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Modeling Plausible Impacts of land use change on wildlife habitats, Application and validation: Lisar protected area, Iran

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ABSTRACT: The present study aims to simulate the spatial pattern of land use change in Lisar protected area, Iran. Land cover maps for 1989, 2000, and 2007 were depicted using TM, ETM+, and IRS LISS-III images of the area at stake. Images were classified using a merge of unsupervised and supervised classification. CA-Markov model was used to predict land cover maps as a top-down approach in investigating land use change. A comparison was made between the predicted and actual land use map of 2007 in order to examine the precision of the predicted *map* and the validation of the CA-Markov model. Finally, by computing the rate of land use change on wildlife habitats, we examined the possible impacts of land use change on wildlife habitats. Meanwhile, the impact of variables on degradation in the region was studied to develop a bottom-up model, which enabled us to predict the possible impact of socio-economic drivers on protected areas. The findings of the study suggest that the region will experience a degradation of at least 5 hectares where the population increases by 0.71 or more in the predicted period of time. Moreover, if the trend of land exploitation and current management policy of the region continue as before, the region will experience at least 5.2 hectares degradation on the sensitive habitats.

Key words: Land cover change, CA_MARKOV, Spatial pattern, socio-economic drivers

INTRODUCTION

Protected areas are deemed pivotal in the conservation of biodiversity, and they play a central role in sustainable development strategies (Armsworth *et al.,* 2011; Garc´ýa-Frapolli *et al.,*2007). Governed by a number of stakeholders, protected areas have a wide range of management aims (Dudley,2008). The 4th category of IUCN gives a hint to protected areas principally managed for conservation through management interference (IUCN,1994). With the multiple objectives of protected areas, (Runte 1997; Sellar,1999),to concentrate on the social preferences, institutional structures and conflicting opinions of what is important becomes crucial. Preparing management plans for protected areas is essential for the well-being of the natural and cultural resources which are managed (Dudley, 2008) However, it can be challenging since all these concerns have to be taken into consideration. Land use/cover change which comes in the wake of mostly unintentional development is a major cause of wildlife habitat loss and leads to the destruction and degradation of natural habitats (Makhdoum, 2008a, 2010; Verburg *et al.,* 2006; Thomas & Middleton, 2003). Degradation is the result of a complex interaction of biophysical factors and has various economic and social causes, which must be taken into account altogether when developing new management approaches (Makhdoum 2008a; Geist & Lambin, 2002; Veldkamp & Fresco, 1996). Therefore, linking social survey information from local stakeholders to land-cover change is becoming a focused subject in different researches (Lorena & Lambin, 2009; Ellis & Porter-Bolland, 2008; Geoghegan *et al.,* 2001; Makhdoum,1999). Managers will be able to come up with more appropriate solutions for conserving natural resources if they understand the social and economic factors that cause degradation and land use change (Verburg *et al.,* 2006; Gallopin, Funtowicz,2001).

To detect and analyze land use and land cover change, satellite remote sensing and geographic information system (GIS) have been widely utilized (Falahatkar *et al.,* 2011; Peterson *et al.,* 2009). Analyzing the trend of changes in the past and predicting changes in the future have a central role in

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decision making and long term planning (Lambin et al, 2006). A key instrument in investigating and studying land use and land cover change is modeling (Falahatkar *et al.,* 2011; Lambin *et al.,*2006; Schneider & Pontius, 2001).A model can help to explore the functioning of a system by developing "what – if" scenarios and to visualize land use configuration that stems from the changes in a society (Verburg *et al.,* 2006; Couclelis,2005; Bousquet & Le Page, 2004).So far, numerous models have been developed and utilized to predict land use change(Verburg *et al.,*2004). They have been classified as mathematical equation based, system dynamic, statistical, expert system, evolutionary, cellular, hybrid models and more (Parker *et al.,* 2003; Lambin *et al.,* 2003; Briassoulis, 2000; Jeffers,1982). There are two main approaches to land use change modeling. Having influences from landscape ecology, top-down models are pattern oriented and based on remote sensing and census data (Costa *et al.,* 2007). Bottom – up models influenced by land ecology (Makhdoum, 2008b) elucidate the actors of land changes as heterogeneous and variable actors in time and space (Parker *et al.,* 2003). However many researchers have followed just one of the mentioned approaches in their studies , in this paper which aims to simulate the spatial and conceptual patterns of land use change in Lisar protected area, Iran, a combination of top-down and bottom- up approaches was used to explore the effects of land use change on the area in different scales.

