Perceptive Factors That Affect Household Food Consumption Among Different Grassland Areas: A Case Study Based on Fuzzy Cognitive Map

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Food consumption acts as an intermediary between ecosystems and human systems in grassland areas. In this study, we generated a fuzzy cognitive map (FCM) to obtain a semi-quantitative assessment of impact factors on food consumption in the Xilin Gol Grassland, China, from the perception of local rural households. Based on it, the food consumption impact factors networks of households in Xilin Gol Grassland were created. Results showed that household recognition of food consumption impact factors differed among grassland transects in both amount and category, and the results of principal component analysis (PCA) ascertain such differences and transitions. Livestock breeding, income, local economic development, consumption habit, age, food price, and cost were the most important impact factors mentioned by both farmers and herdsmen. From south to north in the grassland transects, households' cognition of ecological and economic factors increased, and the cognition of personal and social factors decreased. Differences in supply, culture, customs, and socioeconomic characteristics affected the cognition of households and their livelihoods, which influenced impact factors as well as associated connections. The role of livestock breeding also validated the connection between human actives and the grassland ecosystem. Results from this study can be used as a reference for policymakers during decision-making processes respective of regional sustainable development.

Keywords: food consumption, fuzzy cognitive map, household perception, grassland areas, Xilin Gol grassland, Inner Mongolian Plateau

1 INTRODUCTION

Food consumption is a basic requirement for human survival (Zhen et al., 2012). In grassland areas, food is directly produced from limited grassland resources (Zhao et al., 2004; Fu et al., 2009). However, food consumption is connected to the consumption and provision of ecosystem services, which reveals relationships between ecosystems and human activities (Millennium Ecosystem Assessment, 2005; Zhen et al., 2008). Ecologically, grassland areas are extremely vulnerable, while the food consumption habits of residents are solely and directly obtained from the resources it produces (Du et al., 2015). However, under socioeconomic development, a

progressively increasing population and resultant consumption requirements cause more acute contradictions and clashes between human activities and local ecosystems, challenging regional development, particularly in grassland areas (Cao et al., 2010; Barthold et al., 2013). Meanwhile, the conservation and governance of grassland was proved to be usually extremely complex around the world, which strongly needs the coordination of different stakeholders (Manolache et al., 2020; Hou et al., 2021).

The United Nations General Assembly Sustainable Development Goals (SDGs) for food consumption, which is linked to both Goal 2 (Zero Hunger) and Goal 12 (Responsible Consumption and Production), play an important role in issues related to global sustainable development (Yang et al., 2019). On the other hand, in certain developing countries, acts of resource predation and exploitation during urbanization and socioeconomic development have caused regional development sustainability issues, likes land degradation, water pollution, food waste and its environmental related problems, coronary heart disease and other health problems of residents, and so on (Tilman and Clark, 2014; Reynolds et al., 2015; Li et al., 2021).

This study used the Xilin Gol Grassland in North China as a case study, being one of the largest grassland areas in China. The agro-pastoral transitional zone in North China transects through the southern section of the Xilin Gol Grassland. Due to its sensitive, vulnerable environment as well as its appreciable human activity, this region faces significant challenges respective of sustainability (Gerbens-Leenes and Nonhebel, 2002; Zhen et al., 2010b). Together, local and central governments have invested greater than 200 million RMB into regional ecological projects (Xilin Gol League Statistics Bureau, 2019). Moreover, policies implemented in this region have significantly affected the living and production standards of local residents (Wu et al., 2012; Yang and Zhen, 2019), which have also impacted their daily food consumption habits. This region comprises a multinational residency, such as the Han, Mongolian, and the Hui, to name the most prevalent (Xilin Gol League Statistics Bureau, 2019). Cultivated land is mainly distributed within the southern border of the Xilin Gol Grassland, which produces a limited supply of food that makes it difficult to meet all regional needs (Liu et al., 2018). Thus, food consumption in this region is complex, and household perceptions on food consumption impact factors will consequently vary, which brings challenges to quantitatively evaluate the regional food consumption impact factor from different stakeholders. However, understanding household perceptions on food consumption impact factors will help to build social safety nets, which would contribute to the food system resilience and regional resource sustainable development (Fan et al., 2020; Zhan and Chen, 2021).

Studies on impact factors related to food consumption have primarily focused on economic, social, and ecological factors. Economic factors include income, development, urban–rural economic differences, price, and markets (Zhai et al., 2009; Zhen et al., 2010a; Baquedano and Liefert, 2014; Csutora and Vetőné Mózner, 2014; Chaves et al., 2017); social factors include those related to an aging population, urbanization, cultural diversity, and festivals (Han, 2013; Hu, 2016; Deng et al., 2018; Nikolay, 2018); ecological factors include seasonal variations, land-use diversity, climate, and the environment (de Ruiter et al., 2014; Hu, 2016; Yang and Zhen, 2019). Data from statistics, questionnaires, and remote sensing are the most commonly used data sources for studies on food consumption impact factors (Rasmussen et al., 2016; Troubat and Grünberger, 2017; Zhen et al., 2018; Li et al., 2019). Nevertheless, studies on the perception of food consumption impact factors of stakeholders remain insufficient, and in the Xilin Gol Grassland there is an obvious lack of qualitative and quantitative analyses on food consumption impact factors applying effective approaches.
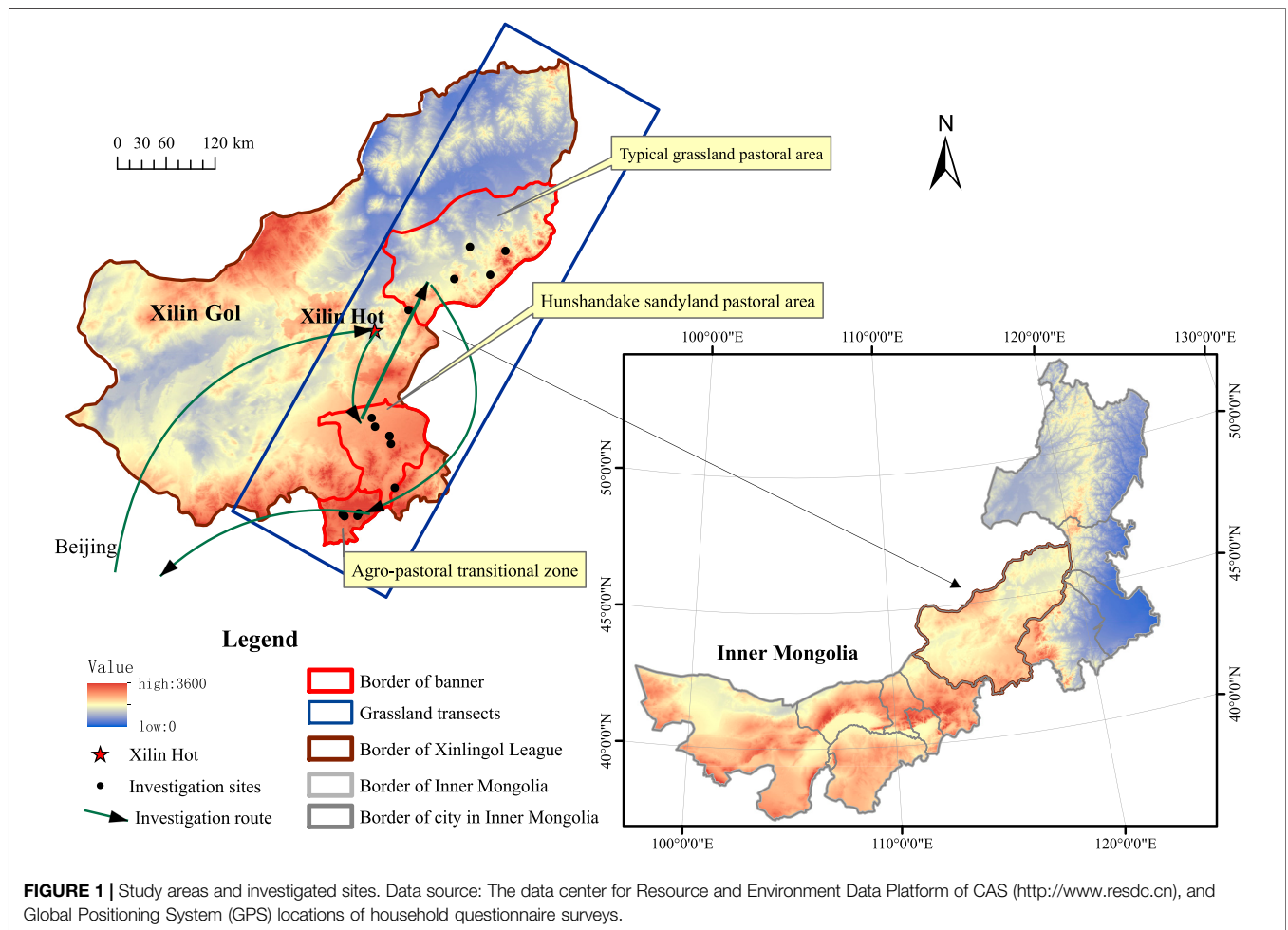
Fuzzy cognitive map (FCM) is a semi-quantitative modeling tool that can also be used as a framework, which in turn can be applied to compare knowledge derived from non-technical experts (Özesmi and Özesmi, 2004; Ozesmi, 2006). This technique can help to reveal the cognition of farmers and herdsmen as well as to build a network of a particular situation or system respective of the research issue in question (Reckien, 2014). FCM has been successfully used in geographic, sociologic, ecologic, and economic disciplines (Kok, 2009; Glykas, 2010; Reckien et al., 2013). Moreover, it is easy to use, effective to conduct, and good at attending complex and subjective conceptions, and it could well reflect different group people's perceptions without requiring a large sample size (Chan et al., 2012; Reyers et al., 2013; Teixeira et al., 2018).

