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High Resolution Satellite Data for Land Use/Land Cover Mapping - A Case Study of Bilara Tehsil, Jodhpur District

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Abstract: The availability of high-resolution Indian satellite data from IRS P-6 LISS-IV has made a significant impact on the mapping potential of natural and man-made resources. Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring anthropogenic changes in the arid western Rajasthan. High-precision land-use land-cover GIS mapping was carried out using IRS-P6 LISS-IV-MX data of 2011-12 and information was also generated on existing land use/land cover with their spatial distribution. The main objectives of the present study was to interpret satellite data for land use/land cover mapping and to generate geo-database in GIS format. Ground truthing was also conducted to verify the doubtful features in the satellite image. Major land use/land cover classes identified in this area were crop land, forests and plantation, wastelands, drainage, rural and urban settlements and water body. The study area consist 1451.89 km^2 lands and out of which 82.30% area under agriculture land use and only 2.55%, 0.27% and 4.76% were taken up by the built up land (including hamlets, urban and rural areas), forest and grassland and grazing land respectively. The study concluded that the LISS-IV is a better source of data for natural resource mapping over commonly used satellite imagery and can serve the diverse application of needs of the user communities. This study not only provides the high-resolution land-use maps for Bilara tehsil, but it also yields accurate area estimates of different land-use types, in particular with grassland, and crop land. This enables analysis of potential land availability and suitability for biomass production and other sustainable land uses.

Key words: high resolution multispectral satellite data, land use/land cover mapping, GIS format, ground trothing.

Remote sensing has been recognized as a useful means of supplying up-to-date information on natural and anthropogenic activities. However, interfacing of GIS technology with remote sensing provides maximum information content and analysis capabilities and thus be of benefit to land-use planners (Nellis *et al.*, 1990). So far, it has been widely recognised (Welch, 1985) that there are many advantages to combine remotely sensed data with existing spatial image and statistical data, and thereby maximising the information upon which responsible decisions for land-use planning can be made (Paul *et al.*, 1992). Availability of high spatial resolution satellite imagery has made various opportunities and advantages to understand land use, resource assessment, and environmental monitoring issues in a better way. These satellite data are multispectral as well as panchromatic and can be acquired any time of the year. The advantage offered by these data include improved land cover characterization, capability to monitor change over time, digital processing capability, and data that are compatible with Geographic Information System technologies. The improvements in spatial and spectral resolution of the sensors, and computer hardware and image processing software have now made this technology competitive with traditional approaches for mapping land cover at local scales. The land use map, as a source of thematic information, has always been an important component of agricultural, rural, urban and regional planning; land improvement programs, watershed management, agricultural productivity improvement and scientific research involving carbon cycle, hydrologic cycle, energy budget studies, weather/climate prediction etc. (NRSC, 2012).

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Study Area

The Bilara tehsil is situated in the south-eastern part of the Jodhpur district between latitudes of 26°20′54.243″ and 26^{0}25′53.695″ N and Longitudes of 73°22′55.33″ and 73°53′19.113″E. It occupies an area of 1451.89

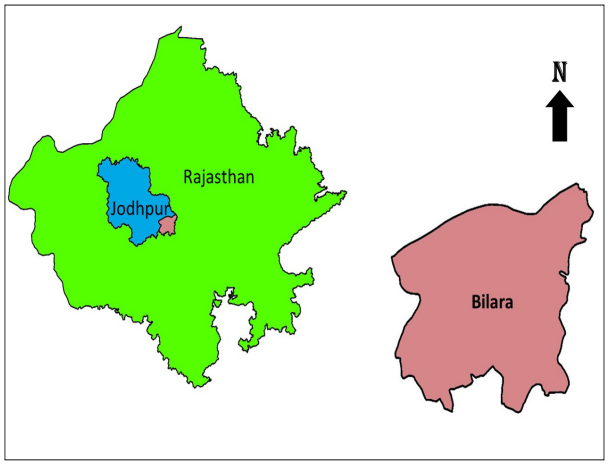

Fig. 1. Location map of Bilara Tehsil.

sq. km and bounded by Pali district in the east and south and north-west and Nagaur district touches in the north-east. It falls under region 2 of the agro-ecological map (NBSS and LUP Pub. 24) and in the II B zone, named as transitional plain of Luni Basin (Fig. 1).

