Using Remote sensing and GIS to survey surface water in Hanoi, Vietnam

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Abstract. Surface water plays a vital role in the living environment. The shrinking surface water area in urban areas is one of the main culprits causing serious environmental problems such as flooding, ecosystem imbalance, etc. In Vietnam, surface water area in the urban center is rapidly declining due to urbanization, especially in the capital - Hanoi, where the urbanization rate is highest. This study examines the mutation in surface water area in several central districts in Hanoi through the period of 1993-2020 using remote sensing images and GIS. The result shows that the surface water area in the research region decreased gradually over the years from 5881.2 hectares to 4328.7 hectares. This parameter dropped more steeply in recently established districts and those adjacencies namely Thanh Tri, Gia Lam, and Dong Anh than in central districts, Hoan Kiem and Hai Ba Trung for instance. Especially, In 2000 and 2007 the rate of reduction was highest. This finding is useful for urban planners, managers, and policymakers involved in Vietnam's sustainable urban development process.

Keywords: GIS, remote sensing, urban management, water surface management

1 Introduction

On Earth, most water is bound in the oceans, in ice caps, or stored as groundwater or ground ice. Only a small percentage (ca. 0.01%) of Earth's water resources is fluid inland water. Surface water is any body of water found on the Earth's surface, including both the saltwater in the ocean and the fresh water in rivers, streams, lakes reservoirs, and ponds. Surface water bodies are the main source of freshwater for all human beings. Water is one of the vital components of the ecological environment, which plays an important role in

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human survival and socioeconomic development[1]. One of the most vital natural resources is water, these water resources are becoming increasingly strained throughout the world[2]. Under the effects of climate change and human activities, the spatial and temporal distribution of water bodies has been changing, and the shortage of water resources is becoming increasingly serious worldwide[3]. Water information is widely used for many purposes[3], it is also important in land use planning, development and protection of the environment, as well as flood protection and mitigation, urban management [4, 5].

In Vietnam, the water surface area is much narrowed due to the urbanization process, especially the water surface area in large urban areas, including Hanoi city.

Hanoi went through major city planning stages in 1998[6] and 2008[7] with the expansion of administrative boundaries and many policies and projects for infrastructure, urban development, and shrinking surface water. The rapid development of urbanization in the last decades has greatly changed the spatial distribution and the area of the surface water body in Ha Noi. There have been statistical studies on changes in surface water in Vietnam by traditional methods, which have not provided an overview of space and time, quantitative and qualitative. This is important information for urban planners and managers in planning, management, and decision-making in the process of sustainable urban development.

Hanoi has had a change in surface water area in the period 1993-2020, the change in surface water area has caused many harmful impacts on the environment. The statistics on the database as well as the maps showing the spatial distribution of the water surface over the years are not available or incomplete due to statistics by traditional methods, without the application of remote sensing images. and GIS.

Since the 1970s, researchers have conducted a considerable amount of research on the extraction of boundaries between water bodies and other ground-based objects [8-10]. Remote sensing provides information about objects at or near the surface of the Earth and atmosphere based on radiation reflected or emitted from those objects[11, 12]. Remote sensing techniques, with their advantages of large area coverage, integration, speed, and periodicity, have been widely used to delineate surface water [9, 13, 14]. Remote sensing techniques play a crucial role in monitoring water bodies and assessing river dynamics, providing effective support to surface water management[15]. Remote sensing technology has become indispensable in monitoring changes in water bodies due to its characteristics of high spatio-temporal coverage[16]

Over the past decades, various methods mapping surface water using satellite imagery and GIS[17, 18] with many software. ArcGIS is a general-purpose GIS software system developed by ESRI. It is an extensive and integrated software platform technology for building operational GIS[19]. Using ArcGIS software to create maps showing the change of water surface area in space and time over the years of the study area. In addition, the study used tools in ArcGIS software to quantify the change of water surface area. This information is stored in the GIS database system to support managers in storing, stacking data, and analysing spatially.

2 Study site and data

Hanoi is the capital of Vietnam, which is located along the banks of the Red River, in the center of Northern Vietnam. Hanoi is now located from 20°53' to 21°23' North latitude and 105°44' to 106°02' East longitude. Hanoi is an ancient city that had been established and developed for almost 1,000 years since 1010. Hanoi region, lying on a plain, far from the sea, belongs to the hot climatic zone under the influence of the South and Northeast monsoons. Location and shape of the area are shown in Figure 1.