Although the food consumption impact factors were well known to be associated to economic, social, and ecological dimensions, the relationships between different impact factors still need more exploration, the main impact factor in different areas would be varied, and the quantitative evaluation of stakeholders' perceptions (especially household perceptions) is insufficient and needs more discussion. The objective of this study is to quantitatively evaluate the household perceptions of food consumption impact factors. This study used primary data obtained from interviews with local residents based on FCM in combination with regional land-use data to analyze issues related to food consumption impact factors. We tried to explore food consumption impact factors on the perception of local households, analyze key impact factors, and explain the formation of cognitive differences on food consumption impact factors within different transect areas of the Xilin Gol Grassland. An investigation of food consumption impact factors in this region can not only be used to help to understand coupling relationships between human systems and ecosystems, but such an investigation can also provide an empirical reference for policymakers' decisions associated with regional development.

2 METHODS

2.1 Study Areas

The Xilingol League is within the central Inner Mongolia Autonomous Region, China. It belongs to the Mongolian Plateau, at an altitude of 800–1,800 m. Annual precipitation is 288 mm; annual evaporation is between 1,700 and 2,600 mm; and

FIGURE 1 | Study areas and investigated sites. Data source: The data center for Resource and Environment Data Platform of CAS (http://www.resdc.cn), and Global Positioning System (GPS) locations of household questionnaire surveys.

the annual average temperature is 3.60°C. It comprises two county-level cities, one county, nine banners, and two districts. At the end of 2019, the total registered population was 1.04 million, of which the rural population accounted for 54.26%, and those of Han nationality accounted for 63.69%, while those of Mongolian nationality accounted for 31.75%. The total land-use area of the Xilingol League is 200,000 km², including 180,000 km² of grassland and 5,859.50 km² of forestland, accounting for 89.90% and 7.10% of total land-use area, respectively. Grassland is the primary land-use type in the Xilingol League. Cattle and sheep are the main livestock raised in this region. In 2019, the annual per capita disposable income of residents of the Xilingol League was 32,460 yuan, of which the per capita annual disposable income of urban residents was 40,778 yuan, while the per capita annual disposable income of rural residents was 17,391 yuan (Xilin Gol League Statistics Bureau, 2019).

The Xilin Gol Grassland is expansive (i.e., 2.03×10^5 km²). It is situated on the Mongolian Plateau, while most of its area lies within the Xilingol League. Land-cover types of the Xilin Gol Grassland can be subdivided as follows: typical grassland, desert grassland, cultivated land, and sporadic grassland. The carrying capacity of these grassland land-use types gradually decrease directionally, exhibiting a gradient change from north to south, which constitutes the Xilin Gol Grassland transects. In this study, we selected three typical Xilin Gol Grassland transects for our investigation: the West Ujimqin Banner, a typical pastoral grassland area; the Zhenglan Banner, a pastoral area of the Hunshandake Sandy Land; and the Taibus Banner, an agro-pastoral transitional zone (**Figure 1**). The West Ujimqin Banner is in the eastern region of the Xilingol League, while the Zhenglan Banner and the Taibus Banner are in the southern region. All three banners are located in arid and semiarid transitional zones, namely, where annual precipitation is approximately 400 mm and annual evaporation is extremely high (>1,800 mm). Ecosystems within the study areas are considered extremely vulnerable.

2.2 Fuzzy Cognitive Map Data Collection
2.2.1 Interviews Conducted and Fuzzy Cognitive Map Construction
We conducted interviews with local residents living in rural areas of the Xilingol League, China, from July 20 to August 5, 2019. Typical farmer or herdsman households were interviewed in West Ujimqin, Zhenglan, and Taibus banners. Data were generated through FCM applying oral, face-to-face interviews. The interviewees were chosen from family members who best

knew general information concerning food consumption and relative information concerning the whole family. The interviews focused on the following question: "What are the impact factors on your family food consumption?" Interviewees answered this question and explained why the factors were important, how these factors affected their daily food consumption, and what the connections is between these factors.

