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ANALYSIS OF THE SPATIO-TEMPORAL AND SEMANTIC ASPECTS OF LAND-COVER/USE CHANGE DYNAMICS 1991–2001 IN ALBANIA AT NATIONAL AND DISTRICT LEVELS

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Abstract. In the turmoil of a rapidly changing economy the Albanian government needs accurate and timely information for management of their natural resources and formulation of land-use policies. The transformation of the forestry sector has required major changes in the legal, regulatory and management framework. The World Bank financed Albanian National Forest Inventory[1] project provides an analysis of spatially explicit land-cover/use change dynamics in the period 1991–2001 using the FAO/UNEP Land Cover Classification System for codification of classes, satellite remote sensing and field survey for data collection and elements of the object-oriented geo-database approach to handle changes as an evolution of land-cover/use objects, i.e. polygons, over time to facilitate change dynamics analysis.

Analysis results at national level show the trend of natural resources depletion in the form of modifications and conversions that lead to a gradual shift from land-cover/use types with a tree cover to less dense tree covers or even a complete removal of trees. Policy failure (e.g., corruption, lack of law enforcement) is seen as the underlying cause. Another major trend is urbanisation of areas near large urban centres that change urban-rural linkages. Furthermore, after privatisation agricultural areas increased in the hills where environmental effects may be detrimental, while prime agricultural land in the plains is lost to urbanisation.

At district level, the local variability of spatially explicit land-cover/use changes shows different types of natural resources depletion. The distribution of changes indicates a regional prevalence, thus a decentralised approach to the natural resources management could be advocated.

Keywords: agriculture, deforestation, land-cover/use change dynamics, object-oriented approach, urbanisation

1. Introduction

In the early 1990s, Albania entered a period of transition from a central-based planned economy to a market economy. Early efforts to introduce democracy and build a market economy were severely undermined by the socio-economic crisis and generalised unrest that followed the financial collapse of 1997. The lack of a democratic culture, the absence of dialogue between different political tendencies and a limited understanding of the concept of national interest amongst political leaders have often prevented the development and implementation of sound policies to address the many issues that Albania faces (CEC, 2002).

Despite disruptions in production caused by energy shortages (e.g., even in the capital Tirana there is no 24 h regular power supply), real Gross Domestic Product (GDP) growth in 2001 reached the target of 7.3%. However, GDP per capita remains one of the lowest in Europe (around 1,400 €) and the overall impact of economic growth remains limited on the poorest layers of the population (CEC, 2002). Around a quarter of the population is considered to be living below the poverty line (World Fact Book, 2005). Construction and services mainly contributed to the GDP increase, with growth rates of 17% and 12% respectively. Industrial production grew around 6% but this sector is weak and its contribution to the overall GDP growth limited. Industries are often obsolete, non-viable and incapable of competing with European industry. Efforts of government to improve the poor national road and railway networks, a long-standing barrier to sustained economic growth, are very slow. Agriculture, which still accounts for slightly more than 50% of Albania's GDP, grew by 3.5%. The privatisation process led to the break up of the former 550 collective farms, which catered for the state processing and marketing agencies, into 467,000 smallholder farms that operate very often at little more than subsistence level. Although for their type quite productive, they are not price competitive and about 75% of farm production is home consumed. These growth figures are not fully reliable, since official figures provide inadequate coverage of private sector activity (CEC, 2002).

In Albania, the post-collectivisation ownership status was identical for collective and state farmlands due to the nationalisation of all land after the Second World War. Therefore the government could apply the same land reform procedures to collective and state farmlands: (physical) distribution of collective (76% of Total Agricultural Lands (TAL)) and state farmlands (24% of TAL) (Swinnen, 1999). The pre-collectivisation land ownership distribution was highly unequal (3% of the population owned the land) resulting in historical justice and social equity being conflicting objectives. Being the poorest and most rural economy of the Central and Eastern European Countries, Albania has 50% of its working population employed in agriculture and agriculture has a prominent economic role. Government decided to redistribute the land to the rural households on an equal per capita basis with partial financial compensation for former owners. This choice is consistent with equity considerations in choosing a land reform procedure. The distribution of even a small piece of land to farm workers has had an important effect on their income and food security situation. Land distribution was also a preferable choice from the efficiency point of view: low technology agriculture, labour-intensive farming structures and imperfect (or missing) capital markets (Swinnen, 2000).