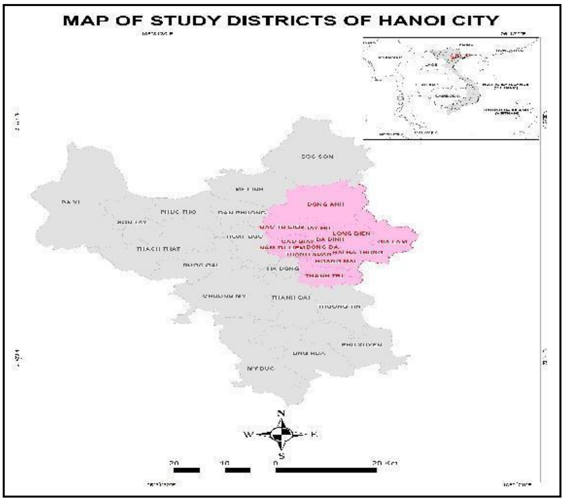

Figure 1. Map of the Study Area

The study area includes central districts in Hanoi, where the urban development rate is significantly high and there are many ponds and lakes that were leveled and alternated by tall buildings and new urban areas. Pollution and flooding increased sharply during the study period.

3 Data collection

Landsat image data types from Landsat 8 were acquired from the internet in order to achieve the study's final goal. These satellite photos were captured in 1993, 2000, 2007, 2015, and 2020 (table 1). The selection of these years is based on the period of transition in Hanoi's planning, for instance 1993 being the year following the 1986 renovation year and prior to the Government's decision to expand Hanoi's administrative boundaries in 2008. Thanks to this plan, many peri-urban districts were upgraded to districts whereas numerous urban construction and development projects have been carried out so far. The satellite photos selected at the moment of capture are not cloud-encrusted and are not limited to flood season.
The administrative boundary map of Hanoi and the traffic map are also used in the study to investigate the change of surface water according to districts and traffic belts.

Table 1. Remote sensing images

Satellite	Study Years	Wavelength (µm)	Band	Spatial Resolution (meters)
Landsat 5 (TM)	1993	Band 1: 0.45 – 0.52	Blue	30
		Band 2: 0.52 – 0.60	Green	30

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		Band 3: 0.63 – 0.69	Red	30
		Band 4: 0.76 – 0.90	Near IR	30
		Band 5: 1.55 – 1.75	Mid IR	30
		Band 6: 10.4 – 12.5	Thermal	120
		Band 7: 2.08 – 2.35	SWIR	30
Landsat 7 (ETM+)	2000	Band 1: 0.450 – 0.515	Blue	30
		Band 2: 0.525 – 0.605	Green	30
		Band 3: 0.630 – 0.690	Red	30
		Band 4: 0.760 – 0.900	Near IR	30
		Band 5: 1.550 – 1.750	Mid IR	30
		Band 6: 10.40 – 12.5	Thermal	60
		Band 7: 2.080 – 2.35	SWIR	30
		Band 8: 0.52 – 0.92	Pan	15
Landsat 5 (TM)	2007	Band 1: 0.45 – 0.52	Blue	30
		Band 2: 0.52 – 0.60	Green	30
		Band 3: 0.63 – 0.69	Red	30
		Band 4: 0.76 – 0.90	Near IR	30
		Band 5: 1.55 – 1.75	Mid IR	30
		Band 6: 10.4 – 12.5	Thermal	120
		Band 7: 2.08 – 2.35	SWIR	30
Landsat 7 (ETM+)		Band 1: 0.450 – 0.515	Blue	30
		Band 2: 0.525 – 0.605	Green	30
		Band 3: 0.630 – 0.690	Red	30
		Band 4: 0.760 – 0.900	Near IR	30
		Band 5: 1.550 – 1.750	Mid IR	30
		Band 6: 10.40 – 12.5	Thermal	60
		Band 7: 2.080 – 2.35	SWIR	30
		Band 8: 0.52 – 0.92	Pan	15
Landsat 7 (ETM+)	2015	Band 1: 0.450 – 0.515	Blue	30
		Band 2: 0.525 – 0.605	Green	30
		Band 3: 0.630 – 0.690	Red	30
		Band 4: 0.760 – 0.900	Near IR	30
		Band 5: 1.550 – 1.750	Mid IR	30

