PAPER • OPEN ACCESS

Household perceptions of factors that affect food consumption in grassland areas: a case study in the Xilin Gol Grassland, China

To cite this article: Wanni Yang and Lin Zhen 2020 *Environ. Res. Lett.* **15** 115007

View the article online for updates and enhancements.

Environmental Research Letters

Household perceptions of factors that affect food consumption in grassland areas: a case study in the Xilin Gol Grassland, China

Wanni Yang[1,2,3] and **Lin Zhen**[2,3]

1 China Center for Agricultural Policy, School of Advanced Agricultural Sciences, Peking University, No.5 Yiheyuan Road, Haidian District, Beijing, 100871, People's Republic of China
2 Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, 11A Datun Road, Chaoyang District, Beijing, 100101, People's Republic of China
3 College of Resources and Environment, University of Chinese Academy of Sciences, A19 Yuquan Road, Shijingshan District, Beijing, 100049, People's Republic of China

E-mail: zhenl@igsnrr.ac.cn

Abstract

Food consumption acts as an intermediary that connects ecosystems with human systems in grassland areas. In this study, we used fuzzy cognitive mapping to quantitatively assess the factors that affect food consumption in the Xilin Gol Grassland, China, from the perspective of local rural households. We found that household perceptions of the factors that affect food consumption differed among parts of the grassland transects in both the number and the strength of these factors. Livestock numbers, household income, regional economic development, consumption habits, age, and infrastructure were the most important factors mentioned by the farmers and herders, but herders were more sensitive to ecological and economic factors, whereas farmers focused more on personal and social factors. The differences in the main factors between study areas revealed the key economic, social, and ecological dimensions. Our results provide a reference for policymakers to develop improved policies to encourage regional sustainable development.

1. Introduction

Food consumption is essential for human survival, but perceptions of this consumption vary among regions and cultural backgrounds. In grassland areas, food comes directly from the grassland areas and the food supply is limited [1, 2]. Food consumption depends on the ecosystem's provision of services, and is determined by the relationship between ecosystem services and human activities [3, 4]. However, in grassland areas, the ecosystem is often very vulnerable and the food consumed by local residents comes primarily from that ecosystem, which creates pressure on the local ecosystem [5].

Moreover, socioeconomic development increasingly affects consumption patterns, and often leads to increasing contradictions between human activities and local ecosystem needs, and these contradictions create challenges to regional development, especially in grassland areas [6, 7]. In the sustainable development goals released by the United Nations [8], food consumption is linked to goal 2 (eliminating hunger) and goal 12 (responsible consumption and production). Consumption therefore plays an important role in sustainable development issues around the world [9]. Despite the importance of these goals, citizens of some developing countries have developed predatory ways of exploiting and using environmental resources during urbanization and socioeconomic development, and this has led to sustainability issues during regional development [10].

For example, northern China's Xilin Gol Grassland, one of the country's largest grassland areas, is located in the agro-pastoral transitional zone. Due to the grassland's sensitive and fragile environment and intensive human activities, this area faces serious challenges to sustainability [11, 12]. The local government and China's national government have invested more than 2×10^8 RMB for regional ecological projects [13]. Policies such as the Grassland Ecological Compensation Policy and the Beijing-Tianjin Sandstorm Source Project that have been implemented in

this area have greatly affected the lives and production of local residents [14, 15]. This, in turn has affected the daily food consumption of residents. For example, because of the strict ecological policy, local herders reduced their family livestock number and increased the percentage of cows; this affected the family meat supply, leading families to eat more beef than mutton, in contrast with the previous dominance of mutton [9]. Moreover, residents of this area come from many national backgrounds, including Han Chinese, Mongolian, Hui, and Man [13], and each of these groups has different cultural preferences. The grassland's cultivated land is mainly distributed near its southern border, and the limited food supply provided by this land cannot meet all regional needs [16]. Thus, the issues related to food consumption in this area are complex, and this suggests equally complex household perceptions of the factors that affect their food consumption.

Several researchers have studied food consumption and the factors that affect consumption in rural regions [17–19]. However, there have been few studies in pastoral regions and agro-pastoral transitional zones [9], especially in Inner Mongolian of China. Studies of the factors that affect food consumption have mainly focused on economic, social, and ecological factors. The economic factors include household income, the level of economic development (e.g. GDP), economic differences between urban and rural areas, prices of food and other necessities, and access to markets [20–24]. The social factors include problems related to an aging population, urbanization, cultural diversity, and cultural practices such as festivals that require specific foods [25–28]. The ecological factors include the time of year, land-use diversity, climate, and many environmental factors [9, 26, 29]. The main food consumption impact factors in different areas are different even the different transitional zones. The agro-pastoral transitional zone in China is from northeast China to Tibet. Research showed that in Northwest China household food self-supply and household income affected family food consumption pattern [30]; in Tibet household food consumption was affected by policy and transportation accessibility [31, 32]; in Inner Mongolia household food consumption was relative to culture, family self-supply and income [9, 26], etc. Statistical data, questionnaire responses, and remote sensing data are the most commonly used data in studies of the factors that affect food consumption [17, 33–35]. Several study about stakeholder perception conducted before and revealed people's concerning indicator for fresh food production [36], meat industry [37], food risk [38] and so on. Nevertheless, there have been insufficient studies of stakeholder perceptions of these factors, particularly in the Xilin Gol Grassland, where we found rare qualitative and quantitative analyses of these factors.

Fuzzy cognitive mapping is a semi-quantitative modeling tool that provides a framework for comparing knowledge obtained from non-technical experts [39, 40]. It can help to reveal how social groups such as farmers and herders think about an issue and allow researchers to build a network model of a situation or system [41]. It has been successfully used in the fields of geography, social science, ecology, and economics [42–44]. Such studies are easy to conduct and effective at revealing complex and subjective beliefs [45–47]. They are particularly useful during preliminary research to identify factors and relationships that should be examined in more depth in future research.

In this study, we used primary data obtained from interviews with residents of the Xilin Gol Grassland to support fuzzy cognitive mapping, and combined this data with regional land-use and socioeconomic data to identify the factors that affect food consumption in this region. Our objectives were to use the perceptions of local households to explore these factors, identify the key impact factors, and reveal differences in these factors among residents of the grassland. We focused on these factors to help us understand the coupling relationships between the region's human systems and its ecosystems, and to provide empirical support for future regional development and the associated policy development.

2. Methods

2.1. Study area

The Xilingol League lies in the central part of China's Inner Mongolia Autonomous Region. It belongs to the Mongolian Plateau, with an elevation that ranges from 800 to 1800 m asl. Annual precipitation totals 288 mm, and annual pan evaporation ranges between 1700 and 2600 mm. The annual average temperature is $3.60\,°C$, with mean monthly temperatures ranging from $-20\,°C$ in January to $21\,°C$ in July. The league comprises two county-level cities, one county, nine banners, and two districts. The total registered population was 1.036×10^6 at the end of 2016, of which rural people accounted for 35.5%. The population's ancestry is 64.2% Han Chinese and 31.3% Mongolian. The Xilingol League covers 200 000 km², including 180 000 km² of grassland and 5860 km² of forest, which amount to 90.0% and 2.9% of the total area, respectively. Cows and sheep are the main livestock raised in this region, but camels and horses are also raised because of their high economic value, especially in Taibus Banner. In 2016, the per capita disposable income of residents was 25 554 yuan per year, of which the per capita disposable income of urban residents was 32 903 yuan per year, versus 13 188 yuan per year for rural residents [48].

Most of the Xilin Gol Grassland is located within the Xilingol League. The grassland cover can be
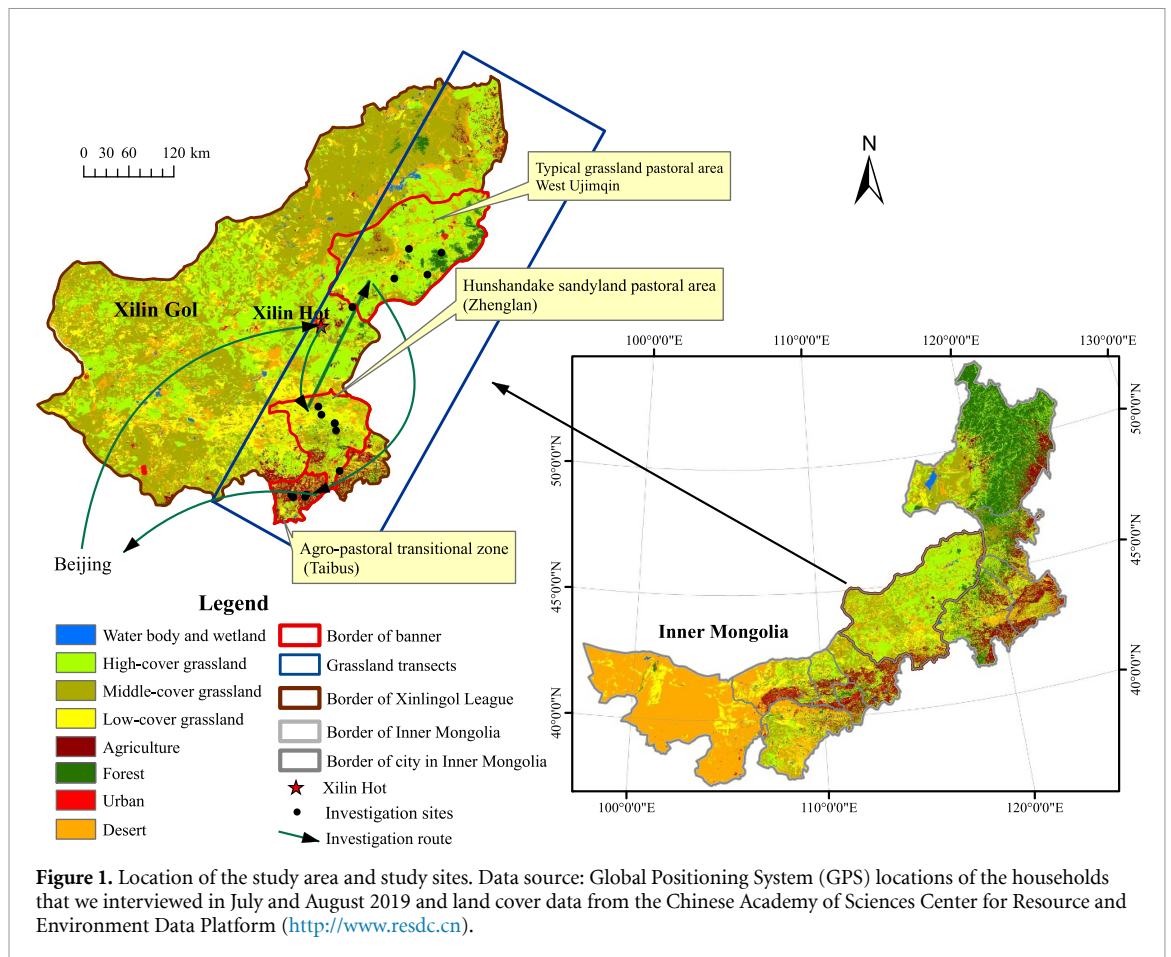
Figure 1. Location of the study area and study sites. Data source: Global Positioning System (GPS) locations of the households that we interviewed in July and August 2019 and land cover data from the Chinese Academy of Sciences Center for Resource and Environment Data Platform (http://www.resdc.cn).

