# Tourist food consumption and its arable land requirements in tourist destinations

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**Abstract:** Determining the resource intensity and environmental impacts of tourist food consumption is important for the design of sustainable development strategies for tourist destinations. Yet, studies aiming to accurately quantify the environmental repercussions of tourist food consumption for specific destinations are rare and take limited account of temporal changes in food consumption patterns among tourists. This study contributes to knowledge by calculating the impact of temporal changes in tourist food consumption on arable land requirements (ALR) in Lhasa, Tibet. It finds an 8% per capital per meal increase in tourist food consumption within the 2013-2015 period which translates into over 50% increase in ALR. The study further pinpoints that 84% of the increased ALR is attributed to dietary changes in tourist food consumption, i.e. grown consumption of meat. Lastly, the study shows that, in 2015, nearly 62% of the arable land area of the Lhasa region was required to meet growing tourist demand for food.

**Keywords:** tourism; food consumption; natural resource intenasity; carrying capacity; arable land requirements; Tibet, China

## 1 Introduction

The rapid development of tourism poses severe challenges to regional sustainable development by intensifying competition for natural resources and driving environmental pollution (Gössling, 2002). The need to supply various types of consumables for tourists without accelerating environmental degradation therefore represents an important task of the sustainable development of any tourist destination. Food is a key component of tourist consumption (Frisvoll et al., 2016) which makes a manifold contribution to tourism’s (un)sustainability (Sims, 2009). An effective food supply is vital for regional sustainable development, especially in those destinations that cater for sustained tourist demand (Chen and Han, 2017). Although people consume food regardless of whether or not they are tourists, the structural characteristics of tourist food consumption are significantly different from those of non-tourist consumption (Large and Medium City Food Development Research Group, 1990; Li et al., 2019a). The differences in food consumption patterns between tourists and local residents complicate food supply in tourist destinations and make it difficult to model. The need to understand the food consumption behavior of tourists has long been recognised, especially from the viewpoint of making accurate quantitative assessments of its scope and scale (Mak et al., 2012b) .

Acknowledging that tourists' spending on food can comprise up to a third of their total holiday expenditures (Bélisle, 1983; Telfer and Wall, 2000; Torres, 2003), and recognizing that even entire destination choices can be driven by tourist interests in and/or preferences for food (Cohen and Avieli, 2004; Hall and Sharples, 2003), understanding tourist food choice is becoming an important driver of (foodservice) business innovation and food supply management in many destinations (Mak et al., 2012a; Raj and Griffin, 2017). For example, the passion of many tourists for local flavours has driven demand and supply of local food while, in contrast, the desire of many tourist to stick to familiar food choices has intensified demand and supply of 'western' foodstuffs (Mak et al., 2012a). Most important is that, as tourism grows, the local area must increase its food production and, in some cases, it may even import foodstuffs from other regions in order to meet the growing demand for food from tourism. For example, almost three quarters of foodstuffs consumed by tourists in Majorca (Spain) are sourced outside the island which results in excessive carbon footprint of this destination's food procurement and logistics (Filimonau et al., 2011).

Increased demand for food from tourism contributes to the development of the sector of foodservice provision at a destination (Coles and Hall, 2008; Mak et al., 2012a) but comes at a cost of significant environmental externalities. For example, the need for more food inevitably leads to excessive wastage, both at the point of food production and food distribution (Wang et al., 2017). What is more, the environmental impact of food consumption by tourists is not only limited to the food itself (so-called 'direct' impacts), but also includes numerous embedded (or 'indirect') impacts within the food supply chain, such as arable land, water, and energy (Gustavsson et al., 2011; Scialabba et al., 2013). For example, tourism growth may significantly increase arable land requirements for the food supply of tourist destinations (Gössling, 2002) while there is good correlation between an increase in tourist arrivals to a destination and food resource intensity, including food waste generation (Arbulu et al., 2017). Indeed, it is estimated that, annually, approximately 75 billion meals are consumed by tourists and these meals are usually cooked of high quality foodstuffs which require abundant land resources to produce (Rutty et al., 2015).

Despite the importance of better understanding the correlation  between food consumption and arable land requirements (ALR) for the design of the sustainable development startegies in popular tourist destinations, the related research agenda remains limited. (Gerbens-Leenes et al., 2002) explored the impact of food consumption on ALR but focused on local residents, rather than tourists. Food consumption highly depends on food production while food production requires agricultural land (Gerbens-Leenes et al., 2002). It has been reported that feeding an adult in a developed country requires on average 0.03 ha of arable land (Cai et al., 2002). In addition, studies on food consumption both in New York State and the UK show that the land requirements for consumption of animal products are higher (De et al., 2015; Peters et al., 2007). A seminal study on the impact of food consumption on ALR in China was conducted by (Zhen et al., 2010). This study found that the land required to produce food depends on population size, consumption patterns, land resource endowment and the level of farm intensification. A number of studies  have applied quantitative assessment to determine the impact of changes in food consumption on ALR (Gao et al., 2017; Jiang et al., 2015; Kastner et al., 2012; Tian et al., 2017). In particular, Gao et al.(2017) systematic analysed the potential of vacating arable land for grass of farmers in Tibet, China based on the developed method of studying the relationship between food consumption and cultivated land demand by Gerbens-Leenes et al. (2002). The results of Jiang et al. (2015) indicate that the urban economic development significantly affect the ALR for food production. Both Kastner et al. (2012) and Tain et al. (2017) use the decomposition approach to determine the main driving factors of ALR for food consumption. While these studies are important to better understand temporal changes in food consumption on ALR, they were based on the data extracted from (inter)national data bases, rather than on the empirical data obtained via field consumer surveys. Further, existing studies explored the temporal changes in ALR caused by the food consumption of residents, rather than tourists, thus lacking an important element of analysis given that tourists represent a sizeable and increasingly large consumer segment in many destinations.

Rational use of arable land resources to meet the growing food demand is one of the national priorities in China (Chen, 2007). It becomes particular important in light of growing middle class the representatives of which travel more often. The inflow of tourists drives regional shifts in food consumption in China and leads to the distribution of ALR, especially in the regions hosting a large number of tourist arrivals. Therefore, it is important to study the impact of tourist food consumption on ALR in tourist destinations, especially for tourist destinations in the regions with relatively scarce availability of arable land resources, such as the Qinghai-Tibet Plateau.

Therefore, the objectives of this study are to: (i) quantify the tourist food consumption and its change over time in a major tourist destination of the Qinghai-Tibet Plateau i.e. the city of Lhasa; (ii) assess the ALR for tourist food consumption and its temporal change in accord with changes in tourist food consumption (if any); and (iii) identify the determinants of temporal changes in ALR due to tourist food consumption. The remainder of this paper is structured as follows. Section 2 provides details of the materials and methodology used to achieve the research objectives. Section 3 reports on the findings. Section 4 discusses conclusions and recommendations for optimizing use of arable land resources and promoting (more) sustainable development of tourist destinations with relative scarcity of arable land. Importantly, while being a case study of Lhasa, this project aims to provide (more) generalisable insights into how forecast changes in tourist food consumption can affect future ALR in other tourist destinations.

## 2 Materials and Methods

### *2.1 Study area*

Lhasa is the capital of Tibet located on the Qinghai-Tibet Plateau. Tibet had an arable land area of 35878 ha and the population of about 905000 inhabitants in 2015 (Lhasa Municipal People's Government, 2015; Tibet Autonomous Region Statistics Bureau and Tibet Survey Corps of the National Bureau of Statistics, 2016).

In 2015, the number of tourists visited Lhasa was 11.79 million, representing an increase of 27.4% from 2014, and tourism revenues accounted for 41.1% of Lhasa's GDP (Lhasa City Statistics Bureau, 2016). While tourism has clearly become a leading industry driving Lhasa's economic growth, it imposes irreversible impacts on Lhasa's natural environment which is fragile and remote. Lhasa is located in the hinterland of the Qinghai-Tibet Plateau and has an average elevation of over 3650 meters. Much of the natural resources consumed in Lhasa are imported from other regions in China. Lhasa thus represents a good case study of a large city which has to balance out the strive for tourism development with the need to conserve the environment and rationalise the consumtion of natural resources.

