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PRESENT STATUS AND CAUSE OF LAND DESERTIFICATION IN THE YARLUNG ZANGBO RIVER BASIN①

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ABSTRACT: The Yarlung Zangbo River basin is a spacial zone in the south of Xizang, the types, distribution and causes of desertified lands have special features. The type, area, distribution and damage of desertification land in the Yarlung Zangbo River basin are firstly analysed in detail by using latest investigation information. According to the classification criteria of desertified land types and grades, the desertified land in the Yarlung Zangbo River basin can be divided into three grades and five types: fixed sand (dune) land, semi-bare sand and gravel land, semi-fixed sand (dune) land, base sand and gravel land, and shifting sand (dune) land. The desertified lands in the basin are mainly distributed in the wide-valley floor and tributary junction area. The main factors affecting desertification are fragile eco-environment, climate warming and drying and over-exploitation of land resources. The man-made factors leading to desertification in the Yarlung Zangbo River basin are over-cutting and over-grazing, dominated by over-grazing.

KEY WORDS: Yarlung Zangbo River basin, land desertification, desertification cause, man-made factor

The Yarlung Zangbo River, a large river with highest altitude in the world, 2057 km in length, flows through the southern part of the Qinghai-Xizang(Tibet) Plateau from west to east and drains an area of 240 480 km^2 being a sensitive area to the environmental changes (Guan *et al.*, 1984; Yang *et al.*, 1989). The Yarlung Zangbo River basin has always been a political, economic and cultural core zone of Xizang. According to 1993 statistical data, the basin's population, cultivated land area and grain output respectively occupied 47.4%, 73.3% and 76.4% of the Xizang Autonomous Region's totals, although the basin's land area only accounts for 20% of Xizang's total area. This shows that the basin holds a very important position in the social and economic development of Xizang.

The studies on desertification in the region can not only fill up the research blank but also enrich the content and theory of desertification research, which will contribute to the studies of global changes.

1 PRESENT STATUS OF LAND DESERTIFICATION IN THE YARLUNG ZANGBO RIVER BASIN

Land desertification includes a series of wind-sand activity processes, such as soil wind erosion, wind-sand stream, shifting sand accumulation and sand dune migration etc. The land affected by such processes is called desertified land (Dong *et al.*, 1996).

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Desertified land in the Yarlung Zangbo River basin is diversified in types, distributed widely and causes great damages, thus forming one of the severely desertified regions in China.

1.1 Types and Area of Desertified Land

According to the classification criteria of desertified land types and grades, the desertified land in the Yarlung Zangbo River basin can be divided into three grades and five types (Table 1), with a total area of 314.1 $\times 10^4$ km^2, or 13.1 % of the basin's total land area. Among these desertified lands moderate desertified land is the most common, accounting for 53.3 % of its total, slight desertified land makes up 42.8 % and severe desertified land only 5.1 %. This fact suggests that desertification in the basin as a whole is still in the on-going stage and is tending to continuously expand.

1.2 Distribution of Desertified Land

It can be seen from Table 1 that desertified lands in the Yarlung Zangbo River basin are characterized by extensive but relatively concentrated distribution in the distribution scale and are mainly distributed in its middle and upper reaches, and also show a discontinuous strip and patchy distribution features. Desertified lands in the basin are mainly distributed in the wide-valley floor and tributary junction area. Since 63 % of middle section of the Yarlung Zangbo River is composed of alternately distributed wide-valleys, narrow-valleys and gorges, dominated by wide-valleys, desertified lands in the basin show a discontinuous distribution pattern (Dong, 1996) and almost occur every where, including aits, valley flats, alluvial and pluvial terraces, alluvial and pluvial fans, dry riverbeds and mountain slopes. According to typical investigation in the middle reaches of the "One River and Two Tributaries" (the Yarlung Zangbo River, the Lhasa River and the Nyangqu River), the desertified land area percentages in the above-mentioned geomorphic units are 25.7 %, 17.8 %, 10.6 %, 34.1 %, 4.5 %, and 7.2 % respectively.

