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Conversion of life zone to ecologically less valuable land cover in Iran

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Key words: Holdridge system, Land use, Life zones, Physiognomic types.

Abstract

The life zones of Iran were mapped using the Holdridge system based on biotemperature and precipitation maps of Iran. Conversion of each life zone to an ecologically less valuable land use/cover was determined based on comparing the life zones and the current land cover of Iran. Results showed that Iran contains 26 life zones. The most extensive life zone is subtropical desert life zone covering 21.9% of the area of the country. Periarid class is the largest humidity province (34.2 % of Iran) followed by arid class (24.8 % of Iran). According to the physiognomic types, most area of Iran (35%) is covered by desert life zone followed by scrub (30.4%), steppe (18.7%), forest (10.2%), woodland (5.6%) and tundra (0.14%) life zone. 87% of woodland, 64% of forest, 61% of steppe and 21% of scrub life zone were converted to less ecologically valuable land covers. Steppe life zone was the life zone with the largest area (37%) being converted to agricultural lands followed by forest (23%) and woodland (22%) life zone. The smallest area (14%) being converted to agricultural lands was the area with the potential of having scrub life zone. The conversion of forest life zone to agricultural lands and moderate rangelands, the conversion of steppe and scrub life zone to agricultural lands and that of woodland life zone to poor rangelands were the largest types of negative conversions. The Holdridge life zone system can be an efficient approach for comparing potential vegetation and actual vegetation.

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Introduction

Life zone is defined as an ecological altitudinal or latitudinal zone characterized by specific climatic conditions and vegetation (Heyer, 1967). Life zone can be subdivided into associations based on site conditions such as soil and microtopographic data (Holdridge, 1967). Life zone approach is important in ecosystem mapping, since it is based on climatic factors influencing ecosystem processes and it recognizes ecophysiological responses of plants (Lugo *et al.,* 1999). Classification of life zones is important for determining the vegetation-environment relationships, assessing the effects of global climate change on the distribution of vegetation (Emanuel *et al.,* 1985; Solomon and Shugart, 1993), studying species diversity and evaluating the changes in vegetation during successional stages (Lugo *et al.,* 1999). A variety of models have been developed for classification of life zones using temperature (Merriam, 1898), geography techniques (Bailey, 1980), biogeographical criteria (Smith, 1974), potential evapotranspiration, temperature and precipitation criteria (Box, 1981) and biogeography, biogeochemistry and fire disturbance (Daly *et al.*, 2000). These models predict the patterns of potential vegetation. One of the most efficient and applicable methods for classification of life zones is the Holdridge life zone system (Holdridge, 1967). This method is objective (Lugo *et al.,* 1999) and requires minimum data on mean annual precipitation and biotemperature. The Holdridge system strongly considers the driving forces of ecosystem structure and provides explicit rules for using information to classify ecosystems (Bailey and Hogg 1983). Based on this system, 38 classes of life zones are defined (Fig. 1). The study of life zone conversion is necessary for comparing the potential vegetation and actual vegetation, understanding natural and human-driven environmental changes (Liu and Chen, 2006), planning and sustainable management of ecosystems, biodiversity conservation (Triantakonstantis *et al.,* 2013) and predicting the future changes in land covers (Zhang *et al.,* 2014). Liu *et al.* (1998) studied the changes in life zone distribution in north-east china by comparing the potential vegetation and the actual one and stated that the percentage cover of forests was decreased from 70% to 27% and about 23% of the area was replaced by agricultural vegetation and industrial use. Zheng *et al.* (2006) determined the Holdridge life zone diversity for assessing the dynamics of vegetation distribution. For restoration of an area, the potential vegetation needs to be identified by determining the life zones of the area. This study focuses on comparing the potential vegetation and the actual vegetation in Iran based on the physiognomic types of the Holdridge life zones. Totally, the distribution areas of woody plants of Iran (Javanshir, 1976) include: 1-Hyrcanian area dominated by *Quercus, Buxus Carpinus, Zelkova, Parrotia,* and *Fagus* species (Fig. 2). 2- Zagros area along the south west of Iran dominanted by woody species of *Quercus, Amygdalus* and *Acer*. 3- Khalij and Oman areas with the dominant woody species of *Ziziphus* and *Prosopis* along the Persian Gulf and *Acacia,Nannorhops, Avicennia* and *Rhizophora* species along the Oman sea. 4- Iran-Touranian mountainous regions along the western and southern slopes of Zagros forests and along the south slopes of Hyrcanian regions extended toward the northeast and the northwest of Iran, covered by *Juniperus, Pistacia, Amygdalus* and *Berberis* woody species, and Iran-Touranian plain regions covering most of the central and eastern parts of Iran, dominated by *Artemisia, Astragalus, Zygophyllum, Tamarix, Haloxylon, Anabasis, Salsola, Calligonum, Acantholimon, Acanthophyllum,* and *Cousinia*. The objectives of this research were to classify and describe the life zones of Iran using the Holdridge life zone system and to determine the area of each life zone converted to an ecologically less valuable land use/cover type based on comparing the life zones and the actual land cover of Iran.

