Assessing Land Cover Change Trajectories in Olomouc, Czech Republic

Mukesh Singh Boori, Vít Voženílek

***Abstract*—**Olomouc is a unique and complex landmark with widespread forestation and land use. This research work was conducted to assess important and complex land use change trajectories in Olomouc region. Multi-temporal satellite data from 1991, 2001 and 2013 were used to extract land use/cover types by object oriented classification method. To achieve the objectives, three different aspects were used: (1) Calculate the quantity of each transition; (2) Allocate location based landscape pattern (3) Compare land use/cover evaluation procedure. Land cover change trajectories shows that 16.69% agriculture, 54.33% forest and 21.98% other areas (settlement, pasture and water-body) were stable in all three decade. Approximately 30% of the study area maintained as a same land cove type from 1991 to 2013. Here broad scale of political and socio-economic factors was also affect the rate and direction of landscape changes. Distance from the settlements was the most important predictor of land cover change trajectories. This showed that most of landscape trajectories were caused by socio-economic activities and mainly led to virtuous change on the ecological environment.

***Keywords*—**Remote Sensing, land use/cover, Change trajectories, Image classification.

I. Introduction

SOCIO-ECONOMIC activities have been one of the most important factor for land cover change trajectories. In place of two dates of change in satellite imageries, researchers are more focus on temporal land cover change trajectories [1]-[3]. In European Union (EU) 43% land is farmland and 26% arable. For Czech Republic it`s 54% and 37% respectively [4]. Only 17% of farmland is farmed by the landowners and this is the second lowest in EU [3]. These growing environmental problems in recent decades frequently ensue from two dominant trends in the current use of agricultural land within Europe [4]: intensification and specialization in some areas accompanied by marginalization and abandonment in others. Earlier land cover change in Czech Republic have analyzed by many authors. These studies focused on the influence of extreme fragmentation of agricultural land ownership as an important driver of homogenization of rural landscape patterns were presented by [5], [6]. Historical maps reaching back to the mid-18th century were used by [7] to analyses long-term land-cover changes in 21 cadastral units of Central Bohemia. They mention that 18 to 5 permanent grassland and 6% to less than 1% surface water area were decrease.

Mukesh Singh Boori was scientist in NOAA/NASA and now in Palacky University Olomouc, 17. listopadu 50, 771 46 Olomouc, Czech Republic (phone: 420-732287744; e-mail: mukesh.boori@upol.cz).

Vít Voženílek is with the Palacky University Olomouc, 17. listopadu 50, 771 46 Olomouc, Czech Republic (e-mail: vit.vozenilek@upol.cz).

Trajectory analysis is a new method for land cover change research based on each pixel`s in time series. [8] Developed a trajectory-based hierarchical decision tree to delineate warm season grass (WSG) and cool season grass (CSG) for long term WSG/CSG mapping. Temporal trajectory is using to discover land use/cover change trends by constructing the ‘curves’ or ‘profiles’ of multi-temporal data [9]. The concept of trajectory to change has attracted some attention from a theoretical viewpoint. These trajectories defined as trends over time among the relationships between the factors. These factors shape the changing nature of human–environment relation and their effects within a particular region [10], [11]. This takes widely different forms and depends on circumstances, regional contexts, and governmental policies. These studies have further highlighted the importance of understanding landscape dynamics for sustainability and conservation purposes [12], [13].

Remote sensing data are particularly useful due to the cost and time associated with traditional survey methods [14], [15]. These techniques have become viable alternatives to conventional survey and ground-based mapping methods [16]. Remote sensing and geographic Information Systems are powerful and effective tools for assessing the spatial and temporal dynamics of landscape trajectories [17], [18]. Remote sensing data provide valuable multi-temporal information of the processes and patterns of land cover change. GIS is useful for mapping and analyzing these patterns [19]. In addition, retrospective and consistent synoptic coverage from satellites is particularly useful in areas where changes have been rapid [20]. Furthermore, since digital archives of remotely sensed data provide the opportunity to study historical land use/cover changes, the geographic pattern of such changes in relation to other environmental and human factors can be evaluated. In addition, accurate and comprehensive land cover change trajectories statistics are useful for devising sustainable development and planning strategy [21], [22]. It is therefore very important to estimate the rate, pattern and type of land cover change trajectories in order to predict future changes for sustainable development.

This paper present land cover change trajectories analysis for forest, agriculture and others (settlement, pasture and water body) for three decades (1991, 2001 and 2013) in the Olomouc, Czech Republic. This research seeks to: (1) Capture the spatio-temporal variability of landscape change trajectories in Olomouc, (2) Comparing RS, GIS and socio-economic factors in Olomouc. Pre- and post-classification comparison techniques have been extensively used [23], [24]. In the pre-classification approach procedure such as image differencing

[25], band rationing [26], change vector analysis [27], direct multi-date classification [28], vegetation index differencing [29] and principle component analysis [30] have been developed [31]. These techniques are useful for locating the change but they are unable to identify nature of change [32].

