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. In this paper, in view of the imperfect evaluation criteria in the "National demonstration community of comprehensive disaster reduction (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 weak. 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, human 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 effectiveness of disaster management, and it has become an active focus of research on disaster prevention and reduction in recent years. As the basic component of urban public disaster prevention and reduction strategies, communities play an important role in urban safety systems. More attention

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

53   In recent years, China has experienced several major disasters, including the Sichuan (Wenchuan)
54 earthquake, the Yushu, Qinghai earthquake, and the Zhouqu debris flows in Gansu Province. Therefore,
55 the concept of comprehensive disaster reduction capability has gained significant traction. It is
56 generally recognized that comprehensive improvements in the disaster reduction capability will reduce
57 or mitigate the causalities and property loss caused by disasters (Hu, 2013). Prior to the International
58 Day for Disaster Reduction in 2006, the State Council of China convened the "Symposium on
59 enhancing the comprehensive disaster reduction capability", which focused on comprehensively
60 strengthening China's comprehensive disaster reduction capability. The concept of comprehensive
61 disaster reduction involves four main aspects: first, preparing for and defending against various kinds
62 of disasters; second, preparing to respond at different stages during the development of a disaster; third,
63 integrating various resources; and fourth, applying various disaster reduction approaches (Lyu, 2011).
64 Many studies have addressed the disaster reduction capability in China and other countries, and their
65 results have been adopted by the governmental organizations and committee and applied in actual
66 regional disaster management situations. These studies have mostly focused on single types of disasters
67 (Francesco Dottori et al., 2017; Zhang, 2004), single aspects of disaster reduction (Boris F et al., 2016;
68 Daniel Green et al., 2017), and the comprehensive regional disaster reduction capability (Ma, 2007).
69 Relatively few studies have addressed disaster reduction at the community scale. Although some
70 authors have constructed index systems for the ability of communities to prevent and mitigate disasters,
71 they did not propose an in-depth or specific quantitative method (Smith et al., 2017; Yi, 2012). In this
72 paper, we aim to fill this gap in knowledge by proposing a quantitative method of evaluating CCDRC.
73 We construct an index system for CCDRC. We quantitatively evaluate CCDRC using grey target
74 modeling and overlay analysis of GIS，and use the SND as a case study to demonstrate our calculations
75 referring to the distribution status of NDCCDR. We analyze the spatial distribution of CCDRC in the
76 study area with the goal of providing decision support for efficient disaster response management by
77 local government. The evaluation indices in this paper have the completeness, availability and
78 quantifiable characteristics. The model has the advantages of simple construction, space transferability,
79 simple operation, and multiple characteristics of evaluation results. Therefore, the method introduced in
80 this paper is universal.

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2. Construction of an index system for evaluating the CCDRC

2.1 Defining the CCDRC

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

2.2 Creating an index system for evaluating CCDRC

100 The NDCCDR uses demonstration as a means to enhance a community's ability to reduce disaster
101 risk. The document defines ten aspects of organizational management mechanism, disaster risk
102 evaluation, infrastructure of disaster prevention and mitigation and so on as the basic elements for
103 compliance with the disaster reduction demonstration community (Office of National Disaster
104 Reduction Committee, 2010). The wide-abroad implemented CBDRM attach importance to software
105 construction but despise hardware environment construction. Compared with these disadvantages, the
106 NDCCDR not only strengthen the planning and construction of software such as community residents'
107 awareness and skills for disaster reduction, disaster reduction publicity and training, but also has taken
108 into account the construction of community disaster reduction hardware such as shelters and material
109 reserves. However, the above indicators are not enough to fully reflect the CCDRC. Therefore, based
110 on the meaning of CCDRC, we consider quantitative factors including a community's economic status,
111 rescue and safeguarding resources, and engineering defenses, as well as qualitative factors including
112 disaster risk evaluation, organizational management, and public awareness of disaster prevention.
113 Taking account of the universality, availability and quantifiable characteristics of indicators, we
114 construct the evaluation index system of CCDRC. Our index system is made up of six primary indices
115 and a total of 31 secondary indices, which mainly includes two types of attribute (spatial attribute and
116 non spatial attribute), involve binary, numerical, and categorical data. The indices are listed in Table A1
117 of the Appendix A.

