sense of proper emergency behavior. Enhancing residents'

465 consciousness regarding disaster prevention and reduction will also help attract volunteers to join  
 466 disaster prevention and reduction teams and eventually strengthen the overall cognitive capability of  
 467 the public in the study area.



468 (a) Relative level of engineering defense capability (b) Relative level of social and economic base  
 469 **Figure 7. Relative level of engineering defense and social economic base support capability in Tongan Town.**

470 (2) It is also important to collectively manage and reinforce the effectiveness of disaster relief  
 471 measures and safeguards. Because the disaster management capability of communities in the study area  
 472 is relatively good (Fig.6(c)), we compare it to the target center degree of the community rescue and  
 473 support capability to yield a plot of the target center degree for the community rescue and support  
 474 capability (Fig. 8). This index is close to the minimum of the target center degree (0.333), in contrast to  
 475 the disaster management capability. We conclude that it is important to reinforce the disaster rescue and  
 476 support capability, including strengthening coordination between the relevant governmental  
 477 departments, investing in multiple aspects of disaster reduction and allocation of per capita medical  
 478 resources, appointing disaster information personnel, and setting aside more rescue and emergency  
 479 material. These measures will fundamentally strengthen the disaster rescue and support capability in  
 480 the study area.



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 489 **Figure 8. Curve for the target center degree of rescue and support capability**

492 (3) Similarly, the engineering disaster defense capability should also be strengthened. As shown in  
 493 Figure 6(d) and Table 2, the engineering defense capability in the study area is a bimodal distribution.  
 494 Communities with an excellent grade (including Dongzhu, Shishan Street, and some of Xushuguan)  
 495 account for 33.8% of the study area, while communities with a moderate or poor grade account for 35.5%  
 496 and 30%, respectively. We conclude that internal resources in the study area should be allocated in a  
 497 better manner; the engineering defense capability of the communities graded excellent can be leveraged  
 498 in planning, construction, maintenance and management. These strategies will reinforce the  
 499 engineering defense capabilities of communities throughout the study area.

## 500 5. Conclusions

501 Community disaster prevention and reduction is a basic component of urban disaster prevention  
502 and reduction and plays an important role in the urban security system. In this paper, we constructed an  
503 index system to evaluate the CCDRC; the system includes six primary and 31 secondary indices. We  
504 used entropy-weighted gray target modeling to determine the CCDRC, and GIS spatial overlay analysis  
505 to map the spatial distribution of disaster reduction capability grades. We focused on the SND as a case  
506 study and obtained the following conclusions:

507 (1) The area's CCDRC is relatively low; communities with a poor grade account for 63.1% of the  
508 study area, and those with an excellent grade account for only 8.3%. Additionally, the spatial  
509 distribution of CCDRC is uneven. The eastern communities have relatively good capability, while the  
510 western communities adjacent to Lake Taihu have poorer capability. The Shishan Street community,  
511 located in the southeastern part of the study region, has the strongest CCDRC. However, the CCDRC  
512 in the region has a good foundation and it also has large potential for improvement. After analyzing  
513 these results, we propose that CCDRC can be most improved by enhancing their level of public  
514 cognitive ability, rescue and support capacity, and engineering defenses.

515 (2) In general, the CCDRC of the NDCCDR is at the forefront in the study area, but the CCDRC  
516 among the NDCCDR is not balanced. As shown in Fig.5, among the NDCCDR, the CCDRC of Ylian  
517 is rated "excellent", but Hxiang or Yxin is "good". The CCDRC primary indices of the NDCCDR are  
518 also quite different from each other. As we can see in Fig.6, the public cognitive capability and the  
519 rescue and support capability of the NDCCDR show a general poor feature, but their engineering  
520 defense capabilities and disaster management capability are in the overall advantage. Above  
521 discussions fully indicate that the CCDRC of NDCCDR is not necessarily good. On the contrary, the  
522 evaluation and construction of CCDRC is not only the focus of community disaster prevention and  
523 reduction work, but also the standard for the continuous improvement, construction and promotion of  
524 the NDCCDR. Based on above analysis, we can combine the NDCCDR construction with the CCDRC  
525 construction, from point to face, and ultimately improve the overall level of CCDRC in the region.