II. Methodology

A. Study Area, Data and Image Classification

The study area cover Olomouc region, which is located in north-eastern Czech Republic between 49°45´ N, and 17°15´ E (Fig. 1). The border between the Olomouc region and Poland in the north is 104 km long. The other neighbors are the Moravskoslezský Region in the east, the Zlín Region and the Jihomoravský Region in the south and the Pardubický Region in the west. The geographical layout of the region is rather unusual. There are lowlands at the Polish borders, followed by the Jeseníky mountain range with Praded (map) the highest mountain (1,492 m above sea level), while the southern part (again) comprises lowlands – the flat and fertile land of Haná. This region is one of the most fertile areas of the Czech Republic. Its elevation is 219 m (719 ft) and total area is 103.36 km^2. Its total population is 101,003 with 987/km^2 density.

This region is characterized by coniferous forests (*Pinus sylvestris* L. and *Picea abies* L. Karst.) and large aapa mires. Deciduous trees, mainly *Betula* spp., occur to a lesser extent and located in the northern boreal vegetation zone. Highest fells and alpine vegetation are found in the north-western part of the study region in the Jeseniky mountain area. A large number of lichen pastures with forest are located in the eastern and north-eastern mountainous part of the Olomouc region. The most important late winter pastures with arboreal lichens are located in the western, central and southern parts of the Olomouc Region [33]. Summer and autumn pasture with vegetation are consisting in mires, lake and riversides. Moist forest and fresh forest are present in the north-eastern, south-western, eastern and western parts of the Olomouc Region [34].

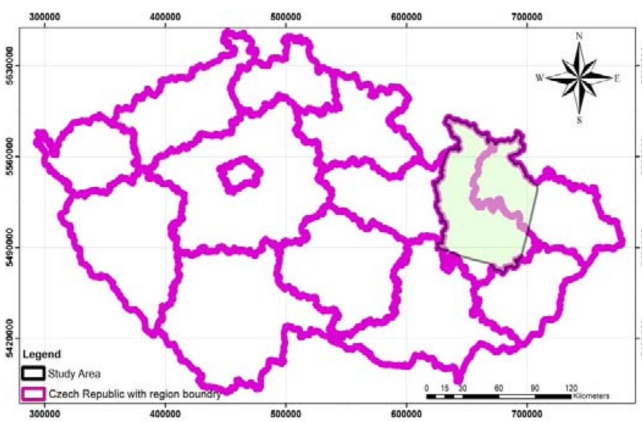

Fig. 1 Study area: Jeseniky mountain region, Olomouc

NASA Landsate TM and ETM+ data (1991, 2001 & 2013) were used for land cover change trajectory in Olomouc as it's free of cost. ArcGIS 10.1 software was used for all image preparation, spatial analysis and mapping. Topographic database provides the most accurate and uniform information for map products covering the entire country, so geographic corrections were performed on the base of topographic sheets and then registered (UTM WGS84) all images. 26 ground control points (GCPs) were used for registration. All GCPs were dispersed throughout the scene, yielding a RMS error of less than 0.5 pixels. The photographs were acquired with a frame camera that was designed to support mapping, charting and geodesy in addition to two high-resolution cameras. Aerial photographs from 2013 were also used for ground truth in land cover classification. All bands except thermal band were used for classification.

After pre-processing and geometric correction, all satellite images used for classification to know changes in between two dates in the study area. A number of methods are available for temporal land use change detection, including: (i) post-classification comparison, (ii) classification of multi-temporal data sets, (iii) principal components analysis (PCA), (iv) temporal image differencing and rationing, (v) change vector analysis and (vi) spectral mixture analysis. The main emphasis of the study was on change in natural forest cover (i.e. deforestation) and areas under intensive cultivation. In satellite image classification, vegetated area was comprised mixture of surface materials such as different canopy components, bare soil, water and shadow. The spectrum measured by the sensor was therefore a mixture of each of these components [34].

This research work report the finding of post-classification comparison between two dates images in the study area. First unsupervised classification and then supervised maximum likelihood classification (MLC) were used to obtain the best results from remotely sensed data. Gaussian distribution [35] was applied in each image. In supervised classification training sites were based on reference data and ancillary information. In last, post-classification refinement was used to improve the accuracy of classification. Three major land cover classes were identified: forest, agriculture and others (water body, pasture and settlements). In this research work three land cover classes for three time nodes were used in the trajectory analysis to monitor land use/cover change dynamics.

We used simple metrics for quantifying the landscape structure and their behavior predicated across all evaluation [36], [37]. In ArcGIS, an iterative multi-objective land allocation procedure was used to resolve conflicts decision heuristic and carried out change trajectories over the landscape. The definition of forest cover was minimum 30% canopy coverage which provides a distinct delineation between scrub areas and dene forest. Follow-up field work was conducted in October 2013 and February 2014, to determine ambiguous land-cover classification. Visit study area to determine major changes and there causes by observations and informal interviews of local people. This also provided a secondary validation of the classification accuracy for the most current image date.