3. Evaluating the CCDRC

119 Our index system has the following characteristics: (1) it is hierarchical, but includes numerical,

120   binary, and categorical data; thus, these data cannot be processed in a standard way, and it is difficult to
121   determine their weights using traditional methods; (2) the index data do not have empirical values, and
122   the quantity of data is small, so quantitative evaluation is difficult; and (3) the same index differs
123   spatially, can evolve between communities and can be transformed to an index with consistent
124   polarization. Based on the aforementioned characteristics, we use grey target modeling to evaluate the
125   comprehensive disaster reduction capability of a single community. Next, we use GIS overlay analysis
126   to create a map showing the spatial distribution of the CCDRC throughout the region.

3.1 Entropy weighted grey target model

128   For evaluating data that involves a small sample and sparse and uncertain information, we first set
129   a grey target and take the bull's eye of the grey target as the standard model. The model is divided into
130   different grades based on the degree to which the model to be evaluated is close to the target center
131   (that is, the target center degree). This method is the traditional grey target model (Deng, 2002). We can
132   then consider the degree to which the various evaluation indices influence the target center degree and
133   use the entropy weight method to determine the weight of the evaluation indices, which will yield more
134   objective and fair evaluation results. This methodology constitutes the improved grey target model, or
135   the entropy-weighted grey target model (Li et al., 2012; Li et al., 2013; Li et al., 2016). The target
136   center degree of various spatial units can be calculated by the following Eq.(1):

137
$$\Gamma\left(X_0(j), X_i(j)\right) = \sum_{j=1}^{n} w_j \frac{minmin\Delta_{0i}(j) + 0.5maxmax\Delta_{0i}(j)}{\Delta_{0i}(j) + 0.5maxmax\Delta_{0i}(j)}, \tag{1}$$

138   The fraction on the right side of the equation is the target center coefficient of index j (j=1, 2, …, n)
139   with a spatial unit of i; $\Delta_{0i}(j)$ is the corresponding grey correlation difference; and w_j is the weight of
140   index j. Equation (2) shows the formula for calculating the entropy weight, as follows:
141
$$w_j = \left(1 - \overline{H}_j\right) / \left(n - \sum_{j=1}^{n} \overline{H}_j\right), \tag{2}$$
142   where $\overline{H}_j$ is the conditional entropy of index j (Jin, 1994; Lian, 2004).

3.2 GIS spatial overlay analysis

144   Spatial overlaying is an important spatial analysis method in GIS. The method overlays two or
145   more image layers on the same scale in the same region to generate a new image layer with multiple
146   attributes. The new image layer synthesizes the attributes of the original image layers; this new layer
147   represents a new spatial relationship as well as indicating the relationship between the attributes of the
148   original image layers based on logical operations (Gong et al., 2001; Yang et al., 2016; He et al., 2015).
149   Overlaying a polygon image layer includes both intersection and superposition (Fig.1). Both the range
150   and attribute of a spatial unit will change after the intersection operation. This kind of overlay requires
151   logical operations and also includes complicated topological operations on spatial objects. After the
152   superposition operation, the range of the spatial units will not change, but the attributes will, mainly
153   because of the logical operations. When there many image layers are included in the operation, their
154   weights must be considered. In this paper, to determine a community's CCDRC, we take the
155   community as the evaluation unit and the image layers corresponding to various evaluation indices as
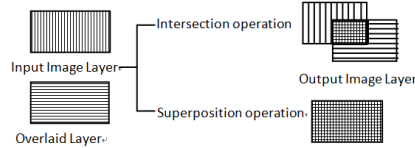156   the objects of operation; we use the entropy-weighted grey target model for the superposition
157   operation.
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166 **Figure1. Schematic diagram of overlay operation.**

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168 **3.3 Evaluation method and process**

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

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

180 $$Tx_i(U_j) = min\left(x_i(U_j), x_0(U_j)\right)/max\left(x_i(U_j), x_0(U_j)\right), \tag{3}$$

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

183 $$\Delta_{0i}(j) = \left|1 - Tx_i(U_j)\right|, \tag{4}$$

184   (2) Calculation of conditional entropy $\overline{H}_j$ for index U_j: the relative distance between the index

185 U_j in unit i and the standard value $x_0(U_j)$ can be expressed with the closeness degree d_{ij}, as follows:

186 $$d_{ij} = 1 - \left[max\left(x_i(U_j), x_0(U_j)\right) - min\left(x_i(U_j), x_0(U_j)\right)\right]/\delta X_j, \tag{5}$$

187 where δX_j is the difference between the maximum and minimum of index j for all the spatial units of
188 the study area. The normalized value of the uncertainty measurement (that is, the conditional entropy)
189 for the relative significance of this index can be expressed as follows:

190 $$\overline{H}_j = \frac{1}{lnm}\sum_{i=1}^{m}(d_{ij}/d_j)ln(d_{ij}/d_j), \tag{6}$$

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

192   (3) Calculation of the target center degree and grades for the various spatial units: first, we
193 calculated the entropy weight w_j of the various indices j using Eq.(2). Next, using Eq.(1), we calculated
194 the target center degree of the corresponding primary index of the different spatial units and the target
195 center degree of the corresponding CCDRC.

