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Assessment of Ecological integrity in a landscape context using the Miankale peninsula of Northern Iran

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ABSTRACT: Identification of rapid degradation of ecological resources requires effective environmental monitoring including ecological integrity assessment .Our first aim is to analyze ecological integrity in a landscape context while developing a method to assess integrity in spite of a dearth of historical data. We used a Spatial-Temporal Reference Framework for land cover maps for assessing ecological integrity change, emphasizing changes in patch types and configuration. Land cover is used as a surrogate for habitat. Habitat condition is the main point of this research in assessing ecological integrity. Our second aim is to recognize, through a case study of the above, the ecological integrity of the Miankale peninsula of Miankale Biosphere Reserve on Iran's Caspian Sea coast in the east latitude of 53˚ ،24΄ ،50˝ and north altitude of 36˚ ،56΄ ،45˝. Land cover data were obtained from Landsat TM5 of 1985 and compared with current condition images from Landsat TM5 of 2010. Landscape metrics show that Minakale's natural semi-dense shrub lands are fragmented; with the number of patches increasing and average patch area decreasing. This implies a fall in habitat available to its dependent bird species. In conclusion, considering birds' habitat and its aggregation as a measure of integrity, landscape metrics show ecological integrity of Miankale has decreased and signals of habitat loss have appeared in study area. More detailed analysis in ecosystem scale is suggested as the complementary research to find the best indicator for assessing the integrity of the ecosystem.

Key words: Ecological Integrity, landscape, Land cover, Miankale Peninsula, Iran

INTRODUCTION

Addressing rapid degradation of ecological resources usually requires an effective environmental monitoring method. The concept of integrity first time was used by Leopold to define ecological communities' characteristics in terms of sustainability (Muller & Bukhard, 2007). This concept was introduced after that of ecosystem health and it may solve some ambiguities in the concept of ecosystem health. Karr defines integrity as a capability of an ecosystem to support and maintain a community of living organism with species composition, diversity and functional organizations comparable with its normal and natural condition (Karr, 1999). Integrity refers to a system's completeness and capability of maintaining its function, order, and self-organization under different outside circumstances (Bertollo, 2001).Barkman (2002) defines ecological integrity as the capability of self-conservation of a natural system against ecological disturbances which tend to induce a hiatus in self-organization capacity of ecological systems.

Developing integrity indicators can be a quantitative tool for assessing the ecological situations. Moreover, these indicators provide effective tools to reveal condition that needs to be managed. A habitat integrity indicator can be derived by a comparison of the current habitat conditions to the assumed or ideal capability or to a reference condition (Tiner, 2004, Juntii & Rumble 2006) while

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necessary information is existed. Different kinds of indicators have been suggested for integrity indicators; De Boer (1983) and Zonneveld (1983) considered plants as integrity indicators. Some amphibians were regarded as integrity indicators by Fisher and Shaffer (1996), Welsh and his colleagues (1997) and Adams (1999). Finally some species of birds and mammals were considered as integrity indicators by some other scientists (Temple & Wiens, 1989, Strafield and Bleloch, 1983, Reunanen et al 2000). Karr (1981) refers to some approaches which focus on communities or guilds as indicators of ecological integrity. Indicators of ecological integrity can be found at many organizational levels including species, landscape, and ecosystem (Carignan, 2001). The aim of this study is to analyze ecological integrity of Miankale peninsula in northern Iran in a landscape context and developing a method to assess integrity in spite of a dearth of historical data which is a common situation in conserving natural areas around the world. Presenting the dynamic attribute of ecological systems is a way to approach ecological integrity issues. Understanding system integrity is related to and dependent upon knowledge about ecosystem process and transformations over time and space. Thus understanding landscape-scale dynamics can be an effective approach to assessing ecological integrity. Knowing changes in landscape patterns, we can indicate change in processes and thus in ecological stressors. Landscape pattern results from biological and physical processes acting over time, so practical information about ecological process is derived from landscape pattern. Various processes have changed over time in the peninsula: increasing level of water table, succession, transformation of natural rangelands and shrub lands to farmlands, and grazing intensity (DOE, 2002). Such changes affect habitat quality, habitat loss and eventually cause loss of ecological integrity.

