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Development paths of people's sustainable livelihood based on climate change: a case study of Yunnan minority areas

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Abstract

Purpose – This study aims to evaluate the characteristics of climate change in Yunnan minority areas and identify an effective path to promote sustainable livelihoods based on climate change.

Design/methodology/approach – Taking Yunnan Province as an example, based on the expansion of the traditional sustainable livelihood framework, the authors constructed a system dynamics (SD) model of sustainable livelihood from the six subsystems of natural, physical, financial, social, human and cultural and tested the accuracy and effectiveness of the model with data from Cangyuan County. By adjusting these parameters, five development paths are designed to simulate the future situation of the livelihood system and determine the optimal path.

Findings – Climate change has exacerbated the vulnerability of people's livelihoods. In future, each of the five development paths will be advantageous for promoting sustainable livelihoods. However, compared with Path I (maintaining the status quo), Path III (path of giving priority to culture) and Path IV (path of giving priority to economic development) have more obvious advantages. Path II (path of giving priority to people's lives) gradually increases the development rate by promoting people's endogenous motivation, and Path V (path of coordinated development) is better than the other paths because of its more balanced consideration.

Originality/value – The analytical framework of sustainable livelihoods based on the characteristics of minority areas is broadened. By constructing a SD model of the livelihood system, the limitations of traditional static analysis have been overcome and a development path for promoting sustainable livelihoods through simulation is proposed. This study offers a theoretical framework and reference method for

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livelihood research against the backdrop of climate change and a decision-making basis for enhancing climate adaptability and realizing sustainable livelihoods.

Keywords Climate change, Livelihood vulnerability, Sustainable livelihood, System dynamics model, Path of coordinated development

Paper type Research paper

1. Introduction

Climatic conditions are the sum of the temperature, precipitation, relative humidity, solar radiation and other atmospheric elements and their changes. Climate change usually lasts for decades or longer and poses a major threat to the safety of people's lives and property. Its adverse consequences have raised worldwide concern (Ani *et al.*, 2022), particularly in developing countries (Chandio *et al.*, 2022a, 2022b). Specifically, climate change has considerably impacted the utilization of natural resources, infrastructure construction, income increases, people's participation in social organizations, health and education and cultural heritage (Adger *et al.*, 2005). Climate change has led to an increase in extreme weather events. The negative effects of extreme climate are more severe than those of general climate change, and as such, they have drawn the attention of academic researchers and policymakers (Meehl *et al.*, 2000; Easterling *et al.*, 2000). The human society is gradually becoming vulnerable to climate change, which is not conducive to maintaining social stability and sustainable benefits (He *et al.*, 2021). As climate change and extreme climate phenomena continue, their impacts will expand. Hence, research on climate change should consider not only the ecological environment but also local cultural traditions, economic development, social welfare, culture and education, among other broad areas (Aryal *et al.*, 2018).

Earlier studies have discussed the impact of climate change on farmers' planting strategies (Wu *et al.*, 2021), biodiversity (Zhu *et al.*, 2015), transportation infrastructure (Kim and Li, 2020), financial stability (Liu *et al.*, 2021), tourism income increase (Leal Filho, 2022), human security and development (Ani *et al.*, 2022), death and injury rates and social psychological pressure (Cheng *et al.*, 2010), social cooperation networks (Ofoegbu and New, 2021), cultural responses (Garai *et al.*, 2022) and other fields. These studies cover natural, physical, financial, social, human and cultural categories that are directly related to people's lives. However, these studies tended to focus on a single area and failed to discuss the impact of climate change on people's livelihoods. In addition, although the impact can be evaluated, the simulation and control function of future development trends based on the background of climate change are weak; thus, it is difficult to find problems in the process of livelihood development and then propose a specific path for sustainable livelihood development. The definition of livelihood was first proposed by Robert Chambers, who believed that it was a way to make a living based on assets, capabilities and activities. When people are faced with pressure and disasters, if they can restore, maintain or even improve their assets and provide the following generation with more opportunities to survive and flourish, their livelihoods can be considered sustainable (Natarajan *et al.*, 2022). The sustainable livelihood theory assumes that people live in vulnerable backgrounds and have multiple livelihood capitals. Different livelihood strategies are formed by adopting distinct ways of livelihood capital combination and utilization, thereby showing differentiated livelihood outputs (Natarajan *et al.*, 2022). With the development of sustainable livelihood theory, several organizations have developed sustainable livelihood frameworks with various focuses. The sustainable livelihood framework established by the UK Department

for International Development (DFID) is widely used (Shahbaz *et al.*, 2007). This framework includes five aspects:

(1) Livelihood capital;
(2) Background vulnerability;
(3) Structure and process transformation;
(4) Livelihood output; and
(5) Livelihood strategies.

The core of this framework is livelihood capital, and people's livelihood capital includes natural, physical, financial, social and human capital. In this study, the sustainable livelihood framework organically integrates the impacts of climate change on natural, physical, financial, social and human systems and provides a scientific analysis framework for the construction of a sustainable livelihood system model based on the characteristics of various livelihood capitals. Consequently, in the context of climate change, to reduce losses caused by climate change and promote sustainable socioeconomic development, it is necessary to effectively integrate climate change and sustainable livelihoods and explore the development path of people's livelihoods.

Yunnan Province is not only a guarantee of ecological security in Southwest China but also a strategic channel to maintain national stability and promote national opening-up (Ding *et al.*, 2014). However, Yunnan's unique historical background and geographical environment make it more prone to natural disasters and expose it to higher risks of climate change, which restrict the sustainable development of people's livelihoods (He *et al.*, 2021). Understanding the changes in climate and meteorological disasters in the Yunnan Province and simulating the trend of people's livelihood development against the background of climate vulnerability are essential for formulating policies for economic and social development.

The unique geographical location of Yunnan Province and the way people live and produce makes the vulnerability of local natural conditions more severe and the challenge of achieving sustainable livelihoods greater. In addition, Yunnan Province has the largest number of ethnic minorities in China, and each minority has a unique culture, religious beliefs and customs. The lifestyles and cultures in ethnic areas are colorful and diverse, and people's livelihoods are considerable different from those of other regions. National culture is similar to the traditional five livelihood capitals, which jointly endorse the sustainable development of people's livelihoods and cannot be ignored. Therefore, it is typical and representative to use Yunnan Province as an example to study sustainable livelihood issues in the context of climate change. This study aims to evaluate the characteristics of climate change in Yunnan Province and find an effective path to promote sustainable livelihoods based on climate change. In this context, this study clarifies the change characteristics of climate and meteorological disasters in Yunnan Province, builds a system dynamics (SD) model of livelihoods based on an improved sustainable livelihood framework and tests the effectiveness of the model. Finally, five development paths were designed for the simulation, and the optimal development path was obtained to promote the sustainable development of economic society and people's livelihoods. The findings and recommendations of this study can also be applied to other minority areas.

