

## Pathways to Anti-Fragile Governance and Sustainable Development in the Flower Industry Driven by Big Data: A Case Study Based on Dounan Flower Market in Yunnan

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This study takes the Yunnan Dounan Flower Market as a case example to explore how the Yunnan flower industry can achieve anti-fragile governance and sustainable development driven by big data. Through literature review, case studies, and qualitative research methods, this study elaborates on the applications of big data in data collection and analysis, customer value optimization and precision marketing, operational optimization and production efficiency enhancement, as well as financial risk assessment and prevention within the flower industry. It further discusses how these applications facilitate anti-fragile governance and sustainable development in the flower industry. The research findings indicate that the introduction of big data technology not only significantly improves operational efficiency and market competitiveness in the flower industry but also enhances its ability to cope with market fluctuations and external environmental changes, laying a solid foundation for the sustainable development of the Yunnan Dounan flower industry. This study validates its theoretical and practical value, providing innovative pathways and strategic suggestions for the sustainable development of the flower industry and other related sectors in the post-pandemic era.

**Keywords:** Anti-fragile governance, big data sustainable development, data analysis, flower industry.

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### INTRODUCTION

With the deepening development of globalization and informatization, big data has become a significant force driving the transformation and upgrading of various industries. Particularly in the agricultural sector, the application of big data technology is gradually transforming traditional agricultural production modes and management approaches, providing new pathways for the modernization and intelligentization of the agricultural industry. As an important component of agriculture, the flower industry, due to its unique commodity attributes and market characteristics, has an urgent need for big data technology Timmerman (1981).

The Yunnan Dounan Flower Market, as the largest fresh cut flower trading market in China and even Asia, features a high degree of market sensitivity and volatility in its flower industry. In the face of complex and ever-changing market environments and sudden external shocks (such as the COVID-19 pandemic), the Dounan flower industry has demonstrated strong resilience and adaptability, achieving growth against the trend. Behind this phenomenon, the application of big data technology has played a crucial role.

Through a big data-driven anti-fragile governance mechanism, the Dounan flower industry has not only effectively responded to market fluctuations and external challenges but also achieved sustainable development of the industry Yang Long (2015); (Yang *et al.*, 2006); Huang Chengwei (2010); (Huang *et al.*, 2010); (Wang *et al.*, 2024) (Nthiga *et al.*, 2024).

However, current research on the application of big data in the flower industry is relatively scarce and mostly focused on technical-level discussions, lacking systematic and comprehensive studies. Based on this, this study takes the Yunnan Dounan Flower Market as a case example to deeply analyze the anti-fragile governance and sustainable development path of the flower industry driven by big data. Through literature review, case studies, and qualitative research methods, this study aims to comprehensively elaborate on the applications of big data in data collection and analysis, customer value optimization and precision marketing, operational optimization and production efficiency enhancement, as well as financial risk assessment and prevention within the flower industry. It also explores how these applications promote anti-fragile governance and



sustainable development in the flower industry (Xiong *et al.*, 2021).

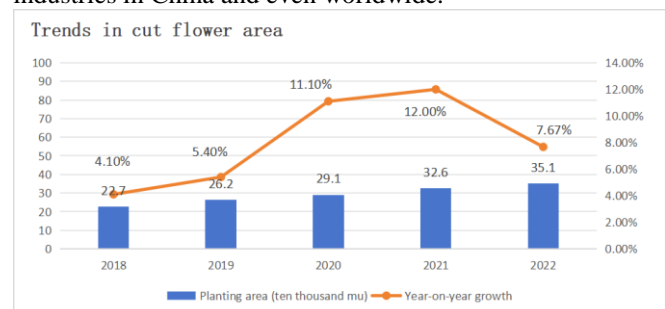
This study, by unveiling the application effects and mechanisms of big data technology within the floriculture industry, provides invaluable insights and references for the transformation, upgrading, and sustainable development of not only the floriculture industry but also other related sectors. Especially in the post-pandemic era, amidst the complex landscape and uncertain factors surrounding global economic recovery, this research offers significant theoretical support and practical guidance for the floriculture industry and other agricultural sectors to tackle external challenges and achieve high-quality development.

## MATERIALS AND METHODS

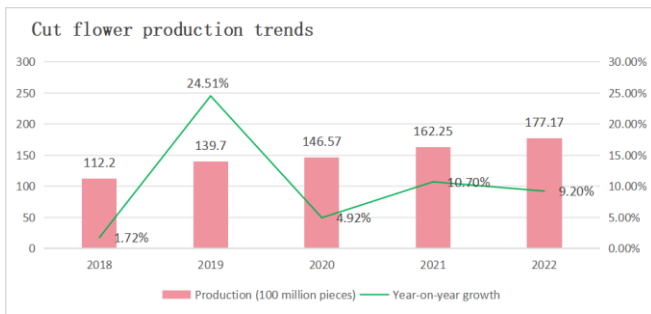
**Research Methodology:** Due to the overall lack of systematic research and analysis in existing studies on the floral industry during and after the pandemic, particularly regarding how the largest flower market in Asia navigated the "pandemic era," this study opts for a case study approach based on two primary considerations. First, the research question primarily possesses explanatory characteristics, focusing on how the Yunnan Dounan Flower Market developed during the pandemic—a typical "HOW" question (Yin *et al.*, 2009). Second, in situations where qualitative research is inadequate and variable scopes are uncertain, using questionnaires or scales alone to collect data and employing quantitative research methods to analyze the influencing factors and processes of Dounan Flower Market's navigation through the "pandemic era" is relatively less feasible. Qualitative analysis methods are more effective in such cases. Therefore, this paper adopts the grounded theory method. Based on primary data obtained from field research interviews and secondary data collected, it conducts an in-depth analysis of the anti-fragile governance practices of the Yunnan Dounan Flower Market driven by big data during the COVID-19 pandemic. The study explores the influencing factors of how Dounan Flower Market leveraged big data to achieve sustainable development amidst the pandemic and attempts to theoretically construct the key factors influencing Dounan Flower Market's anti-fragile governance and sustainable development, as well as their interaction mechanisms.