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

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

204   **4. Example calculations**

205   **4.1 The distribution status of NDCCDR**

206   Since the National Disaster Reduction Committee and Ministry of Civil Affairs of China
207   organized the selection of NDCCDR in 2008, nearly three thousand community have been selected (or
208   once been selected) in succession. Figure 2 (a) is the nationwide distribution map of NDCCDR in 2017.
209   The map shows that the selected communities are mainly distributed in the relatively developed capital
210   region (Beijing, Tianjin and Hebei, 117), the Yangtze River Delta (Jiangsu, Zhejiang, Shanghai, 241),
211   the Pearl River Delta (Guangdong, 126) and Shandong Province (92), accounting for 38.9% of the total
212   number. Figure 2 (b) shows that there are respectively 15 communities in Nanjing and Suzhou cities,
213   which are cities with the largest number of NDCCDR in Jiangsu province (115). The distribution status
214   shows that the NDCCDR construction of Suzhou is in the forefront of China；nevertheless，the
215   construction of NDCCDR is a demonstration project of comprehensive disaster reduction work in
216   China, and it is also a component part of strengthening the comprehensive disaster reduction ability
217   across our country. Taking SND as an example, with 8 communities currently selected as the NDCCDR,
218   the NDCCDR construction work is obviously among the highest in China. However, the region has
219   jurisdiction over 82 communities, and the number of NDCCDR accounts for only 10% of the total
220   community. In addition, the evaluating index system of NDCCDR is imperfect compared with that of
221   CCDRC, and the NDCCDR is not necessarily consistent with the CCDRC. According to above two
222   aspects, we select SND as the research area to calculate and analyze the CCDRC. The characteristics
223   and distribution of the regional CCDRC can partially reflect the current situation and construction
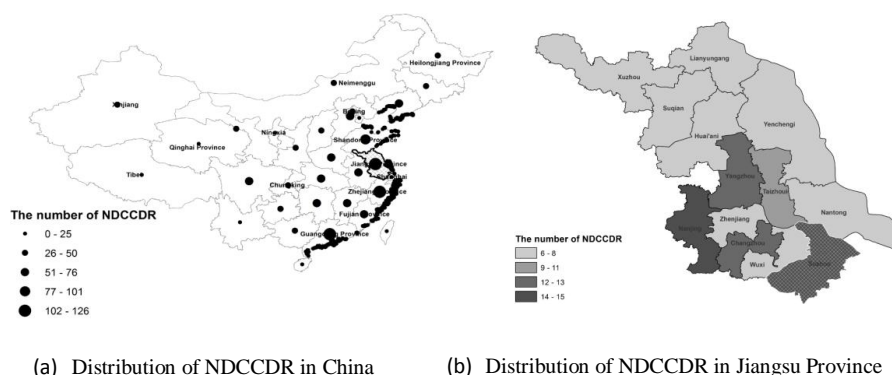224   direction of CCDRC in China.

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

Figure 2. Distribution status of the NDCCDR in China.

