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Full Length Research Paper

Using Landsat data to determine land use/land cover changes in Gümüşhane, Turkey

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Sustainable land use and development require timely, accurate and detailed information of land resources as well as changes in the land resource. 'What is changing in where' question is answered by multiple observations over a period of time. Remote sensing technology provides such a monitoring requirement. The aim of this study was to analyze land use/ land cover (LU/LC) changes between 1975 and 2000 in Gümüşhane, Turkey, using satellite images. Three Landsat images from 1975, 1987 and 2000 were used to determine changes. A post classification technique was used based on a hybrid classification approach (unsupervised and supervised). Images were classified into five LU/LC types; urban, agriculture, forest, pasture and other lands. It is found that significant changes in land cover occurred between the years 1975 and 2000. The results showed an increase in urban, forest and agriculture and a decrease in pasture and other lands between 1975 and 2000. In this period, urban land increased from 1.25 to 3.78% of the total area. While the area of pasture decreased from 26.74 to 23.44% of the total area, the area of forest and agriculture increased from 37.32 to 39.51% and from 8.83 to 13.27%, respectively.

Key words: Image classification, change detection, remote sensing, land use/land cover.

INTRODUCTION

Remote sensing (RS) has an important role in rapidly providing data for geographical information systems (GIS), especially for determining the land use/land cover (LU/LC) analyses (Maxwell et al., 2003; Oetter et al., 2000). With the advent of the Landsat programme in 1972, there was an immediate interest in the potential for forestry and agricultural land cover analyses over larger areas in a more efficient manner than traditional air photo interpretation (Lillesand and Kiefer, 2000; Haack and Jampoler, 1994; Mundia and Aniya, 2005; Yuan et al., 2005). One of the advantages derived from the digital format of the imagery was that it made it possible to use computers in automated interpretation. The use of computers for analysis held great promise for reducing time and effort in vegetation mapping. Another immediate saving resulted from the digital format and geometric fidelity of the data which greatly facilitated integration of the resulting LU/LC maps into GIS. LU/LC mapping from satellite imagery has been dominated by use of data from the reflective wavelengths of the solar spectrum, primarily the visible, near infrared and mid-infrared. The initial sensor used for LU/LC mapping was the Landsat Multispectral Scanner (MSS) which has four broad spectral bands in the visible and near-infrared wavelengths. Landsat 4 included a new sensor called the Thematic Mapper (TM), which has 6 reflective bands with 30 m spatial resolution and a thermal band (Skidmore, 2003; Cihlar et al., 2000; Aplin et al., 1997; Wilkie; Finn, 1996).

Digital change detection is the process that helps in determining the changes associated with LU/LC properties with reference to geo-registered multi-temporal remote sensing data. It helps in identifying change between two (or more) dates that is uncharacterised of normal variation. Several procedures of LU/LC change detection using digital data have been proposed which could aid in updating resource inventories (Singh, 1989). These methods include comparison of land cover classifications (Howarth and Wickware, 1981; Todd, 1977), multi-date classification (Estes et al., 1982;

