The Egyptian Journal of Remote Sensing and Space Sciences (2015) **18**, 17–26

HOSTED BY

ELSEVIER

National Authority for Remote Sensing and Space Sciences

**The Egyptian Journal of Remote Sensing and Space Sciences**

www.elsevier.com/locate/ejrs
www.sciencedirect.com

RESEARCH PAPER

# Land use/cover disturbance due to tourism in Jeseníky Mountain, Czech Republic: A remote sensing and GIS based approach

**Mukesh Singh Boori** *, **Vít Voženílek**, **Komal Choudhary**

*Palacky University Olomouc, 17. listopadu 50, 771 46 Olomouc, Czech Republic*

Received 26 March 2014; revised 11 November 2014; accepted 1 December 2014
Available online 27 December 2014

**KEYWORDS**

Remote sensing;
GIS;
Tourism;
Land cover classification

**Abstract** The Jeseníky Mountains tourism in Czech Republic is unique for its floristic richness. This is caused mainly by the altitude division and polymorphism of the landscape, climate and soil structure. This study assesses the impacts of tourism on the land cover in the Jeseníky Mountain region by comparing multi-temporal Landsat imageries (1991, 2001 and 2013) to describe the rate and extent of land-cover changes. This was achieved through spectral classification of different land cover classes and by assessing the change in forest; settlements; pasture and agriculture in relation to increasing distances (5, 10 and 15 km) from three tourism sites with the help of ArcGIS software. The results indicate that the area was deforested (11.13%) from 1991 to 2001 than experienced forest regrowth (6.71%) from 2001 to 2013. In the first decade pasture and agriculture areas increased and then in next decade decreased. The influence of tourism facilities on land cover is also variable. Around each of the tourism site sampled, there was a general trend of forest removal decreasing as the distance from each village increased, which indicates tourism does have a negative impact on forests. However there was an opposite trend from 2001 to 2013 that indicates conservation area. The interplay among global (tourism, climate), regional (national policies, large-river management) and local (construction and agriculture, energy and water sources to support the tourism industry) factors drives a distinctive but complex pattern of land-use and land-cover disturbance.
© 2014 Production and hosting by Elsevier B.V. on behalf of National Authority for Remote Sensing and Space Sciences. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

## 1. Introduction

The Olomouc region has a rich diversity of activities and capable of pleasing the most demanding visitors. This is a place for enthusiasts of historical and natural monuments, winter sports, and bicycle tours. The Jeseníky Mountains offer a paradise full of natural treasure and hundreds of well-marked routes for hikers and cyclists, along with countless educational trails, caves, waterfalls and viewing towers. The

* Corresponding author at: Dept. of Geo-informatics, Section of Earth Science, Palacky University, Olomouc, Czech Republic. Tel.: +420 585634519 (O), +420 732287744 (M), +420 585639196 (R).
E-mail addresses: mukesh.boori@upol.cz (M.S. Boori), vit.vozenilek@upol.cz (V. Voženílek).
Peer review under responsibility of National Authority for Remote Sensing and Space Sciences.

http://dx.doi.org/10.1016/j.ejrs.2014.12.002
1110-9823 © 2014 Production and hosting by Elsevier B.V. on behalf of National Authority for Remote Sensing and Space Sciences.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

natural centre of the Olomouc region is the city of Olomouc with its distinguished monument, the Holy Trinity Column, which is inscribed on the UNESCO World Heritage List (Czech Tourist Authority, 2011). Its area is 5267 $km^2$ (January 1, 2006), 6.7% of the national territory, making it the 8th largest region in the country. As of H1 2009 there are 642,080 inhabitants (6.1% of the population of the Czech Republic, the 6th most populated region in the country). Its 397 communities make up for 6.4% of all communities in the country (Ministry of Regional Development, 2013). Olomouc, the regional capital with a population of 100,168 is the 5th largest city in the Czech Republic. There are 13 towns and cities with populations exceeding 5000 in the region (Czech Business Authority, 2010) and most attractive place for tourism.

The early 1990s produced a boom in tourism for Czech Republic as the country of architecture and rich culture was ‘rediscovered’ by Western Europeans curious to visit a country formerly hidden behind the Iron Curtain. The tourism boom brought US$ 4 billion per annum to the state budget (Czech Tourist Authority, 2011) with almost no marketing and promotion. Prior to the collapse of communism, the service sector (and hence the tourism industry) in the Czech Republic was weakly developed (Holland et al., 2003). The universal right to work, common to all ex-communist countries, favoured employment in heavy industries and/or collective agriculture. But earlier neither, private ownership of enterprises nor NGO activity was permitted it (Start, 2001). As in the rest of Eastern Europe, since the fall of the Iron Curtain in 1990 the economy underwent rapid transition, most notably the collapse of the primary sector and consequently rising unemployment. Between 1980 and 2000, the contribution of secondary industries to the GDP fell from 63% to 43%, while the contribution of tertiary industries increased from 30% to 53% (EBRD STAS, 2001).

Last five decades agriculture and forested landscapes have been transformed by economic and social development (Gaughan, 2006; Lambin and Geist, 2003; Walker, 2004; Wright, 2005). These transformations are important components of land cover disturbance and global environmental change (Foley et al., 2005; Moran, 2005; Rindfuss et al., 2004). The most rapid and significant include deforestation as a consequence of urbanization, agricultural expansion, logging and pastoral expansion (Boori and Ferraro, 2012; Lambin and Geist, 2003). Von Thunen model (Mather, 1986) explained the use of natural resources by the tourism industry. It explains that resource extraction increases with decreasing urbanization distance due to transportation cost (Chaplin and Brabyn, 2013). This evidence is outdated for developed world (Sinclair, 1967) due to improved infrastructure.

Land cover disturbance and environmental impact of tourism are particularly critical in mountain regions (Boori et al., 2014). Mountain communities are typically less affluent than their counterparts in lowland regions and poverty is still a fact in many mountain areas (Godde et al., 2000; Messerli and Ives, 1997). Infrastructure development is hampered by difficult access and harsh climate (Singh and Mishra, 2004). The drawing of policies and plans is less effective in mountain areas because historically these areas have been of marginal concern for decision-makers and therefore neglected in development priorities (Messerli and Ives, 1997). Moreover, policy implementation is undermined by political instability, which often characterizes mountain areas due to their proximity to national and international borders (Nepal and Chipeniuk, 2005). On top of these factors, there are peculiar conditions of mountain areas that make them more vulnerable, such as land cover disturbance, environmental fragility and tourism seasonality. High-altitude ecosystems are inherently fragile and characterized by low resiliency and therefore they are particularly susceptible to human interference such as soil and vegetation trampling, disturbance to native wildlife and waste dumping (Arrowsmith and Inbakaran, 2002; Buckley et al., 2002). High altitude recreation sites are characterized by extreme seasonality because accessibility and favorable climatic conditions are restricted to the short summer season. Consequently, human-induced disturbances on the land cover and environment are concentrated in this period, that is also the peak season for several biological processes such as mating, vegetation growth, migration, spawning etc. (Geneletti and Dawa, 2009).