We provided an example to the interviewees at the outset of the interviews. We then formulated a food consumption impact factor network and drew it on a white A4 sheet of paper. The interviewees ascribed links between the factors and assigned the point of each link from −5 to 5. The direction of each link had a corresponding arrow. When the factor had a positive impact, the interviewees would give a positive score, while a negative score was graded when an increase in one caused a decrease in another. The absolute value of the score represents a higher impact. The networks were drawn by the interviewers under the instructions of the interviewees. During the interview, the interviewees could add or change the factors or revise the weights at their discretion. The final version of each network was approved by the interviewee. Personal details of the interviewees were also obtained under a guarantee that their information would only be used for scientific purposes (i.e., not for commercial use). Personal details included the name of the participant, the location where the participant lived, vocation, age, education, family size, rangeland and cropland size, nationality, income and its explicit structure, and interview date.

The interviews were undertaken in Mandarin and Mongolian, depending on the language abilities of the interviewees. Locals were used as translators, such as officials who worked at the local grassland observation station, the head of the village, and young college students, while also helping the interviewers to communicate with each interviewee. Approximately 50% of interviewees required a translator to guarantee that the interviews were conducted successfully, and a total of 67 interviews were conducted.

All interviewees were selected using the proposed sampling method along with a stratified random sampling method. First, we used the proposed sampling method to determine the scope of the survey, accounting for the typical land-use categories of each study area. Second, we selected the study sites using stratified random sampling. Towns and villages were selected from those that qualified. Five towns or sumu (sumu is the town-level system used in the Inner Mongolia Autonomous Region of China) in West Ujimqin, four sumu in Zhenglan, and three sumu in Taibus banners were selected as the investigated sites (**Supplementary Appendix SA**). A random sampling method was used to select families to be interviewed given the low population densities of the study areas (i.e., a population density of 0.2 people per km^2), the considerable distance between the different families interviewed, and the unsure situation of whether any family member was at home. We randomly selected a route within the study area to conduct a questionnaire survey of farmers and herdsmen who we meet along the route. We continued our surveys until no new factors were identified, which ensured that our sampling size was adequate and reflected a true representation of resident perceptions. The way of determining the sample size was proved to be valid in previous studies (Reckien, 2014; Teixeira et al., 2018; Yang and Zhen, 2020).

2.2.2 Basic Information of the Interviewees

In total, we interviewed 21 families in West Ujimqin, 21 families in Zhenglan, and 25 families in Taibus banners during our 2019 field survey. The basic information, investigation sites, and the investigation route are shown in **Figures 1** and **2**. All families interviewed were from 17 villages or gacha (gacha is the village-level system used in the Inner Mongolia Autonomous Region of China) (**Supplementary Appendix SA**). There was an increase in the average age of the interviewees from a north-to-south direction among grassland transects. Moreover, the percentage of those of Mongolian nationality decreased, and the percentage of female interviewees significantly increased directionally (**Figure 1**).

Differences in socioeconomic characteristics and awareness of food consumption impact factors of families in the three study areas are shown in **Table 1**, wherein rangeland size, education, cow breeding scale, sheep breeding scale, and household income exhibited both strong and significant differences among the three areas investigated. Cropland size, family size, and subsidies also exhibited significant differences among the three study areas. On the other hand, intermediate factors only exhibited slightly significant differences.

2.3 Data Analysis

Over the 67 interviews, residents identified 33 different direct factors and 136 connections (**Supplementary Appendix SB**). All factors were classified into four categories: ecological factors (12), social factors (6), economic factors (5), and personal factors (11). Here we follow the dimensions in Millennium Ecosystem Assessment (2005) and classified the impact factors into ecological dimension, social dimension, and economic dimension. In our study, personal factors mainly referred to individual characteristic information (i.e., individual's age, health status, vocation, etc.), which is usually taken into consideration in the empirical analysis studies. Personal factors are quite different from the social factors or economic factors, which mainly referred to the objective macro social and economic elements that affected household food consumption. Thus, when we classified the impact factors mentioned by our interviewees, we had the "personal factors" dimension besides the ecological dimension, social dimension, and economic dimension. The classification method was proved to be effective in a previous study (Yang and Zhen, 2020). The specific list of each factor type is shown in **Table 2**, and each classification provided four dimensions from which to analyze impact factors in the different study areas and the connections between the different impact factor types.

With the classification of the food consumption impact factors, we further formulated a 33 × 33 metric for each banner with the score and frequency information of each network captured from our field survey. The mean of the scores of each factor was determined, and the network of food consumption impact factor in three banners were formulated based on these three metrics. All
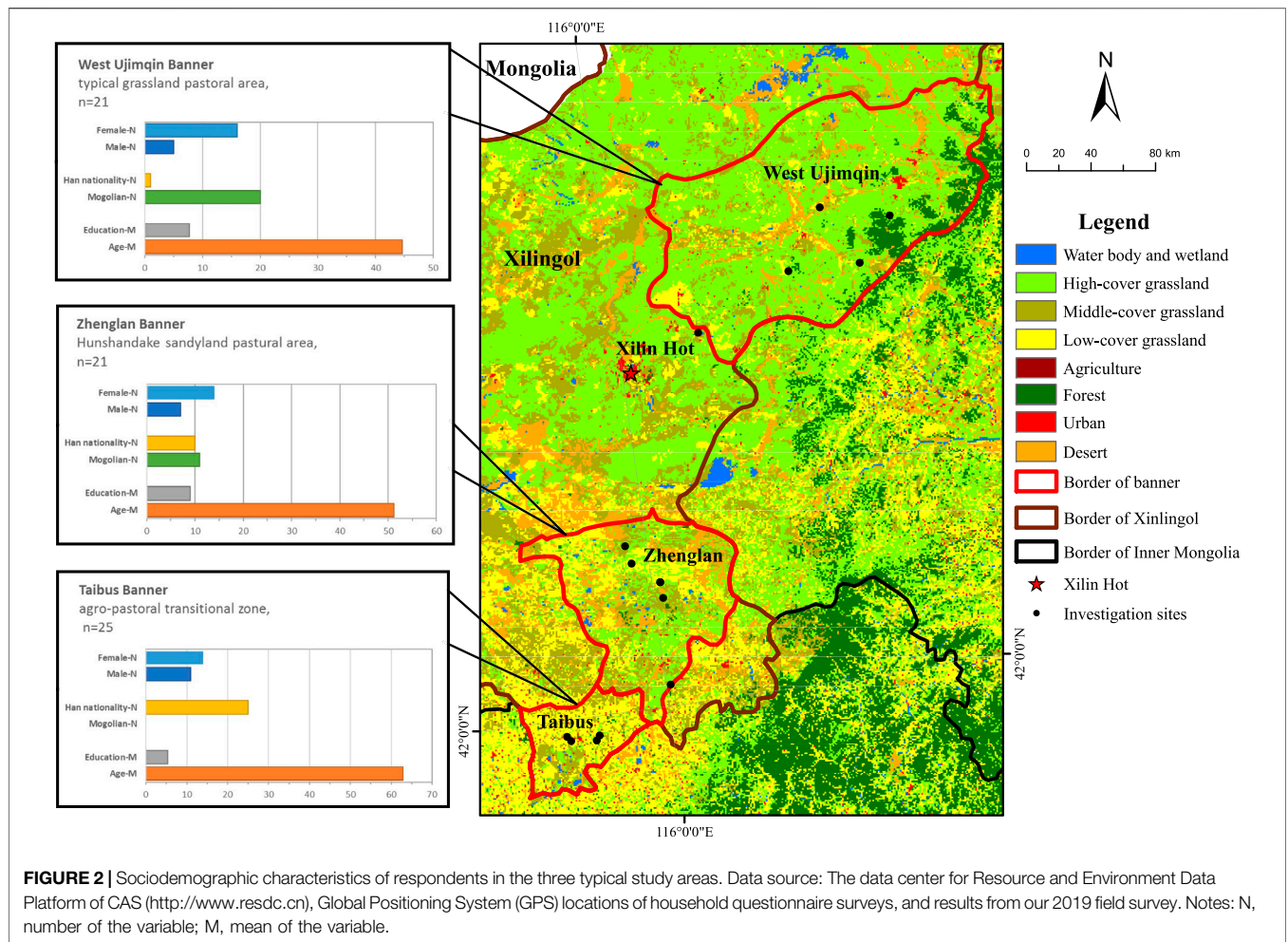
FIGURE 2 | Sociodemographic characteristics of respondents in the three typical study areas. Data source: The data center for Resource and Environment Data Platform of CAS (http://www.resdc.cn), Global Positioning System (GPS) locations of household questionnaire surveys, and results from our 2019 field survey. Notes: N, number of the variable; M, mean of the variable.

