agriculture

Article

Improving Farmer Livelihood Resilience to Climate Change in Rural Areas of Inner Mongolia, China

Zhiying Han [1], Yeo-Chang Youn [1,2], Seunguk Kim [1] and Hyeyeong Choe [1,3,*]

[1] Department of Agriculture, Forestry, and Bioresources, College of Agriculture and Life Sciences, Seoul National University, 1 Gwanakro, Gwanakgu, Seoul 08826, Republic of Korea; hanzhiying@snu.ac.kr (Z.H.); youn@snu.ac.kr (Y.-C.Y.); adrenaline@snu.ac.kr (S.K.)
[2] Institute of Sustainable Social-Ecological Systems, Seongsudong 1-ga, Seoul 04779, Republic of Korea
[3] Research Institute of Agriculture and Life Sciences, Seoul National University, 1 Gwanakro, Gwanakgu, Seoul 08826, Republic of Korea
* Correspondence: hy.choe@snu.ac.kr

Abstract: This study evaluates how resilient farmers' livelihoods are to climate change and what factors influence this resilience. To measure resilience, we constructed an indicator system based on the livelihood resilience analysis framework. We surveyed 42 experts and 630 farmers after a climate change disturbance in Aohan Banner, Inner Mongolia, from August to October 2021, and analyzed these data using the comprehensive index method. Meanwhile, we used a multiple linear regression model to analyze the key factors affecting farmer livelihood resilience across different livelihood types and towns. We found that farmers who primarily worked in agriculture had the highest resilience scores and that livelihood resilience differed by geographical location; specifically, livelihood resilience gradually declines from southern to northern areas and from forest and forest-grassland to grassland locations. The results also show that education level, agricultural technology training, transportation infrastructure, accessibility of information, awareness of climate change, climate change perception, change in livelihood strategies, family size, and the holding size of the arable area are positively associated with farmer livelihood resilience, while household head age is negatively associated with resilience. We therefore advise that policymakers should diversify agricultural livelihoods, afforest surrounding arable areas, improve transportation infrastructure, increase learning activities and skill training for farmers, and publicize climate change knowledge.

Keywords: climate change adaptation; livelihood resilience; livelihood types; surrounding land uses

Citation: Han, Z.; Youn, Y.-C.; Kim, S.; Choe, H. Improving Farmer Livelihood Resilience to Climate Change in Rural Areas of Inner Mongolia, China. *Agriculture* **2023**, *13*, 2030. https://doi.org/10.3390/agriculture13102030

Academic Editors: Tiziano Gomiero, Lisa Lobry de Bruyn and Ji Li

Received: 23 August 2023
Revised: 6 October 2023
Accepted: 17 October 2023
Published: 20 October 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Climate change is undoubtedly the most severe and noticeable environmental issue worldwide [1,2]. Events caused by global warming, such as extremely hot weather and heavy precipitation, threaten to worsen living standards, especially in low-income countries, which have relatively weak resilience and high socio-economic vulnerability to climate change [3–7]. In most developing countries, climate change severely affects socio-economic development and, consequently, the livelihoods of residents [8]. It particularly impacts agricultural systems, upon which many rural households in developing countries base their livelihoods [9]. Since severe climate change profoundly impacts rural societies, including their fresh water supplies, food security, and agricultural incomes [10], strategies to adapt to climate change are needed for rural societies to be sustainable.

Given the increasing impact of climate change on socio-ecological systems, resilience has gradually become a new concept in discussions of how to deal with climate change because it encapsulates the ability of socio-ecological systems to adapt to global warming [11–15]. Resilience was first proposed by Holling [16] as a conceptual tool for measuring the persistence of an ecosystem and its ability to maintain its original state after being disturbed by external forces. Increasingly, resilience is being widely applied in a variety of research areas, including socio-ecological systems [12,17], climate change [18,19], natural disasters [20], and sustainable agriculture [21]. Resilience theory provides a new tool for studying ecological environments, natural resource management, and sustainable socio-economic development by analyzing the ability of systems to adapt to climate change.

Farmers are the basic units of productive and reproductive activities in rural areas [22], and their ability to adapt to climate change is related to the sustainable development of their livelihoods [23]. "Farmer livelihood resilience" to climate change refers to a farmer's capacity to maintain the structure and function of their livelihood system and to adapt, learn, and transform in the context of climate change [15].

Evaluating farmer livelihood resilience after climate disasters is a critical research topic. Research on livelihood resilience mainly focuses on several key areas: (1) conceptual understanding. Uy et al. [24] took six coastal villages in the Philippines as research objects to understand the micro-level favorable conditions for adapting to climate change through the perspective of livelihood. (2) Evaluation framework construction. The sustainable livelihoods framework was first proposed by the British Department for International Development (DFID) [25]; Speranza et al. [17] constructed a framework for analyzing livelihood resilience; and Sina et al. [26] developed a framework for assessing livelihood resilience in post-disaster displacement situations. (3) Analysis of influencing factors. Wen et al. [27] found that household savings and per capita income significantly impacted farmer livelihood resilience to climate change in the Loess Plateau region, while Campbell [28] measured the livelihood resilience of Jamaican coffee farmers under environmental changes and found that land tenure and gender issues were important influencing factors. (4) Resilience level measurement. Nasrnia and Ashktorab [29] used the sustainable livelihood method to assess household livelihood resilience in the Bakhtegan basin. (5) Discussion on livelihood resilience and strategies. Zhou et al. [20] investigated and analyzed the characteristics and correlation between livelihood resilience and livelihood strategies of 327 households in the Sichuan earthquake-stricken area.

In general, existing studies have paid limited attention to the regional aspects of farmer livelihood resilience, especially the systematic investigation of farmer livelihood resilience and its influencing factors in different geographical areas. Additionally, while most of these studies evaluated and analyzed farmer livelihood resilience through factors such as livelihood capital and socio-economic variables, few scholars have conducted a comprehensive analysis of farmer livelihood resilience from the perspective of mental perception and environmental conditions. Consequently, it is difficult to comprehensively understand the influencing factors of subjective farmer livelihood resilience. To address these gaps, it is important to measure farmer livelihood resilience across various livelihood types and spatial patterns. It is also crucial to analyze the factors influencing farmer livelihood resilience from the perspectives of socio-economic characteristics, external environmental factors, and mental perception [30,31]. Furthermore, it is noteworthy that many scholars have focused their research on China's relocation areas [32,33], special ecological environment areas (e.g., Loess Plateau) [27,34–36], specialized industrial chain regions (e.g., tea, apple, and citrus farmers) [35,37,38], poor mountainous areas [39,40], tourist attractions [41,42], and wetland heritage sites [43]. Few research studies have concentrated on agricultural counties. However, as a major agricultural country, China faces persistent challenges related to "Three Rural Issues"—agriculture, rural areas, and farmers. Therefore, it is necessary to study the agricultural areas mainly based on agriculture to provide valuable insights into increasing farmer income, promoting agricultural development, and ensuring rural stability.

This study's objectives were as follows: (1) to assess farmer livelihood resilience to climate change according to type of livelihood and location and (2) to identify the factors influencing farmer livelihood resilience to climate change. This study evaluates the resilience of farmers' livelihoods from the perspective of their livelihood type and geographical location simultaneously and provides a reference for government decision-makers and farmers seeking to adopt effective livelihood strategies to cope with climate change.

In this study, we used the livelihood resilience analysis framework proposed by Speranza et al. [17] with three dimensions: buffering, self-organizing, and learning capacity, to evaluate farmers' livelihood resilience.

"Buffer capacity" refers to whether the system can maintain the same structure, function, identity, and structural and functional feedback when disturbed [17,44]. Previous studies have used the following indicators to measure buffer capacity: household laborers [27,38], health and environmental issues [45,46], arable area per capita [23,47], soil capability index [48,49], housing quality [23,38,50], savings [27], and assets [51].

"Self-organization capacity" is the ability of farmers in agricultural systems to participate in social, economic, and institutional environments and form flexible networks [17,52]. Previous studies have used the following indicators to measure this capacity in relation to farmers' livelihood: social network [46,50], neighborhood trust [17,38], market access [38,45,46], leadership [38,47,53,54], specialized cooperative [46,53,55], grain self-sufficiency [17], and access to credit [56].

"Learning capacity" refers to whether farmers can learn, acquire, memorize, and disseminate knowledge and skills and convert them into actual livelihood capital [38]. A high learning capacity enables farmers to respond quickly to external disturbances and shocks by adjusting their livelihood strategies to improve livelihood resilience [38,57]. Previous studies have used the following indicators to measure learning capacity: education of household head [53], previous work experience [56,58], information accessing capacity [17,27,38,56], purchase of insurance [38,56,59], education investment [17,27,53], technical training [53,56], and knowledge transfer capability [17].

Livelihood resilience can help farmers to recover their livelihoods when they are affected by climate change [15]. Factors influencing farmer livelihood resilience include their socio-economic characteristics, external environmental factors, and mental perception [30,31]. Specifically, socio-economic characteristics include non-agricultural level of income [60], highest level of education [26], age of household head [61], family size [53,62], and arable area [20,63]. External environmental factors include agricultural technology training [64], the convenience of transportation [53], accessibility of information [65], and change in livelihood strategies [66]. Mental perception includes awareness of climate change [67] and climate change perception [35,68].

This study is organized as follows. First, based on the livelihood resilience analysis framework [17], we constructed an indicator system [69,70] to assess farmer livelihood resilience in the face of climate change. Second, we conducted separate questionnaire surveys of agricultural experts and farmers. We selected an agricultural county, Aohan Banner of Inner Mongolia in China, as the research area. We set the study in five different regions in the Aohan Banner and used a sampling survey to collect data on critical factors that influence farmer livelihood resilience. Third, the analytic hierarchy process (AHP) was used to analyze agricultural experts' survey data to determine the weight of three dimensions of farmer livelihood resilience to climate change. Fourth, we then used data standardization, the entropy weight method (EWM), and the comprehensive index method [38,71] to measure livelihood resilience using the farmers' survey data, which quantitatively evaluated the capacity of farmers' livelihood systems to restore their essential function and structure after being disturbed by climate change. Finally, we used a multiple linear regression model to analyze the critical factors influencing farmer livelihood resilience across different livelihood types and towns. The study flowchart is shown in Figure 1.