## 2. Objectives and study area

The main objectives of this research were to monitor the impacts of tourism activity on land cover disturbance in the area of forest, agriculture, pasture and settlements from 1991 to 2013 on Jeseníky Mountains in the Olomouc region. Recent studies related to land cover disturbance and recreational ecology showed that mountain tourism had adverse effects on natural areas, protected areas and wetlands (Stevens, 2003; Buntaine et al., 2006). The impact of tourism development on forest resources and alpine vegetation, biodiversity has been well documented (Boori et al., 2010; Stevens, 2003) as well as its impact in terms of air pollution and noise (Shah et al., 1997). Typical mountain recreation activities include trekking, climbing expeditions, cultural tours, river rafting and bird gazing. In particular, high-altitude mountain trekking experienced a significant rise in popularity over the last decade that has led to a steep increase in the number of trekkers (Chatterjea, 2007; Geneletti and Dawa, 2009). Trail use is one of the fastest growing recreational activities and it is causing widespread impacts on ecosystems and landscape disturbance (Lynn and Brown, 2003). The Jeseníky PLA is spread out in the very northern part of Moravia and the Czech part of Silesia. The frontier is in between Moravia-Silesia and Olomouc regions in the Bruntál, Jeseník and Šumperk districts with the coordinate of 49°45′ N, 17°15′ E (Fig. 1).

## 3. Methodology

### *3.1. Data and pre-processing*

NASA's archive of Landsat images to the public without charge has created the opportunity for the cost-effective use of remote sensing for monitoring land cover anywhere on earth. Landsat 5 TM, Landsat 7 ETN+ SLC-on and Landsat 8 OLI/TIRS images (WRS II Path 190, Row 25; 9 Oct. 1991, 14 April 2001, 24 September 2013) were used for this research which were selected for their clarity and being at least 10 years apart. ArcGIS 10.1 software was used for all image preparation, spatial analysis and mapping. Topographic maps served as the base maps and were rectified (UTM WGS84) to the road layer with a nearest-neighbor resampling (RMSE $< 0.5$ pixels, or $< 15$ m). Image-to-image registration was performed on the

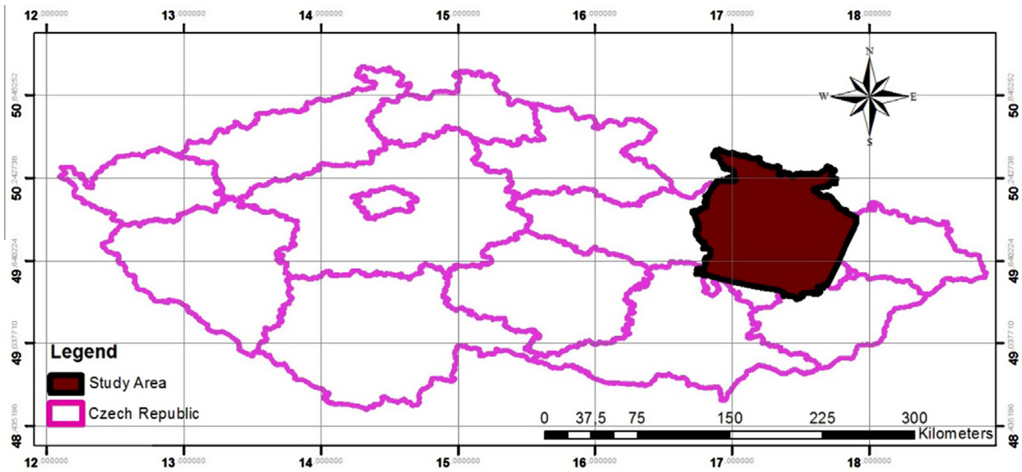


**Figure 1** Study area: Jeseníky Mountain region Olomouc, Czech Republic.

other images. After completing the registration, each image was radiometrically calibrated to correct for sensor related, illumination and atmospheric sources of variance (Green et al., 2005). Chaplin and Brabyn (2013) used remote sensing and GIS to investigate the impacts of tourism on forest cover in the Annapurna conservation area Nepal.

The ancillary data used in this research include:

- Photos and field notes recorded in 2013 during a trek around the study area;
- Google Earth images used as reference data during the classification and validation phases of the analysis;
- GIS layers of the study area, which include roads, rivers, ecological boundaries and land-cover maps obtained from the European Space Agency (ESA) and the United States Geological Survey.

### *3.2. Field data collection*

Field work was conducted to determine ambiguous land-cover classification and to visit area of major change to determine causes of the changes with both observation and informal interviews of local people. This also provided a secondary validation of the classification accuracy for the most current image date. A *Trimble* hand-held GPS with an accuracy of 10 m was used to map and collect the coordinates of important land use features during pre- and post-classification field visits to the study area in order to prepare land-use and land-cover maps (Boori and Amaro, 2011).

### *3.3. Normalized Difference Vegetation Index (NDVI) calculation and change detection*

The Normalized Difference Vegetation Index (NDVI) is calculated as (NIR − red)/(NIR + red), where red corresponds to Landsat TM band 3 and near-infrared to band 4. Continuous NDVI values range from $-1$ to $+1$. High values closer to $+1$ are associated with healthy green vegetation and standing biomass. NDVI was calculated for each image date and then used to calculate standard normal deviates ($Z$-scores) to minimize the influence of seasonal variation and inter-annual differences (Jensen, 2005). The use of the standard normal deviates reduces much of the potential effect of inter-annual climate variation. This is necessary when using anniversary dates and calibrated imagery, in a region influenced by heavy rainy season precipitation amounts.

### *3.4. Image classification*

In this research work, first we used unsupervized classification and after field visit or identification of land cove classes, we used supervized classification on the basis of training sites. Forest was defined as $>30\%$ tree canopy closure to separate the dense forest area from scrub and agriculture lands. Non forested land includes an aggregation of the other land covers water, pasture (which at this time of year includes agriculture, which presents as bare soil, within this cover), built and scrub. The DEM was used to separate the high and low elevation area.