Climate

The tehsil experiences semi-arid to sub-humid type of climate. Mean annual rainfall (1971-2015) of the district is 374 mm. Rainy days are limited to maximum 15 in a year. Almost 80% of the total annual rainfall is received during the southwest monsoon, which enters the district in the first week of July and withdraws in the mid of September. As the tehsil lies in the desert area, extremes of heat in summer and cold in winter are the characteristic of the desert. Both day and night temperatures increase gradually and reach their maximum in May and June respectively. The temperature varies from 49°C in summer to 1°C in winter. The annual maximum potential evapotranspiration in the district is quite high and is highest (264.7 mm) in the month of May and lowest (76.5 mm) in the month of December.

Physiography

Major physiographic units are sand dunes, alluvial plains, ridges and hillocks. The area between Bilara and Jodhpur is covered by alluvium deposited due to fluvial action of Luni river system. The eastern part of the tehsil exhibits gentle undulating topography interrupted by small ridges of hard rocks. Regional slope is from north-east towards south-west direction. Orientation of alluvial plain area follows the Mitri River and Luni River and its tributaries. The sand dunes are transverse and longitudinal types formed due to aeolian action and overlie the denuded consolidated formations. Ridges and hillocks are common features in Bilara tehsil. A chain of escarpments and ridges composed of comparatively resistive rocks like granite, rhyolite and Jodhpur sandstone are found in the east of Bilara. The alluvial and sand filled valleys are separated by the ridges whose crest elevation ranges from 325 to 460 m amsl. Luni river enters Jodhpur district near village Jhak in Bilara tehsil. However, in major part of the tehsil, the drainage is essentially ephemeral and internal.

Soil

Three types of soil is found: (i) Red desertic soils: These types of soils are most predominant soils. These are pale brown to reddish brown soils, loose and well drained and texture varies from sandy loam to sandy clay loam. (ii) Desert soils: Desert soils occupy a considerable area and in the northern and western part. These are mainly windblown sand and soils of inter-dunal depressions. (iii) Sand dunes: Sand dunes occupy a small part in northern and north-western margin. These are sandy to loamy sand, loose, structure less and well drained.

Hydrogeology

Ground water occurs under unconfined to semi-confined conditions in rocks of Delhi Super Group, and Bilara limestone. It is the most potential aquifer in the district. The limestone exposures are found between Khawaspura and Bilara. Siliceous and cherty limestone and dolomites with association of shale beds are quite common. In Borunda-Bilara area, limestone is mostly dolomitic, grey to dark grey at places, inter bedded with thin cherty layers. In Borunda-Ransigaon-Bilara area, limestone beds are highly crumpled and show development of caverns formed due to solution activities. Thickness of limestone varies from a few meters to more than 100 m. The yield of wells in both the areas varies largely because of considerable variation in limestone characters. In Borunda - Bilara area, discharge of wells varies from 12 to 272 $m^3 hr^{-1}$ with a drawdown in the range of 3 to 16 m (CGWB, 2013).

Groundwater status

Estimate of dynamic groundwater resources are cause of concern. However, due to encountering of Bilara Limestone, groundwater quality in deeper zones are somewhat better. During pre-monsoon, shallow (2.10 to 34.54 m) water level exists in the tehsil, whereas during post-monsoon, shallow (0.30 to 37.60 m) water level exists. Seasonally, water level falls in the western margins of the tehsil up to 0-2 m whereas rise in water level has been observed up to 2-4m during May to November period.

Population characteristics

According to 2011 census, population of the tehsil was 251,946 persons, of which 130,451 (51.8%) were male and 121,495 are female. Urban population of Bilara was 71,396 whereas rural population constitute 180,550 (71.7%) and sex ratio was 931 females per thousand males. The tehsil had an average literacy rate of 57%, lower than the national average of 59.5%; with male literacy of 73% and female literacy of 40%.

Materials and Methods

The geometrically corrected IRS P6 LISS-IV and Cartosat-1 PAN merged data, within the desired framework was the primary input for LULC classification and mapping (NRSC, 2012). A good amount of legacy data on themes like wasteland, forest, vegetation etc. also formed an important source of reference for LULC classification. In order to create logical linkages and harmonization among various categories, LULC classification was used (NRSA, 2006). LULC classes which are required for planning are basically few and fall mainly in the land cover categories. The completed land-use GIS databases were analysed with ArcMap summary and statistic tools to provide statistical information.