This study contributes to existing research in the following ways. First, an analytical framework for sustainable livelihoods in minority areas was constructed. Existing studies are mostly limited to the DFID sustainable livelihood analysis framework, focusing on the natural, physical, financial, social and human fields. However, national culture is the sum of

material and spiritual wealth that can reflect the characteristics of a nation and directly affect the livelihood strategies and methods of people in minority areas. Therefore, by considering the characteristics of minority areas, this study adds to the analysis of local culture, effectively complements the traditional sustainable livelihood framework and provides a reference for promoting the localization of livelihood development in other regions and countries. Second, the development of livelihood systems is simulated dynamically, and the development path of sustainable livelihood is suggested. Existing studies on livelihoods are mostly static analyses, lack long-term dynamic simulations and predictions and fail to present the dynamic processes and evolution laws of livelihood development. The SD model can satisfy the dynamic and complex characteristics of the livelihood system and has unique advantages in analyzing the evolution law of the livelihood system and proposing its sustainable development strategy. Third, climate change has become a common problem facing the whole country and even the whole world. In the context of climate vulnerability, this study uses the Yunnan Province as an example to explore the development path of sustainable livelihoods, which can provide an important reference for other regions to cope with the adverse effects of climate change and achieve sustainable development.

The remainder of this paper is organized as follows. Section 2 describes the changes in climate and meteorological disasters in Yunnan Province. Section 3 constructs a SD model for livelihood development and verifies its accuracy. In Section 4, five development paths are designed, and an optimal path is selected. Section 5 summarizes the study and proposes policy implications.

2. Analysis of climate change and meteorological disasters in Yunnan province

Recently, against the background of global climate change, the climate of Yunnan Province has also undergone considerable changes. Abnormal extreme climate events occur frequently, and meteorological disasters are more serious. Affected by this model, Yunnan Province is more vulnerable to the impact of climate change owing to its unique geographical terrain (Cheng and Xie, 2008). According to statistics, among the natural disaster losses in Yunnan Province, the disaster losses caused by climate change are the heaviest (Li and Li, 2013). The number of rainfall days in Yunnan gradually decreased, whereas the rainstorm frequency increased. In addition, the cold air activities on the low-latitude plateau were less than those in the north, making it more difficult for Yunnan to resist the cold and more vulnerable to losses caused by strong cold air and cold-wave weather. Therefore, the low-temperature and frost disaster has become one of the main disasters in Yunnan (Yao *et al.*, 2018). Yunnan is a province in China prone to hail disasters. Owing to the high disaster rate of hail, the gale, hail and lightning disaster has also become the most common meteorological disaster in Yunnan (Duan *et al.*, 2017).

To clarify climate change and meteorological disasters in Yunnan Province, the main natural disasters in Yunnan Province from 2015 to 2019, such as rainstorm induced flood (landslide and mud–rock flow); gale, hail and lightning disaster; and low-temperature and frost disaster, were compared with the national average level, and the total meteorological disaster situation of various meteorological disasters in Yunnan Province was summarized and analyzed.

The data in this study were obtained from the Yearbook of Meteorological Disasters in China, the Yearbook of Lincang, the Yearbook of Cangyuan Wa Autonomous County and the relevant government documents from 2015 to 2019, reflecting the climate and meteorological disasters in Yunnan Province. To build the SD model of sustainable livelihood, relevant data on the natural, physical, financial, social, human and cultural

subsystems of Cangyuan Wa Autonomous County in Yunnan Province were collected, and the descriptive statistics are shown in Table 1.

A summary of the rainstorm-induced flood (landslide and mud-rock flow) disaster is presented in Appendix Figure A1. The disaster area of crops in the Yunnan Province in 2015, 2017 and 2018 were 231,000 hectares, 186,000 hectares and 151,000 hectares, respectively, all of which exceeded the national average. In addition, from 2015 to 2019, the number of people affected by the disaster and damaged houses in Yunnan Province far exceeded the national average. The direct economic loss caused by the rainstorm induced flood (landslide and mud–rock flow) was also high.

As shown in Appendix Figure A2, although the losses caused by the gale, hail and lightning disaster decreased in 2015–2019 and the disaster area of crops was gradually lower than the national average, the number of houses damaged by the gale, hail and lightning disaster and the direct economic loss were significantly higher than the national average.

VarName	Unit	Obs	Mean	SD	Min	Median	Max
GDP	10^8 Yuan	5.00	40.48	4.60	34.05	41.33	47.71
General budget expenditure	10^8 Yuan	5.00	21.61	2.43	18.42	21.07	25.07
Value added of primary industry	10^8 Yuan	5.00	10.43	1.50	8.85	9.98	13.13
Value added of secondary industry	10^8 Yuan	5.00	12.70	1.03	11.61	12.70	14.39
Value added of tertiary industry	10^8 Yuan	5.00	17.35	2.75	13.55	17.54	21.43
Per capita disposable income of urban residents	Yuan	5.00	24,584.40	2,916.24	20,627.00	24,528.00	28,848.00
Per capita disposable income of rural residents	Yuan	5.00	9,595.60	1,273.32	7,899.00	9,498.00	11,513.00
Expenditure of people's living funds	10^8 Yuan	5.00	17.70	2.01	15.56	16.98	20.74
Medical expenditure	10^8 Yuan	5.00	1.67	0.58	1.19	1.51	2.79
Education expenditure	10^8 Yuan	5.00	3.64	0.52	3.02	3.73	4.20
Culture, sports, and media expenditure	10^8 Yuan	5.00	0.23	0.03	0.18	0.23	0.27
Social security expenditure	10^8 Yuan	5.00	3.51	0.44	2.95	3.47	4.23
Population	10^4 People	5.00	18.86	0.12	18.68	18.85	18.99
Rural population	10^4 People	5.00	12.02	0.33	11.59	11.93	12.55
Urban population	10^4 People	5.00	6.84	0.45	6.13	6.92	7.40
Per capita GDP	Yuan	5.00	21,453.74	2,321.61	18,228.05	21,768.67	25,123.75
Number of old-age insurance participants	10^4 People	5.00	11.78	0.50	10.84	11.92	12.22
Number of medical insurance participants	10^4 People	5.00	13.33	5.83	1.67	16.14	16.44
Number of teaching and administrative staff	People	5.00	2,335.80	133.54	2,164.00	2,410.00	2,503.00
Per capita years of education	Year	5.00	8.78	0.50	8.10	8.80	9.50
Per capita road area	Square meter	5.00	16.44	1.47	15.24	15.91	19.27
Number of books in the library	10^4 volumes	5.00	5.77	0.17	5.53	5.75	6.00
Screening times of ethnic films	Time	5.00	1,332.67	199.82	1,075.00	1,361.00	1,562.00
Annual number of domestic and foreign tourists	10^4 trips	5.00	370.51	164.29	163.29	352.96	612.67
Total tourism revenue	10^4 Yuan	5.00	359,399.40	200,818.49	120,992.00	326,701.00	671,657.00
Grain yield	Ton	5.00	77,120.00	1,527.61	74,200.00	77,500.00	78,600.00
Grain crops area	10^4 Mu	5.00	34.23	0.86	32.86	34.76	35.09

Table 1.
Descriptive statistics

Source: Public statistics and authors' calculations

In particular, the number of people affected by the disaster exceeded the national average for five consecutive years, and the disaster had a negative impact on Yunnan Province.

As shown in Appendix Figure A3, the situation of the low-temperature and frost disaster considerably changed from 2015 to 2019. The disaster area of crops and the number of damaged houses decreased; however, the direct economic loss caused by the disaster was extremely serious. The number of people affected by the disaster significantly exceeded the national average, seriously hindering the sustainable development of people's livelihoods.