**Case Selection:** This study adheres to the principle of case typicality (Pettigrew *et al.*, 1990). The selection of the most representative Yunnan flower industry as the case study subject primarily considers the following four aspects: Firstly, the Dounan flower industry, as one of the eight key industries in Yunnan Province's strategy to build a world-class "green food brand," not only plays a pivotal role in local socio-economic development but also bears the significant mission of driving the province's agricultural transformation and upgrading, as well as achieving green and sustainable development. In this grand blueprint, "the nation looks to

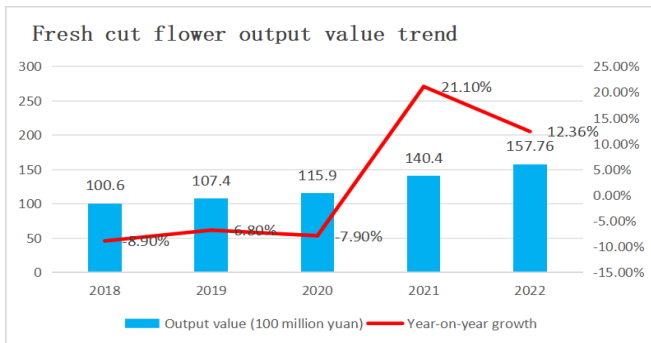
Yunnan for flowers, and Yunnan looks to Dounan" has become an industry consensus. After nearly two decades of vigorous development, the Yunnan Dounan Flower Market has firmly established its position as the largest fresh cut flower trading market in Asia. It is not only the "barometer" and "vane" of China's flower market but also a shining pearl in the global flower industry. Secondly, it aligns well with the research question. The Yunnan Dounan flower industry, characterized by perishability and susceptibility to wilting, faced various challenges during the COVID-19 pandemic when many industries stagnated. However, the Dounan flower industry achieved counter-trend growth. For instance, in 2022, the flower planting area in Yunnan Province reached 1.94 million mu, with an agricultural output value of 42.727 billion yuan. Specifically, the fresh cut flower planting area was 351,000 mu, an increase of 7.7% year-on-year, with a yield of 17.717 billion stems, up 9.2% year-on-year, and an output value of 15.776 billion yuan, up 12.4% year-on-year, accounting for 50% of the national total output, with roses accounting for about 70% of the national total output. To highlight the research objective, namely how the Yunnan Dounan flower industry leverages big data to implement anti-fragile governance and achieve sustainable development during the pandemic, this study primarily selects data from 2018 to 2022 for analysis (as shown in Figures 1, 2, and 3). The research topic possesses considerable research value and significance, providing insights or suggestions for the development of flower industries in other regions. Thirdly, there is an existing foundation of data and information. The author's master's supervisor's project, "Research on Rural Poverty Vulnerability Risk Assessment and Management in Yunnan Province" (project number: 2021J0450), has established preliminary communication with relevant personnel in Dounan, providing rich first-hand data for this study. Lastly, the research team's several continuous on-site investigations and follow-ups ensure theoretical saturation for this study. Fourthly, the "counter-trend growth" and sustainable development of the Yunnan Dounan flower industry during the pandemic are closely related to its utilization of big data. Therefore, this study believes that the big data-driven practices of the Yunnan Dounan flower industry can provide certain references for other flower industries in China and even worldwide.



**Figure 1. Trend of fresh cut flower planting area in Yunnan Province from 2018 to 2022 (data source: industry scheduling).**



**Figure 2. Trend of fresh cut flower production in Yunnan Province from 2018 to 2022 (data source: industry scheduling).**



**Figure 3. Trend of fresh cut flower output value in Yunnan Province from 2018 to 2022 (data source: industry scheduling).**

**Data Collection:** From the beginning of 2022 to October 2023, the research team conducted over ten investigation activities at the Dounan Flower Market in Yunnan. This study employed a combination of online and offline interviews to obtain first-hand interview data. We conducted in-depth semi-structured face-to-face and telephone interviews, as well as on-site observations, with 26 individuals from the Flower Research Institute of Yunnan Academy of Agricultural Sciences, Yunnan Provincial Department of Commerce,

Kunming Huayibao Technology Co., Ltd., Yunnan Dounan Flower Auction Center, Dounan Flower Industry Group, and other institutions. With the consent of the interviewees, all interview contents were recorded and saved using full audio recording and shorthand notetaking. After the interviews, voice-to-text software was used to transcribe the recordings of the interviewees, which were then compared and verified against the shorthand notes from the interviews. Any content requiring adjustment or clarification was further confirmed or corrected with the interviewees themselves. To obtain authentic and valid interview data, facial expressions or tones of voice exhibited by the interviewees during the interviews were also annotated and recorded. A total of 243,000 detailed and reliable first-hand data were collected. Additionally, 137,000 words of second-hand data were obtained by gathering relevant information from the official website of the Dounan Flower Market in Yunnan and compiling related government policy documents and literature. During the process of organizing the collected data, continuous comparisons were made to verify potential errors in the data, and relevant case data were promptly supplemented. The triangulation test (As illustrated in Table 1) was strengthened to ensure the reliability and authenticity of the research content in this study.