238   **4.2 Overview of the study area and data sources**

239   The city of Suzhou is located in the southeastern part of Jiangsu Province in China's Yangtze

240 Delta. It is a major part of the Yangtze River economic zone in Jiangsu. The area has a subtropical
241 monsoon oceanic climate, with four seasons and abundant rainfall. In recent years, although large
242 natural disasters have not occurred, various climate disasters have affected the day to day life of
243 residents. Figure 3(a) shows a map of Suzhou. The study area is the SND, which is located west of the
244 main urban area of Suzhou; it includes one major zone of economic development, three town level
245 administrative districts, and four street administrative areas, totaling 83 communities. Figure 3(b)
246 shows the administrative map. Since the 1990s, the SND has suffered from hailstorms, typhoons,
247 freezing, and floods, which together have caused significant economic losses. In recent years, rapid
248 economic development in Suzhou has resulted in a population boom and increased the frequency of
249 man-made disasters. Thus, the local government has begun to focus more attention on enhancing the
250 CCDRC in the area. Thus, eight communities, including Ylian, Hxiang, and Shshan, have been
251 designated as NDCCDR (see shaded areas in Fig.3 (b)). These communities are mainly located in
252 Xushuguan Town in the northeastern part of the study area and along Shishan Street in the southeastern
253 study area. Thus, these communities have relatively strong organizations for responding to disasters
254 and management capabilities, and they have focused on improving their ability to address disasters.
255 However, CCDRC should also consider other aspects such as the community's rescue and support
256 capability and engineering defenses. The model we present in this paper addresses the measurement
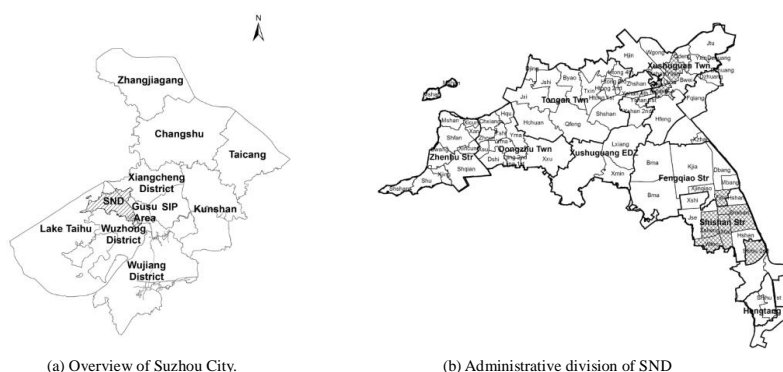257 and analysis of these aspects so that they can be strengthened.

(a) Overview of Suzhou City.　　　　　　　　　(b) Administrative division of SND

Figure3. Overview of research area and administrative district.

272 In this paper, the data used for empirical calculation and analysis are from Suzhou City's spatial
273 database, which includes the image layers for the districts, towns, and administrative boundaries
274 including the communities, roads, water systems, and buildings (Fig. 4). The data were updated and
275 examined before use. Table A1 of the Appendix A shows the indices of the non-building area ratio, the
276 fortified area ratio of buildings, and the community road density, which were obtained using the
277 statistical computation function of ArcGIS 10.2 software.

4.3 Calculation of CCDRC in the region

279 We surveyed and conducted statistical analyses on all 83 communities in the study area; we
280 obtained effective sample data for 72 communities, which we used as the basic data. According to the
281 grey target theory, we built the community-based influence space of the index sequence from six
282 aspects, namely, disaster risk evaluation capability, rescue and support capability. In the light of

Figure4. Image layer of spatial data in the study area.

formula (1) - (6), we calculated the entropy weight, constructed the grey correlation difference information, and then obtained the target center degree. During the calculation, we need to pay attention to the index polarity. Except for number of group event disasters, number of fire disasters and the disaster risk intensity, all other secondary indices are maximum polarity indices.

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

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 / Evaluation index	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	**0.045**
Disaster reduction capital investment (10,000 RMB/year)	0.34	0.35	0.50	0.38	0.36	0.80	0.33	0.34	**0.065**
Number of emergency rescue teams	0.52	0.45	0.57	0.52	0.42	0.42	0.35	0.48	**0.023**
Disaster information personnel (persons)	0.34	0.34	0.34	0.34	0.34	0.35	0.34	0.34	**0.059**
Reserve of rescue materials (10,000 RMB)	0.34	0.35	0.37	0.36	0.34	0.36	0.35	0.37	**0.036**
Per capita medical resources (/10,000 persons)	0.33	0.33	0.33	1.00	1.00	0.35	0.33	0.34	**0.061**
Target center degree	**0.454**	**0.451**	**0.495**	**0.602**	**0.588**	**0.554**	**0.440**	**0.454**	