The overall situation of meteorological disasters during 2015–2019 is shown in Appendix Figure A4. The disaster area of crops in Yunnan Province first decreased and then increased from 2015 to 2019, showing an overall increasing trend, and exceeded the national average for three years. Although the affected population showed a downward trend, the number of people affected by the disaster in Yunnan Province was higher than the national average. The direct economic loss caused by meteorological disasters fluctuated and the losses in Yunnan Province in 2015 and 2018 were also significantly higher than the national average. In 2018, national rainfall increased sharply. Among all types of meteorological disasters, rainstorms and flood disasters are prominent, causing heavy direct economic losses, and Yunnan Province is one of the most severely affected provinces. Therefore, although the economic losses caused by the gale, hail and lightning disaster and the low-temperature and frost disaster were lower than the national level, the total economic losses caused by the rainstorm induced flood (landslide and mud–rock flow) disaster rose sharply, resulting in large total economic losses caused by various meteorological disasters in 2018.

3. System dynamics model

3.1 Methodology

SD can effectively simulate complex systems and has been widely used in system analysis, decision-making and policymaking (Bach *et al.*, 2020). This model can describe the relationship between different exogenous factors and different systems, define and analyze different scenarios (Faeid *et al.*, 2020; Hosseini *et al.*, 2021; Qudrat-Ullah *et al.*, 2018) and determine the optimal strategy by adjusting the parameter values of each scenario (Hendalianpour *et al.*, 2022).

Climate change affects the natural, physical, financial, social, human and cultural fields of people in minority areas, which are the basic elements of their livelihood systems. In this study, the livelihood system includes six subsystems:

(1) Natural;
(2) Physical;
(3) Financial;
(4) Social;
(5) Human; and
(6) Cultural.

Among them, the natural subsystem supports the livelihood system, providing people with living resources; the physical subsystem provides infrastructure and fundamental guarantee for people's production and life; the financial subsystem is the driving force to meet the needs of people's education, health and social interactions; the social subsystem is the integration of natural, physical, financial, human and cultural subsystems, which plays a key role in the transmission of various resources; the human subsystem is the core of the livelihood system and the starting point and foothold of sustainable development; and the culture subsystem is the soul and power source of sustainable livelihoods. From the

perspective of system theory, the six subsystems are interconnected and interact, thereby forming a complex giant system, that is, the livelihood system. Furthermore, livelihood system has a more complex internal structure and action mechanism than common systems. Sustainable livelihood not only depends on the development of each subsystem but also needs to consider the interaction between subsystems. Consequently, SD models are highly applicable and superior for analyzing the feedback relationships among the natural, physical, financial, social, human and cultural subsystems and finding the optimal development path for a sustainable livelihood.

3.2 Subsystem analysis and variable selection

3.2.1 Natural subsystem. The natural subsystem contains the basic resources for regional development and plays a central role in maintaining social resilience, enhancing social well-being and promoting economic growth and sustainable development (Guerry *et al.*, 2015; Bateman and Mace, 2020; O'Keeffe *et al.*, 2022). The area and yield of crops are the basis for ensuring food security and providing important support for sustainable livelihoods (Leng *et al.*, 2019). In addition, grain yield affects people's income and health status and will further affect human, financial and other subsystems (Numfor *et al.*, 2022). Therefore, the natural subsystem mainly focuses on variables, such as grain crop area and grain yield.

3.2.2 Physical subsystem. The physical subsystem includes the production mode and infrastructure required by people to maintain their livelihoods, ensure their basic lives and improve their productivity. Generally, infrastructure plays a key role in maintaining and enhancing urban resilience, mainly including roads, communications, energy infrastructure and other elements. Accessibility to public transport is crucial for reducing vulnerability (Datola *et al.*, 2022), which is reflected in the total length of roads (Shen *et al.*, 2009). On the one hand, with economic development and an increase in investment in infrastructure construction, traffic accessibility has gradually increased. On the other hand, improvements in traffic conditions will promote the development of economic activities and local tourism, forming a virtuous circle that promotes economic growth. Therefore, the core role of road accessibility cannot be ignored in the physical subsystem.

3.2.3 Financial subsystem. Sustainable development of the financial subsystem is the goal and concrete embodiment of sustainable livelihoods. Economic growth provides people with better means of production, educational resources, health services, social networks and cultural accessibility and promotes the development of other subsystems. At the same time, the development of natural, physical, social, human and cultural subsystems will eventually be reflected in economic growth. The main variables involved in the financial system include GDP, per capita GDP, the value added of the three industries, total tourism revenue and the per capita disposable income of urban and rural residents.

3.2.4 Social subsystem. The social subsystem can influence people's attitudes toward climate change based on their social networks, which plays a significant role in enriching their adaptation knowledge, improving their willingness to pay for adaptation costs and improving their ability to cope with the risks associated with climate change (Es *et al.*, 2020). People are aware of the important role of the social system in health and medical care, including mental health, health status, mortality and accessibility to medical care (Zhang *et al.*, 2006). The social system compensates for deficiencies in natural, physical, human and financial systems (Mladovsky and Mossialos, 2008). It plays a decisive role in promoting human health, controlling the increase in medical expenditures caused by accelerating aging and encouraging people to participate in various types of insurance (Peng and Lin, 2018; Ko *et al.*, 2018). Therefore, the social subsystem focuses on participation in old-age and medical insurance.

3.2.5 Human subsystem. The human subsystem is mainly reflected in the population and education levels (Shen *et al.*, 2009), among which education services and status are the keys to sustainable development (Datola *et al.*, 2022). When people are affected by climate change, they pay more attention to improving their viability and weakening their willingness to seek education, thus showing more serious vulnerability (Pandey *et al.*, 2017). In the livelihood system, economic development and close social interaction can promote the optimization of educational resources and the improvement of education levels. With the growth of the population and improvement in education, people will enhance the endogenous power and decision-making ability of development and realize the improvement of natural, physical, financial, social and cultural capital. In this study, the human subsystem includes the total population, urban and rural population, education expenditure, number of teaching and administrative staff and per capita years of education.

3.2.6 Cultural subsystem. The risks and losses caused by climate change will not only appear in material forms but will also put pressure on nonmaterial forms such as culture, values, beliefs and art forms. Different cultural expressions produce different attitudes toward risk, which is key to the study of climate change (Doloisio and Vanderlinden, 2020). With the spread of social system, the cultural system has affected how people produce and use natural resources. A unique cultural atmosphere enhances the attractiveness of local tourism. Hence, the cultural system affects other subsystems of the livelihood system that cannot be ignored. Based on the characteristics of the research area, the cultural subsystem in this study mainly includes the variables of culture, sports and media expenditure; the number of books in the library; and the screening times of ethnic films.

3.3 Model construction

3.3.1 Causality diagram. Based on the analysis and interaction of the above six subsystems, a causality diagram of the sustainable livelihood system is shown in Figure 1.