**Model Construction**

**Open Coding:** Open coding involves the process of segment-by-segment, sentence-by-sentence, and word-by-word coding of collected and organized primary and secondary text data. It assigns appropriate labels to phenomena described in the original data, identifies logical relationships between concepts, and categorizes concepts with similar meanings. This is a process of developing concepts and categorization (Chen, 2022; Jia *et al.*, 2020). In this paper, we conducted coding for the industrial cases of the Dounan Flower Market in Yunnan, extracting content related to the research theme from the original data, initially conceptualizing the relevant information, and forming initial categories. As shown in Table 2, 'a' represents the labeling of original data, 'aa' represents conceptualization, and 'A' represents the formation of initial categories. To ensure the utility of the coding results, two individuals used the qualitative analysis software Nvivo12 Plus to code the same text data until both concepts

**Table 1. Sources of Case Data.**

Data types	Data source		Volume of text
Primary Data	Interview Data	Interviews were conducted with multiple organizations involved in the Yunnan Dounan flower industry, primarily targeting 26 individuals from the Flower Research Institute of Yunnan Academy of Agricultural Sciences, Yunnan Provincial Department of Commerce, Kunming Huayibao Technology Co., Ltd., Yunnan Dounan Flower Auction Center, Dounan Flower Industry Group, and flower farmers.	More than 240,000 words
Secondary Data	Third-party related websites	China Economic Net, Kunming Municipal Agriculture and Rural Bureau Website, Yunnan News, SOHU, etc.	More than 130,000 words
	Publicly available corporate materials	Promotional materials of the Dounan flower industry, including paper materials, official account materials, and relevant company annual reports.	

**Table 3. Results of Axial Coding for Data on the Flower Industry in Dounan, Yunnan.**

Initial Categories	Main Categories		
Anti-Fragile Governance and Sustainable Development Data Analysis, Information Collection, etc. (A5, A16, A26, A24, A9, A2, A22, A1) Enhancing Quality, Improving Services, etc. (A23, A14, A11, A21, A15)	Data Collection and Analysis Optimization of Customer Value Precision Marketing Operational Optimization Financial Risk Assessment		
Constructing Consumer Profiles, Optimizing Marketing Strategies, etc. (A17, A3, A4, A18) Optimization of Post-harvest Handling, Construction of Inventory Management Systems, etc. (A25, A19, A20, A10, A7) Risk Assessment and Early Warning, Financial and Insurance Services, etc. (A13, A8, A12, A6)			
offline trading model.			
Flower farmers and florists can quickly complete transactions through the platform and view transaction records and settlement status in real-time.	a13 Utilizing Big Data to Complete Transaction Processes	aa13 Facilitating Transactions through Big Data (a13, a64, a75)	A26 Enhancing Transactions (aa13, aa33, aa42)
The Dounan Flower Market utilizes big data technology to conduct in-depth analysis of consumer purchasing behavior, preferences, and social media activities.	a16 Leveraging Big Data to Analyze Consumer Behavior	aa15 Analyzing Consumer Behavior through Big Data (a16, a89, a105)	A17 Building Consumer Profiles (aa15, aa31, aa3)
The flower market is able to provide personalized flower recommendations and shopping experiences to consumers, enhancing their satisfaction and loyalty.	a32 Big Data Provides Personalized Recommendations and Shopping Experiences	aa19 Enhancing Consumer Services through Big Data (a32, a35, a121)	A14 Enhancing Services (aa19, aa4, aa12)
Establish a soil-less cultivation production base for flowers integrating water and fertilizer, and vigorously promote the soil-less cultivation model that integrates water and fertilizer.	a53 Implementing Soil-less Cultivation Models through Big Data	aa22 Optimizing Cultivation Models through Big Data (a53, a73, a66)	A12 Optimization of Cultivation Models (aa22)
A comprehensive data collection system is constructed through big data technology, gathering multi-dimensional information including historical transaction data, real-time transaction data, consumer behavior data, and flower growth cycle data.	a57 Collecting and Organizing Information through Big Data Technology	aa42 Building an Information Collection System through Big Data (a57, a83, a96)	A16 Information Collection (aa42, aa10, aa14, aa27)
By monitoring market data in real-time, the Dounan Flower Market utilizes algorithms to identify potential market risks, such as price fluctuations and supply chain disruptions. Once a risk is identified, the system can automatically send alerts to flower farmers, florists, and relevant institutions, reminding them to take timely measures to address the risk and minimize losses.	a68 Identifying Potential Market Risks through Big Data	aa24 Building Risk Assessment and Early Warning through Big Data (a68, a4, a110)	A13 Assessing Risks and Providing Early Warning (aa24, aa38, aa3)
The Dounan Flower Market has introduced an intelligent logistics system, utilizing technologies such as the Internet of Things (IoT) and GPS to monitor the transportation process of flowers in real-time.	a84 Monitoring Transportation Processes through Big Data	aa26 Building an Intelligent Logistics System through Big Data (a84, a58)	A20 Building an Intelligent Logistics System (aa26, aa30)
The system is capable of intelligently forecasting the inventory demand for flowers through comprehensive analysis of sales data, inventory data, and market demand data.	a87 Forecasting Inventory Demand through Big Data	aa28 Establishing an Inventory Management System Utilizing Big Data (a87, a92, a88)	A19 Establishing an Inventory Management System (aa28, aa39, aa35)
By analyzing the effects of different marketing channels and campaigns, the flower market can gain insights into which channels and campaigns are more effective at attracting consumers and which strategies are more conducive to promoting sales.	a91 Analyzing Marketing Strategies through Big Data	aa32 Optimizing Marketing Strategies through Big Data (a91, a36, a49, 103)	A3 Optimization of Marketing Strategies (aa32, aa8)
By analyzing data such as the growth cycle, harvesting time, and storage conditions of flowers, the flower market can formulate scientific and reasonable post-harvest handling plans to extend the shelf life of flowers and reduce losses.	a102 Formulating Reasonable Handling and Preservation Plans through Big Data	aa37 Optimizing Post-harvest Handling and Preservation through Big Data (a102, a33)	A25 Optimization of Post-Harvest Handling (aa37)
The platform leverages big data technology to conduct deep analysis of transaction data, providing convenient financial services and launching insurance products for flower farmers and florists.	a117 Providing Financial and Insurance Services through Big Data	aa40 Optimizing Finance and Insurance through Big Data (a117, a74, a55)	A8 Optimization of Financial and Insurance Services (aa40, aa34)
.....	.....	.....	.....
	A total of 124 tags	A total of 43 concepts	A total of 26