### *2.2. System definition*

In this study, we obtained the primary data on tourist food consumption via a field survey weighing the food ordered by tourists in Lhasa restaurants. ALR were subsequently calculated based on the indicators that are available in previously published research. We defined that:

(1) The tourist food consumption survey was deployed in the Chengguan District of Lhasa because it represents an urban area with the high concentration of restaurants;
(2) To measure the temporal changes in tourist food consumption, the survey was first conducted in 2013 and then repeated in 2015;
(3) Tourist food consumption captured by the survey included both the foodstuffs eaten and uneaten/wasted (edible portion) as the net food purchased/consumed by tourists;
(4) Food was divided into ten major categories: pork, beef, lamb, poultry, aquatic products (fish and crustaceans), eggs, pasta, vegetables, rice, and fruits. For simplicity of analysis, the former six categories of food are defined as 'animal-based foods' and the latter four categories are defined as 'plant-based foods'). Beans, potatoes, wheat flour, and corn products were classified under 'pasta' while nuts, dairy, and condiments were not considered in this study because of the relatively small ratios of consumption of these items in the regional food diet;
(5) Three factors, namely the (growing) population of tourists, technological progress, and dietary patterns were considered the main impact factors of tourist food consumption on ALR.

### *2.3 Field survey administration*

The field survey was conducted in July and August of 2013 and then 2015, i.e. during the 'high' tourism season. The procedure of random sampling, the sample classification criteria, and the process of direct-weighing operations were followed as prescribed in (Wang et al., 2017; Wang et al., 2018). A total of 46 restaurants with 290 tables in total were investigated in 2013 and a total of 23 restaurants with 73 tables in total were investigated in 2015 to establish patterns of tourist food consumption and the temporal changes within. Of the 46 restaurants investigated in 2013, 10 were large-sized restaurants, 14 were medium-sized restaurants, and 22 were small-sized restaurants; of the 23 restaurants investigated in 2015, 5 were large-sized restaurants, 9 were medium-sized restaurants, and 9 were small-sized restaurants. Detailed information on the studied restaurants (e.g. location and types) is shown in Figure 1. In total, 290 tables, 909 tourists, and 1,297 dishes were investigated in 2013; while 73 tables, 232 tourists, and 338 dishes were investigated in 2015 (Figure 2). Notably, there was no same surveyed restaurants in 2013 and 2015 due to our random stratified sampling and the great change of restaurant managers/operators (Wang et al., 2018). Besides, due to the limitations of objective sampling and pragmatic challenges such as economic and labor cost, as well as their difference in different years, the samples also are different in terms of qualitity.

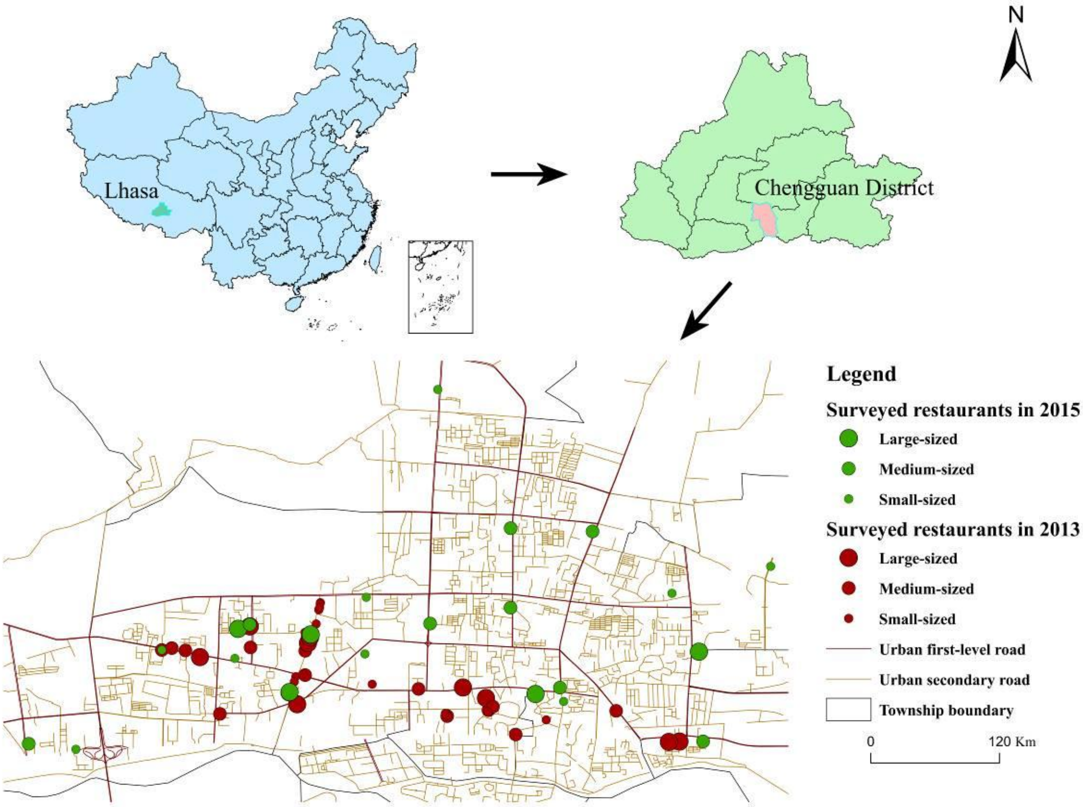


Figure 1. The distribution of surveyed restaurants in Lhasa in 2013 and 2015.

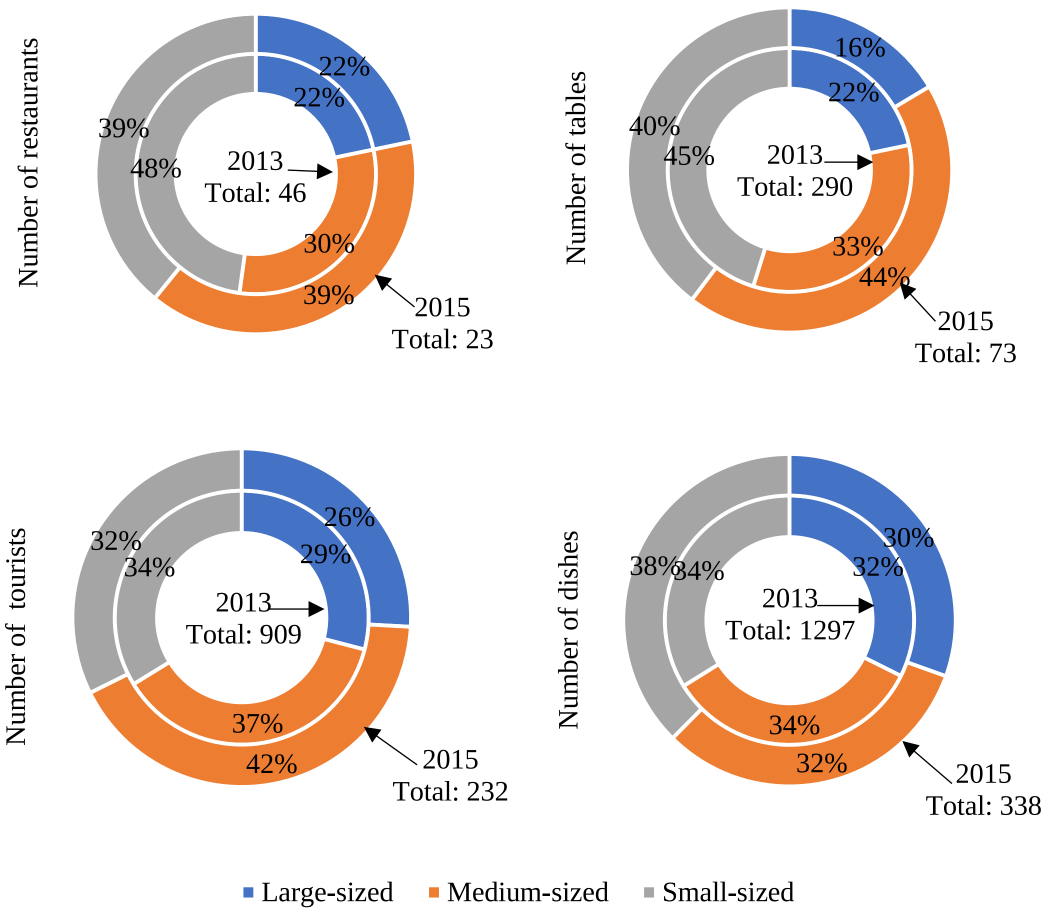


Figure 2. The total number and share of surveyed restaurants, tables, tourists, and dishes in Lhasa.