MATERIALS & METHODS

The highly bio-diverse Miankale Biosphere Reserve in northern Iran is situated at the south east corner of the Caspian Sea (Fig. 1). It consists of two parts: an aquatic area consisting of the Miankale wetland and Gorgan bay, and a terrestrial part, which includes the sands pit of the Miankale peninsula, and also a few small Islands. Miankale is a suitable habitat for different kinds of wild life, especially local and migrant birds. The Miankale peninsula on the north latitude of 53˚ ‹24΄ ‹50˝ and east-altitude of 36˚ ‹56΄ ‹45˝ was the focus of this study. Peninsula is ecologically isolated and surrounded by agricultural activity, so this was chosen as the unit of study.

In this area of about 12200 ha there are three vegetation formations; the shrub, heath, and grassland formations. The shrub Formation is mainly *Punica granatum*, and is located in completely dry parts of the Peninsula, especially in the West. A large extent of the study area was covered by Pomegranate shrub lands and many of local birds were dependent to this habitat (DOE, 2002). Pomegranate shrub lands in Miankale peninsula can be classified in three types (Table 1):

Table 1. three types of Pomegranate shrub lands in Miankale

type	Crown coverage	Area (hectare)
Punica granatum+ Rhamnus pallasii	65%	5079
–Punica granatum Rabus persicus	50%	3436
Punica granatum	75%	1617

Source: DOE, 2007

Heath formation includes *Rubus persicus* and *Juncus aculeatus*. A variety of grasses exists among the shrubs and heaths.

Historical information on the area is scarce and there are few historical documents that describe the natural condition of Miankale (Vahid Mazandarani, 2000). These documents refer to this fact that Miankale had a very high diversity of wild life in about 85 years ago. Existence of Caspian tiger (*Panthera tigris*) as a top predator (which today is completely extinct from north of Iran) is an evidence of that high-valued diversity. Besides, documents imply observation of dense pomegranate shrub land in Peninsula and large population of different species of birds at that time (Vahid Mazandarani, 2000). Despite of formal recognition as a biosphere reserve (MAB, 1976) and current significance for migrating water fowl and protected local birds such as Iranian pheasant, the protection of the area remains tenuous.This ecologically valuable ecosystem is subject to anthropogenic disturbance and some signs of dysfunction have appeared due to different disturbance factors notably over -grazing that is one of the most destructive process (DOE ,2002)that affect habitat quality of this area .This trend will influence the ecological sustainability of the Punica shrub lands and other ecological systems. Considering overgrazing as a major disturbance factor, and the ecological isolation of the upland communities of the Miankale Peninsula, this area is large enough for considering home range of many wildlife species, especially bird species related to pomegranate community.

Fig. 1. Location Map of Miankale Peninsula derived from Landsat TM5 scenes of 2010

Land cover maps show spatial distribution of ecological attributes so allowing analyzing ecological process and patterns of biological diversity (Turner *et al.*, 2003). Analyzing of habitat quantity and configuration in parks and protected areas is thus possible using land cover maps (Parmenter *et al.*, 2003). For change detection we used visible and (near) infrared bands in Landsat TM5 30m resolution images, recording spectral changes between similar pixels as a surrogate of land cover change. Regarding the main role of time in the perception of environmental changes, time scope of the study is about 25 years from 1985 to 2010.The results constitute a basic requirement for assessing ecological integrity at landscape scale.

One of the most difficult parts of this kind of research is the insufficiency of reliable and accurate data concerning the natural and intact condition of the study area; we were obliged to consider the semi-natural condition as our reference state. Reference land cover data were obtained from Landsat TM5 of 1985(the best available consistent satellite images). Images were classified after the normalization process. Landsat TM5 of 2010 was the basis for estimating the current condition. A supervised classification was conducted using maximum likelihood estimation.