and categories reached saturation. Through open coding, we ultimately obtained 124 original labels, 43 initial concepts, and 26 initial categories. Due to the extensive and lengthy nature of the coding process, this study only presents a portion of the coding data as an example.

**Axial Coding:** Axial coding refers to the process of establishing organic connections among various categories and concepts formed during open coding, further refining and summarizing them to extract saturated core categories, and establishing higher-level main categories. Based on open

coding, this study re-induces, classifies, compares, and analyzes the codes. It subjectively connects the 10 initial categories abstracted, performs intrinsic relationship connotation and logical induction classification of different categories, and ultimately derives three main categories from the initial ones: government policy support, assistance from internet platforms, and joint efforts from multiple organizations. The connotations of each category and their corresponding categories are shown in Table 3.

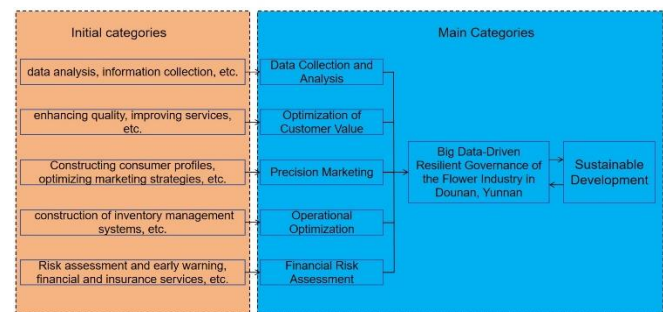
**Selective Coding:** Selective coding is the final stage of grounded theory, which involves identifying the core category from the main categories by analyzing the logical relationships within each category and deriving the relationships among the categories through the core category using a "story line". Through in-depth analysis of the five main categories—data collection and analysis, customer value optimization, precision marketing, operational optimization, and financial risk assessment—along with literature review and continuous dialogue processing of the collected data.

**Theoretical Saturation Check:** Theoretical saturation refers to the point where no new concepts or categories emerge despite the continuous addition of new data. In this study, the reserved 27 interview transcripts were re-imported into Nvivo12plus for a theoretical saturation test. The coding results revealed that the five main categories—data collection and analysis, customer value optimization, precision marketing, operational optimization, and financial risk assessment—had reached saturation, and no new concepts or categories were identified. This indicates that the theoretical framework constructed in this study has passed the theoretical saturation test and possesses a certain degree of practical persuasiveness.

## RESULTS

This study identifies "data analysis" as the core category. The overall story line can be described as follows: In the flower industry of Dounan, Yunnan, the application of big data technology has established an efficient and anti-fragile governance model. Starting with data collection and analysis, this model integrates diverse data sources such as market, production, and external data. Through big data platforms and intelligent analysis technologies, it achieves deep insights and precise predictions for the flower industry. On this basis, the model further optimizes customer value by constructing customer profiles and providing personalized recommendations, thereby enhancing customer satisfaction and loyalty. Meanwhile, the formulation and execution of precision marketing strategies make marketing activities more efficient and precise, facilitating market expansion and sales growth for flower products. In terms of operational optimization, big data not only optimizes supply chain management and logistics efficiency but also enhances the

level of flower breeding, cultivation, and processing through intelligent means. Furthermore, the model constructs a comprehensive financial risk assessment system that effectively prevents and addresses potential threats such as market risk, credit risk, and supply chain risk through real-time monitoring and quantitative assessment. These series of initiatives collectively constitute a big data-driven anti-fragile governance model for the flower industry in Dounan, Yunnan, significantly enhancing the industry's resilience, efficiency, and competitiveness. This ensures the industry's steady progress in a complex and changing market environment, achieving sustainable development. Based on this story line, we ultimately derive an analysis model for the sustainable development of anti-fragile governance in the flower market of Dounan, Yunnan, driven by big data in the era of COVID-19, as shown in Figure 4.