### *2.4 Measurement of food consumption and arable land requirements*

#### *2.4.1 Quantitative accounting of food consumption*

First, per capita food consumption was calculated using the following steps:

For each sample table, the weight of each dish was divided into the weight of each food ingredient included in the dish (e.g. the weight of tomato scrambled eggs would be divided into the weight of the tomato and the weight of the eggs) using the direct-weighing data, dish ingredients, and ingredient proportion data (determined via chef interviews and data from publicly available data sources (Li et al., 2019b), such as Food World (https://www.meishichina.com/), Heart Recipe (https://www.xinshipu.com/), Gourmet (https://www.meishij.net/), ect). Then the weight of each same ingredient was added up to determine the total weight of each food type.

(1) The weight of a cooked food ingredient was converted into the weight of the corresponding raw material using coefficient data from the published literature and survey-estimated data (Table 1).

(2) All food ingredients were classified into the ten categories as defined above, and the total weight of each category was obtained by summation.

(3) Food consumption per capita per meal was then calculated based on the total number of tourists surveyed.

Table 1. Conversion factors from cooked food to raw food (Li et al., 2019b).

| Food group | Food type | | Coefficient of cooked food to raw food | Source |
|---|---|---|---|---|
| Grain | Rice | Steamed rice | 0.45 | (Chappell, 1954) |
| | | Porridge | 0.09 | Survey-based estimate |
| | | Rice flour/Rice noodle | 0.43 | Survey-based estimate |
| | | Pastry | 0.70 | Survey-based estimate |
| | Wheat | Noodles | 0.53 | Survey-based estimate |
| | | Round flat cake | 0.83 | Survey-based estimate |
| | | Steamed bread | 0.67 | Survey-based estimate |
| | | Flour | 0.70 | Survey-based estimate |
| | Maize | Steamed corn bread | 0.50 | Survey-based estimate |
| | | Cooked corn | 0.88 | (Chappell, 1954) |
| | Millet | Millet porridge | 0.09 | Survey-based estimate |
| | Potato | Sweet potato | 3.00 | Survey-based estimate |
| | | Potato | 3.51 | Survey-based estimate |
| Meat | | Pork | 1.43 | (USDA, 1992) |
| | | Beef | 1.43 | (USDA, 1992) |
| | | Lamb | 1.43 | (USDA, 1992) |
| | | Poultry | 1.54 | (USDA, 1992) |
| | | Other | 1.54 | (USDA, 1992) |
| Eggs | | Eggs | 1.00 | (Chappell, 1954) |
| Aquatic products | | Fish and products | 1.18 | Survey-based estimate |
| | | Shrimp and products | 1.18 | Survey-based estimate |
| | | Crab and products | 1.18 | Survey-based estimate |
| | | Shellfish and products | 1.18 | Survey-based estimate |
| Vegetables | | Root vegetables | 1.08 | Survey-based estimate |
| | | Cabbage | 1.08 | Survey-based estimate |
| | | Mustard | 1.08 | Survey-based estimate |

| | | | |
|---|---|---|---|
| | Solanberry | 1.08 | Survey-based estimate |
| | Beans | 1.08 | Survey-based estimate |
| | Melon | 1.08 | Survey-based estimate |
| | Onion and garlic | 1.08 | Survey-based estimate |
| | Leafy vegetables | 1.08 | Survey-based estimate |
| | Tuber and tuberous rooted vegetables | 1.08 | Survey-based estimate |
| | Aquatic vegetables | 1.08 | Survey-based estimate |
| | Perennial vegetables | 1.08 | Survey-based estimate |
| | Edible fungi | 1.08 | Survey-based estimate |
| | Bean products | 0.20 | Survey-based estimate |
| | Soybeans and bean sprouts | 0.11 | Survey-based estimate |
| Fruits | Boiled peanut | 0.91 | Survey-based estimate |
| | Fried peanut | 1.11 | Survey-based estimate |
| | Fruits | 1.00 | Survey-based estimate |

Second, the total tourist food consumption throughout the year was calculated based on the per capita per meal food consumption data combined with the annual tourist population and average number of days spent visiting Lhasa.

The per capita food consumption was first calculated by:

$$AFC_i^t = \frac{FC_i^t}{\sum_{x=1}^{n^t} N_x^t} \quad (1)$$

where $AFC_i^t$ denotes the average per capita per meal tourist food consumption of food category $i$ (where $i$ = 1, 2, 3, …,10, representing pork, beef, lamb, poultry, aquatic products, eggs, pasta, vegetables, rice, and fruits, respectively) in year $t$ (where $t$ = 2013 or 2015); $N_x^t$ denotes the number of tourists at surveyed table $x$ in year $t$, where $N^{2013}$ and $N^{2015}$ are equal to 290 and 73, respectively; and $FC_i^t$ is the total consumption of food category $i$, which is equal to the total consumption of all food types within this category.

The total food consumption of food type $z$ was obtained based on the following equations:

$$FC_z^t = \sum_{y=1}^{m^t} FC_{yz}^t \quad (2)$$

$$FC_{yz}^{t} = CW_{y}^{t} \times \alpha_{yz} \times \beta_{z} \quad (3)$$

$$CW_{y}^{t} = IW_{y}^{t} - PW_{y}^{t} \quad (4)$$

where $FC_{z}^{t}$ is the total consumption of food type *z* (where *z* = 1, 2, 3…40 as defined in Table 1) in the year *t*; $FC_{yz}^{t}$ is the consumption of food type *z* in dish *y* (maximum 1297 in 2013 and 338 in 2015) in the year *t*: $CW_{y}^{t}$ is the weight of dish *y* in the year *t*; $\alpha_{yz}$ is the proportion of food type *z* in dish *y*; $\beta_{z}$ is conversion factor from cooked food type *z* to raw food type *z*; $IW_{y}^{t}$ and $PW_{y}^{t}$ are the initial weight of the cooked food of dish *y* including the plate (prior to tourist consumption) and the weight of the plate carrying dish *y* in the year *t*, respectively.

Based on the per capita food consumption determined above, the equation for calculating the annual total amount of tourist food consumption is:

$$FC_{total}^{t} = \sum_{i=1}^{10} AFC_{i}^{t} \times N_{T}^{t} \times 2 \times D^{t} \quad (5)$$

where $FC_{total}^{t}$ represents the total tourist food consumption in Lhasa in the year *t*; $N_{T}^{t}$ is the total population of tourists in the year *t*, where 2 accounts for two meals a day (lunch and dinner); and $D^{t}$ indicates the average number of overnight tourist stays in the year *t*. It should be noted that the number of overnight stays of tourists in 2013 ( $D^{2013}$) was adopted from the number of overnight stays of international tourists provided in the Yearbook of China Tourism Statistics (National Tourism Administration of the People's Republic, 2014) while the data in 2015 ($D^{2015}$) was obtained from the telephone interview with the Lhasa Tourism Bureau because published data were not available.

*2.4.2 Quantitative accounting of arable land requirements*

We defined the ALR of tourist food consumption as the sum of the area of arable land required to produce each category of food consumed by tourists. Combined with data from (Gerbens-Leenes et al., 2002; Liu and Wang, 2018), the ALR of tourist food consumption in Lhasa were then calculated as described in Figure 3.