MATERIALS & METHODS

located in Guilan province, Lisar protected area enjoys an area of 31142/26 hectares. The area is bounded by 48˚ 32' 45" and 48˚ 56' 10" eastern longitude and 37˚ 53' 16" and 38˚ 02' 05" northern latitude. Fig. 1 shows the location of the area on the map of IRAN, in Guilan province.

The highest altitude class of area is class 3000-3400 meters above sea level, occupying small area of the southeastern and northwestern area. The lowest elevation class of the region is the class of 0 to 100 meters above the sea level, located in the farthest eastern part of the area. Sixteen forest vegetation types, thirty seven species of mammals and 199 species of birds have been recorded in the region (IRAN Department of Environment, 2010). Thematic Mapper (TM),Enhanced Thematic Mapper (ETM +) and Indian Remote sensing Satellite LISS-III (IRS) images of the Lisar protected area were used to provide maps of land use for 1989, 2000 and 2007. The mentioned data were gathered and preprocessed through geometric and topographic corrections. Next, in the data processing stage, unsupervised classification, training samples determination and supervised classification were conducted to depict land use maps (figs. 2,3,4)

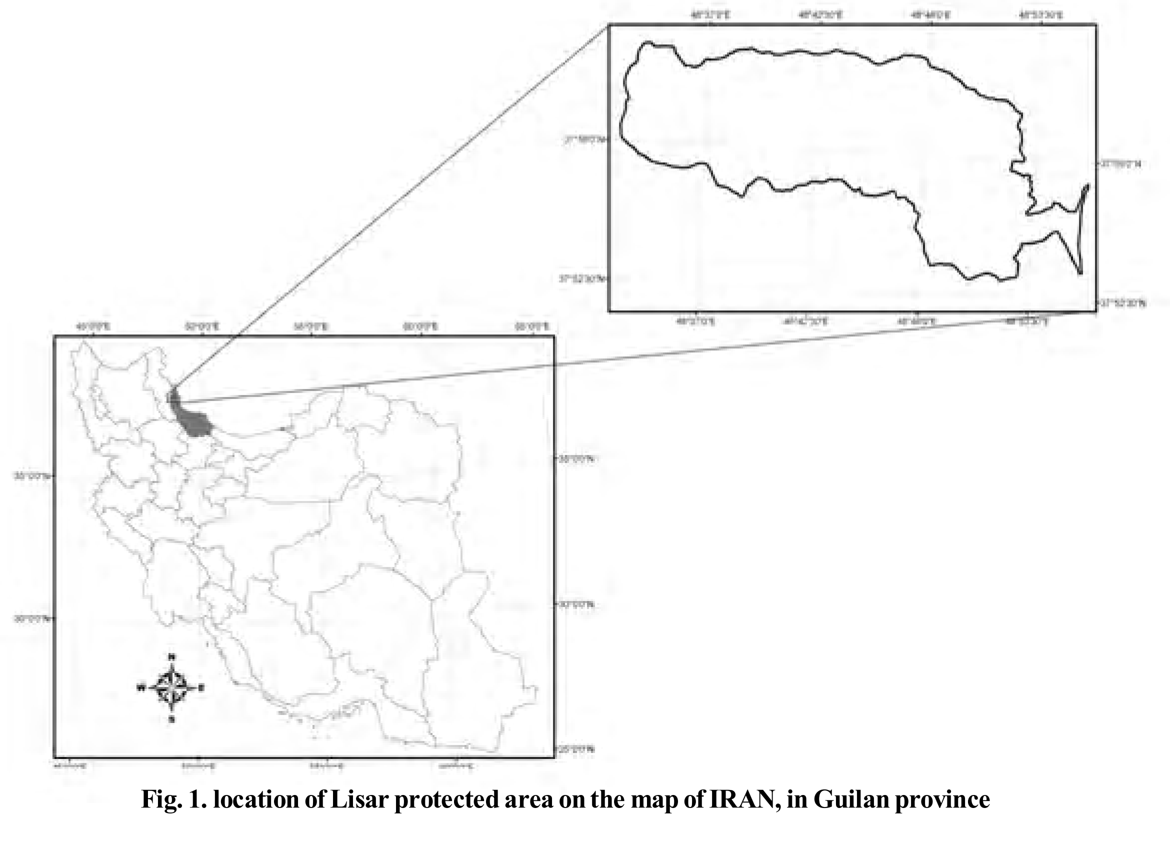

Fig. 1. location of Lisar protected area on the map of IRAN, in Guilan province

Fig. 2. land use map of Lisar protected area (1989)