**Figure 4. Analysis Model for the Sustainable Development of Anti-Fragile Governance in the Flower Market of Dounan, Yunnan, Driven by Big Data.**

## DISCUSSION

The concept of "fragility" initially emerged in disaster research, first proposed by Timmerman (1981) in the field of earth sciences (Timmerman, 1981). Subsequently, in the early 1980s, Gallopín (2006) constructed an "external-internal" analytical framework for fragility while studying sustainable livelihoods. This framework facilitated the widespread application and deepening of the fragility concept across multiple disciplines such as management, sociology, economics, political science, and anthropology, while also evolving into various conceptual definitions. Consequently, research on fragility has gradually become a focal point and important analytical tool in both natural and social sciences (Gallopín, 2006).

Based on the asset vulnerability framework, Moser (1998) classified the assets of urban poor and pointed out that vulnerability refers to the increased livelihood challenges faced by individuals, families, markets, and communities in the absence of assets (Moser, 1998). Lin *et al.* (2006) argued that fragility encompasses two basic connotations: one focuses on the degree of damage caused by disasters to

systems, primarily derived from impact assessments and traditional disaster research pathways, which mainly concentrate on chemical and physical fragility studies while neglecting the proactive coping capabilities of human systems; the other emphasizes that system fragility is a preexisting state before disasters occur, examined primarily from external factors of disasters, mainly explaining the structural factors of human social systems when affected by disasters, and suggesting that fragility originates from inherent traits within human systems, thus also termed as "social fragility" (Lin *et al.*, 2006).

Furthermore, Yang Long (2015); (Yang *et al.*, 2006); Huang Chengwei (2010); (Huang *et al.*, 2010), and others have also quantitatively defined fragility from the perspectives of anticipated poverty, low expected utility, and risk exposure, conducting research and analysis on the measurement of fragility and poverty issues. Tang *et al.* (2010) adopted the World Bank's definition, considering fragility as the possibility of individuals or families experiencing wealth loss or a decline in living standards below socially accepted levels due to exposure to certain risks (Tang *et al.*, 2010; World Bank, 2001).

Currently, after more than half a century of research development, the theory of fragility has gradually matured. Based on existing research findings on fragility, Li (2013) believed that fragility is a collection of related concepts including risk, sensitivity, adaptability, and resilience, and proposed a development research approach aimed at valuing and reducing fragility: "antifragile development." This approach advocates that the primary structure for antifragile community development is "government serving the community," and the capability building is "enhancing regional strength" (Li *et al.*, 2013).

The concept of "Antifragility" was proposed by Taleb in his book "Antifragile: Things That Gain from Disorder," emphasizing that systems can not only resist shocks but also benefit from them and become stronger when facing uncertainties. In the flower industry, antifragile governance mechanisms manifest as the industry enhancing its adaptability and resilience through internal structural adjustments, external resource integration, and multi-party collaboration to cope with various internal and external challenges (Taleb, 2014). As no simple term could be found in existing dictionaries to describe the opposite of "fragile" or "breakable," Taleb (2014) used "antifragility" to outline the significant implications of fragility and antifragility in human social systems (Shen, 2016). Some also believe that antifragility refers to the ability of organizations to maintain good development amidst complexity, variability, randomness, and pressure, enabling them to expand positive effects and reduce negative impacts when facing multiple pressures (Tale *et al.*, 2013). Under the influence of various negative environmental factors such as the COVID-19 pandemic, the antifragility of organizations has received

widespread attention from both academia and the industry (Chen *et al.*, 2023).

However, based on the current research literature, the focus of the research content remains on using mature fragility conceptual models to analyze fragility traits, with research methods emphasizing quantitative analysis. Currently, there is a relative lack of research findings on the antifragile development of resource-based cities. Especially in the era of the COVID-19 pandemic, there is a scarcity of literature on how enterprises and organizations can conduct antifragile governance and how flower enterprises can achieve sustainable development.

The theoretical framework of sustainable development, serving as the core content of modern development paradigms, systematically encompasses three dimensions: economic sustainability, ecological sustainability, and social sustainability. It aims to foster comprehensive progress through harmonious coexistence between humans and nature. This theory emphasizes that while driving economic growth, ecological benefits and social equity must be balanced to ensure the sustainability and long-term nature of development.

Reflection on the causes of environmental issues and their resolution pathways constitutes a significant origin of modern sustainable development thought (Chen *et al.*, 2023). Following the 1972 Stockholm United Nations Conference on the Human Environment, the introduction of the "sustainable development" concept in the 1987 report *Our Common Future*, and the 1992 Rio United Nations Conference on Environment and Development, the concept of sustainable development has garnered increasing attention from academia. Interpretations of sustainable development by Pearce *et al.* (1993); Hong Yinxing (2000) highlight its core principles and goals: coordinated development of economy, society, and environment; sustainable resource utilization; environmental protection and ecological restoration; social equity and intergenerational justice; technological innovation and institutional safeguards; and global cooperation and collective action. Niu Wenyuan (1997); Ren Baoping (2003) contend that the theoretical foundation of sustainable development involves multiple aspects, including the finiteness and value of environmental resources, the dialectical relationship between economic development and environmental protection, and the implementation pathways for sustainable development. Zhou *et al.* (2005) view circular economy as a crucial approach and realization method for sustainable development, emphasizing that under conditions of limited resources and environmental carrying capacity, coordinated development of economy, society, and environment can be achieved through circular and efficient resource utilization (Zhou *et al.*, 2005). Cao Lijun (1999) focuses on constructing an evaluation theory and methodology system, providing tools for quantitative assessment of sustainable development. Arrow *et al.* (2004)

delve into the intrinsic link between consumption and sustainable development from the perspective of consumption patterns. Building on these accumulated studies, the 21st century has witnessed the advancement of global sustainable development into a new model phase, marked by events such as the 2002 World Summit on Sustainable Development, the 2012 Rio+20 Summit, and the release of the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) in 2015.