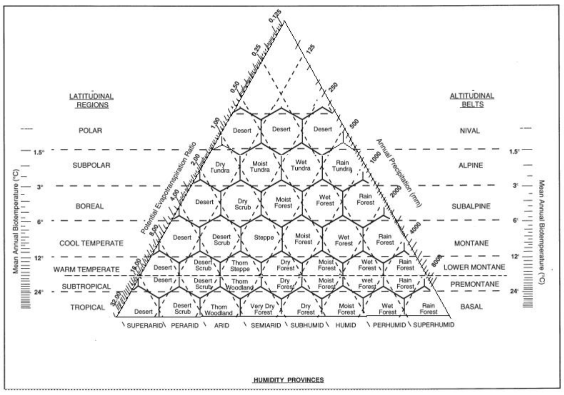

Fig. 1. Diagram for classification of the Holdridge life zones.

Material and methods

The Holdridge life zones

The Holdridge life zone classification system is based on precipitation (P), biotemperature (BT) and potential evapotranspiration (PET). The mean annual BT varies from 0 to 30 °C and is calculated as,

$$BT = \frac{\sum T_i}{12}$$

where T is the mean monthly temperature ($0<T<30$°C). Potential evapotranspiration ratio (PETR) (Fig. 1) is determined as,

$$PETR = \frac{PET}{P} = \frac{BT \times 58.93}{P}$$

The life zone classification map

To produce the life zone classification map based on the Holdridge system, the mean annual precipitation and biotemperature map of Iran were produced. The precipitation map of Iran (Fig 3a) was derived through interpolating the precipitation contour map of Iran produced by National Cartographic Center of Iran (NCCI). The data of 180 synoptic stations throughout Iran from 1955-2005 were applied to produce point layer of biotemperature. The point map was interpolated using kriging algorithm to create the biotemperature map of Iran (Fig 3b). The life zone classification map was then produced based on the classes of precipitation and biotemperature.

The life zone conversion

To determine the area which can contain a specific life zone, but it is converted to a land cover with less ecological value, the produced Holdridge life zone map was crossed with the current actual land cover map of Iran. The conversions studied included the conversion of 1) forest life zone to poor, moderate and good rangeland, woodland, bare land and agricultural (irrigated)-dry farm land, 2) woodland life zone to poor, moderate and good rangeland, bare land and agricultural-dry farm land, 3) steppe life zone to poor rangeland, bare land and agricultural-dry farm land and 4) scrub life zone to agricultural-dry farm land and bare land. The conversion of the life zones to some land cover types of Iran including wetland, kavir, sand dune, saltland and rock (Fig. 2) was not included, since such land covers are mainly formed based on specific edaphic, geomorphologic and hydrologic conditions and their appearance in an area with the potential of having a specific vegetation zone can not be considered as a conversion. The conversion of Holdridge desert life zone was also not included in the study. The only type of negative conversion of a desert is the conversion of the desert to an agricultural land which can cause an impact on habitat loss and consequently a decrease in biodiversity. In turn, agroecosystems provide a range of services including food, forage, bioenergy, carbon storage, etc. (Power, 2010). Then, due to this reason and the lack of more information on the results of the conversion of deserts to agroecosystems, this conversion was not included in the calculations.