Fig. 3. land use map of Lisar protected area (2000)

Fig. 4. land use maps of Lisar protected area (2007)

Maps were assessed for their precision as the first stage in post processing, and kappa index was calculated for each land use map. To specify the changes in the interval between the two dates of images, post classification comparison method was then used. In this method, the two images from different dates were classified and recorded independently. The pixels that had changed in the classification between the two dates were then controlled. Types, places and the amount of change are investigated using cross tabulation analysis. Also, the change in images became observable by examining the two classified images from different dates in the form of a matrix. The outcome of this step was the map of the changes (Fig. 5) and the table for the change in different land uses, while the degree and place of the identified changes was specified in various classes.

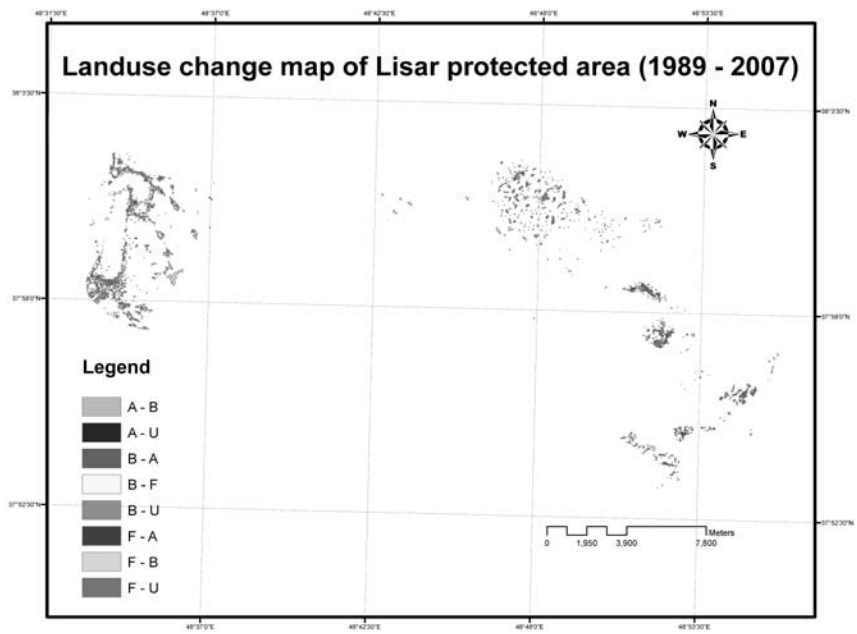

Fig. 5. land use change map of Lisar protected area (1989-2007)

CA_MARKOV model was applied to predict land cover map as a top – down approach in land use change investigation. This model is a combined Cellular Automata (CA) / Markov Chain/Multi-Criteria/ Multi Objective Land Allocation (MOLA) land cover prediction method (Sang *et al.,* 2011). A Markov chain model is utilized to quantify transition probabilities of several land cover categories from discrete time steps. The focus of Markov chain model is on quantity in predictions for land use changes and the spatial parameters are weak in this model (Sang *et al.,* 2011; Mondal & Southworth, 2010). One fundamental assumption in Markov chain models is that land use or land cover is considered as a stochastic process, and different categories are as the states of a chain (Weng, 2002). It means that only the most recent state affects the transition to the next state and it is independent of previous history. In CA model, each cell exists in one of a finite set of states, and future states depend on transition rules based on a local spatiotemporal neighborhood (Falahatkar, 2011; Parker, 2003).CA-based models are powerful to represent nonlinear spatial and stochastic processes (Batty *et al.,* 1997).

