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Cost-Benefit Analysis of Continuous and Rotational Grazing Systems

——A Case Study in Maqu County, China

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Abstract: The rotational grazing systems (RGS) have been advocated as a superior grazing strategy by the Chinese government based on their significant ecological advantage compared to continuous grazing systems (CGS). In practice, however, due to the low-adoption rate of RGS the favorable effect is limited. This study analyzed the total production cost, gross production value, and net margin of CGS and RGS from the perspective of cost benefits. Data were collected from telephone and face-to-face questionnaire survey of 121 randomly sampled households in Maqu County in the Qinghai-Tibet Plateau. The results indicate that although economic benefits were achieved by herder households in both CGS and RGS, the total production costs spent on each sheep unit in RGS were higher than in the overall that of the total households, and the gross production values produced by herder households from livestock products were lower than in the overall that of the total households due to the difference in production practices. This finding suggests that higher production costs may reduce herders' adoption rate of RGS. Furthermore, the transfer from CGS to RGS also implies that herders may have to face the challenge the change in production practices related to native grass availability, forage seeding, supplementary feeding, livestock transfer, and grazing duration. The policy implications of these findings towards the implementation of rotational grazing systems are as follows: first, policy makers can consider bringing higher economic advantages to the adopters of rotational grazing systems via incentives; Second, policy measures should assist herders to be able to adapt more easily to the production practices in RGS.

Keywords: Cost Benefits, Continuous Grazing Systems, Rotational Grazing Systems, Qinghai-Tibet Plateau

1 INTRODUCTION

Natural grassland covers 392 million ha in China, which is 12% of the world's grassland area (Shi et al. 2021). However, due to high-

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intensity continuous grazing and climate change, the grasslands in arid and semi-arid areas have been severely degraded in the past few decades (Chen et al. 2017). In addition, China's government implemented a household responsibility system in the 1980s, whereby grassland and livestock were allocated to individual households, with each household's pastural area fixed by fences, which further aggravated grassland degradation through pasture fragmentation (Huang et al. 2017). This has not only led to a decline in grassland productivity, an increase in soil erosion and dust storms, but it has also seriously impeded the sustainable development of animal husbandry (Li et al. 2013; Pulido et al. 2018). Therefore, the implementation of effective grazing systems that support ecological sustainability is therefore urgently required in China.

Since the 20th century, rotational grazing has been advocated as a highly effective strategy to maintain productivity and improve livestock management, generally regarded as a more efficient alternative to continuous grazing (Teague et al. 2013; Chen et al. 2018). Compared to continuous grazing on the same pasture year–round, seasonal rotation between different pastures has been shown to prolong the recovery period of grasslands and reduce trampling during livestock roaming (Ren, 2012). Additionally, rotational grazing was also found to increase perennial herbaceous vegetation cover, helping to alleviate grassland degradation (Teague et al. 2004). In 2016, the central government established a goal for the nationwide implementation of rotational grazing, with the aim of reaching 28 million ha by 2020 (MARA, 2016). However, only about 24% of herders in northern China use rotational grazing at present (Shi et al. 2021). This poor adoption rate of rotational grazing systems is therefore limiting their ecological advantage.

As production operators, the ultimate intention of herders is to seek the maximization of economic benefits from their production activities (Xu et al. 2011). However, existing studies focused on comparisons of grassland ecology (e.g. Vegetation Community Biomass, and Biodiversity) or physical livestock outcomes (e.g. Changes in Livestock Productivity and Milk Production) between continuous and rotational grazing (Ren, 2012; Roche et al. 2015; Teague et al. 2013; Vecchio et al. 2019; Zhang et al. 2020), the regional suitability of rotational grazing (Wang et al. 2015) and the system improvement of rotational grazing (Zhou et al. 2015). Although extrapolation by rotational grazing advocates based on the costs of labor, fencing and water on farms in the western United States suggests that the adoption of rotational grazing incurs additional economic costs (Windh et al. 2019), the practical cost benefits of grassland animal husbandry under different grazing systems in China have not been investigated in detail. Considering an inconsistent objective that may exist between the rotational grazing which the Chinese government has recommended based on the ecological advantage and the herders who seeks the economic benefit to engage in production, clarifying the total production cost, gross production value, and net margin of both continuous grazing systems (CGS) and rotational grazing systems (RGS) in helpful for providing theoretical and practical basis for the government to improve the relevant policies.