III. Results

In the image classification agriculture land makes up the largest percent of the Olomouc region with 37%, 42%, and 39% respectively for 1991, 2001, and 2013 (Fig. 2). Forest makes up the next largest land-cover, and occurs predominantly in the more upland areas with greater relief. Forest area decrease dramatically during the first half of the study period from 40% to 29% but then rigid to 35% during the second half of the study. Other classes make up around 25% of the all over the study area for last three decades.

Fig. 2 illustrates the land cover classification results of the study area. This comprehensive analysis of land cover provides both the timing and nature of land cover changes. To simplify for illustration purposes, we categorized three major categories of land cover classes: forest, agriculture and others (settlement, water body and pasture). For example, we can easily derive information since past 30 years. The largest loss of forest was from forest to develop and the largest gain of forest was from barren to forest in the study area. It can also provide new kinds of information about what kind of land cover change occurred on a yearly basis for the entire scene.

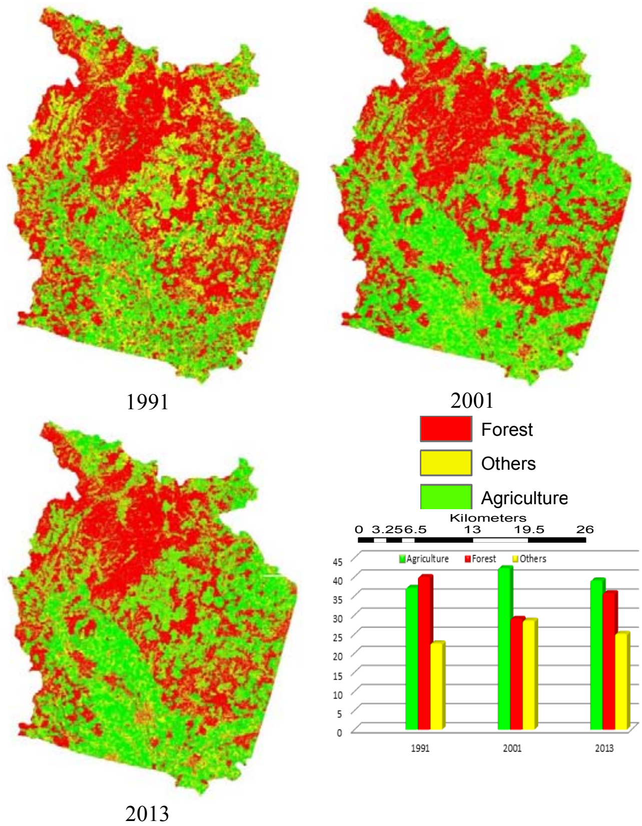

Fig. 2 Land cover classification for the Olomouc region for 1991, 2001, and 2013

The change that occurred in these pixels was observed when viewed from the perspective of the entire time series. This approach allows the identification of the timing of each change, as well as the kind of change. When the time series has been built for a pixel and analyzed for change, it is possible to use the estimated time series models between the changes to identify the land cover class for the pixels at different time periods. For the pixels located at first year, the estimated model preceding the change in 1991 can be used to classify the land cover for the entire time prior to the change. Similarly the estimated method subsequent to the change can be used to identify what land cover came after the change in 1991. The shape of the time series method can be very helpful in land cover classification which is evident in the time series graphs at the bottom, as initially pixels located in year 1991 and 2013 were conifer forest and pixels located in 2001 were a hardwood forest, and they were readily distinguishable by the difference in the amplitude of their time series.

TABLE I
Results of Land Use/Land Cover Classification for 1991, 2001 and 2013 Images Showing Area of Each Category and Class Percentage

Class	1991	%	2001	%	2013	%
Agriculture	743.23	37.16	846.57	42.32	781.9	39.09
Forest	804.02	40.02	581.49	29.07	715.61	35.78
Others	452.48	22.62	571.94	28.59	502.49	25.12
Total	2000		2000		2000	

A. Change Detection

Fig. 2 shows the land cover classifications maps, produced for 1991, 2001 and 2013 from Landsat images, and Fig. 3 shows the area of forest addition and removal. Table I provides the area of each class. The total area of the study was 2000 km^2. From Fig. 2, it is clear that most of the forest is in the northern part of the study area, which has higher elevation and higher rainfall. This area has larger trees suitable for timber production and is closer to major urban areas, such as Bruntál, Šumperk, Jeseník, Rýmařov. In this area forest area was added but this was less than what has been removed. In the flat southern region, Fig. 3 shows that more forest has been removed than added, but the extent of this change was small compared to the changes in the north. The spatial analysis in relation to socio-economic activities confirms this.