The change to a market-oriented economy had also an impact on the natural resources and their management, not only due to privatisation, but also because of the strong land fragmentation as a result of the land distribution and increased urbanisation. For the first time in 50 years people were free to move around. The rural population, particularly in mountainous areas, sharply decreased because of urban drift or migration abroad. The increasing pastoral economy and husbandry caused landscape degradation and natural resources depletion in many regions of the country. Uncontrolled timber harvesting, overgrazing and overexploitation of wood (in a country with a permanent energy shortage) and other forest products have changed environmental assets. The depletion of forest resources, particularly in accessible areas, has become alarming. Scarce possibilities of control and a lenient policy caused severe, sometimes even irremediable, damages to the natural resources of Albania.

The agrarian reform in its first phase led to a fast increase in the construction of (illegal) buildings and new roads. In a subsequent phase many new small farms were abandoned followed by rapid urbanisation as more and more people left the rural areas to become resident in urban centres. These urban centres, however, were not prepared to receive the massive influx of people. In the turmoil of such a changing economy and the spatial and temporal dynamics of land cover/use that are continuously evolving, it is important for the Albanian government to have accurate and timely information for natural resources management, land-use planning and policy development, as a prerequisite for monitoring and modelling land-use and environmental change and as a basis for land-use statistics. Land-cover/use change, as one of the main driving forces of (global) environmental change, is central to sustainable development (Meyer and Turner, 1994; Walker and Steffen, 1997; Walker, 1998; Lambin *et al.*, 2000). In spite of the many achievements in institutional and policy reform, reliable estimates are missing and great uncertainty exists on the actual, real economic potentialities of the natural resources. The quality and quantity of resources at various points in time, the rates by which they have changed, the overall distribution of the land-cover/use types, etc., are not precisely known. Therefore, there are many uncertainties about the strategy to be adopted by government in order to plan a sustainable use of natural resources while preserving biological richness and diversity.

The objective of the study presented in this paper was an inventory of the land-cover/use types in Albania, their location, extent and distribution and an understanding of the change dynamics in the period 1991–2001 at both national and district levels in order to provide to government spatially explicit data and information for a sustainable management of natural resources. While natural resources management policies are formulated at the national level by different ministries, they are mostly executed at district or even commune level. The responsibility for forests and pastures is with the Directorate General of Forests and Pastures (DGFP) of the Ministry of Agriculture and Food (MoAF). The DGFP has District Forest Service Directories (DFSD) in the 36 districts. The Albanian Forestry Project, of which the Albanian National Forest Inventory (ANFI) project that executed the study is a sub-component, is carried out under agreement between the World Bank and MoAF and will transfer the responsibility of about 40% of the forest area directly to the communes. This transfer process is based on the Law "On Forests and Forest Service Police" (No. 7623 dated 13 October 1992) and Regulation "On the Transfer of Forests and Pastures in Use to Communes (No. 308, dated January 1996). According to these legal acts "the communal forests and pastures would be given to users who are permanent inhabitants of the Commune. The agreement –signed contract between the Commune and the users- gives the latter the full rights to all benefits from communal forests and pastures transferred to the Commune" (SDC/FAO/World Bank/Ministero degli Affari Esteri, 2003).

2. Materials and Methods

2.1. Remote sensing materials used

Digital Landsat 7 Enhanced Thematic Mapper (ETM+) imagery has been used to produce the baseline interpretation of 2001 using on-screen digitising and visual interpretation. For the 1991 visual interpretation use has been made of Landsat 5 Thematic Mapper (TM) images (Table I). For interpretation purposes the multiple view approach was selected combining multi-stage sensing (i.e. high-resolution satellite data is analysed in combination with low altitude data such as topographic maps, forest type maps and field survey data), multi-spectral sensing (i.e. data are acquired simultaneously in several spectral bands) and multi-temporal sensing (i.e. data about the terrain is collected at different dates). The 2001 images have been geo-referenced using the topographic maps of the Albanian Military Geographic Institute at scale 1:100,000 (image-to-map approach) and the 1991 images have been geo-referenced according to the geo-referenced 2001 October set (image-to-image approach).