2 MATERIAL AND METHODS

2.1 Study Area

Maqu county of Gansu province, China, located at the northeastern edge of the Qinghai-Tibet Plateau (26°00'–39°47'N, 73°19'–104°47'E). The altitude ranges from 2,900 to 4,000 m with an average annual temperature and precipitation were 1.8°C and 616 mm, respectively. The district averages 2580 h of sunshine and over 270 frost days annually. The natural grassland area covers about 86 ×104 ha and represents an important base for livestock production in Gansu province. In 2020, the total population of Maqu was about 57,000, with around 75% of the local people are herders of yaks and sheep; 89% of their income comes from livestock rearing directly (Du et al. 2022).

2.2 Grassland Grazing System

Yaks and Tibetan sheep are the main types of livestock reared in the Qinghai-Tibet Plateau. In RGS, in late April or early May, livestock are moved from winter pastures (at the base of the mountains) to higher summer pastures, with herders living in tents. In contrast, in CGS, livestock are maintained in one pasture year-round (winter pasture). At around 2 years old, yaks begin to breed between August and September, giving birth between May and June the following year (Cui et al. 2016). Similarly, Tibetan sheep start breeding between August and September at around 1 to 2 years old, giving birth between January and February the following year (Li& Guo, 2016). Yaks are milked from May to September, and after self-consumption and sales, surplus milk is made into ghee and cheese. Forage seeds are sown between June and July and harvested between September and October as a source of winter forage. Herders of Tibetan sheep also need to shear wool, and vaccination of both yaks and Tibetan sheep are performed between June and July. In late September or early October, livestock in RGS is once again moved from summer pastures to winter pastures. Because of the limited availability of pastures and income, at the end of the production cycle in October, herders transport all livestock older than three years old (excluding breeding animals) to local trading markets.

2.3 Data Collection and Analysis

Data were obtained via telephone and face-to-face questionnaire surveys by six local trained enumerators between November 2021 and February. This study randomly selected the villages around Maqu County as the sample area, then the participants were randomly selected with herders from these villages. Information on production costs starting from the completion of the livestock sale in 2020 to the end of the livestock sale in 2021 as well as the materials used in the process were acquired. Ultimately, a total of 121 valid responses were obtained after eliminating 9 questionnaire that had invalid and missing values, with an effective questionnaire rate of 93.08%, among which 83 were from CGS, and 38 from RGS. The collected data were systematically arranged and coded and entered into the STATA16 software for analysis. The results were derived by using descriptive statistics.

To calculate the total production costs, input items like labor, fodder, fence maintenance, dog food, transportation, vaccination, livestock insurance, and veterinarian were considered and they were assessed based on the actual quantity of inputs and the prices paid by the herders. Additionally, the monetary results were initially measured with the RMB, and then converted to USD based on the average exchange rate of the Central Bank of the People's Republic of China in 2021. Livestock calculation units were used to convert to each type of livestock, with one sheep unit being equivalent to a 50-kg adult ewe with a lamb and a daily intake of 1.8 kg of hay per year (MARA, 2020). Total production cost was calculated as:

$$C_{\text{total production (\$/SSU)}} = C_{\text{labor}} + C_{\text{fodder}} + C_{\text{fence}} + C_{\text{dog food}} + C_{\text{transportation}} + C_{\text{vaccination}} + C_{\text{insurance}} + C_{\text{veterinarian}}$$

Depreciation of fences and motorbikes was calculated by the straight-line method; Given that leasing in pasture in lieu of native grass is a way for herders to resolve grass shortages (Yan et al. 2011), the market rental prices for continuous and rotational grazing pastures provided by the local grassland management office were used in this study as a proxy for native grass. Therefore, $C_{\text{pasture rental}}$ stands for $C_{\text{native grass}}$ = Cost on paying for using pasture ($/SSU).

Similarly, gross production value and net margin were calculated as (MARA, 2019):

$$V_{\text{gross production (\$/SSU)}} = V_{\text{income from live livestock sales}} + V_{\text{cash value of remaining live livestock}} + V_{\text{income from livestock by-products sales}}$$

$$\text{Net Margin}_{\text{(\$/SSU)}} = V_{\text{gross production}} - C_{\text{total production}}$$

Where, $C_{\text{income from livestock by-products}}$ = Real income from the sale of milk, ghee, cheese, wool and hide all year round.

