A study on the assessment of the resilience of agricultural system under flood disaster

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Abstract. In order to further understand the flood control and disaster resistance ability of agricultural system, the concept of resilience of agricultural system under flood and waterlogging disaster is given. From four aspects of technology, economy, environment and society, the most representative eight evaluation indexes are selected to build the resilience model of agricultural system under flood disaster, determine the grade standard of each index, introduce TOPSIS method and adopt "two-level empowerment" to quantify the resilience of agricultural system under flood disaster. Taking 13 cities in Jiangsu Province as an example, this paper uses the TOPSIS based assessment model to assess the resilience of agricultural system under flood and waterlogging disasters, and the assessment results are consistent with the actual situation.

1. Introduction

Agriculture is the great cause of the world. Agriculture is the foundation of national economy and the foundation of national independence and social stability. With the impact of global warming and other natural environment, agricultural disasters occur frequently. In order to promote the sustainable and healthy development of agriculture and reduce the occurrence of disasters, it is necessary to study the disaster reduction and resilience of agricultural system.

Agricultural disaster is the main natural disaster in China, especially flood and drought disaster[1]. In recent years, many experts and scholars have carried out relevant research on agricultural flood disaster. Chang jiang [2] has studied that remote sensing technology can easily monitor the impact of flood disaster on crops, and provide important decision-making basis for people to understand the disaster situation, formulate disaster relief plans and post disaster planning. Wan et al. [3] based on the 2017 SAR image and sentinel data, adopted the two-step classification method of pixel and object-oriented to carry out more accurate monitoring and prediction of the flooded area. Zhang Guixiang et al. [4] used the method of gradual elimination to select the index, constructed the index of agricultural flood level by province and verified the rationality of the index, and analyzed the temporal and spatial changes of agricultural flood disaster in this area in the past 50 years. Based on the theory of regional disaster system, Wu Yuyan et al. [5] used entropy method to evaluate the vulnerability of agricultural flood disaster, and used ArcGIS software to draw the spatial distribution map of vulnerability. Liu Lianfang et al. [6] put forward the concept of vulnerability of agricultural flood disaster and made a quantitative evaluation of the vulnerability of agricultural flood disaster. Tian min et al. [7] defined the relevant concepts of disaster and flood disaster, sorted out the risk assessment indicators of disaster and flood disaster, and discussed the research status and existing problems of risk assessment indicators, so as to provide guidance for the study of risk assessment zoning of agricultural flood disaster. Guo et al. [8, 9] took the representative waterlogging years in 1994, 2005 and 2010 in the central and Western Jilin Province as examples, used Ceres come model to simulate the daily growth data of corn in grid cells, established waterlogging index
in growth stage with standard pre precipitation index and relative humidity index, and evaluated the waterlogging disaster. Most of the researches on agricultural flood disaster by the above methods are based on the evaluation system of resilience, vulnerability and vulnerability, and lack of research on the whole resilience of agricultural system under flood disaster.

Based on the characteristics of agricultural flood disaster, the resilience of agricultural system under flood disaster is studied. Holling first applied the concept of resilience to the field of ecology in his pioneering work resilience and stability of ecosystems in 1973. Today, the concept of resilience has been applied in many fields, especially in the field of disaster management [8]. Resilience is regarded as "shield", "shock absorber", or some kind of buffering effect, which can ensure the results are benign or only produce small negative impact. In view of this, the theory of resilience is applied to the flood control of agricultural system by approaching the technique for order Preference by similarity to an ideal solution (TOPSIS) realizes the resilience assessment process of agricultural system under flood disaster, and has further learning and understanding on the disaster resistance ability of agricultural system.

2. The resilience of agricultural system under flood disaster

The concept of resilience provides a new way to study agricultural flood disaster. Resilience is defined as the ability of a system to cope with changes or disturbances while maintaining its basic state (Walker, salt, 2006) [11]. From the initial engineering resilience to ecological resilience, and then to evolution resilience, each revision and improvement enriches the extension and connotation of the concept of resilience. According to Liao, ecological resilience emphasizes the ability to survive, regardless of whether its state changes. [12]

Based on the study of the connotation of resilience theory, the resilience of agricultural system under flood disaster is defined as the capability of absorbing and maintaining its original characteristics, key functions and post disaster recovery under the influence of the risk factor of flood disaster.