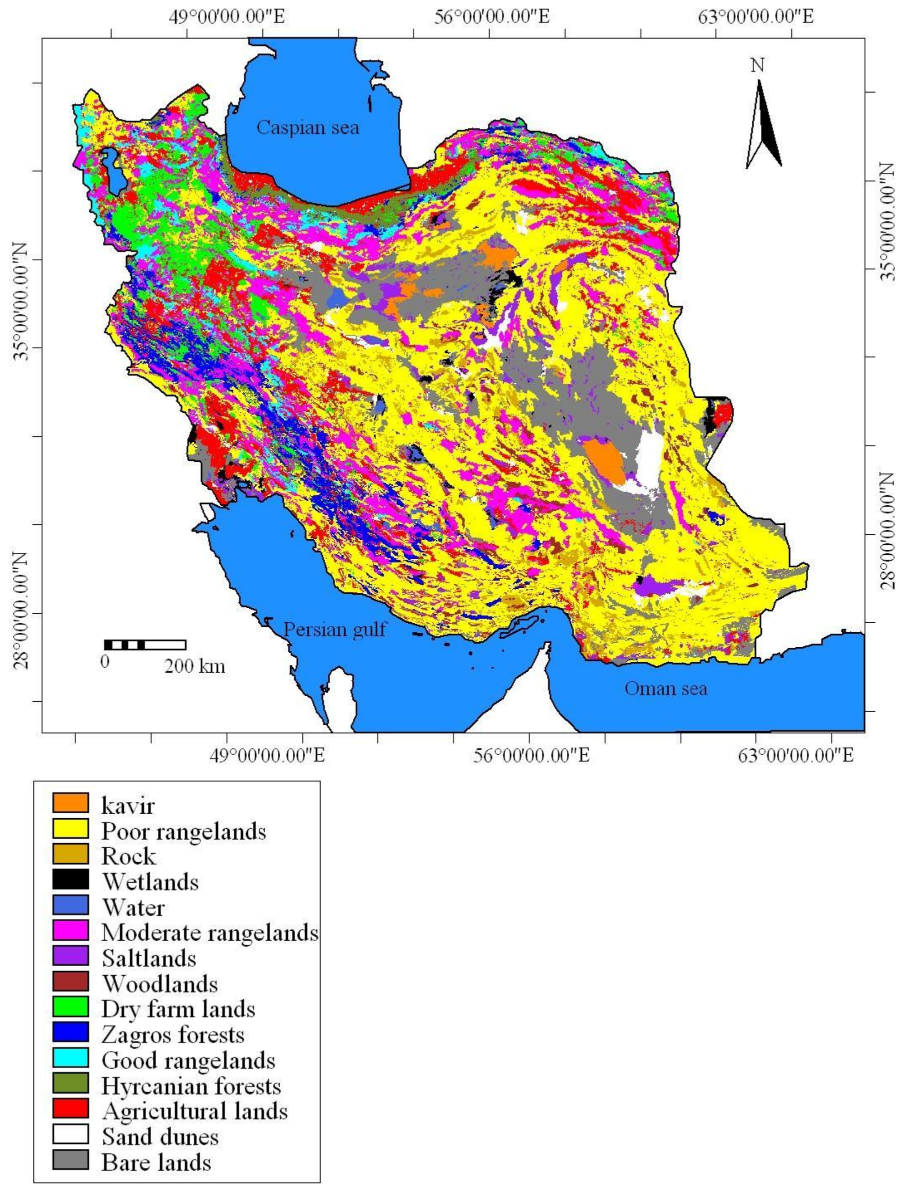

Fig. 2. The Reference land cover map of Iran.