		Band 6: 10.40 – 12.5	Thermal	60
		Band 7: 2.080 – 2.35	SWIR	30
		Band 8: 0.52 – 0.92	Pan	15
Landsat 8-9 (OLI_TIRS)	2020	Band 1: 0.430 – 0.450	Coastal aerosol	30
		Band 2: 0.450 – 0.510	Blue	30
		Band 3: 0.530 – 0.590	Green	30
		Band 4: 0.640 – 0.670	Red	30
		Band 5: 0.850 – 0.880	Near Infrared (NIR)	30
		Band 6: 1.570 – 1.650	SWIR 1	30
		Band 7: 2.110 – 2.290	SWIR 2	30
		Band 8: 0.50 – 0.680	Panchro matic	15
		Band 9: 1.360 – 1.380	Cirrus	30
		Band 10: 10.60 – 11.19	Thermal Infrared (TIRS) 1	100
		Band 11: 11.50 – 12.51	Thermal Infrared (TIRS) 2	100

4 Methodology

4.1 Workflow

Object-oriented classification method is adopted in this study to extract the water surface layer from satellite images in high accuracy. The object-oriented image analysis method is developed based on concept of image objects [20, 21]. This is now one of the most prominent ways for extracting land use patterns through the physical features of ground objects from images[21-23].

The administrative boundary map of Hanoi and the traffic map of Hanoi were collected to accomplish the outcomes of the satellite image analysis. The procedure was divided into three stages (figure 2): pre-processing, processing, and post-classification, with the following steps:

1. image pre-processing including geometry correction, image enhancement.
2. set rule to separate water surface layer on Ecognition software.
3. Evaluate accuracy.
4. transfer results of water surface layer into GIS system on ArcGIS software.
5. water surface change: a) in study area; b) in each district; c) according to the traffic ring.

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6. map of surface water.

4.2 Multi segmentation

Multi-segmentation algorithm to fragment the image is performed based on the selection of weights on shape, scale parameters, compactness, smoothness. These parameters are changed aligning with each scene. Because of the mixture of moist soil and water surface areas, the parameter selection in image fragmentation must be carefully explored. The scale parameter, which is frequently described in terms of pixel size, is also a significant aspect of comprehending information on a picture. In this study, the parameter group for analysis is selected starting from the following group: Scale parameter: 50; shape parameter: 0.75; compactness parameter: 0.5; then parameter adjust these parameters several times. We eventually decided to choose the group: scale parameter: 10; shape: 0.5; compactness: 0.5 to extract water surface.