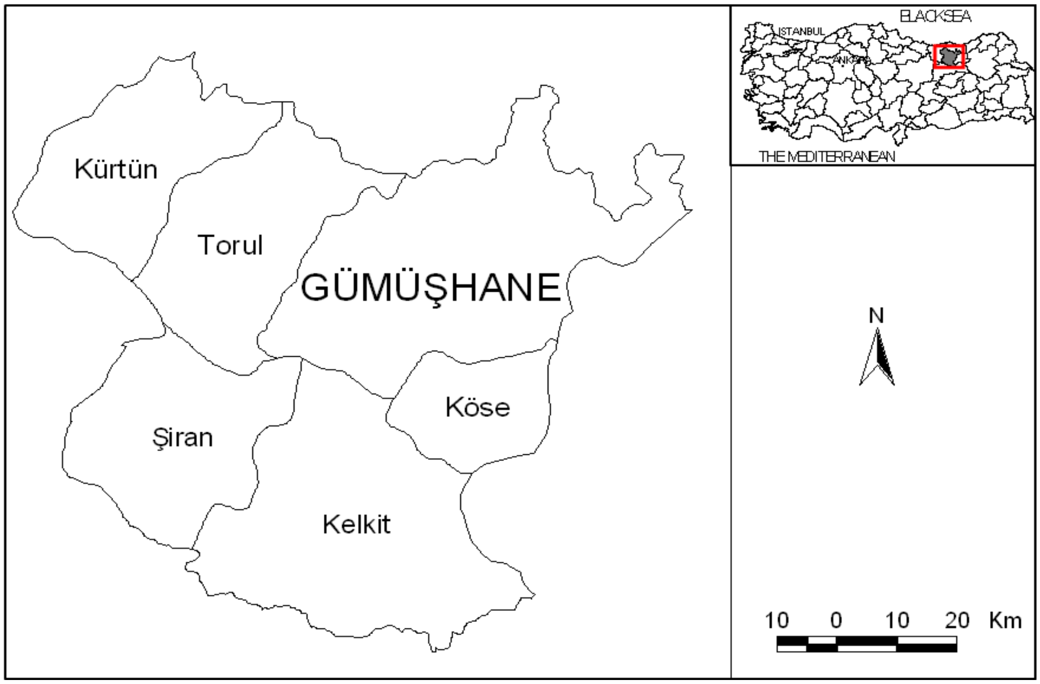

Figure 1. Location of the study area (Gümüşhane City, Turkey).

Schowengerdt, 1983), image differencing/ rationing (Toll et al., 1980; Ingram et al., 1981; Jenson and Toll, 1982), vegetation index differencing (Angelici et al., 1977; Banner and Lynham, 1981; Howarth and Boason, 1983; Nelson, 1983; Singh, 1984), principal components analysis (Richardson and Milne, 1983; Singh, 1984; Lodwik, 1979), change vector analysis (Malila, 1980; Colwell and Weber, 1981) and post-classification comparison (Gordon, 1980; Rutchey and Velcheck, 1994; Mas, 1999; Joyce et al., 1982).

Driving forces such as rapid growth rates of population and urbanization have caused irregular land use in the last two or three decades in Turkey. The country-wide trajectory of LU/LC over the last 30 years has been to decrease the area of forests and increase the area of agricultural lands. Especially, increasing urbanization and agricultural areas have caused decreases in forest area. There are the most important forest areas in Blacksea region of Turkey including Gümüşhane province where the study was conducted. The main aim of this study was to determine LU/LC changes and intense development pressure on environment using multi-temporal satellite data between 1975 and 2000. A comparison will be drawn among land-use patterns in different years (1975, 1987 and 2000) over the selected study area and will determine the affect of changes on land use types.

Study area

The study area covers Gümüşhane province located in the northeast of the Black Sea region, Northern Turkey. The population of study area was about 187 000 in 2000 (TSI, 2010a). The study area extends between longitudes 38° 45' to 40° 12' E and latitudes 39' 45' to 40' 50' N (Figure 1). This area occupies approximately 6715 km^2. Land cover was divided to five classes as urban, forest, agriculture, pasture, and other lands which include mainly barren lands rock surfaces and water bodies.

METHODOLOGY

The methodology used in the study includes the following three stages: Preparation of datasets, image processing, and accuracy assessment. Choosing and geo-rectification of images were performed in the first stage. Spectral analysis of the datasets chosen was performed in the stage of image processing. Accuracy assessment stage was required to determine whether results of spectral analysis were satisfactory for the study.

Preparation of datasets

Datasets used in this study are Landsat MSS acquired on August 21st, 1975, Landsat TM acquired on September 24th, 1987, Landsat ETM acquired on July 17th, 2000 and digital topographic map in the scale of 1:25000 and large scale maps of Gümüşhane. Spatial resolutions of Landsat images used are 79, 30 and 30m, respectively. Landsat images are the main data source which is the main basis of spectral knowledge. These data were used into change detection by integrating with other data sources. Each data scene was geo-referenced to the ED50 datum and UTM Zone 37 North coordinate system. An area of 671 495 ha covering the study area was extracted from the images. Landsat images were geo-

Table 1. Results for accuracy assessment of 1975 LU/LC map.