Quantifying habitat integrity: A habitat perspective has been used to assess integrity of Miankale peninsula. Temporal changes in quantity and suitability of this habitat should be reflected in any index of integrity. Miankale peninsula is well known for supporting various migrant and resident bird populations. Changes in the bird populations can be viewed as a surrogate for changes in habitat conditions (Recher & Serventy, 1991). Communities of local birds have been regarded as the focal indicator of habitat integrity in this research. Pheasant (*Phasianous colchicus*) is considered as representative of the focal indicators of habitat integrity. Pheasants are large, conspicuous, and vocal and live mainly on the ground (McGowan & Garson, 1995) and strongly dependent to pomegranate shrub lands of Miankale from habitat point of view in the study area (DOE,2007).Shrubby cover is often the most productive habitat type for this bird in terms of successful and hatched nests (Robertson, 1996). The pressure of overgrazing in the region is causing habitat loss which is a great threat to the birds' population. Heavy grazing destroys the value of Punica areas for nesting, brood-rearing, and general cover. Prolonged or heavy browsing of the woody plants can eventually reduce or eliminate cover value for dependent birds (DOE,2007) .Hunting by local residents also threatens the population in the study area (DOE,2007).The spatial arrangement of habitat types influences the home range of pheasants. The home range size of pheasants varies throughout their range due to differences in climate, land cover and etc. Changing land cover is one of the most important restricting factors in pheasant's population in Miankale. The home range of the pheasant is normally within about 1600 meters of the hatching site. Daily range seldom exceeds 800 meters (NRCS, 2002). Whether woody or herbaceous, some type of cover with vertical structure is necessary to conceal pheasants from predators and provide escape habitat if detected (Leif, 2005).

Previous researchers (Fraser *et al.,* 2003) showed habitat fragmentation can be used as a stress indicator to assess ecological integrity. Considering this previous finding, by making a grid file, habitat integrity changes were addressed by preparing a class properties file of land cover classes, and calculating selected metrics in FRAGSTATS. The following metrics were used:

Patch Richness (PR), Class Area Proportion (CAP); characterizing the overall evenness diversity of a landscape (Botequilha et al, 2006); Patch Number (PN); showing total number of patches per land cover and Patch Density (PD) that especially demonstrates degree of habitat subdivision. Area-Weighted Mean Patch Size (Area_AM) and Area- Mean Patch Size (AREA_MN); appropriate indicators in measuring patchiness, Radius of Gyration (GYRATE); shows how far across the landscape a patch extends and measures patch connectivity. Any change in GYRATE has a direct relationship to organisms' freedom of movement across the landscape. Contagion; which is integral to landscape pattern and relates to the level of habitat fragmentation (Botequilha *et al.,* 2006) and elimination of habitat value for some species.

RESULTS & DISCUSSION

Fig. 2 shows the classified land cover maps of the study area in two different years (1985 and 2010). The number of patch types increased from six classes to seven classes from 1985 to 2010. The new class resulted from transformation of dense shrub lands of Pomegranate to the low-dense shrub lands.

As Shown in part (a) vast areas of the peninsula were covered by semi-dense shrublands. Comparing part (a) and (b), reduction in area of semi-dense shrub lands and emerging of areas of low dense shrub lands is observable. Also vast areas of rangeland in 1985 have changed to sandy lands mainly due to pressure of overgrazing (DOE, 2007). There was a considerable coverage of rangeland in 1985 that has changed to other land-covers. Those range-lands in some parts transformed to sandy or bare-lands. But in other parts they are replaced by the pomegranate shrub lands with low density because of natural succession processes. Wetland vegetation had a greater coverage in surrounding of the peninsula. But increasing of the water table causes a decline in wetland vegetation. There were some patches of agriculture in both years 1985 and 2010.So there is not an observable change in agricultural patches from the past up to now.