3 RESULTS AND DISCUSSION

3.1 Characteristics of Each Grazing System

As shown in Table 1, labor in the overall study households is performed by family members. Both CGS and RGS, the average available labor (2 people) of households and the average years (2 years) of education of the head of household were the same, but the average age (43 years) and production experience (28 years) of the head of household in RGS were more than in CGS by 2 years. In addition, as the average total area of grassland and total number of livestock per household in RGS were more than in CGS by 128 ha and 128 SSU, respectively, with the total number of households reared yaks alone in RGS was more than in CGS by 5 households, and the total number of households reared both yaks and Tibetan sheep was less than in CGS by 50 households. Although family members are the main laborers in production, a few households in both CGS (1 household) and RGS (1 household) employed labor. Due to different production practices, households in RGS both sowed forage seed (38 households) and transfer livestock seasonally (34 km), while only 3 households in CGS sowed forage seed. Furthermore, CGS (9 km) and RGS (26 km) are a certain distance from the market center, making the motorbike a common vehicle for herders.

TABLE 1 DESCRIPTIVE STATISTICS OF THE CONTINUOUS (CGS) AND ROTATIONAL GRAZING SYSTEMS (RGS)

Variables	Overall (N = 121)	CGS (N = 83)	RGS (N = 38)	Mean difference
Yak rearing (% of households)	67 (55)	31 (37)	36 (95)	5
Mixed rearing[a] (% of households)	54 (45)	52 (63)	2 (5)	50
Age of the household head (years)	42	41	43	2
Available labor per household (people)	2	2	2	0
Time in education of the household head[b] (years)	2	2	2	0
Production experience of the household head (years)	27	26	28	2
Use of hired labor (% of households)	2 (2)	1 (1)	1 (2)	0
Hired labor wage[c] ($[d]/man-days)	15	15	16	1
Distance to the nearest market center (km)	14	9	26	17
Area of grassland per household (ha)[e]	98	58	186	128
Distance between pastures[f] (km)	11	0	34	34
No. of livestock per household (SSU)[g]	155	115	243	128
Sowing of forage seed (% of households)	41 (34)	3 (4)	38 (100)	35
Ownership of a motor vehicle (% of households)	89 (74)	62 (75)	27 (71)	35

Notes: Figures in parentheses indicate the percentages. [a] Mixed rearing includes rearing of yaks and Tibetan sheep. [b] Average time in education represents the total number of years that the household head spent in formal education. [c] The hired labor wage represents the number of man-days at 70 hours a week × 52 work weeks. [d] Based on the exchange rate of the People's Bank of China in December 2021, 1$ = 6.5 RMB. [e] 1 ha = 15 mu. [f] The average distance between pastures represents the distance between summer and winter pastures. [g] SSU represents the standard sheep unit based on the agricultural industry standard of the People's Republic of China, NY/T 3647−2020.
Source: Questionnaire survey, December 2021 to February 2022.

3.2 Production Costs in Continuous and Rotational Grazing Systems

Fodder is the first key input item in the process of livestock rearing. As the livestock in CRS forage in the one pasture year−round, the average cost of pasture rental in CGS was $76.92/ha/year, which was lower than the overall study households ($86.46/SSU) (Table 2). Furthermore, because sowing and harvesting of forage correspond to the period of milking, ghee and cheese making, and sheep shearing, sowing of forage is not prioritized in CGS, resulting in reliance on commercial fodder from January to April ($9.28/SSU), which was higher than the overall study households ($7.46/SSU). In RGS, the average cost of pasture rental was $107.30/ha/year, which were higher than the overall study households. This is because grass and water resources are highly heterogeneous both in spatial and temporal terms, and the mobility characteristic of rotational grazing enhances livestock access to more natural resources (Hobbs et al. 2008). In these conditions, the market price for renting the summer pasture was $184.62/ha/year. Whereas in winter with inadequate native grasses and high commercial forage prices the market price for renting the winter pasture was $246.15/ha/year. In addition, herders sow and harvest their own forage between June and October as a source of hay during the winter months, from January to April. Thus, the average cost of livestock fodder representing only $3.49/SSU which was lower than the overall study households.