Three tourist sites (Olomouc, Rymarov and Jesenilk) were identified to access tourism effect, using the field notes as a guide and spatially located as a point GIS layer. A gradient of tourism proximity was generated using the ArcGIS "multi-ring buffer" tool to produce three concentric circles placed 5 km apart around each of the tourism facilities. Then proximity zone was overlaid on land cover change layer and statistics for each tourism facility and proximity zone. This was further analyzed to calculate the net percentage change in forest, agriculture, pasture, settlements and regression analysis was used to identify trends in change and tourism proximity. This analysis was applied for all three tourism facilities combined with the Olomouc, Rymarov and Jeseníky facilities for 1991, 2001 and 2013 (Fig. 2).

## 4. Results

### *4.1. Overall changes*

Agriculture and forested land makes up the largest percent of the study area with 35%, 40%, area in 1991 and vice versa in 2013 (Table 1). Forest makes up the largest land-cover and

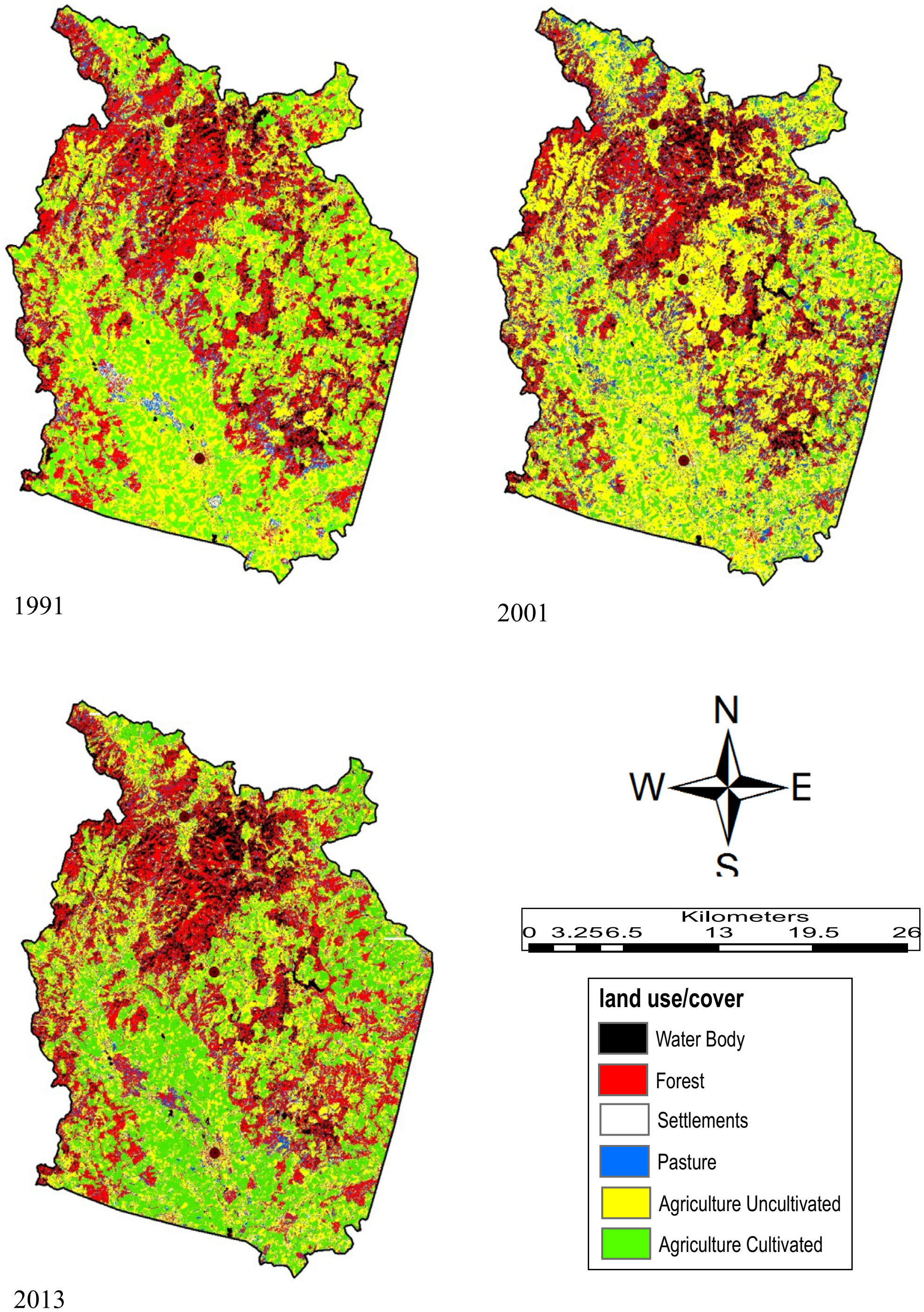


**Figure 2** Land cover change maps for 1991, 2001 and 2013.

occurs predominantly in the more upland areas with greater relief. Forest area decreases (222.53 $km^2$) slightly during the first half of the study period but then increases (35.78 $km^2$) during the second half of the study. Water makes up less than 15% of the upland landscape for all years of the study. Table 1 provides the areas of each class. The total area of the study area was 2000 $km^2$. From 1991 to 2001, there has been a net decrease of forest which is 11.13%. But in 2001–2013, 6.71% forest area was added. Pasture and agriculture were added 4.44% and 5.17% respectively from 1991 to 2001 but both areas reduced (7.08% and 3.23% respectively) from 2001 to 2013. These changes show governmental protection of forest area in between 2001 and 2013. Table 1 shows that there is no change in number of settlements from 1991 to 2001 but for next decade settlements and water body area was increased.

Regarding the management, the analysis of vegetation characteristics shows that in Jesnilk area stands are in better condition, with bigger trees showing larger basal area and larger crowns, showing evidence of little exploitation. The low wood exploitation is also unfavorable to the activation