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

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

319   **4.4 Grading the CCDRC**

320   After inputting the data from Table 1 into ArcGIS 10.2, we conducted the GIS overlay operation
321   using the entropy-weighted gray target model described above, resulting in a map of the distribution of
322   the rescue and support capability in the Shishan Street communities. We repeated this operation for all
323   the communities in the study area and then graded their capabilities based on the target center degree.
324   We used anomalies to create four capability grades, excellent, good, moderate, and poor. Next, we
325   created a map of the distribution of the rescue and support capability grades for the communities in the
326   study area. We repeated the same operation for the disaster risk evaluation, engineering defense, social
327   and economic base support, disaster management and public cognitive capabilities of all the
328   communities, yielding the individual grade distribution maps for each capability. Finally, based on the
329   entropy weight of the primary evaluation indices (Table A1 of the Appendix), we used GIS overlay
330   analysis to determine the total target center degree of the CCDRC for all the communities in the study
331   area. Once divided into grades, based on the minimum information principle, the target center degree
332   should not be smaller than $1/(1+\zeta)$ (where ζ is the resolution coefficient, and its value in Eq. (1) is 0.5).
333   Therefore, the minimum of the total target center degree should be 0.3333. The results show that the
334   maximum total target center degree was 0.6941 for the Wanfeng community of Shishan Street.
335   Therefore, we created four grades in the interval [0.3333, 0.6941] and used these grades to create a map
336   of the spatial distribution of grades of CCDRC (Fig.5). The blank regions in the figure show
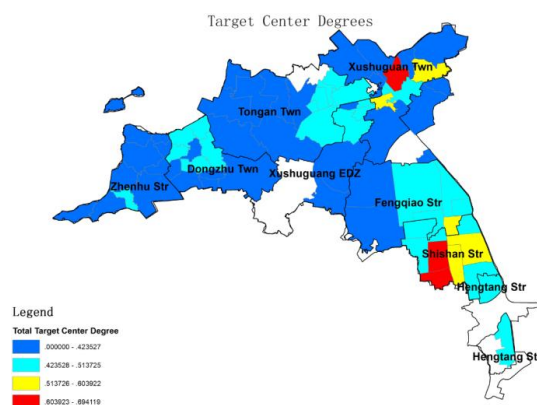337   communities where we could not obtain qualified sample data.

350   **Figure5. Spatial grade distribution map of CCDRC.**

351   **4.5 Result analysis and suggestion**

352   Comparing the spatial distribution of the grades of CCDRC in Fig.5 to the administrative
353   divisions shown in Fig. 3 (b), we observe the following characteristics:
354   (1) The CCDRC in the study area is generally weak. Communities with a poor CCDRC account
355   for 63.1% of the study area, and communities with a moderate grade account for 28.6%; communities

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356   with an excellent grade only account for 8.3%. The distribution of these grades is not accidental but is
357   derived from the spatial distribution of the primary evaluation indices. For convenience of comparison,
358   we set the interval of the target center degree for all the primary evaluation indices to [0.3333, 1]. We
359   then divided the grades based on anomaly values to obtain the spatial grade distribution maps for the
360   primary indices (Fig.6). The figure is descending ordered from the upper left to the lower right based
361   on the entropy weight of the primary evaluation indices. It can be seen that the public cognitive
362   capability (Fig. 6 (a)) and the rescue and support capability (Fig.6 (b)), despite their maximum weight
363   values(0.381 and 0.288,respectively, visible from Table A1 of the Appendix), show a general poor
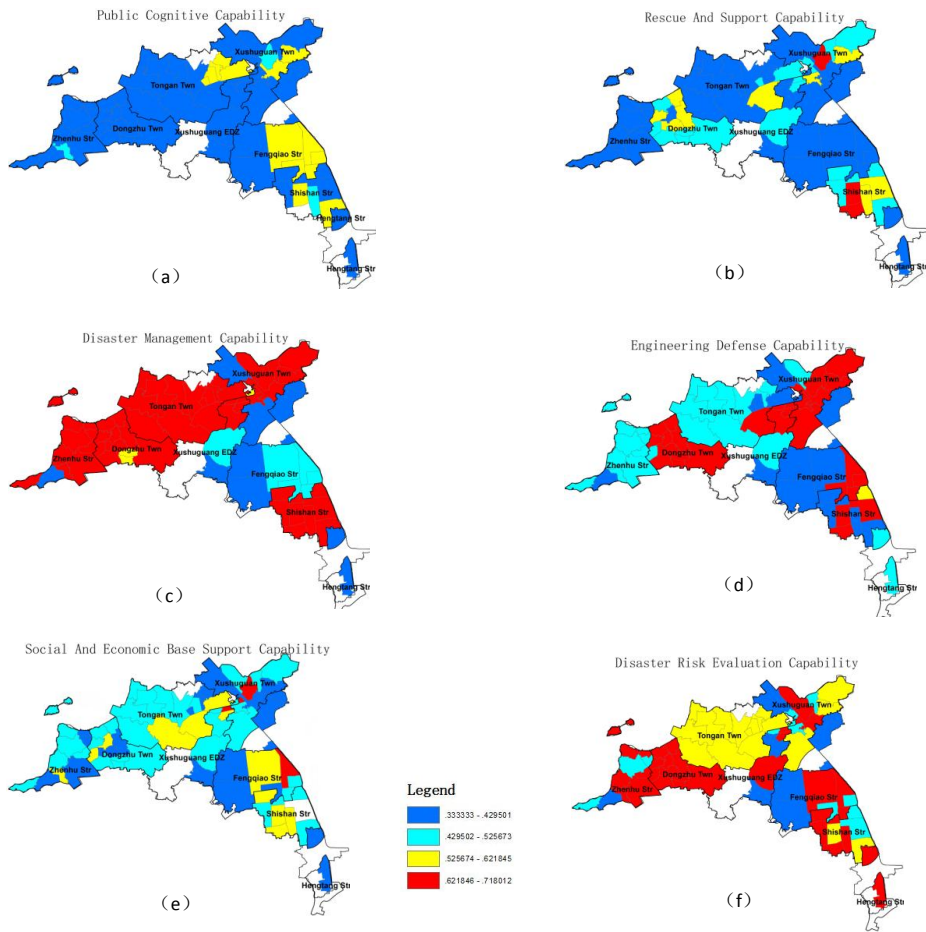364   feature, which is the main reason for the generally weak CCDRC in the study area.