The CA–Markov model, which incorporates the theories of Markov and CA, is about the time series and space for the advantages of forecasting. It can achieve better simulation for temporal and spatial patterns of land use changes in quantity and space (Sang *et al.,* 2011). In this paper the CA–Markov model, has been put into use to simulate land use change and land use pattern for 2025 was projected. Fig. 6 shows 2025 land use projection.

Model calibration, the process whereby parameter values are adjusted to improve a model's goodness of fit, is required to apply any land use change model to any specific case region. The assessment of this goodness of fit with an independent dataset is what constitutes validation. Iterative by nature, the process of calibration and validation stops as soon as a calibration is deemed good enough (Refsgaard & Henriksen, 2004).

Known historical land use changes are simulated by the calibration of land use models. Two sets of data are essential to this process: one dataset for the beginning of the simulation period and the other for the end of it. A calibration can be assessed by simulating land use changes from T1 and T2 and juxtaposing the results with the actual data from land use (Van Vliet, 2009). In the present study, a predicted and a real land use map of 2007 were compared to examine the accuracy of the predicted map and the validation of the CA_MARKOV model.

The changes in variables were investigated to model social drivers of land use changes. According to literature review and the feasibility of utilizing similar

Fig. 6. Land use projection of Lisar protected area for 2025

data in IRAN some variables such as change of family size, change of population, change of literacy and also change of employment were investigated. Also, based on literature review of previous studies in Iran (Makhdoum, 1998, 2008a) to develop this model, the change in land use within the studied period of time was classified into two kinds of change. The degree of change in population, employment, literacy and family size was then computed using the census taken by Iranian statistics center in 1986, 1996, and 2006.The software package SPSS was then used to investigate the relationship between these variables (as independent variables) and land use change (dependent variable) in the studied area and the appropriate model was developed to illustrate the relationship. Furthermore, the relationship between land use change and variables such as the distance from main road (accessibility to main roads), the distance from wildlife habitats, residential areas, and water sources was explored by examining the spatial bottom-up autocorrelation of the above-mentioned variables and then using function of logistic regression in IDRISI software of land ecology (Makhdoum,2008b).

RESULTS & DISCUSSION

The images of TM, ETM+ and IRS LISS III respectively from 1989, 2000 and 2007 were used to produce land use maps of the protected area. Using training samples, collected during summer 2011, and the absolute value of Kappa coefficient, classification accuracy of land use maps was determined to be approximately 86%. Five land classes were defined in the final map: Forest (both natural forest and plantations), urban (both urban and rural settlements), agriculture, Barren (both rangeland and barren) and water (lake and rivers). The kappa coefficient for each land use can be seen in Table 1.

In order to investigate the trend of changes and compare the maps with used CA-Markov model to predict changes, three data change trajectory images for 1989-2000, 2000- 2007 and 1989- 2007 were generated for the protected area (figs. 2,3,4). Table 2 shows the changes in different land uses.

As Table 2 shows in the interval between 1989 and 2007 approximately 299 hectares of forest has been disappeared. A considerable portion of this change is related to expansion of agriculture in the region. Conversion of forest to urban land use is also important. Moreover the results suggest that the region has experienced near 70 hectares land use change in conversion of forest to barren.

The overall precision of the predicted land use change in 2007 on the basis of land use change in 1989 is approximately 74 percent. In the predicted map the area of the predicted forest land was less than the actual area.Urban and agricultural land uses were overestimated and the predicted area of water was underestimated. Table 3 shows the predicted and the real amount and area of each land use. Fig. 7 shows the predicted map for 2007.

The results of the study suggest that there is a relationship between socio-economic variables and the degree of land use change (degradation) in the studied

Table 1. kappa coefficient for land use maps of 1989, 2000 and 2007of Lisar protected area

Land use	Kappa index
1989	0.86
2000	0.88
2007	0.85

Table 2. the amount of changes in different land uses of Lisar protected area

Period of time / Land use change (ha)	89-2000	2000-2007	1989-2007
Forest/urban	89.19	39.15	133
Forest/agriculture	113.94	25.92	139
Forest/barren	65.16	5.94	70.56
Agriculture/urban	26.55	7.65	32.58
Agriculture/barren	2.79	1.35	4.05
Barren/forest	37.17	6.48	43.47
Barren/urban	64.89	4.23	68.04
Barren/agriculture	83.7	6.34	87.84