Family members are the primary source of labor in the animal husbandry production process. The average cost of labor in CGS was $28.35/SSU, which was higher than the overall study households ($23.82/SSU). The livestock are driven from enclosures at dawn and gathered at dusk throughout the year, at a labor cost of $16.71/SSU. Due to the close proximity of households in CGS to the market center, the average labor cost of milk collection and ghee making from May to September was approximately $10.93/SSU. Moreover, 52 households in CGS rear both yaks and Tibetan sheep, the labor cost of sheep shearing was $0.07/SSU. As mentioned above, because the sowing and harvesting of forage corresponds to the period of milking, ghee and cheese making, and sheep shearing, only 3 households in CGS plant forage, representing an average labor cost of only $0.006/SSU. Routine fence repairs, livestock vaccinations and sales represent average labor costs of $0.41/SSU, $0.06/SSU, and $0.13/SSU, respectively. In RGS, the average cost of labor was $13.93/SSU, which was lower than the overall study households. Livestock is released and gathered less frequently in RGS. In addition, livestock are transferred between summer and winter pastures and vice versa in early October and late April, respectively. The costs of labor for releasing and gathering livestock as well as transferring them between pastures were $7.31 and $0.11/SSU, respectively. Moreover, because households in RGS were relatively far from the market center, milk collected by herders at dusk is not guaranteed to be delivered on the same day. Milking, ghee and cheese making represent labor costs of around $5.83/SSU. In addition, because only 2 households in RGS rear both yaks and Tibetan sheep, the cost of sheep shearing at only $0.01/SSU. Herders tend to sow forage inside the livestock enclosures between June and July utilizing livestock manure as fertilizer, with subsequent harvest between

September and October. This represented an average labor cost of $0.14/SSU. Repair of damaged fences, livestock vaccinations and sales represented labor costs of $0.39, $0.05, and $0.10/SSU, respectively.

The boundaries between neighboring household pastures throughout the grassland grazing area are defined by fencing. The average cost of fence maintenance in CGS was $4.52/ha, which was higher than the overall study households ($4.29/ha). The construction cost of grassland fences nationally was 38.08 $/ha (MARA, 2003), and the service life was about 10 years (Cao et al. 2011), with an annual depreciation of 3.81 $/ha. In addition to the depreciation cost, repair and replacement of damaged fences is routinely performed at an average cost of $0.71/ha. In RGS, the average cost of fence maintenance was $4.58/ha, which was higher than the overall study households. Meanwhile, the cost of repairing and replacing damaged fences was $0.77/ha.

Motorbikes are the main vehicle for herders. The average cost of transportation in CGS was $2.92/SSU, which was higher than the overall study households ($2.41/SSU). One explanation for this is the yak milking season, which runs from June to September, and the high demand for freshness. Milking is performed both in the morning and evening, and the milk is transported to collection points is on the same day at a cost of $2.15/SSU. Additionally, wool is sheared between June and July, and most is transported to collection points. Livestock are transported to markets in late September or early October, with the expense of the rental truck depending on the number of livestock to be sold. In this period, livestock are slaughtered early at around 3 to 4 years old, and the average transportation cost of truck rental was $0.76/SSU. In RGS, the average cost of transportation was $1.29/SSU, which was lower than the overall study households. Due to the distance from the market center, herders spent only $0.90/SSU on transportation because milk collected at dusk is not delivered to collection points on the same day, ultimately reducing the amount of milk that is sold. Moreover, a portion of 3~6 years old livestock is usually sold, resulting in an average truck rental cost of $0.38/SSU.