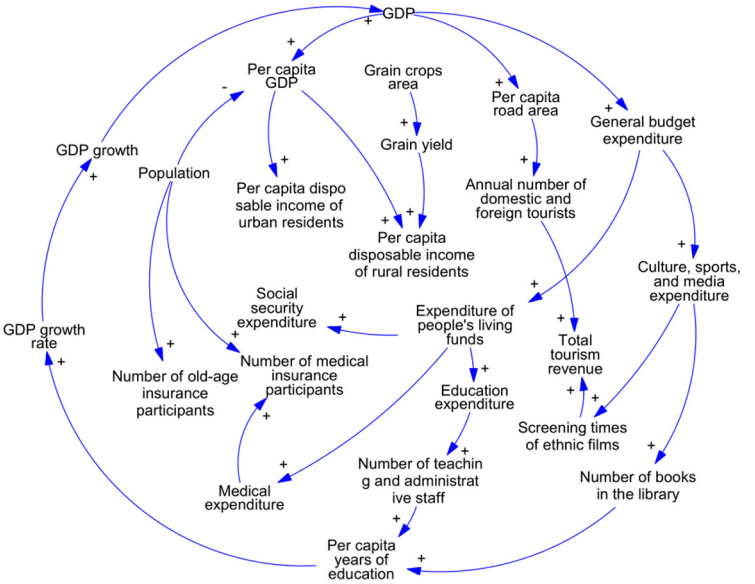
3.3.2 Stocks and flows diagram. Based on the causality diagram of the sustainable livelihood system, a stocks and flows diagram of the sustainable livelihood system was constructed using the Vensim software platform (Figure 2). Using the methods of field investigation, data analysis, variable definition, regression analysis and grey prediction, the values of variables in the model were determined and a SD equation was constructed to describe the quantitative relationship among the variables. The geographical boundary of the simulation is in Cangyuan Wa Autonomous County, Yunnan Province, and the time boundary is 2015–2027. Taking 2015 as the initial year, the simulation interval is one year and 2020–2027 are the forecast years.

3.4 Model verification

After the SD model is constructed, the accuracy of the model structure and operation results should be verified to ensure its applicability to policymaking. Visual inspection showed that the boundaries of the SD model and the structure of the flowchart are reasonable. Furthermore, the equation writing function of the Vensim software confirms the accuracy of the model structure (Hendalianpour *et al.*, 2022). The historical test compares the actual data with the simulation results, ensuring that the model could accurately simulate the real behavior of the system. The formula used is as follows:

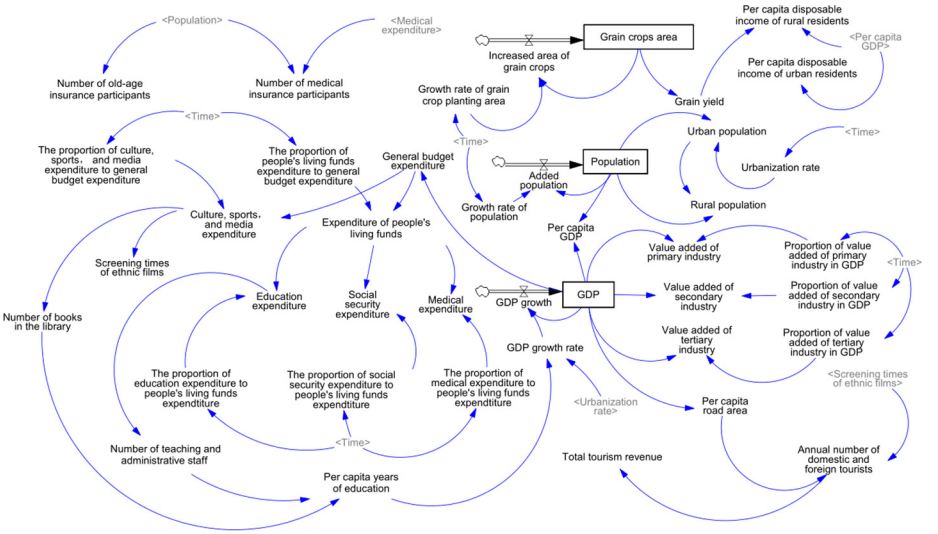
$$Error = \frac{A_t - S_t}{A_t} \times 100\% \tag{1}$$

where A_t signifies the actual value, S_t specifies the analog value and *Error* denotes the error between them. Generally, the absolute value of the error should be within the range of



Source: Created by authors using Vensim PLE software

Figure 1.
Causality diagram of the sustainable livelihood system



Source: Created by authors using Vensim PLE software; authors' calculations

Figure 2.
Stocks and flows diagram of the sustainable livelihood system

10%–15%, which indicates that the model can accurately describe the actual behavior of the system to predict future development (Tian and Li, 2022).

In this study, taking the data of 2015 as the initial value, the development of the livelihood system from 2015 to 2019 is simulated and the simulation results of the main

variables in the system are compared with the real data. As shown in Table 2, the simulation results were consistent with the actual development of the livelihood system. Except for one error that was slightly higher than 10%, the absolute values of the other errors were less than 10% and most of them were less than 5%, indicating that the model can describe the actual behavior of the system well and has a high degree of authenticity. This model can be used to predict the future development of the livelihood system (Liu *et al.*, 2022).

4. Path design and selection

Recently, the climate in Yunnan Province has changed significantly, and the negative impact of meteorological disasters has gradually expanded, becoming the main source of livelihood vulnerability. This has brought great challenges to the development of people's natural, physical, financial, social, human and cultural subsystems. Livelihood vulnerability restricts sustainable livelihoods. To cope with climate change and overcome the adverse impacts of meteorological disasters on people's production and life, a SD model was developed by considering Cangyuan Wa Autonomous County in Yunnan Province as an example to determine the evolution trend of people's natural, physical, financial, social, human and cultural subsystems based on climate vulnerability, effectively deal with the adverse impacts of livelihood vulnerability and better serve sustainable development strategies.

4.1 Path design

By adjusting the model parameters, this study formulates five development paths to simulate and compare the development of livelihood systems under different paths to provide a reference for decision-makers and realize the sustainable development of people's livelihoods.

Path I: Maintaining the status quo. Based on current developments, the simulation was implemented without changing the system parameters.

Path II: Path of giving priority to people's lives. From the perspective of increasing investment in people's lives, this path increases the proportion of people's living funds expenditure to general budget expenditure by 2%, based on Path I, and the other variables remain unchanged.

Path III: Path of giving priority to culture. Starting with the increase in cultural expenditure, this path increases the proportion of culture, sports and media expenditure to general budget expenditure by 2%, based on Path I, and the other variables remain unchanged.

Path IV: Path of giving priority to economic development. Starting with improvements in GDP, this path increases the GDP growth rate by 2%, based on Path I, and the other variables remain unchanged.

Path V: Path of coordinated development. This path comprehensively considers the coordinated development of six subsystems. Based on the above four paths, the proportion of people's living funds expenditure to general budget expenditure; the proportion of culture, sports and media expenditure to general budget expenditure; and the GDP growth rate will increase.

Based on the above analysis, the following research hypothesis is proposed. Compared to prioritizing people's lives, culture and economic development, paying attention to the coordinated development of various subsystems can better promote the realization of sustainable livelihoods.