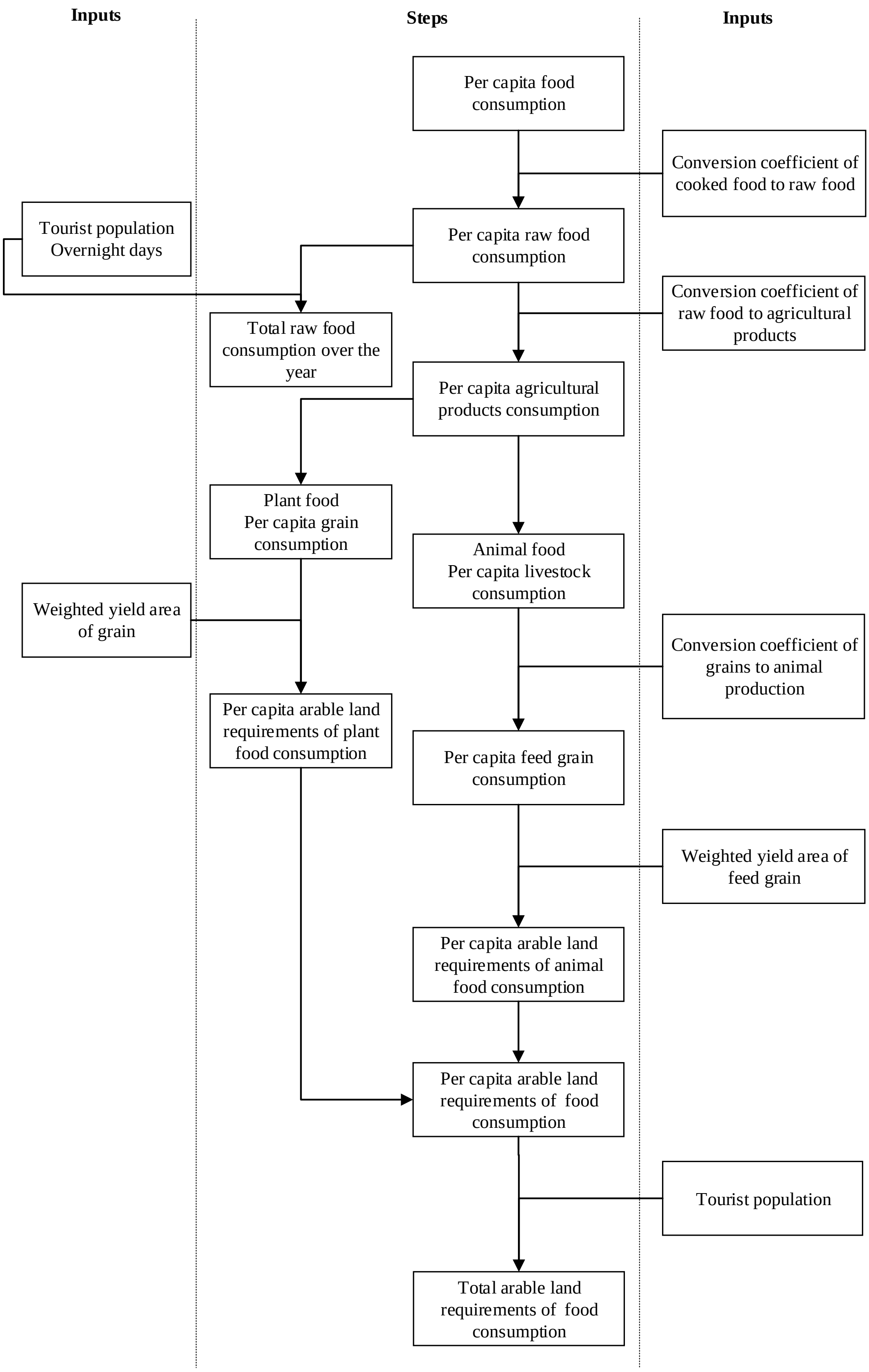


Figure 3. Flow chart of calculation of arable land requirements (ALR) (Gerbens-Leenes et al., 2002; Liu and Wang, 2018).

The ALR of tourist food consumption were divided into the plant-based food ALR (vegetables, rice, pasta, and fruits), $P_{land}$ , and the animal-based food ALR (pork, beef, lamb, poultry, aquatic products, and eggs), $A_{land}$ . In order to calculate the ALR, cooked food consumption must first be converted into raw food consumption (using the factors inTable 1) and raw food consumption must then be converted into agricultural product consumption using the conversion coefficients shown in Table 2. It should be noted that animal-based foods must be converted to corresponding fodder consumption. The conversion coefficients used for this are shown in Table 3. We adopted a proportion of feed grain in fodder accounts of about 74% in which the main component of the feed grain was corn (82%), followed by wheat (10.3%), then rice (7.7%) (Zhao et al., 2014). Additionally, due to the limitations of the data, it was assumed that the source of animal-based food production was consistent with the source of the feed grain. Particularly, for the feed grain consumed by local beef and mutton in Tibet, we distributed the ALR to wheat and barley in a ratio of 2:1 and the ALR of local pork feed grain was calculated using the national average ALR in 100% of corn (Gao et al., 2017). The detailed calculation process of $P_{land}$ and $A_{land}$ is as follows:

$$P_{land}^{t} = \sum_{i=1}^{4} \frac{AFC_i^t \times C_{1i}}{Y_i^t} \tag{6}$$

$$A_{land}^{t} = \sum_{i=5}^{10} \frac{AFC_i^t \times C_{1i} \times C_{2i}}{Y_i^t} \tag{7}$$

where the sum of $P_{land}$ and $A_{land}$ is the tourist food consumption per capita per meal demand for arable land, $R_{land}$ , as in:

$$R_{land}^{t} = P_{land}^{t} + A_{land}^{t} \tag{8}$$

The annual ALR of tourist food consumption were then calculated by:

$$SR_{land}^{t} = R_{land}^{t} \times N_T^t \times 2 \times D^t \tag{9}$$

where $C_{1i}$ refers to the conversion of raw category *i* food to its corresponding agricultural product; $Y_i$ refers to the weighted grain production per unit area of category *i* food, shown in Figure 4; $C_{2i}$ refers to the amount of feed grain consumed by the unit livestock production of category *i* animal-based food; and $SR_{land}$ is the annual total ALR of tourist food consumption.

Table 2. Conversion coefficients from raw food to agricultural products.

| Raw food | Agricultural products | $C_1$ (t/t) (Wang et al., 2018) |
|---|---|---|
| Pork | Slaughter pigs | 1.63 |
| Beef | Slaughter cattle | 2.11 |

| | | |
|---|---|---|
| Lamb | Slaughter sheep | 2.25 |
| Poultry | Slaughter poultry | 1.49 |
| Aquatic products | Aquatic products | 1.18 |
| Eggs | Eggs | 1.18 |
| Vegetables | Vegetables | 1.5 |
| Fruits | Fruits | 1.2 |
| Rice | Paddy | 1.48 |
| Wheat | Wheat | 1.49 |

Table 3. Conversion coefficient from fodders to animal production.

| Animal production | Pork | Beef | Lamb | Poultry | Aquatic products | Eggs |
|---|---|---|---|---|---|---|
| $C_2$(t/t) (Li et al., 2012) | 3.3 | 2.6 | 2.1 | 2.5 | 1.9 | 2.1 |