A Brovey fusion procedure was applied to the False Colour Composite (FCC) 453 multi-spectral imagery at 30 m resolution with panchromatic band at 15 m

TABLE I
Landsat 7 ETM+ and 5 TM frames used for interpretation

	Acquisition date			
Landsat Path-Row	Landsat 7 ETM+		Landsat 5 TM	
185-032	25 October 2000	19 June 2000	23 September 1991 9 September 1992	3 June 1991
186-031	3 October 2001	9 May 2000	30 September 1991	9 May 1991
186-032	3 October 2001	28 May 2001	14 September 1991	9 May 1991

TABLE II
The Brovey fusion formula

$R = 4$, $G = 5$, $B = 3$, $I =$ panchromatic band		
Red layer	Green layer	Blue layer
$[R/(R + G + B)]^{*}I$	$[G/(R + G + B)]^{*}I$	$[B/(R + G + B)]^{*}I$

resolution (Table II). The result is imagery that is characterised by the pixel resolution of 15 m of the panchromatic band and the spectral resolution of the multispectral bands of the FCC. The procedure enhances the visual quality of the imagery and consequently facilitates detection of different vegetation types. In addition, band 3 has been filtered with an edge-sharpening filter, kernel 3×3, to reduce fuzzy noise. The same procedure has been applied to the FCC 432 (Agrotec S.p.A., 2003a).

In the interpretation process various levels of complexity exist, from simple direct recognition of objects in the scene to inference of site conditions. The interpreters use the process of convergence of evidence to successfully increase the accuracy and detail of the interpretations. During the interpretation process special attention was paid to: (1) the spatial coherence of polygons, i.e. are the boundaries in the appropriate place and have the same logical and functional thinking been applied in a consistent manner in the area of interpretation; and (2) the thematic coherence, i.e. is the label given to the polygons correctly describing their contents and are other areas with similar features described in the same manner. A continuous crosschecking of the 1991 and 2001 interpretations was necessary in order to guarantee spatial and thematic coherence within the interpretations and between them. The 2001 interpretation has been validated using 431 field observations and 111 additional observations. The overall thematic accuracy of the 2001 interpretation at the level of LCCS domains and land cover groups, discussed in the next section, is 85% (Agrotec S.p.A., 2003a).

2.2. Land-cover/use classification applied

The 1991 and 2001 land-cover/use interpretations apply the FAO/UNEP Land Cover Classification System (LCCS), endorsed by the Land Use and Cover Change (LUCC) program element of the International Biosphere-Geosphere Programme (IGBP) and International Human Dimensions Programme (IHDP) on Global Environmental Change, for definition of classes to ensure harmonisation of the data with existing data sets at international level while at the same time standardising the method used for description of land-cover/use features (Di Gregorio and Jansen, 2000; LANES, 1998; McConnell and Moran, 2001; FAO, 2002; Jansen and Di Gregorio, 2002). The defined classes used in both interpretations are shown in Table III with their groupings at different levels of aggregation (Agrotec S.p.A., 2003a,b).

TABLE III

The land-cover/use classes with overall accuracy of 85% at land cover group level (Agrotec S.p.A. 2003a,b)

LCCS category	LCCS LC domain	LC group	User description	User label
Dichotomous Phase	Aquatic Vegetation (AV)		Aquatic vegetation	0AQ
Cultivated areas and managed lands (A11)	Tree and Shrub Crops (TC)		Broadleaved arboriculture mainly for wood/timber production. Plantation with *Populus* spp. and *Juglans* spp.	1AB
			Coniferous arboriculture mainly for wood/timber production. Plantation with *Pinus* spp.	1AC
			Fruit trees or shrub crops; when the crop is young and still unproductive another crop may be intercropped on the same field.	1FR
	Herbaceous Crops (HC)		Cultivated areas with herbaceous crops on level land; when not in actual use the fallow field area may be used for pasture.	1CU
			Cultivated areas with herbaceous crops on sloping land; when not in actual use the fallow field area may be used for pasture.	1CS
	Managed Lands (ML)		Vegetated Urban Area(s)/Park(s) (green areas inside built-up areas).	1UP
(Semi-) natural vegetation (A12 and A24)	Forests (FO)	Broadleaved (FOB)	Broadleaved evergreen forest	2BE
			Broadleaved deciduous forest. *Quercus* spp. and/or *Ostrya* spp. are dominant, usually coppice	2BD
			Creek and riverine broadleaved deciduous forest	2CR
			Broadleaved deciduous forest with dominant *Fagus silvatica*. 'Mixed' means a mixture of broadleaved species.	2FS

