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Social network efficiency of multiple stakeholders on agricultural drought risk governance — A southern China case study

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ABSTRACT

Social network research in respect of multi-stakeholders in the field of disaster risk governance is receiving increasing attention. Analyzing connection efficiency helps each stakeholder to coordinate relationships for disaster governance. Based on questionnaire and multi-indicator analysis, the study constructs a M-S-S-P-I (Multi-Scale-multi-Stakeholder-multi-Process-multi-Indicator) system and establishes a social network encompassing the government, village committee, household, and enterprise in drought risk governance. The results are as follows. (1) In the process of drought risk governance, the households are not sufficiently motivated to be adequately prepared and the government does not provide adequate instructions in the recovery. (2) From each stakeholder's perspective, the averages of the connection proportion show a trend of enterprise (0.91) > government (0.65) > village committee (0.58) > household (0.12), and the ranges of the proportion are quite large. The social network of households displays features of closure and unbalance. (3) Considering the soft factors in efficiency evaluation, from the "quantity" view, the value of the village stakeholders is low and from the "quality" view, it presents a trend of the trust degree < communication convenience degree ≈ function understanding degree ≈ assistance effectiveness degree. The trust between stakeholders and the connection efficiencies of households and enterprises in the social network need to be strengthened. The purpose of this study is to provide references for enhancing cooperation efficiency among multiple stakeholders so that they are able to form a consilience of drought risk governance.

1. Introduction

In recent years, the social network among multiple stakeholders has received increased attention in the field of integrated disaster risk governance [1,2]. Social networks are used to express the relationships and the flow of information and material between people [3,4], and the networks usually include the following parts: (a) Nodes, which can represent subjects, such as people, organizations, countries, and teams. (b) Edges, which indicate the relationships between the nodes [5,6]. The social network between the government, enterprises, and individuals is the key in risk governance [7,8]. Understanding of the cooperation efficiency of multi-stakeholders promotes the better coordination of relationships, transmission of information, and sharing of resources [9,10], and it also facilitates better decision-making in respect of disaster preparedness, responsiveness, and recovery [11,12]. It can be seen that the analysis of connection efficiency is of great significance for enhancing the efficiency of integrated disaster risk governance [13,14].

The construction of social networks is the first step of studying the connection efficiency between stakeholders. The main approaches include questionnaire, literature analysis, which provide many references for the construction of social networks of disaster risk governance [15–19]. (1) In the questionnaire, a study queried the disaster-affected nodes in order to determine with which nodes they would cooperate during the drought and then connected the nodes mentioned by the respondents to establish the disaster management network [20]. Other studies have consulted senior disaster managers to list disaster governance nodes, and then connected the nodes to build a management network [21,22]. (2) In the literature analysis, Lassa built a social

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network of disaster risk governance by connecting the nodes that had transaction records in the 1300 post-disaster financial documents [23], and Saban established a typhoon emergency social network by connecting the nodes that had communication records in 2391 disaster emergency reports [24].

Quantifying the connection situation comes after building up the network. The methods are concentrated in two aspects: (1) Based on topological relationship. Commonly used indicators are degree, closeness, density, etc [25,26]. The above indicators reflect the importance of a given node in the network, or the impact of a given node on other nodes, or the tightness of the entire network [27–30]. There was study using "degree" to find the top 10 most important units in the wildfire response process [31], or using "closeness" to analyze the influence of a given node on the others under the seismic cascade effect scenario [32], or using "density" to research the tightness of the cooperation among stakeholders in disaster risk governance [11,33]. (2) Based on "edge" weight assignment. Generally, weights are given to the communication situations between nodes or the attributes of the nodes [34]. For instance, a study assigned a 0–3 wt to the edge according to the communication frequency between the nodes in responding to a typhoon [24].There was also a study that counted the number of times that the nodes commented to each other during a disaster as edge's weight [17]. Still some studies gave weights to the "edges" by computing the node's similarity of speech on the website [35]. The above methods lay the foundation for the calculation of the connection efficiency in this paper.

Besides the calculation of connection situation, some scholars realize that the connection state between nodes is affected by many "soft factors" [36]. Some studies found that the trust, consensus will improve the connection efficiency between the nodes [21,22]. Some studies pointed out that the leadership and mutual understanding affected the connection efficiency of the nodes when using resources [37]. There were also studies suggesting that the personal experience of the nodes, the effective communication, and the cohesion between them have an important influence on their relationship [38,39]. Still have studies pointed out that information, resources, knowledge, as well as experience, system, culture, etc. played a crucial role in cooperation, thus affecting disaster risk governance [38,40]. Further quantification of the soft factors' influence is of great significance for understanding the cooperation. However, few studies have taken it into consideration for quantitative evaluation recently.

Based on the above, it is found that the calculation of connection situation is mostly according to the topology of the network itself or a simpler assignment for the "edge", they are still insufficient to understand the "good degree" of relationship between stakeholders. In addition, although research has focused on the impact factors, it is mostly at a qualitative level. In order to make a further research in stakeholders' relationship, the paper quantifies the connection state of multi-stakeholders considering both topological structure of social network and the impact factors. The main steps are as follows: (1) Construct the social network with 3 drought phases by using questionnaire and literature analysis, and analyze communication process between the government, households, and enterprises at different scales. (2) Adopt the "connection proportion" to explore the communication breadth between stakeholders. (3) Build up the soft indicators, such as the communication convenience, to quantify the connection efficiency (i.e. to understand how good the relationship is). The study set up an M-S-S-P-I (Multi-Scale-multi-Stakeholder-multi-Process-multi-Indicator) system of social network research and quantify many "soft factors" in the stakeholders' cooperation when resisting drought. It aims to provide references to improve the efficiency of multi-stakeholders and form a consilience in the integrated risk governance of drought.

2. Materials and methods

2.1. Study area

Dingcheng District, which is in the northern Hunan province of China, is one of the national grain bases and one of the most severely drought-affected areas [41,42]. Based on the annual precipitation data of 752 meteorological stations nationwide from 1951 to 2012, the average annual distribution pattern of meteorological drought intensity in China over the past 60 years has been obtained by calculating the annual average precipitation anomaly. The paper chooses Dingcheng (main paddy agricultural area), near the station where the precipitation anomaly is less than −45% as a study area.

The terrain slopes from the southwest to the northeast, and about 30% of the area consists of hillocks, 25% of mountains, and 45% of plains and water bodies (Fig. 1). The climate is continental, but it is also humid. Precipitation is 1300 mm annually, but it is unevenly distributed, and it varies greatly from year to year. The paper constructs the D-Value indicator (Formula 1), which is the difference between the average precipitation (1991–2012) and water demands of crops in the corresponding growth period. D-Value can reflect the water deficit during the growth period of the crop, and if its value is negative, indicating that the crop's water demand is not satisfied, and the drought is prone to occur during the corresponding growth stage. In July to September, during the critical period of crop growth, due to the subtropical high air pressure control, the weather is sunny and hot, and evaporation is strong. Natural precipitation often cannot meet crops' water demands. The D-Value of mid-season rice, late-season rice and cotton were almost negative at all, and the highest water deficit in early August reached −37.5, −36.0 and −30mm respectively (Fig. 2). So it often caused summer and autumn drought.where precipitation and crop water demand are both the average level in each ten days.