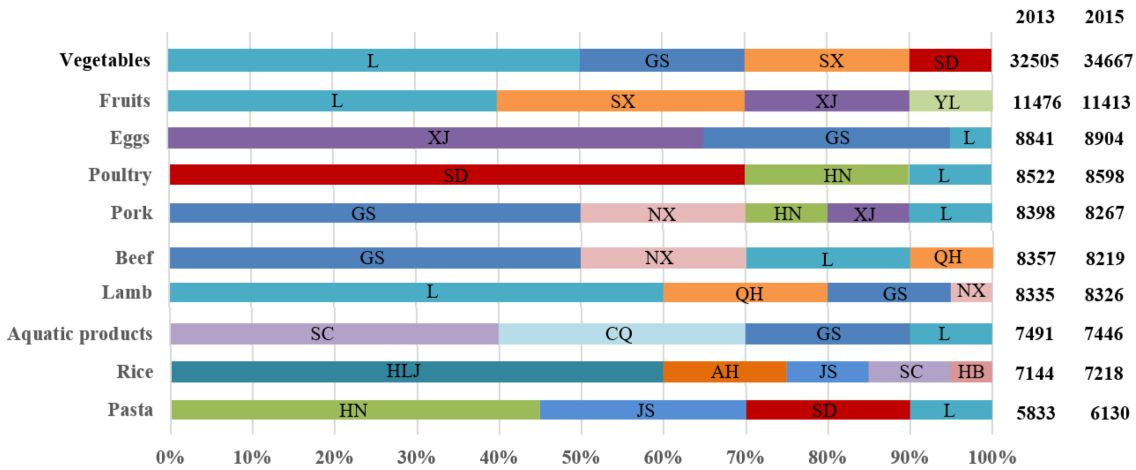


Figure 4. Main sources of food supply and weighted average grain yield (kg/ha) of agri-food products in the study area. Note: **L** is the Tibet Autonomous Region; **GS** is Gansu province; **SX** is Shanxi province; **SD** is Shandong province; **XJ** is Xinjiang province; **YN** is Yunnan province; **HLJ** is Heilongjiang province; **AH** is Anhui province; **JS** is Jiangsu province; **SC** is Sichuan province; **HB** is Hubei province; **HN** is Henan province; **CQ** is Chongqing province; **NX** is Ningxia province; and **QH** is Qinghai province. More information on the source of this data was detailed in (Wang et al., 2018).

The change in ALR over a certain period of time can then be determined as the difference between the ALR at the beginning and the end of the studied period by:

$$SR_{land}^{t-t_0} = SR_{land}^{t} + SR_{land}^{t_0} \quad (10)$$

*2.4.3 Kaya identity and decomposition of arable land requirements*

In order to establish the main drivers of changes in ALR due to tourist food consumption, the Kaya identity, proposed by Japanese energy economist Yoichi Kaya

(Kaya, 1990) was applied. The Kaya identify enabled this study to analyze each of the ALR according to its primary function, as follows:

$$SR_{land} = \sum_i SR_{land_i} = \sum_i \left( N_T \times \frac{SR_{land_i}}{K_i} \times \frac{K_i}{N_T} \right) \quad (11)$$

where $N_T$ is the total tourist population in Lhasa; $K_i$ is the caloric energy of food in category $i$; and $SR_{land_i}$ is the ALR for food category $i$.

Supposing that $T_i = \frac{SR_{land_i}}{K_i}$ and $C_i = \frac{K_i}{N_T}$, Equation (11) becomes:

$$SR_{land} = \sum_i N_T \times T_i \times C_i \quad (12)$$

indicating that the ALR of tourist food consumption in Lhasa are determined by three driving factors: $N_T$, indicating the tourist population factor, defined as the total tourist population over the entire year in the study area; $T_i$, indicating the technological progress factor, defined as the ALR per unit of caloric energy; and $C_i$, the dietary pattern factor, defined as the per capita food consumption.

The change in the ALR of tourist food consumption in Lhasa was then analyzed using an additive logarithmic mean Divisia index (LMDI). The change in the ALR from year $t_0$ to year $t$ is given by:

$$\Delta SR_{land} = SR^{t}_{land} - SR^{t_0}_{land} \quad (13)$$

where $\Delta SR_{land}$ is the total change in ALR between year $t_0$ and year $t$; $SR^{t}_{land}$ is the total ALR in year $t$; and $SR^{t_0}_{land}$ is the total ALR in year $t_0$. The effects contributing to $\Delta SR_{land}$ include the tourist population scale effect ($N_T$), the technological progress effect ($T_i$), and the dietary pattern effect ($C_i$). Therefore, Equation (13) can be expressed as:

$$\Delta SR_{land} = SR^{t}_{land} - SR^{t_0}_{land} = \Delta N_T + \Delta T_i + \Delta C_i \quad (14)$$

Each variable on the right side of Equation (14) is calculated as follows:
The tourist population scale effect:

$$\Delta N_T = \Delta SR_{landN_T} = \sum_i \left( \frac{SR^{t}_{land_i} - SR^{t_0}_{land_i}}{\ln SR^{t}_{land_i} - \ln SR^{t_0}_{land_i}} \times \ln \frac{N^{t}_T}{N^{t_0}_T} \right) \quad (15)$$

The technological progress effect:

$$\Delta T_i = \Delta SR_{landT_i} = \sum_i \left( \frac{SR^{t}_{land_i} - SR^{t_0}_{land_i}}{\ln SR^{t}_{land_i} - \ln SR^{t_0}_{land_i}} \times \ln \frac{T^{t}_i}{T^{t_0}_i} \right) \quad (16)$$

The dietary pattern effect：

$$\Delta C_i = \Delta SR_{landC_i} = \sum_i \left( \frac{SR^{t}_{land_i} - SR^{t_0}_{land_i}}{\ln SR^{t}_{land_i} - \ln SR^{t_0}_{land_i}} \times \ln \frac{C^{t}_i}{C^{t_0}_i} \right) \quad (17)$$

Using Equations (15)–(17), Equation (14) becomes:

$$\Delta SR_{land} = \Delta SR_{landN_T} + \Delta SR_{landT_i} + \Delta SR_{landC_i} \quad (18)$$

# 3 Results

## *3.1 Tourist food consumption in Lhasa*

### *3.1.1 Per capita food consumption*

Tourist food consumption per capita per meal in 2015 (945 g) increased by 8% compared with that in 2013 (893 g) (Figure 5). Significant differences were revealed between tourist consumption according to each food item. In 2013, the most consumed foodstuff was vegetables (284 g, 32% of the meal), followed by pork, pasta, and poultry (190 g, 21%; 107 g, 12%, and 103 g, 12%, respectively). But in 2015, aquatic products (143 g, 17%) surpassed poultry to become the fourth largest meal ingredient. For animal-based foods, it is worth noting that the consumption of aquatic products and lamb both increased significantly and the consumption of eggs and other meats including beef, poultry, and pork decreased. For plant-based foods, vegetables and pasta were consumed more and rice was consumed less in 2015 compared with 2013. The consumption of fruits remained almost unchanged.

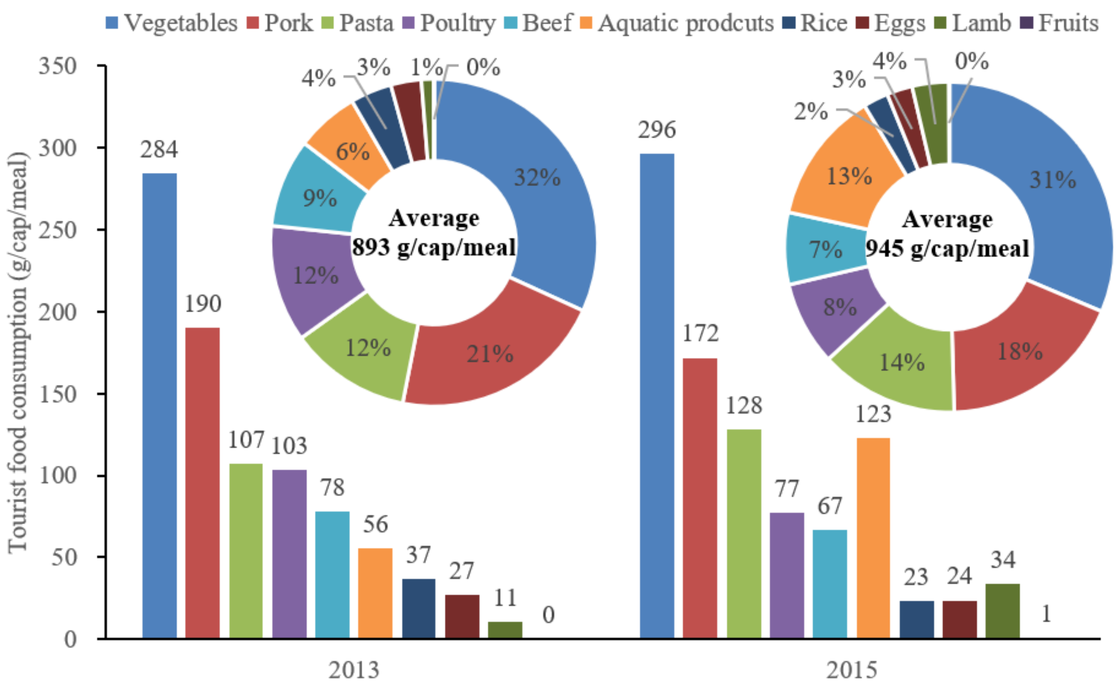


Figure 5. Tourist food consumption per capita per meal in 2013 and 2015 in Lhasa.