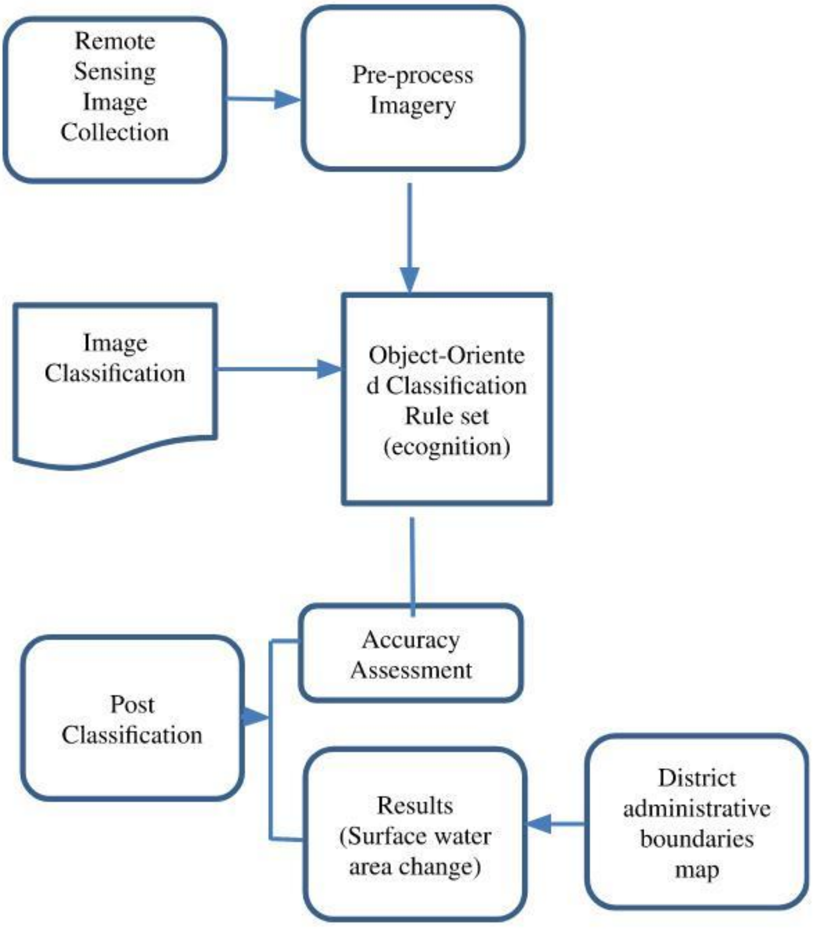

Figure 2. Workflow of study

4.3 Developing the rule sets

The rule set is significant in water surface classification because it prevents the water surface from wet soil areas. As this study is only focused on the water surface layer, we will divide the entire image into two main classes: 1) The surface layer of water (including rivers, lakes, canals, etc.) 2) The rest part. The brightness feature in mean in Layer values is employed in this research to survey and extract water surface. The results of the image processing surveys suggest that the brightness value in the rule set is less than 30 and it is possible to separate the moist soil layer from the water surface area.

4.4. Accuracy Evaluation

The Kappa index is adopted to assess the accuracy of classification findings[24-26]. The software utilized to assess classification results includes Global Mapper; XtoolPro in ArcGIS; and GoogleEarth. The number of sample points was chosen based on the formula, and the results revealed that the classified images achieved high accuracy, with the Kappa index ranging from 0.8 to 0.9 for 4 scenes.

5 Result and Discussion

The water surface area is calculated using the Calculate Geometry tool in ArcMap software and compared with each other through the overlay of maps of each year. A surface water area map was established using ArcGIS software (figure 3) depicts the change in surface water area by space; surface water polygons vanished during the research, most notably in the north-eastern region.

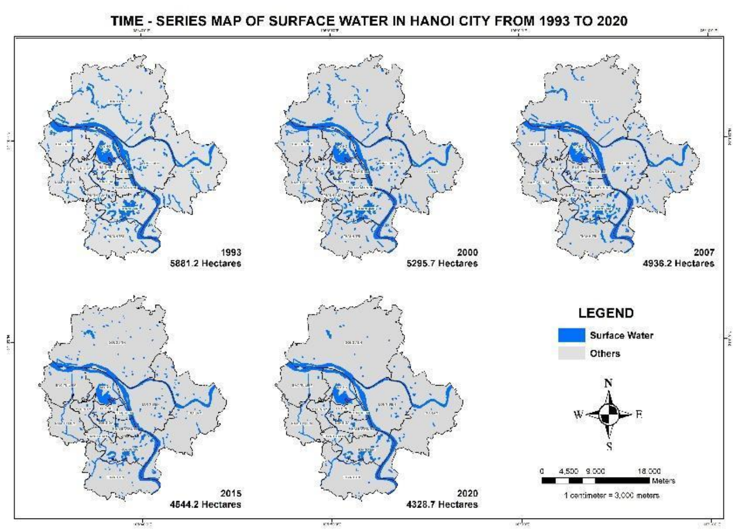

Figure 3. Map of surface water area

The surface water area mutated remarkably between 1993 and 2020, as illustrated by figure 4 below. The overall picture has been that surface water area has decreased sharply from 5881.2 hectares to 4328.7 hectares. Especially, the period from 1993 to 2007 witnessed the greatest loss despite the two Hanoi master plans adopted in 1998 and 2008.