TABLE 1 | Overview results of fuzzy cognitive map (FCM) indices, the number of factors per category, and additional indicators between typical areas.

	p-value	West Ujimqin (n = 21) X ± SE	Zhenglan (n = 21) X ± SE	Taibus (n = 25) X ± SE
Direct impact factors (no. for the 4 dimensions)	0.617[ns]	6.95 ± 2.18	6.9 ± 2.43	7.44 ± 1.56
Intermediate factors (no. for the 4 dimensions)	0.095[a]	3.43 ± 2.34	5.33 ± 4.34	4 ± 1.35
Rangeland size (ha)	<0.001[b]	167.71 ± 108.37	79.75 ± 50.19	0.25 ± 0.46
Cropland size (ha)	0.009[b]	0 ± 0	0 ± 0	2.88 ± 5.83
Family size (no. of people)	0.010[c]	3.62 ± 0.20	3.62 ± 0.29	2.72 ± 0.22
Education (no. of year)	0.003[b]	7.71 ± 0.70	9.00 ± 0.69	5.4 ± 0.79
Cow breeding scale (no.)	<0.000[b]	34.57 ± 9.28	41.80 ± 7.04	2.44 ± 0.74
Sheep breeding scale (no.)	<0.000[b]	317.14 ± 49.81	34.90 ± 11.92	5.84 ± 3.02
Household income (×10³ yuan per year)	<0.000[b]	181.49 ± 101.67	138.43 ± 90.21	24.05 ± 15.22
Subsidies (×10³ yuan per year)	0.039[c]	8.02 ± 6.52	8.00 ± 11.06	3.15 ± 2.65

Data source: Results from our 2019 field survey and developed from our previous study (Yang and Zhen, 2020). Values are means ± SE.

[ns]*No significant; tested using ANOVA.*

[a]*Significant at 10% level.*

[b]*Significant at 1% level.*

[c]*Significant at 5% level.*

connections between the impact factors in the FCM networks were scored by each interviewee. The results of each factor were classified by the score, and they were then sorted into four degrees: very light $(0 < V < 1)$, light $(1 \leq V < 2)$, important $(2 \leq V < 3)$, and very important $(3 \leq V < 4)$ (**Table 3**). Although scores were expected to be between −5 and 5, results showed that the final scores were between −4 and 4. The grading of FCM results provided a standard by which to analyze and sort impact factor results.

TABLE 2 | Food consumption impact factors and their classification under four dimensions. Data source: All factors derive from our 2019 field survey.

Dimension	Ecological factors	Social factors	Economic factors	Personal factors
Factors included	Livestock breeding			
	Season			Consumption habit[a]
	Planting			Age
	Nutrition	Infrastructure	Income	Family size
	Cropland	Policy	Local economic development	Health
	Rangland	Festival	Food price	Vocation
	Food security	Culture and customs	Market[a]	Consumption pattern
	Food quality	Vehicle	Cost	Awareness[a]
	Residence	Education		Conformity[a]
	Climate			Living habits[a]
	Production[a]			Nationality
	Fertilizers			
Total	12	6	5	11

[a]Notes: Production, food production supplied by lands; Market, food market maturity; Awareness, awareness of health, nutrition and market; Conformity, Conformity with neighbors or cultural traditions; Living habits, way of life of farmer or herdsmen; Consumption habit, personal preferences (e.g., the husband prefers meat, the wife prefers vegetables).

TABLE 3 | Grading of the effect degree in fuzzy cognitive map (FCM) results.

Source Range	Grade
$0 < V < 1$	Very light
$1 \leq V < 2$	Light
$2 \leq V < 3$	Important
$3 \leq V < 4$	Very important

TABLE 4 | Degree of influence scores of the different food consumption impact factors and the frequency mentioned by interviewees.

		Taibus	Zhenglan	West Ujimqin
Frequency	Ecological factor	8	9	9
	Economic factor	5	4	5
	Social factor	3	5	4
	Personal factor	7	10	9
Cumulative score	Ecological factor	9.5	9.7	7.4
	Economic factor	7.6	5.7	6.7
	Social factor	1.8	3.3	2.5
	Personal factor	10.2	7.7	6.1

Data source: Results from our 2019 field survey.

3 RESULTS

3.1 Overview of Food Consumption Impact Factors of Household Perceptions

Among the household perceptions of the interviewees, we found 33 factors that affected food consumption in their daily lives. However, these factors differed among the different study areas. In pastoral areas (Zhenglan and West Ujimqin banners), the total number of impact factors was relatively high compared to the agro-pastoral transitional zone (Taibus Banner). The average food consumption impact factors of households in these three areas were similar; namely, we found approximately seven direct impact factors and four intermediate impact factors (**Table 1**).

Among the four dimensions of these impact factors, personal factors and ecological factors were the most important factors from the perception of households in the three study areas

(**Table 4** and **Figure 3**). In the Taibus Banner, ecological factors and personal factors were mentioned more often by interviewees (i.e., nine times per capita), which also yielded the highest scores compared to the other two factor types. In the Zhenglan Banner, personal factors were mentioned more often compared to ecological factors, while economic factors were mentioned the least. However, economic factors ranked third in scores. This phenomenon was also reflected in West Ujimqin Banner, which means that even though residents did not mention economic factors as often when asked about household food consumption impact factors, they subconsciously ranked economic factors high. Additionally, although residents of the Taibus Banner did not mention ecological factors and personal factors as often as residents of the Zhenglan and West Ujimqin banners did, they nevertheless gave high scores to these two dimensions. Residents in the Taibus Banner appeared to ignore social factors by mentioning it the least and giving it the lowest score, which could reflect that social development in pastoral areas (such as Zhenglan and West Ujimqin banners) alternated rapidly during these particular years, and their residents felt these changes and their resultant impacts on their own lives more sensitively and directly, which resulted in them focusing on this dimension more.