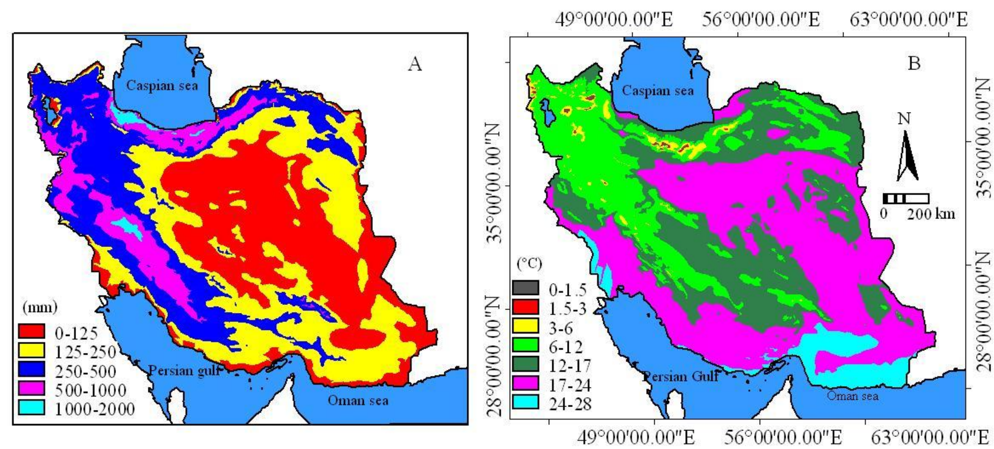

Fig. 3. A) Mean annual precipitation (mm) and B) mean annual biotemperature (°C) map of Iran.

Results

The Holdridge life zones of Iran

Classification of the life zones of Iran using the Holdridge system showed that Iran contains 26 life zones (Fig. 4). The area of each life zone based on latitudinal region, humidity province and physiognomic type is presented in table 1. The most extensive life zone is subtropical desert life zone which covers 22.1% (364581 km^2) of the country followed by cool temperate steppe, warm temperate desert scrub and subtropical desert scrub which cover 13.5%, 12.7% and 11.4% of the country (Fig 4). The life zone with the smallest coverage is subpolar moist tundra covering 0.004% of the area of Iran (66 km^2). Based on the latitudinal regions, Iran contains one polar, 2 subpolar, 4 boreal, 5 cool temperate, 5 warm temperate, 6 subtropical and 3 tropical life zones. The largest latitudinal life zone is the subtropical life zone covering 40.4% of the country followed by warm temperate life zone which covers 30.4 of the country. The smallest latitudinal life zone is subpolar life zone (0.03%). Based on the humidity provinces, periarid life zone is the largest humidity life zone covering 34.2 % of the country followed by arid life zone (24.8 % of Iran). The least area of the country is covered by the superhumid life zone (0.15%). According to the physiognomic types, most area of Iran (35%) is covered by desert life zone followed by scrub (30.4%), steppe (18.7%), forest (10.2%) and woodland (5.6%) life zone and the least area is covered by tundra (0.14%) (Fig. 5).

Table 1. Percentage of the area of Iran life zones, latitudinal regions, humidity provinces and physiognomic types.

Life zone grouping	
Life zone	
Subpolar moist tundra	0.004
Boreal dry scrub	0.03
Subpolar wet tundra	0.03
Boreal rain forest	0.04
Polar desert	0.09
Subtropical rain tundra	0.11
Subtropical moist forest	0.11
Cool temperate wet forest	0.28
Tropical thorn woodland	0.3
Cool temperate desert	0.43
Warm temperate moist forest	0.43
Boreal moist forest	0.59
Boreal wet forest	0.85
Subtropical dry forest	1.15
Tropical desert scrub	2.91
Warm temperate dry forest	2.96
Tropical desert	3.15
Cool temperate desert scrub	3.42
Cool temperate moist forest	3.82
Warm temperate thorn steppe	5.15
Subtropical thorn woodland	5.27
Warm temperate desert	9.16
Subtropical desert scrub	11.42
Warm temperate desert scrub	12.66
Cool temperate steppe	13.5
Subtropical desert	22.12
Physiognomic type	
Tundra	0.14
Woodland	5.57
Forest	10.23
Steppe	18.65
Scrub	30.44
Desert	34.97
Latitudinal region	
Subpolar	0.03
Polar	0.09
Boreal	1.51
Tropical	6.36
Cool temperate	21.25
Warm temperate	30.38
Subtropical	40.38
Humidity province	
Superhumid	0.15
Perhumid	1.16
Superarid	3.15
Humid	5.04
Semiarid	13.84
Subhumid	17.64
Arid	24.83
Perarid	34.19