Table 2.
Comparison of analog values and actual values

Variable	Value	2015	2016	2017	2018	2019
GDP (10^8 Yuan)	Analog value	34.05	35.75	37.94	40.62	44.32
	Actual value	34.05	37.40	41.91	41.33	47.71
	Relative error	0.00%	−4.41%	−9.48%	−1.73%	−7.10%
Value added of primary industry (10^8 Yuan)	Analog value	8.85	8.98	9.03	10.61	12.20
	Actual value	8.85	9.40	9.98	10.80	13.13
	Relative error	0.00%	−4.42%	−9.50%	−1.73%	−7.10%
Value added of secondary industry (10^8 Yuan)	Analog value	11.66	12.14	13.03	11.41	12.22
	Actual value	11.66	12.70	14.39	11.61	13.15
	Relative error	−0.01%	−4.40%	−9.47%	−1.73%	−7.11%
Value added of tertiary industry (10^8 Yuan)	Analog value	13.55	14.63	15.88	18.58	19.91
	Actual value	13.55	15.30	17.54	18.91	21.43
	Relative error	−0.01%	−4.41%	−9.49%	−1.74%	−7.09%
Per capita disposable income of urban residents (Yuan)	Analog value	20,708.90	21,654.00	22,919.80	24,528.70	26,675.30
	Actual value	20,627.00	22,380.00	24,528.00	26,539.00	28,848.00
	Relative error	0.40%	−3.24%	−6.56%	−7.57%	−7.53%
Per capita disposable income of rural residents (Yuan)	Analog value	7,908.00	8,655.53	9,476.68	10,436.40	11,504.80
	Actual value	7,899.00	8,658.00	9,498.00	10,410.00	11,513.00
	Relative error	0.11%	−0.03%	−0.22%	0.25%	−0.07%
Number of books in the library (10^4 volumes)	Analog value	5.46	5.61	5.62	5.75	5.85
	Actual value	5.53	5.65	5.75	5.92	6.00
	Relative error	−1.24%	−0.66%	−2.23%	−2.82%	−2.42%
Screening times of ethnic films (time)	Analog value	1,065.34	1,434.16	1,455.24	1,775.64	2,023.17
	Actual value	1,075.00	1,361.00	1,562.00	–	–
	Relative error	−0.90%	5.38%	−6.83%	–	–
Annual number of domestic and foreign tourists (10^4 trips)	Analog value	168.03	247.22	343.53	465.26	631.22
	Actual value	163.29	233.54	352.96	490.11	612.67
	Relative error	2.90%	5.86%	−2.67%	−5.07%	3.03%
Total tourism revenue (10^4 Yuan)	Analog value	110,695.00	207,704.00	325,684.00	474,806.00	678,109.00
	Actual value	120,992.00	188,189.00	326,701.00	489,458.00	671,657.00
	Relative error	−8.51%	10.37%	−0.31%	−2.99%	0.96%
Per capita road area (square meter)	Analog value	14.61	15.09	15.71	16.48	17.53
	Actual value	15.38	15.24	15.91	16.39	19.27
	Relative error	−5.03%	−0.98%	−1.24%	0.53%	−9.01%

(*continued*)

Table 2.

Variable	Value	2015	2016	2017	2018	2019
Number of old-age insurance participants (10^4 people)	Analog value	10.65	11.11	11.49	11.75	12.27
	Actual value	10.84	11.77	11.92	12.14	12.22
	Relative error	−1.75%	−5.66%	−3.63%	−3.19%	0.39%
Number of medical insurance participants (10^4 people)	Analog value	16.17	16.16	16.11	16.14	16.30
	Actual value	15.98	16.14	16.30	16.10	16.44
	Relative error	1.16%	0.15%	−1.16%	0.23%	−0.83%
Population (10^4 people)	Analog value	18.68	18.8014	18.9029	18.9729	19.1095
	Actual value	18.68	18.78	18.85	18.986	18.99
	Relative error	0.00%	0.11%	0.28%	−0.07%	0.63%
Per capita years of education (year)	Analog value	7.89	8.17	8.41	9.04	9.16
	Actual value	8.10	8.40	8.80	9.10	9.50
	Relative error	−2.61%	−2.74%	−4.40%	−0.67%	−3.60%

Source: Authors' calculations

4.2 Simulation results and path selection

Based on the simulation of the above five paths, this study selects variables such as GDP, value added of the primary industry, value added of the secondary industry, value added of the tertiary industry, per capita disposable income of urban residents, per capita disposable income of rural residents, number of books in the library, screening times of ethnic films, annual number of domestic and foreign tourists and total tourism revenue to display the simulation results under the five paths.

As shown in Figure 3, regardless of the development path adopted, the GDP and value added of the three industries will increase steadily over time. Path I has the slowest development rate, Path IV has a strong promotional effect on the primary and secondary industries and Path III considerably promotes the development of the tertiary industry, thereby realizing steady GDP growth. Compared to Paths III and IV, although the absolute value of economic growth is not dominant in Path II, the economic growth rate accelerates in the long run. This is because increasing expenditures on education, medical care and social security can continuously improve health and education levels and form an endogenous

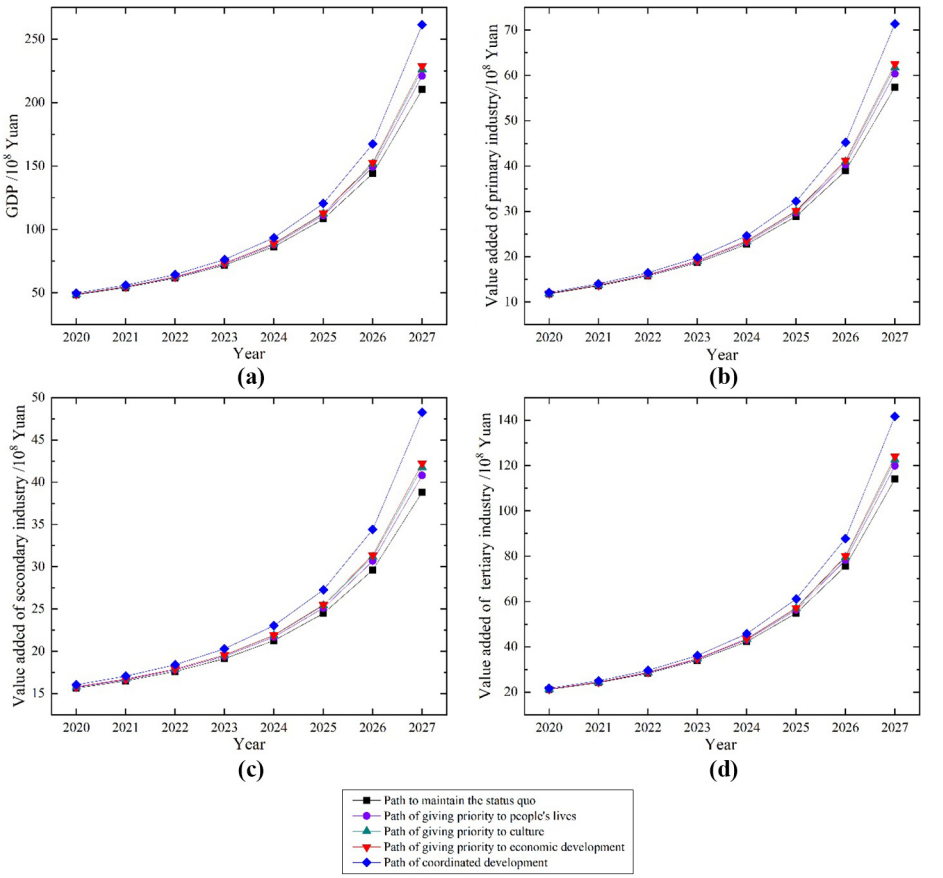
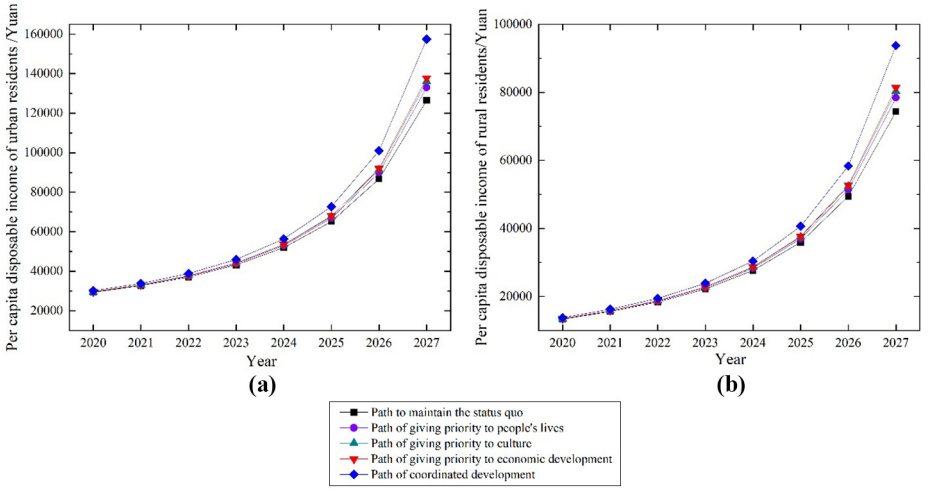