Analysis of structural and functional variables showed that the perception of intermediate factors, family size, rangeland size, cropland size, sheep breeding numbers, cow breeding numbers, education, household income, and subsidies of residents in Taibus, Zhenglan, and West Ujimqin banners significantly differed (**Table 1**).

Principal component analysis (PCA) indicated a relatively clear grouping of residents in Taibus, Zhenglan, and West Ujimqin banners (**Figure 4**; **Supplementary Appendix SC**). The first PCA axis explained 31.89% of the total variation and was strongly correlated to cow breeding scale and sheep breeding scale ($R > 0.6$). This axis can be interpreted as the complexity of husbandry systems, for which residents of the typical pastoral area (West Ujimqin Banner) were on the right and residents of the agro-pastoral transitional zone were on the left side of the spectrum. The second axis explained 14.83% of the total variation
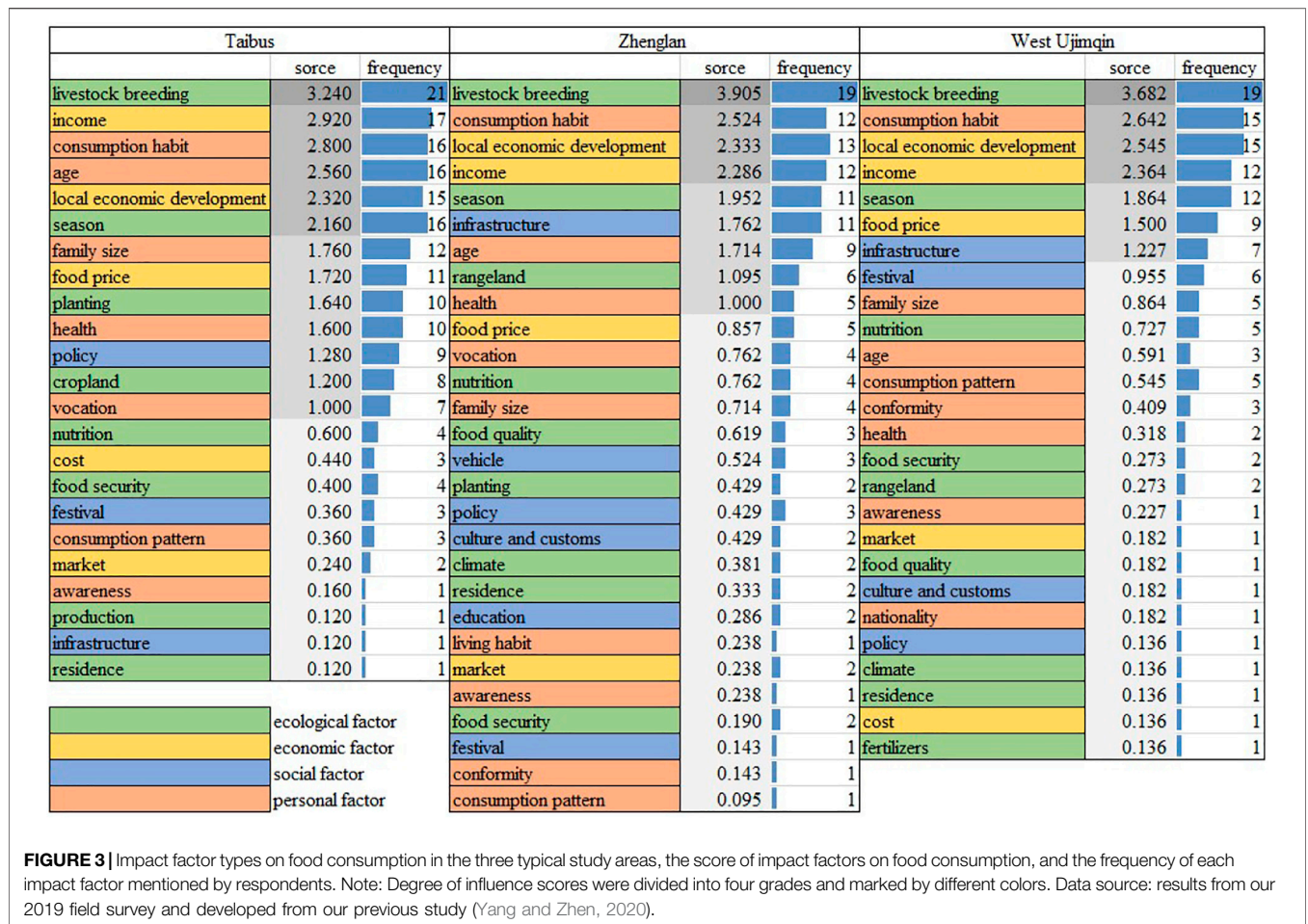
Taibus	sorce	frequency	Zhenglan	sorce	frequency	West Ujimqin	sorce	frequency
livestock breeding	3.240	21	livestock breeding	3.905	19	livestock breeding	3.682	19
income	2.920	17	consumption habit	2.524	12	consumption habit	2.642	15
consumption habit	2.800	16	local economic development	2.333	13	local economic development	2.545	15
age	2.560	16	income	2.286	12	income	2.364	12
local economic development	2.320	15	season	1.952	11	season	1.864	12
season	2.160	16	infrastructure	1.762	11	food price	1.500	9
family size	1.760	12	age	1.714	9	infrastructure	1.227	7
food price	1.720	11	rangeland	1.095	6	festival	0.955	6
planting	1.640	10	health	1.000	5	family size	0.864	5
health	1.600	10	food price	0.857	5	nutrition	0.727	5
policy	1.280	9	vocation	0.762	4	age	0.591	3
cropland	1.200	8	nutrition	0.762	4	consumption pattern	0.545	5
vocation	1.000	7	family size	0.714	4	conformity	0.409	3
nutrition	0.600	4	food quality	0.619	3	health	0.318	2
cost	0.440	3	vehicle	0.524	3	food security	0.273	2
food security	0.400	4	planting	0.429	2	rangeland	0.273	2
festival	0.360	3	policy	0.429	3	awareness	0.227	1
consumption pattern	0.360	3	culture and customs	0.429	2	market	0.182	1
market	0.240	2	climate	0.381	2	food quality	0.182	1
awareness	0.160	1	residence	0.333	2	culture and customs	0.182	1
production	0.120	1	education	0.286	2	nationality	0.182	1
infrastructure	0.120	1	living habit	0.238	1	policy	0.136	1
residence	0.120	1	market	0.238	2	climate	0.136	1
			awareness	0.238	1	residence	0.136	1
			food security	0.190	2	cost	0.136	1
			festival	0.143	1	fertilizers	0.136	1
			conformity	0.143	1			
			consumption pattern	0.095	1			

Legend:
- ecological factor
- economic factor
- social factor
- personal factor

FIGURE 3 | Impact factor types on food consumption in the three typical study areas, the score of impact factors on food consumption, and the frequency of each impact factor mentioned by respondents. Note: Degree of influence scores were divided into four grades and marked by different colors. Data source: results from our 2019 field survey and developed from our previous study (Yang and Zhen, 2020).

and separated residents in sandy grassland pastoral areas (Zhenglan Banner) from residents in typical grassland pastoral areas (West Ujimqin Banner). This axis was strongly correlated to the number of direct impact factors as well as the number of intermediate factors and subsidies ($R > 0.6$), which can be interpreted as the complexity of the policy systems. Moreover, PCA results also revealed the transition of grassland transects. From north to south, the group moved from the right side of the axis to the left side. For residents in typical grassland pastoral and agro-pastoral transitional areas, variance was relatively low; however, for residents in the sandy grassland pastoral area (Zhenglan Banner), the variance was relatively higher and the distribution was scattered.