Francis et al. [13] Based on the study of the concept of resilience and the framework of resilience assessment, gave the framework of resilience assessment as shown in Figure 1. In view of this, according to the definition of resilience of agricultural system under flood disaster, combined with the research and exploration of relevant scholars [5] [7] [14] [15] on agriculture, 8 resilience assessment frameworks of agricultural system under flood disaster were given from the perspectives of technology, economy, environment and society As shown in Figure 2, the evaluation model of agricultural system resilience under flood disaster is constructed. (In the model, a stands for absorptive capacity, b stands for adaptive capacity, c stands for restorative capacity, and the following marks represent the specific resilience characteristics corresponding to the evaluation index.)

The model selects the most representative eight evaluation indexes from four aspects, which systematically reflects the resilience of agricultural system under flood disaster. The three resilience characteristics of absorption capacity, adaptability and recovery capacity are corresponding to the evaluation indexes, which further improves the feasibility and operability of the evaluation model.

Fig.1. Resilience assessment framework
3. The assessment of the resilience of agricultural system under flood disaster

Tab 1. Grading of evaluation indexes.

| Index                                | Corresponding description     |
|--------------------------------------|-------------------------------|
| Degree of Agricultural Mechanization (kW/ hm²) | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
| C1                                   | <0.035 | 0.050> C1≥0.035 | 0.065> C1≥0.050 | 0.080> C1≥0.065 | ≥0.080 |
| Reservoir density C2                 | worse | poor | General | good | better |
| Per capita net income of farmers (yuan) | C3     | <9500 | 12000>C3≥9500 | 14500>C3≥12000 | 17000>C3≥14500 | ≥17000 |
| Government per capita agricultural appropriation (yuan) | C4     | <2000 | 4000>C4≥2000 | 6000>C4≥4000 | 8000>C4≥6000 | ≥8000 |
| Forest coverage (%) C5               | <10   | 25>C5≥10 | 40>C5≥25 | 55>C5≥40 | ≥55 |
| Precipitation in flood season (May-Oct) (mm) | C6     | ≥1000 | 1000>C6≥850 | 850>C6≥700 | 700>C6≥550 | <550 |
| Population density (person/ hm²) C7  | <120  | 300>C7≥120 | 500>C7≥300 | 800>C7≥500 | ≥800 |
| Paddy field density C8               | <0.15 | 0.25>C8≥0.15 | 0.35>C8≥0.25 | 0.45>C8≥0.35 | ≥0.45 |

3.1 Determine the evaluation index level

The 8 assessment indexes given in the assessment model of agricultural system toughness under the flood disaster in Figure 2 are divided into 5 grades, and the toughness represented in turn are: worse (Level 1), poor (Level 2), general (Level 3), good (Level 4), better (Level 5). See Table 1 for the specific division standards. As the evaluation indexes given in Table 1 are mostly described by quantitative interval and fuzziness, for the convenience of calculation, for the evaluation indexes with interval range value, the minimum value corresponding to the grade is used, and for the evaluation indexes with fuzzy description, the advantages and disadvantages of the index on the impact of toughness are quantified as 1-5 points, respectively corresponding to 1 of the toughness of agricultural system under flood disaster Five grades from to 5. See Table 2 for the detailed quantitative description.
### 3.2 TOPSIS method

TOPSIS is a simple multi-objective decision analysis method, which can judge the evaluation object by comparing the difference between the evaluation object and the optimal solution and the worst solution. The central idea of TOPSIS is to calculate the closeness of each evaluation object to the rational solution. The closer the closeness is to 1, the closer the evaluation object is to the optimal level, and the closer the closeness is to 0, the closer the evaluation object is to the worst level.