The present study was carried out using very high resolution IRS-P6 LISS-IV-MX data of 2011-12 and information on existing land use/land cover and their spatial distribution was generated and a comparison was made

Table 1. The classification schema followed, under present study

Level-1	Level-2	Level-3
Built up	Built up (Urban)	Core urban
		Peri urban
	Built up (Rural)	Village
		Mixed Settlement
		Hamlets and dispersed households
	Mining/Industrial	Mining/Industrial
	Transportation	Transportation
Agricultural land	Crop land	Crop land
	Agriculture plantation	Agriculture plantation
Forest	Forest	Forest
	Forest plantation	Forest plantation
Grassland and grazing land	Grassland and grazing land	Grassland and grazing land
Wastelands	Salt affected	Salt affected
	Gullied/ravenous	Gullied/ravenous
	Waterlogged	Waterlogged
	Scrub land	Scrub land - Dense
		Scrub land - Open
	Sandy areas	Sandy areas
	Barren rocky	Barren rocky
Water bodies	River/Stream/Drain	River/stream/drain
	Canal	Canal
	Lakes/ponds	Lakes/ponds
	Reservoir/tanks	Reservoir/tanks

Source: SIS-DP Manual, NRSC, 2011.

Table 2. Data used and their corresponding parameters

Time period	Satellite sensor	Scale	Outlook
2011-12	IRS-P6 LISS-IV MX	1:10,000	5-days of repetivity Spatial Resolution: 5.8 m (2.5 m; PAN/MX) Operates in three spectral bands - 0.52-0.59; 0.62-0.68 and 0.77-0.86 µm
2009-10	AWiFS	1:50,000	Five day repeat cycle Spatial Resolution: 56 m Operates in four spectral bands - three VNIR one SWIR, i.e., Bands (4): 0.52-0.59; 0.62-0.68; 0.77-0.86 and 1.55-1.70 µm
2005-06	LISS-III	1:50,000	24-days of repetivity Spatial Resolution: 23.5 m Operates in three spectral bands-(B2) 0.52-0.59; (B3) 0.62-0.68; (B4) 0.77-0.86 and (B5) 1.55-1.70 µm;

with the earlier mapping done using LISS-III data of 2005-06 and AWiFS data of 2009-10 (Table 2). Required ground truthing was conducted to verify the doubtful features in the satellite image.

Results and Discussion

Natural resource management is a complex undertaking, influenced by environmental, economic, social and other factors. Traditional field survey methods and satellite survey techniques often use quite different criteria for classifying land uses. Anthropogenic land-cover and land-use (LCLU) changes have profound climate and environmental impacts. One of the most extreme cases of LCLU change is urbanization. Agricultural land use in the region depends to a large degree on crop