*3.1.2 Total food consumption*

The total tourist food consumption in Lhasa increased by 58% from 43929 tons in 2013 to 69491 tons in 2015 (Figure 6a). In absolute value, all food consumption increased except rice. Vegetable consumption increased the most (7820 tons, 56%), followed by aquatic products (6287 tons, 230%), pasta (4159 tons, 79%), pork (3298 tons, 35%), lamb (1958 tons, 365%), and beef (1060 tons, 28%). The increase in poultry, eggs, and fruits consumption was all less than 700 tons. Rice consumption decreased by 93 tons (5%) (Figure 6b). In total, the consumption of animal-based foods increased by 17385 tons (65%) and the consumption of plant-based foods increased by 11920 tons (57%).

Composition wise, the contribution of aquatic products, lamb, and pasta increased by 7 percentage points, 3 percentage points, and 2 percentage points, respectively; while the contribution of pork, poultry, beef, rice, and vegetables decreased by 3 percentage points, 4 percentage points, 2 percentage points, 2 percentage points, and 1 percentage point, respectively. The contribution of fruits and eggs showed no significant change.

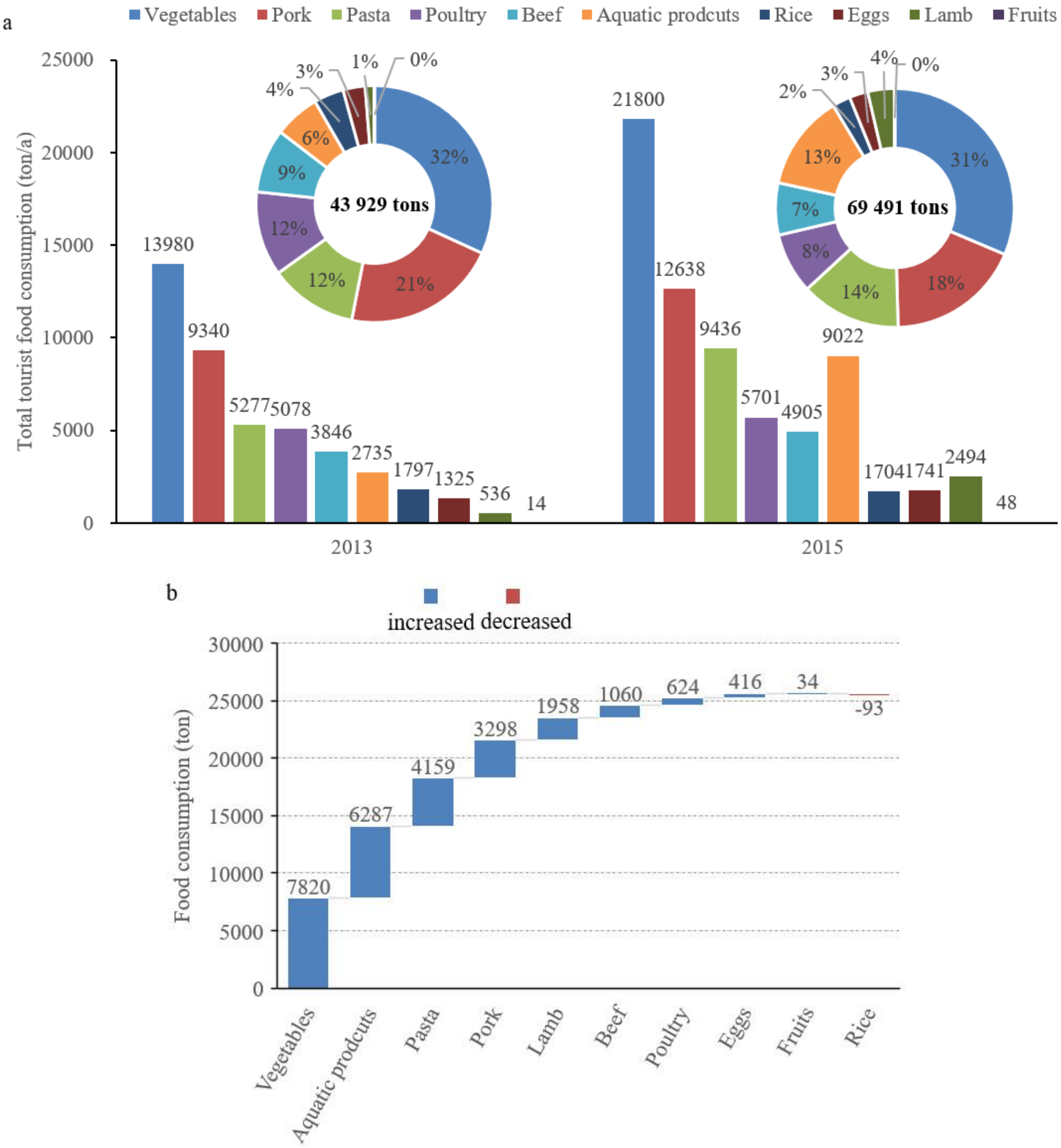

Figure 6. (a) Total tourist food consumption and composition in 2013 and 2015, and (b) the change in tourist food consumption from 2013 to 2015 in Lhasa.

## *3.2 ALR of tourist food consumption in Lhasa*

### *3.2.1 Total ALR*

The total ALR of tourist food consumption in Lhasa increased by more than 50% from 14376 ha in 2013 to 22210 ha in 2015 (Table 4). The ALR attributed to tourist food consumption was equal to nearly 41% and 62% of the arable land area of the Lhasa region in 2013 (34900 ha) and 2015 (35878 ha), respectively (Tibet Autonomous Region Statistics Bureau and Tibet Survey Corps of the National Bureau of Statistics, 2014; Tibet Autonomous Region Statistics Bureau and Tibet Survey Corps of the National Bureau of Statistics, 2016). Of this increase in ALR, 84% was caused by the increased consumption of animal-based foods (Figure 7) with the largest contribution made by pork (42%), beef (18%) and poultry (13%) in 2013. In 2015, pork remained the largest contributor to ALR (37%), followed by beef (15%), but then aquatic products (12%) replaced poultry in the top-3 contributors. Compared with meats, vegetables, and grain (pasta and rice), the ALR of fruits contributed the least both in 2013 and 2015 due to small overall consumption of these foodstuffs. In contrast, the contribution of pork decreased the most (5 percentage points) and that of aquatic products increased the most (6 percentage points). The decrease in the ALR of pork can be attributed to the decrease in feed grain yield while the increase in the ALR of aquatic products can be attributed to their overall increase in food consumption which indicating the changing ditary patterns.