Various desertified lands in the basin, as a whole, exhibit a better unity. Except for bare sand and gravel lands, the absolute values of various desertified land areas are the highest in the middle reaches and the least in the lower reaches, and the desertified land in the middle reaches occupies 45 % - 68 % of its total (Table 1). The percentages of various desertified lands are the highest in the upper reaches, where the bare sand and gravel lands occupy 28.8 %, while the corresponding percentages in the middle reaches is 4.1 % and even less in the lower reaches.

Table 1 Type and area of desertification land in Yarlung Zangbo River basin

Regions	Degree and type of desertification											
	Severe desertification		Moderate desertification				Slight desertification				Total	
	Mobile dunefield		Semifixed dunefield		Bare sand and gravel land		Fixed sand (dune) field		Semi-bare sand and gravel land			
	area (10^4 ha)	%	area (10^4 ha)	%	area (10^4 ha)	%	area (10^4 ha)	%	area (10^4 ha)	%	area (10^4 ha)	%
Upper reaches	6.9	43.5	8.0	33.6	76.2	54.2	3.8	32.1	54.6	44.7	149.5	47.6
Middle reaches	8.7	54.9	15.6	65.3	64.2	45.7	8.1	67.9	67.3	55.2	163.9	52.2
Lower reaches	0.2	1.6	0.3	1.1	0.1	0.1	0.0	0.0	0.1	0.1	0.7	0.2
Total	15.8	100.0	23.9	100.0	140.5	100.0	11.9	100.0	122.0	100.0	314.1	100.0

1.3 Desertification Damages

Various desertified lands in the Yarlung Zangbo River basin cause a variety of damages to the production and people's lives in the region (Table 2), such as productive land loss, soil wind erosion, nutrient loss, biological productivity reduction, pollution of air, water and food, agricultural and stock raising failures, shifting sand burying buildings, canals and roads etc. According to incomplete investigations in various prefectures in the basin, the

damages caused by desertification are quite serious, in some places the desertification even poses a serious threat to the local people's existence. For instance, the Zhongba County town in the upper reaches, moved to the present address in 1964, is now entirely surrounded by shifting sand, parts of streets have been covered by 20 - 60-cm sand layer and some houses have been entirely buried, which is forcing the residents of the town to select a new settlement.

Table 2 Damages and economic loss caused by desertification in the Yarlung Zangbo River basin

Regions	Damages					Annual direct economic loss ($\times10^4$ yuan)	Annual total economic loss ($\times10^4$ yuan)	Annual economic loss rate (yuan/km^2)	Per capita loss (yuan/person)
	Cultivated land ($\times10^4$ ha)	Grass land ($\times10^4$ ha)	Village (ind)	Highway (km)	Canal (km)				
Lhasa	0.33	5.33	2	21.0	3.0	981.0	3924.0	399.4	26.3
Nyingchi	0.01	7.02	8	11.3	13.0	580.2	2320.8	51.7	42.7
Shannan	0.37	1.33	2	20.0	5.0	984.0	3936.0	126.5	33.2
Xigazê	2.17	317.60	450	240.0	165.0	48000.0	192000.0	2385.7	823.5
Total	2.88	331.28	462	292.3	186.0	50545.2	202180.8	2101.8	465.8

2 ANALYSIS ON LAND DESERTIFICATION CAUSES IN THE YARLUNG ZANGBO RIVER BASIN

It is generally believed that desertification is an environment (land) degradation processes with wind drift activity as main mark in arid and semiarid areas resulting from the influences of climate changes and human activities (Dong *et al*., 1995). Similarly, the occurrence and development of land desertification in the Yarlung Zangbo River basin is also closely related to the eco-environment conditions, climatic changes and human activities.