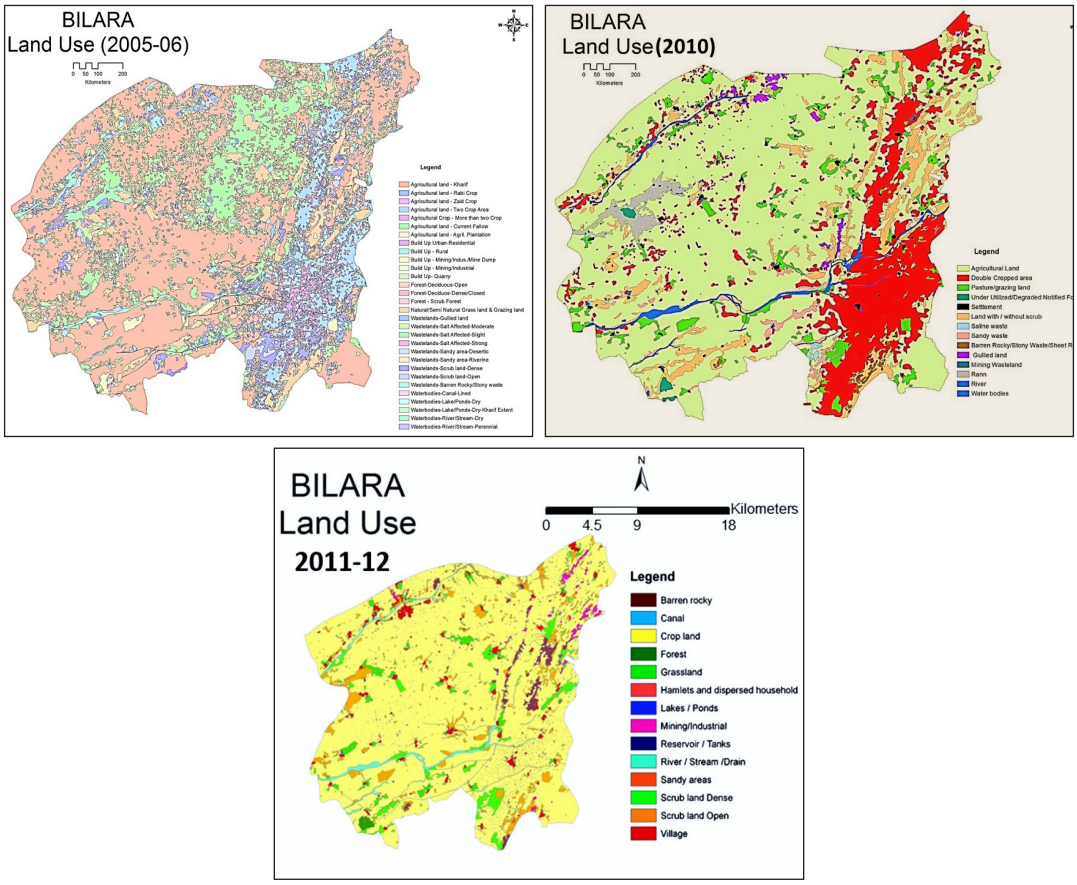

Fig 2. Land use / land cover maps of Bilara tehsil.

yield. But, interactions between food demand, biomass energy and forest preservation are driving both food prices and land-use changes. These land-uses generate different resources for the population: fuelwood in natural vegetation areas, food for subsistence and market needs in cropland and fallow, livestock in pastoral land. These different land-uses compete for land. Also, these land-use categories do not strictly coincide with land-cover types. (Fig 2)

Settlement

It is an area of human habitation developed due to non-agricultural use and that has a cover of buildings, transport and communication, utilities in association with water, vegetation and vacant lands. All places with a municipality, corporation or cantonment or which are declared as notified town areas and which satisfy the criteria of a minimum population of 5000, at least 75% of whose male working population is non-agricultural and with a population density of over 400 persons per sq. km are classified as urban settlement (Census, 2001). The urban settlements are generally compact and are larger in spatial extent than the rural settlements. Urban settlement were broadly categorized into Core urban and Peri-urban area for planning purpose. Whereas, rural settlements have been broadly classified into three types: Core village area, Hamlets or dispersed household and mixed settlement based on the characteristics, association and spatial extent. Villages are built up areas in rural areas, smaller in size, mainly associated with agriculture and allied sectors and non-commercial activities with population size less than 5000, generally limited supporting facilities that are unique to urban areas like hospitals, industries, institutions etc. Area under settlement has increased from 1.31% in 2005 to 2.48% in 2012 and showed a growth of 1.17% in the area under settlement. This is due to increase in economic and educational activities in the Bilara town so people migrated here for the jobs and other issues. Since farms are quite away from the core villages, so farmers have shifted their itself and constructed *kutcha* or *pucca* hamlets as well as sheds for animals. This is another cause for the increase in settlement (Table 3).