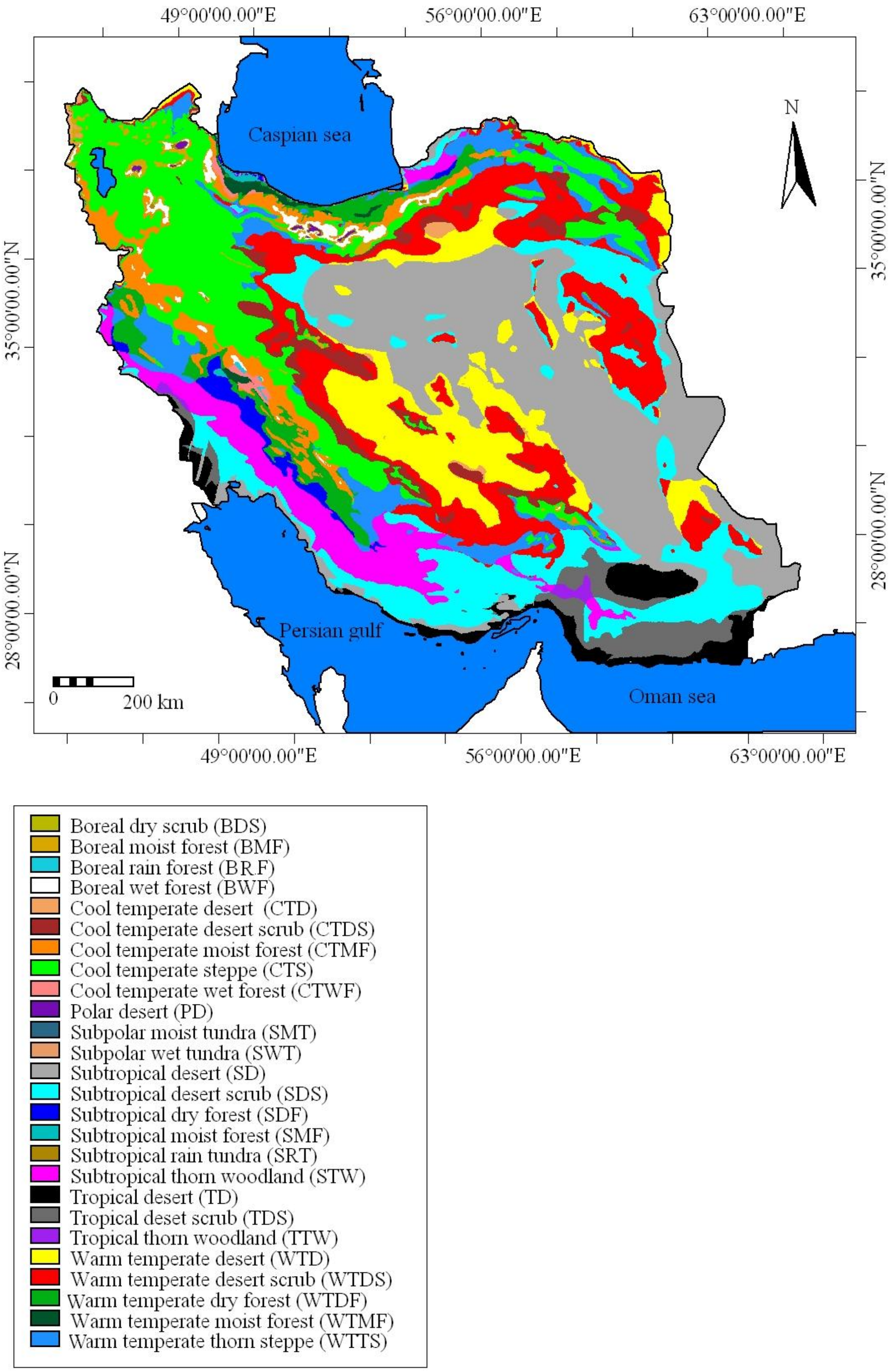

Fig. 4. Classification of the life zones of Iran using the Holdridge system.