2.2. Data

In order to more accurately quantify the connection efficiency, this paper sorts out the connotation of stakeholders' relationship by literature review and finds that "communication frequency" [40], "understanding" [43], "assistance effectiveness" [44], "trust" [45,46] and "communication convenience" [47] affect the cooperation efficiency, thus affecting the disaster management. Therefore, the paper considered the above main connotations and constructed the indicator system in Table 1.

According to Table 1, the corresponding questionnaires were designed and field surveys were conducted. The sample selection strategies were mainly as follows. (1) Select the main person in charge or the person with professional experience in each agricultural department. (2) Choose rural areas with severe drought and developing economy as sample villages to ensure the representativeness. (3) Choose large tenants and small holders of land to ensure sample diversity.

Based on the above strategy, we conducted 4 times of fieldwork from Feb. 13th – 17th, Sep. 9th – 13th, Nov. 27th – Dec. 3rd in 2017 and Sep. 17th – Oct. 8th in 2018. Open interviews and questionnaires were used to collect data of mutual contact. We investigated units at the district, township, village, and individual scale levels. **For the district-level,** we visited the government, the Civil Affairs Bureau, the Agriculture Bureau, the Water Conservancy Bureau, the Drought Relief Headquarters, the Meteorological Bureau, the Finance Bureau, and the Development and Reform Bureau to collect 19 questionnaires. **For the township level,** a total of 71 questionnaires were collected from all the towns including the Governments, Agro-technical stations, Water Conservancy Stations, and Civil Affairs Offices. **For the village level,** we interviewed 56 Village Committees, including the Party Secretary, Accountant, and collected 168 questionnaires and we randomly sampled households to collect 1009 questionnaires. **For the individual enterprise level,** we also visited the main agricultural enterprises, where a total of 8

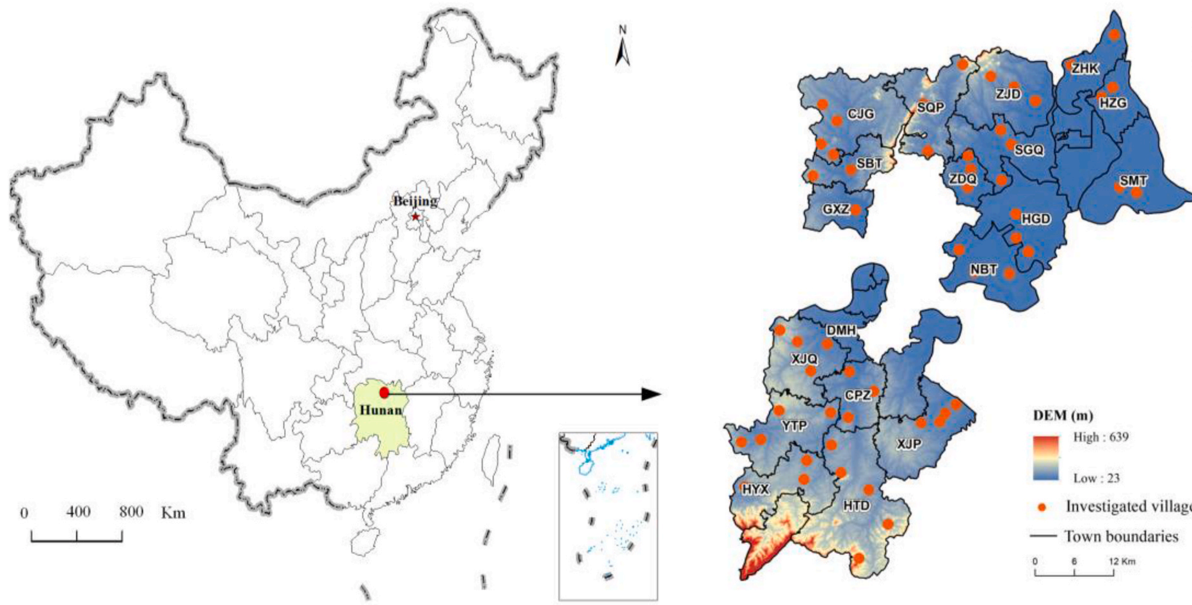


Fig. 1. Location of Dingcheng District and distribution of investigated villages.

$$D - Value = Precipitation - Crop\ water\ demand \quad (1)$$

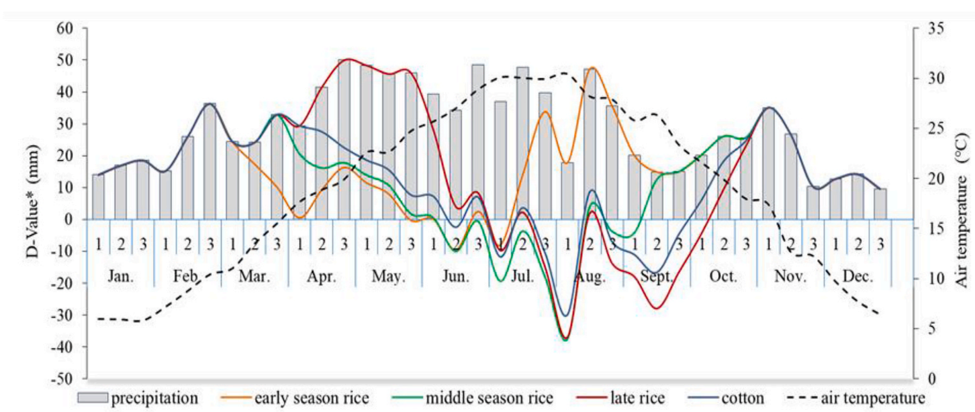


Fig. 2. Matching of precipitation and water demand of crops in Dingcheng District, *D-Value: difference between the precipitation and water demands of crops in the corresponding growth period, and if D-value is negative, indicating crops are in a state of water deficit and more prone to drought in the corresponding growth stage.

questionnaires were collected (there were approximately 10 related enterprises in Dingcheng). A total of 1275 valid questionnaires of all kinds of stakeholders were collected (The validity rate of the questionnaire reached more than 95%). The statistical characteristics of the sample were shown in Appendix 1.