The application of sustainable development theory in the flower industry is primarily manifested in the following aspects: Firstly, it emphasizes resource conservation and efficient utilization. As a resource-intensive industry, the flower industry heavily relies on production factors such as land, water, pesticides, and fertilizers. Therefore, achieving sustainable development necessitates the adoption of environmentally friendly technologies like water-saving irrigation and precise fertilization in the production process, thereby reducing resource consumption and enhancing resource utilization efficiency. Secondly, it underscores environmental protection and ecological balance. Flower cultivation may lead to environmental issues such as soil pollution and water eutrophication, exerting pressure on ecosystems. Hence, the flower industry should prioritize maintaining ecological balance during its development, mitigating environmental impacts through adjustments in planting structures and green pest control methods. Lastly, it focuses on fulfilling social responsibilities and enhancing economic benefits. As a vital component of the agricultural economy, the development of the flower industry should balance economic benefits with social responsibilities. While fulfilling social responsibilities by providing employment opportunities and promoting farmers' income growth, it should also enhance industrial competitiveness through technological innovation and brand building, achieving a win-win situation for both economic and social benefits.

Amidst the backdrop of the COVID-19 pandemic, the flower industry faces unprecedented challenges and opportunities. On one hand, the pandemic has significantly impacted the flower industry's supply chain and market demand; on the other hand, it has also accelerated the pace of digital transformation in the flower industry, presenting new opportunities for sustainable development. Therefore, how to achieve sustainable development in the flower industry during and after the pandemic has become an urgent and important issue to address. This study, based on big data-driven theory and using the case of Dounan Flower Market in Yunnan, will delve deeply into the pathways and strategies for achieving sustainable development in the flower industry under the pandemic context.

Since its formal introduction in a special issue of *Nature* in 2008 (Waldrop, 2008), the concept of "Big Data" has rapidly garnered widespread attention from numerous scholars, leading to profound transformations in scientific research and

management practices. Hey *et al.* (2009), from a natural science perspective, highlighted that human scientific research is entering the fourth paradigm marked by "data-intensive scientific discovery". Building on this foundation, Mi *et al.* (2018) further elaborated that social science research is also undergoing a transition from qualitative, quantitative, and simulation-based approaches to a fourth research paradigm driven by big data, signaling the comprehensive arrival of the big data era. Chen *et al.* (2020) argued that the rapid development of big data has had significant impacts, altering the ways and processes of management decision-making and value creation; they condensed and elucidated the changes and roles induced by big data from the perspectives of paradigms and innovation. Chen *et al.* (2022) explored new paradigms of corporate governance in the context of big data, focusing on its empowerment of capital market governance, its drive in product competition market governance, and its restructuring of control market governance. As the core driving force in the information age, big data, characterized by its volume, velocity, variety, and value (low density but high overall value)—the "4V" characteristics—has sparked a data revolution globally. From macro-level information management to micro-level industry applications, such as the automotive industry (Tan *et al.*, 2020), smart restaurant sector (Qian *et al.*, 2019), and retail precision marketing (Xiong *et al.*, 2021), big data has demonstrated its unique value and potential. To align with this trend, governments worldwide have responded actively by formulating and implementing big data development strategies, aiming to leverage advanced data analytics techniques to tap into data resources, optimize governmental decision-making processes, enhance public service efficiency, and facilitate economic transformation and upgrading.

In the agricultural sector, the application of big data is gradually transforming the traditional "weather-dependent" model of farming. Xie *et al.* (2022) regarded big data as a crucial production factor and delved into how it optimizes the agricultural industrial structure, as well as the material basis, micro-mechanisms, transformation pathways, and organizational forms that propel agricultural digital transformation and innovation, thereby fostering the development of precision and smart agriculture (Wang *et al.*, 2021). Lu *et al.* (2022) reviewed data collection technologies, analyzed the application of big data in agricultural economic research, and discussed some potential roles of big data. Through real-time monitoring and analysis of information such as soil moisture and crop growth conditions, big data technology assists farmers in achieving precise fertilization, irrigation, and pest and disease prevention and control. Simultaneously, it optimizes agricultural supply chain management and constructs an integrated solution (Ruan *et al.*, 2020), enhancing agricultural production efficiency (Liu *et al.*, 2019) and market competitiveness.

Although there is relatively limited research on the application of big data in the floral industry in existing literature, it cannot be overlooked that big data plays a pivotal role in this sector, which holds vast development potential. Through deep analysis of data on market demand and consumer preferences, floral businesses can more accurately formulate production plans and market strategies, effectively mitigating risks in the floral industry and achieving sustainable development.

**Case Analysis and Discussion:** In delving deeply into the pathways of big data-driven anti-fragile governance and sustainable development in the flower industry of Dounan, Yunnan, this case study unveils the innovative strategies and achievements of the Dounan Flower Market amidst complex environments such as the COVID-19 pandemic. Through an in-depth analysis of extensive data from the Dounan Flower Market spanning from 2018 to 2022, combined with qualitative research methods, particularly the analysis of primary interview data and secondary data, this study forms systematic insights into how big data drives the transformation and upgrading of the flower industry.