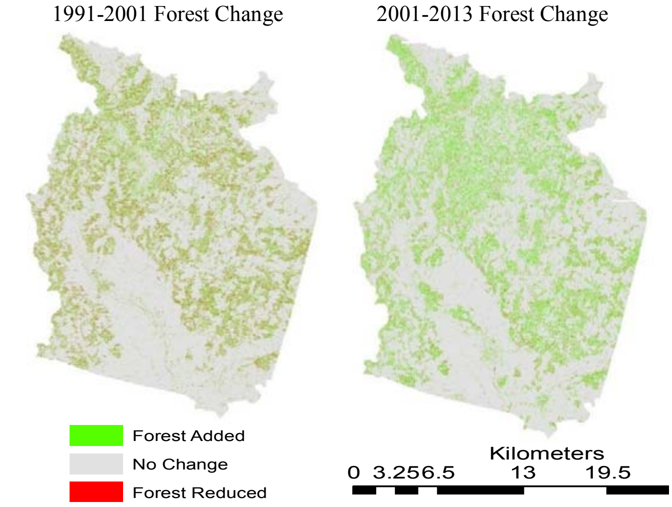

Fig. 3 Increase and decrease in forest cover

Change trajectories between the years 1991, 2001, and 2013 were compared on a pixel-by-pixel basis to examine possible land-cover disturbance (Table II). Thirty three percent of the landscape remained in the same land-cover class from 1991 to 2013. Two-date changes (1991–2001 and 2001–2013) show that, 2300 km^2 forest and 1500 km^2 agriculture area was stable in last two decades. 140 km^2 agriculture, 20 km^2 forest and 18 km^2 pasture area were encroached by settlements from 2001 to 2013. In 2001, 260 km^2 other classes and 480 km^2 agriculture area added in forest area. 313 km^2 others and 127 km^2 agriculture areas were removed from forest area from 1991 to 2001. 118 km^2 agriculture and 245 km^2 other class area added in forest class. Stable forest cover area was mostly located in high elevation area of the mountain, especially in Jesenilk, Bruntal, Sumperk and Rymarov.

TABLE II
TYPES OF CHANGES BETWEEN 1999 AND 2013 FOR AREAS ANALYZED

1991-2001	Forest	Others	Agriculture	Total
Forest	2340	313	127	2780
Others	262	427	437	1126
Agriculture	480	901	1525	2906
Total	3082	1641	2089	6812
2001-2013				
Forest	2348	277	467	3092
Others	245	477	902	1624
Agriculture	118	479	1495	2092
Total	2711	1233	2864	6808

This study employed the post-classification change detection technique, which was efficient in detecting the nature, rate and location of changes, and has been successfully used by a number of researchers in the study of natural resources [31]. An overlay procedure using the GIS was adopted in order to obtain the spatial changes in land cover during two intervals: 1991–2001 and 2001–2013. Application of this technique resulted in a two-way cross-matrix, describing the main types of change in the study area. Cross tabulation analysis on a pixel-by-pixel basis facilitated the determination of the quantity of conversions from a particular land cover class to other land use categories and their corresponding area over the period evaluated. A new thematic layer containing different combinations of ‘‘from–to’’ change classes was also produced for each of the two three-class maps (Table II).

On the basis of Landsat datasets, producer accuracy was calculated for all potential change pixels at three decade time steps. In the study area, within-class and between-years reveal different characteristics of change. Fig. 3 shows examples of within-class and between-year changes for 1991-2001 and 2001-2013. The within-class distances appear to highlight the contrast between forest and non-forest area in a given year. The between-year changes were noisier, but highlight locations with large differences between two years including newly changed area and agricultural area that were inherently more variable.

B. Analysis Based On Trajectories

This three decade trajectories analysis was focus on forest, agriculture and different factors drive changes in the region. Two-date changes (1991–2001 and 2001–2013) show stable non-forest (agriculture and others) areas cover over 38% landscape while stable forest cover (F–F) drops from 54% (Table III). In the study area old permanent agriculture regrowth and regrowth with new clearing class was 1.07% of the total area. Forest regrowth with new clearing and old permanent forest regrowth area was around 4% of the total area. Old permanent agriculture clearing area was approximately 2% of the total area. The 3-date change trajectories allow us to determine a single pixel’s trajectory over time with more details (Table III).

In the study many small fields were cleared and then were reforested (O–F–F), while many other small areas had O–F–O trajectories. Our field observations demonstrated that these were smallholder fields of shifting agriculture that were growing maize, pineapples, or other cash crops, that were probably used in restaurants in Olomouc region. There was not any recent agriculture regrowth (O–O–A) and recent forest regrowth (O–O–F) class in the study area. But due to some specific location requirement old agriculture with regrowth (A–O–A) and old permanent agriculture clearing (A–O–O) was present (Fig. 4).