Class name	Class number	Producer's accuracy (%)	Number sample	Number of samples in class				
				1	2	3	4	5
Forest	1	86.52	6795	5879	50	98	648	120
Urban	2	82.45	547	1	451	61	3	31
Agriculture	3	93.54	4213	16	39	3941	62	155
Pasture	4	85.09	11797	989	22	479	10038	269
Other	5	76.86	5104	24	26	256	875	3923
		Total	28456	6909	588	4835	11626	4498
User's accuracy (%):				85.09	76.70	81.51	86.34	87.22

*Overall classification accuracy: 85.16%.

referenced using digital topographic map of 1:25000 scales and digitized vector maps of Gümüşhane in 1:1000 scales.

Image processing

Post-classification comparison change detection, the most commonly used quantitative method of change detection, was selected to perform LU/LC change detection in this study. It requires rectification and classification of each remotely sensed image. After the classification of image separately, resulting maps are then compared on a pixel-by-pixel basis using a change detection matrix.

Radiometric correction of the images had already been carried out, so it was not applied. Geometric rectification is critical for producing spatially corrected maps of LU/LC changes through time. Geometric correction was done by satellite image belonging to the year of 2000 and maps of study area at the scales of 1:25000 and 1:1000 and also control points obtained by GPS.

Nearest neighbour interpolation was followed during re-sampling, because the brightness values of pixels are not changed and re-sampling time is short at this method. While in bilinear interpolation, loss of the data due to edge correction is more than the nearest neighbour method and process time is very long.

An unsupervised classification approach allows natural spectral clusters to be defined with a high degree of objectivity. The ISODATA (Iterative Self-Organizing Data Analysis) algorithm was used to identify spectral clusters from the Landsat data. It uses minimum spectral distance to assign a cluster for each candidate pixel. The approach for finding clusters by this algorithm is relatively straightforward and has considerably intuitive appeal (Vanderee and Ehrlich, 1995). As a result of ISODATA algorithm, fifteen land use classes were generated to collect training data.

Training areas for the land cover classes were determined using ancillary geological, land use, and field survey data. Each training area consisted of at least 70 image pixels to satisfy the 10 × n criterion, where n is number of bands used for the classification (Congalton and Green, 1999). The training areas provided essential independent reference data for identifying LU/LC types within the Landsat scenes as well as for accuracy assessment.

Landsat data of three dates were independently classified using the supervised classification method of maximum likelihood algorithm. Spectral signature files for all classes were subsequently created and used by maximum likelihood classifier to categorize the continuum of spectral data in the entire image. The classified images were further smoothed with a majority filter with a 3 × 3 kernel to reduce the number of misclassified pixels (Guler et al., 2007). Independently classified images were then compared with each other to determine the changes of LU/LC types.

Accuracy assessment

An equalized stratified random sampling approach was used to assess the accuracy of each of the three land cover classifications. The overall accuracy and a KAPPA analysis were used to perform classification accuracy assessment based on error matrix analysis. Using the simple descriptive statistics technique, overall accuracy is computed by dividing the total correct value (sum of the major diagonal) by the total number of pixels in the error matrix.

Accuracy assessment was performed for 1975, 1987 and 2000 LU/LC maps. A stratified random sampling design was adopted in the accuracy assessment. For the 1975 LU/LC map, results show an overall accuracy of 85.16% (Table 1). In terms of producer's accuracy, all classes were over 80% except urban, which was 76.70%. Similarly, accuracy assessments for 1987 and 2000 LU/LC maps were performed and results were reported in Tables 2 and 3, respectively.

RESULTS

Interpretation of images and producing of results were completed with the help of GIS. Landsat images used in this study were taken from different months of the years. Although these images belong to consecutive months, when climate and land cover characteristic and agricultural production system of the region are taken into account, it is expected to get some considerable changes in the classification results depending on the image dates. This issue is particularly considered in the interpretation of the study results.