1) **Establish initial evaluation matrix** $A_k$. Assuming that there are $m$ units to be evaluated and $n$ evaluation indexes, the initial evaluation matrix $A_k$ is obtained.

$$A_k = (a_{ij})_{m \times n} = 
\begin{bmatrix}
a_{11} & \cdots & a_{1n} \\
\vdots & \ddots & \vdots \\
a_{m1} & \cdots & a_{mn}
\end{bmatrix} \quad (1)$$

In the formula, $A_k$ is the initial evaluation matrix under different conditions ($k = 0, 1$); $A_0$ is the initial evaluation matrix based on the grading value of toughness evaluation index; $A_1$ is the initial evaluation matrix based on the actual data; $a_{ij}$ is the $j$th evaluation index of the $i$th unit to be evaluated ($i = 1, 2, \ldots, m$); $j = (1, 2, \ldots, n)$.

2) **Establish standardized decision matrix** $B_k$. The initial evaluation matrix $A_k$ is dimensionless. For the larger and better index, then:

$$b_{ij} = \frac{a_{ij} - \min_j(a_{ij})}{\max_j(a_{ij}) - \min_j(a_{ij})} \quad (2)$$

For the smaller and better index, then:

$$b_{ij} = \frac{\max_j(a_{ij}) - a_{ij}}{\max_j(a_{ij}) - \min_j(a_{ij})} \quad (3)$$

Where: $b_{ij}$ is the dimensionless form of $a_{ij}$; $\min_j(a_{ij})$ and $\max_j(a_{ij})$ are the minimum and maximum values of elements in the $j$-th column of matrix $A_k$ respectively.

$$B_k = (b_{ij})_{m \times n} \quad (4)$$

3) **Determine index weight.**

"First level empowerment": the analytic hierarchy process is used to give weight to experts from four perspectives of technology, economy, environment and society.

"Second level empowerment": Taking the absorptive capacity, adaptive capacity and resilience as the measurement description of toughness characteristics with units of "pieces", and taking the ratio of the "number" of toughness characteristics of each evaluation index and the "total number" of toughness characteristics of all evaluation indexes in the corresponding evaluation angle as the weight of the evaluation index. The weight $W$ is:

$$W = [\omega_1, \omega_2, \ldots, \omega_j]^T \quad (5)$$

In the formula: $\omega_j$ is the weight value of the $j$-th index.

4) **Construct the weighted standardized decision matrix** $C_k$ of matrix $A_k$.

$$C_k = (c_{ij})_{m \times n} = B_kW \quad (6)$$

5) **The positive ideal solution** $C^+$ and the negative ideal solution $C^-$ of the weighted standardized decision matrix $C_0$ are determined.

$$C^+ = [\max(c_{ij})] = [c^+_1, c^+_2, \ldots, c^+_j]$$

$$C^- = [\min(c_{ij})] = [c^-_1, c^-_2, \ldots, c^-_j] \quad (7)$$

In the formula, $c^+_j$ and $c^-_j$ are the positive and negative ideal solutions of the index in the $j$-th column of matrix $C_0$.

6) Calculate the distance $S^+_i$ and $S^-_i$ between each object to be evaluated and the positive and negative ideal solutions.
$$S_i^+ = \sqrt{\sum_{j=1}^{n}(c_{ij} - c_j^+)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}(c_{ij} - c_j^-)^2}$$

(8)

7) Calculate the closeness $E_{i}^+$ between the object to be evaluated and the rational solution.

$$E_{i}^+ = \frac{s_i^+}{s_i^- + s_i^+} (0 \leq E_{i}^+ \leq 1)$$

(9)

3.3 Determining the resilience grade standard of agricultural system under flood disaster

According to formula (1) and table 2, the initial evaluation matrix $A_0$ of resilience evaluation index grade can be obtained.

$$A_0 = \begin{bmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 1000 & 0 & 0 \\
0.035 & 2 & 9500 & 2000 & 10 & 850 & 120 & 0.15 \\
0.050 & 3 & 12000 & 4000 & 25 & 700 & 300 & 0.25 \\
0.065 & 4 & 14500 & 6000 & 40 & 550 & 500 & 0.35 \\
0.080 & 5 & 17000 & 8000 & 55 & 0 & 800 & 0.45 \\
\end{bmatrix}$$

According to formula (2) - (9) and according to the scale of sticking schedule, the resilience grade of agricultural system under flood disaster is divided, as shown in Table 3.

