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The influence of rural road development on forest extent changes over the three time periods: A case study of Chegeni region, Lorestan province

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Abstract

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The objective of this study was to investigate the influence of the development of road quality (surfacing condition and road type) and road quantity (road density and distance to main road) on forest extent changes in a region in Zagros forests of Iran over the three time periods of 1960s, 2000s and 2010s. Ranks of 1 to 5 were assigned to road quality. Forest extent changes were analysed on digital aerial photo mosaic. The Spearman and Pearson correlation coefficients were used to test the relationship between the road parameters and forest extent changes. Results showed that rural-forest road network has more influence on settlement development. Forest extent was correlated negatively with the road quality. Moreover, there were more disturbances to native forests closer to roads. It was concluded that forest cover decrease was associated with physical parameters including access to roads, cultivation practices, road quality and settlement development.

Keywords: road density; surfacing quality; forest cover; cultivation; aerial photo mosaic

Road network provides consistent basis for settlement access to the main and secondary public transport system (Jacoby 2002; Khandker et al. 2009). A settlement can be developed by transportation of services and facilities on road network and accessibility to markets and natural resources such as forest, sea, mines and etc. (Hawbaker et al. 2004; Kašková 2004; Roberts et al. 2006). In non-commercial forests at the west of Iran, road network are built due to the forest conservation and settlements connectivity. It was reported that forest extent changes in Iranian non-commercial forests are affected by increasing the rural road length and density (Hosseini et al. 2012a). Indeed, there was direct and meaningful relation between access to rural roads and land use changes (Mohammadi 2006; Buys et al. 2010). A study about the role of rural roads showed that there was positive relationship between road density and development of forest settlements and cultivation practices at the northern forests of Iran (Hosseini et al. 2012b).

Adedeji et al. (2014) assessed the effects of road quality (surface condition, road width, number of lane and reliability in all season), trip condition (farm, social, market and work trips), trip frequency (daily, weekly, fortnightly, monthly and occasionally) and traffic type (motorcycle, car, bus and lorry) on settlement development. Results showed

that the settlement and cultivation practices developed by improving road transportation. DeLuca (2007) reported that the forest extent changes in a region have historically been associated with spatial expansion of connection networks.

Rural roads can change in forest extent along roads (Laurance et al. 2009; Du et al. 2014). Population change and village development affect local land management and this can change forest extent across villages over time (Bahreini, Maknoon 2001; Savill et al. 2003). The objective of this study was to investigate the influence of the development of rural road quality (surfacing condition and road types) and quantity (density of roads and distances to main road) on forest extent changes over the three time periods of 1960s, 2000s and 2010s.

MATERIAL AND METHODS

Study area. The study area is located in Chegeni region in a mid-moist and dry forest of the northwest of Lorestan province, Iran (longitude from 33°36' to 33°42'E and latitude from 47°50' to 47°56'N). The region with an area of 6,861 ha ranges from 1,050 to 1,575 m a.s.l. The deciduous forest of study area has been established on lime stone, marl stone and sand stone. The mean annual precipitation and temperature are 504.3 mm and 28°C, respectively. *Quercus brantii* Lindley, *Pistacia atlantica* Desfontaines, *Crataegus aronia* (Linnaeus) Bosc ex de Candolle, *Pyrus communis* Linnaeus and *Prunus* sp. are the dominant tree species in the region (Fig. 1). There are 20 villages in Chegeni region which their general information has been shown in Table 1. Most of the people in the region were agronomist and rancher. Fig. 2 shows the flowchart of step by step of current research.

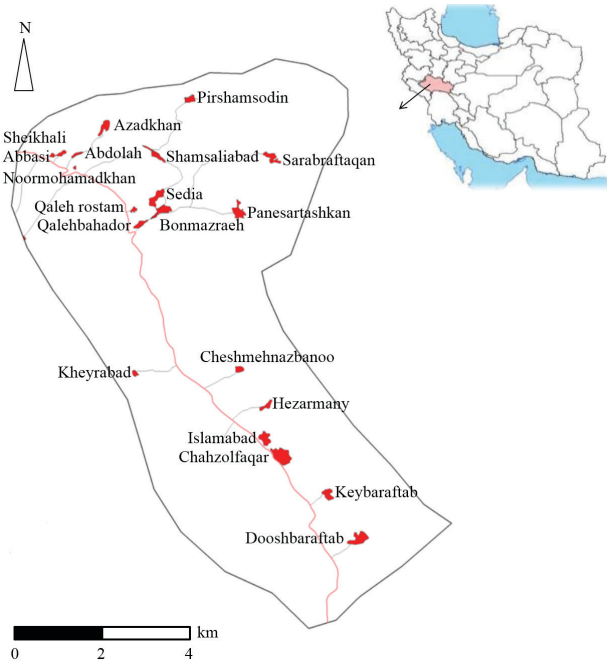

Fig. 1. Spatial position of the studied villages in Chegeni region, Lorestan province, Iran