**Table 1** Land cover areas ($km^2$) change for 1991, 2001 and 2013.

| Class | Area | % | Area | % | Area Diff. | % Diff. |
|---|---|---|---|---|---|---|
| | 1991 | | 2001 | | | |
| Water | 209.85 | 10.49 | 243.77 | 12.19 | 33.92 | 1.7 |
| Forest | 804.02 | 40.2 | 581.49 | 29.07 | −222.53 | −11.13 |
| Settlement | 29.87 | 1.49 | 26.42 | 1.32 | −3.45 | −0.17 |
| Pasture | 213.03 | 10.65 | 301.75 | 15.09 | 88.72 | 4.44 |
| Agriculture | 743.23 | 37.16 | 846.57 | 42.33 | 103.34 | 5.17 |
| Total | 2000 | 100 | 2000 | 100 | | |
| | 2001 | | 2013 | | | |
| Water | 243.77 | 12.19 | 298.85 | 14.94 | 55.08 | 2.75 |
| Forest | 581.49 | 29.07 | 715.61 | 35.78 | 134.12 | 6.71 |
| Settlement | 26.42 | 1.32 | 43.55 | 2.18 | 17.13 | 0.86 |
| Pasture | 301.75 | 15.09 | 160.09 | 8 | −141.66 | −7.08 |
| Agriculture | 846.57 | 42.33 | 781.9 | 39.09 | −64.67 | −3.23 |
| Total | 2000 | 100 | 2000 | 100 | | |

of vegetative regeneration for holm oak stands, which may in the long term endanger its sustainability. Conversely, the coppice resource dominates, trees are degraded and the abundance of holm oak coppices emphasizes the intensity of wood exploitation. When tree cover is maintained, it is often due to bushy stands, resulting from the degradation of previous tree clusters. During field visit and key note interviews, we find that tourism and socioeconomic activities are responsible for these land cover disturbance.

### 4.2. Types of change

Change trajectories between the years 1991, 2001 and 2013 were compared on a pixel-by-pixel basis to examine possible land-cover disturbance (Table 2). Thirty-three percent of the landscape remained in the same land-cover class from 1991, 2001 to 2013. Two-date changes (1991–2001 and 2001–2013) show 950 $km^2$ forest and 3000 $km^2$ agriculture area was stable in last two decades. 140 $km^2$ agriculture, 20 $km^2$ forest and 18 $km^2$ pasture area encroached by settlements from 2001 to 2013. Stable forest cover mostly was located in high elevation areas of the mountain especially in Jesenilk, Bruntal, Sumperk and Rymarov.

However, it may not absolutely represent the real land cover disturbance because of the difficulty of modeling the factors influencing this disturbance and the magnitude of human reaction capacity. On the other hand, the pressure exerted on forest depends on the socio-economic and tourist context and may change in the future, according to the disturbance that these societies are experiencing. Indeed, the rapid opening up of the study area due to tourism since the 1980s, the development of commercial agriculture and the national and international development initiatives—electrification in 2002, the introduction of the gas stove, the emergence of the cell phone in 2005, foreign aid offered by different NGOs—have widely contributed to accelerating the land disturbance of practices as well as creating new production systems likely to partially reduce the pressure exerted on the forest and agriculture. One example of these tendencies is the slight decline of pastoralism, which reduces the cutting of leaf fodder during the cold season.

### 4.3. Impact of tourism

Table 3 summarizes the changes in land cover extent by proximity for all 3 tourism facilities. From 1991 to 2001 forest

**Table 2** Types of changes between 1999 and 2013 for areas analyzed.

| Class | Water | Forest | Settlement | Pasture | Agriculture | Total |
|---|---|---|---|---|---|---|
| *Cross table 1991–2001* | | | | | | |
| Water | 235.38 | 148.87 | 0.47 | 20.04 | 19.8 | 424.56 |
| Forest | 266.97 | 974.07 | 8.02 | 331.45 | 202.03 | 1782.53 |
| Settlements | 0.35 | 31.94 | 5.66 | 39.84 | 66.12 | 143.92 |
| Pasture | 1.53 | 77.09 | 2.12 | 135.31 | 259.78 | 475.84 |
| Agriculture | 12.38 | 72.37 | 168.32 | 333.33 | 3404.05 | 3990.44 |
| Total | 516.62 | 1304.33 | 184.58 | 859.97 | 3951.78 | 6817.29 |
| *Cross table 2001–2013* | | | | | | |
| Water | 318.72 | 161.83 | 4.6 | 15.68 | 19.68 | 520.51 |
| Forest | 179.63 | 988.09 | 20.39 | 50.45 | 57.76 | 1296.32 |
| Settlements | 0.12 | 12.49 | 11.79 | 5.54 | 156.41 | 186.35 |
| Pasture | 2.36 | 462.99 | 18.74 | 120.7 | 262.02 | 866.81 |
| Agriculture | 3.3 | 237.62 | 140.5 | 322.02 | 3239.15 | 3942.59 |
| Total | 504.12 | 1863.03 | 196.02 | 514.38 | 3735.02 | 6812.57 |