Livestock insurance is intended to mitigate losses from disease, weather, and wildlife attacks, all of which can result in livestock deaths. The average cost of insurance in CGS was $0.75/SSU, which the same as in the overall study households ($0.75/SSU). Because livestock insurance is uniform throughout the pastoral area, herders only underwrite 10% of the cost per livestock based on government subsidies. Disease epidemics are one of the main causes of mass livestock mortality, thus, herders vaccinate their livestock annually to minimize damage. The average cost of livestock vaccination in CGS was $0.18/SSU, which was higher than the overall study households ($0.17/SSU). It was thought to be related to the relatively close proximity to market centers. Such close proximity increases the availability of information on disease epidemics, increasing the likelihood of additional vaccinations, on top of the four basic vaccinations provided by the government. In RGS, the average insurance cost was $0.75/SSU, which was the same as for the overall study households. As with CGS, because the standard insurance rate and government subsidy is uniform, the cost of insurance per SSU was similar in RGS. The average cost of livestock vaccination was $0.15/SSU, which was lower than the overall study households. Such relatively low expenditure on vaccines might be explained by the fact that the average distance from the market center was greater in RGS, resulting in less awareness of epidemic prevention and fewer purchases of additional vaccines beyond the four basic vaccines provided by the government.

Most herders also own dogs in order to prevent livestock from being stolen or attacked by wild animals. The average cost of dog food in CGS was $0.12/SSU, which was lower than the overall study households ($0.18/SSU). Commonly, leftover food is the main source of dog food, although households with more than one dog often have to purchase extra commercial food to supplement this. In RGS, the average cost of dog food was $0.32/SSU, which was higher than the overall study households. The relatively high cost of dog food is possibly because of the larger number of livestock in RGS, which may result in a relative increase in the number of dogs owned. However, the total number of dogs owned by each household was generally no more than three in RGS.

Veterinary expenses generally reflect medicine provisions. The average cost of the veterinarian in CGS was $0.07/SSU, which was higher than the overall study households ($0.06/SSU). Their relatively high veterinary costs can be explained by the tendency of herders in pastoral area to treat diseased livestock using readily available medicine based on their own experience or via consultation with a veterinarian. In RGS, the average cost of veterinarian was $0.04/SSU, which was lower than the overall study households. As with CGS, livestock with mild symptoms are most likely to be treated by the herders themselves based on past experience or consultation with other herders. Moreover, the limited number of veterinarians in the area often prevents home visits, further reducing the veterinary expenditure.

TABLE 2 PRODUCTION COSTS IN THE CONTINUOUS (CGS) AND ROTATIONAL GRAZING SYSTEMS (RGS)

Item	CGS (N = 83)	RGS (N = 38)	Overall (N = 121)
Pasture rental[a] ($/ha)	76.92 (0.00)	107.30 (2.32)	86.46 (14.22)
Livestock fodder[b] ($/SSU)	9.28 (1.35)	3.49 (0.57)	7.46 (2.94)
Fence maintenance[c] ($/ha)	4.52 (0.68)	4.58 (1.03)	4.29 (0.87)
Dog food ($/SSU)	0.12 (0.59)	0.32 (0.47)	0.18 (0.56)
Livestock vaccination ($/SSU)	0.18 (0.04)	0.15 (0.02)	0.17 (0.04)
Veterinarian[e] ($/SSU)	0.07 (0.60)	0.04 (0.19)	0.06 (0.51)
Transportation[f] ($/SSU)	2.92 (1.94)	1.29 (1.00)	2.41 (1.86)
Livestock insurance ($/SSU)	0.75 (0.17)	0.75 (0.05)	0.75 (0.14)
Labor[g] ($/SSU)	28.35 (16.46)	13.93 (4.67)	23.82 (15.40)

Notes: Figures in parentheses indicate the standard deviation of the means. [a] The cost of renting summer and winter pastures for 6 months in RGS was $92.31/ha and $123.08/ha, respectively. [b] Livestock fodder includes the cost of hay, corn, forage seed. [c] Fence maintenance includes the cost to repair pasture fencing, and livestock enclosures as well as depreciation costs. [d] Dog food includes the commercial nutritional food purchased for dogs. [e] Veterinarian includes the cost of medicine and veterinary consultation. [f] Transportation includes the cost of owning a motorbike (fuel, maintenance and depreciation costs) and truck rental. [g] Labor includes the family members and employees; Daily wage based on the actual expenses paid to herders, and working hour represents the sum of the time spent by herders in all activities over the year. A full year is 70 hours per week × 52 work weeks. Under total production costs, the cost of pasture rental and fence maintenance based on unit pasture area will be calculated on the basis of standard sheep unit.
Source: Questionnaire survey, December 2021 to February 2022.