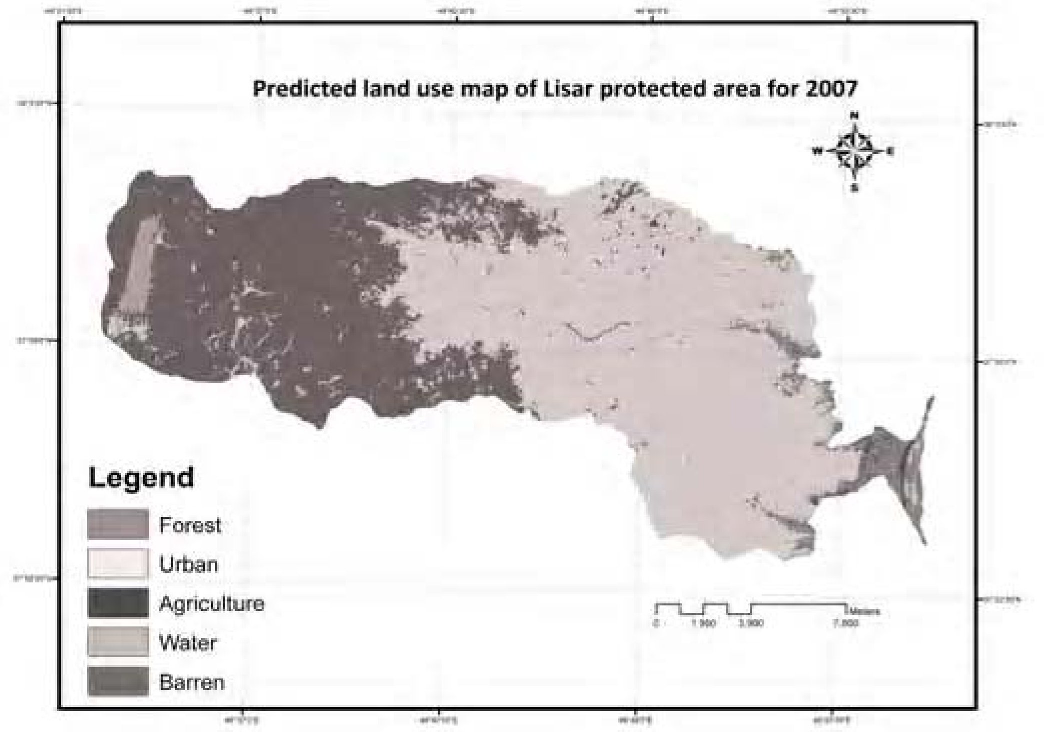

Fig. 7. Predicted land use map of Lisar protected area for 2007

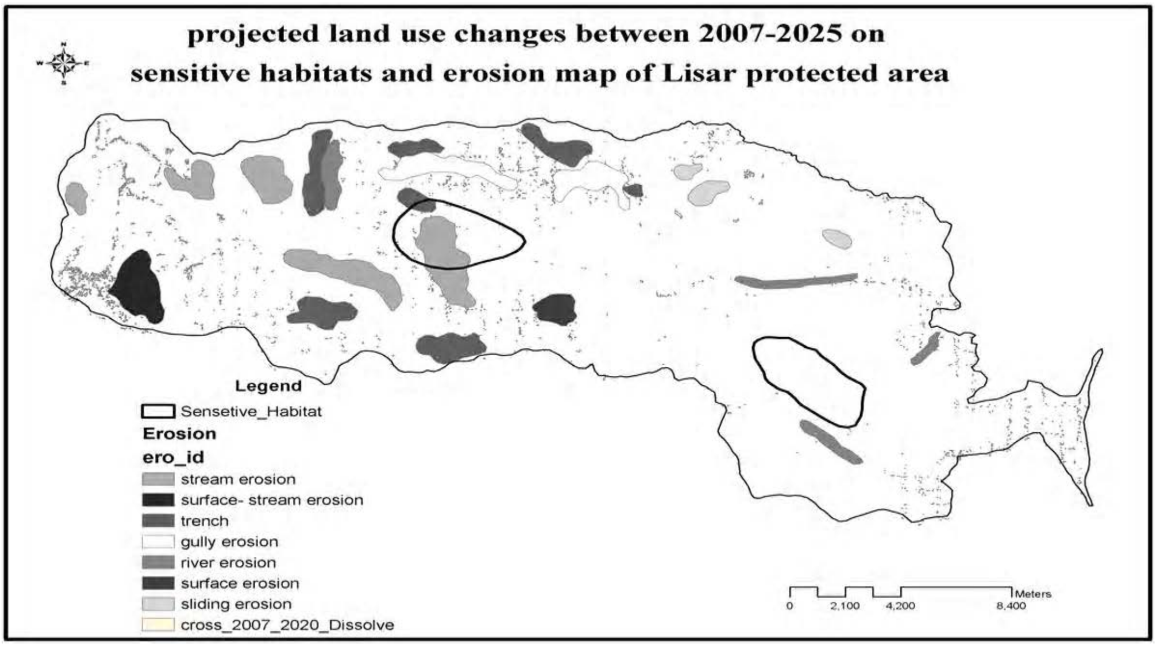

Fig. 8. Projected land use changes of Lisar protected area for 2007-2025 on sensitive habitats and erosion map

area and the most compatible model with the available information is binary logistic regression model. According to the results of the SPSS software analysis, there is a significant relationship between percentage of population change(x) and land use change (p), which generated the following statistical model:
P= exp (18.03 x – 12.772) / [1+ exp (18.03 x – 12.772)]
To develop this model, the change in land use within the studied period of time was classified into two kinds of change: “without change and change up to 5 hectares”, and “ a change of 5 hectares or more”. As the above formula presents, results of investigation showed that just degree of change in population have a significant role in land use change. Regarding to cut point of the model which was considered equal to 0.5, it can be understand that where population increases by 0.71 or more in the predicted period of time, the region will have at least 5 hectares degradation. The Overlay of the sensitive habitats map prepared for Lisar protected area Management Plan (IRAN Departent of Environment,2010) and the map of land use change projected for 2025 showed that If the trend of land exploitation and the current management policy of the region continue as before, the region will experience at least 5.2 hectars of degradation on sensitive habitats. Furthermore, patch fragmentation occurs as a result of degradation (Fig. 8). It means that in contrast to the aim of management plans both habitat loss and habitat degradation will occur in the protected area.In addition, the erosion map shows that the sensitive patch which is likely to be exposed to degradation is located on the stream erosion area and will be prone to more degradation. Therefore, it has priority over other sensitive habitat patches for conservation.

CONCLUSION