**Table 3** Net land cover change from 0 to 15 $km^2$ area summary table.

| Class | 1991 | | 2001 | | Area Diff. | % Diff. | 2013 | | Area Diff. | % Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area | % | Area | % | | | Area | % | | |
| *Olomouc* | *0–5 km* | | | | | | | | | |
| Water | 0.34 | 0.4 | 0.34 | 0.4 | −0.01 | 0 | 0.36 | 0.43 | 0.023 | 0.03 |
| Forest | 5.25 | 6.14 | 4.78 | 5.72 | −0.46 | −0.42 | 10.92 | 12.98 | 6.136 | 7.26 |
| Settlements | 4.35 | 5.1 | 8.50 | 10.17 | 4.15 | 5.07 | 7.02 | 8.35 | −1.478 | −1.48 |
| Pasture | 2.74 | 3.2 | 6.19 | 7.41 | 3.46 | 4.21 | 6.43 | 7.64 | 0.236 | 0.24 |
| Agriculture | 72.75 | 85.16 | 63.80 | 76.31 | −8.95 | −8.85 | 59.37 | 70.6 | −4.43 | −5.71 |
| Total | 85.43 | 100 | 83.61 | 100 | | | 84.10 | 100 | | |
| | *5–10 km* | | | | | | | | | |
| Water | 1.70 | 0.71 | 2.27 | 0.95 | 0.57 | 0.24 | 2.05 | 0.84 | −0.22 | −0.11 |
| Forest | 15.00 | 6.24 | 11.21 | 4.68 | −3.79 | −1.56 | 22.60 | 9.26 | 11.39 | 4.59 |
| Settlements | 6.82 | 2.84 | 10.57 | 4.41 | 3.75 | 1.57 | 8.65 | 3.55 | −1.92 | −0.86 |
| Pasture | 8.37 | 3.48 | 17.99 | 7.50 | 9.62 | 4.02 | 14.90 | 6.11 | −3.09 | −1.40 |
| Agriculture | 208.44 | 86.73 | 197.67 | 82.46 | −10.77 | −4.27 | 195.77 | 80.24 | −1.9 | −2.22 |
| Total | 240.33 | 100.00 | 239.71 | 100.00 | | | 243.97 | 100.00 | | |
| | *10–15 km* | | | | | | | | | |
| Water | 8.15 | 2.07 | 7.83 | 1.96 | −0.32 | −0.11 | 4.64 | 1.19 | −3.19 | −0.77 |
| Forest | 50.38 | 12.77 | 32.92 | 8.23 | −17.46 | −4.53 | 58.07 | 14.87 | 25.15 | 6.63 |
| Settlements | 11.37 | 2.88 | 17.66 | 4.42 | 6.29 | 1.54 | 12.17 | 3.12 | −5.49 | −1.30 |
| Pasture | 22.25 | 5.64 | 37.78 | 9.45 | 15.53 | 3.81 | 32.49 | 8.32 | −5.29 | −1.13 |
| Agriculture | 302.50 | 76.65 | 303.58 | 75.94 | 1.08 | −0.71 | 283.21 | 72.51 | −20.37 | −3.43 |
| Total | 394.65 | 100.00 | 399.77 | 100.00 | | | 390.58 | 100.00 | | |
| *Rymarov* | *0–5 km* | | | | | | | | | |
| Water | 2.59 | 3.13 | 3.84 | 4.72 | 1.25 | 1.59 | 3.56 | 4.34 | −0.28 | −0.38 |
| Forest | 14.88 | 17.94 | 10.05 | 12.35 | −4.84 | −5.59 | 14.79 | 18.03 | 4.75 | 5.68 |
| Settlements | 0.98 | 1.18 | 2.92 | 3.58 | 1.94 | 2.40 | 1.98 | 2.42 | −0.93 | −1.16 |
| Pasture | 4.37 | 5.27 | 7.12 | 8.74 | 2.75 | 3.47 | 4.83 | 5.89 | −2.29 | −2.85 |
| Agriculture | 60.12 | 72.48 | 57.46 | 70.61 | −2.66 | −1.87 | 56.88 | 69.32 | −0.58 | −1.29 |
| Total | 82.94 | 100 | 81.38 | 100 | | | 82.05 | 100 | | |
| | *5–10 km* | | | | | | | | | |
| Water | 11.77 | 4.89 | 25.99 | 10.88 | 14.22 | 5.99 | 27.56 | 11.59 | 1.57 | 0.71 |
| Forest | 92.97 | 38.62 | 63.77 | 26.69 | −29.20 | −11.93 | 82.17 | 34.55 | 18.40 | 7.86 |
| Settlements | 3.31 | 1.37 | 3.02 | 1.26 | −0.29 | −0.11 | 4.67 | 1.96 | 1.65 | 0.70 |
| Pasture | 22.97 | 9.54 | 28.12 | 11.77 | 5.15 | 2.23 | 17.67 | 7.43 | −10.45 | −4.34 |
| Agriculture | 109.74 | 45.58 | 118.03 | 49.40 | 8.29 | 3.82 | 105.76 | 44.47 | −12.27 | −4.93 |
| Total | 240.76 | 100.00 | 238.93 | 100.00 | | | 237.83 | 100.00 | | |
| | *10–15 km* | | | | | | | | | |
| Water | 27.65 | 7.01 | 58.54 | 15.66 | 30.89 | 8.65 | 55.55 | 13.75 | −2.99 | −1.91 |
| Forest | 140.70 | 35.66 | 105.49 | 28.22 | −35.21 | −7.44 | 133.45 | 33.03 | 27.96 | 4.81 |
| Settlements | 5.33 | 1.35 | 6.93 | 1.85 | 1.60 | 0.50 | 7.88 | 1.95 | 0.95 | 0.10 |
| Pasture | 31.96 | 8.10 | 46.00 | 12.31 | 14.04 | 4.21 | 27.84 | 6.89 | −18.16 | −5.41 |
| Agriculture | 188.95 | 47.89 | 156.87 | 41.96 | −32.08 | −5.92 | 179.33 | 44.38 | 22.46 | 2.42 |
| Total | 394.59 | 100.00 | 373.83 | 100.00 | | | 404.05 | 100.00 | | |
| *Jesenik* | *0–5 km* | | | | | | | | | |
| Water | 9.81 | 11.87 | 27.437 | 28.31 | 17.63 | 16.44 | 12.34 | 15.29 | −15.09 | −13.02 |
| Forest | 31.25 | 37.82 | 20.851 | 21.51 | −10.40 | −16.31 | 27.73 | 34.35 | 6.88 | 12.84 |
| Settlements | 1.51 | 1.83 | 1.555 | 1.6 | 0.04 | −0.23 | 2.48 | 3.08 | 0.93 | 1.48 |
| Pasture | 9.74 | 11.79 | 11.345 | 11.7 | 1.61 | −0.09 | 8.48 | 10.5 | −2.87 | −1.29 |
| Agriculture | 30.32 | 36.7 | 35.74 | 36.87 | 5.42 | 0.17 | 29.69 | 36.78 | −6.05 | −0.09 |
| Total | 82.63 | 100 | 96.93 | 100 | | | 80.73 | 100 | | |
| | *5–10 km* | | | | | | | | | |
| Water | 35.25 | 14.54 | 31.53 | 13.86 | −3.72 | −0.68 | 57.59 | 24.01 | 26.06 | 10.15 |
| Forest | 122.84 | 50.68 | 86.11 | 37.86 | −36.73 | −12.82 | 104.04 | 43.37 | 17.93 | 5.51 |
| Settlements | 1.42 | 0.59 | 1.20 | 0.53 | −0.22 | −0.06 | 3.71 | 1.55 | 2.51 | 1.02 |
| Pasture | 26.98 | 11.13 | 37.76 | 16.60 | 10.78 | 5.47 | 19.97 | 8.32 | −17.79 | −8.28 |
| Agriculture | 55.91 | 23.07 | 70.85 | 31.15 | 14.94 | 8.08 | 54.57 | 22.75 | −16.28 | −8.40 |
| Total | 242.40 | 100.00 | 227.45 | 100.00 | | | 239.88 | 100.00 | | |