| Level | $S_{i}^+$ | $S_{i}^-$ | $E_{i}^+$ | Description ( $E_{i}^+$ ) |
|-------|-----------|-----------|-----------|---------------------------|
| 1     | 0.1895    | 0         | 0         | [0, 0.1544)               |
| 2     | 0.0982    | 0.0179    | 0.1544    | [0.1544, 0.5385)          |
| 3     | 0.045     | 0.0525    | 0.5385    | [0.5385, 0.8959)          |
| 4     | 0.0126    | 0.108     | 0.8959    | [0.8959, 1)               |
| 5     | 0         | 0.1895    | 1         | 1                         |

4. Resilience of agricultural system under flood disaster in Jiangsu Province

Jiangsu Province is located in the lower reaches of the Yangtze River and the Huaihe River. It is close to the Yellow Sea. There are many rivers and lakes. More than 290 large and small lakes are interwoven with the river network of the Yangtze River, the Huaihe River, the canal and many other rivers. The water system is relatively complex, known as the "flood corridor". Jiangsu Province is located in the East Asian monsoon region, with four distinct seasons, the same period of rain and heat, concentrated precipitation in the flood season, and high water levels in rivers and lakes. Meanwhile, because it is located in the main channel of the advance and retreat of the Chinese summer monsoon, the location and scope of the rain belt are variable, and the possibility and sensitivity of flood disaster are high. Therefore, taking Jiangsu Province as the research object, the model is used to evaluate the resilience of agricultural system under flood disaster.

4.1 Evaluation object data

Based on the data provided by Jiangsu forestry bureau, Water Affairs Bureau, Department of agriculture and Statistics Bureau of Jiangsu Province, collect the data of each index from 2014 to 2018, take the average value, and get the standardized data shown in Table 4 according to the standards given in Table 1 and table 2.
Tab 4. Standardized data of cities in Jiangsu Province

| City      | C₁  | C₂  | C₃  | C₄  | C₅  | C₆  | C₇  | C₈  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|
| Nantong   | 0.035 | 1 | 17000 | 2000 | 25 | 1000 | 500 | 0.15 |
| Lianyungang | 0.080 | 5 | 12000 | 2000 | 25 | 550  | 500  | 0.25 |
| Huai'an   | 0.065 | 3 | 12000 | 2000 | 25 | 700  | 300  | 0.35 |
| Yangzhou  | 0.050 | 2 | 17000 | 2000 | 10 | 700  | 500  | 0.50 |
| Taizhou   | 0.035 | 1 | 17000 | 2000 | 10 | 850  | 800  | 0.45 |
| Suqian    | 0.065 | 2 | 12000 | 2000 | 25 | 550  | 500  | 0.25 |
| Nanjing   | 0.065 | 4 | 17000 | 6000 | 25 | 1000 | 800  | 0.25 |
| Suzhou    | 0.065 | 1 | 17000 | 6000 | 20 | 1000 | 800  | 0.25 |
| Wuxi      | 0.050 | 4 | 17000 | 2000 | 25 | 1000 | 800  | 0.25 |
| Changzhou | 0.065 | 5 | 17000 | 2000 | 25 | 1000 | 800  | 0.25 |
| Zhenjiang | 0.065 | 3 | 17000 | 2000 | 25 | 1000 | 550  | 0.35 |
| Xuzhou    | 0.050 | 3 | 14500 | 2000 | 25 | 550  | 800  | 0    |
| Yancheng  | 0.035 | 1 | 18000 | 2000 | 25 | 850  | 300  | 0.25 |

4.2 Assessment of the resilience of agricultural system under flood disaster in Jiangsu Province

According to formula (1) and table 4, establish the initial evaluation matrix $A_1$ of each city in Jiangsu Province.