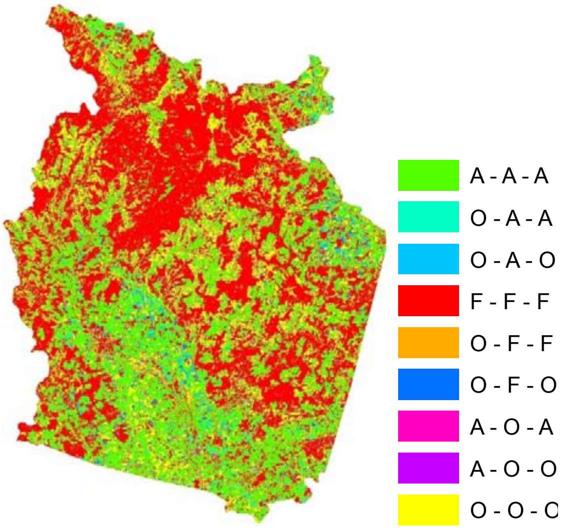

Fig. 4 Land-cover classification trajectories for 1991–2001–2013 in the Olomouc ''F'' refers to forest, "A" agriculture and ''O'' to other classes (pasture, settlements, water body)

After change trajectory calculation, distribution maps of all the trajectories in the study area from 1991 to 2013 were generated. In the map, green, red and yellow pixels stand for "no change", while others stand for all kinds of "change". However, some trajectories would never happen and some others may take much small parts in all the trajectories so that they can be omitted. Through majority analysis with a 5×5 mask, the scattered trajectories with small count numbers in the whole area were assigned the value of neighbors in majority. It suggests that these changes were extensively induced by organized human activities, which coincides with the local practical situation. The study area suffers serious soil loss, which has brought great damage to the local residents. In order to conserve soil, the government has called on the local people to take measures to better the ecological environment.

TABLE III
LAND-COVER CHANGE TRAJECTORIES IN OLOMOUC AND THEIR DESCRIPTIONS 1991, 2001, 2013

	Change trajectory			Description	Area (km^2)	%
	1991	2001	2013	LULC change classes		
1	Agriculture	Agriculture	Agriculture	Stable primary or secondary agriculture	333.79	16.69
2	Other	Agriculture	Agriculture	Old and permanent agriculture regrowth	11.57	0.58
3	Other	Agriculture	Other	Agriculture regrowth with new clearing	9.88	0.49
4	Forest	Forest	Forest	Stable primary or secondary forest	1086.57	54.33
5	Other	Forest	Forest	Old and permanent forest regrowth	9.81	0.49
6	Other	Forest	Other	Forest regrowth with new clearing	61.66	3.08
7	Agriculture	Other	Agriculture	Old agriculture clearing with regrowth	8.32	0.42
8	Agriculture	Other	Other	Old and permanent agriculture clearing	38.76	1.94
9	Other	Other	Other	Stable primary or secondary others	439.64	21.98
10	Other	Other	Agriculture	Recent agriculture regrowth	-	-
11	Other	Other	Forest	Recent forest regrowth	-	-

During the first and second periods, the main trajectories were dominated by deforestation transitions that led to the decline of old growth forest and the increase of arborous shrub land as a result of logging practices. A remarkable finding was, however, that the transition from old growth forest to arborous shrub land changed from highly systematic in the first period to highly random in the second, similar to the majority of the transitions affecting native forest cover between 1991 to 2001. This finding suggests that the same type of transition (deforestation in this case) can be caused by either permanent or sudden forces that take place in the landscape. In the study area, the period of random changes (and coincidentally of a large amount of swap change) coincides with the beginning of the globalization process, characterized by trade liberalization policies and structural adjustment reforms which opened up the economy to international trade, favored international investments, and reduced the role of the state in favor of market mechanisms to drive development [38]. The arrival of salmon and mussel farming and the transnational processing industries shows us how the globalization process manifested itself in the study area. During the 1991 to 2001, rural migration rates and urban population increased, thus expanding the demand for firewood, the main product extracted from native forests in northern part. Added to this increased logging, the "woodchips exporting boom" (early 1990's to mid-2000's), led to abrupt deforestation, as indicated by the direct change from old growth and secondary forest to shrub lands through clear cutting.

IV. DISCUSSION

This work provides an empirical assessment of land cover change dynamics in Olomouc region. The results show that forest cover changes involve a series of complex trajectories, some of which are cyclical and reversible, while others are more linear and permanent. These diverse trajectories are consistent with a highly dynamic landscape dominated by forms of small-holder land use that reflect heterogeneous livelihood strategies. In-depth analysis of the transition matrices allowed us to separate systematic from random transitions, which revealed unexpected dynamics. Usually, in rural landscapes is dominated by peasant farming system. Forest cover loss is attributed to shifting cultivation. Our results, however, show that native forest has been systematically replaced by a range of other covers and land uses over time, and that agricultural expansion is just one of the direct causes of forest decline.