**Table 3** (*continued*)

| Class | 1991 | | 2001 | | Area Diff. | % Diff. | 2013 | | Area Diff. | % Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area | % | Area | % | | | Area | % | | |
| | *10–15 km* | | | | | | | | | |
| Water | 40.97 | 11.55 | 51.49 | 14.64 | 10.52 | 3.09 | 78.76 | 22.14 | 27.27 | 7.50 |
| Forest | 157.95 | 44.54 | 126.54 | 35.98 | −31.41 | −8.55 | 143.81 | 40.43 | 17.27 | 4.45 |
| Settlements | 2.75 | 0.78 | 3.77 | 1.07 | 1.02 | 0.30 | 6.04 | 1.70 | 2.27 | 0.63 |
| Pasture | 36.69 | 10.35 | 51.78 | 14.72 | 15.09 | 4.38 | 23.48 | 6.60 | −28.30 | −8.12 |
| Agriculture | 116.29 | 32.79 | 118.09 | 33.58 | 1.80 | 0.79 | 103.62 | 29.13 | −14.47 | −4.45 |
| Total | 354.65 | 100.00 | 351.67 | 100.00 | | | 355.71 | 100.00 | | |

area was reduced in 0–5, 5–10 and 10–15 $km^2$ distance in all three tourist sites. But it was increased from 2001 to 2013. In Olomouc there was negligible forest area from 0 to 15 $km^2$ so the total area of forest removal was very less. In the village of Rymarov, removal of forest area was more than double of Olomouc. As Jesenilk has a very high dense forest area removal of forest area was very high. In Jesnilk from 0 to 5, removal of forest was 16.31%, 5–10 km was 12.82% and from 10 to 15 km removal of forest was 8.55% area from 1991 to 2001. It could be concluded that tourism villages do have an impact on the forest (Table 3), however there was a considerable geographical variation also responsible for changes. In Olomouc and Rymarov agriculture area was decrease but pasture area was increased from 1991 to 2001 for all 0–15 $km^2$ distance. Both areas were decreased from 2001 to 2013 for all 0–15 $km^2$ distance. For Jesenilk, pasture and agriculture both have similar behavior like Rymarov.

The analysis of overall disturbance in Jesnilk area through remote sensing appears that many areas mapped as "stable" also experienced a strong exploitation of vegetation which may have led to qualitative land cover disturbance. More generally, the various canopy cover mapped using remote sensing may show very different morphology. This means that the changes in terms of area and percentage cover revealed by remote sensing analysis may neglect at least locally, the qualitative disturbance of the vegetation.

Fig. 3 shows the proportional change in forest with increasing distance from the three tourist sites. These graphs provide trend lines, which show both positive and negative relationships between land cover change (Forest, Agriculture, Settlements, Water body, Pasture) and distance from village. A positive trend shows that with less distance from the city/villages there was more removal of forest, agriculture (relative to the forest, agriculture area available), which is what you would expect based on Von Thunen's model of resource use (increasing resource use with decreasing distance to markets). In Olomouc from 1991 to 2001 water was stable, forest, and agriculture were in negative direction and settlement, pasture was in a positive direction for all three distances (0–15 $km^2$). In 2001–2013 forest was protected and increased in positive direction. Other classes was stable or in negative direction. In Rymarov forest and agriculture were in negative direction but rest classes were grown in positive direction from 1991 to 2001. In next decay forest was grown in positive direction but rest classes were stable or over all in negative direction. Jesnilk result was also very much similar to Olomouc and Rymarov (Fig. 3). This was showing forest protection from 2001 to 2013. Bruntal, Sumperk, Jeseník, Rymarov, Zabreh, Unicov, Litovel and Prostejov were in an area of forest and pasture development and located at the northern part of the study area. Hranice, Opava, Krnov, Stemberk, Olomouc, Vitkov, Mohelnice and Prerov were in an area of agriculture oriented and located in south part of study area.

Fig. 3 also displays the separate trends in forest change in relation to distance for each of the three analyzed places. Olomouc is located in the southern part of study area and is a relatively large town with plenty of visitors and through traffic from trekkers, tourists, which explains the high level of forest removal. The trend line has a positive relationship indicating decreasing forest removal at a greater distance from the settlement. Jesenilk also shows the same positive relationship and a high proportion of forest removal. Rymarov is in an area with little agriculture, suggesting that tourism and socioeconomic activities could be the main reason for forest harvesting. There has also been a road development in this area allowing tourists to reach Jesnilk much faster than in the past. The new road could also make it easier to export logs from this region.

## 5. Discussion

At lower altitudes a mixture of agriculture and forestry should be implemented. However, to meet the needs of the local population and tourist that would grow substantially in the next 5–10 years a portion of the land must be used for grain production. Nevertheless, some of this land could be reused for forestry at some time in the future. The recommended reallocations were tested in a few experimental sites and more or less reflected the land use practice in reality (Geneletti and Dawa, 2009). In any assessment the accuracy of the final results is subject to the accuracy of the input data layers. Some data (e.g., land cover) had a definite boundary, whereas other variables (e.g., climate and socio-economic) had a vague boundary. Therefore, the final results involved some uncertainty and should be treated with caution (Boori and Amaro, 2010a; Start, 2001).

The irrational way of land use such as conversion from woodland to farmland has led to land degradation. However, through reallocation of land that has been excessively exploited to a new use (commensurate with its potential, this problem could be remedied (Rindfuss et al., 2004). The recommended optimal allocation emphasized the ecological suitability for exploitation of natural resources and encouraged mixed farming with forestry, pasture and stockbreeding. Naturally switching from farming to forest would reduce grain output. However, improving farmland productivity through construc-