3.3 Gross Production Values and The Net Margin in Continuous and Rotational Grazing Systems

Livestock and by-products were the main source of cash income for herders. As shown in Table 3, the average gross production value of $235.08/SSU in CGS, which was higher than the overall study households ($233.14/SSU). In October, buyers and sellers trade livestock based on local market prices and physical examinations of each animal, the livestock production value of $222.98/SSU in CGS, while the production value of livestock by-products was only $12.10/SSU. The impact of animal husbandry production on the welfare of producers can be evaluated in terms of the net margin. The average total production cost in CGS was $91.11/SSU, which were lower than the overall study households ($103.07/SSU). After deducting the total costs of inputs in the production process, the average net margin ultimately obtained by herder household in CGS was $143.96/SSU, which was higher than the overall study households ($135.70/SSU). The cash income in RGS was also represented by sales of livestock and livestock by-products, with the average gross production value of $228.92/SSU, which was lower than the overall study households. Among these, the livestock production value of $224.63/SSU, while that of livestock by-products was only $4.29/SSU. Additionally, the average total production cost in RGS was $111.26/SSU, which were higher than the overall study households. After deducting the total production costs, the average net margin ultimately obtained by herder household in RGS was $117.66/SSU, which was lower than the overall study households.

TABLE 3 PRODUCTION VALUES AND ECONOMIC IN THE CONTINUOUS (CGS) AND ROTATIONAL GRAZING SYSTEM

(RGS)

Item	CGS (N = 83)	RGS (N = 38)	Overall (N = 121)
Livestock[a] ($/SSU)	222.98 (47.29)	224.63 (3.81)	223.50 (39.16)
Livestock by-products[b] ($/SSU)	12.10 (4.41)	4.29 (1.95)	9.65 (5.27)
Gross product value ($/SSU)	235.08 (49.14)	228.92 (4.25)	233.14 (40.79)
Total production cost ($/SSU)	91.11 (53.52)	111.26 (67.04)	103.07 (47.79)
Net margin ($/SSU)	143.96 (69.21)	117.66 (67.38)	135.70 (69.45)

Note: Figures in parentheses indicate the standard deviation of the means. [a] Livestock includes live sales of yaks and Tibetan sheep. [b] Livestock by-products include milk, ghee, cheese, wool, and hide.
Source: Questionnaire survey, December 2021 to February 2022.

4 CONCLUSIONS

Rotational grazing has been strongly advocated by the Chinese government based on their ecological advantage; however, it has yet to be widely adopted by many herders. Although previous studies have compared continuous grazing system and rotational grazing system in terms of grassland ecology and physical livestock outcomes, the practical cost benefits of grassland animal husbandry in

China have yet to be confirmed. Therefore, this study analyzed the total production cost, gross production value, and net margin of continuous grazing system and rotational grazing system.

This study performed an empirical analysis of the questionnaire findings from 121 households, and the main findings showed that although economic benefits were achieved by herder households in both continuous grazing system and rotational grazing system, the total production costs spent on each sheep unit in rotational grazing system were higher than in the overall study households, and the gross production values from livestock products produced by herder households were lower than in the overall study households due to the difference in production practices. Taken together, these results suggested that higher production costs may reduce adoption rate of rotational grazing system by herders from the perspective of cost benefits. This finding is consistent with those of Windh et al. (2019) which showed that higher investment discouraged ranchers from adopting rotational grazing system in the western farms of the United States. Furthermore, the transfer from continuous grazing system to rotational grazing system also implies that herders may have to face the challenge the change in production practices related to native grass availability, forage seeding, supplementary feeding, livestock transfer and grazing duration. The insights gained from this study may be of assistance to the government in reconsidering the feasibility of rotational grazing policy; unless rotational grazing policy can both bring higher economic advantage to herders and enable them to more easily adapt the production practices in rotational grazing system, large-scale rotational grazing is unlikely to be achieved by means of publicity alone. However, despite these findings, this study has certain limitations that are worth noting. First, the Gannan grassland in the Gansu pastoral area was selected as the research area for this study only. Further studies can expand the pastoral area to promote the general applicability of the findings. Second, this study only analyzed one production cycle due to time limitations, and further research on the long-term changes of cost benefits under different grazing systems is warranted.

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