Table 1. General information of villages located in Chegeni region

Village	Household	Population	Average age of population (yr)	Literacy		Monthly income (USD)
				illiterate	literate	
Dooshbaraftab	64	388	23	143	168	500
Keybaraftab	36	176	21	56	108	505.3
Chahzolfaqar	117	588	23	188	323	657.9
Islamabad	37	197	17	65	116	526.3
Kheyrabad	4	37	24	13	19	223.7
Hezarmany	17	83	23	22	53	289.5
Cheshmehnazbanoo	27	129	24	30	83	289.5
Qaleh bahador	47	230	18	44	157	526.3
Sedia	172	792	18	164	569	657.9
Qaleh rostam	20	90	22	19	63	394.7
Panesartashkan	111	585	23	217	325	460.5
Sarabraftaqan	89	466	25	115	294	342.1
Shamsaliabad	46	223	21	54	149	407.9
Pirshamsodin	27	137	25	25	100	342.1
Bonmazraeh	13	76	22	14	58	315.8
Sheikhali	16	82	24	10	67	315.8
Abbasi	14	63	21	8	43	315.8
Abdolah	14	76	23	14	55	315.8
Noormohamadkhan	55	232	24	51	155	315.8
Azadkhan	46	190	23	54	118	368.4

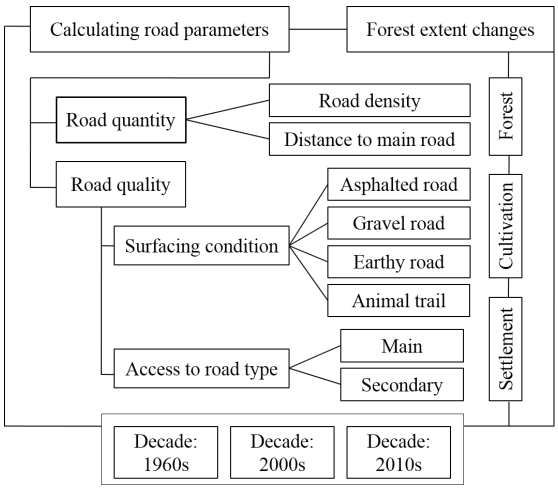

Fig. 2. Flowchart of research steps in current study

Estimating road parameters. Road network was taken from digital aerial photo mosaic. Then, the total length of road and distances of villages to main road was measured in Arc GIS (Version 9.3, 2008) for each decade of 1960s, 2000s and 2010s. Road density was calculated using Eq. 1 for a total area of 6,861 ha:

$$RD = \frac{RL}{A} \quad (1)$$

where:
RD – road density (m·ha^{-1}),
RL – total length of road in region (m),
A – area of the region (ha).

Surfacing condition of road was recorded as ranks of 1, 2, 3 and 5 for animal trail, earthy, gravel and asphalt road and 4 and 5 for secondary and main roads, respectively (Table 2). Eq. 2 was used to calculate road quality index:

$$\text{Final rank of road quality} = AT + SR + ER + MR + GR + AR \quad (2)$$

where:
AT – animal trail,
SR – secondary road,
ER – earthy road,
MR – main road,
GR – gravel road,
AR – asphalt road.

Table 2. Ranks of road quality (road type and surfacing condition)

Road quality	Rank
Animal trail	1
Earthy road	2
Gravel road	3
Secondary road	4
Main road	5
Asphalt road	5

Estimating forest extent changes. In order to determine forest extent changes in the study area from 1960s to 2010s. The forest map was produced using a digital aerial photo mosaic for each decade. The images were geo-referenced using GPS and digital elevation model. PCI Geomatica (Version 9.1, 2014), Arc GIS 9.3, ILWIS Academic (Version 3.0, 2005), Idrisi Kilimanjaro and Google Earth softwares were used in this step of research.