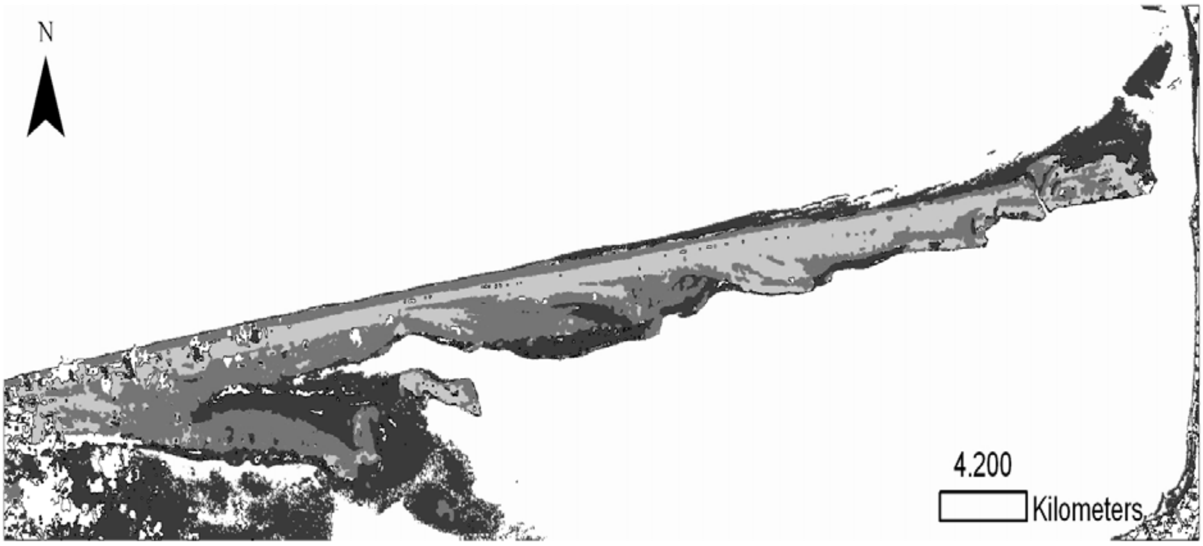
Table 2 shows briefly the results of FRAGSTAT analysis. Result of CAP and PLAND as area metrics showed the class area proportion of semi-dense shrub-lands is decreased from 6054.21 ha to 2892.96 ha. PLAND metrics showed such decline in area of shrub lands from 5794 ha to 2768 ha as well. In contrast, these metrics showed the emergence of low dense shrub-land patches as a new type of class in land cover map. Besides, these metrics showed decline of wetland vegetation since 1985 to 2010 that is because of increasing of Caspian Sea water. Area of sand dune based on CAP metric is increased from about 2170 ha to about 2537 ha .PLAND shows an increase of about 0.4 % in Sand-dune areas.

Metrics of Patch number (PN) showed that there was a reduction of shrub lands patches from 182 to 149, as well as decreasing of their area. In fact, these patches are being divided. Field surveys demonstrated that this is mostly from clear cutting and anthropogenic fire and transformation to agricultural land. Number of sandy patches decreased from 497 to 424 whereas related area metric (PLAND) showed an increase in area of such patches. So decreasing of the patch numbers is because of aggregation of sandy areas due to loss of shrub-lands. The number of water patches decreased while their area has increased .That is because of increasing of water table. The number of rangeland patches increased from 425 to 506. This increase is parallel with declining of the area of these patches. That is a reason of rangeland division.
Results of PD metric are similar to PN metric.
Average patch area of shrub lands (Area_AM) was reduced from 1780.26 ha in 1987 to 910.95 ha in 2010. Using AREA_MN as a complementary metric that is weighted by patch area, we detected that most shrub land patches are relatively large but there are also some small patches among them.