$$A_1 = \begin{bmatrix}
0.035 & 1 & 17000 & 2000 & 25 & 1000 & 500 & 0.15 \\
0.080 & 5 & 12000 & 2000 & 25 & 550 & 500 & 0.25 \\
0.065 & 3 & 12000 & 2000 & 25 & 700 & 300 & 0.35 \\
0.050 & 2 & 17000 & 2000 & 10 & 700 & 500 & 0.35 \\
0.035 & 1 & 17000 & 2000 & 10 & 700 & 500 & 0.35 \\
0.065 & 2 & 12000 & 2000 & 25 & 550 & 500 & 0.25 \\
0.065 & 4 & 17000 & 6000 & 25 & 1000 & 800 & 0.25 \\
0.065 & 1 & 17000 & 6000 & 20 & 1000 & 800 & 0.25 \\
0.050 & 4 & 17000 & 2000 & 25 & 1000 & 800 & 0.25 \\
0.065 & 5 & 17000 & 2000 & 25 & 1000 & 800 & 0.25 \\
0.065 & 3 & 17000 & 2000 & 25 & 1000 & 550 & 0.35 \\
0.050 & 3 & 14500 & 2000 & 25 & 550 & 800 & 0 \\
0.035 & 1 & 18000 & 2000 & 25 & 850 & 300 & 0.25 
\end{bmatrix}$$

According to formula (2) - (9) and comparison with table 3, the results of resilience assessment of agricultural system under flood disaster in Jiangsu Province are shown in Table 5.

Tab 5. The result of resilience assessment of agricultural system under flood disaster in Jiangsu Province

| City      | $S_1^{+}$ | $S_1^{-}$ | $E_1^{+}$ | Level |
|-----------|-----------|-----------|-----------|-------|
| Nantong   | 0.1438    | 0.0263    | 0.1545    | 2     |
| Lianyungang | 0.0174 | 0.1478    | 0.8947    | 3     |
| Huai'an   | 0.0495    | 0.0529    | 0.5165    | 2     |
| Yangzhou  | 0.0878    | 0.0366    | 0.2941    | 2     |
| Taizhou   | 0.1431    | 0.0289    | 0.168     | 2     |
| Suqian    | 0.0848    | 0.0317    | 0.272     | 2     |
| Nanjing   | 0.0177    | 0.1117    | 0.8629    | 3     |
| Suzhou    | 0.1300    | 0.0443    | 0.2541    | 2     |
| Wuxi      | 0.0289    | 0.0984    | 0.7726    | 3     |
| Changzhou | 0.0201    | 0.154     | 0.8845    | 3     |
4.3 Analysis of evaluation results

It can be seen from table 5 that the resilience level of the agricultural system under the flood disaster in each city of Jiangsu Province is level 2 and level 3, among which the closeness degree of Nantong, Taizhou and Yancheng is relatively low, which is relatively easy to occur flood disaster, and it is difficult to take effective control measures in the face of flood disaster; the closeness degree of Lianyungang, Nanjing and Changzhou is relatively high, which is relatively not easy to occur flood disaster, even if it occurs take effective measures.

The study shows that the flood disaster in Jiangsu Province is mainly light disaster and medium disaster, which is consistent with the above-mentioned overall assessment results; the northwest, East and riverside areas of Jiangsu Province are relatively serious flood disaster areas, and Yancheng and Nantong areas are the most serious. The above characteristics are consistent with the assessment results. The results show that the model is an effective and reasonable method to evaluate the risk of flood disaster.

5. Conclusion

(1) Based on the understanding of the connotation of the resilience theory, this paper applies the resilience theory to the agricultural flood disaster, puts forward the concept of the resilience of the agricultural system under the flood disaster, and selects eight most representative evaluation indexes from four angles of technology, economy, environment and society, and takes the three resilience characteristics of absorption ability, adaptability and recovery ability into account to give the agriculture under the flood disaster industry system resilience evaluation model, and use TOPSIS method and "two-level weighting" to quantify the model;

(2) Jiangsu Province is selected as the research object, and the model is applied. The evaluation results are consistent with the actual situation, which verifies the feasibility of the model;

(3) In this paper, the study of agricultural disaster only selects the perspective of flood disaster. Other agricultural disasters need further research and exploration by relevant scholars. At the same time, the assessment model proposed in this paper needs further improvement.

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| City      | Absorption | Adaptability | Recovery Ability | Resilience Level |
|-----------|------------|--------------|------------------|-----------------|
| Zhenjiang | 0.045      | 0.0633       | 0.5588           | 3               |
| Xuzhou    | 0.0485     | 0.0566       | 0.5386           | 3               |
| Yancheng  | 0.1426     | 0.0282       | 0.1561           | 2               |
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