divided into typical grassland, desert grassland, cultivated land, and sparse grassland (figure 1). The carrying capacity of these grassland types gradually decreases from south to north.

In this study, we selected three typical areas of the Xilin Gol Grassland for investigation: the West Ujimqin Banner, which is a typical pastoral grassland area; the Zhenglan Banner, which is a pastoral area of the Hunshandake Sandy Land; and the Taibus Banner, which is an agro-pastoral transitional zone (figure 1). The three areas represent a north to south transect through changing environments and ecosystems. The West Ujimqin Banner is in the eastern part of the Xilingol League, whereas the Zhenglan Banner and Taibus Banner are located in the southern part of the league. All three banners are in an arid to semi-arid transitional zone, with annual precipitation around 400 mm, and the annual pan evaporation is very high (>1800 mm). The ecosystems in these study areas are very vulnerable to degradation (table 1).

2.2. Data collection

2.2.1. Interviews and data collection

We interviewed representative local residents living in the three rural areas of the Xilingol League from 20 July to 5 August 2019. Details of our sampling are provided later in this section. Data were generated by means of fuzzy cognitive mapping during face

to face interviews. The interviewees were one person per family who understood the family's food consumption and other key details such as their livelihood, education, and so on. Food consumption types of rural people in the Xilin Gol Grassland mainly included grains, vegetables, fruits, meat, eggs, milk and non-staple food [9]. In this study, we did not use a standardized questionnaire to guide the interviews, since our goal was to discover the factors that interviewees considered important rather than their responses to preselected factors that we considered important. Instead, we asked a simple question: 'What factors affect your food consumption?.'

We showed an example of a fuzzy cognitive map to the interviewees before we started the interview. We then asked them to define the factors that they believed would affect their food consumption and to draw the relationships among these factors on a piece of paper. They assigned links between the factors and rated the strength of each link from −5 (i.e. increasing one factor strongly decreased the other factor) to +5 (increasing or decreasing one factor produced the same change in the other factor). The direction of each link was shown with an arrow. The larger the absolute value of the score, the stronger the impact. The networks were drawn by the interviewers in response to the instructions of the interviewees. Appendix A provides a typical

Table 1. Basic information of the study areas.

Study area	Dominant vegetation	Annual average temperature (°C)	Annual precipitation (mm)	Pan evaporation (mm)	Main food consumption categories[*]	Land Area (km^2)
West Ujimqin	Typical grassland	1.2	350	1800	meat, vegetables, and fruits	22 400
Zhenglan	Desert grassland	1.2	365	1926	meat, grains, vegetables, and fruits	10 200
Taibus	Grassland and cropland	2.4	400	1900	grains, vegetables and fruits	3415

Data sources: West Ujimqin (2018); Zhenglan Banner (2018); Taibus Banner (2018).[*] from our previous study [9, 14].

example of a map. During the interview, interviewees could add or change the factors or their weights. The final version of each network was approved by the interviewee. We obtained personal details from the interviewees and promised that this information would remain confidential and would only be used for our scientific research. The personal details included the interviewee's name, household location, gender, vocation (farmer, herder, or both), age, education (number of years of school), family size, rangeland and cropland area managed by the household, ancestry, household income, and the interview date.

The interviews were undertaken in Mandarin Chinese or Mongolian, depending on the language preferences of the interviewees. Local people such as officials working at the local grassland observation stations, the head of the village, or young people who were college students acted as translators when this was necessary to ensure clear communication with each interviewee. About 50% of interviewees needed assistance from the translator. We conducted a total of 67 interviews.

The interviewees were chosen by stratified random sampling. First, we defined the scope of the survey based on the typical land use categories in each of the three study areas. Second, we identified the study sites using stratified random sampling based on whether the site was dominated by herder or farming households. We interviewed households in 5 towns or sumu (sumu is the town-level administrative division used in the Inner Mongolia Autonomous Region) in West Ujimqin Banner, 4 towns or sumu in Zhenglan Banner, and 3 towns in Taibus Banner as our study sites. Appendix B summarizes their names and characteristics. We used pseudo-random sampling to choose the families that we interviewed at each site because the low population density (i.e. 0.2 person per km^2) led to a large distance between families, and required concentration of the families in some locations. We continued our surveys until no new factors were identified, thereby ensuring that the fuzzy maps adequately represented each interviewee's

perceptions, which was proved to be effective in the previous studies [47].

Beside the first-hand data, we also obtained the statistical data from 2000 to 2017 of three study areas. The data included GDP, population, regional livestock number, and income. These data were obtained from the local government's websites (Xilin Gol League, http://www.xlgl.gov.cn; West Ujimqin Banner, http://www.xwq.gov.cn/; Zhenglan Banner, http://www.zlq.gov.cn; Taibus Banner, http://www.tpsq.gov.cn).

2.2.2. Basic information about the interviewees
We interviewed 21 families in West Ujimqin, 21 families in Zhenglan, and 25 families in Taibus in 2019. Figure 1 shows the locations of the interview sites, and table 2 summarizes the demographic characteristics of the interviewees. The average age of the interviewees increased from north to south, accompanied by a decrease in the proportions of Mongolian families and female interviewees (table 2). The socioeconomic characteristics of the families also differed among the study areas.

2.3. Data analysis
Our 67 interviews revealed 28 different factors that directly affected food consumption (table 3). We classified the factors into four dimensions: ecological factors (10), social factors (5), economic factors (5) and personal factors (8). Here our classification referred to the usual sustainable development indicator and dimension [3], while the factors relative to the personal characteristic and personal emotion were sorted as the personal dimension. Four dimensions consisted of all types of the impact factors.

Each interviewee scored the strengths of the relationships among the factors in the fuzzy cognitive maps. These strengths (V) were divided into four degrees: very weak ($0 < V < 1$), weak ($1 \leq V < 2$), important ($2 \leq V < 3$), and very important ($3 \leq V < 4$). Although we expected the scores to be between -5 and 5, in practice the interviewees only assigned values between -4 and 4.

Table 2. Socioeconomic characteristics of the respondents in the three study areas.

		West Ujimqin banner (21 families)	Zhenglan banner (21 families)	Taibus banner (25 families)
Gender	Male	5	7	11
	Female	16	14	14
Ancestry	Han	1	11	25
	Mongolian	20	10	0
Average	years of education	7.7	9.0	5.4
Average	age	44.6	51.2	62.9

Table 3. Factors that affected food consumption identified by the interviewees and their classification into four dimensions.

	Dimension			
	Ecological factors	Social factors	Economic factors	Personal factors
	Livestock number	Infrastructure*	Household income	Consumption habits*
	Season*	Policy*	Regional economic development	Age
	Planting*	Festival*	Food price	Family structure
	Nutrition*	Culture and customs	Food market maturity	Health
	Cropland area	Transportation accessibility	Cost of production	Vocation
	Rangeland area			Consumption pattern*
	Food security			Awareness of health, nutrition and market
	Food quality			Conformity*
	Residence*			
	Climate			
Total	10	5	5	8

Note: Season means 'seasonal availability of food'. Planting means 'crop and vegetable types planted'. Nutrition means 'nutritional quality of the food'. Residence means 'urban or rural (especially rural area with grassland)'. Infrastructure means 'the length of roads'. Policy means 'government ecological restoration policy'. Festival means 'special foods for certain festivals'. Consumption habits means 'personal preferences (e.g. the husband prefers meat, the wife prefers vegetables)'. Vocation means 'herder, farmer, or both'. Consumption pattern means 'regional consumption behaviors (e.g. when people eat mutton, they drink alcohol; family usually stock and eat a whole sheep or beef in winter)'. Conformity means 'Conformity with neighbors or cultural traditions'.

3. Results

3.1. Overview of the factors that affect food consumption

According to the interviewees, 28 factors affected the food consumption in their daily life (table 3). However, the factors differed among the study areas. In the pastoral areas (Zhenglan and West Ujimqin), interviewees identified more direct and indirect factors than in the agro-pastoral transitional zone (Taibus) (figure 2(a)). However, the numbers did not differ significantly between the three areas, with an average of 7 direct impact factors and 4 indirect intermediate impact factors in each area.

Among the four dimensions of the impact factors, personal and ecological factors were perceived as the most important factors in all three banners, with both a greater number of mentions (figure 2(b)) and a greater cumulative score (figure 2(c)) than the other factors. The key impact factors analysis also indicated that interviewees showed stronger cognition in personal and ecological factors, which we will discuss in section 3.2.