2.3. Methods

2.3.1. Basic idea

Based on the idea of multi-scale, multi-stakeholder, multi-process, and multi-indicator synthesis, this study constructed a research system of social network efficiency. It was mainly carried out through the following steps (Fig. 3): (1) A social network of drought risk governance was built based on the information, material, and technology exchanges of the multi-stakeholders in three phases (before, during, and after drought). (2) From core stakeholders' view, the extent of their contact was analyzed through the connection proportion (ci, Formula 1). (3) Referring to the idea of "quantity" + "quality" with bidirectional perspective, we constructed 5 indicators (a, b, c, d, e) as set out in Table 1. The quantity was expressed through "a", while "b, c, d and e" expressed the quality of relationship. The integrated connection efficiency between stakeholders was obtained by the average of the 5 indicators. Finally, there was a bidirectional analysis between each pair of stakeholders (Stakeholder A ⇄ Stakeholder B).

2.3.2. Questionnaire and literature analysis

(1) Questionnaire: From 2017 to 2018, 3 surveys were conducted to obtain the data. The main contents of the questionnaires were as follows. a. The basic information of the interviewees, such as their working years and job responsibilities. b. Their perception of the local drought; for example, their attention to the drought, their perceived risk of the local drought, their perceived impact of the drought on the local life, and their perceived necessity to prevent the risk of drought. c. Nominate the stakeholders that they cooperate with and how they fight drought; for example, in the phase of preparedness, response, and recovery, which stakeholders need to be contacted, what kind of information needs to be

Table 1
Social network investigation of various stakeholders*(main contents of questionnaire).

Indicator*	Questions	Response	People**
Ci	Have you ever had contact with the following people?	1. Yes 2. No	GD,AD, WD,CD, MD,FD, DD, GT, AT,WT, CT, VC, HO,AE, IC
A	How often do you discuss with the following people?	Three-point scale (not at all discussed to strongly discussed)	
B	How clear are you to the job of the following people?	Five-point scale (not at all clear to strongly clear)	
C	How much do you think the following people are helpful to you?	Five-point scale (not at all helpful to strongly helpful)	
D	How much do you trust the information provided by the following people?	Five-point scale (not at all trust to strongly trust)	
E	How convenient is your communication with the following people?	Five-point scale (not at all convenient to strongly convenient)	

Indicator*: (1) ci (Connection proportion); a(Communication frequency, which is an expression for the number of communication times of stakeholders); b (Functional understanding degree, which shows the understanding of each other's work content, responsibilities and so on); c (Assistance effectiveness degree, which shows the effectiveness of help from others in solving their own difficulties); d (Trust degree, which shows the trust on the information provided by others); e (Communication convenience degree, which is a description of the communication convenience between stakeholders).
People**: **District-level:** Government (GD), Civil Affairs Bureau (CD), Agriculture Bureau (AD), Water Conservancy Bureau (WD), Meteorological Bureau (MD), Finance Bureau (FD), Development and Reform Bureau (DD). **Township level:** Governments (GT), Agro-technical stations (AT), Water Conservancy Stations (WT), and Civil Affairs Offices (CT). **Village level:** Village Committees (VC), Households (HO). **Individual enterprise level:** Agricultural Enterprises (AE), Insurance Company (IC).

exchanged, and how to distribute disaster relief materials. d. Evaluate their cooperation using the Likert scale mentioned in Table 1. (2) Literature analysis. Collects documents such as emergency plans for drought relief of relevant departments, government plans for responding to natural disasters, county statistical yearbooks and so on, supplementing the material and information exchange between stakeholders. Combining the above two methods, the social network for disaster processes in respect of before, during, and after the drought was set up.

2.3.3. Quantitative analysis of multiple indicators

Quantitative analysis of multiple indicators is widely used in many research [48,49]**.** In this study, the indicators in Table 1 are calculated in the following two ways (Formula 2,3,4). In the formulas, connection proportion ($\boldsymbol{CI_{SA}}$) reflects the extensive degree of contact between the stakeholders (based on the network topology); connection efficiency for each indicator ($\boldsymbol{In^x_{(S\to A)}}$) and the integrated indicator ($\boldsymbol{Ing_{(S\to A)}}$) are the quantification results of connection efficiency considering of "soft factors":

(1) Calculation of the connection proportion ($\boldsymbol{CI_{SA}}$). The question1 in Table 1 was used to calculate $\boldsymbol{CI_{SA}}$. formula 2 is as follows:

$$CI_{SA} = \frac{N_{SA}}{S_{sum}} \tag{2}$$

$\boldsymbol{CI_{SA}}$,. is the connection proportion from the perspective of the S group responding to whether they have had contact with A, $\boldsymbol{N_{SA}}$ is the number of people in the S group who have had contact with group A, and ***Ssum*** is the total number of people in group S being surveyed.

(2) Calculation of the single and integrated connection efficiency. The former is the normalization process, and the latter is the integrated process. The indicators a, b, c, d, and e in Table 1 correspond to one question. (I) For each indicator, the score of each person in each group is standardized and then averaged, which represents the connection efficiency for one single indicator $\boldsymbol{In^x_{(S\to A)}}$ (Formula 3). (II) We then obtain the integrated connection efficiency $\boldsymbol{Ing_{(S\to A)}}$ by averaging all the 5 single connection efficiency (Formula 4, There are two main ways to integrate indicators: one is weight assignment, and the other is directly the sum or the average of scores [50]. The paper refers to the first method for indicator integration. Each indicator is considered equally important, so the weights here are the same).

$$In^x_{S-A} = \frac{1}{Ssum}\sum_{i=1}^{Ssum}\left(\frac{xi - x\min}{x\max - x\min}\right) \tag{3}$$

$$Ing_{S-A} = \frac{1}{5}\left(In^a_{S-A} + In^b_{S-A} + \ldots\ldots + In^e_{S-A}\right) \tag{4}$$

$\boldsymbol{In^x_{(S\to A)}}$ is the single connection efficiency from the perspective of the S group, who assess their connection with group A at the $\boldsymbol{x}$ indicator. ***Ssum*** is the total number of the S group being surveyed. $\boldsymbol{x_i}$ is the score of the *i*th respondent of the S group at the indicator $\boldsymbol{x}$, and the $\boldsymbol{x}$ are the indicators of a, b, c, d and e, respectively. $\boldsymbol{Ing_{(S\to A)}}$ is the integrated connection efficiency from the perspective of the S group members in assessing their connection with the A group.

3. Results

3.1. Construction and analysis of social network of drought risk governance in dynamic process

The study constructed a social network of drought resistance process showing different scales and stakeholders in 3 phases (before, during, and after the drought) to exchange material, information, and technology. It lays a foundation for studying the connection efficiency of the multi-stakeholders (The abbreviations in the text are shown in the legends):

Before drought happens, on the district scale, CD signs an agreement on disaster relief materials with the supermarket (SU) in advance, MD carries out drought monitoring and forecasting, AD promotes high-quality planting varieties, and WD arranges the maintenance work on the conservancy facilities. On the town scale, AT sells seeds and guides technology, and WT inspects the main reservoirs and ponds of each village. On the village scale, VC communicates with HO on the policies and regulations promulgated by the higher authorities. In addition, insurance was recommended to HO by the government and village committees. At this time the network is dominated by the government and shows the characteristic of "top-down and no crossover of each main kind of stakeholders" (Fig. 4a).