In the last period (2001-2013), most forest cover transitions became systematic again, driven by new forces that led to different cycles of old growth forest decline. The most systematic transition and relevant in terms of magnitude, was the change of old growth to secondary forest at an average annual rate. This very recent forest degradation relates mostly to peasant agricultural system and can be associated to an increasing firewood demand from an expanding population in urban areas outside of the cities/villages [39].

The above land use change trajectories and trends indicate significantly increasing pressure on available land resources in the study area, leading to the cultivation of increasingly marginal areas, which again leads to dramatic soil fertility decline. It is imperative that these trends are taken into consideration when developing strategies for agricultural development in Olomouc. However, it may not absolutely represent the real land cover disturbance because of the difficulty of modelling 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 were experienced. Land use/cover changes were mainly caused by human activities and natural forces.

Overall, the results reflect the conflicting interactions between physical and human systems in the study area. In this respect, a key question to address is how to generate the incentives that move individuals from conflicting relation with their natural system, toward more sustainable landscape transitions and trajectories without the regulatory presence of the government (e.g. a ban on logging). Worldwide, land is private property and its usufruct is an important right for the landowner, which implies its free use and also determines its value. The forest dynamics described in this study to systematic economic forces such as firewood and industrial timber demand. If these landowners continue to degrade their forest resources at the rates observed between 1991, 2001 and 2013, by 2020 few and small patches of old growth forest can be expected to remain [40].

V. Conclusion

In this research work, land cover change trajectories for three different dates from 1991 to 2013 were extracted from satellite imageries by object oriented classification methods. Classification results were calibrated with ground truth trajectories. These results are useful to spatio-temporal variability of landscape pattern and their change trajectories with natural factors. Analysis based on these landscape trajectories demonstrates that major parts of land use/cover changes have been caused by human activities, most of which, under the direction of local government, have mainly led to virtuous change in the study area. This study was carried out on small study area with three major land cover classes. The significant body of data containing accurate spatial and thematic detail that was yielded by the analysis sheds considerable light on recent land cover and its dynamics. So in the later research, more influential factors would be taken into the analysis, including some human geographical factors and economic geographic factors, such as transport, social economy and so on.

References

[1] M.S. Boori, V. Vozenilek, "Land use/cover, vulnerability index and exposer intensity". *Journal of Environments*. Vol. 1(1): 2014 pp. 01 – 07.

[2] M.S. Boori, V. Vozenilek, "Remote sensing and GIS for Socio-hydrological vulnerability". *Journal of Geology and Geosciences (JGG), ISSN 2329-6755*. Vol. 3(3), 2014, pp. 01 – 04, *Doi:10.4172/2329-6755.1000e115*

[3] Eurostat, "Farm structure survey. Structure of agricultural holdings 2007. Luxembourg: European Communities". Online source http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database (1.11.2012).

[4] F. M. Brouwer, "The relation between agriculture, land use and policy in Europe". In Kaleidoscopic view on social scientific global change research in the Netherlands, 2001, pp. 8e10.

[5] M.S. Boori, V. Vozenilek, J. Burian, "Land-cover disturbances due to tourism". Proceedings of the Fifth International Conference on Innovations in Bio-Inspired Computing and Applications IBICA 2014. Springer International Publishing, pp. 63-72.

[6] P. Sklenicka, T. Lhota, J. Cecetka, "Soil porosity along a gradient from forest edge to field". Bodenkultur, 2002, 53, 191e197.

[7] M.S. Boori, R.R Ferraro, "Microwave polarization and gradient ratio (MPGR) for global land surface phenology". *Journal of Geology and Geosciences (JGG), ISSN 2329-6755*. Vol. 2(2), 2013, pp. 01 – 10, *Doi:10.4172/2329-6755.1000114*

[8] S, J. Skalo, B. Engstová, "Methodology for mapping non-forest wood elements using historic cadastral maps and aerial photographs as a basis for management". Journal of Environmental Management, 2010, 91, 831e843.

[9] C. Wang, B.E. Jamison, A.A. Spicci, "Trajectory-based warm season grassland mapping in Missouri prairies with multi-temporal ASTER imagery". Remote Sensing of Environment 114 (3), 2010, pp. 531–539.

[10] M.S. Boori, R.R. Ferraro, "Northern Hemisphere snow variation with season and elevation using GIS and AMSR-E data". *Journal of Earth Science and Climate Change (JESCC), ISSN 2157-7617*. Vol. S12: 001, Special Issue 2012, pp. 01 – 06, *Doi:10.4172/2157-7617.S12-001*

[11] Kasperson, J.X., Kasperson, R.E., Turner, I.I. B.L., (1995). Regions at Risk. United Nations University Press, Tokyo.

[12] M.S. Boori, "Avaliação de impacto ambiental e gestão dos recursos natuarias no estuário Apodi Mossoró, nordeste do Brasil". Library thesis from Federal University of Rio Grande do Norte, Brazil, 2011.