(Continued on next page)

TABLE III
(Continued)

LCCS category	LCCS LC domain	LC group	User description	User label
		Coniferous (FOC)	Coniferous forest (Med.) on level land	2CA
			Coniferous forest (Sub-Med.) on sloping land	2CB
			Coniferous forest (Alpine) on steep land	2CC
			Coniferous forest (Med.) on level land / Beaches (The code for this class is: 2CA/6BC).	COB
		Mixed (FOM)	*Fagus silvatica* pure and mixed with coniferous forest (<30%)	2FC
	Forests or Woodlands		Broadleaved deciduous forest. *Quercus* spp. and/or *Ostrya* spp. dominant, usually coppice / Cultivated areas with herbaceous crops on sloping land (The codes for this mixed class are: 2BD/1CS or 2BD/1FR or 2DO/1CS or 2DO/1FR; rare to have 1CU inside).	CXB
	Woodlands (WL)	Broadleaved (WLB)	Broadleaved evergreen woodland	2EO
			Broadleaved deciduous open forest. *Quercus* spp. are dominant (coppice)	2DO
			Broadleaved deciduous open forest with *Fagus silvatica* dominating. 'Mixed' means a mixture of broadleaved species.	2FB
		Coniferous (WLC)	Coniferous open forest (Med.) on level land	2OA
			Coniferous open forest (Sub-Med.) on sloping land	2OB
			Coniferous open forest (Alpine) on steep land	2OC
		Mixed (WLM)	*Fagus silvatica* pure and mixed with coniferous open forest (<30%)	2FO

(Continued on next page)

TABLE III
(Continued)

LCCS category	LCCS LC domain	LC Group	User description	User label
	Thickets and Shrublands (TS)		Mediterranean macchia	2MM
			Mediterranean macchia/Broadleaved deciduous forest. *Quercus* spp. and/or *Ostrya* spp. are dominant, usually coppice. (The codes for this mixed class are: 2MM/2BD or 2MM/2DO or 2MG/2BD or 2MG/2DO).	MXB
			Maquis and garigue. (incl. low Med. macchia)	2MG
			Maquis and garigue. (incl. low Med. macchia) / Cultivated areas with herbaceous crops on sloping land (The codes for this mixed class are: 2MG/1CS or 2MG/1FR or 2MM/1CS or 2MM/1FR; rare to find 1CU inside).	CXM
	Grasslands/Pastures (GL)		Sparse trees and shrubs with open to closed grass cover and rock outcrops; these areas are used as pastures.	2SR
			Sparse trees and shrubs with very open grass cover and rock outcrops; these areas are used as pastures.	2GR
Artificial Surfaces (B15)	Built Up Areas (BU)		Built-up areas. Urban and industrial areas (including road network)	5UR
Bare areas (B16)	Bare Areas (BA)		Beaches	6BC
			Bare rocks and/or soils (includes bare areas due to human activities such as mining or environmental degradation).	6RS
Water bodies (B27 and B28)	Water Bodies (WB)		Artificial perennial water bodies	7AA
			Natural perennial water bodies	8AN

Land-cover/use change has to recognise that changes come in two types: (1) conversion from one land cover category to another (e.g., from cultivated to built-up area); and (2) Modification within one category (e.g., from forest to woodland, from thicket to shrubland, etc.). These two types of change have implications for the methodology used to describe and classify land cover/use (Jansen and Di Gregorio, 2002). Conversion implies an evident change, whereas modifications are much less apparent. The latter requires a greater level of detail to be accommodated. With a system based upon class names the latter type of change cannot be captured unless the system contains an ample set of classes.

In the past the emphasis of change studies has been on conversions, whereas more recently there has been increased recognition of the processes of modification (Lambin *et al.*, 2003).