Table 4. Arable land requirements (ALR) of different types of food and their percentages in 2013 and 2015 (Unit: ha).

| Food category | 2013 | | 2015 | |
|---|---|---|---|---|
| | ALR | Percentage of total ALR | ALR | Percentage of total ALR |
| Pork | 5983 | 42% | 8224 | 37% |
| Beef | 2524 | 18% | 3274 | 15% |
| Poultry | 1864 | 13% | 2075 | 9% |
| Pasta | 1348 | 9% | 2294 | 10% |
| Aquatic products | 819 | 6% | 2717 | 12% |
| Vegetables | 645 | 4% | 943 | 4% |
| Eggs | 442 | 3% | 577 | 3% |
| Rice | 372 | 3% | 349 | 2% |
| Lamb | 376 | 3% | 1752 | 8% |
| Fruits | 1 | 0% | 5 | 0% |
| Total | 14376 | | 22210 | |

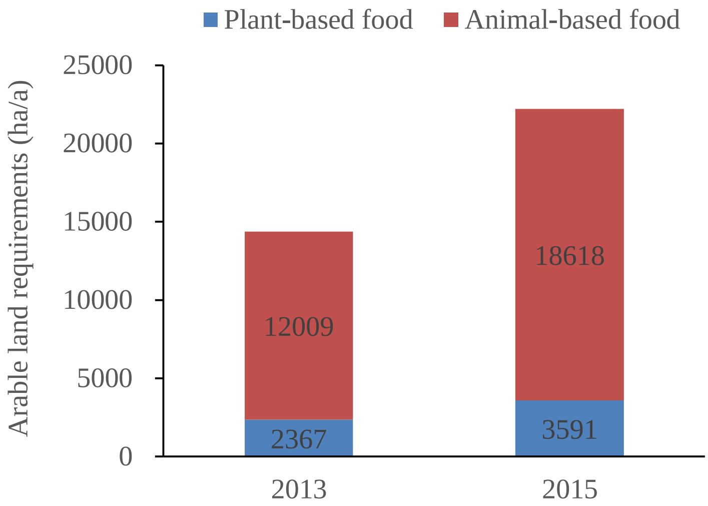


Figure 7. Arable land requirements (ALR) of plant-based and animal-based food consumption by tourists in 2013 and 2015 in Lhasa.

*3.2.2 Decomposition of ALR*

According to the results of the decomposition of ALR, it was established that the ALR increased by 7834 ha from 2013 to 2015. The tourist population scale effect was the most major factor contributing to this increase (6929 ha) , while the dietary pattern effect was the second largest contributor (899 ha), and the technological progress effect was the smallest, almost negligible, contributor (6 ha) (Figure 8).

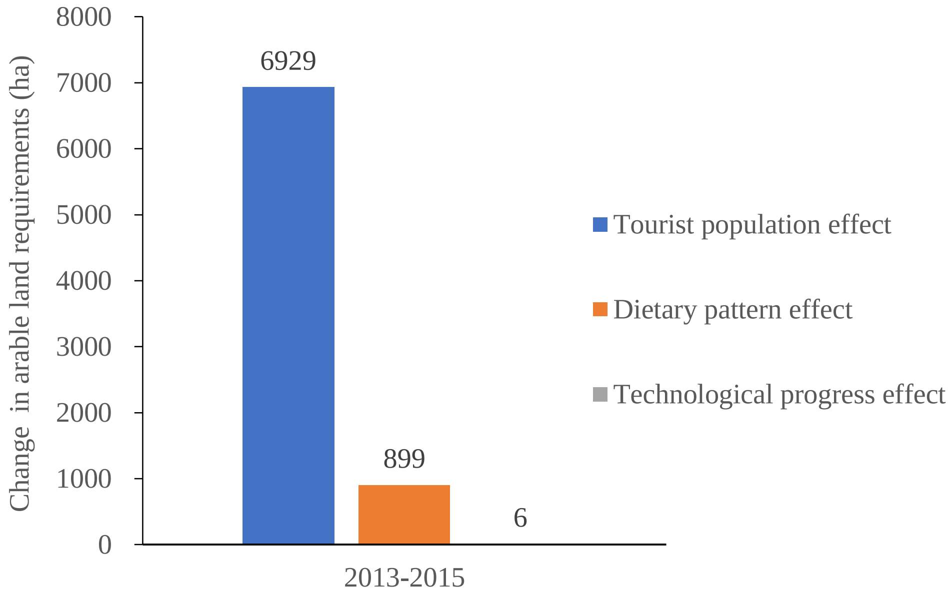


Figure 8. Contribution of tourist population effect, dietary pattern effect, and technological progress effect to changes in arable land requirements (ALR) of tourist food consumption in Lhasa.

## 4 Discussion and Concluding remarks

### *4.1 Analysis and comparison*

The per capita tourist food consumption in 2013 and 2015 quantified in this study were both a bit smaller than that in 2011 (Wang et al., 2016). The reason for this difference mainly rests within the consumption of spirits/liquor, which was not included in the current study but accounted for in the study by (Wang et al., 2016). Further, when comparing the results of this study with the outcome of the research project on food waste generated by the sector of foodservice provision in Lhasa from 2011 to 2015 (Wang et al., 2018), the observed increase in the per capita food consumption within the period of 2013-2015 may be not because tourists eat more, but because they waste more. The results of the previous study determined that per capita food waste of tourists in 2011 was 135 ±3 g per meal and increased to 144 ±4 g per meal in 2015 with an annual rate of increase of 1.67% (Wang et al., 2018). Moreover, the amount of food waste generated by tourists was found to be significantly higher than that of local residents, especially in 2015 (144 ±4 g vs. 86 ±2 g) (Wang et al., 2018). This clearly demonstrates that while the rapid development of tourism brings economic growth and increased employment to Lhasa, the irresponsible consumer behavior of tourists, in this case as manifested in food waste generation, imposes a series of adverse effects on a destination. Food waste implies inefficient input of resources and excessive emission of greenhouse gases (Gustavsson et al., 2011). Thus, the problem of tourist-generated food waste in a popular tourist destination cannot be ignored, especially for the city of Lhasa, which has limited resources and an extremely fragile natural environment.

The per capita tourist food consumption in Lhasa was more than two times that of household food consumption in China (Li et al., 2018; Xiong and Wang, 2017). This indicates disproportionate food consumption patterns of tourists. Local households in Lhasa are usually familiar with how much they can eat and what they eat, i.e. they have well-established dietary patterns, and so they consume more suitable quantities of food and waste less. Being away from home, many tourists find it difficult to control the quantities and character of food eaten due to the unfamiliar environment and often impulsive consumption (Li et al., 2019a). Therefore, tourist food consumption will inevitably be higher than household food consumption, thus imposing disproportionately higher environmental impacts, especially in the 'indirect' form. Additionally, it should be noted that the significant increase in aquatic product consumption from 2013 to 2015 as calculated in this study was primarily because there were fewer fish restaurants in Lhasa in 2013 as compared against 2015. Thus, the consumption of aquatic products in 2015 was inevitably higher than that in 2013. The increase in the consumption of lamb and the decrease in the consumption of eggs, beef, poultry, and pork indicates changes in the dietary structure of tourists visiting Lhasa. These changes are somewhat different from the changes in the dietary structure of household food consumption recorded for both urban and rural China. For example, the per capita per year poultry consumption of urban residents and rural residents in China both increased by about 16% in 2015 compared with 2013 (Sheng, 2014; Sheng, 2016).

The significant increase in total tourist food consumption can be mainly attributed to the significant increase in tourist arrivals in Lhasa, which increased by 48% from 7.99 million in 2013 to 11.79 million in 2015, and somewhat assigned to the overall increase in per capita food consumption as mentioned previously. With the rapid economic development of China, the wealth of its residents is increasing and their pace of life is accelerating. Thus, eating out is becoming an important form of food consumption for many residents. Accompanying these developments, tourism in China has witnessed the fastest development in recent years, with total domestic tourist arrivals increasing by 22%, from 3260 million person-trips in 2013 to 3990 million person-trips in 2015 (National Tourism Administration of the People's Republic, 2014, 2016), indicating the growing prosperity of the tourism industry. Tourist food consumption, an important and specific form of away-from-home food consumption, has therefore become increasingly common. Furthermore, tourists tend to eat better variety and larger quantities of food when being away from home compared to their in-home food consumption, causing the observed increase in per capita food consumption. This increasing food consumption has undoubtedly increased the pressure imposed by the food supply on the environment of many tourist destinations.