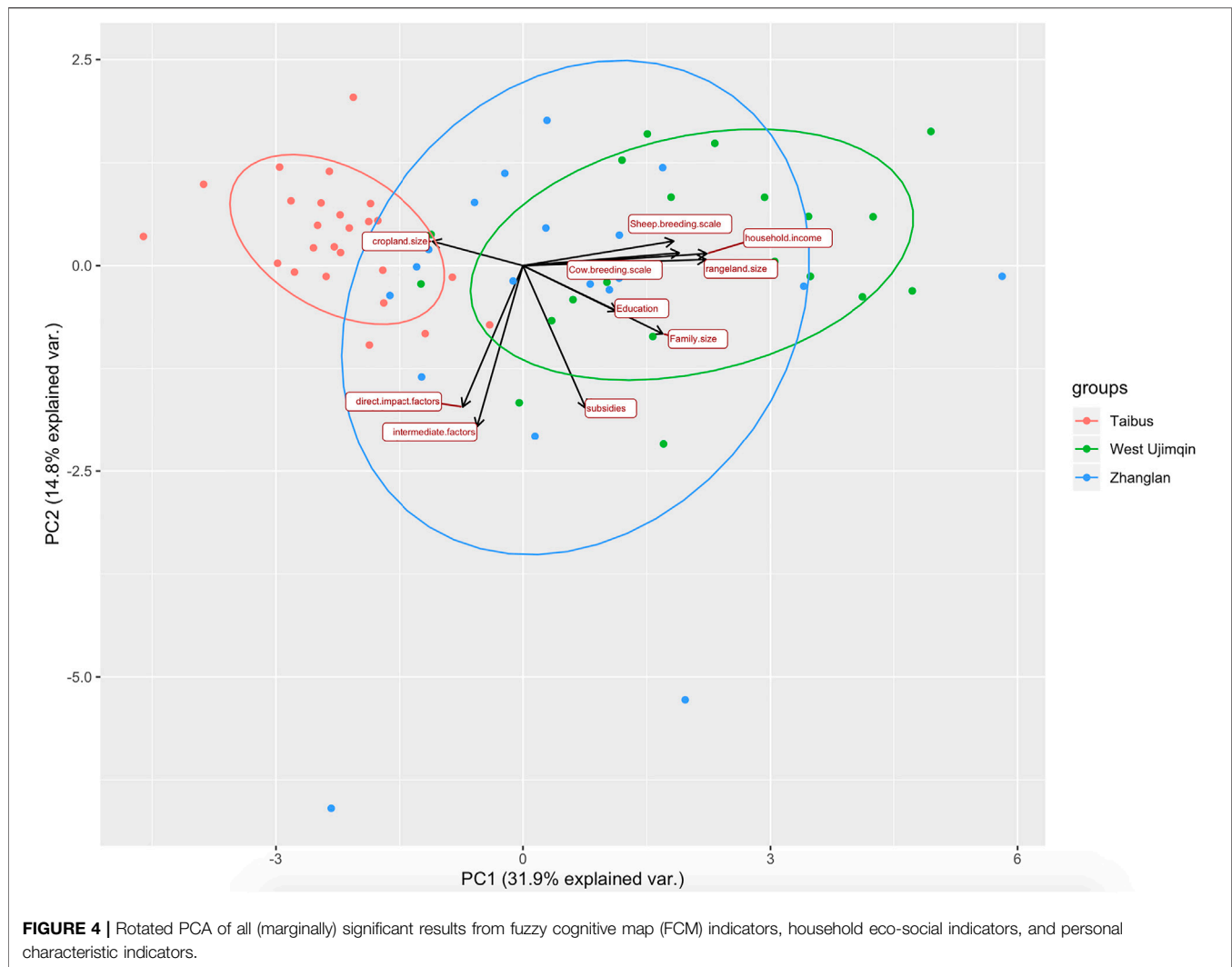## 3.2 Key Impact Factors and Characteristics Among Grassland Transects

Livestock breeding, income, local economic development, consumption habit, age, food price, and cost were the most important impact factors mentioned by farmers and herdsmen (**Figure 3**), and these factors interacted the most with other factors (**Figure 5**). Among the grassland transects, residents were more concerned with an ecological factor (livestock breeding) in northern areas (Zhenglan and West Ujimqin

banners) than in southern areas (Taibus Banner). Additionally, one personal factor (consumption habit) and two economic factors (income and local economic development) ranked after ecological factors in pastoral areas (Zhenglan and West Ujimqin banners), while in the agro-pastoral transitional area (Taibus Banner), one economic factor (income) ranked as the second most important factor. This revealed that from north to south, residents were more concerned with economic and personal factors compared to ecological factors.

Ecological Factors
In the daily food consumption of residents, livestock breeding was the most important impact factor in all three study areas (**Table 4** and **Figure 3**). Livestock breeding directly impacted food consumption, and its role as an intermediate factor was affected by different factors of differing dimensions that in turn directly affected food consumption.

In grassland areas, livestock breeding was one of the most important factors affecting the food consumption of residents, representing the food supply of rural families, which was a factor in both pastoral areas (West Ujimqin and Zhenglan banners) and the agro-pastoral transitional zone (Taibus Banner). However, these areas also exhibited a trend along grassland transects; namely, livestock breeding primarily had an effect on factors

FIGURE 4 | Rotated PCA of all (marginally) significant results from fuzzy cognitive map (FCM) indicators, household eco-social indicators, and personal characteristic indicators.

that alternated from ecological and economic to economic and personal from north to south (**Figure 5**). In particular, livestock breeding was significantly affected by rangeland in pastoral areas (West Ujimqin and Zhenglan banners). Moreover, the number of affected factors that were influenced by livestock breeding tends decreased from north to south.

Personal Factors

Consumption habit was the most important personal factor. It ranked as an important factor in all three study areas (**Figure 3**) and actively interacted with other factors (**Figure 5**). It was affected by income, vocation, nationality, and other factors, and it changed near areas of economic development. Moreover, consumption habit changed along with time, after which all such changes transformed into consumption habits that affected the daily food consumption of residents.

Particularly, age was shown to have an important impact on food consumption in Taibus Banner, revealing the aging problem in this area. The average age of residents in Taibus Banner is 62.88 years, which confirms that residents living in this area are mainly elderly compared to Zhenglan (51.24 years) and West Ujimqin (44.62 years)

banners (**Figure 2**). Only elderly people choose to remain in Taibus Banner due to the extremely scarce available rangeland and cropland area per family compared to pastoral areas (**Table 1**), and income from agriculture is too low to provide a comfortable living for young people. This aging problem results in a tendency of residents to eat less while also having a restricted diet choice; moreover, it also indirectly impacts food consumption by affecting health, income, vocation, and residence factors (**Figure 5**).