526 This paper takes the municipal area as the case study area, analyzes and compares the CCDRC  
527 and its primary indices between communities in the jurisdiction area. All the pertinent suggestions are  
528 beneficial to the regional functional departments to carry out disaster prevention and mitigation  
529 planning, resource allocation, resident mobilization and administrative decisions within the jurisdiction,  
530 so as not to complicate the implementation of the CCDRC construction due to coordination across  
531 jurisdictions. Suzhou is regarded as a strong economic city in China. Great efforts have been made to  
532 prevent and reduce disaster (It is evident from the number of CCDRC.). However, from the analysis  
533 results of this paper, the CCDRC of Suzhou is still not satisfactory. It also shows that our CCDRC  
534 building has a long way to go. The overall strengthening of China's CCDRC will continue for a long  
535 time.

536 Due to the large number of indices in this paper, there must be redundancy between data, so  
537 information reduction should be carried out before evaluation. From the perspective of overall plan of  
538 national comprehensive disaster reduction work, we should prepare to respond at different stages  
539 during the development of a disaster. Therefore, the resilience capability to disaster should also be  
540 included in the index system. These two aspects are the deficiencies of this paper and need to be  
541 solved in future research.

542 Appendix A:

Table A1. Evaluation Index system and the entropy weights of the CCDRC.

Primary indicator (entropy weight)	Meaning of index	Secondary index	Entropy weight	Meaning of index	Data type
Disaster risk evaluation capability (0.005)	Qualitative and quantitative assessment capability by means of hazard identification (including natural and man-made hazards), hazard tracing and frequency recording	Number of group event disasters (times/year)	0.001	Number of disasters with casualties or property loss caused by grouped events.	Categorical
		Number of fire disasters (times/year)	0.001	Number of disasters caused by the fire (intentionally or unintentionally set).	
		Disaster risk	0.003	Based on safety and an investigation of vulnerable groups, from 1-4 (weak to strong).	
Rescue and support capability (0.288)	It refers to the ability to deal with emergencies after disasters and to provide materials, equipment and manpower for emergency relief, which is affected by the preparation of plans, communication facilities, material reserves, financial support and rescue teams.	Compilation of comprehensive asylum map	0.045	Whether the comprehensive asylum map of community is compiled; 1 means "yes", and 0 means "no".	Binary
		Disaster reduction capital investment (10,000 RMB/year)	0.065	Capital investment specified by the community for disaster prevention and reduction.	
		Number of emergency rescue teams (teams)	0.023	Number of emergency rescue teams organized by government, community, and other social organizations.	
		Disaster information personnel (persons)	0.059	Staff appointed by the community that is responsible for publicizing disaster information.	
		Reserve of rescue materials (10,000 RMB)	0.036	Converted value of goods and materials allocated or reserved by the community for disaster-related response.	
		Per capita medical resources (/10,000 persons)	0.061	(Number of medical personnel × Number of beds)/total pop	
Engineering defense capability (0.148)	It refers to the ability of disaster prevention and mitigation formed by various engineering measures, which is determined by the number, scale and standard grade of disaster prevention projects built to prevent and mitigate disaster occurrence in the region.	Ratio of open space (%)	0.006	The higher the open space (such as green areas) ratio in the community, the stronger the buffering capability of disasters and the settlement capability of post-disaster personnel.	
		Internal road density (km/km <sup>2</sup> )	0.013	The road length inside the unit area of the community; the higher the density, the more efficient the disaster prevention and emergency response.	
		Standard proportion of building fortifications (%)	0.001	The ratio between the planned residential area and the total area of community buildings; the higher the standard fortification ratio, the stronger the residential defense capability.	
		Total length of drainage pipeline (km)	0.030	Total length of drainage lines (such as rainwater and sewage) and other drainage lines in the community.	
		Completion rate of fire protection facilities (%)	0.099	Degree of integrity of facilities used for water collection, firefighting and related purposes.	
		Area of underground civil defense facilities (m <sup>2</sup> )	0.009	Total construction area of underground residential facilities such as underground car park garages.	
		Ratio of population from 18-60 years old (%)	0.009	Ratio of population aged 18-60 to the total registered household registration population in the community (village).	
Social and economic base support capability (0.012)	The ability to provide human, financial, resource and environmental support for disaster prevention and mitigation is mainly affected by the level of socio-economic development, the amount of disposable financial revenue and the level of infrastructure development in a region.	Income per capita (10,000 RMB)	0.003	Income per capita of the community.	
Disaster management capability (0.159)	It refers to the ability to organize and coordinate various forces reasonably and effectively in order to effectively achieve disaster prevention and mitigation, to formulate reasonable policies, systems and mechanisms, and to flexibly use various methods. It is mainly influenced by such factors as the perfection of the legal system, the ability of social mobilization, the ability of scientific and technological support.	Daily management system	0.001	Whether a performance appraisal system of comprehensive disaster reduction has been established, including institutional measures for the daily management of related personnel and maintenance and management of disaster prevention and reduction facilities.	Binary
		Periodic inspection system	0.003	Whether hidden dangers are regularly monitored and emergency plans and response for vulnerable populations are reviewed.	
		Periodic examination system	0.004	Whether comprehensive disaster reduction plans are regularly reviewed, and specific improvement measures are formulated to address the insufficiencies.	
		Social mobilization mechanism	0.007	Whether a social mobilization mechanism is established.	