In the present study, the role of land use change modeling in providing the required information to plan and manage the protected areas was investigated. Complementary information was gathered by adopting two different approaches in this study. In The top-down approach, remote sensing and geographic information system were used to picture the future land use patterns, and in the bottom-up approach, which was modeled on the basis of agents’ behavior, the social drivers of land use change and their relationship with land use change were determined. According to Verburg (2006), different modeling approaches do not necessarily answer similar research questions and to use different models, different research questions have to be considered. As costa et al. (2009) put it, if the focus is on examining change patterns, then top-down approach is used. However, if spatial location for changes is not important and only specifying socio-economic drivers of land use change is focused on, agents’ behavior for modeling approach is applied. The present study, which concerns mainly with the effect of land use change on wildlife habitats and indirectly on planning and managing the protected areas, includes bottom- up analysis of social factors for changes as well. Verifying the findings of Bosquet & Lepage(2004), the current study suggests that by using land use change modeling and what-if scenarios the outcomes of managerial decisions and development in a society can be predicted and visualized. To manage the protected areas more efficiently, different scenarios can fuction as warning systems and reduce the uncertainty resulting from changes in socio-economic and political systems. Our results indicate two kinds of change scenarios: without change and change up to 5 hectares or more. Furthermore, as it’s been mentioned in different studies (Verburg, 2006; Costa et al.2009), the scarcity and type of the available data is a limitation in using different models. Due to the unavailability of comprehensive economic and political data, it was impossible to investigate the effect of such factors on land use change in this study, although it is not easy to apply all different scales and examine all the aspects of the studied system. Yet, incorporating complementary approaches in creating (developing) an outlook from different respects is beneficial and it is recommendable to develop more effective approaches to the management of land and protected areas.

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