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The service values' structure and change of different ecosystems of the protected area for water supply of city—taking the Yunlong reservoir of Kunming city as an example

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ABSTRACT

It is very important to study the value change of ecosystem services of the protected area for water supply of cities to wholly know the law and status of ecosystem services and its value of the protected area for water supply, and to supply scientific basis and decision references for the sustainable use of water resources and the management of the protected area for water supply. The paper structured an assessment system consisted of five indexes (food production, gas adjusting, climate adjusting, hydrology adjusting, and waste treatment) on the basis of the classification of ecosystem and its services, used Gaodi Xie et al.'s method for valuing ecosystem service on the basis of experts' knowledge, and studied on the services' value change of different ecosystems of the Yunlong reservoir. The result showed that the three service values of gas adjustment, climate adjustment, and hydrological adjustment were formed into a core service value of the forest ecosystem of the protected area for water supply; under the premise of ensuring food production service value, waste disposal service value of farmland ecosystem occupied a main status; water area ecosystem focused on hydrological adjustment service and waste disposal service. The service value of food production was mainly contributed by the forest and farmland ecosystems; the other four adjustment service values were mainly contributed by forest ecosystem.

Keywords: The service values' change; Different ecosystems; Protected area for drinking water supply of city; The Yunlong Reservoir of Kunming

1. Introduction

At present, the safety issue of drinking water is increasingly drawing an attention of the international organization; the United Nations has confirmed that the 2005–2015 is "ten years of international action for the water of life" [1]. For a long time, insufficient input and not enough ecological environment construction and protection resulted in the reducing of water yield, the descending of water quality, and the reducing of ecosystem service capacity in the area for water supply of city. One of the main reasons is that people do not treat water ecosystem services as

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a natural capital, which causes unsustainable behavior, such as waste of water resources and irrational use [2].

The study on ecosystem services and its value evaluation pays more attention on the international scope since putting forward the concepts of ecosystem services. The domestic study on value assessment of terrestrial ecosystems services has made a greater progress [3], but study on ecosystem services of the protected area for water supply is less. This paper studied structure and change of services value of different ecosystems taking the protected area for water supply of Kunming Yunlong reservoir as an example, to get a comprehensive knowing about characteristic and law of the ecosystem service and its value, and to provide scientific basis and decision reference for protection, utilization, and scientific management of water resources.

2. General situation of study area

2.1. Background of study area

Yunlong reservoir is currently the only one that reaches protection goal in six centralizing protected area for water supply of Kunming, occupying over 60% of the total water supply in the whole city, and a leading centralizing protected area for water supply in Kunming city [4] (Fig. 1).

Fig. 1. Administrative scope for protected area for water supply of Yunlong reservoir (Source: Water Resource Management Bureau in Luquan County).

2.2. General situation about natural geography and social economy of study area

The protected area for water supply of Yunlong reservoir is located in Yunlong village, Luquan county, north of Kunming, and the total basin is 745 km^2 long. Overall topography is that northwest is high and southeast is low, and the elevation of the highest and lowest point is 3,130 and 2,024 m, respectively. The climate type is northern subtropical monsoon climate. Forest coverage rate is 69.7%. The area of forestry land is the largest, occupying 69.1% of the land area; unused land occupies 13.6%; cultivated land occupies 10.4%; other agricultural land occupies 5%; building land occupies 1.5%; and garden occupies 0.4%.

The first industry is a backbone, and agriculture and animal husbandry are the main income sources; the third industry mainly includes transportation, wholesale and retail, accommodation catering and going out for work; the second industry lags, only has a little building and mining.

3. Types of ecosystem and ecosystem services of study area

3.1. Types of ecosystem

The protected area for water supply is a compound system of nature–economy–society, which can be divided into four ecosystem types: water ecosystem, forest ecosystem, farmland ecosystem, and town ecosystem (this study does not involve the town ecosystem). This division is conducive to combine the types of land use of the protected area for water supply and to obtain and use relevant data. The ratio of each ecosystem type in spacial scale can be referred to land use type.