From the view point of each banner, the factors in four dimension also showed the differences. In Taibus Banner, ecological (8 times per interviewee) and personal factors (7 times) were mentioned most often and social factors were mentioned least often (3 times). In Zhenglan Banner, personal factors were mentioned most frequently (10 times), and economic factors were mentioned least frequently (4 times), although economic factors were ranked 3rd instead of 4th in the cumulative scores. In West Ujimqin Banner, the pattern was similar to that in Zhenglan, which means that even though residents did not mention economic factors frequently (5 times), they ranked the economic factors highly. Although Taibus residents did not mention ecological factors and personal factors as often as residents in Zhenglan and West Ujimqin did, they gave both dimensions higher scores. Residents in Taibus considered the social factors to be least important, with the fewest mentions (3 times) and lowest score (1.8 in total). This may be because socioeconomic development in the pastoral areas (Zhenglan and West Ujimqin) has been very rapid since 2008. We will discuss this in more

Table 4. Overview of the fuzzy cognitive mapping results for the number of factors per dimension and additional indicators for the three study areas. Values are means±SE.

	p-Value	West Ujimqin ($n = 21$)$X \pm SE$	Zhenglan ($n = 21$)$X \pm SE$	Taibus (n = 25)$X \pm SE$
Impact factors (no. for the 4 dimensions)	0.617 ns	6.95 ± 2.18	6.9 ± 2.43	7.44 ± 1.56
Rangeland size (ha)	<0.001***	2515.71 ± 353.74	1289.64 ± 219.63	4.87 ± 1.30
Cropland size (ha)	0.0106*	0 ± 0	0 ± 0	42.41 ± 17.55
Family size (no. of people)	0.010*	3.62 ± 0.20	3.62 ± 0.29	2.72 ± 0.22
Education (no. of years)	0.003**	7.71 ± 0.70	9.00 ± 0.69	5.4 ± 0.79
Number of cows (no.)	<0.001***	34.57 ± 9.28	41.80 ± 7.04	2.44 ± 0.74
Number of sheep (no.)	<0.001***	317.14 ± 49.81	34.90 ± 11.92	5.84 ± 3.02
Household income (10^4 yuan per year)	<0.001***	18.62 ± 2.14	13.83 ± 1.95	2.40 ± 0.31

Significance (ANOVA): ns, not significant; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
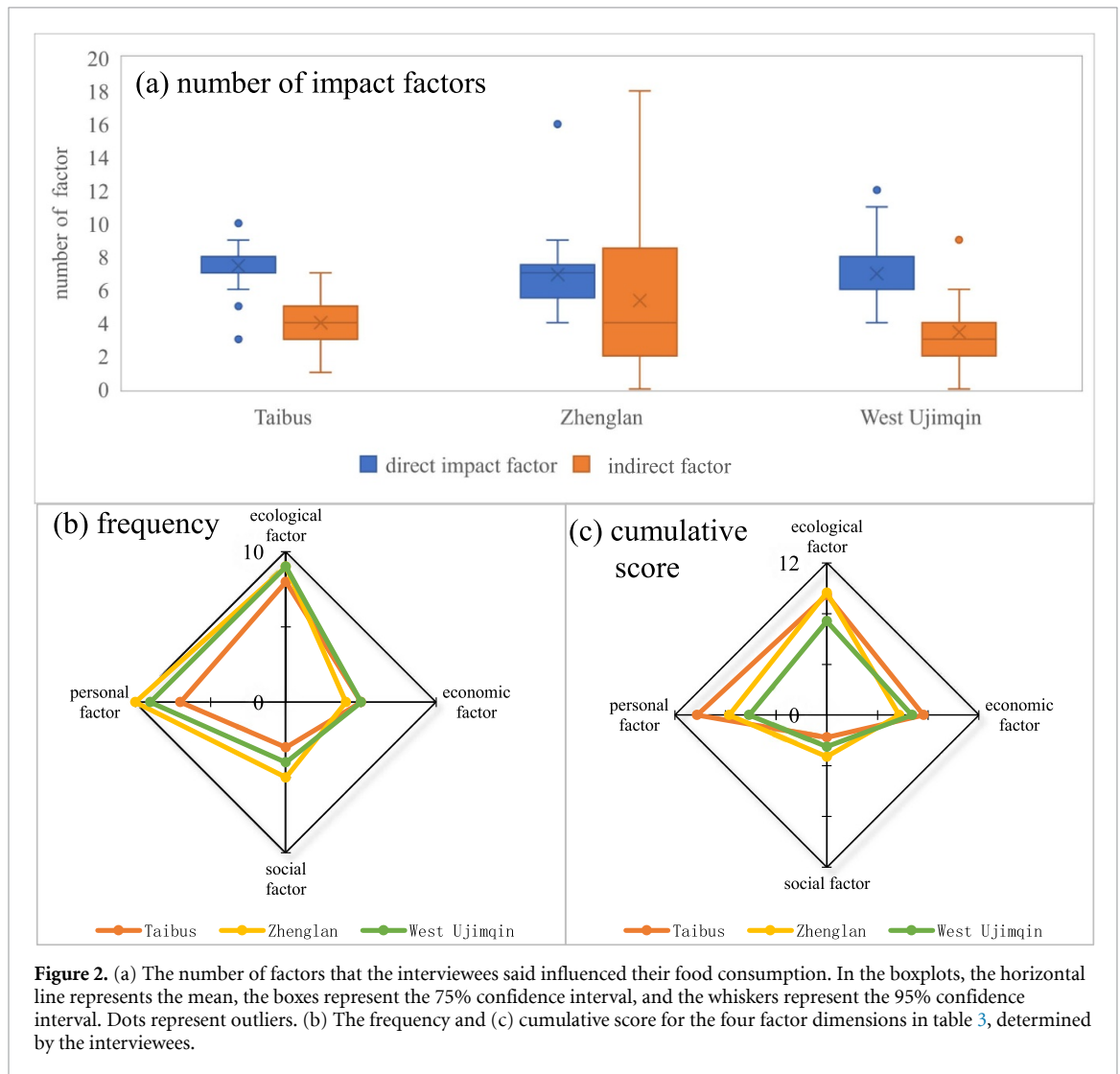
Figure 2. (a) The number of factors that the interviewees said influenced their food consumption. In the boxplots, the horizontal line represents the mean, the boxes represent the 75% confidence interval, and the whiskers represent the 95% confidence interval. Dots represent outliers. (b) The frequency and (c) cumulative score for the four factor dimensions in table 3, determined by the interviewees.

detail later in the paper. The residents of these areas strongly perceived the changes and the impacts on their lives, which would lead them to focus more on this dimension.

Our analysis of the structural and functional demographic variables showed that residents in Taibus, Zhenglan, and West Ujimqin banners differed significantly in their perceptions of impact factors,

family size, rangeland size, cropland size, number of sheep, number of cows, years of education, household income, and subsidies (table 4).

3.2. The key impact factors and their characteristic

Livestock numbers, household income, regional economic development, consumption habits, age, and infrastructure were the most important impact factors mentioned by the interviewees and showed the most interactions with other factors (figure 3). In all study areas, the high scores that interviewees gave goes to livestock numbers, household income, regional economic development, consumption habits, which were all showing $V > 2.0$ (important degree). Especially, age was thought as an important factor affected household daily food consumption in Taibus, where $V = 2.6$, showing important degree compared to other two areas). Besides, though the social factors were ranked lower than other factors, infrastructure were scored highest among all the social factors in West Ujimqin ($V = 1.8$) and Zhenglan ($V = 1.2$), which also showed distinguishing difference between pastoral areas and agro-pastoral transitional zone ($V = 0.1$ in Taibus). Thus, in this paper we focus on these important factors and analyzed their characteristic.

Additionally, through the key impact factors we found that interviewees paid more concerns on the ecological factors and economic factors, which could also find the clue s in figure 2—interviewees showed high frequency and high cumulative score in ecological factors, while relative low frequency and high cumulative score in economic factors. It suggested that ecological factors likes livestock numbers are so important that interviewees all mentioned them frequently as well as gave high score; though interviewees mentioned economic factors not so often, they tended to gave high score as long as they gave the economic factors a nomination.

Among all these key factors, interviewees were more concerned about ecological factors (livestock number) in the northern areas (Zhenglan and West Ujimqin) than in the southern area (Taibus) (figure 3). In addition, personal factors (especially consumption habits) and economic factors (especially household income and regional economic development) were ranked as the second and third-most important groups of factors after the ecological factors in the pastoral areas (Zhenglan and West Ujimqin), whereas in the agro-pastoral transitional area (Taibus), ecological factor (livestock number) was also ranked first, and economic factors (especially household income) were ranked as the second-most important factors. These results suggest that as we moved from the north to the south, residents became more concerned about the economic and personal factors and less concerned about the ecological factors.

3.2.1. Ecological factor: number of livestock

In all three study areas, the number of livestock was considered the most important factor ($V > 3$ in the three study areas) that affected daily food consumption (figure 3). The number of livestock directly affects a resident's food consumption by defining the size of this food resource, but also affects food consumption indirectly by its effect on household income. This was true in all three areas.