Figure 3.
Simulation results of (a) GDP, (b) value added of primary industry, (c) value added of secondary industry and (d) value added of tertiary industry under five paths

Source: Authors' calculations

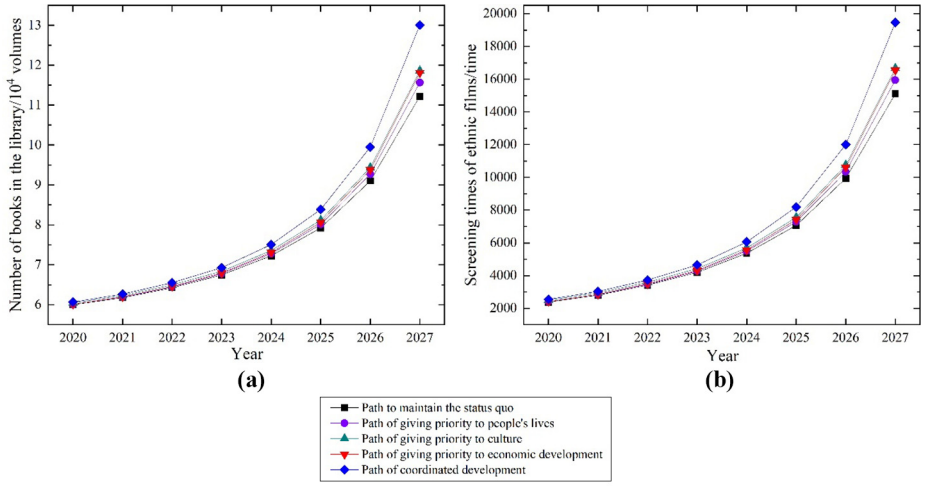
motivation for the sustainable development of livelihoods. Finally, the path of coordinated development considers the people's actual needs in life, culture, economy and other aspects and has the most significant development advantages. Similarly, changes in disposable income for urban and rural residents are shown in Figure 4. The income increase effect of the coordinated development path was most significant, followed by Paths IV, III and II. Although the path to maintaining the status quo will also promote an increase in the disposable income of urban and rural residents, this is not obvious compared to other paths.

As shown in Figure 5, the number of books in the library and the screening times of ethnic films show a gradually accelerating growth trend under different development paths,



Source: Authors' calculations

Figure 4. Simulation results of (a) per capita disposable income of urban residents and (b) per capita disposable income of rural residents under five paths



Source: Authors' calculations

Figure 5. Simulation results of (a) the number of books in the library and (b) the screening times of ethnic films under five paths

but the growth rates are different. Based on different cultural development priorities, compared with Paths II and III, the path of prioritizing culture has considerably promoted the strengthening of the local cultural atmosphere and the improvement of cultural resources and services. In addition, the path of coordinated development shows the greatest advantage in promoting the development of the cultural subsystem.

Local economic development can bring investment growth in infrastructure, road transportation and other aspects and can improve the convenience of tourism. The development and inheritance of the local culture can promote tourism competitiveness, attract more tourists and increase tourism income. As shown in Figure 6, the promotion of the four development paths to tourism was greater than maintaining the status quo. The effects of Paths II–IV strengthened, and the growth rate of the coordinated development path was the largest.

4.3 Discussion

Based on the SD model, five development paths were designed: a path to maintain the status quo, a path of prioritizing people's lives, a path of prioritizing culture, a path of prioritizing economic development, a path of coordinated development and the development situation of the five paths by 2027. The comparative analysis results show that the path of coordinated development considers people's livelihoods, culture and economy and has the most obvious advantages, making it the optimal path for sustainable livelihoods. Thus, the research hypotheses are verified. Based on the feedback relationships between the six subsystems, the following reasons can be derived for the significant advantages of the coordinated development path. On the one hand, economic development has improved people's access to natural resources, infrastructure, culture, education and social security. On the other hand, the dissemination of education, medical care, culture, knowledge and skills can enhance local tourism attraction, production efficiency and people's endogenous motivation, to make livelihood sustainable.

Compared with existing research, although some scholars have studied the impact of climate change on natural (Zhu *et al.*, 2015; Chandio *et al.*, 2020; Zhang *et al.*, 2022; Chandio *et al.*, 2022a, 2022b, 2023), physical (Kim and Li, 2020), financial (Liu *et al.*, 2021), social (Ofoegbu and New, 2021),

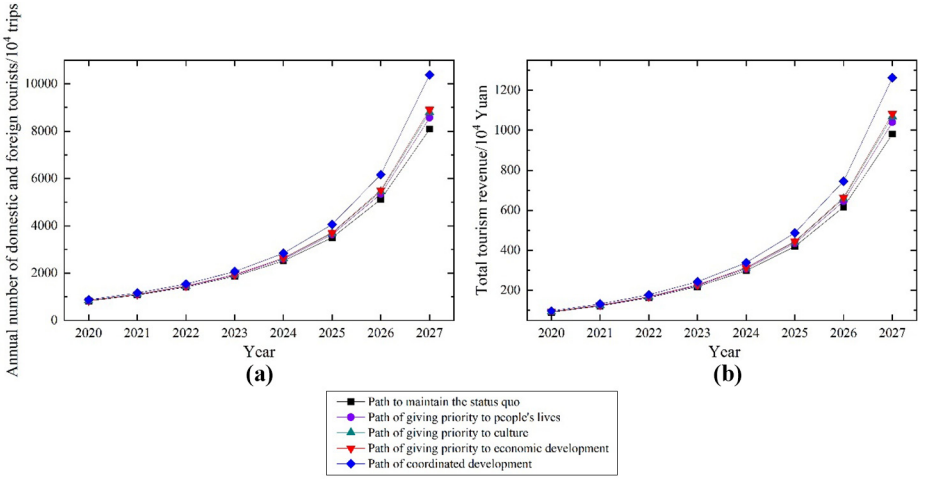


Figure 6.
Simulation results of (a) annual number of domestic and foreign tourists and (b) total tourism revenue under five paths

Source: Authors' calculations

human (Ani *et al.*, 2022) and cultural systems (Chandio *et al.*, 2022a, 2022b), the existing research is scattered and fragmented and the scientific theoretical system cannot be used to effectively integrate the various systems. This study compensates for this deficiency based on a sustainable analysis framework and improves the sustainable analysis framework to better reflect the cultural characteristics of different regions. In addition, existing research on sustainable livelihoods is often limited to static analysis and comparative analysis, which compensates for the existing static analysis by constructing a SD model of sustainable livelihoods and dynamically simulating and predicting the level of development under five paths, which can ultimately produce the optimal development path for sustainable livelihoods.