		Comprehensive disaster reduction archive	0.114	Whether a comprehensive disaster reduction archive is established, with archival information such as text and photos that is standard, complete, and easy to consult.	
		Comprehensive disaster reduction demonstration community	0.023	Whether or not the community is a national comprehensive disaster reduction demonstration community.	
		Quality of demonstration community archive	0.004	Archive quality for the demonstration community's process of comprehensive disaster reduction (completeness and degree of conformity); 0 indicates "poor", 1 indicates "relatively good", and 2 indicates "good".	Discrete
Public cognitive capability (0.381)	It refers to the means of raising the public's awareness of disaster prevention and mitigation through traditional propaganda methods such as holding propaganda activities for disaster prevention and mitigation, issuing propaganda materials and first aid drills, installing disaster early warning display screens, setting up publicity signals for disaster reduction and other modern communication technologies, and the proportion of volunteers participating in disaster prevention and mitigation can also be reflected. Public ability in this area.	Proportion of volunteers (%)	0.036	Proportion of volunteers to the total population of the community.	
		Frequency of disaster reduction publicity activity (times/year)	0.130	Number of publicizing activities carried out every year for disaster prevention and reduction and the number of participants.	
		Number of promotional columns	0.032	Number of columns publicizing disaster prevention and reduction.	
		Number of promotional materials developed (copies)	0.061	Number of publicity materials that have been developed (such as popular science books for disaster prevention and reduction).	
		Disaster early-warning display screen	0.035	Whether the community (village) has a display terminal for disaster early warning (display screen).	Binary
		Publicizing official account of disaster reduction	0.067	Whether there is a WeChat official account for publicizing disaster prevention and reduction (1 indicates "established" and 2 indicates "not established").	Binary
		Frequency of emergency practice (times/year)	0.020	Number of emergency practice activities organized every year.	

544 Note: The indices without a data type annotation are numerical.

545

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550 The data used to create the evaluation indices include (1) spatial data from Suzhou's database,  
551 which were used to calculate indices with ArcGIS software; and (2) attribute data from the Department  
552 of Civil Affairs of Suzhou and statistical analysis by the Civil Affairs Bureau of SND (these data were  
553 obtained from summaries for the various streets).

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