However, we also observed a trend from north to south, in which the number of livestock was affected by a change in priorities from ecological factors (number of livestock, season, rangeland) and economic factors (household income, regional economic development) to economic factors (household income, regional economic development, food price) and personal factors (consumption habits, age, family structure). Especially in the pastoral areas (West Ujimqin and Zhenglan), the number of livestock was strongly affected by the rangeland area. Also, the number of interviewees who emphasized the number of livestock tended to decrease moving from north to south.
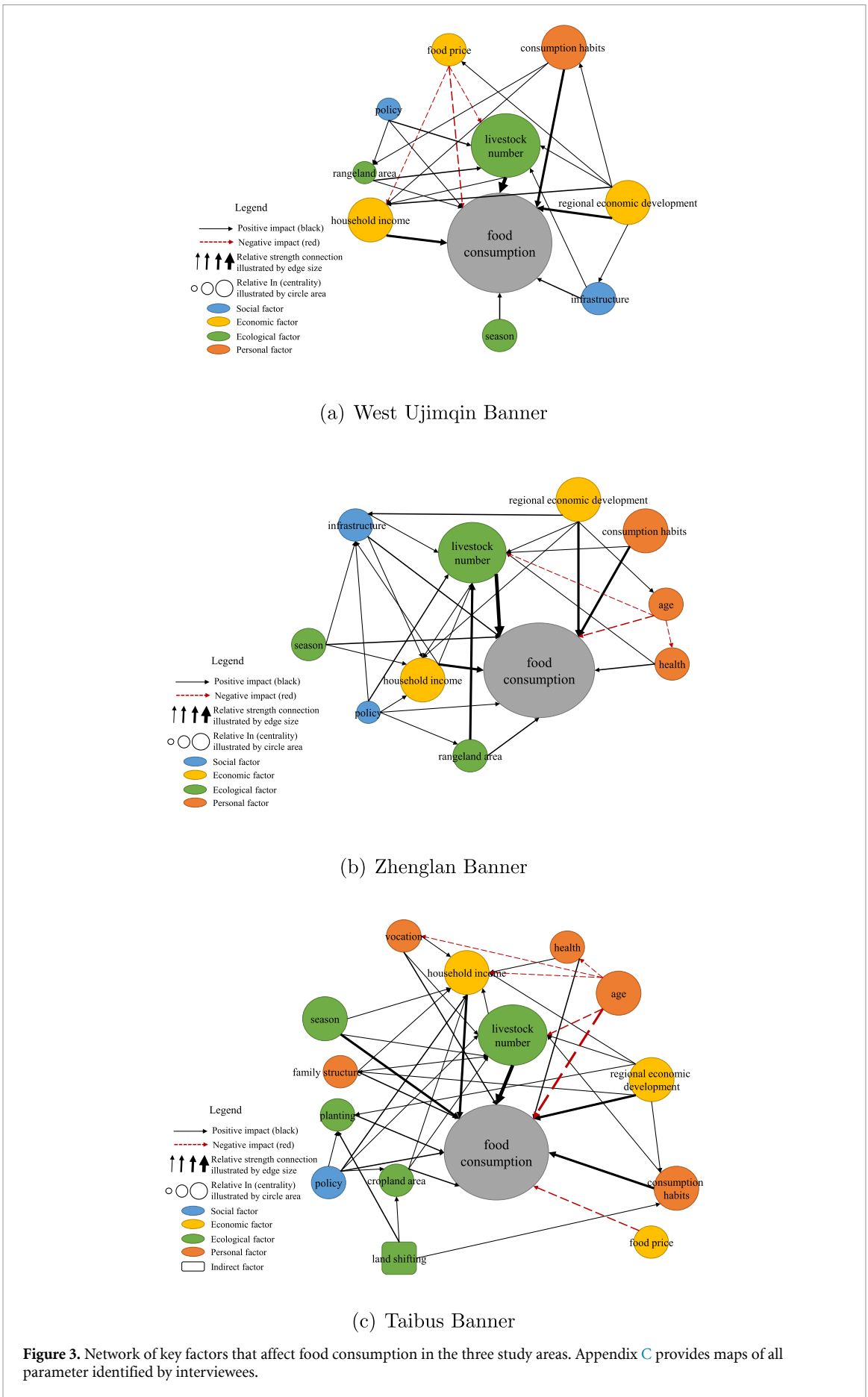
3.2.2. Personal factors: consumption habits and age

The most important personal factor involved consumption habits ($V > 2.5$ in all three study areas). In all three study areas, this was ranked as one of the most important factors, and one that interacted strongly with the other factors (figure 3). These habits were mainly affected by household income, vocation, and ancestry, and all of these factors were also affected by regional economic development. Even though residents' consumption behaviors have probably changed over time in response to other changes in their lives (e.g. rapid economic development), these changes were reflected in their consumption habits at the time of our interviews.

Age had a particularly important impact on food consumption in Taibus ($V = 2.6$), which relates to the problem of an aging population in this area. Residents' average age in Taibus was 62.9, which is more than 10 years older than in the other regions (table 2). In addition, the areas of rangeland and cropland for each family were smaller in Taibus than in the two pastoral areas (table 4), and interviewees considered their income from agriculture too low to provide a comfortable life for young people; as a result, it was mostly old people who chose to stay in rural areas in Taibus. The aging problem affected consumption directly by leading residents to eat less and restrict their food choices, and indirectly by affecting their health, income, vocation, and residence location (figure 3).

3.2.3. Economic factors: regional economic development and household income

Regional economic development is one of the most important economic factors that affected other factors that in turn affect food consumption ($V = 2.5$

(a) West Ujimqin Banner

(b) Zhenglan Banner

(c) Taibus Banner

Figure 3. Network of key factors that affect food consumption in the three study areas. Appendix C provides maps of all parameter identified by interviewees.

in West Ujimqin, $V = 2.3$ in Zhenglan, $V = 2.3$ in Taibus) (figure 3). In the pastoral areas, economic development improved the infrastructure and increased household income, thereby changing ways of life and affecting food consumption. In the agro-pastoral transitional zone, interviewees believed that their nutrition had improved and that their number of livestock had increased, making herding more profitable, and this affected their choice of vocation and food consumption.

Household income was another important economic factor that interacted with many other factors and differed among the three study areas ($V = 2.4$ in West Ujimqin, $V = 2.3$ in Zhenglan, $V = 2.9$ in Taibus) (figure 3). In the pastoral areas (Zhenglan and West Ujimqin), household income was mainly affected by factors related to animal husbandry such as the number of livestock, cost of production, food price, food market maturity, agriculture policy, and area of rangeland. In the agro-pastoral area (Taibus), household income was mainly affected by the personal and social factors (i.e. vocation, health, family help, family structure).

3.2.4. Social factor: infrastructure
In the pastoral areas, infrastructure had the highest score among the social factors ($V = 1.8$ in Zhenglan, $V = 1.2$ in West Ujimqin), but in Taibus, it had a much weaker effect on food consumption ($V = 0.1$; table 4, figure 3). Due to the large grassland area, the infrastructure (mainly roads) was poor and limited residents' access to markets and the outside world in the pastoral areas. Along with economic development and government policy, the infrastructure improved, thereby improving food consumption and offering more diverse food choices that became easier to access. However, in the agro-pastoral area (Taibus), which had a higher population density and a smaller area, the cost for governments to build basic infrastructure was lower and rural residents found it easier to get access to local markets where they could obtain more food, thereby weakening the strength of the social factors in this area (figure 3).

4. Discussion

4.1. Key factors that affected food consumption
Based on changes in the socioeconomic characteristics of the study areas from 2000 to 2017 and the basic information on farmers and herders that we obtained in the 2019 field survey, we analyzed the social, economic, and ecological dimensions of the study areas to reveal causes of the differences in the number of livestock, household income, regional economic development, consumption habits, and age in the three typical areas based on the fuzzy cognitive mapping (figure 3).

The number of livestock differed greatly among the three study areas. The number of livestock in

the study area also decreased (in response to a government policy to prevent overgrazing) at different rates from 2000 to 2017. In 2017, the number of livestock in West Ujimqin was 930 900, versus 365 600 in Zhenglan and 191 200 in Taibus (figure 4(c)). The residents of West Ujimqin tended to herd more sheep, whereas residents of Zhenglan tended to herd more cattle, and residents of Taibus tended to herd a small number of animals with a high economic value, such as camels and horses. In addition, the size of rangeland decreased moving from north to south (table 4), and this may have affected the number and type of livestock owned by a family.

With economic development, the per capita GDP and household income of interviewees have grown rapidly since 2000. The per capita GDP of West Ujimqin increased from 9680 yuan (2000) to 153 971 yuan (2017), an increase to 15.9 times the original value; the per capita GDP of Zhenglan increased from 5005 yuan (2000) to 85 583 yuan (2017), an increase to 17.1 times the original value; and the per capita GDP of Taibus increased from 3035 yuan (2000) to 26 767 yuan (2017), an increase to 8.8 times the original value (figure 4(a)). The household disposable income of residents in West Ujimqin (23 662 yuan) was always highest, and the income decreased from north to south (figure 4(b)). Moreover, the GDP differences between the three areas widened during the study period, which suggests there were significant regional differences in the economic conditions. The number of livestock decreased from 2000 to 2017 in West Ujumqin and Zhenglan, but remained relatively constant (despite some fluctuation) in Taibus. Besides, residents in Xilingol League witnessed a significant wealth growth in the past decades, on one hand it was mainly contributed by the resource exploitation (i.e. mining) [6], which also posed challenges to regional sustainable development; on the other hand, the rapid economic development would change residents' daily food budget as well as daily food consumption structure [16], which raised new demand for regional food supply.

Consumption habits and age also differed significantly between the three regions. Previous research on our study areas showed that the food consumption by residents of the three study areas differed greatly in quantity, structure, and preference. In West Ujimqin, residents tended to consume meat, vegetables, and fruits; in Zhenglan, residents tended to consume meat, grains, vegetables, and fruits; and in Taibus, residents tended to consume grains, vegetables and fruits (table 1). This suggests changes in the diet from primarily pastoral to primarily agricultural areas.

The mean age of residents of the three study areas increased from north to south, from 45 years in West Ujimqin to 51 in Zhenglan and 63 in Taibus. However, the total population of each region remained stable from 2000 to 2017 (figure 4(d)). However, the age structure in Taibus represents a potential

problem. On the one hand, the banner had a much higher population than the other two regions (figure 4d) as well as a high population density (62 persons per km^2; table 1, figure 4d); on the other hand, large numbers of rural people have moved into the banner's cities to find jobs, leaving a growing proportion of elderly people in rural areas. Many of the elderly people are unable to find jobs in the city or preferred to remain in rural areas due to the low cost of living.

As GDP increased, infrastructure development also increased, especially in terms of the construction of roads. In Taibus, the small land area (table 1) means that construction of roads has not caused problems related to access to food supplies; that is, a relatively small number of roads can meet the needs of residents. However, in West Ujimqin and Zhenglan, which are larger, governments have had more serious problems building sufficient roads.