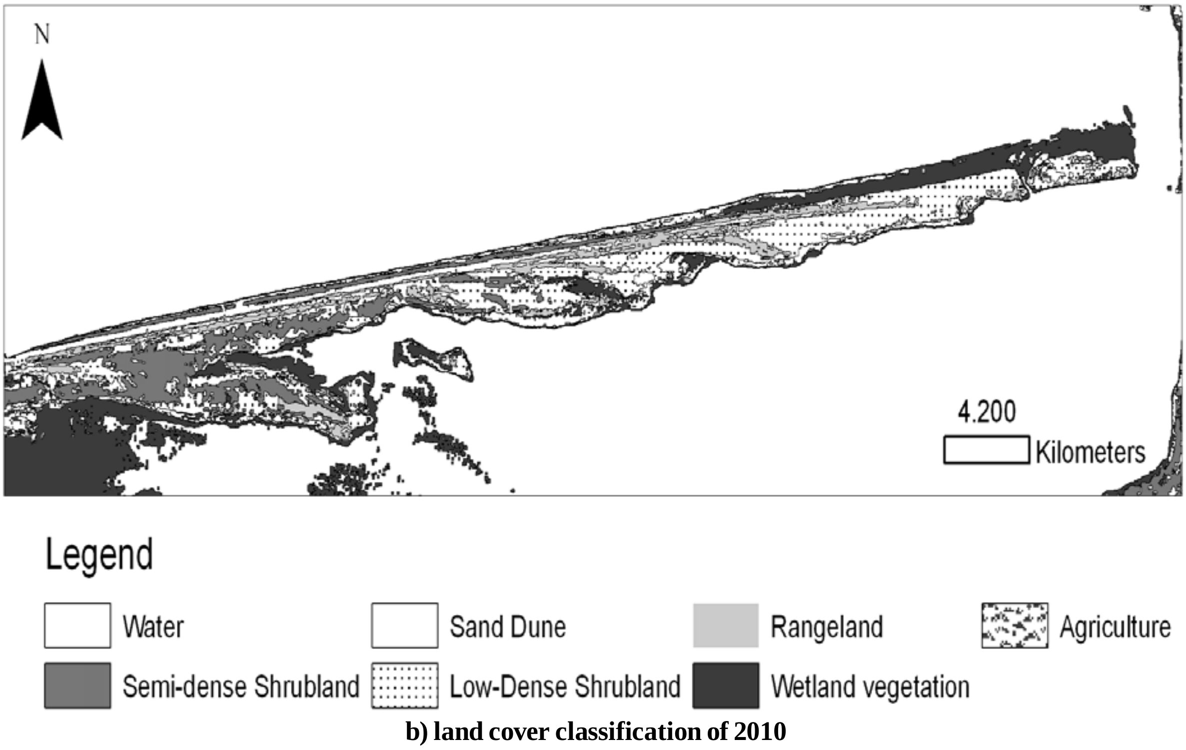
Area_AM of sand-dune patches shows again an increase in average area of sand-dune from 189.45 ha to 299.36 ha. Area_MN metric proves the increase in mean area of sandy patches.

GYRATE_AM showed decreasing connectivity (from about 5475 ha to about 2461 ha) in the focal habitat of semi-dense shrub land and consequent habitat loss for the focal species of birds , but the connectivity of sandy patches based on result of this metric increased from 568.68 ha to 2591.55 ha.

CLUMPY metric as a Contagion one does not show considerable change in Semi-dense shrub lands, but rangeland-patches show decline in this metric. That is because some parts of rangelands changed to sandy lands due to overgrazing**.** Additionally, as mentioned there was an opposite process of succession from rangeland to low dense shrubby land.



a)land cover classification of 1985



b) land cover classification of 2010

Fig. 2. Land cover classifications of Miankale Peninsula derived from (a) 1985 and (b) 2010 Landsat TM5 data

Table 1. Results FRAGSTATS analyses of Miankale peninsula landscape in 1987 and 2010