3.2. Types of ecosystem services

Based on the classification of the *Millennium Ecosystem Assessment* [5,6], referenced Costanza et al. [7] and related research, considered the characteristics

and specificity of ecosystems of the protected area for water supply, ecosystem services were divided into five types: food production, gas adjustment, climate adjustment, hydrological adjustment, and waste treatment (Table 1). First of all the supply services is water resource which is direct value and can be calculated by water price. The paper pays more attention to consider the indirect value for the study area, so the supply services did not conclude water resources supply.

An important issue must be pointed out that a part of the ecosystem services cannot be directly used for human, which MA [5,6] referred to this part as "support services." The support services are those ecosystem services which are necessary to produce all other ecosystem services; their difference with supply services, adjustment services, and cultural services is that they affect human beings in an indirect way [8]. The "support services" of ecosystems is not the final product and it should not be valued; humans' benefit from the ecosystem can only be the final product. Support services, like the internal service of the general service sector, must maintain normal business, which can not be enjoyed by customers, so it should not be calculated. Yuanzhao Hou et al. also disagree on valuing such as "forest nutrient accumulation" service [9]. Therefore, this study does not evaluate the value of support services and cultural services of ecosystems of the protected area for water supply.

4. Research method and data sources

The paper studied the structure and changes of the value of different ecosystems' supply service and adjustment service on the protected area for water supply of Yunlong reservoir of Kunming with a method of ecosystem service valuation based on experts' knowledge by Xie et al. [10].

The annual area data of each ecosystems of the protected area for water supply were based on the data of corresponding land use types and statistical data were obtained from relevant references. The water ecosystem area data in 2008 were obtained by adopting the Worldview-1 full color image data of 10 July 2008, applying eCogniton developer (Yi Kang) image processing software and ArcGis9.2 geographical information system, and using the method of combining object-oriented classification and visual interpretation to extract relevant information on the basis of a large number field work. Specific methods and steps are as follows:

(1) Economic value of food production service offered by a unit area of farmland ecosystem.

The study treated corn, barley, potato, and wheat with larger sowing area or statistic area as the main crop types, used per unit yield, nationwide average price data of five years, etc. to calculate the economic value of the natural grain's unit yield of unit area of farmland every year according to the formula (1) [10].

$$E_a = \frac{1}{7}\sum_{i=1}^{n}\frac{m_i p_i q_i}{M} \quad (i = 1, \ldots, n) \tag{1}$$

In the formula: E_a—the economic value of food production services provided by per unit area of

Table 1
Types and descriptions of ecosystem service

Level types	Level 2 types	Comparing with the classification of Constanza	Ecosystem types and descriptions
Supply services	Food production	Food production	Farmland, forests, waters
	Production of raw materials	Production of raw materials	Do not have
Adjustment services	Gas adjustment	Gas adjustment	Waters, forests, farmland
	Climate adjustment	Climate and disturbance adjustment	Waters, forests, farmland
	Hydrological adjustment	Water adjustment, water supply	Waters, forests, farmland
	Waste treatment	Waste treatment	Waters, forests, farmland
Support services	Maintain soil	Erosion control maintains the sediment, soil formation, nutrient cycling	Have but without evaluation
	Biodiversity maintenance	Pollination, biological control, habitats and genetic resources	Have but without evaluation
Cultural services	Providing esthetic landscape	Leisure entertainment, culture	Do not have

farmland ecosystem (CNY/ hm^2); i—types of crops, the major crops are corn, barley, potatoes, and wheat (depending on sown area); p_i—the national average price of type i crops (CNY/t); q_i—the per unit yield of type i crops (/hm^2); m_i—The crop area of type i crops (hm^2); M—the total area of n types food crops (hm^2); 1/7—the economic value of natural ecosystems without human input is 1/7 of the economic value of food production services provided by the current unit area of farmland.

The unit price of food production service provided by ecosystems of the Yunlong Reservoir each year, respectively, were: 663.74CNY/hm^2 (1995), 794.23 CNY/hm^2 (2004), 507.73 CNY/hm^2 (2006), 599.64 CNY/hm^2 (2007), 714.33 CNY/hm^2 (2008).

(2) Ecosystem services value of unit area of ecosystems.

Used the latest Chinese ecosystem services value equivalent of ecosystem unit area developed by Xie et al. [10], multiplied by unit price of food production services to give each ecosystem service price of Yunlong reservoir each year.

(3) Ecosystem services value.