The size of the whole study area is 671 495 ha. Distribution of the area for 1975, 1987 and 2000 LU/LC classes was summarized in Table 4. Corresponding classification was also represented as map and chart in Figures 2 and 3, respectively. Spatial variation of each LU/LC classes over time can be clearly visible on Figure 2. Throughout the time period of study, urban areas have increased from 8 367 ha in 1975 to 25 351 ha in 2000 for the study area which represents an increase of 202.99% in land area (Table 4). Forest and agriculture areas have

Table 2. Results for accuracy assessment of 1987LU/LC map.

Class name	Class number	Producer's accuracy (%)	Number sample	Number of samples in class				
				1	2	3	4	5
Forest	1	77.70	22055	17137	70	175	4402	271
Urban	2	84.34	1130	34	953	49	6	88
Agriculture	3	89.92	14707	150	65	13224	222	1046
Pasture	4	89.27	46619	2998	21	1340	41616	644
Other	5	82.70	14325	31	68	1936	443	11847
		Total	98836	20350	1177	16724	46689	13896
User's Accuracy (%):				84.21	80.97	79.07	89.13	85.25

*Overall classification accuracy: 85.78%.

Table 3. Results for accuracy assessment of 2000 LU/LC map.

Class name	Class number	Producer's accuracy (%)	Number sample	Number of samples in class				
				1	2	3	4	5
Forest	1	89.03	30477	27134	298	671	1438	936
Urban	2	89.92	5220	158	4694	184	91	93
Agriculture	3	87.79	26193	205	719	22995	1680	594
Pasture	4	78.15	67741	3162	44	3730	52940	7865
Other	5	93.33	67465	310	53	144	3993	62965
		Total	197096	30969	5808	27724	60142	72453
User's accuracy (%):				87.62	80.82	82.94	88.03	86.90

*Overall classification accuracy: 86.62%.

Table 4. Results of LU/LC cover classification for 1975, 1987 and 2000 images showing area of each class, class percentage and area changed.

Class name	1975 Land use/cover		1987 Land use/cover		1975-1987 Area changed	2000 Land use/cover		1987-2000 Area changed	1975-2000 Area changed
	(ha)	%	(ha)	%	(ha)	(ha)	%	(ha)	(ha)
Urban	8367	1.25	13367	1.99	5000	25351	3.78	11984	16984
Forest	250622	37.32	201927	30.07	-48695	265288	39.51	63361	14666
Agriculture	59299	8.83	84944	12.65	25644	89102	13.27	4158	29802
Pasture	179530	26.74	143579	21.38	-35952	157412	23.44	13833	-22118
Other	173676	25.86	227678	33.91	54002	134341	20.01	-93336	-39334
Total	671495	100	671495	100		671495	100		

also shown an increase of 5.85 and 50.26% in land area respectively between 1975 and 2000. According to Table 4, on the other hand, a decrease was observed for pasture and other land areas between 1975 and 2000. Percentages of the reduction in land area were calculated as 12.32 and 22.65% respectively.

A comparison between 1975 and 1987 resulted in an increase for urban, agriculture and other land classes which corresponds the size of 5 000, 25 644 and 54 002 ha, respectively while a reduction was detected for forest (48 695 ha) and pasture (35 952 ha) lands. Contrary to country-wide trend, an increase in forest area was detected between 1987 and 2000. This may be explained by the fact that there was a constant human migration from Gümüşhane to other cities of Turkey for the time period. Parcelling to this, an imported amount of decrease in previously livestock activities, which made pressure on forest areas, was reported (TSI, 2010b; TSI, 2010c). Thus, meadows, heath and partly barren lands could be converted to forest areas.