5. Conclusion and policy implications

Founded on the analysis of climate characteristics from 2015 to 2019, the changes in climate and meteorological disasters in Yunnan Province are clarified. The authors constructed a sustainable livelihood SD model that includes natural, physical, financial, social, human and cultural subsystems and designed five development paths by adjusting the model parameters. Hereafter, the performances of the five paths are simulated and compared to explore the optimal livelihood development path over the next eight years. The conclusions are as follows: climate change has brought about serious livelihood vulnerabilities that are closely related to sustainable livelihoods. Yunnan is a region inhabited by ethnic minorities in China, as well as a poverty-stricken area. Ethnic minorities, especially in mountainous areas, depend mainly on the weather for food and are more vulnerable to climate change and natural disasters. Under the guidance of the Sustainable Development Goals, it is necessary to effectively link climate change and livelihood research and pay more attention to cultural systems. Although maintaining the status quo and giving priority to the development of the economy, people's lives and culture are conducive to the improvement of people's quality of life, the path of coordinated development can better achieve stability and long-term development of people's livelihoods.

This study has several policy implications. First, government departments should attach great importance to the effect of climate change on livelihood development. Climate change constitutes the background of livelihood vulnerability and affects all subsystems of the livelihood system. In the current context of global climate change, to promote the stable development of social economy, governments at all levels must pay more attention to the characteristics of climate change and its possible losses, formulate early warning and response mechanisms in advance and incorporate responses to meteorological disasters into local economic construction and social development planning to ensure that losses from climate change can be minimized. Second, the authors focus on the integrated and coordinated development of different capital types. When the government formulates relevant development policies, it should not only protect and develop superior capital but also constantly optimize livelihood shortcomings, narrow attribute differentiation and promote the transformation between different livelihood capitals. With respect to the natural subsystem, minority areas often have fragile ecological conditions and limited recovery capacity, and once destroyed, they find it difficult to repair themselves, which is not conducive to the long-term development of the local people. Therefore, in the process of developing and constructing villages in minority areas, it is necessary to strengthen the awareness of environmental protection, pay attention to the protection of ecology and pay attention to the protection of architecture and reasonable layouts, especially for the protection of local historical monuments and other cultural heritage sites. In terms of the physical subsystem, it is necessary to focus on improving the transportation situation, strengthening the improvement of infrastructure such as water and electricity and

increasing investment in infrastructure. Different administrative regions should break boundaries and establish regional linkage mechanisms. Regarding the financial subsystem, government departments should be fully based on the natural environment and resource conditions of ethnic minority areas and focus on creating special industries with ethnic advantages by conducting research, understanding market demand, systematically conducting scientific industrial planning and guiding industries to follow paths suitable for local development. In the social subsystem, the government should strengthen guidance to increase the participation rate in pension and medical insurance. In addition, community events such as folk-dance competitions, film screenings, reading events, singing competitions, folklore shows and ethnic embroidery competitions need to be organized regularly to broaden people's social networks. In terms of the human subsystem, all regions should conduct health promotion actions, strengthen the construction of teaching staff, implement educational support policies and improve their education levels. At the same time, schools and teachers should provide psychological counseling to minority students and guide them to enjoy equal education. Regarding the cultural subsystem, relevant departments need to improve the cultural protection system, raise awareness about cultural protection and properly protect traditional national cultural heritage and relics. At the same time, it is necessary to promote the integration and development of cultural tourism, highlight the connotation of national culture, enrich the forms of cultural tourism and enhance its competitiveness.

Its shortcoming is that this study is only based on the background of climate change, and the simulation results show the development path of sustainable livelihoods in the future without considering livelihood strategies, which is a subject worthy of further study. Therefore, a better understanding of the differences in sustainable development paths with different livelihood strategies is required. In future studies, by comparing the development of livelihood capital using different livelihood strategies, the authors propose targeted sustainable livelihood development suggestions for people with different lifestyles.

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Further reading

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Appendix

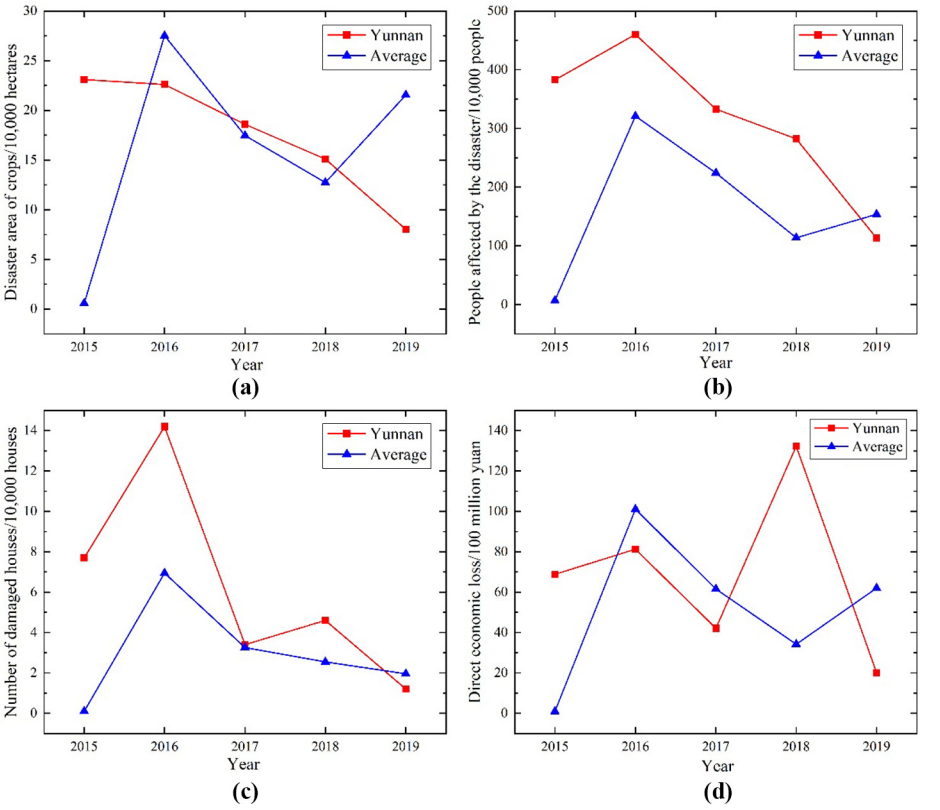

Figure A1. Rainstorm induced flood (landslide and mud–rock flow) disaster situation of (a) crops, (b) people, (c) houses and (d) the economy