The logical ordering of classes in the LCCS Legend Module facilitates the analysis phase because classes are grouped according to major land cover category, followed by occurring land cover domains. A matrix with these groupings of classes filled with change dynamics statistics facilitates the interpretation of identified changes. Three different areas can be identified in the matrix (Table IV): (1) the areas where no land-cover/use change occurred; (2) the areas where modifications within or between domains occurred; and (3) various types of conversion (e.g., reforestation or deforestation). The same matrix can be used for the interpretation of the likely causes of land-cover/use change such as deforestation, forest fragmentation, afforestation, reforestation, etc.

The analysis of the spatial extent of the different types of land-cover/use changes will permit a further inside in the prevailing land-cover/use change trends. The spatial and temporal land-cover changes should be linked to socio-economic developments in order to understand land-use changes. Land-use characterises the human use of the land-cover type. For example, forests can be used for selective logging, for recreation, or not at all.

2.3. Applied change mapping procedure in the geo-database

In most change studies the state of land cover at a certain point in time is compared to the state at a later moment. This approach is basically focussing on a representation

TABLE IV
Change matrix

Class codes[a]	1a	1b	1c	2d	2e
1a	(1)	(2)	(2)	(3)	(3)
1b	(2)	(1)	(2)	(3)	(3)
1c	(2)	(2)	(1)	(3)	(3)
2d	(3)	(3)	(3)	(1)	(2)
2e	(3)	(3)	(3)	(2)	(1)

[a]The number indicates the land cover category and the letter indicates the land cover class.

of temporal data in which snapshots (e.g., satellite image interpretations) are created for each moment in time. In what one could call a Geographic Information System (GIS) Overlay Approach this means that the land cover state at t_1 is overlain with t_2, t_2 with t_3, t_3 with $t_{3+k,}$ etc. The result of such overlays (in raster format) is a sequential representation of the dispersion of a class in other classes. However, such representations usually do not contain the immediate link between the spatial and temporal dimensions of the changes that occurred between t_1 and t_{1+k}.

The approach to spatial and temporal analyses is more integrated when developing a different approach to databases that do not only store the state of land cover/use at different moments in time but also documents the relationships between such states (Figure 1). Thus, the database may not only contain relationships but also the processes that led up to these relationships. Versions are described in relation to a key state that can be located at a certain time, and through version identifiers one can store just changes instead of a complete version. The events and states are modelled as object classes with different roles; "events" are used to describe what happened, is happening or will happen during the lifespan of an object, whereas "states" certify what has changed, is changing or will change. Events can be modelled independently from these states; the object is depicted by different instances to different classes of events and states. Furthermore, if all this information

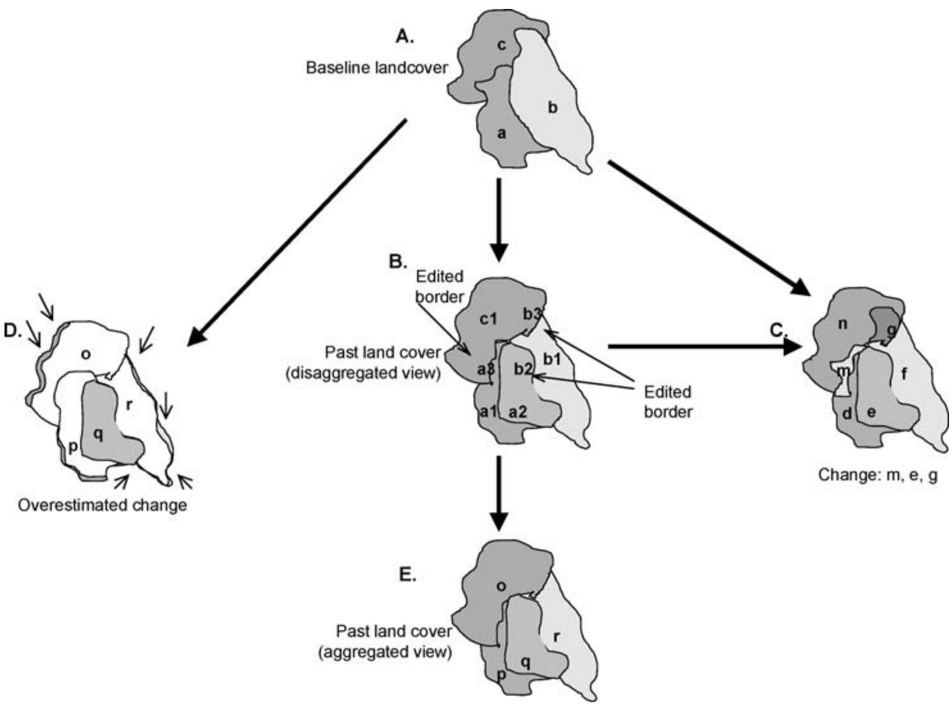

Figure 1. Physical implications of land-cover/use change mapping.

is contained in a database one can reduce the amount of data to be stored and easily track the history of a polygon. This Object-Oriented Analysis (OOA) approach is closely linked to databases and data modelling.