As an important resource for food cultivation, arable land is a prerequisite for sustaining food production and subsequent consumption. Previously published research has indicted that the arable land required to produce food is determined by many factors, including population size, consumption patterns, and technological factors, such as crop yield area (Kastner and Nonhebel, 2010; Kastner et al., 2012; Luan et al., 2014; Penning et al., 1995; Zhen et al., 2010). Thus, higher food consumption levels and increased tourist arrivals mean greater ALR. Presently, the food consumption structure of Chinese residents appears to be gradually shifting from a vegetarian diet to a more affluent diet which is increasingly including meat (Zhai et al., 2005). For example, the consumption of cereals has decreased in China while the consumption of meats, eggs, and aquatic products grows steadily (Li, 2007; Wang and Yang, 2007). With the continued economic development and urbanization in China, this intense-ALR diet will continue to intensify. As a form of away-from-home consumption, tourist food consumption has significantly increased the pressure on the food supply chains within tourist destinations and, subsequently, imposed extra pressure on their arable land resources. This pressure is well noticeable for Lhasa, which is on a high plateau with limited arable land resources (35878 ha) (Tibet Autonomous Region Statistics Bureau and Tibet Survey Corps of the National Bureau of Statistics, 2016). In 2015, the 21542 ha of ALR used to meet tourist demand for food was equivalent to 62% of the city's total arable land area. This underlines the importance of designing strategies for reducing the ALR attributed to tourist food consumption in such plateau areas with their fragile environments and high pressures on natural resources in order to promote (more) sustainable development of a destination.

Food consumed by tourists is typically from both in-region and out-of-region markets (Halldorsdottir and Nicholas, 2016; Mak et al., 2012a). Thus, on the one hand, the increase in food consumption can be satisfied by an increase in local food supply or by the import of foodstuffs from other regions (OECD and FAO, 2016). On the other hand, the increase in food consumption imposes pressures not only on the local arable land resources (‘direct’ pressures), but also upon those of other regions (‘indirect’ pressures). According to the early field survey of comprehensive wholesale markets of agricultural products in Lhasa in 2012, more than 80% of food on average was imported from other regions due to the limited resources of the Lhasa region (Wang et al., 2018). Considering the significant resource consumption and emissions of greenhouse gases incurred in the process of food transportation (Mangmeechai, 2016; Tassou and G. De-Lille, 2009; Wakeland et al., 2012), excessive food consumption, high animal-based food diets, and food waste generated by tourists not only apply significant pressures on the natural resources and the environment of popular tourist destinations, such as Lhasa, but also constitute a significant threat to the sustainable use of resources and the health of the entire regional (or even national) ecosystems.

### 4.2 Possible mitigation strategies

In the context of the rapid tourism development, the correlation between tourist population growth and unreasonable consumption patterns becomes clear and has a noticeable impact on natural resources of tourist destinations. The increase in food consumption and the accompanying pressures on ALR manifest this impact particularly well. Accordingly, the following mitigation strategies can be considered based on the findings of this study:

(1) In view of the significant contribution of the tourist population factor to ALR, reasonably controlling the tourist population and considering the spatial allocation of food resources may offer effective and readily implementable measures for alleviating the pressures on the demand for arable land in tourist areas with a fragile environment and scarce natural resources. It is also conceivable that the reception pressure of local tourist 'hotspots' could be reduced by adopting tourist diversion in those areas.

(2) Although the effect of the dietary structure factor on ALR is smaller than that of the tourist population factor, from the perspective of tourism economic development it is more feasible and effective to relieve the resource pressure of tourism on destinations by improving the food consumption structure and managing the consumption behavior of tourists. Notably, a high animal-based food consumption pattern requires significant utilization of arable land resources. Thus, a shift from an animal-based diet to a plant-based diet could have manifold benefits for environmental sustainability of food consumption and food production, as well as for the (more) rational use of arable land resources (Schönhart et al., 2009). Notably, the intensely animal-based diet of residents across China, especially during away-from-home food consumption, has triggered a series of health problems, including obesity and high blood pressure (Du, 2014). Therefore, it is necessary to re-examine the nutritional needs and the healthy diets to scientifically guide and adjust the dietary patterns and the structure of both resident and tourist populations in popular tourist destinations. Reducing the consumption of food with relatively high ALR, such as meats, and increasing the consumption of fruits, vegetables, and eggs can provide (more) balanced nutrition and (more) environmentally sustainable food consumption.

(3) Notably, although technological progress was not found to provide any substantial alleviation of the increase in ALR attributed to tourist food consumption in the current study, the contribution of technological advancements to the potential reduction of ALR still should not be ignored (Liu and Wang, 2018). In the future, in addition to reasonably managing tourist flows in Lhasa and its consumption patterns, the vigorous development of agricultural science and technology to improve land productivity and the utilization rate of arable land is recommended. Additionally, managing food consumption patterns by tourists and investing in food waste mitigation should become a national and regional target to realize the (more) sustainable use and development of China's land resources and to promote sustainable tourism.

### 4.3 Conclusions

As the most basic tourism commodity, tourist food consumption has an important impact on local food demand and food supply (Frisvoll et al., 2016; Rutty et al., 2015; Wang et al., 2017). This study examined the associated ALR to accommodate temporal changes in tourist demand for food in the popular tourist destination of Lhasa on the Qinghai-Tibet Plateau and established the main factors contributing to the changes in ALR via empirical analysis. The main conclusions are as follows:

(1) Food consumption per capita per meal in 2015 (945 g) was 8% higher than in 2013 (893 g). Noticeably, the consumption of aquatic products and lamb were both significantly higher in 2015 than in 2013.
(2) Total tourist food consumption per year in Lhasa increased by 58% from 43929 tons in 2013 to 69491 tons in 2015. Vegetable consumption increased the most (7820 tons or 56%), followed by aquatic products (6287 tons or 230%) and pasta (4159 tons or 79%).
(3) The total ALR of tourist food consumption in Lhasa increased by more than 50%, from 14378 ha in 2013 to 22210 ha in 2015, and 84% of this increase was caused by an increase in animal-based food consumption of tourists. Pork contributed the most to the total ALR both in 2013 (42%) and 2015 (37%).
(4) Among the drivers of increased demand for arable land, the tourist population effect was the most important factor, followed by the dietary patterns of tourists. The effect of technological progress had a small, but noteworthy, effect on the increase in ALR.

### *4.4 Limitations and further research directions*

The results of this study contributed to the first evaluation of the effect of tourism on ALR in a tourist city (Lhasa, on the Qinghai-Tibet Plateau), thus outlining the avenue for future research which can set to explore the prerequisites of the (more) sustainable planning and management of natural resources in other destinations. However, there remains some space for improvement and progress in similar future research. If the following limitations were to be addressed, the findings of future similar studies could be made more robust:

- First, the studied sample was not constituted by exactly the same restaurants surveyed in 2013 and 2015 because the sector of foodservice provision, globally and in China, is characterised by rapid changes in business and ownership models.
- Second, food consumption during breakfast and consumption of other foodstuffs (for example, dairy and beverages drinks) were excluded from analysis due to their relatively minor levels of consumption in China. Thus, the ALR determined in the current study are likely to be somewhat underestimated. What is more, consumption of dairy and beverages may be more popular in other destinations, thus calling for the need to include them into the scope of analysis.
- Third, the accuracy of the feed grain source was limited in this study. We assumed that the source of animal-based food production was consistent with the source of the feed grain due to limited data. Inevitably, there will be some accompanying bias in the results. This also reflects the lack of relevant research data, which must be generated by the relevant departments (e.g. tourism management departments or agricultural management departments) of specific countries and/or tourist destinations to strengthen and improve the quality of

data collection and better support the development and improvement of related scientific research work in the future.

## Disclosure

No potential conflict of interest was reported by the authors.

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