Economic Factors

Local economic development is one of the most important economic factors (**Figure 3**), which also affects other factors that impact food consumption (**Figure 5**). In pastoral areas, with economic development, infrastructure improved and household income increased, which changed people's way of life while also affecting food consumption. In the agro-transitional zone, our interviews confirmed that nutrition improved and livestock breeding became progressively more profitable, which affected both people's choices of vocation and their food consumption habits.

Income is another important economic factor that actively interacts with other factors and reveals regional differences
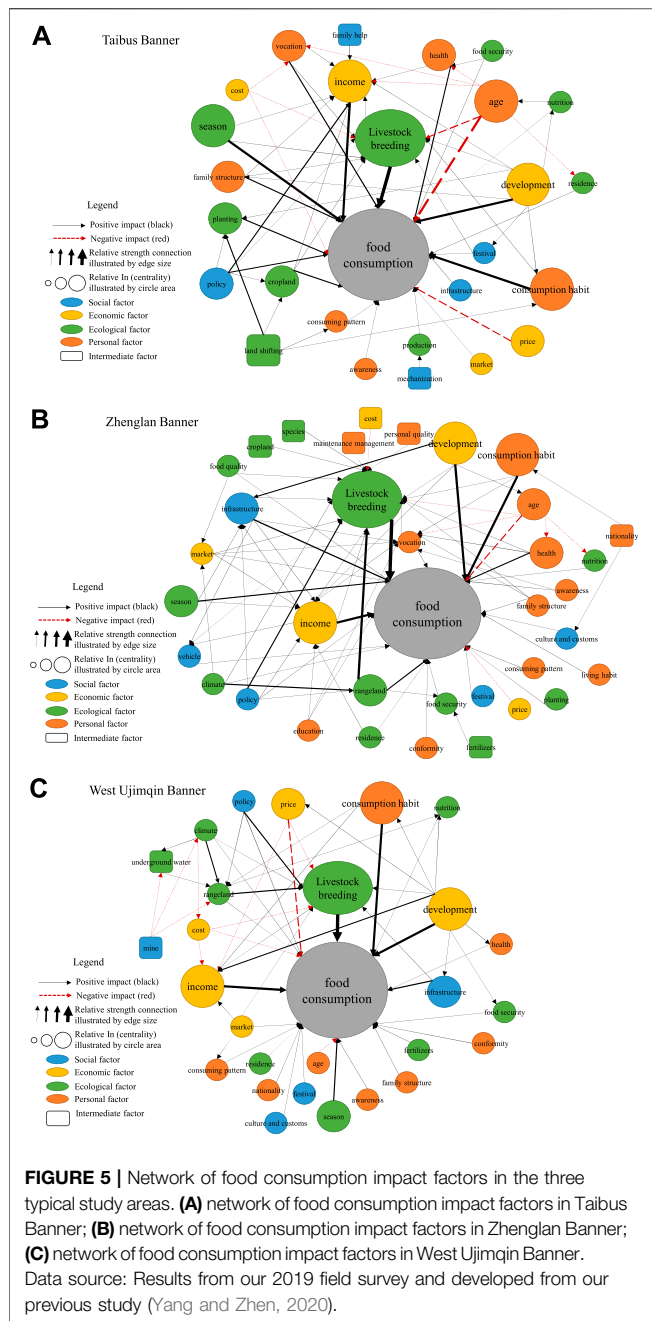
FIGURE 5 | Network of food consumption impact factors in the three typical study areas. **(A)** network of food consumption impact factors in Taibus Banner; **(B)** network of food consumption impact factors in Zhenglan Banner; **(C)** network of food consumption impact factors in West Ujimqin Banner. Data source: Results from our 2019 field survey and developed from our previous study (Yang and Zhen, 2020).

(**Figures 3** and **5**). In pastoral areas (Zhenglan and West Ujimqin banners), income was mainly affected by factors associated with animal husbandry, such as breeding, cost, price, market, policy, and rangeland (**Figure 5**). While in the agro-pastoral area (Taibus Banner), income was mainly affected by personal and social factors (i.e., vocation, health, family cooperation, and family structure) (**Figure 5**).

Social Factors

The impact factor degree of infrastructure in pastoral areas was light (**Table 3** and **Figure 3**), yielding the highest score among the social factors, while the impact factor degree of infrastructure in

Taibus Banner was very light and only impacted food consumption slightly (**Figure 5**). Due to the large area of grassland, infrastructure (mainly roads) is poor and limits residents' connection to markets and the outside world in pastoral areas. Thus, with economic development and policy, infrastructure improves, which benefits food consumption and increases food choice diversity and ease of access. However, in agro-pastoral areas such as Taibus Banner, with its large population density and limited area, government costs used to build basic infrastructure are relatively lower, making it easier for rural residents to access local markets and subsequently food, which ultimately deceases the impact of social factors in this area (**Figure 5**).

4 DISCUSSIONS

4.1 Formation of Cognitive Differences in Food Consumption Impact Factors

Food supplies resulted in different perceptions of impact factors on food consumption. From north to south among grassland transects, grassland cover decreased (**Figure 2**); thus, the dependence of local residents on local ecosystems for food consumption differed (Yang et al., 2019). The superior conditions in West Ujimqin and Zhenglan banners tended to benefit animal husbandry, providing higher incomes to families as well as affecting their food consumption habits, culture, and customs. It is important to note that livestock breeding is culturally significant to local residents in this region of China. However, in Taibus Banner, namely, the agro-pastoral transitional area, the limited land area and land conditions make it difficult for residents to rely on livestock breeding and agriculture practices to meet food consumption needs and subsistence goals, where available grassland and cropland of residents are limited and income and subsidies are low compared to the other two banners. Consequently, residents are forced to work in other vocations to earn more money for their families; thus, in Taibus Banner, livestock breeding primarily affects household food consumption and interacts less with other factors because residents only breed animals for personal consumption and not to make money.

Cultural and custom differences also contributed to the different perceptions of impact factors on food consumption. From north to south among grassland transects, the percentage of residents of Mongolian nationality decreased with family grassland size and household income (**Table 2**). Such differences affected the food consumption habits of residents in both category and amount, which primarily revealed differences between pastoral areas (West Ujimqin and Zhenglan banners) and the non-pastoral area (Taibus Banner). Residents in pastoral areas (mainly of Mongolian nationality) tend to eat more meat (beef and mutton) given that they breed cows and sheep, and their food consumption customs tend to incorporate a lot of meat (Hu, 2016; Yang et al., 2019). Additionally, such culture and customs encourage the tendency of residents to work within animal husbandry, which not only accrues a higher income but also supports

the availability of meat for their daily food consumption. The culture and customs of residents in pastoral areas also make them more sensitive to their surrounding environments given that their lives are more reliant on the grassland they subsist on, which also suggested that residents of West Ujimqin and Zhenglan banners were more aware of ecological impact factors on food consumption than residents of Taibus Banner (see **Figure 4**).