2.1 Main Factors Affecting Desertification

Fragile eco-environment Although it is warm and humid in the lower reaches, cold and dry in the upper reaches, the climate of the Yarlung Zangbo River basin as a whole is dominated by the plateau's arid, semiarid and subhumid climate, and the arid zone occupies 70 % of the basin's total area, with an annual precipitation ranging from 150 - 400 mm (Zhang *et al*., 1982). In addition, owing to the influence of subtropical westerly jet, the altitude of high-level westerly jet in winter and spring is low, with higher speed. This coupling with high relief in the west and low relief in the east, makes the wind direction parallel to the river valley strike, enhances the wind intensity and frequency. Hence, wind in the region is strong, frequent and persistent, the highest wind velocity might reach up to 32.5 m/s, the maximum monthly mean wind velocity is 4.7 m/s and the maximum annual number of wind days is 172 days. Because wind season often occurs concurrently with dry season, soil wind erosion in the region is serious (Dong *et al*., 1994). The wide-valley depressions in the basin are distributed like a string of beads (Yang *et al*., 1983), water flow is slow in the wide-valley section, river course has numerous forks, aits and shallows, and thus forming numerous wide sandy or gravel alluvial and pluvial plains and wide-shallow stream beds. During the low water period in winter and spring, these alluvial and pluvial sandy river beds are exposed to surface and supply abundant sand material to the river valley. Owing to harsh natural conditions, the forest cover in the basin is very low, for example, the forest cover in Lhasa, Shannan and Xigazê areas are 0.15 %, 5.8 % and 0.54 % (LMBXAR, 1992) respectively, and large amount of sand material is directly exposed to the ground surface. Dry climate, frequent wind, sandy ground surface and sparse vegetation make the eco-environment of the region extremely fragile, all these provide a dynamic condition and material basis for the development of land desertification. In addition, the simultaneous occurrence of wind season, dry season and vegetation wilting also increases the intrinsic risk of land desertification.

Climate warming and drying The Qinghai-Xi-

zang Plateau as a sensitive region of environment evolution has very obvious response to the global changes (Li, 1992). Under the influences of the plateau's environmental changes, the climate of the Yarlung Zangbo River basin significantly became drier and warmer in recent years. The period from the 1950s to the 1960s was a rainy stage, then the precipitation decreased from the 1970s to the 1980s, although the precipitation increased in recent years it is much less than the end of the 1950s (Fig. 1, Table 3). The difference of precipitation anomaly percentage of the region in the 1980s and the period from the 1950s to the 1960s was over - 10.5 % and the corresponding value in Zetang area was - 22.3 %, suggesting a significant desiccation of the climate in the region. The temperature of the region was the lowest in the 1960s, higher in the 1970s, fluctuatedly rose in the 1980s and maintained higher temperature in recent years (Fig. 1, Table 4). The differences of temperature anomaly in various districts generally exceeded 0.2 ℃, of which it was 0.8 ℃ in Lhasa, suggesting a significant temperature rising phenomenon. With the rise in temperature and the falling in humidity, the evaporation of the basin increases, soil becomes drier and runoff decreases, all these lead to the further deterioration of the basin's eco-environment and promote the occurrence and development of desertification.

Table 3 Mean precipitation anomaly percentage and difference (%)

	Qinghai-Xizang Plateau (Dong *et al*., 1993)	Lhasa	Zetang	Xigazê	Nyingchi
1950s	+ 2.6	+ 3.5			+ 13.4
1960s	- 0.3	+ 9.5	+ 8.8	+ 10.7	- 2.5
1970s	- 0.4	+ 0.9	+ 4.7	- 1.5	- 3.3
1980s	- 2.4	- 11.7	- 13.5	- 9.1	+ 2.9
1960s - 1950s	- 2.9	+ 6.0			- 15.9
1970s - 1960s	0.0	- 8.6	- 4.1	- 12.2	- 0.8
1980s - 1970s	- 2.0	- 12.6	- 18.2	- 7.6	+ 6.2
Start-stop interval difference	- 5.0	- 15.2	- 22.3	- 19.8	- 10.5