According to unit price of ecosystem services and ecosystems area, using the formula (2), the total economic value of ecosystem services of Yunlong reservoir each year (Table 2) was calculated.

$$V = \sum_{i=1}^{5} \sum_{j=1}^{3} A_j E_{ij} \quad (i = 1, 2, \ldots, 5; j = 1, 2, 3) \tag{2}$$

In the formula: V is the total value of ecosystem services (CNY), A_j is the area of j types of ecosystems, E_{ij} is unit price of i type's ecosystem services of j types of ecosystems (CNY/ hm^2 a), i is the type of ecosystem service, and j is ecosystem types.

5. Result and analysis

5.1. Structure and change of all types of service value of different ecosystems

5.1.1. Forest ecosystem

Service value of food production was always the least; service value of waste treatment took the second place; and the main service values were gas adjustment, climate adjustment, and hydrology adjustment in all service value each year, which showed the main value structure of forest ecosystem services (Fig. 2). The change tendency chart showed that the value of food production service fluctuated nearly 0.1 hundred million CNY, and the curve was more straight which showed that the value was stable; the value of waste treatment service fluctuated nearly 0.4–0.6 hundred million CNY, and experienced the change from increasing to decreasing before 2006, and had a tendency of steady growth after 2006; and the core of forest ecosystem service value onsisted of the main three ones: gas adjustment, climate adjustment, and hydrology adjustment in which change curves were very similar (Fig. 3).

5.1.2. Farmland ecosystem

The service value of waste treatment of farmland ecosystem occupied main position on the premise of guaranteeing basic service value of food production. The three service values, viz. gas adjustment, climate adjustment, and hydrology adjustment, had some contribution in different year, which showed that the service value of farmland ecosystem was very all-sided. However, the numerical value was lower, and the highest one only approached 0.25 hundred million CNY (0.249 hundred million CNY for 2004) (Fig. 4). The change tendency chart showed that all service

Table 2
The annual ecosystem service value of the study area. Unit: × 10^8 CNY

Classify	1995	2004	2006	2007	2008
Farmland	0.72 (11.6%)	0.87 (11.8%)	0.27 (6.0%)	0.29 (5.6%)	0.32 (5.2%)
Forest	4.67 (75.4%)	5.56 (75.3%)	3.26 (72.0%)	3.92 (75.2%)	4.81 (78.3%)
Water	0.80 (12.9%)	0.95 (12.9%)	1.00 (22.0%)	1.00 (19.2%)	1.01 (16.4%)
Total value	6.19 (100%)	7.38 (100%)	4.53 (100%)	5.21 (100%)	6.14 (100%)

Note: In the case of the absence of the water area of data of 2006 and 2007. Take the average of the total value of ecosystem services of water ecosystems 1995, 2004 as the ecosystem service value in 2006 and 2007, that is assuming that both of the total value of the water ecosystem services in 2006 and 2007 were 100 million CNY.

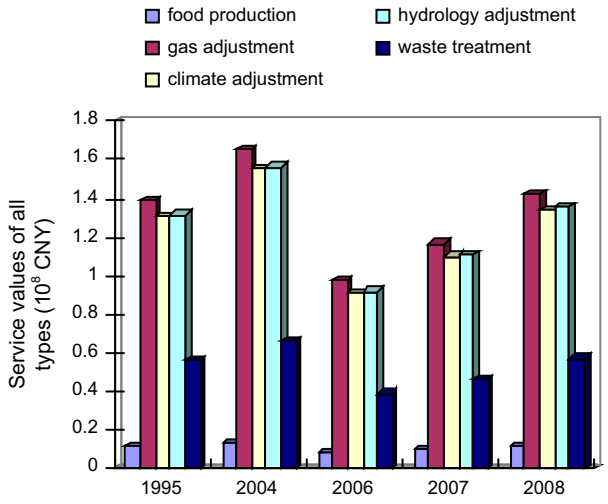

Fig. 2. Value composition for all types of service of forest ecosystem.