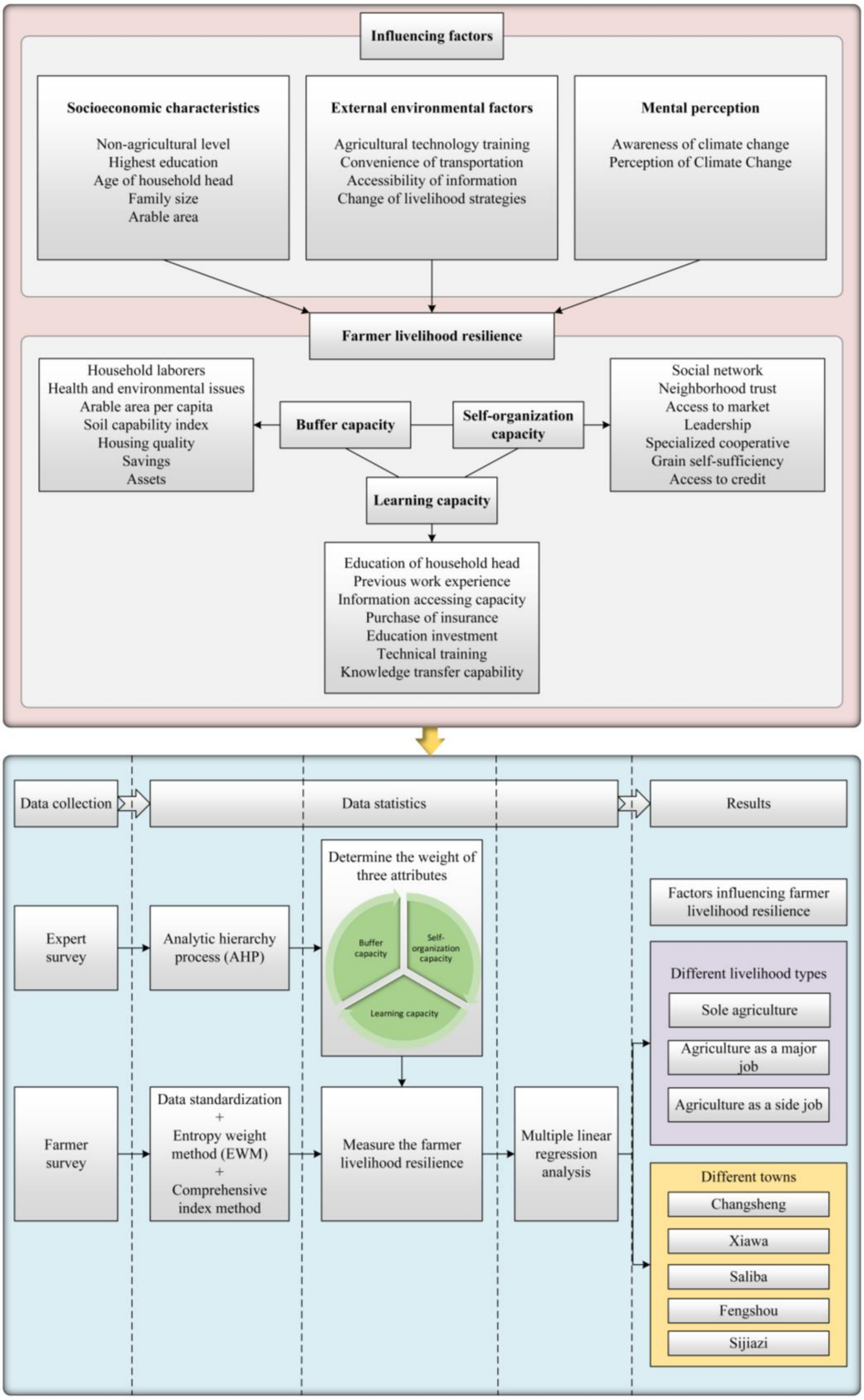

Figure 1. Study flowchart (note: the pink box above represents the theoretical framework of this study including the dimensions and indicators of farmer livelihood resilience and influencing factors. The blue box below is an outline of the methods and results of this study).

2. Materials and Methods

2.1. Study Area

Aohan Banner is a county located in the southeast of Chifeng in Inner Mongolia, China (41°42′–42°02′ N, 119°30′–120°54′ E) (Figure 2). Its total area is 8294 km^2 [72], and its altitude ranges from 300 to 1250 m. Aohan Banner comprises 16 towns with a total population of 595,743 and a total of 249,055 households in 2021, including 492,700 rural residents and 176,600 rural households [72]. The region's rural residents make up the majority of its population, and most residents rely on agriculture for their livelihoods, including herding and forestry. The distribution of natural vegetation differs across regions and gradually transitions from south to north from forest and forest-steppe to steppe [73].

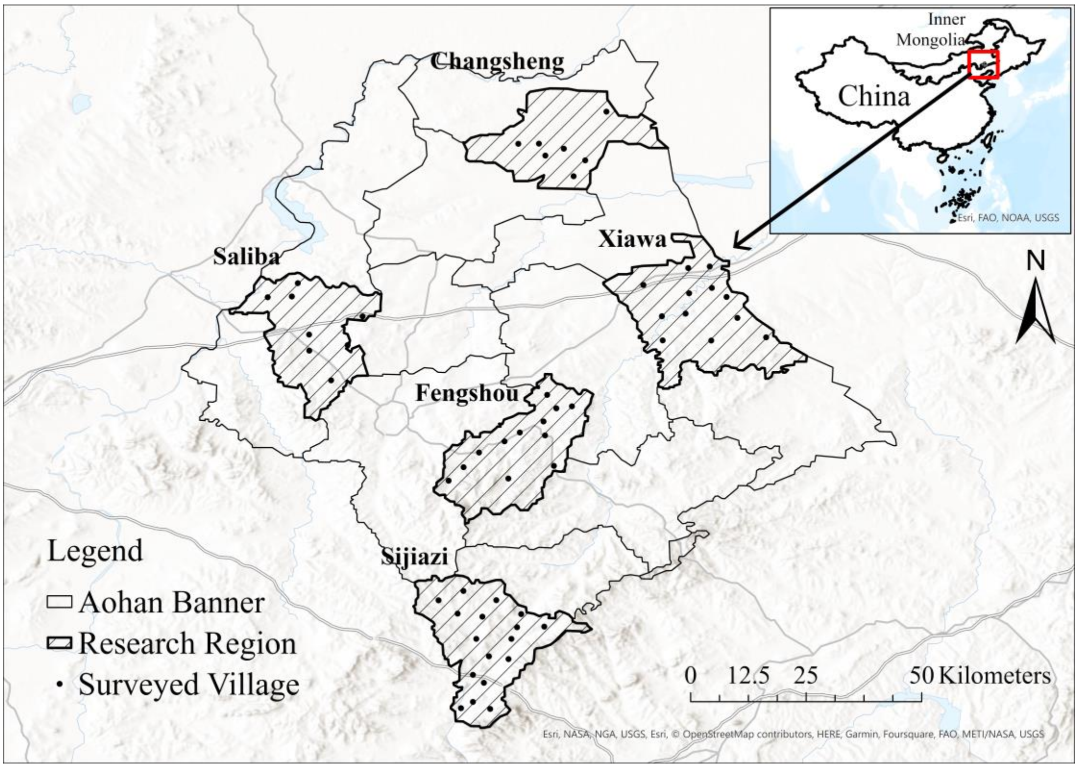

Figure 2. Location of the study area.

Aohan Banner has several advantages for analyzing farmer livelihood resilience to climate change. First, Aohan Banner is an important commodity grain production base in China [74], and in August 2012, the Food and Agriculture Organization of the United Nations (FAO) certified the dry farming system in Aohan Banner as a Globally Important Agricultural Heritage System (GIAHS). Second, Aohan Banner is located in a semi-arid area with poor natural conditions—soil desertification is now deepening due to global warming, making the area prone to sandstorms and other disasters in the spring and autumn [75]. In addition, climate change is also causing droughts in Aohan Banner. In recent years, these droughts have primarily been caused by frequent extreme climate events influenced by El Niño [76].

2.2. Questionnaire Surveys

2.2.1. Expert Survey

We conducted surveys among agricultural experts to determine the weight of three dimensions of farmer livelihood resilience to climate change. We utilized expert sampling to ensure that highly knowledgeable experts were included in our research. This method was chosen to enhance the credibility and validity of our findings by incorporating the insights of experts with relevant and extensive knowledge in the field [77]. First, we constructed a sample pool from a list of experts. We identified 42 experts with many years of experience in agricultural and forestry economics and environmental policy through a literature and Internet search. We then contacted the experts via email and mobile messaging apps to maximize accessibility and engagement, explaining the purpose and importance of the study, and attaching questionnaire content. Among them, 35 experts agreed to answer the questionnaire and returned it to us, with a response rate of 83.3%. The survey questions asked the experts to compare pairs of dimensions and assign them scores ranging from 1 (A is the same as B) to 9 (A is extremely important than B), as shown in Table S1 in the Supplementary Materials [78].

2.2.2. Farmer Survey

Our research strictly followed the rights and privacy of the farmers interviewed, ensuring their voluntary participation and preventing potential harm. The personal data collected from farmers were anonymized and securely stored to ensure their privacy and security. Meanwhile, our research adhered to the principles of transparency and honesty so that other researchers can replicate our findings, thus ensuring their legitimacy, ethics, and credibility.