The socioeconomic characteristics of the three study areas also affected the perception of residents on food consumption. From north to south among grassland transects, residents exhibited significant differences in age, education, and family size (**Table 2**). From north to south, the average age of local residents increased, the family size decreased, and the level of education confirmed that residents of Taibus Banner were overall less educated (**Table 2**). These factors may lead to differences in awareness and cognition on food consumption impact factors.

Additionally, family subsidies differed among these different areas (**Table 2**), which was mainly affected by policy. Resident perception on policy will therefore affect their food consumption habits, particularly in Taibus Banner (with a score of FCM = 1.28) (**Figures 3** and **4**).

4.2 Livestock Breeding as an Intermediate Factor That Connects Human and Ecological Systems

In grassland areas, food consumption in the daily lives of local residents mainly derives from the grassland system they inhabit. The impact that livestock breeding poses to food consumption is in fact the impact that food supply has on food consumption. Thus, breeding becomes both the most important factor and the direct factor on food consumption (**Figures 3** and **4**). Family income in grassland areas mainly derives from livestock breeding. Thus, livestock breeding affects household income that in turn indirectly affects food consumption, which is a key feature of grassland areas (Hu, 2016). Additionally, due to the ecological vulnerability of grassland areas, any degeneration will directly affect livestock breeding and family income (Zhen et al., 2018), which also reveals the interaction between the human system and the ecosystem.

The role of livestock breeding in our results reflected the relationship between food consumption and the ecosystem. Food consumption is one of the most important human activities, and the supply of food consumption comes from the ecosystem. Typically, in grassland areas, mutton, beef, and milk directly come from animal husbandry. When residents increase their consumption demand for these foods, people need to raise the breeding scale of cattle or sheep. For herdsmen, if they raise more cattle and sheep, they will have the opportunity to have more household income. Thus, they have an incentive to expand the family breeding scale, which would lead to overgrazing in the grassland areas. However, overgrazing is one of the most severe causes of grassland degradation (Liu et al., 2018; Hou et al., 2021). Therefore, understanding the relationship between food consumption and the ecosystem is the basis for us to pursue sustainable development goals.

4.3 Differences in Household Perceptions Among Grassland Transects

In the Xilin Gol Grassland, grassland transects form naturally. Environmental differences show that they affect local culture, customs, and the perceptions of local residents (Hu, 2016; Yang et al., 2019). In different areas of grassland transects, socioeconomic characteristics of local residents differed as well as the cognition of local residents to the grassland systems they inhabit, indicating that the environment has an important role in human systems and directly impacts human activities in different areas of the Xilin Gol Grassland. Moreover, human activities are significantly negatively affected by changes in ecologically vulnerable environments over the short term (Liu et al., 2018). From south to north among grassland transects, residents tended to rely more on grassland through livelihood by production. Thus, the cognition of residents of grassland systems increased, and they were more sensitive to ecological grassland factors in both number and structure. Other studies that have focused on different aspects of this topic have also shown the effects of transition of grassland transects (Hu et al., 2019; Yang and Zhen, 2019).

4.4 The Implications of Residents' Food Consumption Impact Factors to Policymakers

Understanding farmers' and herdsman's perceptions on food consumption impact factors will be helpful for policymaking. For example, in pasture areas, livestock breeding is recognized as the most important factor that affects food consumption, which is also related to the herdsmen family income as well as the balance of the local ecosystem. The adequate supply of mutton, beef, and milk increases the risk of coronary heart diseases for people living in grassland areas. For policymakers, they need to release policies to guide residents to healthier food consumption patterns, as well as keep the balance between grassland ecosystem and husbandry, which should be based on the understanding of the role of livestock breeding for local residents. In the agro-pastoral transitional zone, besides the ecological factors of livestock breeding, the economic factors were the main concern of local rural residents. It was noted that when local residents are led to better and healthier food consumption patterns, income could be one of the main barriers. Understanding different kinds of stakeholders' perceptions will help people or organizations work together (Manolache et al., 2020).

4.5 About the Representative of the Sample Size in This Study

One of the strategies of the FCM is that a large sample size is not a mandatory requirement, and the process of our data collection strictly follows the instruction of the guidelines of FCM and previous studies' experience. In our study, we have the results that came from 67 interviewees in total to be representatives of local rural residents' status. In order to test the effectiveness of our results on a limited sample scale, we divided all the interviewees in

each banner into two groups randomly to compare the results in three banners (since we have numbered the interviewees randomly, we had group 1 with an even number and group 2 with an odd number). The results showed that there was no significant difference between the two groups in all three banners in terms of scores or frequency of the factors (**Supplementary Appendix SD**). On the one hand, whether in West Ujimqin, Zhenglan, or Taibus, the scale of food consumption impact factors revealed by the interviewees were close (**Supplementary Appendix SD1**); on the other hand, the high-scored factors and high-frequency factors in different groups within the banner were similar and consistent with the results of the whole banner (**Supplementary Appendix SD2**). Thus, we believed that our results could well reflect the household perceptions.

4.6 Limitations of Our Study

The FCM method was used as an effective way to analyze household perceptions on food consumption and provided semi-quantitative modeling results in this study. However, this study has some limitations. On the one hand, this method cannot assess impacts of unknown factors. On the other hand, this method is influenced by recency bias. For example, residents tended to remember the impact of extreme climate events, and such events were cognitively fortified within their minds, which could exaggerate the weight of relative factors. This shortcoming could be overcome by using a time lag to conduct surveys, which we may explore in future studies.

5 CONCLUSION

This study used primary data by conducting interviews using FCM in three typical areas in the Xilin Gol Grassland to quantitatively analyze food consumption impact factors on household perceptions. Results showed that from north to south along grassland transects of the Xilin Gol Grassland, the awareness of rural residents on food consumption impact factors differed. Such differences were shown in both the amount of factors and the categories of factors. Moreover, PCA was able to clearly distinguish between the three areas (groups) while also confirming the transition among grassland transects. Livestock breeding, income, local economic development, consumption habit, age, food price, and cost were the most important impact factors mentioned by farmers and herdsmen. However, residents of pastoral areas (West Ujimqin and Zhenglan banners) were more focused on ecological and economic factors; while residents of the agro-pastoral transitional zone (Taibus Banner) were less focused on ecological factors compared to the other two areas and were more focused on personal factors and social factors. Differences in supply, culture and customs, and socioeconomic characteristics affected the cognition and livelihood of residents, which influenced impact factors and their mutual connections.

Network analysis has become an increasingly used approach among practitioners, which could help to better understand different kinds of stakeholders' perception to coordinate to achieve common goals. The study of food consumption impact factors on household perceptions can help us to better

understand the food consumption behavior of residents, which will also benefit our understanding of relationships between human activities and ecosystems, providing a potential reference for policymakers.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for this study with human participants, in accordance with the local legislation and institutional requirements. The participants provided their informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LZ conceived and designed the methods and framework. WY performed and adjusted the implementation, analyzed the data and wrote the manuscript. WY contributed to the interpretation of the data, discussion of results, writing and revision of the manuscript. YW contributed to the data collection, data analysis and manuscript revision. YX contributed to manuscript revision and language polishing in the revised version. All of the authors have read and approved the final manuscript.

FUNDING

ACKNOWLEDGMENTS

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.704149/full#supplementary-material

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