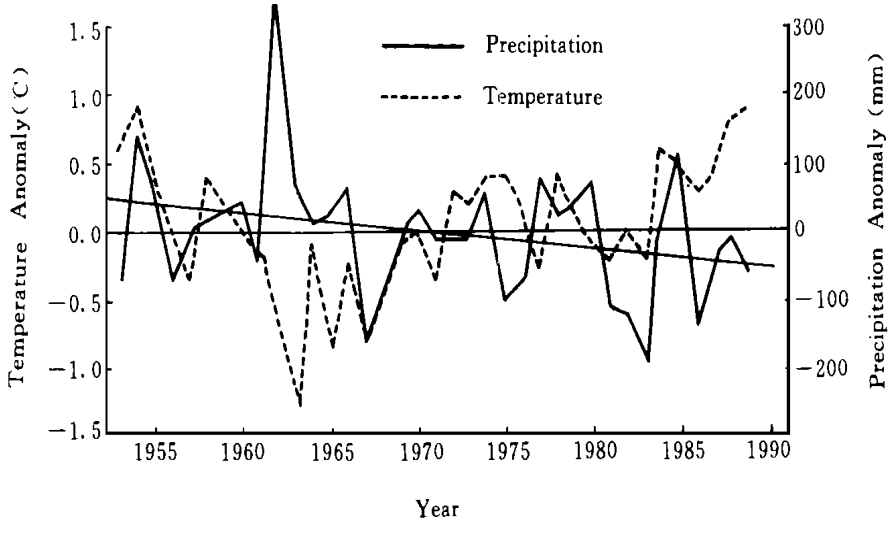

Fig. 1 Climate change curve of Lhasa

Over-exploitation of land resources The Yarlung Zangbo River basin is the birthplace of Tibetan nationality, also the central zone of Tibetan people's activity. The relation between man and environment in the region has developed from the stage of single natural renewable resource utilization to the stage of artificially intensifying

Table 4 Anomaly and difference of temperature (°C)

	Lhasa	Zetang	Xigazê	Nyingchi
1960s	- 0.5	- 0.2	- 0.2	- 0.1
1970s	0.0	- 0.2	0.0	0.0
1980s	0.3	0.2	0.2	0.1
1970s - 1960s	0.5	0.0	0.2	0.1
1980s - 1970s	0.3	0.4	0.2	0.1
1980s - 1960s	0.8	0.4	0.4	0.2

land reproductivity. In particular, the population in the region has more than doubled in recent several decades, per capital land and water share have greatly decreased, this leads to continuous enlargement of land exploitation in scale and intensity and thus results in over-exploitation of land resources, mainly manifesting in overgrazing, over-cutting and over-cultivation. For instance, the annual population growth rate in the central part of the middle reaches of the "One River and Two Tributaries" basin is 23.5‰, during the period 1959 - 1993 the cultivated land area increased from 8.47×10^4 ha to 10.08×10^4 ha and livestock population increased from 4.6169 million sheep units to 8.4944 million sheep units. In the same period the per capita cultivated land area decreased from 0.21 ha to 0.12 ha. Per animal occupying grassland area decreased from 1.03 ha to 0.56 ha. During the cold season the over-stocking rate reached up to 50.3%. Some 4000 - 6000 ha of natural shrub forest were destroyed for collecting fuel each year. In the 15 years from 1970 to 1985, the shrub forest with a coverage of over 40% has decreased by 70% in the Dangxun County north of Lhasa. Such irrational human activities inevitably exert an important influence on the development of desertification.

2.2 Analysis on Desertification Causes

The above analyses show that the eco-environment in the Yarlung Zangbo River basin is fragile, it has potential conditions and high risk of land desertification. In addition, the climate in the region is one of the most active eco-environment factor, climatic changes may cause eco-environmental alteration and lead to the directional and property changes of ground external agents, the climate desiccation and warming will inevitably bring about vast tract of land in the region to evolve towards desert-like environment. As a result, the over-exploitation of land resources in the region will further destroy the originally sparse vegetation and exacerbates the desertification processes. This shows that land desertification in the Yarlung Zangbo River basin is dominated by natural desertification process, and natural factors in combination with man-made factors accelerate such processes and make it fall into vicious cycle.

In order to further reveal the desertification causes, Zhanang County, a region located at middle reaches of the basin with macroscopic and microscopic representativeness, was selected to conduct quantitative analysis. At first, a principal component analysis was made to make clear the roles of climatic changes and human activities in the desertification processes (Table 5). The results show that whether in a large area or a small area of the basin, the load of man-made factor is the highest with respect to the first principal component. However, the load of climatic factor is not significantly different from that of man-made factor. As for the second principal component, the load of climatic factor is highest. Similarly, in the third principal component the load of man-made factor is the highest. This shows that climatic factors and man-made factors almost play an equally important role in the land desertification development of the Yarlung Zangbo River basin. Then, a comprehensive analysis of the effects of various factors on the desertfication processes and their relations to the desertified land area were conducted (Table 6). The results show that if only the climatic changes and the human activity conditions are taken into account, the correlation coefficient of per animal occupying grassland area, annual mean temperature, and annual precipitation is the highest., However, if all the factors are considered, the correlation coefficient of deflation-prone soil ratio and forest cover is the highest. This shows that various conditions and factors of the region play an important and decisive roles in the desertification development. On the other hand, the correlation coefficient of various factors does not show a significant difference, this implies the comprehensive effect of various factors.