Cropland

These are the areas with standing crop as on the date of satellite overpass. Cropped areas appear in bright red to red in colour with varying shape and size in a contiguous to non-contiguous pattern. They are widely distributed in different terrains; prominently appear in the irrigated areas irrespective of the source of irrigation. Three cropping seasons exist in the study area viz., kharif (June/ July-September/October), rabi (November/ December-February/March) and *zaid* (April-May). Crop land category also includes area under kharif, rabi, *zaid* season as well as two crop and more than two crop areas. This also includes fallow lands, which are areas taken up for cultivation but are temporarily allowed to rest, un-cropped for one or more seasons, but not less than one year. Bilara is the only tehsil in the district where area under cropland has remained almost static but area under current fallow has been varying due to the vagaries of

Table 3. Area under different land use/land cover classes

Land cover classes	% area under LULC (2005)	% area under LULC (2010)	% area under LULC (2012)	% Change between	
				2005 & 2010	2010 & 2012
Crop Land	83.23	83.72	81.53	0.49	(-)2.19
Barren rocky/stony waste/ sheet rock/gullied area	0.77	0.86	1.00	0.09	0.14
Land with/without scrub	6.32	7.68	7.56	1.36	(-)0.12
Mining wasteland	0.18	0.22	0.79	0.04	0.57
Pasture/grazing land	6.51	4.49	4.63	-2.02	0.14
River	1.37	1.36	1.37	-0.01	+0.01
Settlement	1.31	1.68	2.48	0.37	0.80
Under utilized/degraded notified forest	0.13	0.21	0.27	0.08	0.06
Water bodies	0.18	0.23	0.41	0.05	0.18
Total	100.00	100.00	100.00		

monsoon. There are no significant changes in this category due to availability of underground as well as surface water resources. Pichiyak Dam and Surpura Dam are the main sources of water supply. Water is available at a depth of 250-300 feets. There are plenty of tube wells in the tehsil. Net irrigated area was hardly 19% of the total area. About 8619 ha and 5784 ha area has been under irrigation for food grain and oil seeds production. About 11182 km^2 area is sown more than once in the tehsil.

Mining/industrial area

Mine/quarry are the areas subjected to removal of earth material (both surfacial and sub-surfacial) by manual and mechanized operations. Large scale quarrying and mechanization results in mining and mine dumps. It includes surface rocks and stone quarries, sand and gravel pits, brick kilns and associated features like mine dumps, abandoned mine pit, etc. Bilara tehsil is known for the quarrying of limestone material like Borunda, Bitan, Haryiadhana, Khejarla, Sambharia, Jhak, and Ransigaon. Different grades of limestone is found in the Bilara-Borunda belt. Majority of the mines are around the town itself. Low-grade quartz is also quarried around Bhakharion Ki-Dhani. Around 0.79 per cent area of the tehsil is under this category that has increased over the period of time, as shown in the Table 3.

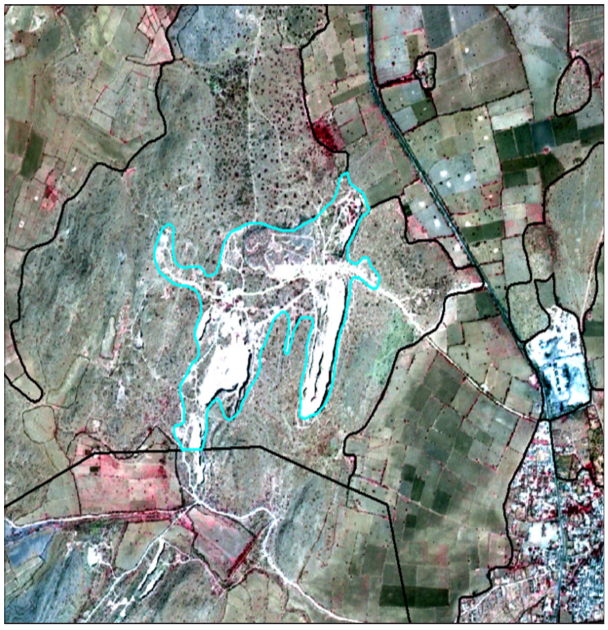

Fig. 3. Mining/industry area (near Barna village).