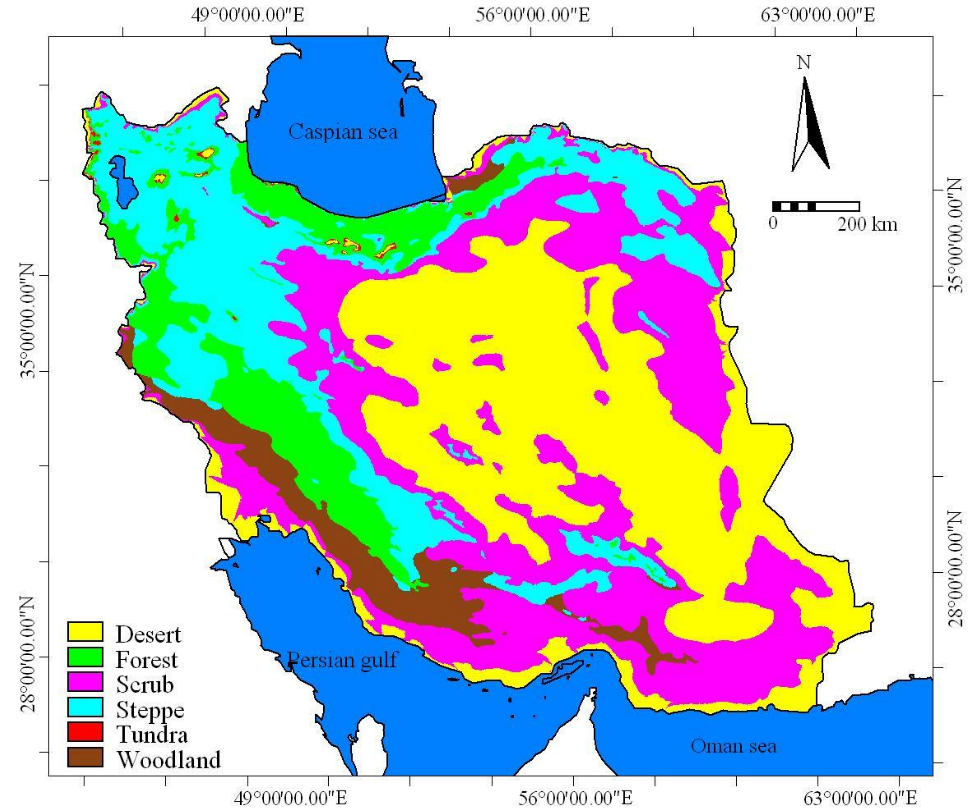

Fig. 5. Holdridge life zones of Iran based on physiognomic types.

Conversion of the life zones

Table 2 shows the results of crossing the produced Holdridge life zone map and the actual land cover map of Iran. The percentage area of each life zone (based on physiognomic type) covered by the land covers of Iran is presented in table 3. 35.1% of the area classified as forest life zone is covered by forest cover, 22.8% of the area is converted to agricultural-dry farm land, 20.7% to moderate rangeland, 12.1% to good rangeland, 8.4% to poor rangeland, 0.8% to woodland and 0.08% to bare land. That is, 64.9% of the area of forest life zone is converted to an ecologically less valuable cover type. Moderate and good rangelands were considered as a part of steppe life zone, but only 30.3% and 8% of the area which can contain steppe life zone is occupied by moderate-good rangelands and ecologically more valuable land cover (forest and woodland) respectively, and 23.6%, 37.1% and 0.94% of the area of this life zone is converted to poor rangeland, agricultural-dry farm land and bare land respectively (a total of 61.6%). 2 % and 11% of the area with the potential of having woodland life zone contains woodland and more ecological valuable cover (forest) respectively, and 44% is changed to poor rangeland, 22.1% to agricultural-dry farm land, 17.6% to moderate rangeland, 2.4% to good rangeland and 1% to bare land (a total of 87% negative conversion). Poor rangelands of Iran were considered as a part of scrub life zone. Then, 62.5% of the area of this life zone is unchanged, 16.6% of the area is under a more valuable land cover (1.2% forest, 3.4% woodland, 11.3% moderate rangeland, 0.7% good rangeland), but 14% is under the croplands and 6.9% is changed to bare lands.