By the end of 2020, the total population of Aohan Banner was 597,790 [79]. With a margin of error set to 4–5% at a 98% confidence level, a sample size consisting of 543 to 847 people was considered most appropriate. To determine whether farmer livelihood resilience differed across different regions, five towns representing the north, south, east, west, and middle of Aohan Banner were selected. These towns were Changsheng, Sijiazi, Xiawa, Saliba, and Fengshou, which have 14, 17, 12, 8, and 12 administrative villages, respectively. We conducted a random sampling survey with 10 farmers in each of these 63 administrative villages in August, September, and October of 2021, with a total of 630 questionnaires. We excluded 34 questionnaires that were incomplete or contained illogical information. This left 596 valid questionnaires for analysis, with an effective recovery rate of 94.6%.

Ten civil servants engaged in agriculture and rural-related work reviewed the questionnaire draft to assess its suitability. The farmer questionnaire comprised four parts: (1) farmer buffer capacity, (2) farmer self-organization capacity, (3) farmer learning capacity, and (4) influencing factors.

Referring to the classification of farmers' livelihood types by previous studies [38,80], we divided farmers' livelihood types into only agriculture, agriculture as a major job, and agriculture as a side job according to the proportion of household agricultural income in total household income (see Table S2 in the Supplementary Materials).

2.3. Questionnaire Analysis

2.3.1. Analytic Hierarchy Process for Expert Survey

The analytic hierarchy process (AHP) is widely known as a method for collecting the opinions of various experts to support rational decision-making [81,82]. The decision factor weights can be expressed as follows [83,84]:

$$A' \times V' = \lambda_{max} \times V', \quad (1)$$

where A is the square matrix obtained by means of pairwise comparison, λ_{max} is the maximum eigenvalue, and V is the eigenvector. The consistency index (CI) shows that Matrix A has greater consistency when λ_{max} approaches n, as indicated in Formula (2).

$$\text{Consistency Index (CI)} = \frac{\lambda_{max} - n}{n - 1}, \quad (2)$$

We calculated the vector's final importance by integrating the relative weights of the determinants and multiplying the weights based on the ranking of the alternatives. The weighting equation for the alternatives is as follows:

$$W_i = \sum (W_j)\left(\mu_j^i\right), \tag{3}$$

where W_i is the total weight of the alternative i, W_j is the relative weight of the valuation standard j, and μ_j^i is the weight of the alternative i relative to the valuation standard j.

2.3.2. Data Standardization and Weight of the Index for Farmer Survey

To eliminate the influence of dimensional and order of magnitude differences among each measure index from the farmer survey, the original data of each measure index needed to be standardized [38]. We accordingly applied the extremum processing method, as shown in Formula (4) [85].

$$x_{ij}^* = \frac{x_{ij} - m_j}{M_j - m_j}, \tag{4}$$

where x_{ij} is the original data of row i and column j, m_j is the minimum value of the original value of column j, M_j is the maximum value of the original value of column j, and x_{ij}^* is the standardized data of row i and column j, $x_{ij}^* \in [0, 1]$.

We used the entropy weight method (EWM) to determine the weight of the farmer livelihood resilience index, as shown in Formulas (5)–(8).

$$P_{ij} = \frac{x_{ij}^*}{\sum_{i=1}^{m} x_{ij}^*} \tag{5}$$

$$e_j = -\frac{1}{\ln m} \times \sum_{i=1}^{m} P_{ij} \ln\left(P_{ij}\right) \tag{6}$$

$$g_j = 1 - e_j \tag{7}$$

$$\omega_j = \frac{g_j}{\sum_{j=1}^{n} g_j}, \tag{8}$$

where P_{ij} is the proportion of the ith sample farmer index under the jth indicator,e_j represents the entropy of the jth indicator, g_j represents the different coefficient of the jth indicator, and ω_j represents the weight of the jth indicator (i = 1, 2,. . ., m; j = 1, 2,. . ., n).

2.3.3. Comprehensive Index Method

The comprehensive index method [38] was adopted to measure the resilience of farmers' livelihoods, as shown in Formulas (9)–(12).

$$B_i = W_b \sum_{j=1}^{7} \omega_j x_{ij}^* \tag{9}$$

$$S_i = W_s \sum_{j=8}^{14} \omega_j x_{ij}^* \tag{10}$$

$$L_i = W_l \sum_{j=15}^{21} \omega_j x_{ij}^* \tag{11}$$

$$R_i = B_i + S_i + L_i, \tag{12}$$

where x_{ij}^* represents the standardized value of the jth indicator of the ith sample farmer, ω_j represents the weight of the jth indicator; W_b, W_s, and W_l represent the weights of the dimension layers of buffer capacity, self-organization capacity, and learning capacity, respectively, calculated using the AHP for the expert survey; B_i, S_i, and L_i represent the buffer capacity, self-organization capacity, and learning capacity of the ith sample farmer, respectively; and R_i represents the farmer livelihood resilience index.

2.3.4. Analysis of Factors Influencing Farmer Livelihood Resilience

We utilized the multiple linear regression model to analyze the influencing factors of farmer livelihood resilience, because this model is more suitable for our research. Although both logistic regression and multiple linear regression are generalized linear models, logistic regression is usually used to deal with the situation where the dependent variable is classified data. The dependent variable in our study was livelihood resilience, which we treated as a continuous variable. Therefore, multiple linear regression was deemed more appropriate [38,86–89]. We applied the multiple linear regression analysis after confirming that there was no multicollinearity between variables (Formula (13)).

$$R = \alpha + \beta_i F_i + \mu_i, \quad (13)$$

where R is farmer livelihood resilience, α is a constant, β_i is the coefficient of the ith variable, F_i represents possible factors influencing the resilience of the farmers' livelihoods to climate change, and μ_i is the disturbance term (i = 1, 2, . . .). We defined the influencing factors based on the existing literature and the actual conditions of farmers (see Table S3 in the Supplementary Materials for the specific definitions).

We selected town location and livelihood type as dependent variables and conducted a one-way ANOVA, a statistical technique used to compare the means of three or more independent groups [90] given one categorical independent variable and one continuous dependent variable [91].

3. Results

3.1. Relative Weight of Three Farmer Livelihood Resilience Dimensions Based on the Analytic Hierarchy Process for the Expert Survey

The AHP results showed that the weights of buffer capacity, self-organization capacity, and learning capacity were 0.3335, 0.3263, and 0.3402, respectively (see Table S4 in the Supplementary Materials). The experts thought that learning capacity was most important for farmer livelihood resilience to climate change, followed by buffer capacity and self-organization capacity.

3.2. Sociodemographic Characteristics of Interviewed Farmers from Valid Farmer Survey Data

Among the 596 farmers who answered effectively, their specific socio-demographic characteristics were as follows: their average gender value was 0.53, indicating a relatively balanced gender ratio. The age of farmers ranged from 18 to 82, with an average age of 49. The average marital status of farmers was married. The average value for the educational level of farmers was 2.07, concentrated at the junior high school level. The average value for the annual household agricultural income of farmers was 2.97, at approximately 40,000–59,999 RMB (see Table S5 in the Supplementary Materials).

3.3. The Classification of Farmers' Livelihoods Based on the Farmer Survey

Among the 596 valid respondents, 201 households (33.72% of the sample) made their livelihoods based on only agriculture, 203 households (34.06%) engaged in agriculture as a major job, and 192 (32.22%) engaged in agriculture as a side job (see Table S6 in the Supplementary Materials).

3.4. Farmer Livelihood Resilience Index Weights from the Farmer Survey

The results of the farmer livelihood resilience index in all farmer survey samples and their weight coefficients are shown in Table S7 of the Supplementary Materials. Among them, health and environmental issues, grain self-sufficiency, and educational investment accounted for the highest weights of buffer capacity, self-organization capacity, and learning capacity, respectively.

3.5. Farmer Livelihood Resilience

3.5.1. Farmer Livelihood Resilience across Different Livelihood Types

The one-way ANOVA tests for different livelihood types revealed significant differences in farmer livelihood resilience across different livelihood types. Specifically, farmers who engaged in agriculture as a major job type (0.306) had the highest levels of resilience, followed by those who engaged in agriculture as a side job (0.290), and those who only worked in agriculture (0.264) (see Table S8 in the Supplementary Materials). Farmers who considered agriculture one of their major jobs ranked first in buffer capacity, self-organization capacity, and learning capacity. Conversely, farmers who only worked in agriculture exhibited relatively weak capacities in these three dimensions. Regardless of the type of farmer, learning capacity was more highly evaluated than buffer capacity, and buffer capacity more highly than self-organization capacity.

Farmer livelihood resilience ranged from 0 to 0.8 (Figure 3). The livelihood resilience levels of farmers who only worked in agriculture, worked in agriculture as a side job, and worked in agriculture as a major job were mainly concentrated in the ranges of 0.186–0.365, 0.201–0.377, and 0.211–0.398, respectively. From highest to lowest, the medians of the three types of livelihood resilience were as follows: agriculture as a major job—0.295); agriculture as a side job—0.266; and only agriculture—0.250.

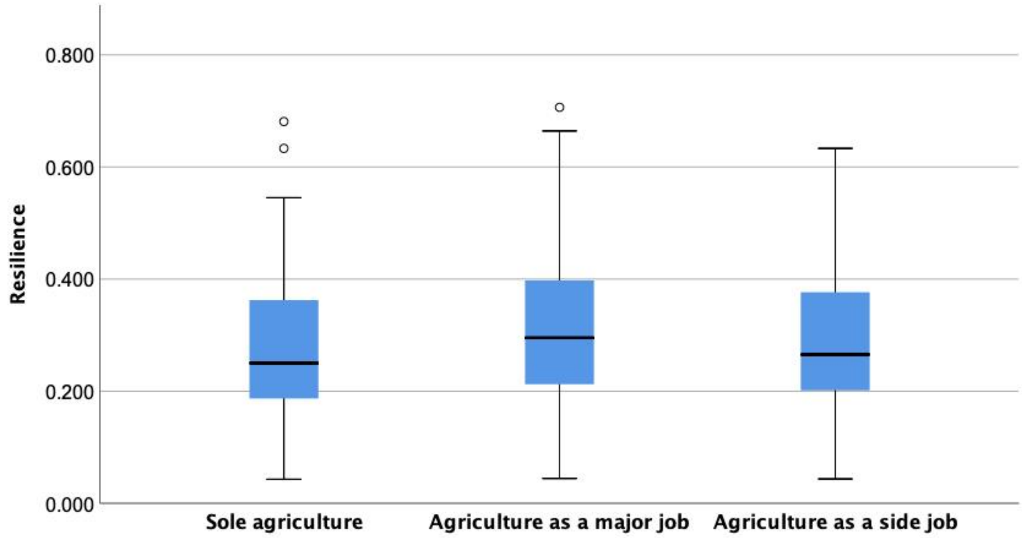

Figure 3. Farmer livelihood resilience across different livelihood types (note: hollow circles represent outliers).