Table 5 Load matrix of principal components

Factors	Entire basin			Zhanang county		
	First principal component	Second principal component	Third principal component	First principal component	Second principal component	Third principal component
Temperature	- 0.5354	0.7202	0.2671	0.1082	0.7301	- 0.5945
Precipitation	- 0.7842	0.0312	0.1790	- 0.6218	- 0.5851	- 0.1125
Wind velocity	0.7654	- 0.3700	0.2972	0.8398	- 0.3143	- 0.1286
Population density	0.5595	0.7163	0.3419	- 0.8980	- 0.1417	0.1598
Cultivation land area	0.4792	0.5213	- 0.6571	- 0.4116	- 0.3733	- 0.7584
Per animal occupying grassland area	- 0.8905	- 0.0479	- 0.2015	- 0.7921	0.2524	0.0836
Characteristic root	2.8231	1.4430	0.7809	2.7069	1.1991	0.9903
Contribution	47.0512	24.0608	13.0150	45.1152	19.9844	16.5058
Cumulative contribution	47.0512	71.1120	84.1270	45.1152	65.0996	81.6054

Table 6 Correlation coefficient of principal components

Entire basin		Zhanang county	
Affecting factors	Correlation coefficient	Affecting factors	Coefficient
Annual mean temperature	0.7393	Easily erodible soil area ratio	0.9775
Annual precipitation	- 0.4176	Forest cover	0.9574
Annual mean wind velocity	0.2295	Rainfed land area	0.8756
Rural population density	- 0.0170	Rural population density	- 0.2718
Cultivated land area	0.2766	Cultivated land area	0.9493
Annual per capita income	- 0.3182	Annual per capita income	- 0.0660
Per animal occupying grassland area	- 0.4189	Degraded grassland area	0.8893
Livestock population	0.8219	Livestock population	0.9480

3 THE ROLE OF MAN-MADE FACTORS IN THE LAND DESERTIFICATION OF THE YARLUNG ZANGBO RIVER BASIN

The role of man-made factors in the land desertification is a crucial issue and debating focus in desertification study (Dong *et al*., 1993a; Dong *et al*., 1993b). As for the study of desertification in northern China, it is generally believed that the main factor of desertification is man's improper economic activities (Zhu *et al*., 1981; Dong, 1992). The preceding analysis on land desertification causes in the Yarlung Zangbo River basin shows that so far as the desertification causes is concerned, especially the man-made factor is significantly different from that of vast region of northern China, it is a non-leading factor and has quite different acting ways.

3.1 Main Acting Ways of Man-made Factor

The main factors leading to desertification in mixed farming and grazing region in northern China at present are over-cultivation, over-grazing and over-cutting, dominated by over-cultivation (Zhu *et al*., 1989). Although the Yarlung Zangbo River basin is also a mixed farming and grazing region and also suffers from over-cutting, the main factor leading to desertification is over-grazing.

Over-cultivation According to natural resources and environment conditions of the Yarlung Zangbo River basin, it should adopt protective measures to energetically develop irrigation agriculture and properly develop rainfed agriculture. In fact, uncontrolled cultivation in the region is widespread without any protective measures. At present, effective irrigation land in the region is less than

60 % and various protective forest area is less than 6000 ha. Although the cultivated land area is expanding, its total area only occupies 0.66 % of the basin's total area, of which rainfed cultivated land accounts for 0.26 %, while the desertified land occupies 13.1 % of the basin's total area. This shows that although over-cultivation is a factor affecting the desertification in the region, it is not an important factor and only has limited effect.

Over-cutting Fuelwood occupies a certain percentage in the basin's living energy source, mostly collecting from natural shrub forests and steppe shrub, such as psammophile scholartree etc. However, fuelwood only constitutes a small percentage of the region's living fuel and quite a good deal of fuelwood collects from natural mountain shrub forest ratter than sandy land shrub. Hence, desertified land area directly caused by over-cutting is relatively small. In one word, over-cutting is not an important factor although it has a certain influence on the desertification of the region, for example, although the total desertified land area in the upper basin occupies 47.6 % of the entire region, it is seldom affected by cutting activities.