Polygons are defined by a set of boundaries. Land-cover/use boundaries are linear objects demarcating different land-cover/use faces that experience a succession of changes in their positions during their lifespan. The history of each Land-Cover/use Boundary (LCB) is unique and shows the geographical, i.e. in the sense of relative position referenced to a baseline map, significance of a LCB over the development of environments, landscapes, anthropological activities, socio-economic aspects, etc. Each LCB has its own space-time path that represents its lifespan (Figure 2). A LCB begins to exist when it is for the first time mapped (creation) and has an existence period (existence) along which alterations can occur due to the evolution of the environment; it may happen that a LCB ceases to exist (demise) when it shares common characteristics on both of its sides (i.e. left area has the same semantic attribute of right area). The detection of change in LCB involves the description of the evolution of LCB at an earlier time (i.e. 1991) that accounts for the LCB being the way it is at a later point in time (i.e. 2001). The development of the boundary follows a longitudinal configuration (or a sequential one) without any branching; in other words, a boundary can only be alive and unique but it cannot become something else.

A combination of the GIS Overlay approach and the OOA approach has been adopted at polygon level for the land-cover/use change analysis in order to be able to handle changes as an evolution of land-cover/use objects over time. The 1991 polygons are described by what has changed in their state, i.e. the spatial extent of the polygon formed by a set of land-cover/use boundaries and/or the polygon label (land-cover/use class) vis-à-vis their state in 2001. This allows quick identification of "hotspots" of change. The GIS approach has been applied for a quick general

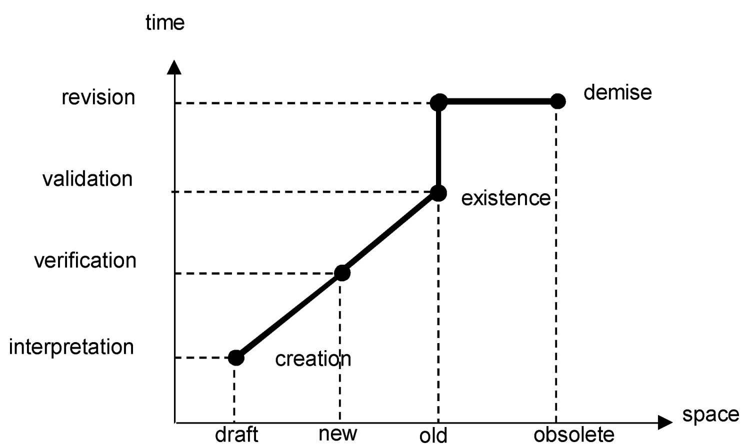

Figure 2. A possible space-time path for a Land Cover Boundary (LCB).

overview, whereas the OOA approach has been used to understand the relationships between changes.

Past land cover/use (i.e. 1991) has been interpreted starting from the present validated land-cover/use layer (i.e. 2001). In practice, the interpretation of 2001 has been overlain on the 1991 satellite images. Where change was identified polygon boundaries and/or labels were updated in order to match the 1991 land cover/use and the change in state of the polygons recorded. This approach allowed minimising errors induced by creating a new layer. In fact, a certain amount of difference in physically drawing a new layer is to be accounted for (Figure 1). This would lead to an overestimation of change in terms of especially spatial extent.