Table 2. Results of crossing the produced Holdridge life zone map and the actual land cover map of Iran.

	Kavir	Poor rangelands	Moderate rangelands	Good rangelands	Rock	Wetlands	Water	Saltlands	Woodlands	Zagros forests	Hyrcanian forests	Agricultural lands	Dry farm lands	Sand dunes	Bare lands	Total
BDS	0	10	31	61	5	0	0	0	2	0	0	3	0	0	0	112
BMF	0	245	798	908	26	0	0	0	39	77	1	173	166	0	1	2434
BRF	0	59	79	3	0	0	0	0	1	25	0	4	0	0	0	171
BWF	0	263	1359	1256	33	0	3	0	10	298	46	118	104	0	2	3492
CTD	126	523	316	263	89	10	0	47	17	46	13	33	78	0	179	1740
CTDS	10	5998	3523	192	889	87	8	101	692	146	22	1116	747	0	465	13996
CTMF	0	1082	3878	2531	92	7	10	0	96	2709	1271	1636	2282	0	26	15620
CTS	0	12349	13775	3066	240	99	1088	17	503	1641	168	9721	11749	2	629	55047
CTWF	0	139	197	59	0	0	0	0	12	354	373	25	1	0	0	1160
PD	0	13	147	172	12	0	0	0	0	4	0	6	0	0	0	354
SD	4363	32470	1178	2	2713	1853	959	6614	847	81	3	1912	13	4835	32494	90337
SDF	0	877	863	36	11	3	50	0	71	1423	335	635	371	0	3	4678
SDS	0	28073	2388	127	3062	353	224	973	1224	699	0	4657	287	831	3744	46642
SMF	0	2	61	0	0	0	1	0	0	46	25	294	0	0	0	429
SMT	0	0	3	12	0	0	0	0	0	0	0	0	0	0	0	15
SRT	0	49	159	214	5	0	0	0	0	10	0	10	0	0	0	447
STW	0	8955	3729	521	374	153	116	74	359	2347	21	3851	770	2	211	21483
SWT	0	3	15	97	0	0	0	0	0	0	0	7	0	0	0	122
TD	0	6027	134	1	697	318	53	1416	140	11	0	1215	0	546	2146	12704
TDS	0	6957	243	2	1502	142	10	379	40	25	0	1075	33	191	1320	11919
TTW	0	619	89	0	231	1	0	0	65	13	0	153	41	7	10	1229
WTD	192	20591	2968	265	2978	501	478	1058	896	79	36	2295	489	266	4170	37262
WTDF	0	774	1147	226	44	5	9	0	104	4028	2476	2153	1029	0	0	11995
WTDS	0	29093	6476	407	2368	74	146	303	1810	465	12	6980	848	254	2230	51466
WTMF	0	26	204	9	0	0	0	0	0	144	919	453	1	0	0	1756
WTTS	0	5191	5179	516	131	14	13	2	606	2980	71	3706	2381	3	73	20866
Total	4691	160388	48939	10946	15502	3620	3168	10984	7534	17651	5792	42231	21390	6937	47703	407476

BDS: boreal dry scrub, BMF: boreal moist forest, BRF: boreal rain forest, BWF: boreal wet forest, CTD: cool temperate desert, CTDS: cool temperate desert scrub, CTMF: cool temperate moist forest, CTS: cool temperate steppe, CTWF: cool temperate wet forest, PD: polar desert, SMT: subpolar moist tundra, SWT: subpolar wet tundra, SD: subtropical desert, SDS: subtropical desert scrub, SDF: subtropical dry forest, SMF: subtropical moist forest, SRT: subtropical rain tundra, STW: subtropical thorn woodland, TD: tropical desert, TDS: tropical desert scrub, TTW: tropical thorn woodland, WTD: warm temperate desert, WTDS: warm temperate desert scrub, WTDF: warm temperate dry forest, WTMF: warm temperate moist forest, WTTS: warm temperate thorn steppe.