By comparing the characteristics of the livelihood resilience indicators of farmers with different livelihood types (see Table S9 in the Supplementary Materials), we found that farmers who only worked in agriculture had relatively weaker scores than other types of farmers for indicators such as household laborers (B_1), housing quality (B_5), assets (B_6), leadership (S_4), specialized cooperative (S_5), education of household head (L_1), purchase of insurance (L_4), educational investment (L_5), technical training (L_6), and knowledge transfer capacity (L_7). The scores of the farmers who only worked in agriculture were 1.985 (B_1), 2.157 (B_5), 1.945 (B_6), 0.080 (S_4), 0.149 (S_5), 2.905 (L_1), 0.791 (L_4), 2.408 (L_5), 0.507 (L_6), and 0.766 (L_7), respectively, being lower than the average scores for all farmers, which were 2.114 (B_1), 2.194 (B_5), 2.282 (B_6), 0.153 (S_4), 0.211 (S_5), 3.077 (L_1), 0.886 (L_4), 2.529 (L_5), 0.601 (L_6), and 0.800 (L_7). Farmers who worked agriculture as a side job had relatively weaker scores than other types of farmers for indicators such as arable area per capita (B_3), soil capability index (B_4), assets (B_7), neighborhood trust (S_2), access to market (S_3), grain self-sufficiency (S_6), access to credit (S_7), previous work experience (L_2), and information accessing capacity (L_3). The scores of farmers who worked agriculture as a side job were 8.862 (B_3), 1.813 (B_4), 15.526 (B_7), 4.255 (S_2), 3.536 (S_3), 0 (S_6), 0.984 (S_7), 3.880 (L_2), and 3.979 (L_3), respectively, being lower than the average scores for all farmers, which were 10.748 (B_3), 1.888 (B_4), 19.438 (B_7), 4.324 (S_2), 4.880 (S_3), 0.032 (S_6), 0.985 (S_7), 4.151 (L_2), and 4.087 (L_3).

3.5.2. Farmer Livelihood Resilience across Different Towns

The ANOVA tests showed significant differences in farmer livelihood resilience in different towns (see Table S10 in the Supplementary Materials). Specifically, from highest to lowest, the farmer livelihood resilience rankings of the studied towns were as follows: Sijiazi (0.350), Fengshou (0.323), Saliba (0.259), Xiawa (0.256), and Changsheng (0.195). Learning capacity was relatively higher than buffer capacity in these five towns, and buffer capacity was somewhat higher than self-organization capacity. These results for the three dimensions were the same across livelihood types.

Farmer livelihood resilience in different towns is shown in Figure 4. Farmer livelihood resilience decreased gradually from Sijiazi (0.350) in the south to Changsheng (0.195) in the north.

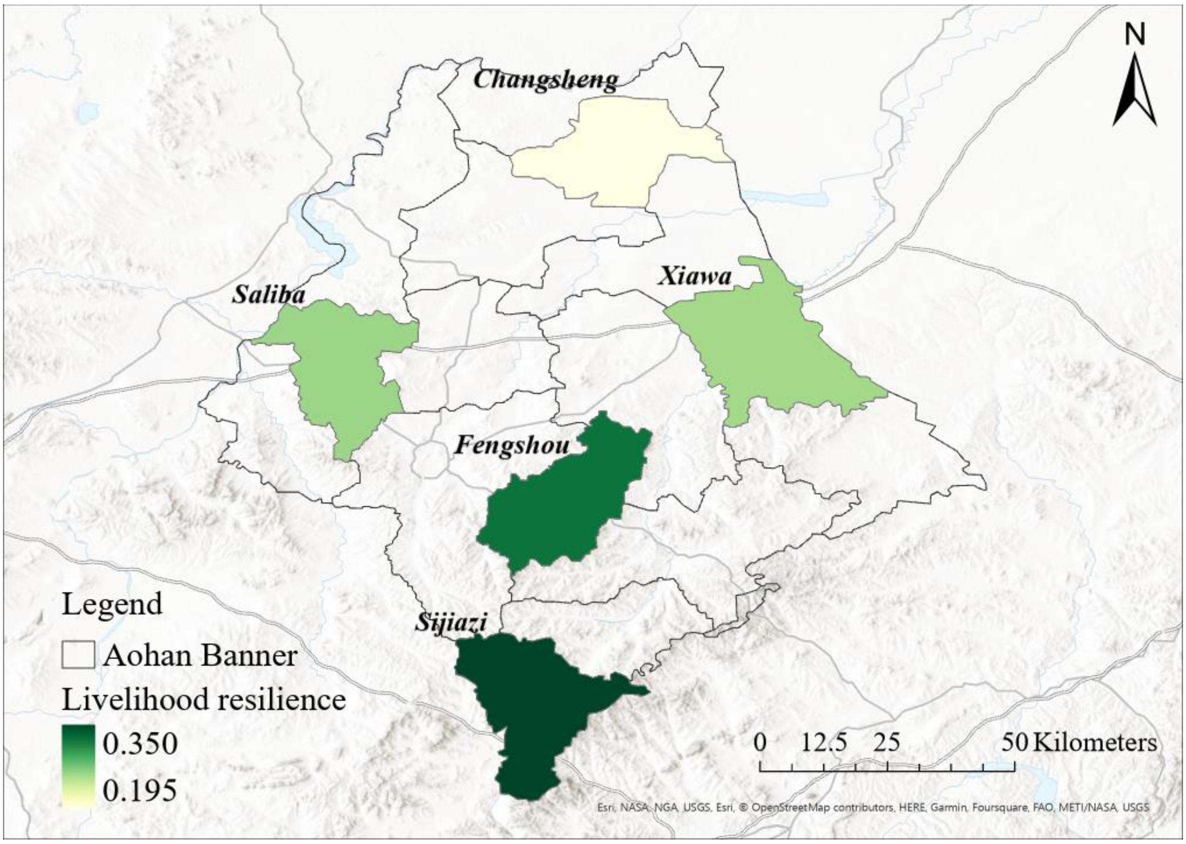

Figure 4. A map of farmer livelihood resilience in different towns.

The regional differences in farmer livelihood resilience indicators in different towns (Table S11 in Supplementary Materials) showed that the town with the lowest farmer livelihood resilience (Changsheng) was more vulnerable to climate change than other towns in relation to health and environmental issues (B_2), leadership (S_4), grain self-sufficiency (S_6), education investment (L_5), and knowledge transfer capability (L_7). In detail, the score for the health and environmental issues (B_2) of farmers in Changsheng was 0, lower than the average of 0.139; the score for leadership (S_4) was 0.05, lower than the average for all farmers investigated, 0.153; the score for grain self-sufficiency (S_6) was 0, lower than the average of 0.032; the score for education investment (L_5) was 1.763, lower than the average of 2.529; the score for knowledge transfer capability (L_7) was 0.538, lower than the average for all farmers, 0.800. However, arable area per capita (B_3) was the highest in Changsheng, which had the lowest farmer livelihood resilience, with a score of 24.469, higher than the average of 10.748. On the other hand, farmers in Sijiazi, which had the highest farmer livelihood resilience, were evaluated as being weak compared to farmers in other towns in terms of the soil capability index (B_4), grain self-sufficiency (S_6), and information accessing capacity (L_3). Specifically, the score for the soil capability index (B_4) in Sijiazi was 1.721, lower than the average of 1.888; the score for grain self-sufficiency rate (S_6) was 0, lower than the average of 0.032; and the score for information accessing capacity (L_3) score was 3.536, lower than the average of 4.087.

3.6. Factors Influencing Farmer Resilience to Climate Change

Table S12 of the Supplementary Materials shows the results for the influencing variables of farmer livelihood resilience. The regression analysis of factors influencing the livelihood resilience of farmers showed that the highest educational level, family size, arable area, agricultural technology training, convenience of transportation, accessibility of information, change in livelihood strategies, awareness of climate change, and climate change perception had a positive effect on farmer livelihood resilience, while the age of the household head had a negative effect on farmer livelihood resilience (Figure 5). The regression analysis of factors influencing the livelihood resilience of farmers with different livelihood types showed that the highest educational level, family size, agricultural technology training, accessibility of information, change in livelihood strategies, awareness of climate change, and climate change perception had a positive effect on the livelihood resilience of farmers who worked in agriculture as a major job (0.295), while the non-agricultural level and age of the household head had a negative effect on the livelihood resilience of these farmers. The highest educational level, family size, agricultural technology training, accessibility of information, change in livelihood strategies, and awareness of climate change had a positive influence on the livelihood resilience of farmers who worked in agriculture as a side job (0.266). Non-agricultural level, highest educational level, family size, arable area, agricultural technology training, convenience of transportation, awareness of climate change, and climate change perception had a positive influence on the livelihood resilience of farmers who only worked in agriculture (0.250), while the age of the household head had a negative influence on the livelihood resilience of these farmers (Table S13 in Supplementary Materials).