Figure6. Spatial grade distribution map of various primary evaluation indexes in the community

396   (2) The spatial distribution of the CCDRC is uneven. The eastern communities have relatively
397   greater CCDRC than the western communities adjacent to Lake Taihu. Communities in the
398   southeastern part of the research area generally have the strongest capabilities, and the CCDRC on
399   Shishan Street are the strongest. The communities of Xsheng and Wfeng have the best capabilities; the

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400 community of Ylian, located in Xushuguan Town (in the northern part of the study area) has a grade of
401 excellent, and Hxiang and Yxin have grades of good. In contrast, the CCDRC is poor for most
402 communities on Zhenhu Street and in the towns of Dongzhu and Tongan, in the western research area
403 adjacent Lake Taihu. As mentioned in Sect. 4.2, all eight communities of NDCCDR in the research area
404 are located in Xushuguan Town and Shishan Street, and these communities selected as the 10 aspects
405 of organization management and disaster risk evaluation. Figures 6 (c) and (f) show that most of them
406 have excellent grades for disaster management capability and disaster risk evaluation; on the other
407 hand, their engineering defense capabilities (Fig.6 (d)) and social and economic base capabilities (Fig.6
408 (e)) are also in the overall advantage. Other communities, including Zhenhu Street (in the western
409 study area) and the town of Tongan (in the central part of the study area) have an excellent disaster
410 management capability, but their other primary evaluation indices are weaker. The uneven spatial
411 distribution of the disaster reduction capability is also related to the location. Shishan Street is
412 comprised of new urban villages constructed at the end of the twentieth century; it is bordered to the
413 east by the urban area of Suzhou (in the Gusu District), which has well-developed community facilities
414 and a high population. The Hxiang and Ylian communities are located in the central part of the town of
415 Xushuguan, which has a similar setting as Shishan Street. The towns of Tongan, Dongzhu, and Zhenhu,
416 in the western study area, are located on the edge of the Suzhou urban area. Most structures are houses
417 built by individual farmers or as part of settlement communities; living expenses are relatively low, and
418 there is a large transient population. The CCDRC in these communities is thus relatively weak.

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

423 Table 2. Area ratio for the different grades of the primary evaluation indices and CCDRC in the study area
424 (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

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

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

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

439   (1) Several measures should be taken to improve the cognitive level in the communities. Because

440 its weight is largest, the public cognitive capability significantly affects the CCDRC. Figure 6(a) and
441 Table 2 both demonstrate that the public cognitive capability in the research area is insufficient,
442 communities with a poor grade account for 82.4% of the study area. In modern communities with
443 highly developed means of communication, many measures can be used to improve the public
444 cognitive capability. For example, some measures include creating official ways to disseminate disaster
445 reduction information, developing publicity material, setting up disaster early-warning display screens,
446 and increasing the amount of publicity material to increase residents' knowledge of disaster prevention
447 and reduction. Better publicizing disaster reduction activities will help residents understand the dangers
448 of disasters and instill a common sense of proper emergency behavior. Enhancing residents'
449 consciousness regarding disaster prevention and reduction will also help attract volunteers to join
450 disaster prevention and reduction teams and eventually strengthen the overall cognitive capability of
451 the public in the study area.