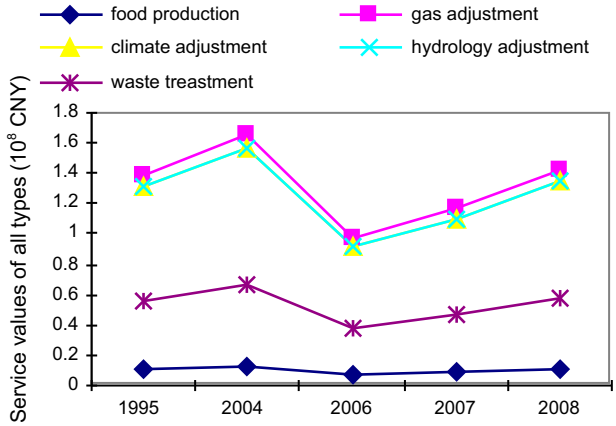

Fig. 3. Value change tendency for all types of service of forest ecosystem.

values maintained 0.05–0.1 hundred million CNY after 2006, had slight increasing and more stable trend relatively from 2006 to 2008 after the change from increasing to decreasing before 2006. Interestingly, change curves for all service values of farmland ecosystem were very similar, which together formed the service value of farmland ecosystem (Fig. 5).

5.1.3 Water ecosystem

Both the service value of food production and gas adjustment maintained 0.011–0.015 hundred million CNY, and can almost be ignored relative to service value of hydrology adjustment and waste treatment occupying absolute advantage, which was very identical with properties and function of water ecosystem of

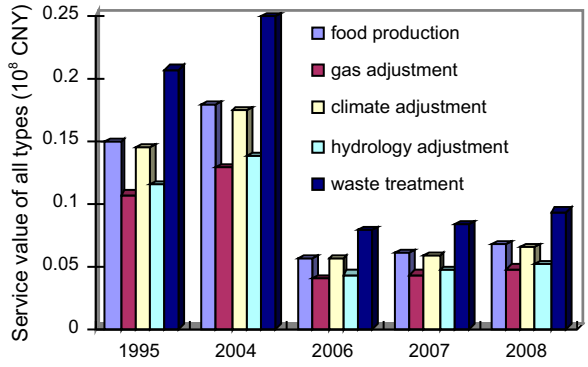

Fig. 4. Value structure for all types of service of farmland ecosystem.

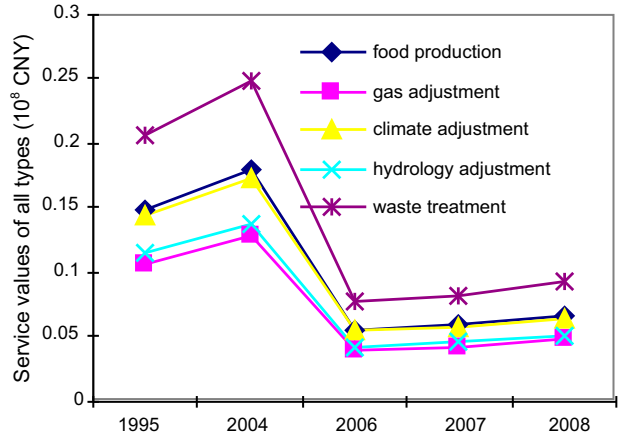

Fig. 5. Value change tendency for all types of service of farmland ecosystem.

the protected area for water supply of the city. In addition, water ecosystem contributed to the service value of climate adjustment in different years, and the numerical value kept about 0.05 hundred million CNY (Fig. 6). The change tendency chart showed that the change tendency cannot be distinguished before and after 2006 and 2007 because of data deficiency of the two years, but, positively, the service value of hydrology adjustment was similar to waste treatment, and the change curve of the service value of climate adjustment and gas adjustment were similar to food production, which showed that the service value of water ecosystem was mainly hydrology adjustment and waste treatment (Fig. 7).

5.2. Contribution of different ecosystem to different service values

The service value of food production was mainly contributed by forest and farmland ecosystem of the

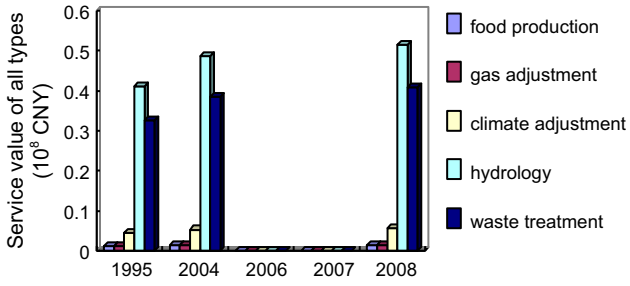

Fig. 6. Value structure for all types of service of water ecosystem.