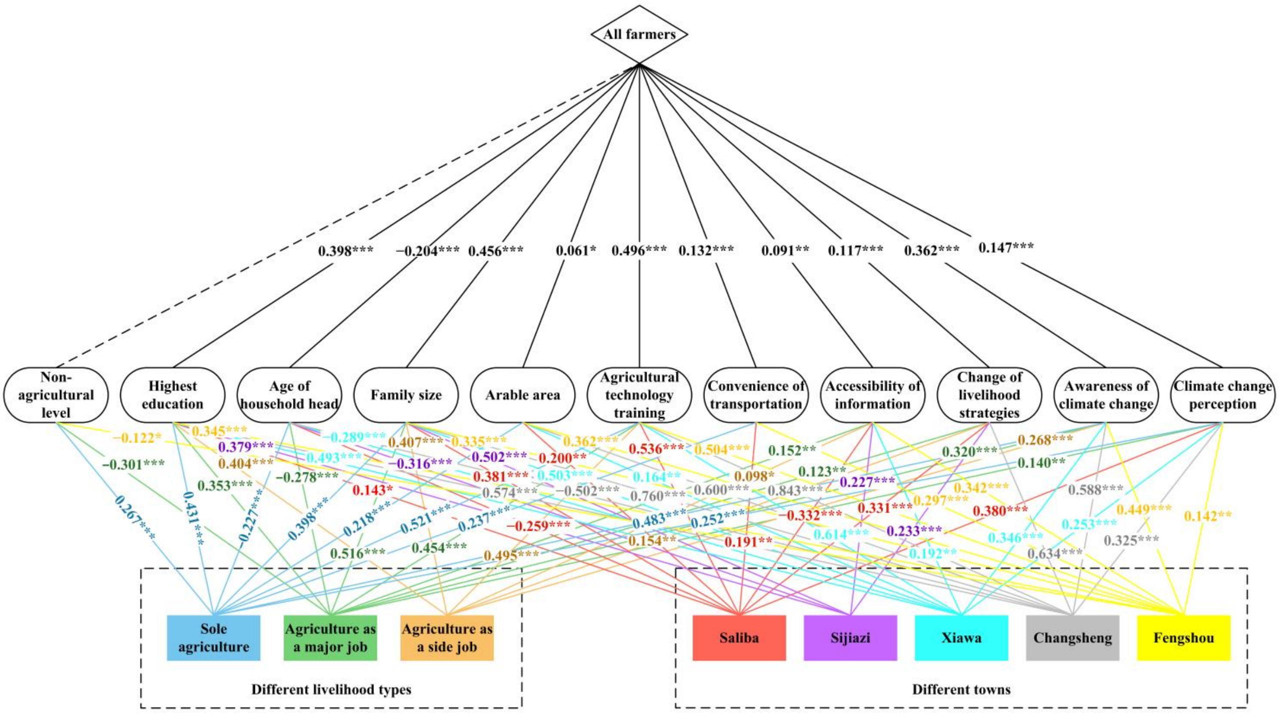

Figure 5. Regression analysis results of factors influencing the livelihood resilience of farmers with different livelihood types and different towns (the solid lines represent significance and the dotted lines represent insignificance. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively).

We found that different factors in each town affected farmer livelihood resilience (Table S14 in Supplementary Materials). The highest educational level, family size, accessibility of information, and change in livelihood strategies had a positive influence on farmer livelihood resilience in Sijiazi (0.350), while the age of the household head had a negative influence on farmer livelihood resilience in Sijiazi. The highest educational level, family size, arable area, agricultural technology training, convenience of transportation, accessibility of information, awareness of climate change, and climate change perception had a positive influence on farmer livelihood resilience in Fengshou (0.323), while the non-agricultural level had a negative influence on farmer livelihood resilience in Fengshou. Meanwhile, the highest educational level, family size, arable area, agricultural technology training, convenience of transportation, change in livelihood strategies, and climate change perception had a positive influence on farmer livelihood resilience in Saliba (0.259), while the age of the household head and accessibility of information had a negative influence on farmer livelihood resilience in Saliba. Additionally, the highest educational level, family size, arable area, agricultural technology training, accessibility of information, awareness of climate change, and climate change perception had a positive influence on farmer livelihood resilience in Xiawa (0.256), while the age of the household head had a negative influence on farmer livelihood resilience in Xiawa. Lastly, the highest educational level, family size, arable area, agricultural technology training, change in livelihood strategies, awareness of climate change, and climate change perception had a positive influence on farmer livelihood resilience in Changsheng (0.195), while the age of the household head had a negative impact on farmer livelihood resilience in Changsheng.

4. Discussion

4.1. Policy Implications

4.1.1. Livelihood Resilience Analysis Framework

The livelihood resilience analysis framework is a specialized tool that applies resilience theory to the specific context of rural livelihoods and development [15]. Our study used the livelihood resilience analysis framework to assess farmer livelihood resilience. Specifically, according to the expert questionnaire survey results, the experts considered farmer learning capacity more critical for livelihood resilience to climate change than buffer capacity and self-organization capacity. Farmers need to constantly acquire new knowledge and skills to adjust their livelihood strategies to environmental changes [20]. Building good livelihood resilience often requires learning and adaptation [66]. Thus, the farmer questionnaire survey results show that farmers also rank farmer learning capacity more highly than buffer capacity and buffer capacity more highly than self-organization capacity. This indicates that the education level in rural areas has rapidly developed as a result of the government attaching great importance to education [92]. To facilitate the sustainable development of farmers' livelihoods, it is necessary to strengthen farmers' buffer and self-organization capacities. Increasing farmers' natural, human, and physical capital can enhance their buffer capacity and therefore help them better navigate livelihood risks due to climate change. In particular, it is important to note that there are few sanitary toilets in rural areas, and it is necessary to popularize them to improve farmers' buffer capacity. Meanwhile, farmers' self-organization capacity can be improved by increasing their grain self-sufficiency, improving their leadership abilities, and optimizing their social network structure. To ensure balanced farmer livelihood resilience, it is necessary to stabilize their livelihood system in the face of climate change by simultaneously strengthening their buffer, self-organization, and learning capacities [17,27]. In June 2022, 17 ministries including the Ministry of Ecology and Environment of China jointly issued the "National Climate Change Adaptation Strategy 2035" [93]. This aims to address the potential impacts of climate change on various sectors in China, including the environment, water resources, agriculture, health, and urban and rural development, among others. It mentioned that agricultural production is directly exposed to climate and environmental stress, and in this regard, it is necessary to promote sustainable agricultural development and ensure the stability of the food supply [94]. Extreme weather events such as heat waves directly affect human health, while vector-borne diseases and lack of health services indirectly increase health risks [93,94]. Therefore, it is necessary to study and formulate health risk assessment programs for climate change, and comprehensively promote health adaptation actions to climate change [93,94].

4.1.2. Farmer Livelihood Resilience across Different Livelihood Types

Our study found that farmer livelihood resilience changes across livelihood type. Farmers who worked in agriculture as a major job had the highest livelihood resilience, farmers who worked in agriculture as a side job had the second-highest livelihood resilience, and farmers who only worked in agriculture had the lowest livelihood resilience. However, these results vary by region. For example, the resilience rankings of different livelihood types are different in Anxi County. Specifically, Ji et al. [38] reported that, in Anxi County, tea farmers who worked in agriculture as a side job had the highest mean value of livelihood resilience, followed by those with a significant job in agriculture, and, lastly, those who only worked in agriculture. We believe that our findings cannot be generalized, as Aohan Banner is a vital pilot site for protecting agricultural heritage worldwide [95] and is an agriculture-oriented county that is less industrialized than Anxi County. However, it is notable that, in both studies, farmers who only work in agriculture were the least resilient. This indicates that the simpler the livelihood strategy, the lower the livelihood resilience. Accordingly, farmers who only worked in agriculture have a relatively weak ability to adapt to and resist the external risks to their livelihood caused by climate change.

4.1.3. Geographical Locations of Farmer Livelihood Resilience

The main restricting factors of the livelihood resilience of farmers in the five towns with different geographical locations are different. The town rankings of farmer livelihood resilience, from high to low, were as follows: Sijiazi, Fengshou, Saliba, Xiawa, and Changsheng. Sijiazi needs to enhance farmers' grain self-sufficiency. Fengshou needs to increase its arable area per capita. Saliba needs to improve housing quality and encourage farmers to participate in specialized cooperation. Meanwhile, in Xiawa, farmers should be encouraged to participate in technical training. Changsheng needs to increase food self-sufficiency, improve leadership, and increase investment in education. The town rankings of farmer per capita income, from high to low, were as follows: Sijiazi, Changsheng, Fengshou, Saliba, and Xiawa [96]. Changsheng's position is the only difference between the rankings of farmer livelihood resilience and farmer per capita income: it has the second-highest per capita income and the lowest livelihood resilience. We expect that Changsheng, located in the north of Aohan, is vulnerable to natural disasters such as drought, low-temperature damage, wind, rainstorms, hail, and frost due to its geographical and climatic conditions [97]. Accordingly, climate change may affect agriculture and farmer livelihood resilience in Changsheng more than in other towns. Farmers resident in Changsheng are much more vulnerable than those in other areas due to drought disasters, having enormous effects on maintaining their traditional activities [74]. Notably, this study highlighted that Aohan's landscape changes from forest to grassland from south to north; as climatic conditions become increasingly dry, farmer livelihood resilience is expected to gradually decrease. The difference between the three environments of forest, savanna, and grassland is mainly caused by the interaction of climate, topography, soil, and human activities [73,75,98]. Specifically, the precipitation in Aohan increases gradually from north to south, while the temperature decreases in the same direction [75]. Additionally, the average wind speed in the north is higher than that in the south [75]. The elevation also varies, with the north at 400–500 m above sea level, the middle at 500–600 m, and the south at 600–800 m [75]. There are four soil types from north to south: aeolian soil, calcareous soil, cinnamon soil, and brown soil [73,75,98]. Human activities, especially land use and cultivation practices, play a significant role in shaping the regional environment [73]. This vulnerability to climate change is reminiscent of the susceptibility of agriculture and economies in sub-Saharan Africa to climate change impacts, particularly the increasing frequency of droughts leading to food shortages and poverty, and affecting economic, social, and environmental resilience [99]. In arid environments, drought has a devastating impact on farmer livelihoods [29]. Scholars have accordingly recommended strengthening and integrating existing technical, policy, and institutional risk management measures to manage drought to reduce its adverse impacts on farmers [99]. In addition, governments need to establish policies to improve the resilience of farmers' livelihoods in the face of drought disasters [27].