[13] M.S. Boori, V.E. Amaro, "Natural and eco-environmental vulnerability assessment through multi-temporal satellite data sets in Apodi valley region, Northeast Brazil". *Journal of Geography and Regional Planning (JGRP), ISSN 2070-1845*. Vol. 4(4), 2011, pp. 216 – 230.

[14] M. Antrop, "Why landscape of the past are important for the future. Landscape Urban Plan". 70, 2005, pp. 21–34.

[15] M.S. Boori, V.E. Amaro, "A remote sensing and GIS based approach for climate change and adaptation due to sea-level rise and hazards in Apodi-Mossoro estuary, Northeast Brazil". *International Journal of Plant, Animal and Environmental Sciences (IJPAES), ISSN: 0976-4550*. Vol. 1(1), 2011, pp. 14–25.

[16] Y. Dong, B. Forster, C. Ticehurst, "Radar backscatter analysis for urban environments". International Journal of Remote Sensing, 18(6), 1997, pp. 1351–1364.

[17] M.S. Boori, V.E. Amaro, "A remote sensing approach for vulnerability and environmental change in Apodi valley region, Northeast Brazil". *World Academy of Science, Engineering and Technology (WASET),*

International Science Index 50, International journal of Environmental, Earth Science and Engineering, ISSN 1307-6892. Vol. 5(2), 2011, pp. 01-11.

[18] J.R. Jensen, M.E. Hodgson, J.A. Tullis, G.T. Raber, "Remote sensing of impervious surfaces and building infrastructure". In R. R. Jensen, J. D. Gatrell, & D. McLean (Eds.), Geospatial technologies in urban environments: Policy, practice and pixels, 2004, pp. 5–20.

[19] M.S. Boori, V.E. Amaro, H. Vital, "Coastal ecological sensitivity and risk assessment: A case study of sea level change in Apodi River (Atlantic Ocean), Northeast Brazil". *World Academy of Science, Engineering and Technology (WASET), International Science Index 47, International journal of Environmental, Earth Science and Engineering, ISSN 1307-6892*. Vol. 4(11), 2010, pp. 44-53.

[20] S. Hathout, "The use of GIS for monitoring and predicting urban growth in East and West St Paul, Winnipeg, Manitoba, Canada". Journal of Environmental Management, 66, 2002, pp. 229–238.

[21] M.S. Boori, V. Vozenilek, J. Burian, "Land-cover disturbances due to tourism in Czech Republic*." Advances in Intelligent Systems and Computing, Springer International Publishing Switzerland. ISSN 2194-5357*. Vol. 303, 2014, pp. 63-72, *Doi:10.1007/978-3-319-08156-4-7*

[22] P. Serra, X. Pons, D. Saurı´, "Land-cover and land-use change in a Mediterranean landscape: a spatial analysis of driving forces integrating biophysical and human factors". Applied Geography, 28, 2008, pp. 189–209.

[23] P. Coppin, I. Jonckheere, K. Nackaerts, B. Muys, E. Lambin, "Digital change detection methods in ecosystem monitoring: a review". International Journal of Remote Sensing, 25(9), 2004, pp. 1565–1596.

[24] A. Singh, "Digital change detection techniques using remotely sensed data". International Journal of Remote Sensing, 10(6), 1989, pp. 989–1003.

[25] R. F. Nelson, "Detecting forest canopy changes due to insect activity using Landsat MSS". Photogrammetric Engineering & Remote Sensing, 49, 1983, pp. 1303–1314.

[26] M.S. Boori, V.E. Amaro, "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". *International Journal of Environmental Sciences (IJES), ISSN 0976-4402*. Vol. 1(4), 2010, pp. 543–557.

[27] R. D. Johnson, E.S. Kasischke, "Change vector analysis: a technique for the multi-temporal monitoring of land cover and condition". International Journal of Remote Sensing, 19, 1998, pp. 411–426.

[28] M.S. Boori, V.E. Amaro, "Land use change detection for environmental management: using multi-temporal, satellite data in Apodi Valley of northeastern Brazil". *Applied GIS International Journal, ISSN 1832-5505*. Vol. 6(2), 2010, pp. 1-15.

[29] J. Hartter, C. Lucas, Gaughan, E. Andrea, L.L. Aranda, "Detecting tropical dry forest succession in a shifting cultivation mosaic of the Yucata´n Peninsula, Mexico". Applied Geography, 28, 2008, pp. 134–149.

[30] P. J. Hardin, M.W. Jackson, S. M. Otterstrom, "Mapping, measuring, and modeling urban growth". In R. R. Jensen, J. D. Gatrell, & D. McLean (Eds.), Geo-spatial technologies in urban environments: Policy, practice and pixels (2nd ed.). 2007, pp. 141–176.

[31] M. K. Ridd, J.J. Liu, "A comparison of four algorithms for change detection in an urban environment". Remote Sensing of Environment, 63, 1998, pp. 95–100.