4.2. Differences in household perceptions

In the Xilin Gol Grassland, there is a natural gradient of ecosystems and environmental conditions from north to south. Our results and previous research suggest that this gradient has affected the local culture, customs, and perceptions of local residents [14, 26, 49]. The socioeconomic characteristics of the residents differed among the three areas, as did their perceptions of the grassland system that sustained them, with both direct and indirect impacts on human systems and activities in the Xilin Gol Grassland. Human activities have adversely affected the region's vulnerable environment; on the one hand, overgrazing and unsustainable use of local natural resources (i.e. grassland, water) led to the environmental issues [6, 7]; on the other hand, since the implementation of key ecological projects (i.e. Grassland Ecological Compensation Policy, Grain for Green) by the government, the local ecosystem has recovered since 1999 [50, 51]. As we moved from north to south along our transect, residents relied less on grasslands for their living and more on agriculture. Thus, their perceptions of the importance of the grassland weakened, and they showed less concern about the ecology of their local grasslands. Such transitions along a grassland transect have been described previously [14, 52]. Furthermore, in the other grassland areas, people's food consumption behaviors were found to be affected not only by infrastructure, consumption habits, household income, local food supplies, and family size [18, 53], but also market accessibility, eco-friendliness, local production, and nutrition [53–55].

Moreover, household perceptions between Han people and Mongolian people showed some differences in the impact factor scale and score of factors (appendi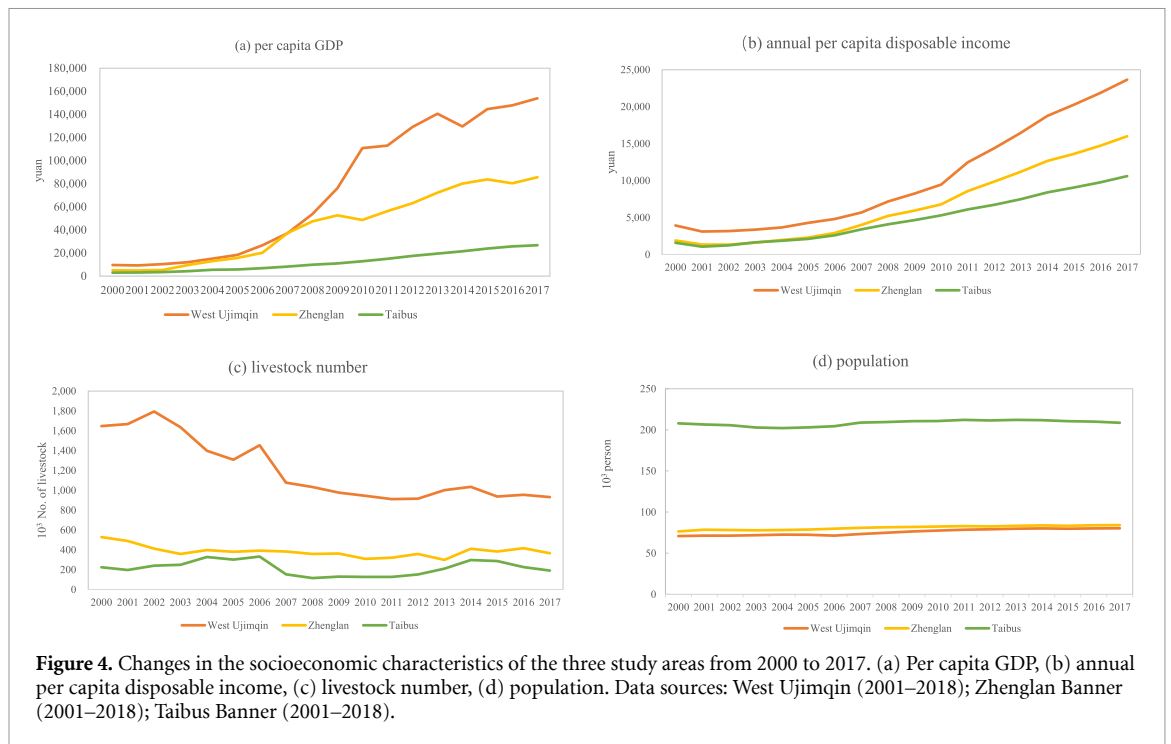x D1). We took Zhenglan as example to divide the interviewees into two group by nationality of the family members, in which Han family group was consist of 11 interviewees and Mongolian family group was consist of 10 interviewees. The results showed that Mongolian interviewees perceived more factors (26) than Han interviewees (18). What's more, Mongolian showed special focus on infrastructure ($V = 2.0$) while Han interviewees especially concerned the season ($V = 2.7$). It suggests that the infrastructure (e.g. road) did affect household food consumption a lot through the food accessibility; while the Han family tend to plant some vegetable in the yard which are one of most important sources of food, and the planting of vegetables is directly relative to the season in this area.

4.3. Limitations of our study

The largest limitation on our study related to budget and time constraints, which limited the number of residents we could interview. In order to test the effectiveness of our results in limited sample scale, we divided all the family into two group randomly to compare the results in three banners. The results showed that there were not significantly difference between two groups in all three banners (appendix D). On one hand, no matter in West Ujimqin (appendix D2), Zhenglan (appendix D3) or Taibus (appendix D4), the scale of food consumption impact factors revealed by the interviewees were close; on the other hand, the high scored factors and high frequency factors in different groups within the banner were similar and kept consistency to the results of the whole banner.

We nonetheless found interesting differences among the three banners that suggest a need for additional research to clarify these differences. Fuzzy cognitive mapping provided an effective way to analyze household perceptions of the factors that affected food consumption and to provide a quantitative (though subjective) description of the study area. However, there are limitations of this approach, including the subjectivity of the assessments of the strength of a given factor that affects food consumption. In addition, our approach cannot assess the impacts of unknown factors. Because we did not provide interviewees with a predetermined list of factors, it is possible that many of them were unaware of some of the factors that other interviewees identified or failed to remember those factors during the interviews. However, this weakness of our research is also a strength, since the interviewees had a chance to identify factors that they considered to be important rather than being biased by our prior choices of factors. Future research should focus on the complete set of factors that we identified in the present study.

Our results are also influenced by various subjective biases. For example, residents tended to remember the impact of recent or extreme climate events, and

Figure 4. Changes in the socioeconomic characteristics of the three study areas from 2000 to 2017. (a) Per capita GDP, (b) annual per capita disposable income, (c) livestock number, (d) population. Data sources: West Ujimqin (2001–2018); Zhenglan Banner (2001–2018); Taibus Banner (2001–2018).

this may have exaggerated the weight they assigned to such factors. This shortcoming could be mitigated by conducting surveys with a time lag in future research to see whether perceptions change.

5. Conclusions

In this study, we used primary data obtained by conducting interviews to support fuzzy cognitive mapping in three typical areas of the Xilin Gol Grassland. We identified the factors that residents believed had affected their food consumption along a north to south transect through the grassland based on household perceptions of the key factors and their relative strengths, and combined those findings with socioeconomic data to analyze the impacts of the key factors in three typical regions of the grassland. From north to south along the transect, perceptions of the factors that affected food consumption changed in terms of both the key factors and their perceived strengths. The number of livestock, household income, regional economic development, consumption habits, age, and infrastructure were perceived as the most important factors. However, the residents of pastoral areas (West Ujimqin and Zhenglan) focused more on ecological and economic factors, whereas residents of the agro-pastoral transitional zone (Taibus) placed less emphasis on ecological factors and were more concerned about personal and social factors. The key factors differed among the three regions, which suggests that local factors influenced the residents' perceptions and the resulting food consumption.

Our data on the factors that influence food consumption are preliminary, but future research to improve our understanding of these household perceptions will provide insights into the relationships between human activities and the grassland ecosystem, thereby providing improved guidance for policy development.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

Appendix A. Example of a record of the fuzzy cognitive mapping that was performed during the field survey

Appendix B. Information about the villages where the interviews were conducted

Banner	Town or sumu	Village or gacha	Number of interviewees
West Ujimqin	Jirengaole Town, Wulanhalaga Sumu, Haoletugaole Town, Bayanhushu Sumu, Bayanhua Town	Shandanbaolige Gacha, Xingaole Gacha, Wuritugaole Gacha, Alatangaole Gacha, Saihannuoer Gacha, Bayanhaoletu Gacha	21
Zhenglan	Sanggendalai Town, Shangdu Town, Saiyinhuduga Sumu, Naritu Sumu	Bayinsurige Gacha, Qinggeletu Gacha, Yirilejihu Gacha, Chaidamu Gacha, Tugurige Gacha, Ligesitai Gacha, Hulusitai Gacha	21
Taibus	Baochang Town, Yongfeng Town, Qianjingou Town	Fuxing Village, Fanmao Village, Tianxingyuan Village, Pingchuan Village	25
Total	12	17	67

Appendix C. Network of all factors that affected food consumption in the three study areas

West Ujimqin banner.

Zhenglan banner.