LAND COVER TYPE	Year	water	wetland vegetation	Sand Dune	Semi dense rangeland	Semi dense shrub land	Agriculture	Low dense shrub land
CAP(ha)	1987	80018,19	9975,51	2170,53	5542,11	6054,21	729,45	0
	2010	85238,01	5914,44	2537,55	2097,81	2892,96	630,09	5179,14
PLAND(%)	1987	76,5798	9,5469	2,0773	5,304	5,7941	0,6981	0
	2010	81,5753	5,6603	2,4285	2,0077	2,7686	0,603	4,9566
PN	1987	1076	453	497	425	182	105	0
	2010	87	334	424	506	149	198	313
PD	1987	1,0298	0,4335	0,4756	0,4067	0,1742	0,1005	0
	2010	0,0833	0,3196	0,4058	0,4843	0,1426	0,1895	0,2996
Area_MN (ha)	1987	74.3663	22.021	4.3673	13.0403	33.2649	6.9471	0
	2010	979.7472	17.7079	5.9848	4.1459	19.4158	3.1823	16.5468
Area_AM(ha)	1987	77043.581	3803.193	189.4518	2501.852	1780.256	79.4599	0
	2010	84952.989	1499.318	299.357	208.1182	910.9491	40.2387	846.3591
GYTARE_AM (ha)	1987	15198.620	4440.836	568.6800	6815.216	5475.130	532.3305	0
	2010	15663.302	3203.733	2591.550	2301.733	2461.293	291.1705	2390.102
CLUMPY	1987	0.9748	0.9024	0.8402	0.9194	0.9192	0.8812	0
	2010	0.8994	0.9002	0.8346	0.8036	0.906	0.8393	0.8393

CONCLUSION

Natural and anthropogenic factors such as overgrazing, fire, transformation of shrub land and range lands to farm land, influence loss of shrub land habitat in Miankale. These factors caused change in habitat area and consequently the resilience of the area may be compromised and it does not recover from stresses. The declining in patch density of Pomegranate shrub lands due to overgrazing added a new patch type; low dense shrub land, to the Miankale peninsula landscape. Results of previous birds census (DOE, 2007) show populations of pheasants in peninsula have declined from the past. Results of this study demonstrate this decline might be habitat related. Pheasants need shrub land habitat (NRCS, 2002), so if Punica shrub land has declined this can be an indicator of loss of habitat for these birds and also an indicator of loss of integrity of the peninsula. Therefore, in attempting to define changes in integrity for Miankale, we shall use Punica landscape metrics as an indicator of ecological integrity. An increasing in Caspian Sea level (DOE,2002)has been a natural influence on water table, changing the landscape composition and configuration in the lower parts of the Miankale peninsulas (as well as in the neighboring Gorgon Bay). It caused a decline in area of aquatic vegetation in Miankale wetland which is a productive habitat for many migrant birds. AREA metrics demonstrate that large shrub land patches still remain in the study area but the high variance in area of these patches shows that there are some small patches of shrubs among them. That might be a signal of increasing fragmentation because of increasing trend of human interference. Fragmentation can be considered as an index of landscape scale ecological integrity. It reduces the size of nesting patches and increases the amount of edge, thus altering ecological interactions (Andren, 1995). Small patch size and associated edge effects negatively affect reproduction of many species of birds (Duebbert and Kantrud 1974, Burger et al. 1994, Paton 1994, Andren 1995, Pasitschniak-Arts and Messier 1995). The results of AREA–AM and AREA_MN also show semi-dense shrub land is fragmented because the number of patches and average patch size area of the semi-dense shrub land decreased. Fragmentation and reduction of semi dense shrub land show the fall in habitat available to its dependent bird species. In addition, connectivity of Pomegranate shrub land patches decreased based on the result of GYRATE metrics. This reduction affects movement of wild life among shrub land patches.

In conclusion, landscape metrics over the 1987-2005 periods demonstrate increasing trend of shrub land patches fragmentation on the Miankale peninsula. Comparing two land covers shows the changes were mostly within patch differences that is a signal of habitat loss in study area. So in dearth of reliable historical data about a natural area, old satellite images can help to make a view to the past condition. Habitat condition can be analysed by preparing land cover maps and use of landscape metrics. Considering birds' habitat and its fragmentation as a measure, landscape metrics show ecological integrity of Miankale has decreased. More detailed analysis in ecosystem scale is suggested as the complementary research to find the best indicator for assessing the integrity of the ecosystem and its quantified level of decline.

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