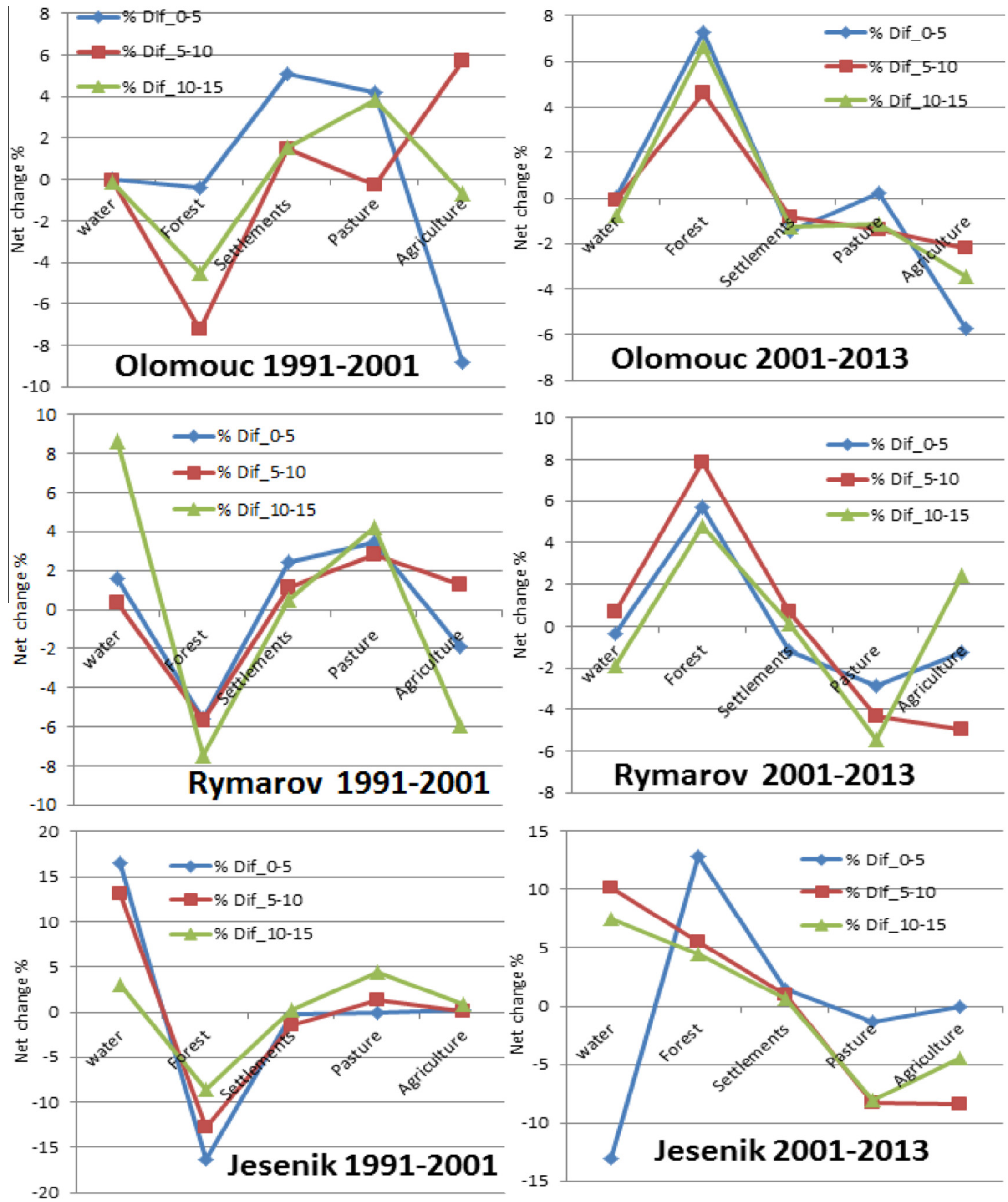


**Figure 3** Net changes in land cover area around individual tourism facilities.

tion of irrigation facilities as well as converting the existing sloped farmland into terraced land to conserve soil and water could compensate these decreases (Lambin and Geist, 2003).

Nevertheless, successful implementation of these recommendations relies on other related measures (Bao et al., 2005). Those farmers disadvantaged by the reallocation should be compensated for their economic loss in the form of a government-sponsored grant. In this way farmers' livelihoods would not be negatively affected. Another means of achieving the reallocation was through cultivation of medicinal herbs. As a perennial vegetative cover these plants could prevent soil erosion. Finally, to reduce overpopulation, reallocation of some of the rural population should be encouraged. With these measures the recommended reallocation could ensure sustainable exploitation of land resources in the study area (Singh and Mishra, 2004).

In this case study our findings indicate that the rationality in forest use still remains unworkable due to the absence of alternatives that would reconcile the ecological resilience, the mitigation of the current degradation trends and the population's needs for livelihood (Chatterjea, 2007; Boori and Amaro, 2010b). More specifically the failure of natural resource management seems also to rely on the impossible equation between growing population needs and the physically limited production capacity of the natural environment (soils, climate) leaving no place to intensification, except with substantial inputs from outside the system. Such a saturation of traditional systems, triggered mainly by the population growth was widely occurring in many places throughout the world (Niamir, 1990; Semwal et al., 2004). The solution relies on a deep transformation of the traditional system, typically changing from self-sufficiency to a higher level of connection with the external economy (people working in cities, multiplication of income sources). This explains why some forests close to urban areas may be in bad condition than forests located in remote traditional areas (Buckley et al., 2002). A comparable environmental breakpoint was reached in the Czech in 19th century with a very strong degradation of mountain areas triggered by tourist and population growth and was overcome during the 20th century with the transition from a self-sufficient production to a wider opening to the national economy.

Most studies related to tourism impact addressed the socio-economic aspects (Geneletti and Dawa, 2009). Very few studies were carried out on the environmental consequences of tourism development and their purpose was to describe the environmental conditions and highlight critical issues rather than to model and assess tourism impacts (Godde et al., 2000; Messerli and Ives, 1997). The lack of environmental data that affected the region when this research was initiated forced us to invest a lot of resources into the construction of a suitable geographical database (Boori and Amaro, 2010a,b). Hence, tools as remote sensing imageries and GIS were largely employed for the baseline study as well as the impact analysis.

## 6. Conclusions

This research provides the evidence of land cover change due to tourism in Jesenik mountain region. Forest area decreases closer to city and it increases after 10 km distance of the city. Tourism facilities have closer proximity and associated with a decrease in forest extent. However this research cannot say that all land cover disturbances were due to only tourism but there were some other factors such as agriculture expansions, timber harvesting, wind and snow damage that could also be responsible for land cover disturbance. It appears that due to market demand forest harvesting, agriculture, pasture, water body and settlement areas were increasing. Climate and elevation was also effect on their extensions. Population growth and increasing of socio-economic activities were also responsible for the land cover disturbance.

## Acknowledgments

The authors gratefully acknowledge the support by the Operational Program Education for Competitiveness – European Social Fund (Project CZ.1.07/2.3.00/30.0041 of the Ministry of Education, Youth and Sports of the Czech Republic). The authors extend sincere thanks to Chaplin and Brabyn for their base line information and guidance.

## References

Arrowsmith, C., Inbakaran, R., 2002. Estimating environmental resiliency for the Grampians National Park, Victoria, Australia: a quantitative approach. Tour Manag. 23, 295–309.

Bao, H.J., Wu, Y.Z., Wu, C.F., Xu, B.G., 2005. Planning and design for eco sustainable farmland consolidation. Pedosphem 15 (3), 327–333.

Boori, M.S., Ferraro, R.R., 2012. Northern Hemisphere snow variation with season and elevation using GIS and AMSR-E data. J. Earth Sci. Clim. Change (JESCC) S12: 001 (Special issue), 01–06. http://dx.doi.org/10.4172/2157-7617.S12-001, ISSN 2157-7617.

Boori, M.S., Vozenilek, V., Burian, J., 2014. Land-cover disturbances due to tourism in Czech Republic. In: Advances in Intelligent Systems and Computing, 303. Springer International Publishing, Switzerland. http://dx.doi.org/10.1007/978-3-319-08156-4-7, p. 63-72.