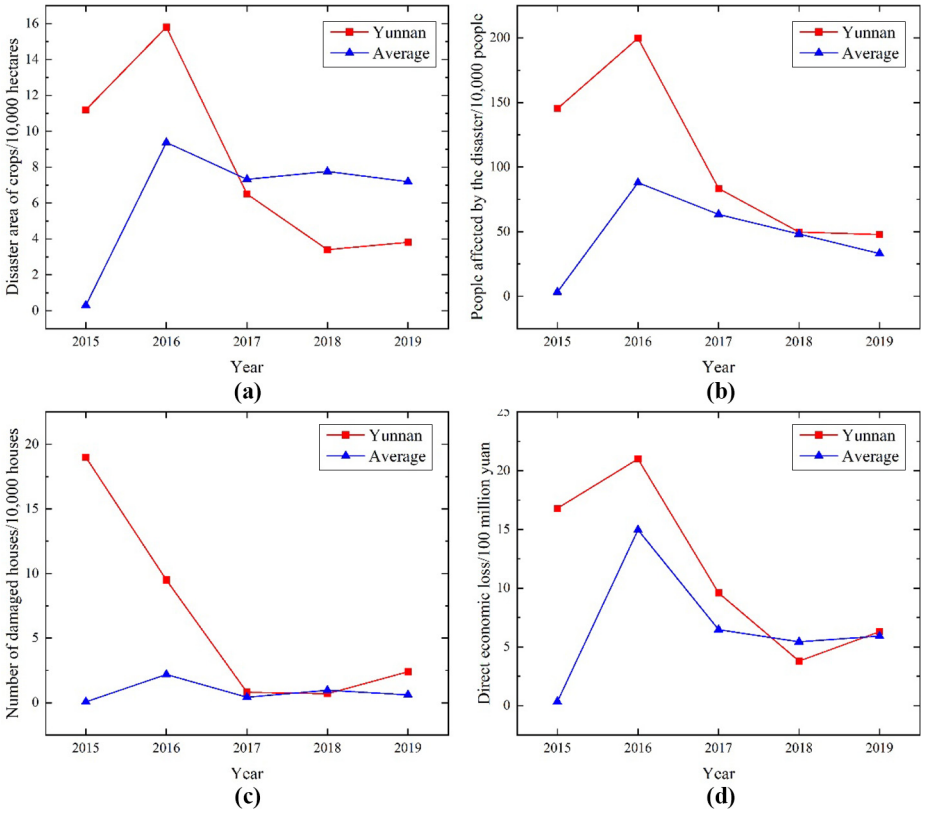

Figure A2. Gale, hail and lightning disaster situation of (a) crops, (b) people, (c) houses and (d) the economy

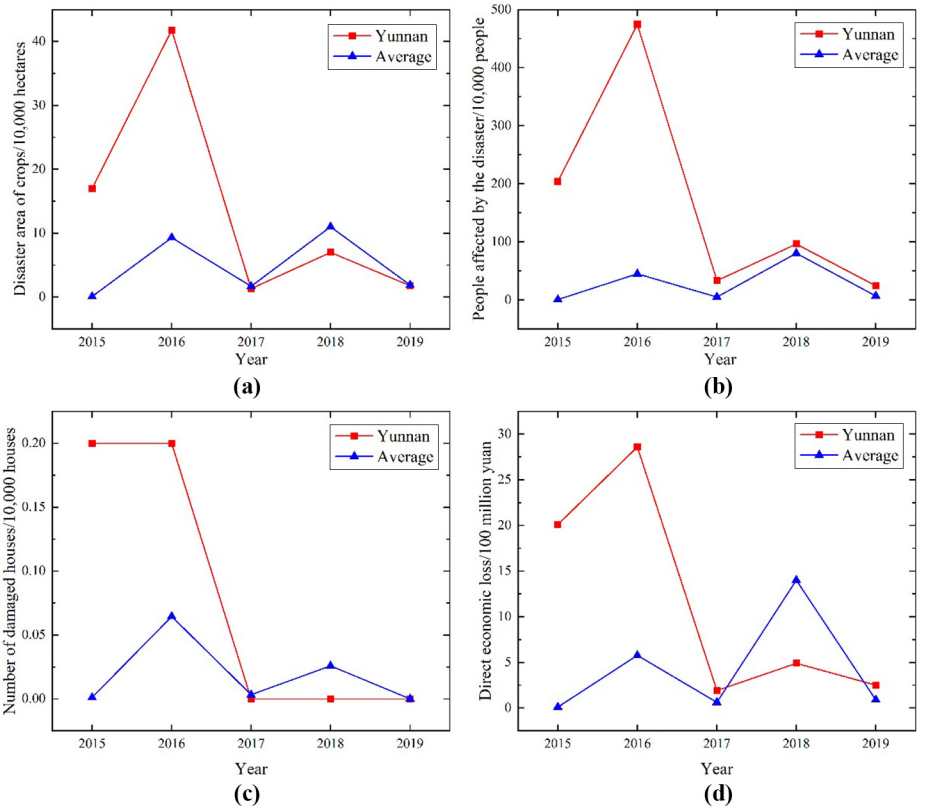

Figure A3.
Low-temperature and frost disaster situation of (a) crops, (b) people, (c) houses and (d) the economy

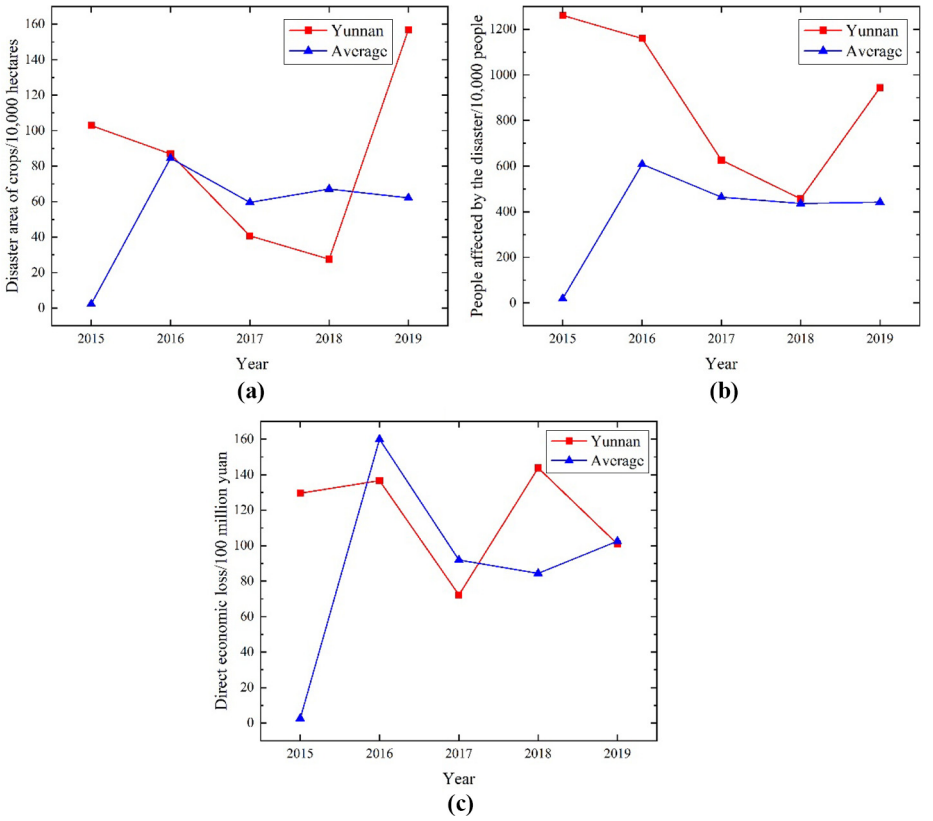

Figure A4. Total disaster situation of (a) crops, (b) people and (c) the economy

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