Taibus banner.
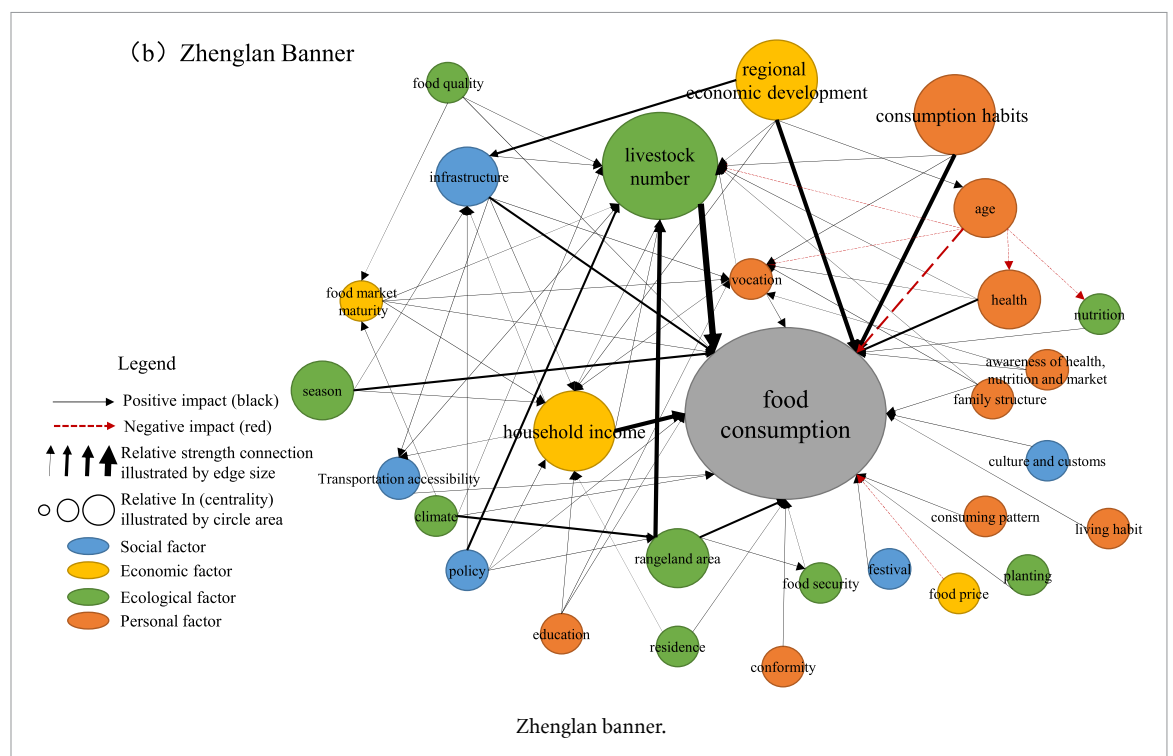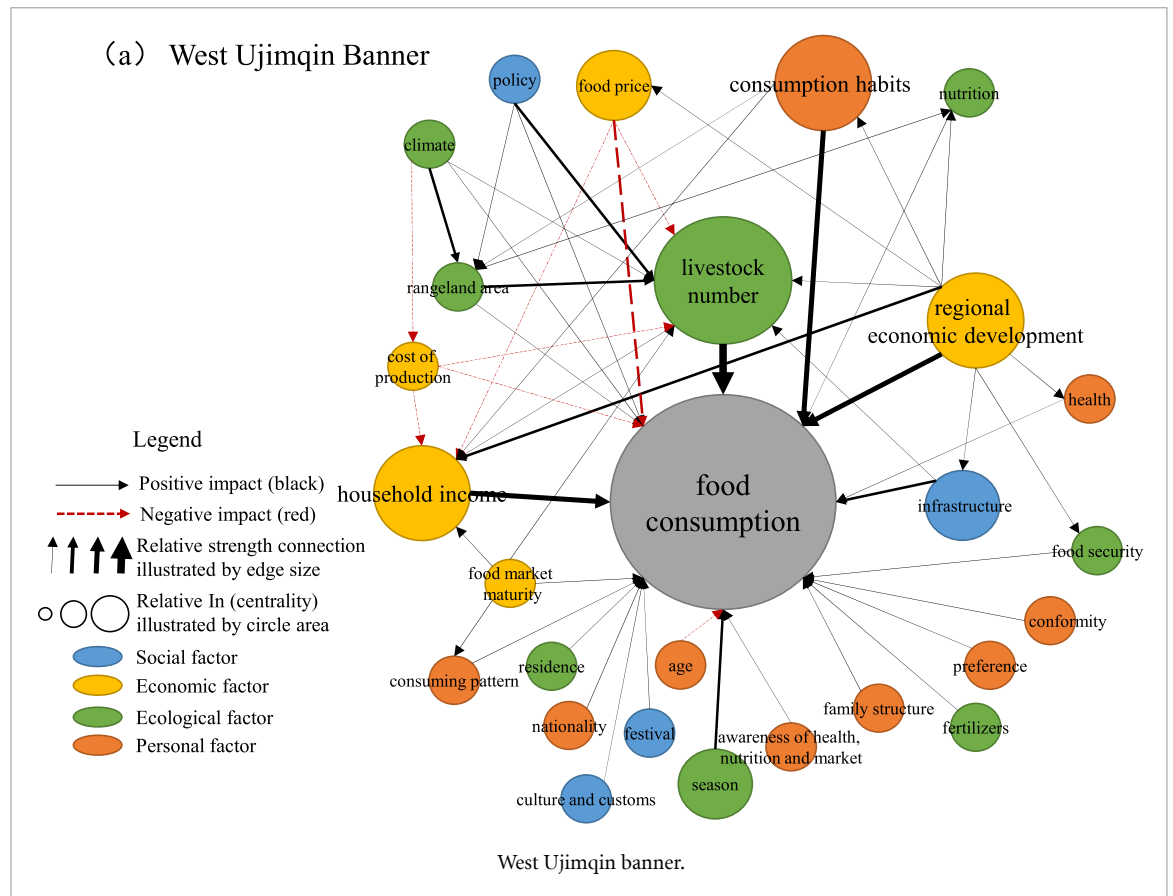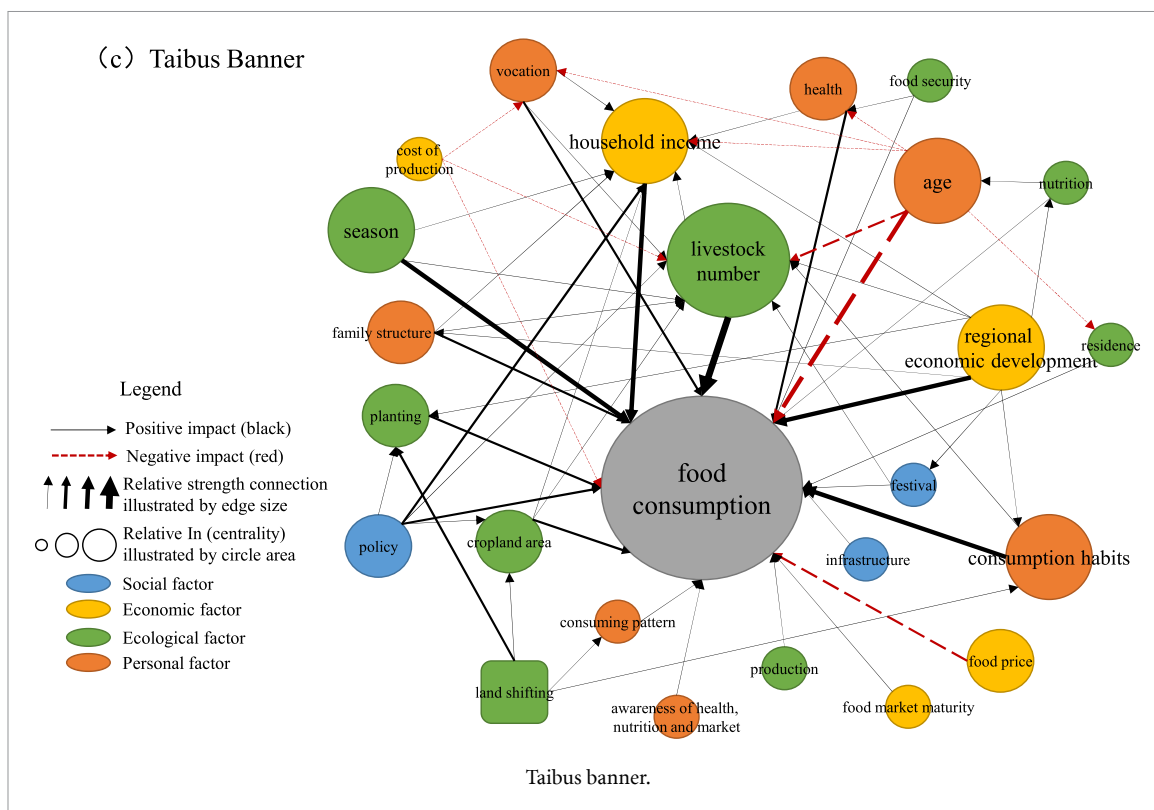
Appendix D. Results of resident's perceptions in different groups

Different nationality group (Zhenglan)					
Group 1-Han family group (X=11)			Group 2- Mongolian family group (X=10)		
factor	score	frequency	factor	score	frequency
livestock number	4.00	8	livestock number	3.83	10
season	2.67	6	consumption habit	2.67	7
consumption habit	2.33	5	regional economic development	2.50	8
household income	2.33	5	household income	2.25	7
regional economic development	2.11	5	infrastructure	2.00	7
rangeland area	1.56	4	age	1.92	6
health	1.44	3	season	1.42	5
age	1.44	3	vocation	1.33	4
infrastructure	1.44	4	nutrition	1.33	4
food price	1.22	3	family structure	0.92	3
planting	1.00	2	tansportation accessib	0.92	3
policy	1.00	3	rangeland area	0.75	2
climate	0.56	1	health	0.67	2
food quality	0.56	1	food quality	0.67	2
culture and customs	0.56	1	food price	0.58	2
family structure	0.44	1	residence	0.58	2
food market maturity	0.33	1	education	0.50	2
food security	0.22	1	living habit	0.42	1
			awareness of health, nutrition and market	0.42	1
			culture and customs	0.33	1
			festival	0.25	1
			climate	0.25	1
			conformity	0.25	1
			food security	0.17	1
			consumption pattern	0.17	1
			food market maturity	0.17	1