[32] J. Brus, M.S. Boori, V. Vozenilek, "Detection and visualizations of ecotones – important landscape pattern under uncertainty". *Journal of Earth Science and Climate Change (JESCC), ISSN 2157-7617*. Vol. 4(3), 2013, pp. 01 – 04, *Doi:10.4172/2169-0316.1000e108*

[33] V. Voženílek, A. Vondráková, A. Brychtová, "Datový model mapy – formalizovaný způsob zápisu sestavení mapy z dat GIS .ročník 59/101, číslo 8 Geodetický a kartografický obzor", ISSN 0016-7096, 2013, pp. 182-186s.

[34] P.V. Bolstad, T.D. Lillesand, "Rapid Maximum Likelihood classification". Photogrammetric Engineering & Remote Sensing, 57, 1991, pp. 67–74.

[35] M.S. Boori, "Coastal vulnerability, adaptation and risk assessment due to environmental change in Apodi-Mossoro estuary, Northeast Brazil". *International Journal of Geomatics and Geosciences (IJGGS), ISSN 0976-4380*. Vol. 1(3), 2010, pp. 620 – 638.

[36] S.B. Hecht, S.S. Saatchi, "Globalization and forest resurgence: changes in forest cover in El Salvador". BioScience, 57(8), 2007, pp. 663-672.

[37] A. Carmona, L. Nahuelhual, C. Echeverría, A. Báez, "Linking farming systems to landscape change: an empirical and spatially explicit study in southern Chile". Agriculture, Ecosystems and Environment, 139, 2010, pp. 40-50.

[38] M.S. Boori, V. Vozenilek, "Remote sensing and land use/cover trajectories, vulnerability index and exposer intensity". *Journal of Geophys & Remote sensing*. Vol. 3(3), 2014, pp. 01 – 07. *Doi:10.4172/2169-0049.1000123*

[39] S.L. Marín, L. Nahuelhual, C. Echeverría, "Projecting landscape changes in southern Chile: simulation of human and natural processes driving land transformation". Ecological Modelling, 2011, doi:10.1016/j.ecolmodel.2011.04.026.

[40] M.S. Boori, V.E. Amaro, A. Targino, "Coastal risk assessment and adaptation of the impact of sea-level rise, climate change and hazards: A RS and GIS based approach in Apodi-Mossoro estuary, Northeast Brazil". *International Journal of Geomatics and Geosciences (IJGGS), ISSN 0976-4380*. Vol. 2(3), 2012, pp. 815 – 832.

Prof. Dr. Mukesh Singh Boori (Asst. Prof) involve in European Union Project as well as Visiting Assistant Professor in Palacky University Olomouc, Czech Republic since 04/2013 and University of Leicester (Honorary Fellow 2014) funded by European Union. He joined JECRC University India since 01/2013. He was Scientist in Satellite Climate Studies Branch (NOAA/NASA), selected by National Research Council (NRC), Central Govt. of USA, Washington DC, USA. At the same time he completed his Postdoc from University of Maryland, USA (10/2012). He has done PhD (*EIA & Management of Natural Resources*) from Federal University – RN (UFRN), Natal –RN Brazil (08/2011), funded by Brazil-Italy Govt. fellowship. He has done Predoc (*Earth & Environmental Science*) from Katholieke University Leuven, Belgium (08/2008), selected by Ministry of Human Resource Development (MHRD) New Delhi, India and funded by Govt. of Belgium. He has done MSc (*Remote sensing & GIS*) from MDS University Ajmer (2004) and BSc (*Bio-group*) from University of Rajasthan, Jaipur, India (2002). In early career, he was scientist in JSAC/ISRO (2006-2007) and before that Lecturer (PG) at MDS University Ajmer (2005-2007Sessions). He received international awards/fellowships from UK, USA, Brazil, Italy, Indonesia, Belgium, Czech Republic and India. He known Six Language and visit four Continents for Awards, Meetings, Trainings, Field Trips and Conferences. He is an active Organizing Committee Member in Earth & Space Science Conferences, Co-Chaired a session and gave Conference Opening Ceremony Speech as Reynold Speaker (08/2012) at Chicago, USA. He is editor and member of more than 10 International Scientific Societies/Journals/Committees, related to Earth & Space Science, which include organize conferences. His prime research interest is "EIA and Management of Natural Resources through Remote Sensing & GIS Technology". He has more than 40 International Publications including Books as a first author on Vulnerability, Risk Assessment and Climate Change.

Research interest: Remote Sensing & GIS, Vulnerability & Risk Assessment, Digital Image Processing, Thermal & Microwave remote sensing, Satellite Generate Brightness Temperature, Earth Observation, Land Use/Cover Change Trajectories, Geoscience/Geo-informatics, Bio-Geography, Biodiversity, Hydrology, Climate Change, Environmental Impact Assessment, Management of Natural Resources, Land Resources Management, Sustainable Development & Disaster Management, Remote Sensing Applications in: Forest, Agriculture, Ecosystem, Ecology, Urban & Desert Study.