Table 3. The percentage area of each life zone covered by the current land covers of Iran.

	Current land cover								
	Zagros forests	Hyrcanian forests	Woodlands	Poor rangelands	Moderate rangelands	Good rangelands	Dry farm lands	Agricultural lands	Bare lands
Hodridge life zone based on Physiognomy									
Forest	21.97	13.14	0.8	8.37	20.72	12.13	9.54	13.25	0.08
Steppe	6.22	0.32	1.49	23.61	25.51	4.82	19.02	18.07	0.94
Woodland	10.85	0.1	1.95	44.01	17.55	2.39	3.73	18.41	1.02
Scrub	1.19	0.03	3.36	62.49	11.28	0.7	1.71	12.32	6.91

Tundra life zone covers only 0.14% of the area of Iran and it was not included in the calculations.

Discussion

The Holdridge life zones of Iran and the conversion of each life zone to the current land covers of Iran were determined. The efficiency of the Holdridge system has been proved in classification of life zones (Lugo *et al.,* 1999). The present study enabled to compare the potential vegetation and the actual vegetation of Iran and to determine the area of each life zone converted to an ecologically less valuable land cover. The conversion of natural ecosystems to ecologically less valuable land covers can result in the decrease of a variety of goods and services (Costanza *et al.,* 1997). The findings of this research revealed that largest area of the woodland, forest and steppe life zones of Iran was converted to a less valuable land cover. The conversion of forest life zone to agricultural land and moderate rangeland, the conversion of steppe and scrub life zone to agricultural land, and that of woodland life zone to poor rangeland were the largest types of negative conversions. The conversion the life zones to agricultural lands has been occurred due to human activities and the conversion to rangelands with less favorable conditions is resulted from climatic changes and inappropriate activities such as overgrazing (Saumel *et al*., 2011), early grazing and shrub cutting for firewood. The smallest area of negative conversion was related to the conversion of scrub life zone. This resulted from more favorable environmental conditions of the forest, woodland and steppe life zone than the scrub life zone for agriculture and livestock grazing. Dependant on the physiognomy of the life zones, the conversion of each of the life zone to a lower level may result in losses to ecosystem services. For example, the conversion of forests to rangelands may cause losses such as losses of soil organic matter, decrease in soil fertility and increase in carbon dioxide flux to the atmosphere (Garcia-Oliva *et al.,* 1994). Land use conversion from grassland/steppe to cropland can result in a variety of losses such as soil organic matter (Chen *et al.,* 2007) and net loss of soil carbon to the atmosphere. Shrublands/scrublands with a low productivity tend to have higher densities of rare endemic plants, and low productivity of these ecosystems makes them sensitive to human–made disturbances (Hansen *et al.,* 2005). Agricultural activities can be the cause of a variety of disservices including loss of habitat for conserving biodiversity (Falcucci *et al.,* 2007), nutrient runoff, pesticide poisoning of human and non-target species (Zhang *et al.,* 2007). In the present study, a small part of the area classified as woodland, steppe and scrub life zone is occupied by a more valuable land cover. These included the appearance of forest in the areas classified as woodland, the appearance of forest and woodland vegetation in the steppe life zone and that of forest, woodland, good and moderate rangelands in the scrub life zone. This may be occurred because of the positive climatic changes in those areas. Zheng *et al.* (2006) stated that the positive climate change can contribute to the life zone diversity and more stable environment. Considering that agricultural and grazing activities are inevitable and necessary for human wellbeing, efficient agricultural management such as plant breeding and appropriate grazing strategies through management of grazing intensity and time are necessary to prevent land cover changes. The mapped life zones of Iran can be used to assess the potential vegetation and facilitate the reclamation and restoration of negatively converted land covers.

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