During the drought, WDH is established to dispatch all major departments. On the district scale, WD is responsible for pumping and transferring water. AD is responsible for field production guidance, CD delivers relief materials, MD transmits meteorological data, and artificial rainfall is required in an emergency. Other departments are always ready to cooperate with relief work. On the town scale, the drought-relief headquarters of each town (WTH) is established to lead other stations, AT guides the drought-resistant seedlings, WT commands the water transfers, and CT is responsible for the distribution of disaster relief materials. On the village scale, the emergency response team (VCT) is established to lead others and HO go into the field almost every day. At this time the network is dominated by the WTH and shows the characteristics of "synchronization with top and down, and the multi-stakeholders have close connections" (Fig. 4b).

In the post-drought phase, on the district scale, GD organizes employment recruitment and AD guides the adjustment of the planting structure. At the town and village scales, IC and AD carry out drought

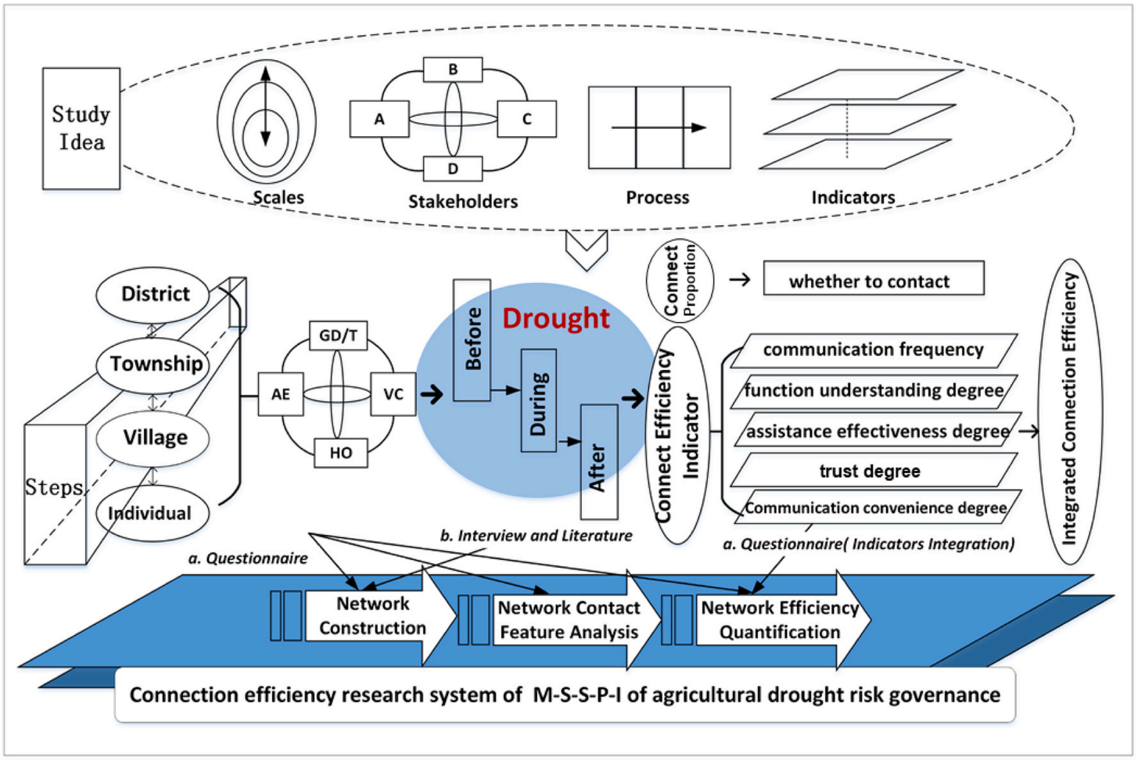


Fig. 3. Research Flow. The study is based on the ideas of M-S-S-P-I (1) The scales include district, township, village and individual scales. The stakeholders include government leaders, village committees, households, agricultural enterprises, and others. The drought process refers to the phases of before, during, and after a drought; The multiple indicators comprise the connection proportion (ci), communication frequency (a), functional understanding degree (b), assistance effectiveness degree (c), trust degree (d), and communication convenience degree (e). (2) The research is carried out by the following steps: First, construct a social network of drought risk governance. Second, based on network topology, calculate the connection proportion (ci) to analyze the network characteristics. Finally, quantify the network connection efficiency by a number of soft indicators (based on weight assignment and indicator integration).