**Application of Big Data in Data Collection and Analysis:** The application of big data technology has significantly enhanced the data collection and analysis capabilities of the Dounan flower industry. By establishing an efficient data acquisition system, the Dounan Flower Market is able to collect and process real-time multi-dimensional information such as market transaction data, consumer behavior data, and flower growth cycle data. This information is deeply mined through big data platforms and intelligent analysis techniques, providing accurate market forecasts and price guidance for flower farmers and merchants, thereby greatly enhancing market transparency and responsiveness.

**Customer Value Optimization and Precision Marketing:** Based on big data analysis, the Dounan Flower Market has further achieved customer value optimization and precision marketing. Through detailed analysis of consumer behavior data, the flower market is able to understand the actual effects of different channels and marketing activities, thereby adjusting strategies to more precisely attract and retain consumers. This data-driven marketing model not only improves the effectiveness of marketing activities but also enhances customer satisfaction and loyalty, laying a solid market foundation for the long-term development of the Dounan flower industry.

**Operational Optimization and Production Efficiency Improvement:** In terms of operational optimization, the application of big data also demonstrates significant potential. The Dounan Flower Market has comprehensively optimized the production, breeding, and processing links of flowers through big data technology. For example, by analyzing data such as the growth cycle and harvesting time of flowers, the flower market is able to formulate scientific and reasonable post-harvest handling plans, thereby extending the shelf life

of flowers and reducing losses. At the same time, big data also facilitates the improvement of supply chain management and logistics efficiency for the flower market, ensuring the timely delivery and freshness of flower products.

**Financial Risk Assessment and Prevention:** In the aspect of financial risk assessment, the application of big data technology enables the Dounan Flower Market to better prevent and respond to potential threats such as market risk, credit risk, and supply chain risk. Through real-time monitoring and quantitative assessment, the flower market can promptly identify and address potential issues, thereby reducing uncertainties in the operational process. This data-based risk assessment mechanism significantly enhances the resilience and risk-resistance capability of the Dounan flower industry.

**Practices of Sustainable Development:** From the perspective of sustainable development, the application of big data in the Dounan flower industry is also reflected in multiple aspects such as resource conservation and efficient utilization, environmental protection and ecological balance, as well as the fulfillment of social responsibilities. Through data analysis and optimization, the Dounan Flower Market has achieved significant results in environmental protection technologies like water-saving irrigation and precision fertilization, reducing resource consumption and environmental pollution. Simultaneously, big data has also facilitated the flower market in enhancing product quality and market competitiveness, further promoting the green transformation and sustainable development of the flower industry.

In summary, the application of big data technology in the Yunnan Dounan flower industry not only significantly enhances the industry's resilience, efficiency, and competitiveness but also provides strong support for the anti-fragile governance and sustainable development of the flower industry. This successful case not only offers valuable insights and inspiration for the development of the Yunnan flower industry but also serves as an important reference for the transformation and upgrading of agricultural industries in other regions.

**Exploration of Anti-fragile Governance and Sustainable Development Pathways:** Driven by big data, the Yunnan Dounan flower industry has demonstrated strong anti-fragility and potential for sustainable development. Through an in-depth case study of the Dounan Flower Market, we can summarize several key pathways that are not only applicable to the Dounan flower industry but also provide important references for the transformation and development of the global flower industry.

(1) **Data-Driven Smart Decision-Making and Precision Management:** The application of big data technology enables the Dounan flower industry to collect and analyze real-time multi-source data from the market, production, and external sources. Through big data platforms and intelligent analysis

technologies, industry managers can gain deep insights into and make precise predictions about the flower market, thereby formulating more scientific and reasonable production and sales strategies. This data-based smart decision-making model effectively reduces the impact of market volatility on the industry and enhances its risk-resistance capability.

(2) **Customer Value Optimization and Precision Marketing**: Big data also facilitates the Dounan flower industry in achieving deep customer value excavation and precision marketing. By constructing customer profiles and personalized recommendation systems, the industry can more accurately grasp consumer demands and provide customized and differentiated products and services. This consumer-centric business model not only improves customer satisfaction and loyalty but also promotes sustained growth in flower consumption, laying a solid foundation for the industry's sustainable development.

(3) **Operational Optimization and Production Efficiency Improvement**: Big data plays a crucial role in the operational optimization of the Dounan flower industry. Through real-time monitoring and analysis of various data during the production process, the industry can promptly identify and address bottlenecks in production, improving production efficiency and product quality. At the same time, big data also assists the industry in optimizing supply chain management, reducing logistics costs and inventory risks, and further enhancing the industry's competitiveness.

(4) **Risk Assessment and Prevention Mechanism**: In the face of a complex and changing market environment, big data provides an effective risk assessment and prevention mechanism for the Dounan flower industry. Through comprehensive analysis of historical and real-time data, the industry can preemptively identify potential market and supply chain risks and formulate corresponding countermeasures. This forward-looking risk management strategy allows the Dounan flower industry to maintain a high level of adaptability and resilience in the face of uncertainties.

(5) **Innovation in Sustainable Development Models**: Driven by big data, the Dounan flower industry also actively explores new models of sustainable development. By optimizing resource allocation, promoting technological innovation, and environmentally friendly production, the industry achieves coordinated development of economic, social, and environmental benefits. At the same time, big data also assists the industry in strengthening connections and cooperation with domestic and international markets, driving the internationalization process of the flower industry.