3. Different Aspects of Land-Cover/Use Changes

Land-cover/use changes are the results of many interacting processes and each of these operates over a range of scales in space and time (Verburg *et al.*, 2003). Methods for detection and measuring of spatially explicit land-cover/use changes from remote sensing depend on comparisons between data sets acquired at known intervals of time, i.e. 1991 and 2001 in the case of this study. The accuracy of these data sets influences the analysis that can be made. Various sources of potential error exist such as spatial and temporal effects and the extent to which a given land-cover/use class may be recognised unambiguously from its radiometric properties. The key issue is that not only the right combination of data acquisition and data interpretation techniques must be selected, but also the right mixture of remote sensing with conventional techniques must be identified. Remote sensing is a tool and like any other tool its capacity to detect change is limited. This limit is related both to the accuracy with which the land cover/use will be identified on the image and consequently mapped at a certain point in time t_k and also to the rate and extent of change on the ground (Wyatt, 2000).

Land-cover/use change analysis should consider the following aspects:

- Changes in geometry (area and perimeter), i.e. spatial aspects x and y;
- Rate of change, i.e. temporal aspect t; and
- Changes in class label, i.e. semantic aspect s that in a parametric approach may range from a change in the composition of characteristics measured to a change in any of the measured characteristics.

Spatial aspects influence the capacity to detect change in two ways. First, one should consider the spatial resolution of the images in relation to the scale of the changes to be observed: Landsat 5TM and 7ETM+ both at 30 m resolution. Furthermore, the high degree of fragmentation of the landscape in Albania is important in the choice of imagery to detect changes. The occurrence of mixed pixels on different images of the same area may suggest change when there is no apparent change on the ground. Second, geo-referencing of images will cause errors however slight. This type of error is independent of the manner in which geo-referencing is undertaken, i.e. image-to-map (2001 images) or image-to-image (1991 images). Consequently, a proportion of apparent differences between images is due to mis-registration. The interpretations have an actual positional accuracy of not more than 34.5 m on the ground as average with a standard deviation of 18.6 m (Agrotec S.p.A., 2003a).

Temporal aspects should be considered when one tries to reconcile time and frequency of remote sensing data acquisition with the rate of change in the features of interest, i.e. the natural resources. Another problem to be considered is cloud incidence. Therefore the set of images used for a vast area usually covers different periods of time and it is difficult to establish a precise baseline against which to measure changes. Table I shows the used images for 1991 from September, whereas the 2001 images are all from October except one image that is from the year before.

The semantic aspects in a parametric approach may range from a change in the composition of characteristics measured or a change in a single characteristic measured. For example, vegetation changes through the seasons or in the case of cultivated areas there exists an alternation between crops and the land lying bare but such changes are not considered to be of the type of a land-cover/use change. However, due to various reasons the canopy cover of a vegetation type can become less dense, so the characteristic of canopy cover changed. At the same time it is possible that due to the more open canopy cover the species composition changed.

A parametric classification such as the FAO/UNEP LCCS facilitates land-cover/use change studies because the criteria used to define classes function at the same time as the parameters to be observed over time (Jansen and Di Gregorio, 2002, 2004; Jansen, 2004). It therefore assists in determining the *s* aspect of change. Most existing classifications and legends in Europe (UN-ECE, 1989; CEC, 1995, 1999) are based upon class names thereby not facilitating the use of these systems for monitoring purposes. It is more difficult to interpret a change in class names than comparing two sets of parameters.

4. Change Dynamics in the Period 1991–2001

4.1. Analysis of changes at national level

At aggregated data levels the local variability of spatially explicit land-cover/use changes may be obscured, whereas patterns can be showed that at more detailed data levels may remain invisible and vice versa (Veldkamp *et al.*, 2001). The change dynamics show that at national level an area of almost 330,000 ha of the territory, i.e. 11.5%, is subject to land-cover/use change. The results at aggregated land cover group or LCCS domain levels show immediately that the most significant changes