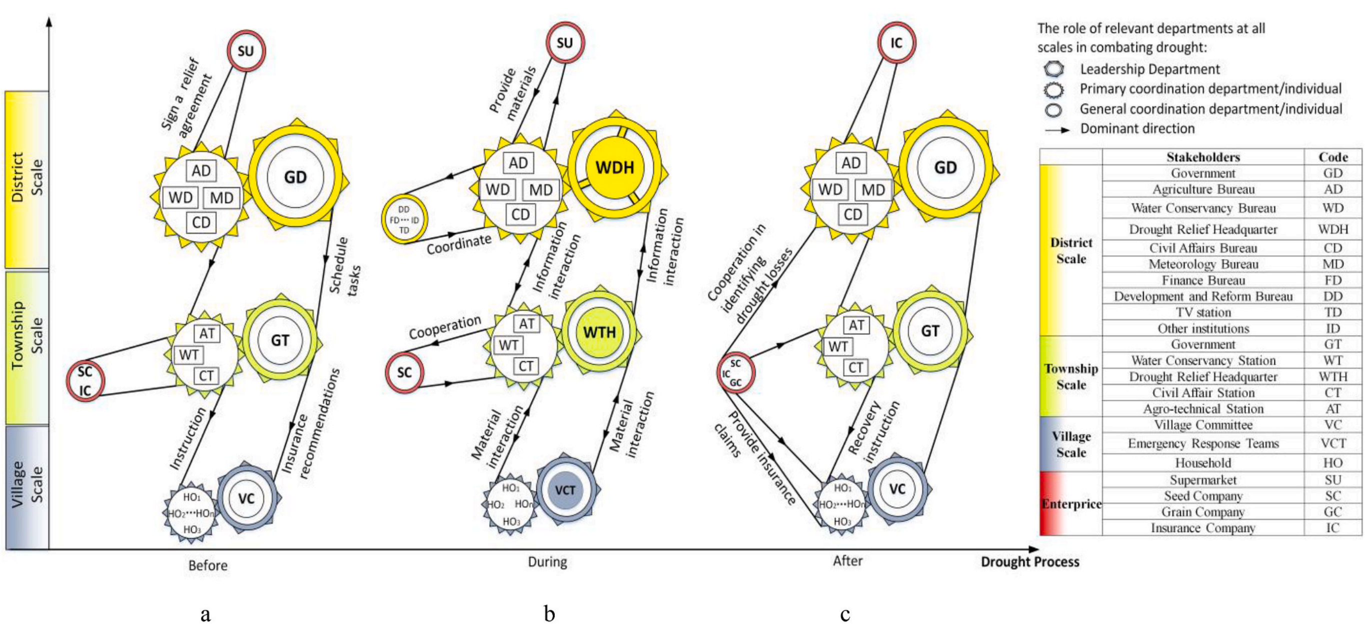


Fig. 4. Social network system of drought process in Dingcheng District, (1) The symbols and table on the right side of the figure are legends. The symbols (different gears) represent the stakeholders that play different functions in the drought resistance process. The table is divided into four dimensions: district, township, village, and enterprise. Each dimension has different stakeholders and a corresponding abbreviation. (2) Within the coordinates is the social network system for drought risk governance. The X-axis represents the disaster process, the Y-axis is the different scales, the line between the gears is the connection between the corresponding stakeholders, and there are descriptions of information and material exchanges of stakeholders on the line. (3) It is to display the entire drought-resistance social network (management structure), which involves the leadership, core, and general stakeholders in the drought-resistance process, so there are a large number of 22 stakeholders. (4) It also shows the government-led management system. The lines between the stakeholders does not indicate the connection proportion and the connection efficiency.

investigation and assess the insurance claims, and AE eases the losses by grain purchases and market price adjustments. HO will replant or go out to work according to the extent of the losses. At this time HO are passive in the contact process, their resilience is weak, and the network shows the characteristics of “bottom-up and market-dominant” (Fig. 4c).

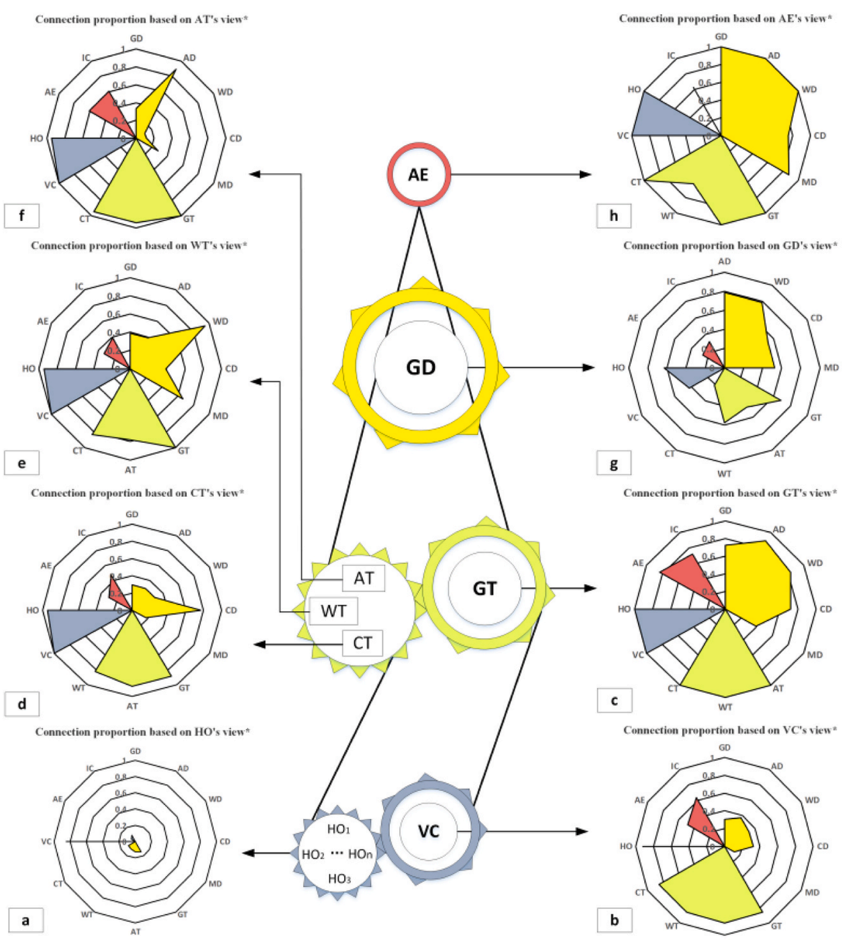
Overall, the social network of the dynamic process presents differences in terms of the phase and scale. The higher the scale of the stakeholder, the more adequate is the drought preparedness. The positivity of HO and social forces to participate in the disaster preparedness, as well as the GD and GT’s guidance in drought recovery (such as multi-channel publicity, large-scale guidance of technology and employment) need to be improved in the cooperation to resist droughts.

3.2. Analysis of social network contact characteristics from the perspective of core stakeholders

In order to research the breadth of the connections between the stakeholders, this study calculated the connection proportion from the perspective of 8 core stakeholders. Each radar chart in Fig. 5 is from the perspective of the 8 core stakeholders.

In the village scale, **from the view of households (HO)** to assess contacts between themselves with others, the average connection proportion was 0.12 (i.e. the mean of all values in Fig. 5a), and the range (the difference between the maximum and minimum values in Fig. 5a) reaches 0.85*(The greater the average, the greater the contact breadth; the greater the range, the greater the contact bias). The contact breadth between HO and others is small, and HO’s communication object is relatively single, and VC are their main contact objects. **From the view of VC,** the average connection proportion was 0.58 and the range was 0.79 (Fig. 5b). VC is important in connecting superior and subordinate stakeholders. The breadth of contact between VC and others is higher than that of HO, but the unbalance of communication objects is also prominent.

In the town and district scale, the town government (GT) has special departments in charge of agriculture and water conservancy, respectively. From the view of GT, the average connection proportion was 0.84 and the range was 0.61 (Fig. 5c), GT communicates with a large number and many types of stakeholders, and the contact breadth between GT and others is relatively large, and the unbalance of communication objects is relatively small. From the view of CT, WT, and AT, they have the most contacts with the stakeholders at the village scale, those are at the same level and the direct superior level (Fig. 5d,e,f), and it can be seen that these departments have a wide contacts with their counterparts and directly affiliated departments. From the view of district government



	Stakeholders	Code
District Scale	Government	GD
	Agriculture Bureau	AD
	Water Conservancy Bureau	WD
	Civil Affairs Bureau	CD
	Meteorology Bureau	MD
Township Scale	Government	GT
	Water Conservancy Station	WT
	Civil Affairs Station	CT
	Agro-technical Station	AT
Village Scale	Village Committee	VC
	Household	HO
Enterprise	Agricultural Enterprise	AE
	Insurance Company	IC

Fig. 5. Connection proportion from different stakeholders’ perspectives, * Explanation of the connection proportion between group A and group B based on A’s perspective: the number of people in group A who have had contact with B/total number of group A being surveyed. (1) Example: in Fig. 5a, based on the households’ perspective (HO), the connection proportion between the households and village committees is 855 (855 households have had contact with the village committees)/ 1009 (a total of 1009 households were surveyed) = 0.85, and the connection proportion between the households and other stakeholders are analogous. (2) Fig. 5b,c, d,e,f,g,and h correspond to the connection proportion based on the perspectives of VC, GT, CT, WT, AT, GD, and AE, respectively. (3) Fig. 5 shows the results of 8 core stakeholders about who they connect. The table in the right displays core and general stakeholders appearing in the radar chart, a total number of 13. (4) The meaning of “the average value, range of connection proportion”: Taking Fig. 5a as an example, the lines pointing to each abbreviation are “connection proportion” from households’ view between themselves and VC, CT, WT, AT, GT, MD, CD, WD, AD, GD respectively. The average of these proportions is 0.12, and the difference of maximum and minimum of these proportions is 0.85. Fig. 5b,c,d,e,f,g,h are analogous.