4.2. Factors Influencing Farmer Livelihood Resilience

We analyzed the factors affecting farmer livelihood resilience using a multiple linear regression analysis and found that education level positively influences farmer livelihood resilience, indicating that the stronger a farmer's learning capacity, the stronger their livelihood resilience. When affected by climate change, farmers can learn new skills and experiences to alleviate their livelihood vulnerability and navigate their livelihood dilemmas. Agricultural technology training positively influences the livelihood resilience of farmers with different livelihood types. The acquisition of diversified new knowledge and skills through agricultural technology training is conducive to predicting climate change and adopting corresponding strategies to improve the adaptability of farmers to climate change. Climate change perception has a positive influence on farmer livelihood resilience: the greater the perception of climate change, the more likely farmers are to adopt effective coping strategies and remain resilient. Meanwhile, household head age had a negative influence on farmer livelihood resilience, indicating that the older the household head, the more conservative they will be when making livelihood decisions [100]. In addition, older household heads often choose a single traditional agricultural livelihood strategy [38], which does not adapt well to climate change. Weak learning and acceptance capacities for new knowledge, technologies, and information makes farmers' livelihoods relatively less resilient to climate change. Family size positively influenced farmer livelihood resilience: the larger the family, the more laborers, and the more reasonable the division of labor, which enhances the ability to resist the effects of climate change. Moreover, arable area has a positive influence on farmer livelihood resilience. The arable area is a lifelong essential and natural form of capital for farmers, especially for farmers who only work in agriculture. When climate change impacts livelihood risk, farmers can protect their income by increasing arable area, adjusting crops, and improving harvest efficiency. In the context of climate change, enhancing farmer livelihood resilience is essential for adapting to uncertain and fragile environments involving disturbances.

4.3. Limitations and Future Improvements

Our study has some limitations that could be addressed in future research. Firstly, due to constraints in both funding and time, our survey sample did not cover all 16 towns, but only selected five towns to represent different regions. Future research could broaden the geographical coverage of the sample area to improve the credibility of the study.

Secondly, although we recruited excellent investigators and conducted training, the survey only adopted the form of a questionnaire survey, and the investigators only raised the questions in the prepared questionnaire. This approach is limited by its lack of understanding of the problems that may arise in field investigations. Future research could use a combination of face-to-face interviews and questionnaires to increase the validity of the data and avoid biases in the results.

Thirdly, our study only mentioned changing livelihood strategies as a factor affecting livelihood resilience, and did not conduct in-depth analysis and research on the actual impact of specific livelihood strategies and production means on farmers' livelihoods. This could be supplemented in future research.

Lastly, the influencing factors of livelihood resilience involved in our study were limited. Future research should aim to identify and explore additional factors that might affect livelihood resilience. Additionally, analyzing the interactions between these factors, including possible complementary and substitutive effects, would enrich the research content and provide a more comprehensive reference for addressing livelihood resilience to climate change.

5. Conclusions

We found that farmers who worked in agriculture as a major job had the highest livelihood resilience, while farmers who only worked in agriculture had the lowest. The results also show that resilience gradually decreases from south to north as the landscape transitions from forest and forest-grassland to grassland. In addition, we found that several factors are positively associated with farmer livelihood resilience, including educational level, agricultural technology training, transportation infrastructure, accessibility of information, awareness of climate change, climate change perception, change in livelihood strategies, family size, and the holding size of the arable area. Conversely, the age of the household head was negatively associated with farmer livelihood resilience.

Based on these results, we recommend that policymakers focus on the following: (1) encouraging farmers to diversify their agricultural livelihoods to reduce dependence on single-crop output and improve resilience to climate change; (2) encouraging farmers to plant native trees around cultivated areas to enhance agricultural biodiversity [101]; (3) improving rural transportation conditions to increase the income and development potential of the rural economy; (4) improving farmers' agricultural knowledge and skills; and (5) publicize climate change knowledge and coping strategies to improve farmers' climate awareness and coping abilities.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture13102030/s1, Table S1: The scoring system we provided to experts when comparing each pair of dimensions; Table S2: The standard for classification of farmers' livelihood types; Table S3: The definitions of factors influencing the farmers' livelihood resilience; Table S4: Experts' insights on the weight of farmers' livelihood resilience dimension; Table S5: Sociodemographic characteristics of the surveyed farmers with valid data; Table S6: The classification of farmers' livelihoods and the percentage of responders in the farmer survey; Table S7: The survey results of farmers' livelihood resilience indicators from all farmers; Table S8: The livelihood resilience value of farmers with different livelihood types; Table S9: The scores of livelihood resilience indicators of farmers with different livelihood types; Table S10: The livelihood resilience of farmers in different towns; Table S11: The scores of livelihood resilience indicators of farmers in different towns; Table S12: Factors influencing farmers' livelihood resilience to climate change and survey results from all farmers; Table S13: Regression analysis results of factors influencing the livelihood resilience of farmers with different livelihood types; Table S14: Regression analysis results of factors influencing the livelihood resilience of farmers in different towns.

Author Contributions: All authors contributed to the manuscript writing. Z.H. conceived the idea, designed the study, conducted the survey, analyzed the data, interpreted the results, and wrote the original draft; Y.-C.Y. contributed to the manuscript review and editing; S.K. made the map and analyzed data; H.C. supervised this work. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2021R1A4A1025553 and No. RS-2023-00277059).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are available upon reasonable request from the first author.

Acknowledgments: We extend our gratitude to the 35 experts for generously sharing their knowledge with our study. We are also grateful for the dedication of our exceptional survey team in collecting the available data. Additionally, we would like to express our heartfelt appreciation to Liang Cheng for his invaluable assistance in data analysis. Last but not least, we are also thankful to all the respondents for their participation in completing the questionnaire.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Gardiner, S.M. Ethics and global climate change. *Ethics* **2004**, *114*, 555–600. [CrossRef]
2. Rahman, M.I.-u. Climate change: A theoretical review. *Interdiscip. Descr. Complex Syst. INDECS* **2013**, *11*, 1–13. [CrossRef]
3. Solomon, S.; Manning, M.; Marquis, M.; Qin, D. *Climate Change 2007—The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2007.
4. Karl, T.R.; Melillo, J.M.; Peterson, T.C.; Hassol, S.J. *Global Climate Change Impacts in the United States*; Cambridge University Press: New York, NY, USA, 2009.
5. Hansen, J.; Sato, M.; Ruedy, R. Perception of climate change. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, E2415–E2423. [CrossRef] [PubMed]
6. Peters, E.B.; Wythers, K.R.; Zhang, S.; Bradford, J.B.; Reich, P.B. Potential climate change impacts on temperate forest ecosystem processes. *Can. J. For. Res.* **2013**, *43*, 939–950. [CrossRef]
7. De Bandt, O.; Jacolin, L.; Thibault, L. *Climate Change in Developing Countries: Global Warming Effects, Transmission Channels and Adaptation Policies*; Banque de France Working Paper; SSRN: Rochester, NY, USA, 2021.
8. Rahman, H.; Hickey, G.M. An Analytical Framework for Assessing Context-Specific Rural Livelihood Vulnerability. *Sustainability* **2020**, *12*, 5654. [CrossRef]
9. Keshavarz, M.; Moqadas, R.S. Assessing rural households' resilience and adaptation strategies to climate variability and change. *J. Arid Environ.* **2021**, *184*, 104323. [CrossRef]
10. Liu, L.; Xu, H.; Ma, S. Understanding of climate change impacts, adaptation and vulnerability in urban areas and rural areas. *Clim. Chang. Res.* **2014**, *10*, 254–259. (In Chinese)
11. Adger, W.N.; Hughes, T.P.; Folke, C.; Carpenter, S.R.; Rockström, J. Social-ecological resilience to coastal disasters. *Science* **2005**, *309*, 1036–1039. [CrossRef]
12. Folke, C. Resilience: The emergence of a perspective for social–ecological systems analyses. *Glob. Environ. Chang.* **2006**, *16*, 253–267. [CrossRef]
13. Walker, B.; Holling, C.S.; Carpenter, S.R.; Kinzig, A. Resilience, adaptability and transformability in social–ecological systems. *Ecol. Soc.* **2004**, *9*, 5. [CrossRef]
14. Walker, B.; Salt, D. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*; Island Press: Washington, DC, USA, 2012.
15. Xiong, S.; Yan, J.; Wu, Y. Review on the resilience of farmers' livelihoods to climate change. *Geogr. Res.* **2020**, *39*, 1934–1946. (In Chinese)
16. Holling, C.S. Resilience and stability of ecological systems. *Annu. Rev. Ecol. Syst.* **1973**, *4*, 1–23. [CrossRef]
17. Speranza, C.I.; Wiesmann, U.; Rist, S. An indicator framework for assessing livelihood resilience in the context of social–ecological dynamics. *Glob. Environ. Chang.* **2014**, *28*, 109–119. [CrossRef]
18. Gautam, Y. Seasonal migration and livelihood resilience in the face of climate change in Nepal. *Mt. Res. Dev.* **2017**, *37*, 436–445. [CrossRef]
19. Tanner, T.; Lewis, D.; Wrathall, D.; Bronen, R.; Cradock-Henry, N.; Huq, S.; Lawless, C.; Nawrotzki, R.; Prasad, V.; Rahman, M.A.; et al. Livelihood resilience in the face of climate change. *Nat. Clim. Chang.* **2015**, *5*, 23–26. [CrossRef]
20. Zhou, W.; Guo, S.; Deng, X.; Xu, D. Livelihood resilience and strategies of rural residents of earthquake-threatened areas in Sichuan Province, China. *Nat. Hazards* **2021**, *106*, 255–275. [CrossRef]
21. Mahmoodi, S.; Hasani Talesh, M. Livelihood resilience of rural households with emphasis on sustainable agriculture (Case study: Khotbe'sara district, Talesh county). *Geogr. Dev.* **2021**, *19*, 119–146.
22. De Sherbinin, A.; VanWey, L.K.; McSweeney, K.; Aggarwal, R.; Barbieri, A.; Henry, S.; Hunter, L.M.; Twine, W.; Walker, R. Rural household demographics, livelihoods and the environment. *Glob. Environ. Chang.* **2008**, *18*, 38–53. [CrossRef]
23. Wang, T.; Shi, Y.; Liu, Q.; Wen, T.; Yang, X. Farmers'Adaptive Capability Against Drought in Semiarid Area in Central Gansu Province: A Case Study in Yuzhong County. *Arid Zone Res.* **2018**, *35*, 992–1000. (In Chinese)
24. Uy, N.; Takeuchi, Y.; Shaw, R. Local adaptation for livelihood resilience in Albay, Philippines. *Environ. Hazards* **2011**, *10*, 139–153. [CrossRef]
25. DFID. *Sustainable Livelihoods Guidance Sheets*; DFID: London, UK, 1999; Volume 445.
26. Sina, D.; Chang-Richards, A.Y.; Wilkinson, S.; Potangaroa, R. A conceptual framework for measuring livelihood resilience: Relocation experience from Aceh, Indonesia. *World Dev.* **2019**, *117*, 253–265. [CrossRef]
27. Wen, T.; Shi, Y.; Yang, X.; Wang, T. The resilience of farmers' livelihood and its influencing factors in the semiarid region of the Loess Plateau—A case study of Yuzhong county. *Chin. J. Agric. Resour. Reg. Plan.* **2018**, *39*, 172–182. (In Chinese)
28. Campbell, D. Environmental change and the livelihood resilience of coffee farmers in Jamaica: A case study of the Cedar Valley farming region. *J. Rural Stud.* **2021**, *81*, 220–234. [CrossRef]
29. Nasrnia, F.; Ashktorab, N. Sustainable livelihood framework-based assessment of drought resilience patterns of rural households of Bakhtegan basin, Iran. *Ecol. Ind.* **2021**, *128*, 107817. [CrossRef]
30. Zhao, X.; Chen, H.; Zhao, H.; Xue, B. Farmer households' livelihood resilience in ecological-function areas: Case of the Yellow River water source area of China. *Environ. Dev. Sustain.* **2022**, *24*, 9665–9686. [CrossRef]
31. Jacobi, J.; Schneider, M.; Bottazzi, P.; Pillco, M.; Calizaya, P.; Rist, S. Agroecosystem resilience and farmers' perceptions of climate change impacts on cocoa farms in Alto Beni, Bolivia. *Renew. Agric. Food Syst.* **2015**, *30*, 170–183. [CrossRef]