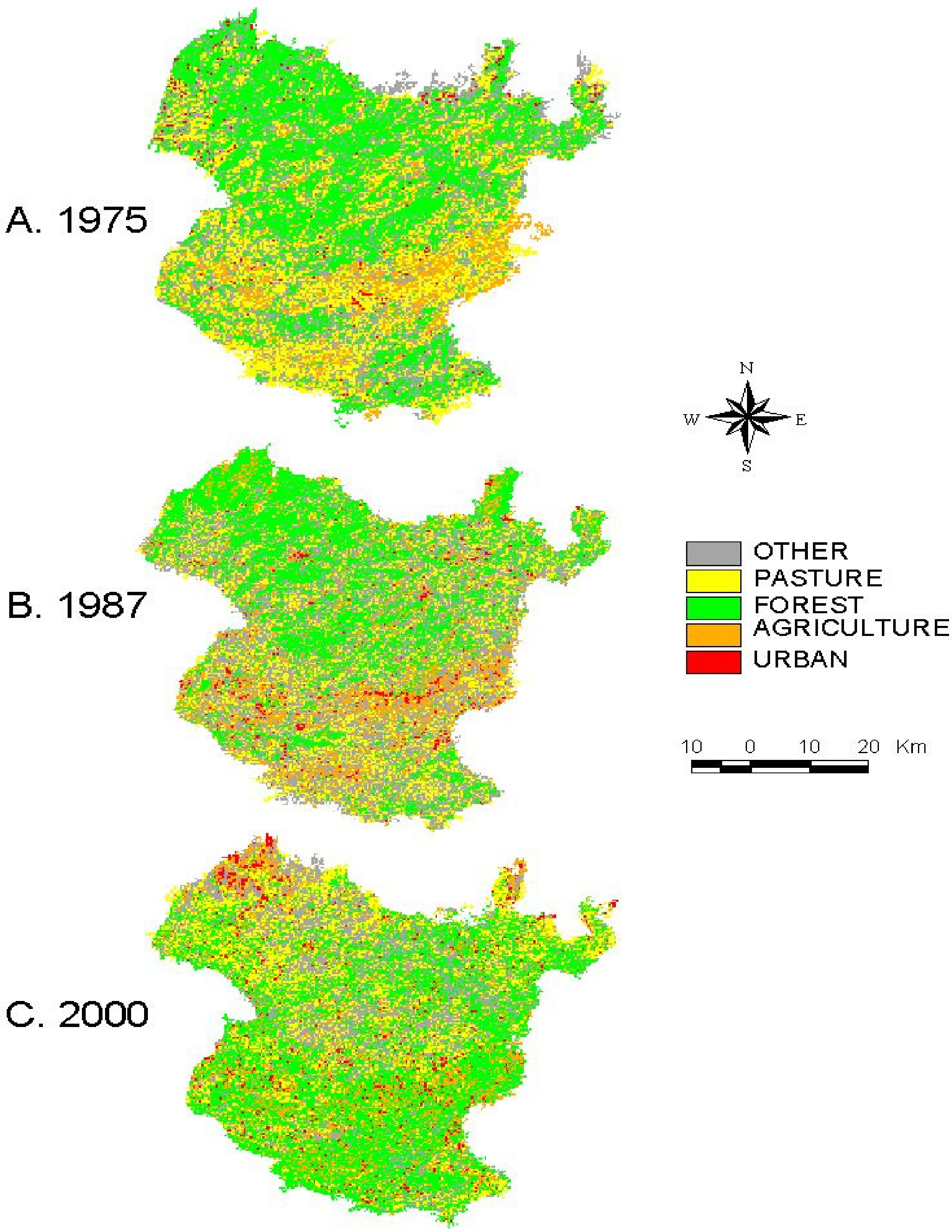

Figure 2. LU/LC classification maps of Gümüşhane for each time step.