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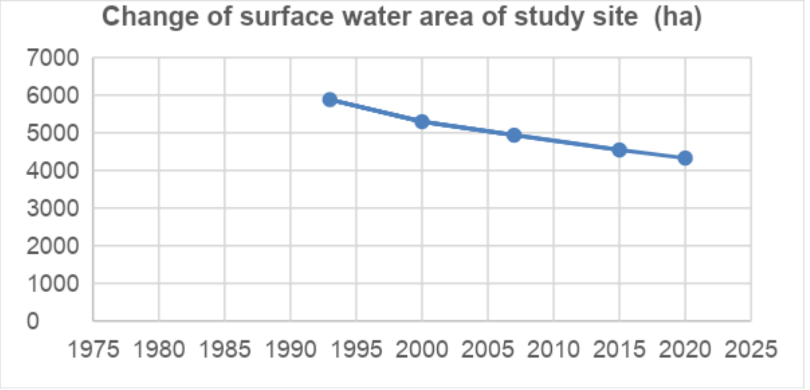

Figure 4. The change of surface water area (in hectares)

The change in surface w in surface water area for four districts namely Hoan Kiem, Ba Dinh, Hai Ba Trung, and Dong Da, which were established in 1981 and are located in the study area's center. The rates of reduction of water surface area are insignificant except from Ba Dinh district, where the surface water area reduced from 128.3 hectares to 98 hectares from 1993 to 2000. Of the four inner city districts, Ba Dinh district lost the most surface water area (43.1 hectares), the remaining districts ranged from 10 hectares to 16 hectares over 30 years.

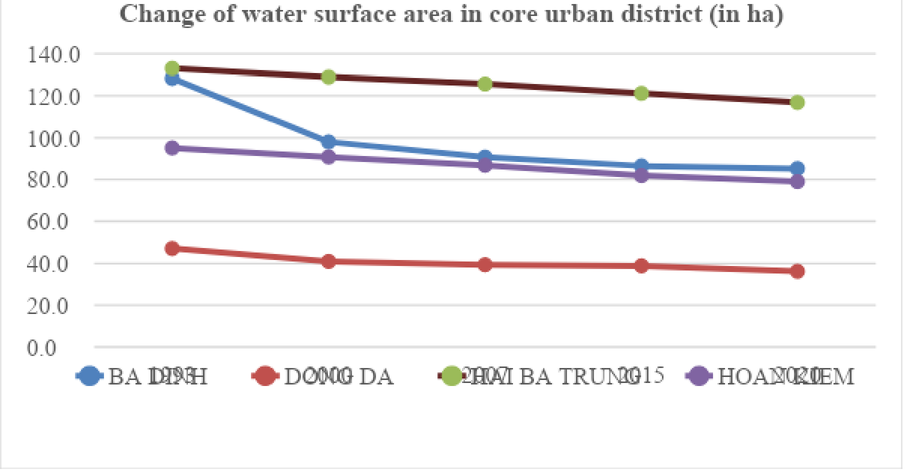

Figure 5. Surface water area of centre districts (in hectares)

New districts established after planning approval decision include Cau Giay, Tay Ho, and Thanh Xuan in 1995-1996, and Long Bien, Hoang Mai in 2003. Although the water surface area of the Thanh Xuan and Cau Giay districts is approximately equal, Thanh Xuan's water surface area is more depleted when decreasing by 14.9 hectares. Established at the same time, in 2020, Tay Ho shrinks the most surface water area from 824.5 hectares to 671.2 hectares. Between 1993 and 2000, the surface water area in Hoang Mai district decreased by only 70 hectares; however, when the district's establishment was decided in 2003, the area of surface water dramatically dropped 214 hectares. Similarly in Long Bien district, after nearly 30 years, the surface water area has lost 142 hectares (figure 6).