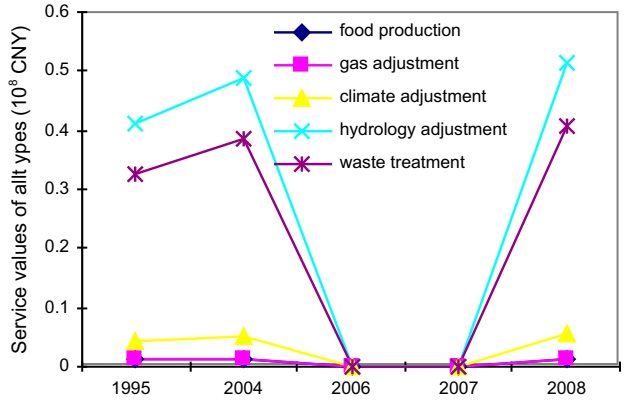

Fig. 7. Value change tendency for all types of service of water ecosystem.

protected area for water supply (Fig. 8). The contribution of farmland ecosystem was higher than forest ecosystem in 1995 and 2004, contrary from 2006 to 2008. This service value of forest ecosystem maintained nearly 0.1 hundred million CNY and had a further increasing trend after experiencing a low ebb in 2006; this one of farmland ecosystem reduced sharply to 0.05 hundred million CNY after a peak (nearly 0.15 hundred million CNY) in 2004, and the range almost reached to about 70%.

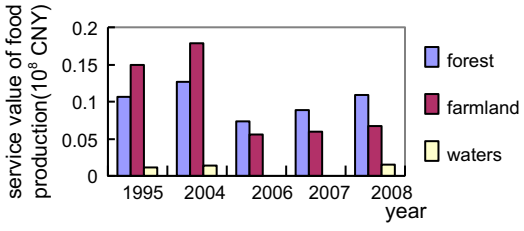

Fig. 8. Service value of food production of different ecosystems.

The service value of gas adjustment was mainly contributed by forest ecosystem of the protected area for water supply, and the contribution of farmland and water ecosystem can be ignored (Fig. 9). This service value of forest ecosystem increased further after a low ebb in 2006, and will maintain nearly 1.5 hundred million CNY.

The service value of climate adjustment was also mainly contributed by forest ecosystem of the protected area for water supply, and the contribution of farmland and water ecosystem can also be ignored (Fig. 10). As a whole, the change trend of the service value of climate adjustment was very similar to gas adjustment.

The service value of hydrology adjustment was mainly contributed by forest ecosystem of the protected area for water supply and then by water ecosystem, and the contribution of farmland ecosystem can be ignored (Fig. 11). This service value of forest ecosystem also increased further after a low ebb in 2006, and will maintain 1.0–1.5 hundred million CNY. The contribution to this service value of water ecosystem was more stable, the numerical value was nearly 0.5 hundred million CNY, and the change trend of the service value was also very similar to gas adjustment and climate adjustment.

The service value of waste treatment was contributed together by forest ecosystem, water ecosystem, and farmland ecosystem of the protected area for

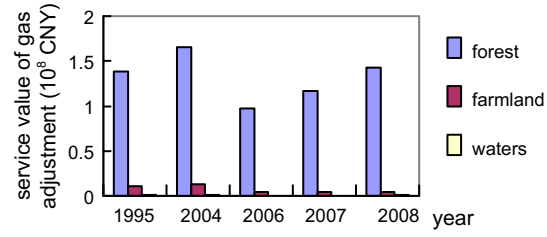

Fig. 9. Service value of gas adjustment of different ecosystems.

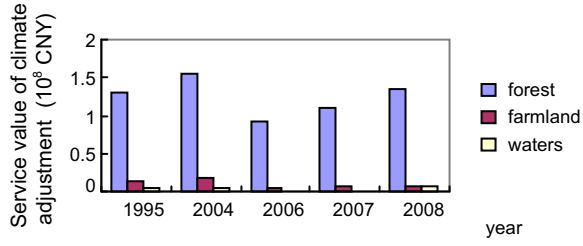

Fig. 10. Service value of climate adjustment of different ecosystems.