ecological factor
economic factor
social factor
personal factor

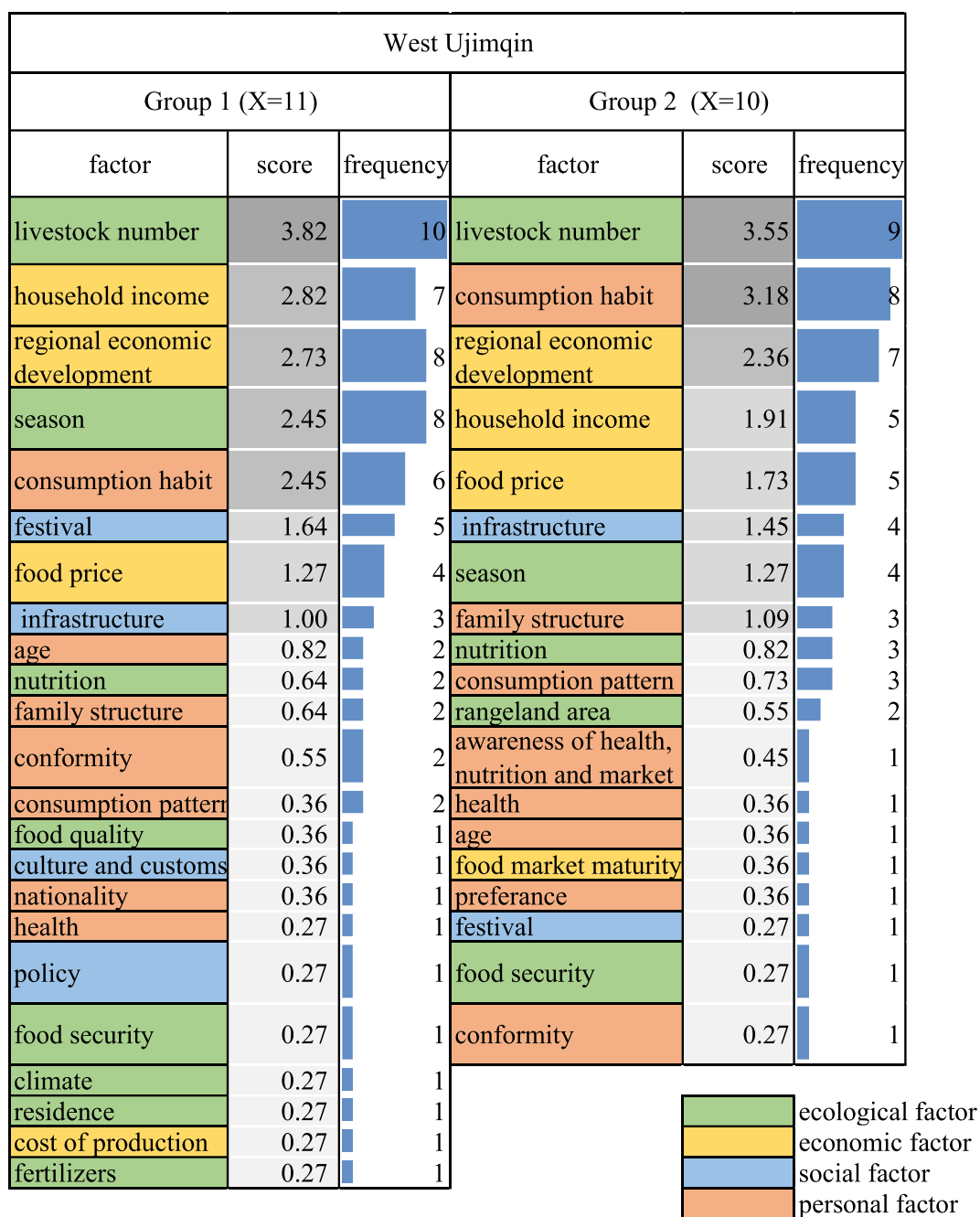Figure D4. Difference between Han people and Mongolian people in Zhenglan.

West Ujimqin					
Group 1 (X=11)			Group 2 (X=10)		
factor	score	frequency	factor	score	frequency
livestock number	3.82	10	livestock number	3.55	9
household income	2.82	7	consumption habit	3.18	8
regional economic development	2.73	8	regional economic development	2.36	7
season	2.45	8	household income	1.91	5
consumption habit	2.45	6	food price	1.73	5
festival	1.64	5	infrastructure	1.45	4
food price	1.27	4	season	1.27	4
infrastructure	1.00	3	family structure	1.09	3
age	0.82	2	nutrition	0.82	3
nutrition	0.64	2	consumption pattern	0.73	3
family structure	0.64	2	rangeland area	0.55	2
conformity	0.55	2	awareness of health, nutrition and market	0.45	1
consumption pattern	0.36	2	health	0.36	1
food quality	0.36	1	age	0.36	1
culture and customs	0.36	1	food market maturity	0.36	1
nationality	0.36	1	preferance	0.36	1
health	0.27	1	festival	0.27	1
policy	0.27	1	food security	0.27	1
food security	0.27	1	conformity	0.27	1
climate	0.27	1			
residence	0.27	1			
cost of production	0.27	1			
fertilizers	0.27	1			

ecological factor
economic factor
social factor
personal factor

Figure D5. West Ujimqin banner.

Zhenglan					
Group 1 (X=10)			Group 2 (X=11)		
factor	score	frequency	factor	score	frequency
livestock number	3.45	9	livestock number	4.40	10
regional economic development	2.82	8	consumption habit	3.20	7
household income	2.27	6	household income	2.30	6
season	2.18	6	regional economic development	1.80	5
consumption habit	1.91	5	season	1.70	5
infrastructure	1.91	6	age	1.60	4
age	1.82	5	infrastructure	1.60	5
health	1.18	3	rangeland area	1.60	4
vocation	1.09	3	food quality	1.30	3
food price	0.91	3	nutrition	1.10	3
policy	0.82	3	culture and customs	0.90	2
family structure	0.73	2	health	0.80	2
rangeland area	0.64	2	food price	0.80	2
residence	0.64	2	tansportation accessi	0.80	2
nutrition	0.45	1	family structure	0.70	2
planting	0.36	1	planting	0.50	1
festival	0.27	1	living habit	0.50	1
climate	0.27	1	climate	0.50	1
tansportation accessi	0.27	1	awareness of health, nutrition and	0.50	1
education	0.27	1	food security	0.40	2
consumption pattern	0.18	1	vocation	0.40	1
food market maturity	0.18	1	food market maturity	0.30	1
			conformity	0.30	1
			education	0.30	1

    □ ecological factor
    □ economic factor
    □ social factor
    □ personal factor
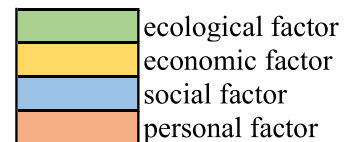
Figure D6. Zhenglan banner.

Taibus					
Group 1 (X=13)			Group 2 (X=12)		
factor	score	frequency	factor	score	frequency
livestock number	3.23	11	consumption habit	4.00	11
regional economic development	2.69	9	livestock number	3.25	10
household income	2.69	8	household income	3.17	9
age	2.38	8	age	2.75	8
health	2.15	7	season	2.50	9
season	1.85	7	food price	2.00	6
consumption habit	1.69	5	regional economic development	1.92	6
planting	1.62	5	family structure	1.92	6
family structure	1.62	6	planting	1.67	6
food price	1.46	5	policy	1.50	5
vocation	1.31	5	cropland area	1.25	4
cropland area	1.15	4	health	1.00	3
policy	1.08	4	vocation	0.67	2
festival	0.69	3	food security	0.58	3
nutrition	0.62	2	nutrition	0.58	2
cost of production	0.54	2	consumption pattern	0.33	1
consumption pattern	0.38	2	cost of production	0.33	1
awareness of health, nutrition and	0.31	1	food market maturity	0.25	1
food security	0.23	1	residence	0.25	1
infrastructure	0.23	1			
food market maturity	0.23	1			

Legend:
- ecological factor (green)
- economic factor (yellow)
- social factor (blue)
- personal factor (orange)
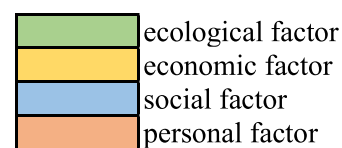
Figure D7. Taibus banner.

ORCID iDs

Wanni Yang ⓘ https://orcid.org/0000-0001-7381-5161

Lin Zhen ⓘ https://orcid.org/0000-0001-6227-4697

References

[1] Zhao T, Ouyang Z, Jia L and Zheng H 2004 Ecosystem services and their valuation of China grassland *Acta Ecolog. Sin.* **24** 1101–10 (in Chinese with English abstract) (http://www.ecologica.cn/stxb/ch/reader/view_abstract.aspx?file_no=040602)

[2] Fu B, Zhou G, Bai Y, Song C, Liu J, Zhang H, Lv Y, Zheng H and Xie G 2009 The main terrestrial ecosystem services and ecological security in China *Adv. Earth Sci.* **24** 571–6 (in Chinese with English abstract) (http://en.cnki.com.cn/Article_en/CJFDTotal-DXJZ200906002.htm)

[3] Millennium Ecosystem Assessment 2005 Ecosystems and human well-being (Washington DC: Island Press)

[4] Zhen L, Liu X and Wei Yun 2008 Consumption of ecosystem services: models, measurement and management framework *Resour. Sci.* (in Chinese with English abstract) **30** 100–6

[5] Du B, Zhen L, De Groot R, Long X, Cao X, Wu R, Sun C and Wang C 2015 Changing food consumption patterns and impact on water resources in the fragile grassland of Northern China *Sustainability* **7** 5628–47

[6] Cao Y, Li X and Liu T 2010 Analysis of problems and causes in grassland eco-compensation-taking Xilinguole as a case *Chin. J. Grassland* **32** 10–16 (https://www.cabdirect.org/cabdirect/abstract/20113020936)

[7] Barthold F K, Wiesmeier M, Breuer L, Frede H G, Wu J and Blank F B 2013 Land use and climate control the spatial distribution of soil types in the grasslands of Inner Mongolia *J. Arid Environ.* **88** 194–205

[8] United Nation 2018 Synthesis The Sustainable Development Goals Report 2018 (Washington, DC: Island Press)

[9] Yang W, Zhen L and Wei Y 2020 Food consumption and its local dependence: A case study in the Xilin Gol Grassland, China *Environ. Dev.* **34** 100470