(GD), the average connection proportion was 0.52, and the range was 0.58 (Fig. 5g). The contact between the GD and others is relatively large, while the unbalance of the communication objects is relatively small.

In the individual enterprise scale, from the view of agricultural enterprise (AE), the average connection proportion was 0.91 and the range was 0.38 (Fig. 5h). It can be seen that the enterprise has a wide contact with others, meanwhile, the unbalance of their communication objects is the smallest. We learned that from investigation, for the benefit of enterprises, they need to communicate with various types of government departments at all levels, households and many other stakeholders, which is one of the reasons for their wide contact and low unbalance.

In general, the average and the range of the connection proportion shows the social network breadth from the perspective of each stakeholder are presented as the trend of the enterprise (0.91) > government (0.65) > village committee (0.58) > household (0.12). The connection proportion range of each stakeholder is more than 0.5 except for enterprises. Except for AE, stakeholders are biased to some degree, especially for HO, they have a strong degree of closure, bias, and geographical restrictions [51,52].

3.3. Quantification of the social network efficiency with multiple indicators from a bidirectional perspective

In order to further explore the connection efficiency (depth) between stakeholders, combined with the calculation scores (based on formula 3 and 4) and the information obtained from the interviews, this paper analyzes the single and integrated connection efficiency respectively. The higher the indicator value, the higher the connection efficiency is considered.

Each square in Fig. 6 is an index evaluation of the stakeholder in the Y-axis to the stakeholder in the X-axis, and two symmetrical squares with the diagonal axis is a bidirectional evaluation of a pair of stakeholders. The lighter the square color, the lower the evaluation score; the greater color difference between the square pairs, the greater the difference between bidirectional evaluation (i.e. "gap").

The communication frequency (Fig. 6a) reflects the frequency of communication between the stakeholders (i.e., the "quantity" evaluation). In general, the assessments of the village scale stakeholders were low; the mutual assessment differences of the stakeholders at village and district scale were the most obvious. From the perspective of households (HO), they had fewer contacts with others. From the perspective of village committees (VC), they had frequent contacts with HO and government at township (GT), with a maximum of 0.96. From the perspective of agro-technical station (AT), civil affairs station (CT), and water conservancy station (WT), their connection frequency with HO, VC, and peers were above 0.8. From the perspective of agricultural enterprise (AE), the frequency was between 0.6 and 0.75. The evaluations by HO was mostly lower than the evaluations given to them by others, with a maximum gap of −0.67 (with water conservancy bureau (WD)), while the gaps in the mutual evaluations of other stakeholders were small.

The functional understanding degree (Fig. 6b), assistance effectiveness degree (Fig. 6c), trust degree (Fig. 6d), and communication convenience degree (Fig. 6e) are reflections of the communication effects ("quality" evaluation). In general, the assessments of the stakeholders at village scale were low, and the mutual assessment differences of HO and AE were great. 1) From the perspective of HO, the average of their evaluations of the indicators b, c, d, and e were 0.58, 0.61, 0.56, and 0.68 respectively, and from the perspective of VC, the average of their evaluations of the 4 indicators were 0.87, 0.84, 0.74, and 0.85 respectively. It can be seen that the scores of farmers and village committees' trust for others are the lowest in the 4 indicators (0.56 and 0.74

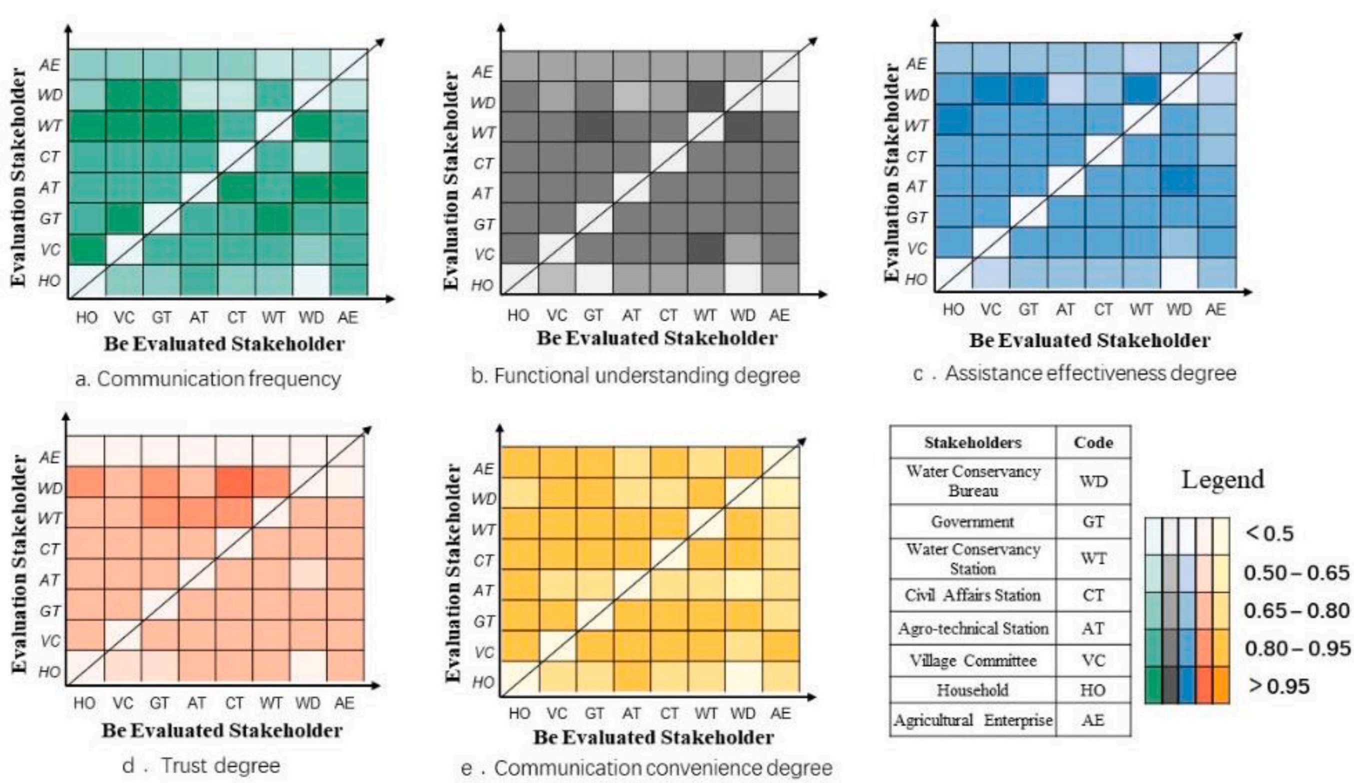


Fig. 6. Social network efficiency of multiple stakeholders in 5 aspects. (1) The Y-axis represents the stakeholders' perspectives, and the X-axis represents the stakeholders who are evaluated. The symmetry result with the diagonal axis is exactly the bidirectional evaluation between the stakeholders. We take Fig. 6a as an example, assuming that the coordinate origin is (0,0), the square of (2,1) in the figure indicates the communication frequency of HO and VC in VC's view, and the square of (1,2), indicates the communication frequency of HO and VC in HO's view.(2) Fig. 6 shows the mutual evaluation of each single connection efficiency among the 8 core stakeholders.