Boori, M.S., Amaro, V.E., 2011. A remote sensing approach for vulnerability and environmental change in Apodi valley region, Northeast Brazil. Int. J. Environ. Earth Sci. Eng. 5 (2), 01–11.

Boori, M.S., Amaro, V.E., 2010a. Detecting and understanding drivers of natural and eco-environmental vulnerability due to hydro geophysical parameters, ecosystem and land use change through multispectral satellite data sets in Apodi estuarine, Northeast Brazil. Int. J. Environ. Sci. (IJES) 1 (4), 543–557.

Boori, M.S., Amaro, V.E., 2010b. Land use change detection for environmental management: using multi-temporal, satellite data in Apodi Valley of northeastern Brazil. Appl. GIS 6 (2), 1–15.

Boori, M.S., Amaro, V.E., Vital, H., 2010. Coastal ecological sensitivity and risk assessment: a case study of sea level change in Apodi river (Atlantic Ocean), Northeast Brazil. Int. J. Environ. Earth Sci. Eng. 4 (11), 44–53.

Buckley, R.C., Pickering, C.M., Warnken, J., 2002. Environmental Management for Alpine Tourism and Resorts in Australia. Tourism and Development in Mountain Regions. CABI Publishing, Wallingford, 27-45.

Buntaine, M.T., Mullen, R.B., Lassoie, J.P., 2006. Human use and conservation planning in Alpine areas of Northwestern Yunnan, China. Environ. Dev. Sustain. 9, 305–324.

Chaplin, J., Brabyn, L., 2013. Using remote sensing and GIS to investigate the impacts of tourism on forest cover in the Annapurna Conservation Area, Nepal. Appl. Geogr. 43, 159–168.

Chatterjea, K., 2007. Assessment and demarcation of trail degradation in a nature reserve, using GIS: case of Bukit Timah nature reserve. Land Degrad. Dev. 18, 500–518.

Czech Business Authority, 2010. Annual Report 2010, Available at: <http://www.businessinfo.cz/files/archiv/dokumenty/cr_regions_olomouc.pdf>.

Czech Tourist Authority, 2011. Annual Report 2011, Available at: <http://czech.kiwano.net/pdf/to02.pdf>.

European Bank for Reconstruction and Development (EBRD) and the state of transition in central and eastern Europe (Resolution 1254 (2001)) stars.coe.int/ta/ta01/ERES1254.HTM.

Foley, J.A., DeFries, R., Asner, G., Barford, C., Bonan, G., Carpenter, S.R., et al, 2005. Global consequences of land use. Science 309, 570–574.

Gaughan, A.E., 2006. Spatial and Temporal Land-Cover Transformation in the Angkor basin: A Changing Landscape in Cambodia, 1989–2005 (Thesis). University of Florida, Gainesville.

Geneletti, D., Dawa, D., 2009. Environmental impact assessment of mountain tourism in developing regions: a study in Ladakh, Indian Himalaya. Environ. Impact Assess. Rev. 29, 229–242.

Godde, M.P., Price, M.F., Zimmermann, F.M., 2000. Tourism and Development in Mountain Regions: Moving Forward into the New Millennium. Tourism and development in mountain regions. CABI Publishing, Wallingford, p. 1–25.

Green, G.M., Schweik, C.M., Randolf, J.C., 2005. Retrieving land-cover change information from Landsat satellite images by minimizing other sources of reflectance variability. In: Moran, E.F., Ostrom, E. (Eds.), Seeing the Forest and the Trees: Human–Environment Interactions in Forest Ecosystems. MIT Press, Cambridge, MA, pp. 131–160.

Holland, J., Burian, M., Dixey, L., 2003. Tourism in Poor Rural Areas.

Jensen, J.R. (Ed.), 2005. Introductory Digital Image Processing: A Remote Sensing Perspective, third ed. Pearson Education, London, UK.

Lambin, E.F., Geist, H.J., 2003. Regional differences in tropical deforestation. Environment 45 (6), 22–36.

Lynn, N.A., Brown, R.D., 2003. Effects of recreational use impacts on hiking experiences in natural areas. Landsc. Urban Plann. 64, 77–87.

Mather, A.S., 1986. Land Use. Longman Group, London, UK.

Ministry of Regional Development, 2013. Tourism in the Czech Republic. Ministry of Regional Development, Prague.

Messerli, B., Ives, J.D., 1997. Mountains of the World: A Global Priority. Parthenon, New York.

Moran, E.F., 2005. Human–environment interactions in forest ecosystems: an introduction. In: Moran, E.F., Ostrom, E. (Eds.), Seeing the Forest and the Trees: Human–Environment Interactions in Forest Ecosystems. MIT Press, Cambridge, MA, pp. 3–21.

Nepal, S.K., Chipeniuk, R., 2005. Mountain tourism: toward a conceptual framework. Tour Geogr. 7, 313–333.

Niamir, M., 1990. Traditional woodland management techniques of African pastoralists. Unasylva 160, 49–58.

Rindfuss, R.R., Walsh, S.J., Turner, B.L.I.I., Fox, J., Mishra, V., 2004. Developing a science of land change: challenges and methodological issues. Proc. Natl. Acad. Sci. U.S.A. 10 (3), 13976–13981.

Semwal, R.L., Nautiyal, S., Sen, K.K., Rana, U., Maikhuri, R.K., Rao, K.S., Saxena, K.G., 2004. Patterns and ecological implications of agricultural land-use changes: a case study from central Himalaya, India. Agric. Ecosyst. Environ. 102, 81–92.

Shah, J., Nagpal, T., Brandon, C.J., 1997. Urban Air Quality Management Strategy in Asia, A Guidebook and a Series of City Reports. The World Bank, Washington, DC, p. 1–188.

Sinclair, R., 1967. Von Thünen and urban sprawl. Ann. Assoc. Am. Geogr. 57, 72–87.

Singh, R.B., Mishra, D.K., 2004. Green tourism in mountain regions — reducing vulnerability and promoting people and place centric development in the Himalayas. J. Mt. Sci. 1, 57–64.

Start, D., 2001. Livelihood Insecurity and Social Protection: A Re-emerging Issue in Rural Development, Development Policy Review. Blackwell Publishing, London, 19 (4).

Stevens, S., 2003. Tourism and deforestation in the Mt Everest region of Nepal. Geogr. J. 169, 255–277.

Walker, R., 2004. Theorizing land-cover and land-use change: the case of tropical deforestation. Int. Reg. Sci. Rev. 27 (3), 247–270.

Wright, S.J., 2005. Tropical forests in a changing environment. Trends Ecol. Evol. 20 (10), 553–560.