[10] Reynolds C J, Piantadosi J, Buckley J D, Weinstein P and Boland J 2015 Evaluation of the environmental impact of weekly food consumption in different socio-economic households in Australia using environmentally extended input–output analysis *Ecol. Econ.* **111** 58–64

[11] Gerbens-Leenes P and Nonhebel S 2002 Consumption patterns and their effects on land required for food *Ecol. Econ.* **42** 185–99

[12] Zhen L, Ochirbat B, Lv Y, Wei Y, Liu X, Chen J, Yao Z and Li F 2010 Comparing patterns of ecosystem service consumption and perceptions of range management between ethnic herders in Inner Mongolia and Mongolia *Environ. Res. Lett.* **5** 015001

[13] Xilin Gol League Statistics Bureau 2016 Xilingol League statistics yearbook (in Chinese) (Beijing: China Statistics Press)

[14] Yang W, Zhen L and Luo Q 2019 Land resource carrying capacity in Xilin Gol Grassland transects: A perspective on food nutritional demand *J. Resour. Ecol.* **10** 614–20

[15] Wu R, Zhen L, Du B, Hu Y, Yan H, Cao X and Long X 2012 Impact of ecological conservation program on lifestyle changes of households in Inner Mongolia *Resour. Sci.* **34** 1049–61 (in Chinese with English abstract) (https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFD2012&filename=ZRZY201206012&v=ES2dYZHMNLmSK%25mmd2FP9tCr7WJcwskpw6aUgDZj%25mmd2FAdpOJn%25mmd2BIRjQ71BhW3WvJJcb78l3t)

[16] Liu Y 2015 Research on change of meat consumption structure of Inner Mongolia rural residents *Ph.D. thesis* (Hohot: Inner Mongolia Agricultural University)

[17] Troubat N and Grünberger K 2017 Impact of survey design in the estimation of habitual food consumption: A study based on urban households of Mongolia *Food Policy* **72** 132–45

[18] Gao Liwei, Xu Z, Cheng S, Xu S, Zhang X, Yu C, Sun Q, Wu J and Qu Y 2017 Food consumption structure and dietary nutrition of residents in rural Tibet *Resour. Sci.* **39** 168–74 (in Chinese with English abstract) (https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFDLAST2017&filename=ZRZY201701017&v=243xTp5UIV7gM%25mmd2FoQOf7526XWacHUaLcjazl5E43q5iqY2NbCxgm4gxAKr4YGcYgL)

[19] Li Y, Wang L, Liu X and Cheng S 2018 Structure and characteristics of food consumption of rural households in Shandong Province: Based on Household Tracking Survey *J. Nat. Resour.* **33** 978–91 (in Chinese with English abstract)

[20] Zhai F, Wang H, Du S, He Y, Wang Z, Ge K and Popkin B M 2009 Prospective study on nutrition transition in China *Nutr. Rev.* **67** S56–S61

[21] Baquedano F G and Liefert W M 2014 Market integration and price transmission in consumer markets of developing countries *Food Policy* **44** 103–14

[22] Csutora M and Vetőné Mózner Z 2014 Consumer income and its relation to sustainable food consumption–obstacle or opportunity? *Int. J. Sustain. Dev. World Ecol.* **21** 512–18

[23] Chaves W A, Wilkie D S, Monroe M C and Sieving K E 2017 Market access and wild meat consumption in the central Amazon, Brazil *Biol. Conserv.* **212** 240–8

[24] Zhen L, Yan H, Hu Y, Wu R, Cao X, Du B, Long X, Li F and Liu X 2012 Consumption of ecosystem goods and services and its impact assessment *Resour. Sci.* **34** 989r–997 (in Chinese with English abstract)

[25] Ji H 2013 An empirical study on food consumption of rural-to-urban migrant workers and its impact factors: based on an investigation in Beijing *Ph.D. thesis* Chinese Academy of Agricultural Sciences An Empirical Study on Food Consumption of Rural-to-Urban Migrant Workers and Its Impact Factors: Based on an Investigation in Beijing (Beijing: Chinese Academy of Agricultural Sciences)

[26] Hu J 2016 Impact of ethnic culture on ecosystem serviceâ case study on Hui & Mongolian ethnic culture in northern farming-pastoral zone of China *Ph.D. thesis* University of Chinese Academy of Sciences

[27] Deng H, Nie F and Li H 2018 The changes and the future demand of the elderly food consumption in urban and rural China 1–7 (in Chinese with English abstract)

[28] Pokachev N 2018 Constructing family identity through consumption rituals of Chinese new year reunion dinner *Ph.D. thesis* (Shanghai: East China Normal University)

[29] de Ruiter H, Kastner T and Nonhebel S 2014 European dietary patterns and their associated land use: Variation between and within countries *Food Policy* **44** 158–66

[30] Zhen L, Cao S, Cheng S, Xie G, Wei Y, Liu X and Li F 2010 Arable land requirements based on food consumption patterns: Case study in rural Guyuan District, Western China *Ecol. Econ.* **69** 1443–53

[31] Wang L, Xue L, Li Y, Liu X, Cheng S and Liu G 2018 Horeca food waste and its ecological footprint in Lhasa, Tibet, China *Resour. Conserv. Recycl.* **136** 1–8

[32] Dermience M, Mathieu F and Li X *et al* 2017 Minerals and trace elements intakes and food consumption patterns of young children living in rural areas of tibet autonomous region, PR China: a cross-sectional survey *Healthcare* vol 5 (Basel: Multidisciplinary Digital Publishing Institute) p 12

[33] Rasmussen L V, Mertz O, Christensen A E, Danielsen F, Dawson N and Xaydongvanh P 2016 A combination of methods needed to assess the actual use of provisioning ecosystem services *Ecosyst Serv.* **17** 75–86

[34] Xue Z and Zhen L 2018 Impact of rural land transfer on land use functions in western China's Guyuan based on a multi-level stakeholder assessment framework *Sustainability* **10** 1376

[35] Yunyun Li, Lingen W and Shengkui C 2019 Tourist's food consumption characteristics and influencing factors in tourism cities on the plateau: an empirical study of Lhasa *Resour. Sci.* **41** 494–508 (in Chinese with English abstract)

[36] Van Boxstael S and *et al et al* 2013 Food safety issues in fresh produce: Bacterial pathogens, viruses and pesticide residues indicated as major concerns by stakeholders in the fresh produce chain *Food Control* **32** 190–7

[37] Bekker J L, Hoffman L C and Jooste P J 2011 Knowledge of stakeholders in the game meat industry and its effect on compliance with food safety standards *Int. J. Environ. Health Res.* **21** 341–63

[38] Van Kleef E, Frewer L J, Chryssochoidis G M, Houghton J R, Korzen-Bohr S, Krystallis T, Lassen J, Pfenning U and Rowe G 2006 Perceptions of food risk management among key stakeholders: results from a cross-European study *Appetite* **47** 46–63

[39] Özesmi U and Özesmi S L 2004 Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach *Ecol. Model.* **176** 43–64

[40] Ozesmi U 2006 *q-bio/0603022* Ecosystems in the mind: Fuzzy cognitive maps of the Kizilirmak Delta Wetlands in Turkey

[41] Reckien D 2014 Weather extremes and street life in India—Implications of Fuzzy Cognitive Mapping as a new tool for semi-quantitative impact assessment and ranking of adaptation measures *Glob. Environ. Change* **26** 1–13

[42] Kok K 2009 The potential of Fuzzy Cognitive Maps for semi-quantitative scenario development, with an example from Brazil *Glob. Environ. Change* **19** 122–33

[43] Glykas M 2010 *Fuzzy Cognitive Maps: Advances in Theory, Methodologies, Tools and Applications* vol 247 (Berlin: Springer)

[44] Reckien D, Wildenberg M and Bachhofer M 2013 Subjective realities of climate change: how mental maps of impacts deliver socially sensible adaptation options *Sustain. Sci.* **8** 159–172

[45] Chan K M, Satterfield T and Goldstein J 2012 Rethinking ecosystem services to better address and navigate cultural values *Ecol. Econ.* **74** 8–18

[46] Reyers B, Biggs R, Cumming G S, Elmqvist T, Hejnowicz A P and Polasky S 2013 Getting the measure of ecosystem services: a social–ecological approach *Front. Ecol. Environ.* **11** 268–73

[47] Teixeira H M, Vermue A J, Cardoso I M, Claros M P and Bianchi F J 2018 Farmers show complex and contrasting perceptions on ecosystem services and their management *Ecosyst. Serv.* **33** 44–58

[48] Xilingol League Statistics Bureau 2018 in Chinese (Beijing: Statistics Press)

[49] Hu J, Zhen L, Sun C Z, Du B Z and Wang C 2015 Ecological footprint of biological resource consumption in a typical area of the Green for Grain Project in northwestern China *Environments* **2** 44–60

[50] Liu M, Dries L, Heijman W, Huang J, Zhu X, Hu Y and Chen H 2018 *Land Degrad. Dev.* **29** 326–36

[51] Zhen L, Du B, Wei Y, Xiao Y and Sheng W 2018 Assessing the effects of ecological restoration approaches in the alpine rangelands of the Qinghai-Tibetan Plateau *Environ. Res. Lett.* **13** 095005

[52] Hu Y, Huang J and Hou L 2019 Impacts of the grassland ecological compensation policy on household livestock production in China: an empirical study in Inner Mongolia *Ecol. Econ.* **161** 248–56

[53] Gao L and *et al* 2017 Food security situation and major grain supply and demand in Tibetan region *J. Nat. Resour.* **32** 951–60 (in Chinese with English abstract)

[54] Halldórsdóttir O and Nicholas K A 2016 Local food in Iceland: identifying behavioral barriers to increased production and consumption *Environ. Res. Lett.* **11** 115004

[55] Grebitus C, Printzis I and Printezis A 2017 Relationship between consumer behavior and success of urban agriculture *Ecol. Econ.* **136** 189–200