Statistical analysis. The Pearson correlation coefficient (for symmetric quantitative variables) and Spearman rank correlation coefficient (for variables with ordered categories) were used to test the relationship between the road parameters and forest extent changes. SPSS software (Version 16, 2004) was used to run the analyses.

RESULTS AND DISCUSSION

Rural road development

The roads benefited local communities by decreasing transportation cost of agricultural commodities and preventing from isolation of villages (Wilkie et al. 2000). Results of current study showed that the length of asphalt and gravel roads have increased over the decades. Indeed, the density and surfacing condition of rural roads improved over the decades (Table 3). The length of animal trail in 1960s was 4,260 m. Animal trail cannot be considered as a part of road network, so it was not computed in calculating road density in that decade. The lack of rural roads and the poor surfacing quality of road has been cited as a major constraint to cultivation activities (Salami et al. 2010).

Forest extent changes

Roads can create permanent fragmentation is a region and alter some land uses (Tanser et al. 2006). Each year, some forest lands are converted to non-forest lands, and some non-forest land is regenerated to forest. Table 4 shows forest extent

Table 3. Changes of rural-forest road parameters in decades of 1960, 2000 and 2010

Decade	Road		Surfacing condition (m)			
	length (m)	density (m·ha^{-1})	asphalt	gravel	earthy	trail
1960	38,710	5.02	0	0	34,450	4,260
2000	36,072	5.26	0	15,273	20,799	0.00
2010	57,995	8.45	29,026	8,308	20,661	0.00

Table 4. Land use changes in decades of 1960, 2000 and 2010

Decade	Extent (ha)		
	forest	cultivation	settlement
1960s	5,953.97	886.039	21.00
2000s	5,268.62	1,513.616	78.77
2010s	4,398.58	2,346.204	116.22

changes between 1960s and 2010s within the study area. Overall, it appears that a large proportion of the forest lands remained stable between 1960s (year 1968) and 2000s (year 2002). 11.5% reduction in forest extent was only observed after 34 years. However, forest extent in the study area decreased by 16.5% in a 14-year period from 2002 to 2016.

Results of current study indicated that the forest clearance through land use changes and shifting cultivation practices was associated with distance to roads and settlements (Fig. 3). It was found that deforestation in China was associated with infrastructural parameters such as the location of rivers, roads

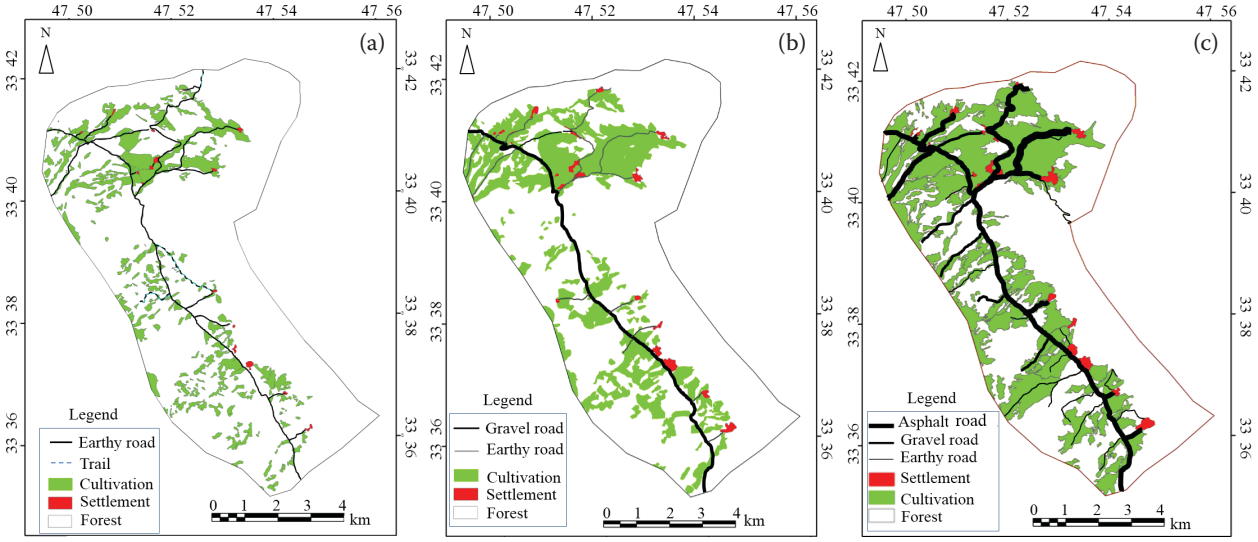

Fig. 3. Forest extent changes in decades of 1960 (a), 2000 (b) and 2010 (c)