452   (a) Relative level of engineering defense capability   (b) Relative level of social and economic base
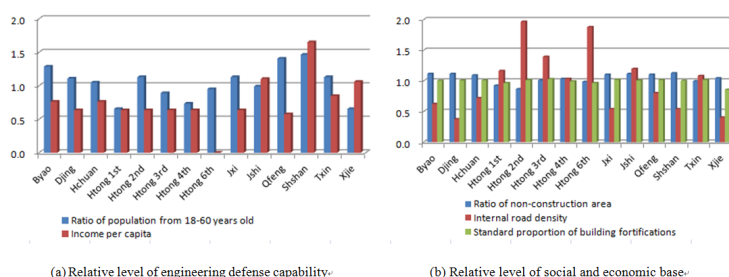
453 **Figure7. Relative level of engineering defense and social economic base support capability in Tongan Town.**

454   (2) It is also important to collectively manage and reinforce the effectiveness of disaster relief
455 measures and safeguards. Because the disaster management capability of communities in the study area
456 is relatively good (Fig.6(c)), we compare it to the target center degree of the community rescue and
457 support capability to yield a plot of the target center degree for the community rescue and support
458 capability (Fig. 8). This index is close to the minimum of the target center degree (0.333), in contrast to
459 the disaster management capability. We conclude that it is important to reinforce the disaster rescue and
460 support capability, including strengthening coordination between the relevant governmental
461 departments, investing in multiple aspects of disaster reduction and allocation of per capita medical
462 resources, appointing disaster information personnel, and setting aside more rescue and emergency
463 material. These measures will fundamentally strengthen the disaster rescue and support capability in
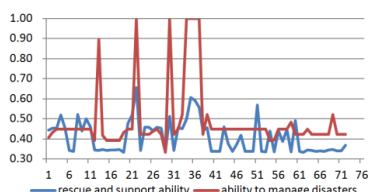464 the study area.

471 **Figure8. Curve for the target center degree of rescue and support capability**

472   (3) Similarly, the engineering disaster defense capability should also be strengthened. As shown in
473 Figure 6(d) and Table 2, the engineering defense capability in the study area is a bimodal distribution.
474 Communities with an excellent grade (including Dongzhu, Shishan Street, and some of Xushuguan)
475 account for 33.8% of the study area, while communities with a moderate or poor grade account for 35.5%

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476   and 30%, respectively. We conclude that internal resources in the study area should be allocated in a
477   better manner; the engineering defense capability of the communities graded excellent can be leveraged
478   in planning, construction, maintenance and management. These strategies will reinforce the
479   engineering defense capabilities of communities throughout the study area.

480   **5. Conclusions**

481   Community disaster prevention and reduction is a basic component of urban disaster prevention
482   and reduction and plays an important role in the urban security system. In this paper, we constructed an
483   index system to evaluate the CCDRC; the system includes six primary and 31 secondary indices. We
484   used entropy-weighted gray target modeling to determine the CCDRC, and GIS spatial overlay analysis
485   to map the spatial distribution of disaster reduction capability grades. We focused on the SND as a case
486   study and obtained the following conclusions:
487   (1) The area's CCDRC is relatively weak; communities with a poor grade account for 63.1% of
488   the study area, and those with an excellent grade account for only 8.3%. Additionally, the spatial
489   distribution of CCDRC is uneven. The eastern communities have relatively good capability, while the
490   western communities adjacent to Lake Taihu have poorer capability. The Shishan Street community,
491   located in the southeastern part of the study region, has the strongest CCDRC. However, the CCDRC
492   in the region has a good foundation and it also has large potential for improvement. After analyzing
493   these results, we propose that CCDRC can be most improved by enhancing their level of public
494   cognitive ability, rescue and support capacity, and engineering defenses.
495   (2) In general, the CCDRC of the NDCCDR is at the forefront in the study area, but the CCDRC
496   among the NDCCDR is not balanced. As shown in Fig.5, among the NDCCDR, the CCDRC of Ylian
497   is rated "excellent", but Hxiang or Yxin is "good". The CCDRC primary indices of the NDCCDR are
498   also quite different from each other. As we can see in Fig.6, the public cognitive capability and the
499   rescue and support capability of the NDCCDR show a general poor feature, but their engineering
500   defense capabilities and disaster management capability are in the overall advantage. Above
501   discussions fully indicate that the CCDRC of NDCCDR is not necessarily good. On the contrary, the
502   evaluation and construction of CCDRC is not only the focus of community disaster prevention and
503   reduction work, but also the standard for the continuous improvement, construction and promotion of
504   the NDCCDR. Based on above analysis, we can combine the NDCCDR construction with the CCDRC
505   construction, from point to face, and ultimately improve the overall level of CCDRC in the region.
506   This paper takes the municipal area as the case study area, analyzes and compares the CCDRC
507   and its primary indices between communities in the jurisdiction area. All the pertinent suggestions are
508   beneficial to the regional functional departments to carry out disaster prevention and mitigation
509   planning, resource allocation, resident mobilization and administrative decisions within the jurisdiction,
510   so as not to complicate the implementation of the CCDRC construction due to coordination across
511   jurisdictions. On the other hand, Suzhou is located in Jiangsu, a strong economic province in China. In
512   recent years, Gross National Product (GDP) has always been the top of the same level cities. Great
513   efforts have been made to prevent and reduce disaster (It is evident from the number of CCDRC.).
514   However, from the analysis results of this paper, the CCDRC of Suzhou is still not satisfactory. It also
515   shows that our CCDRC building has a long way to go. The overall strengthening of China's CCDRC
516   will continue for a long time.
517   The index system is mainly composed of spatial attribute data and non spatial attribute data. We