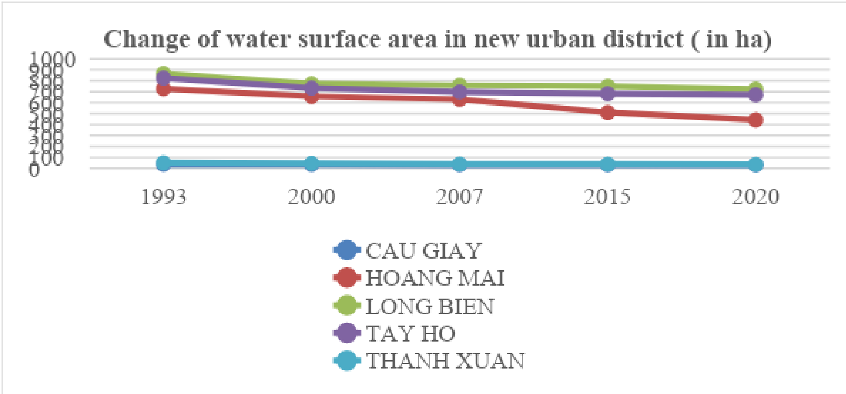

Figure 6. Surface water area of new districts (in hectares)

This research also investigated four Hanoi suburbs that were formed in 1961 namely Tu Liem, Dong Anh, Gia Lam, Thanh Tri. In 2013, the Tu Liem district was divided into the Nam Tu Liem and Bac Tu Liem districts in accordance with the Prime Minister's decision on boundary adjustments. The findings in figure 7 demonstrate that the surface water area is linearly decreasing in each of these districts. Dong Anh district has the highest rate of reduction in nearly 30 years with a figure of 340 hectares, particularly in the period from 1993 to 2000 the maximum surface water loss area reached 226 hectares, then gradually decreased over the years. While the rate of surface water shrinkage in the Nam Tu Liem steadily declines from 2007 to 2020, it is pretty comparable in Bac Tu Liem and Thanh Tri from 2000 to 2015.

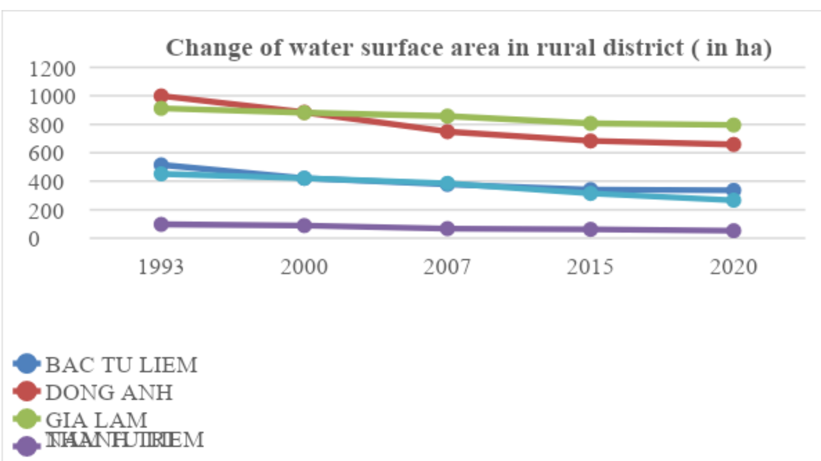

Figure 7. Surface water area of rural districts (in ha)

6 Conclusion

This study reiterates the superiority of Remote Sensing data in studies of land cover change, which provides spatial continuity and temporal consistency and low-cost [27-29]. Remote sensing has the advantages of real-time, wide coverage, and rich information and has become a brand-new technical means to quickly obtain water information to support surface water monitoring[2].

Because remote sensing data comes in a variety of formats and resolutions, the right remote sensing picture must be selected based on the aim and scope of the research. In this investigation, we employed Landsat remote sensing data that was publicly available which provided the requisite accuracy classification findings.

Furthermore, it is apparent that the employment of object-oriented classification methods in satellite image classification results in high accuracy. Combining indicators in the rule set, such as the Brightness index, to distinguish the water surface layer, for example, results in high accuracy and time-saving.

The integration of remote sensing and GIS has resulted in the creation of precise surface water maps that facilitate spatial and temporal analysis, as well as qualitative and quantitative analysis of the land cover reduction process. This successfully assists city planners and managers.

The set of digital maps and GIS database on surface water area of the study area in the period from 1993 to 2020 support urban managers of districts in the study area and Hanoi city. more statistical data from remote sensing and GIS perspectives.

Because Landsat data is openly accessible, it is a data source that is frequently used in other studies. Following that, we intend to use a model to investigate urban flooding issues in conjunction with some other parameters such as altitude and annual purchase volume in the districts with the greatest declining water surface area.

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