respectively). 2) The evaluations of HO were mostly lower than those given by others, with a maximum gap of −0.83、-0.88、-0.83, and −0.9, respectively, and the gaps of AE were at a maximum of 0.38, while the gaps of the other stakeholders were small.

The integrated efficiency (*Ing*) combines the evaluation of “quantity + quality”, which is the integrated result of 5 connection indicators (Fig. 7). The *Ing* of HO and AE were relatively low, and the *Ing* of VC and the stakeholders of township were slightly higher; the gaps in mutual evaluation of HO as well as AE were quite large. From the perspective of HO, VC, GT, WD, and AE, the maximum values were 0.77, 0.89, 0.92, 0.93, and 0.7, respectively. The evaluations of HO were mostly lower than those given by others, with a maximum gap of −0.8 (with WD), while the gaps of the other stakeholders were in −0.18 to 0.21.

Overall, the “quantity” evaluation reflected the fact that the self-perception of importance of HO in the connection needs to be improved, and the “quality” evaluation presented the trend of $d < e \approx b \approx c$, which implied that promoting trust among the stakeholders is quite necessary. From the view of the stakeholders, the integrated efficiency showed the trend of the HO ≈ AE < VC < GT. The participation of HO and AE in the social network, as well as their interaction with leaders needs to be increased.

4. Discussions

The connection between stakeholders has an important impact on the coordination of the agricultural drought risk governance [53]. The work is expected to provide a reference for drought risk governance:

(1) Establish a social network (government-led management system) for drought risk governance, sort out horizontal (government and industry departments), and vertical (upper and lower department) management systems during the entire drought-resistance process, and understand the responsibilities of stakeholders in the phases of “before, during and after the drought”. The analysis of the above system provides a basis for accountability of risk governance.

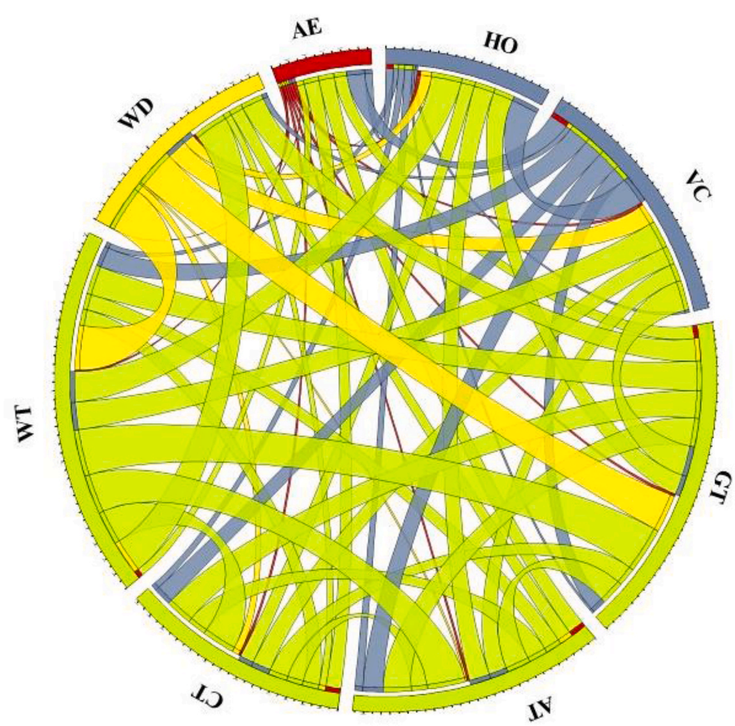
(2) Analyze the extensiveness of communication among core stakeholders, which intends to provide opinions to improve the openness of the stakeholders (for example, more communication channels for farmers are expected to open, so that they can not only talk with the village committees, but also with other technical departments). That is broader exchanges help disseminate information on drought risk governance.

(3) Quantify the “good” degree of contact (connection efficiency), which is to provide opinions for improving stakeholders’ relationship (such as the government should efficiently implement the policy, and common people should cooperate actively, etc.). The improvement of the relationship will help reduce friction in cooperation and improve the efficiency of risk governance.

Meanwhile, in the future, analysis of the contents in Sections 4.1 to 4.2 below may promote the development of soft power research on the connection efficiency of multiple stakeholders.

4.1. Expanding analysis of the impact factors of connection efficiency

Households are the most direct hazard bearing body, and they have the most direct relationship with village committees. The relationship between them is also one of the most significant relationships in the risk governance network. The paper less considered the factors (such as material conditions and risk perception) affecting the stakeholders’ connection under the background of risk governance, so in order to further understand the impact factors, we analyzed the correlation between hard power, soft power impact factors and connection efficiency,



	Stakeholders	Code
District Scale	Water Conservancy Bureau	WD
Township Scale	Government	GT
	Water Conservancy Station	WT
	Civil Affairs Station	CT
	Agro-technical Station	AT
Village Scale	Village Committee	VC
	Household	HO
Enterprise	Agricultural Enterprise	AE

Fig. 7. Bidirectional visualization of the integrated efficiency among multiple stakeholders, In order to express the integrated efficiency more intuitively, this figure amplifies the efficiency by using the exponential function. (1) The strip width $w = 3^{10*Ing}$, the strip emanating from the circumference (no gap with the circle), represents they are the “evaluation stakeholders”, and the strip ending in the circle (where there is a white gap within the circle), signifies that they are regarded as the “be evaluated stakeholders”. (2) Take AE as example, the red color strip is the integrated efficiency with other stakeholders from AE’s perspective, and the other strips ending in the red circumference (with white gaps) are the integrated efficiency with AE from the others’ perspective. (3) Fig. 7 is to show the mutual evaluation of integrated connection efficiency among the 8 core stakeholders.

and then made the following assumptions.