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518 can obtain the spatial attribute data from a regional geographic database. The non spatial attribute data
519 can be obtained by means of community disaster monitoring logs, reports and other historical archives,
520 resident visits and field surveys with the help of local civil affairs department. Therefore, the process of
521 CCDRC calculation and analysis based on entropy weight - grey target model and GIS overlay method
522 in this paper, is generally applicable to most of the provinces in mainland China.

523   As described before, the international community generally follows the model of CBDRM.
524 Although the model pays more attention to software construction than hardware environment
525 construction, countries that continue to suffer from various natural disasters are looking for a
526 manageable community risk management model in recent years, especially in last several years. These
527 countries (or regions) have a good foundation for strengthening the CCDRC.
528 The concrete measures contain the use of community-based early warning systems (Paul J. Smith et al.,
529 2017), community infrastructure exposure risk analysis (S. Fuchs et al., 2015; R. Figueiredo et al., 2016;
530 Saif Shabou et al., 2017), disaster risk reduction education (Avianto Amri et al., 2017) and
531 community-level resilience to disaster (Adriana Keating et al., 2017; Estefania Aroca-Jimenez et al.,
532 2017). The evaluation of CCDRC will help to defend against various kinds of disasters in the
533 community as a whole, respond at different stages during the development of a disaster, integrate
534 various resources, and coordinate various disaster reduction approaches. Through the evaluation of
535 CCDRC, the overall level of CCDRC and the status of the main evaluation indexes can be grasps, so as
536 to make it easy to take specific measures to effectively strengthen the weak links. The benefits will
537 offer to communities that are vulnerable to various kinds of disasters, as well as some challenges, such
538 as different national conditions, unbalanced economic development among countries, great differences
539 in the system of disaster prevention and reduction, and great differences in the organization level of the
540 project. To address these challenges, features that make this approach worth considering in the context
541 of other countries or regions include,

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

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

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

553   On the whole, it is world widely feasible to apply the methods introduced in this paper to evaluate
554 the CCDRC. The research results in this paper can provide a basis for improving the CCDRC and
555 assist with disaster prevention and reduction strategies. They will also serve as a reference for other
556 studies of community-level disaster reduction capability. However, due to the large number of indices
557 in this paper, there must be redundancy between data, so information reduction should be carried out
558 before evaluation. From the perspective of overall plan of national comprehensive disaster reduction
559 work, we should prepare to respond at different stages during the development of a disaster. Therefore,
560 the resilience capability to disaster should also be included in the index system. These two aspects are
561 the deficiencies of this paper and need to be solved in future research.

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562   Appendix A:

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

Primary indicator (entropy weight)	Secondary index	Entropy weight	Meaning of index	Data type
Disaster risk evaluation capability (0.005)	Number of group event disasters (times/year)	0.001	Number of disasters with causalities or property loss caused by grouped events.	
	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).	Categorical
	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.	
Rescue and support capability (0.288)	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 population of community	
	Ratio of non-construction area (%)	0.006	The higher the non-building area (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^2)	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.	
Engineering defense capability (0.148)	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^2)	0.009	Total construction area of underground residential facilities such as underground car park garages.	
Social and economic base support capability (0.012)	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).	
	Income per capita (10,000 RMB)	0.003	Income per capita of the community.	
Disaster management capability (0.159)	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.	
	Periodic inspection system	0.003	Whether hidden dangers are regularly monitored and emergency plans and response for vulnerable populations are reviewed.	Binary
	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)	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	

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		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.	

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

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