32. Li, C.; Wang, L.; Kang, B.; Gao, M. Measurement and Influencing Factors of Livelihood Resilience of Relocated Migrants. *J. Xi 'an Jiaotong Univ.* **2019**, *39*, 38–47. (In Chinese)
33. Ji, T.; Zhou, Z.; Niu, Z.; Zhang, J. A Comparative Analysis of Farmers' Livelihood Resilience before and after Relocation for Poverty Alleviation: A Case Study in the Relocation Site in Zhexiang Town of Zhenfeng County, Guizhou Province. *J. Ecol. Rural Environ.* **2022**, *38*, 1406–1414. (In Chinese)
34. Zheng, D.; Huang, X.; Wang, C. Farmers' livelihood resilience and its optimization strategy in Loess Plateau of north Shaanxi province. *J. Arid Land Resour. Environ.* **2020**, *34*, 9–16. (In Chinese)
35. Wu, X. A Study on the Livelihood Resilience of the Households under Climate Disasters in the Loess Plateau—Based on Apple Households Survey. Master's Thesis, Northwest Agriculture & Forestry University, Yangling, China, 24 May 2019. (In Chinese).
36. Wu, K.; Yang, Q.; Ye, W.; Yang, X.; He, Y. Farmers' livelihood resilience and livelihood construction path in the Loess Plateau. *J. Arid Land Resour. Environ.* **2021**, *35*, 24–30. (In Chinese)
37. Guo, L.; Yinke. Impact of rural complex construction on farmers' livelihood resilience—Taking Zhongxian county of Chongqing as an example. *Chin. J. Agric. Resour. Reg. Plan.* **2020**, *41*, 136–145. (In Chinese)
38. Ji, J.; Hong, X.; Zhu, Y. Study on the Measurement of Tea Farmers' Livelihood Resilience and Influencing Factors: A Case Study of Anxi County. *J. Tea Sci.* **2021**, *41*, 132–142. (In Chinese)
39. He, Y.; Zhang, J.; Qiao, X.; Zhang, Q. Rural households' livelihood resilience in poor mountainous areas under the background of targeted poverty alleviation: A case study of Qinba mountain areas in Henan province. *J. Arid Land Resour. Environ.* **2020**, *34*, 53–59. (In Chinese)
40. Chen, J.; Yang, X.; Yin, S. Measures of the esilience, Effect and Countermeasures of Household Poverty: The Perspective of Household Structure. *China Popul. Resour. Environ.* **2016**, *1*, 150–157. (In Chinese)
41. Chang, J.; Xie, P.; Bie, X. Tourism-driven Changes in Rural Farmers' Livelihood Resilience and Countermeasures for Improvement: Considering the Comparison of Community-Based Participatory Models. *Sci. Technol. Manag. Land Resour.* **2022**, *39*, 27–39. (In Chinese)
42. Chen, J.; Yang, X.; Wen, X.; Deng, M. The theoretical framework and demonstration of rural adaptive evolution in the context of tourism development. *J. Nat. Resour.* **2020**, *35*, 1586–1601. (In Chinese)
43. Ma, S.; Li, C.; Zhang, H. Farmers' Livelihood Resilience and Its Optimization Path in the Yellow Sea Wetland Heritage Area. *J. Ecol. Rural Environ.* 2023. Available online: http://www.ere.ac.cn/CN/10.19741/j.issn.1673-4831.2023.0472 (accessed on 23 September 2023). (In Chinese).
44. Carpenter, S.; Walker, B.; Anderies, J.M.; Abel, N. From metaphor to measurement: Resilience of what to what? *Ecosystems* **2001**, *4*, 765–781. [CrossRef]
45. Thulstrup, A.W. Livelihood resilience and adaptive capacity: Tracing changes in household access to capital in Central Vietnam. *World Dev.* **2015**, *74*, 352–362. [CrossRef]
46. Alam, G.M.; Alam, K.; Mushtaq, S.; Leal Filho, W. How do climate change and associated hazards impact on the resilience of riparian rural communities in Bangladesh? Policy implications for livelihood development. *Environ. Sci. Policy* **2018**, *84*, 7–18. [CrossRef]
47. Yang, Y.; Li, H. Choice of Livelihood Strategies of Farming Households in Collective Forest Areas: Investigations of Zhejiang and Jiangxi Province. *J. Agro-For. Econ. Manag.* **2019**, *18*, 645–655. (In Chinese)
48. Erenstein, O.; Hellin, J.; Chandna, P. Poverty mapping based on livelihood assets: A meso-level application in the Indo-Gangetic Plains, India. *Appl. Geogr.* **2010**, *30*, 112–125. [CrossRef]
49. Speranza, C.I. Buffer capacity: Capturing a dimension of resilience to climate change in African smallholder agriculture. *Reg. Environ. Chang.* **2013**, *13*, 521–535. [CrossRef]
50. Pandey, R.; Jha, S. Climate vulnerability index-measure of climate change vulnerability to communities: A case of rural Lower Himalaya, India. *Mitig. Adapt. Strateg. Glob. Chang.* **2012**, *17*, 487–506. [CrossRef]
51. Zhang, Q.; Zhao, X.; Luo, L.; Wang, Y.; Xue, B. Assessment of the impact of climate change on vulnerability of farmer households'livelihood in an ecologically vulnerable alpine region: Taking Gannan Plateau for example. *Chin. J. Ecol.* **2016**, *35*, 781–790. (In Chinese)
52. Milestad, R.; Darnhofer, I. Building farm resilience: The prospects and challenges of organic farming. *J. Sustain. Agric.* **2003**, *22*, 81–97. [CrossRef]
53. Liu, W.; Li, J.; Ren, L.; Xu, J.; Li, C.; Li, S. Exploring livelihood resilience and its impact on livelihood strategy in rural China. *Soc. Ind. Res.* **2020**, *150*, 977–998. [CrossRef]
54. Lu, P.; Stead, D. Understanding the notion of resilience in spatial planning: A case study of Rotterdam, The Netherlands. *Cities* **2013**, *35*, 200–212. [CrossRef]
55. Quandt, A. Measuring livelihood resilience: The household livelihood resilience approach (HLRA). *World Dev.* **2018**, *107*, 253–263. [CrossRef]
56. Sina, D.; Chang-Richards, A.Y.; Wilkinson, S.; Potangaroa, R. What does the future hold for relocated communities post-disaster? Factors affecting livelihood resilience. *Int. J. Dis. Risk Reduct.* **2019**, *34*, 173–183. [CrossRef]
57. Cooper, S.J.; Wheeler, T. Adaptive governance: Livelihood innovation for climate resilience in Uganda. *Geoforum* **2015**, *65*, 96–107. [CrossRef]