Among the hard power impact factors, the 6 indicators (a, b, c, e, d, Ing in the paper) were positively correlated with the input of production materials, household income per capita, agricultural income, total cultivated land area, and education level of households. The education level passed the 0.01 significant test, with the highest value reaching 0.26. Education has always been considered as an important factor affecting behavior [54,55]. Households with a high education level will be more inclined to communicate with others [56]. To a certain extent, education will promote exchanges and cooperation between stakeholders.

Among the soft power impact factors, the 6 indicators (a, b, c, e, d, Ing in the paper) were positively correlated with drought resistance positivity (p), risk perception (s), risk governance understanding degree (u), and risk governance tolerance (t) (these perception data are obtained from the Likert Scale in the questionnaire). All of them passed the 0.01 significance test (except for the correlation between e and s). The correlation coefficients of p and b, Ing were 0.34 and 0.32, respectively; meanwhile t and c, Ing were both being 0.35. Studies have shown that people with positivity can be more open-minded about communicating with others [57]. People who have a tolerant and understanding attitude towards things will be better at handling interpersonal relationships [58]. It can be seen that increasing positivity and tolerance plays an important role in the cooperation to overcome difficulties.

4.2. Cooperation probability study of multi-stakeholders to resist drought

The connection efficiency in this study reflects the normal state of the social network. When the system encounters an external strike, such as a drought, it is especially important to shift from the normal state to the cohesive state [53]. The normal relationship is the key factor affecting the drought resistance cooperation. How to predict the probability of cooperation from the existing state is a question that is worth exploring.

Scholars paid attention to the linkage probability of stakeholders in the network, which provided many references for the calculation of the cooperation probability [59]. The main methods are node-based prediction, topology-based prediction, social theory-based prediction, and learning-based prediction [60]. The core idea of the above methods is that the similarity between the internal attribute and the external information of nodes affects the probability of contact. The more similar the nodes are, the more likely they are to be connected. There were studies to calculate the linkage probability of two nodes based on the consilience function similarity of the nodes, such as the consistency of their willingness [61,62]. There were also studies that quantify the cooperation probability of nodes considering personal traits. In the future, considering both 6 indicators in this paper and personal attributes in prediction methods mentioned above would be of great significance for calculating comprehensive and dynamic cooperation probability, which is helpful for the research of connection efficiency.

5. Conclusions

The connection efficiency of multiple stakeholders will affect their willingness to cooperate in fighting a drought and thereby influence risk governance. This study built up a M-S-S-P-I connection efficiency research system by constructing the social network in respect of the drought preparedness, response, and recovery process, calculating the connection proportion based on the core stakeholders' perspectives, and quantifying the connection efficiency among them. The research opens up new ideas for the consilience of the multi-stakeholders in integrated drought risk governance.

Combined with a questionnaire and interview, a social network for drought risk governance was set up that included 22 major stakeholders of district level, township, and village scale, and the material and information exchanges were analyzed. It was found that the enthusiasm of households and social forces for disaster preparedness was low, and the government's guidance on drought recovery was weak. The results suggest that the management department should pay attention to encouraging households and social forces to engage in drought preparedness and the government needs to strengthen its recovery guidance.

The connection proportion between the core stakeholders and others was calculated. The average connection proportion from the perspective of stakeholder presented the trend of enterprises (0.91) $>$ government (0.65) $>$ village committee (0.58) $>$ household (0.12), and the connection proportion ranges from stakeholder's perspective were mostly above 0.5. The results show that the social network of households has a strong degree of closure, bias, and geographical restrictions, which implies that the openness of the households needs to be improved. This is of great significance for risk governance.

The study built up multiple soft indicators to quantify the connection efficiency between stakeholders. The quantity evaluation shows that the engagement of the households in communication with others still needs to be improved. The quality evaluation presented the trend of $d < e \approx b \approx c$, which implies that promoting trust among the stakeholders is necessary. Meanwhile, the integrated connection efficiency shows the trend of Households $<$ Enterprise $<$ Village Committees $<$ Township Stakeholders, which indicates that the connection efficiencies of households and enterprises are relatively low. The results will provide references for taking drought resistance measures that are oriented towards farmers, enterprises, and village committees, who are important but easily overlooked.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices.

Appendix 1. Statistical characteristics of household sample

Stakeholders	Sex, %		Age, %		Education*, %		Ratio of A*, %		Ratio of B*, %		Income*, %	
HO			□40	2	I	7	□20	45	□20	41	□100	77
	Male	69	40–50	14	II	38	20–40	15	20–40	5	100–200	17
			50–60	38	III	38	40–60	10	40–60	9	200–400	3

(continued on next page)

(*continued*)

Stakeholders	Sex, %		Age, %		Education*, %		Ratio of A*, %		Ratio of B*, %		Income*, %	
	Female	31	60–70	30	IV	14	60–80	9	60–80	16	□400	2
			□70	16	V	2	□80	21	□80	29		
Likert scale average			a	2.3	B	3.7	c	3.7	d	3.2	e	4.7

Note: * ratio of A (Agricultural income); ratio of B (Working income); Income (Annual family income (10^3 rmb)).

Statistical characteristics of village committees, township and district government, and agricultural enterprises.

Stakeholders	Sex, %		Age, %			Working years, %				Education*, %					Likert scale average				
	Male	Female	□40	40–50	□50	□5	5–10	10–15	□15	I	II	III	IV	V	a	b	c	d	e
VC	77	23	18	20	62	22	15	8	55	1	0	11	56	33	2.6	4.3	4.2	3.5	5.0
GT+	90	10	12	54	35	21	7	7	65	0	0	10	11	79	2.7	4.6	4.5	3.9	5.1
GD	83	17	28	39	33	17	17	0	67	0	0	11	0	89	2.7	4.3	4.4	3.5	5.2
AE	86	14	14	0	86	14	29	14	43	0	0	14	43	43	2.2	3.8	3.5	2.2	4.8

*Education: 1 (illiteracy), 2 (primary school), 3 (junior high school), 4 (high school), 5 (college and above).

GT+: GT here includes agricultural technology stations, water conservancy stations, and civil affairs offices in townships.

Appendix 2. Interview with relevant departments of drought management

(1) Respondent information

Gender	Role	Working Years	Familiarity with local drought relief work
1. Male 2. Female	1. Leadership; 2. general staff; 3. others	1. ≤ 5 2. 5-10 3. 10–15 4.≥15	Four-point scale (not at all familiar to strongly familiar)

(2) List the units that cooperate with your department to resist drought

District Scale	Government	Drought Relief Headquarters	Water Conservation Bureau	Agricultural Bureau
	Civil Bureau	Finance Bureau	Development and Reform Bureau	
Township Scale	Government Agro-technical Station	Drought Relief Headquarters	Water conservation Station	Civil Station
Village Scale	Village Committee	Emergency Response Teams	Household	
Enterprise	Insurance Company	Seed Company	Grain Company	Supermarket

(3) How does your department cooperate with the above departments? And what do you do in different phases?

Unit___ 1.usual time_______ 2. during the drought__________3. after the drought_________

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