**Conclusion:** Based on an in-depth case study of the Dounan Flower Market in Yunnan, this research comprehensively analyzes the anti-fragile governance and sustainable development pathways of the flower industry driven by big data. The main conclusions are as follows:

- (1) **Significant Enabling Role of Big Data:** The application of big data technology in the flower industry has greatly improved the efficiency and accuracy of data collection and analysis. By monitoring key indicators such as soil moisture and crop growth conditions in real-time, the flower industry can achieve precise fertilization, irrigation, and pest control, thereby enhancing production efficiency and product quality. Additionally, big data assists the flower industry in optimizing supply chain management, reducing resource waste, and enhancing market competitiveness.
- (2) **Effective Anti-fragile Governance Strategies:** In the face of external shocks such as the COVID-19 pandemic, the Yunnan Dounan flower industry has achieved growth against the trend through anti-fragile governance strategies. Through flexible adjustments of the internal structure, effective integration of external resources, and close collaboration among multiple stakeholders, the Dounan flower industry has constructed a highly adaptive and resilient industrial ecosystem. This governance model not only effectively resists risks but also promotes self-optimization and upgrading of the industry.
- (3) **Clear Path towards Sustainable Development:** This research reveals the sustainable development pathway of the Yunnan Dounan flower industry driven by big data. By optimizing resource allocation, improving production efficiency, strengthening technological innovation, and cultivating talent, the Dounan flower industry has achieved coordinated development of economic, social, and environmental benefits. This pathway provides valuable references and insights for the development of the flower industry in other regions.

**Theoretical Contributions:** The theoretical contributions of this study are multifaceted and significantly advance our understanding of the role of big data in promoting resilient governance and sustainable development within the flower industry, particularly in the post-pandemic era. The following elaborates on the primary theoretical contributions of this research:

Firstly, this study systematically explores the application of big data technology in the flower industry and unveils its positive impacts on various aspects, including data collection and analysis, customer value optimization and precision marketing, operational optimization and productivity enhancement, as well as financial risk assessment and prevention. Through an in-depth analysis of the case study of Dounan Flower Market in Yunnan, this research fills the gap in comprehensive applied research on big data within the flower industry, providing valuable theoretical references and practical guidance for other similar industries.

Secondly, this study innovatively constructs a big data-driven resilient governance model for the flower industry. Through this model, we clearly observe how big data aids the flower

industry in maintaining robust resilience and adaptability in the face of market fluctuations and external environmental changes. This model not only provides a solid theoretical foundation for the sustainable development of the flower industry but also offers new insights for the transformation and upgrading of other agricultural industries.

Furthermore, this study delves into the sustainable development pathways driven by big data within the flower industry. By optimizing resource allocation, improving production efficiency, strengthening technological innovation, and fostering talent development, the Dounan flower industry has achieved coordinated economic, social, and environmental benefits. The revelation of this pathway not only provides a concrete practical path for the sustainable development of the flower industry but also offers important theoretical support for the green transformation and sustainable development of agricultural industries.

Lastly, this study refines the application framework of resilience theory and sustainable development theory within the flower industry. By deeply analyzing the uniqueness and complexity of the flower industry, this research constructs theoretical models and analytical frameworks that align with the characteristics of the flower industry, providing a solid theoretical foundation for future research.

**Research Limitations:** Although this study has achieved certain results in exploring the anti-fragile governance and sustainable development pathways of the flower industry driven by big data, there are still some limitations:

(1) **Limited Sample Scope.** This research primarily analyzes the case of the Dounan Flower Market in Yunnan, resulting in a relatively limited sample scope. Therefore, the generalizability of the research findings may be somewhat restricted. Future studies could further expand the sample scope to explore the anti-fragile governance and sustainable development pathways of flower industries in different regions and of various types.

(2) **Data Collection and Analysis Methods.** This study employed a combination of online and offline interviews to collect data, followed by detailed text analysis and coding. However, there may be subjectivity and bias in the data collection process, which could affect the objectivity of the research results. Future research could introduce more quantitative analysis methods to enhance the accuracy and reliability of data collection and analysis.

(3) **Improvement of Theoretical Framework.** The application of anti-fragility theory and sustainable development theory in the flower industry is still in the exploratory stage, and the relevant theoretical frameworks are not yet well-established. This study may have certain limitations in constructing the theoretical model. Future research could further refine the relevant theoretical frameworks, providing a more solid theoretical foundation for the anti-fragile governance and sustainable development of the flower industry.

**Future Research Directions:** In response to the limitations and deficiencies of this study, future research can expand and deepen in the following aspects:

(1) **Expanding the Sample Scope:** Select more flower industries from different regions and of various types for case studies to validate and extend the generalizability of the conclusions of this research. By comparing and analyzing the anti-fragile governance and sustainable development pathways of flower industries in different regions, this research can reveal their commonalities and differences, providing more comprehensive guidance for the overall development of the flower industry.

(2) **Introducing Quantitative Analysis Methods:** Incorporate more quantitative analysis methods, such as statistical analysis and econometric models, into the data collection and analysis process to enhance the objectivity and accuracy of the research results. Through quantitative analysis, this research can uncover the intrinsic mechanisms and influencing factors of anti-fragile governance and sustainable development in the flower industry driven by big data.

(3) **Refining the Theoretical Framework:** Further refine the application framework of anti-fragility theory and sustainable development theory in the flower industry. By delving deeper into the specificity and complexity of the flower industry, this research can construct theoretical models and analytical frameworks that align with the characteristics of the flower industry. Meanwhile, strengthen interdisciplinary integration, introduce new theoretical perspectives and analytical tools, and provide richer theoretical support for the anti-fragile governance and sustainable development of the flower industry.

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