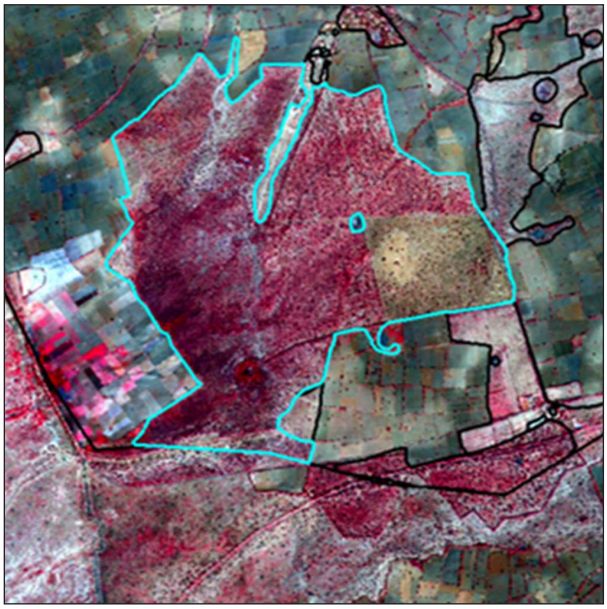

Fig. 4. Forest (near Hariyada village).

Forests

These are the areas bearing an association predominantly of trees and other vegetation types (within the notified forest boundaries) capable of producing timber and other forest produce. Deciduous forest types are of predominantly composed of species, which shed their leaves once a year, especially during summer. Forests exhibit bright red to dark red in colour in varying sizes, smooth to medium texture depending on the crown density, contiguous to non-contiguous in pattern based on their location. The size is usually irregular and discontinuous occupying medium relief hill slopes within the notified areas. Forest blank appear in light yellow to light brown in tone, generally small in size. They possess regular to irregular shape, scattered in the forested areas. Bilara tehsil has not shown any appreciable change in the area under forest since 2005-06 as area under crop land or agriculture is quite high.

Pasture and grazing land

Pastures are the areas of natural grass along with other vegetation, predominated by the former or grass-like plants (Monocots) and non-grass-like herbs. They appear in light red to light brown of varying sizes. They possess irregular shapes with contiguous or non-contiguous appearance. Pastures are mostly located around the settlement areas as well as

Fig. 5. Grassland (near Bilara).

in hill-slopes or close to rivers/streams. They are associated with agricultural lands; dry lands fenced from cultivation, and riverbeds. Grasslands are under light to moderate grazing pressure. Pasture areas have shown a decreasing trend due to encroachment for the agricultural purposes. Also, mining activities are also being operated at some other places.

Land with/without scrub

This is a land, which is generally prone to deterioration due to erosion. Such lands generally occupy topographically high locations, excluding hilly terrain. They appear in light yellow to brown to greenish blue depending on the surface moisture cover and vary in size from small to large having either contiguous or dispersed pattern. Scrublands are associated with moderate slopes in plains and foot hills and are generally surrounded by agricultural lands. Over a period of seven years, area under scrub land has shown an increase of about 1.33%.

Barren rocky/stony waste/sheet rock/gullied area

These are rock exposures of varying lithology often barren and devoid of soil and vegetation cover. They occur amidst hill-forests as openings or as isolated exposures on plateau and plains. Such lands can be easily discriminated from other categories of wastelands because of their characteristic spectral response. They appear in greenish blue to yellow to brownish in colour depending on the rock type. They vary in size with irregular to discontinuous shape with a linear to contiguous or dispersed pattern. Gullies have been formed as a result of localized surface run-off affecting the unconsolidated material resulting in the formation of perceptible channels causing undulating terrain. Gullies have developed from tiny water channels which are hardly a few centimeters deep and, formed as a resultant impact of heavy rainfall and wearing action of run-off generated there from. They appear in light yellow to bluish green in colour depending on the surface moisture and depth of erosion. They vary in size, shape with irregular broken network pattern. They are mostly associated with stream courses and sloping grounds with good rainfall and entrenched drainage. Due to increase in gullied area, particularly along the river banks, only 0.23% area has increased under this category in the tehsil.

Conclusion

Land use information is required for most of the studies as map updating, land use detection, cartography, city planning etc. Higher-resolution imagery helps in precise delineation of land use classes, identification of smaller patches, retained patch shape, and detected narrower, linear patches. With the increase in population, there is an appreciable increase in area under settlement. Due to enhanced mining activities, area under mining has increased from 0.18 to 0.79% during 2005 and 2012. Such imageries are needed to adequately monitor and evaluate land use dynamics, forest loss and conversion, and to delineate potentially important stepping-stone fragments that may serve as corridors in a human-modified landscape. This enables analysis of potential land availability and suitability for biomass production and other sustainable land uses.

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