Over-grazing Although grazing has long been practised as a main landuse way in the mixed farming and grazing region of the basin, grassland productivity and carrying capacity are very low, especially in cold season. Continuously increasing livestock population exerts great pressure on grassland and causes overgrazing, the destruction of grassland vegetation and surface soil disturbance result in land desertification. For instance, the grassland area in the Lhasa region occupies 92.6 % of its total, of which the area with a fresh grass yield exceeding 6000 kg/ha only accounts for 3.4 % and the area with a fresh grass yield below 3000 kg/ha constitutes 76.4 %. The theoretical carrying capacities in warm season and cold season are 3.3755 and 1.3446 million sheep units respectively, over-stocking rates are 10.2 % and 225.9 % respectively, degraded grassland area is 44.6 $\times 10^4$ ha, or accounting for 21.15 % of the region's total area. In the Yarlung Zangbo River basin, overgrazing extent is large, over-grazing intensity is high and over-grazing duration is long, added to this, most wide-valley depressions in the basin are of prolonged over-stocking cold-season grasslands and over-grazing is serious. Hence, over-grazing is a leading man-made factor affecting land desertification of the basin.

3.2 Mechanism of Man-made Factor Action

The effects and action of man-made factors on the desertification are closely related to the destruction of primary vegetation and soil structure. Experiments demonstrated that once the soil structure has been destroyed (Zhu *et al.*, 1994), the soil erosion amount could increase tenfold or more. There exists a negative componental correlation between vegetation cover and soil wind erosion amount. Human activities, such as over-grazing etc. inevitably destroy ground vegetation and soil structure, accelerate wind erosion processes of sandy and gravel surface and thus lead to the occurrence and development of land desertification. For example, the animal trampling, on an average, could increase soil wind erosion amount by 21.2 %, under prevailing wind velocity it could increase by 66.7 %. With the increase in trampling and browsing intensity the soil surface deflation rate could increase 20-fold. The increase in grazing intensity of grasslands due to over-grazing, trampling and browsing leads to surface soil deflation and aggravates a series of sand drift activities. From this it follows that over-grazing is the leading man-made factor responsible for land desertification in the Yarlung Zangbo River basin, followed by over-cutting. And the influence of over-cultivation is an order of magnitude lower than the over-grazing. This conclusion is entirely consistent with the quantitative analytical results.

4 CONCLUSIONS

From above analysis one might reach the following conclusions: the Yarlung Zangbo River basin has three grades, namely slight, moderate and serious grades and five types of desertified lands, i.e. fixed sand (dune) land, semi-bare sand and gravel land, semi-fixed sand (dune) land, bare sand and gravel

land and shifting sand (dune) land, with a total area of 314.1 $\times 10^4$ ha or accounting for 13.1 % of the basin's total area. The distribution of desertified land in the basin has an intensive but relatively concentrated, discontinuous strip and patchy distribution features and geomorphologically they show a diversified characteristics.

Land desertification in the basin has caused a variety of damages to the production and people's lives, annual economic loss reached up to 2.02 billion yuan, annual direct economic loss rate 2101.8 yuan/km^3 and per capita economic loss 465.8 yuan. Hence this region is a serious desertification-hit area in China.

Main factors affecting land desertification in the basin are fragile eco-environment, climate warming and drying as well as undue human activities etc. As a whole, land desertification in the basin is a comprehensively interacted processes of natural factors and man-made factors based on potential factors (conditions), dominated by natural factors, among them the climate warming and drying and man-made activities almost play equally important roles. This suggests that the cause of desertification has a certain zonality.

Man-made factors play a quite different role in the desertification of the basin as compared with other regions of northern China. The roles of man-made factors only occupy a lower weight in the desertification of the basin, while the over-grazing is the leading man-made factor of land desertification and the role of over-cultivation is less significant. Human activities destroyed primary vegetation and soil structure, which in turn accelerates and aggravates land desertification of the basin. The severity of land desertification of the basin is proportional to the destruction scale and intensity of vegetation and soil structure.

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