Conclusions

The aim of the study was to detect LU/LC changes of the Gümüşhane by using Landsat data. To achieve this aim, the most commonly used image classification approaches and algorithms were adopted. The iterative clustering method of unsupervised classification enabled self-optimization of a local optimal representative of the natural clusters in the data. Though affected by the same factors, the accuracy of a supervised classification was

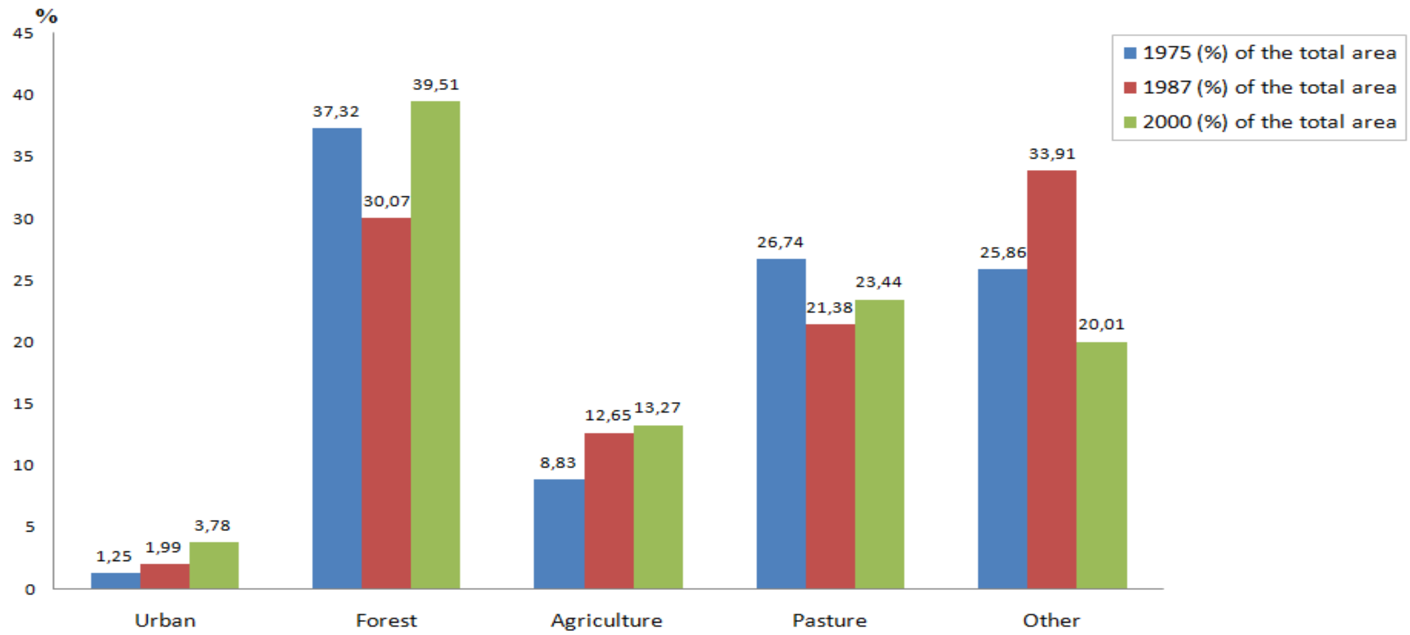

Figure 3. LU/LC types within Gümüşhane throughout the study period (1975 to 2000).

largely controlled by the user's knowledge. This means that high-quality user knowledge could lead to correct classification of known targets while poor user knowledge may mislead rather than help. Accuracy assessment of the data was done by well-known confusion matrix. At this stage, it should be noted that the method merely give a relative assessment rather than the true accuracy of classification. Finally, the stage of image interpretation and map composition was completed to analyse the classified images.

Major results of changing statics for over 25 years in Gümüşhane can be concluded as follows:

1. Coverage of the urban areas has changed from 1.25 to 3.78% which corresponds 16 984 ha net increase over 25 years.
2. Forest coverage has firstly shown a reduction from 37.32 to 30.07% and then an increase to 39.51% corresponding 14 666 ha net increase between 1975 and 2000. This result was supported by reports of governmental agencies.
3. Agricultural coverage has also shown an increase from 8.83 to 13.27% which corresponds 29 802 ha net increase over 25 years.
4. Pasture coverage, on the other hand, has decreased from 26.74 to 23.44% for over 25 years. Over time, conversion to urban areas has also been detected in the pasture class by analysing the images.

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