58. Dhanya, P.; Ramachandran, A. Farmers' perceptions of climate change and the proposed agriculture adaptation strategies in a semi arid region of south India. *J. Integr. Environ. Sci.* **2016**, *13*, 1–18.
59. Cutter, S.L.; Barnes, L.; Berry, M.; Burton, C.; Evans, E.; Tate, E.; Webb, J. A place-based model for understanding community resilience to natural disasters. *Glob. Environ. Chang.* **2008**, *18*, 598–606. [CrossRef]
60. Martin, S.M.; Lorenzen, K. Livelihood diversification in rural Laos. *World Dev.* **2016**, *83*, 231–243. [CrossRef]
61. Tittonell, P. Livelihood strategies, resilience and transformability in African agroecosystems. *Agric. Syst.* **2014**, *126*, 3–14. [CrossRef]
62. Gong, Y.; Yao, K.; Zhang, R.; Liu, B.; Wang, F. Rethinking livelihood resilience after development-induced displacement and resettlement: A case study of Qianping Reservoir. *Int. J. Water Resour. Dev.* **2021**, *37*, 841–864. [CrossRef]
63. Fang, Y.; Zhu, F.; Qiu, X.; Zhao, S. Effects of natural disasters on livelihood resilience of rural residents in Sichuan. *Habitat Int.* **2018**, *76*, 19–28. [CrossRef]
64. Qin, Y.; Shi, X.; Li, X.; Yan, J. Geographical indication agricultural products, livelihood capital, and resilience to meteorological disasters: Evidence from kiwifruit farmers in China. *Environ. Sci. Pollut. Res.* **2021**, *28*, 65832–65847. [CrossRef]
65. Haworth, B.T.; Biggs, E.; Duncan, J.; Wales, N.; Boruff, B.; Bruce, E. Geographic information and communication technologies for supporting smallholder agriculture and climate resilience. *Climate* **2018**, *6*, 97. [CrossRef]
66. Marschke, M.J.; Berkes, F. Exploring strategies that build livelihood resilience: A case from Cambodia. *Ecol. Soc.* **2006**, *11*, 42. [CrossRef]
67. Paudel, B.; Zhang, Y.; Yan, J.; Rai, R.; Li, L.; Wu, X.; Chapagain, P.S.; Khanal, N.R. Farmers' understanding of climate change in Nepal Himalayas: Important determinants and implications for developing adaptation strategies. *Clim. Chang.* **2020**, *158*, 485–502. [CrossRef]
68. Dapilah, F.; Nielsen, J.Ø.; Friis, C. The role of social networks in building adaptive capacity and resilience to climate change: A case study from northern Ghana. *Clim. Dev.* **2020**, *12*, 42–56. [CrossRef]
69. Li, E.; Deng, Q.; Zhou, Y. Livelihood resilience and the generative mechanism of rural households out of poverty: An empirical analysis from Lankao County, Henan Province, China. *J. Rural Stud.* **2019**, *93*, 210–222. [CrossRef]
70. Chang, Y.; Hou, K.; Wu, Y.; Li, X.; Zhang, J. A conceptual framework for establishing the index system of ecological environment evaluation—A case study of the upper Hanjiang River, China. *Ecol. Ind.* **2019**, *107*, 105568. [CrossRef]
71. He, T.; Zhang, L.; Zeng, Y.; Zuo, C.; Li, J. Water quality comprehensive index method of Eltrix River in Xin Jiang Province using SPSS. *Procedia Earth Planet. Sci.* **2012**, *5*, 314–321.
72. Chifeng, S.B. *Chifeng Statistical Yearbook*; China Statistics Press: Beijing, China, 2022. (In Chinese)
73. Li, L. Spatial-Temporal Variability of Soil Organic Carbon in Aohan County, Chifeng. Doctor Dissertation, Inner Mongolia Agricultural University, Hohhot, China, 8 June 2017. (In Chinese)
74. Fan, Y.; Wang, T.; Li, X. Impact of climatic and geological conditions on the industry structure of agriculture, forestry, and animal husbandry in Aohan Banner. *Mod. Agric.* **2016**, 92–94. Available online: https://www.cnki.net/KCMS/detail/detail.aspx?dbcode=CJFD&dbname=CJFDLAST2017&filename=XDNY201612065&uniplatform=OVERSEA&v=OT5keFcbfLgXjKUsPszjgb_grdt1ARLk_WgokNzBNyTkw3xIDo7E_2mboYN8EfgQ (accessed on 22 August 2023). (In Chinese)
75. Zhang, M. Research on the Variation Characteristics of Soil Organic Carbon Pool and Its Carbon Sequestration Potentials in Cultivated Fields in Aohan County, Chifeng. Master's Dissertation, Inner Mongolia Agricultural University, Hohhot, China, 8 June 2017. (In Chinese)
76. Li, X.; Fan, Y.; Wang, t. Drought causes analysis and prevention measures in Aohan banner. *J. North. Agric.* **2016**, *44*, 99. (In Chinese)
77. Etikan, I.; Bala, K. Sampling and sampling methods. *Biom. Biostat. Int. J.* **2017**, *5*, 00149. [CrossRef]
78. Teknomo, K. Analytic hierarchy process (AHP) tutorial. *Revoledu* **2006**, *6*, 1–20.
79. Chifeng, S.B. *Chifeng Statistical Yearbook*; China Statistics Press: Beijing, China, 2021. (In Chinese)
80. Zhao, X. The impact of livelihood capital on the life satisfaction of peasants and herdsmen: A case of Gannan Plateau. *Geogr. Res.* **2011**, *30*, 687–698. (In Chinese)
81. Saaty, T.L. An exposition of the AHP in reply to the paper "remarks on the analytic hierarchy process". *Manag. Sci.* **1990**, *36*, 259–268. [CrossRef]
82. Jo, J.-H.; Choi, M.; Lee, C.-B.; Lee, K.-h.; Kim, O.S. Comparing Strengths and Weaknesses of Three Approaches in Estimating Social Demands for Local Forest Ecosystem Services in South Korea. *Forests* **2021**, *12*, 497. [CrossRef]
83. Jo, J.-H.; Park, S.-H.; Koo, J.; Roh, T.; Lim, E.M.; Youn, Y.-C. Preferences for ecosystem services provided by urban forests in South Korea. *For. Sci. Technol.* **2020**, *16*, 86–103.
84. Saaty, T.L. *Decision making with dependence and feedback: The analytic network process*; RWS publications: Pittsburgh, PA, USA, 1996.
85. Guo, Y.; Yi, P. Character Analysis of Linear Dimensionless Methods. *Stat. Res.* **2008**, *25*, 93–100. (In Chinese)
86. Sun, Y.; Zhao, X. Evolution of livelihood resilience and its influencing factors of out-of-poverty farmers in Longnan mountainous area. *Sci. Geogr. Sin.* **2022**, *42*, 2160–2169. (In Chinese)
87. Zhao, X.; Ren, J. Effect Evaluation and Influencing Factors of Poverty Alleviation Intervention Based on Livelihood Resilience: A Case Study of Longnan Mountainous Area. *Econ. Geogr.* **2023**, *42*, 151–162. (In Chinese)
88. Ramilan, T.; Kumar, S.; Haileslassie, A.; Craufurd, P.; Scrimgeour, F.; Kattarkandi, B.; Whitbread, A. Quantifying farm household resilience and the implications of livelihood heterogeneity in the semi-arid tropics of India. *Agriculture* **2022**, *12*, 466. [CrossRef]

89. Wang, R.; Zhao, X. Can Multiple Livelihood Interventions Improve Livelihood Resilience of Out-of-poverty Farmers in Mountain Areas? A Case Study of Longnan Mountain Area, China. *Chin. Geogr. Sci.* **2023**, *33*, 898–916. [CrossRef]
90. Ross, A.; Willson, V.L. *Basic and Advanced Statistical Tests: Writing Results Sections and Creating Tables and Figures*; Sense Pulishers: Rotterdam, The Netherlands, 2018.
91. Connelly, L.M. Introduction to analysis of variance (ANOVA). *Medsurg Nurs.* **2021**, *30*, 218.
92. Wu, Z. Achievements, challenges, and trends of China's rural education development. *Explor. Free Views* **2021**, *4*, 5–8. (In Chinese)
93. MEE; NDRC; MOST; MF; MNR; MHURD; MT; MWR; MARA; MCT; et al. National Climate Change Adaptation Strategy 2035. 2022. Available online: https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202206/W020220613636562919192.pdf (accessed on 23 September 2023). (In Chinese)
94. Zhou, Z.; Cao, Y. Analysis and Reflection on National Climate Change Adaptation Strategy 2035. *Environ. Prot.* **2022**, *50*, 42–46. (In Chinese)
95. Wang, B. The Study on Green Agricultural Development in Chifeng Aohan Banner. Master Dissertation, Inner Mongolia Agricultural University, Hohhot, China, 10 June 2013. (In Chinese)
96. Zhao, H. The Application of 3S Technology in Returning Farmland to Forest (Grassland) the County Area—Taking Chifeng City Aohan Banner as an Example. Master Dissertation, Inner Mongolia Normal University, Hohhot, China, 15 April 2008. (In Chinese).
97. Huang, S.; Lan, E. *Politics of the People's Republic of China (Inner Mongolia Autonomous Region Volume)*; China Social Publishing House: Beijing, China, 2018. (In Chinese)
98. Li, L.; Qin, F.; Jiang, L.; Yao, X. Vertical distribution of soil organic carbon content and its influencing factors in Aohan, Chifeng. *Acta Ecol. Sin.* **2019**, *39*, 345–354. (In Chinese)
99. Shiferaw, B.; Tesfaye, K.; Kassie, M.; Abate, T.; Prasanna, B.; Menkir, A. Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. *Weather Clim. Extremes* **2014**, *3*, 67–79. [CrossRef]
100. Li, C.; Gao, M. Empirical on impact of new urbanization on rural households' livelihood resilience under migration and relocation for poverty alleviation. *Stat. Decis.* **2019**, *35*, 89–94. (In Chinese)
101. Meldrum, G.; Sthapit, S.; Rojas, W.; King, O. Agricultural biodiversity enhances capacity to adapt to climate change. *New Agric.* **2013**. Available online: https://cgspace.cgiar.org/handle/10568/52109 (accessed on 22 August 2023).

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.