Table 5. Land uses and forest extent changes in an area with radius of 500 m from the centre of each village (1960s to 2010s)

Village	Extent (ha)								
	forest			cultivation			settlement		
	1960s	2000s	2010s	1960s	2000s	2010s	1960s	2000s	2010s
Dooshbaraftab	72.93	62.05	53.64	3.79	8.35	11.52	1.76	8.08	13.30
Keybaraftab	54.32	45.97	28.45	23.26	28.81	45.79	0.90	3.70	4.25
Chahzolfaqar	59.76	54.84	45.19	15.17	19.86	19.86	3.55	12.10	13.43
Islamabad	58.36	50.52	46.69	18.54	23.04	23.57	1.58	5.28	8.25
Kheyrabad	64.86	61.84	49.00	13.58	15.27	26.86	0.05	1.38	2.63
Hezarmany	71.02	67.38	54.29	6.97	7.56	20.38	0.49	3.55	3.82
Cheshmehnazbanoo	70.86	63.81	38.53	6.70	12.39	35.55	0.93	2.29	4.40
Qaleh bahador	45.38	37.39	34.53	32.68	38.42	40.63	0.43	2.68	3.32
Sedia	22.56	21.77	9.15	51.96	44.76	52.29	3.98	11.97	17.05
Qaleh rostam	19.45	12.30	9.3	58.44	65.05	67.59	0.59	1.14	1.57
Panesartashkan	58.70	43.52	19.45	15.55	28.80	44.63	1.24	6.17	14.41
Sarabraftaqan	57.30	41.61	31.87	19.43	32.15	38.91	1.76	4.73	7.71
Shamsaliabad	64.85	32.48	16.53	13.02	42.07	52.49	0.62	3.94	9.47
Pirshamsodin	66.28	47.87	39.06	11.96	27.74	36.13	0.25	2.87	3.30
Bonmazraeh	71.53	60.05	45.85	6.77	18.13	31.96	0.19	0.31	0.682
Sheikhali	45.44	25.88	13.37	32.57	51.01	63.50	0.48	1.60	1.62
Abbasi	49.12	31.01	30.35	29.32	46.78	47.29	0.03	0.70	0.854
Abdolah	45.78	34.97	20.94	32.49	42.79	56.23	0.21	0.73	1.33
Noormohamadkhan	53.47	31.24	16.93	24.84	56.23	59.42	0.18	0.40	2.13
Azadkhan	50.13	49.18	35.97	27.19	24.78	37.50	1.16	4.53	5.01

Table 6. Correlation coefficient among road parameters, village development and forest based on two-tailed Spearman and Pearson tests

Parameter	Distance to main road	Road quality
Distance to main road	1	–0.500*
Road quality	–0.510*	1
Settlement extent	–0.491*	0.650**
Forest extent	0.577*	–0.558*

*significant at probability level of 95%, **significant at probability level of 99%

and settlements (Gao, Liu 2012; Du et al. 2014). Road density and housing density are related. As road and housing density increases, forest landscapes become increasingly fragmented and smaller (Table 5).

Relationship among road development and forest extent change

Results of present study demonstrated that the forest extent was correlated positively with distances to main roads and negatively with road quality ($P < 0.05$). There were more disturbances to forests closer to roads. In addition, the cultivation and settlement development were another strongest influential factor on forest extent reduction. Settlement extent increased with decreasing distance to main road and increasing road quality ($P < 0.05$, Table 6). Similar findings were also observed in researches of Mahapa and Mashiri (2001), Olayiwola and Adeleye (2005) and Phompila et al. (2017).

CONCLUSIONS

Key findings in this research showed that forest extent decrease was associated with physical parameters including access to roads, cultivation practices, road quality and settlement development. Our results provide better understanding of physical drivers of services and facilities development of villages and forest extent change at a local level, which is useful for policy makers to ensure the effective management of land use and forest resources.

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