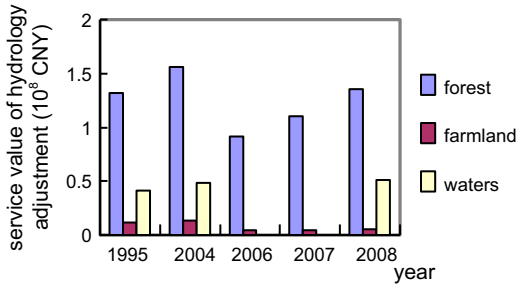

Fig. 11. Service value of hydrology adjustment of different ecosystems.

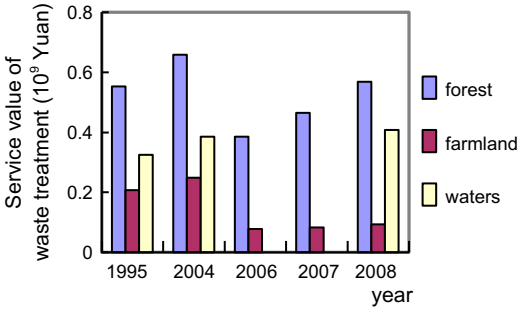

Fig. 12. Service value of waste treatment of different ecosystems.

water supply, but the degree of the contribution of forest, water, and farmland ecosystems was successively from high to low (Fig. 12). The contribution of farmland ecosystem decreased to below 0.1 hundred million CNY (0.078, 0.083, and 0.093) during 2006–2008 from above 0.2 hundred million CNY (0.207 and 0.249) in 1995 and 2004. This service value of forest ecosystem increased further after a low ebb in 2006, and will maintain 1.0–1.5 hundred million CNY. The contribution to this service value of water ecosystem was more stable, the numerical value was nearly 0.4 hundred million CNY, and increased to 0.408 hundred million CNY in 2008 with the process from 0.325 hundred million CNY in 1995 to 0.385 hundred million CNY in 2004; the increasing rate reached to 25.54% among 13 years.

6. Conclusions

(1) Structure and change of all types of services' value of different ecosystems.

Service value of food production of forest ecosystem was always the least; service value of waste treatment took the second place in all service value each year; and the main service value was consisted of gas adjustment, climate adjustment, and hydrology adjustment, which had a clear increasing trend after 2006.

The service value of waste treatment of farmland ecosystem occupied main position on the premise of guaranteeing basic service value of food production, which should be led to be noticed. The three service values, viz. gas adjustment, climate adjustment, and hydrology adjustment, had some contribution in different year, but the numerical values were lower. The slight increasing trend was more stable relatively from 2006 to 2008.

Both the service value of food production and gas adjustment can almost be ignored relative to service value of hydrology adjustment and waste treatment occupying absolute advantage, and the service value of waste treatment should pay more attention. In addition, water ecosystem contributed to the service value of climate adjustment in different years, and the numerical value was not so high.

(2) Contribution change of different ecosystems to different service values.

The service value of food production was mainly contributed by forest and farmland ecosystem of the protected area for water supply. The contribution of farmland ecosystem was higher than forest ecosystem in 1995 and 2004, contrary to 2006–2008. This service value of forest ecosystem had a further increasing trend after experiencing a low ebb in 2006; this one of farmland ecosystem reduced sharply to 0.05 hundred million CNY after a peak in 2004, and the range almost reached to about 70%.

The service values of gas adjustment, climate adjustment, and hydrology adjustment were mainly contributed by forest ecosystem of the protected area for water supply. The three service value had a further increasing trend after a low ebb in 2006. The contribution of water ecosystem to hydrology adjustment was more stable.

The service value of waste treatment was contributed together by forest ecosystem, water ecosystem, and farmland ecosystem of the protected area for water supply, but the degree of the contribution of forest, water, and farmland ecosystems was successively from high to low. The contribution of farmland ecosystem presented a decreasing, forest ecosystem increased further after a low ebb in 2006, and water ecosystem was more stable, and the increasing rate reached to 25.54% among 13 years.

The reason why 2006 is a turning point for all values was that 2006 was a divide; the reservoir finished successfully to store water in that year.

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