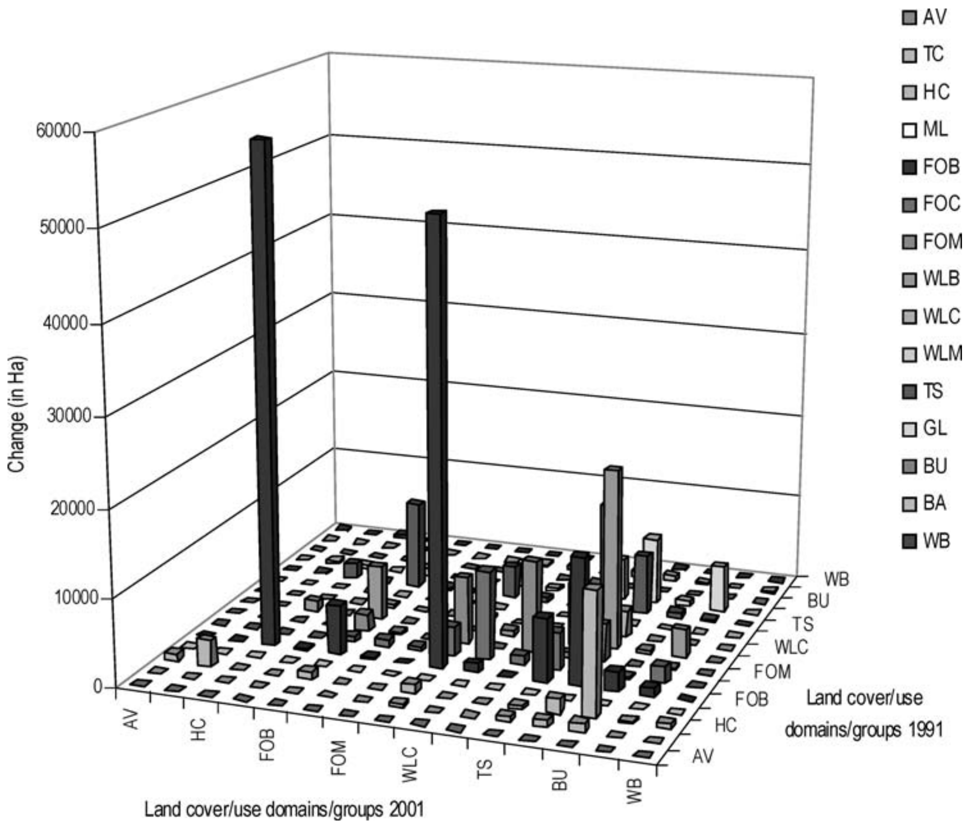

Figure 3. Land-cover/use change by LCCS domain or land cover group. AV = Aquatic vegetation, TC = Tree and shrub crops, HC = Herbaceous crops, ML = Managed lands, FOB = Broadleaved forests, FOC = Coniferous forests, FOM = Mixed forests, WLB = Broadleaved woodlands, WLC = Coniferous woodlands, WLM = Mixed woodlands, TS = Thickets and shrublands, GL = Grasslands, BU = Built-up areas, BA = Bare areas, WB = Water bodies.

occur in the vegetation type classes (Figure 3). The area subject to land-cover/use change dynamics in the vegetation groups and domains comprises 91.2%, whereas 70.0% of this change is redistributed over these classes as modifications. This means that 21.2% is related to change that is unrelated to vegetation, thus changes that can be attributed to land-cover/use conversion. The domains comprising the Cultivated Areas have an area of 7.9% subject to land-cover/use change dynamics and 19.6% of the total land-cover/use change has become agricultural area. The net gain is significant with 11.7%. The two LCCS major land cover categories (Semi-) Natural Vegetation (A12) and Cultivated Areas and Managed Lands (A11) (Table III) explain 99.1% of total change with a redistribution of the areas subject to change of 89.6% to the same categories.

Figure 3 indicates clearly that two types of changes are spatio-temporally dominant: (1) from Broadleaved Forests into Broadleaved Woodlands (50,352 Ha); and

(2) from Broadleaved Forests into Herbaceous Crops (56,977 Ha). These changes are followed by changes of a more limited extent like Broadleaved Woodlands into Grasslands (20,660 Ha), Broadleaved Forests into Grasslands (14,545 Ha) and Herbaceous Crops into Built-up Areas (14,121Ha). Broadleaved Forests are the land cover group with the largest spatio-temporal aspect of change dynamics (139,829 Ha).

A closer look at the land-cover domains is taken by calculating the type of change, i.e. modification within its domain or across related domains, or conversion between non-related domains. The interest of the study is in particular in the forest and woodland (open forest) vegetation types, as well as in those types that can be used for pasture. A better insight is gained by studying what type of change prevails in these LCCS domains in order to discover possible trends (Table V):

- In the Forest (FO) domain modification into Woodland (WL) is prevalent as 25.6% of change can be explained by it. The second most important change as mentioned above, consisting of 17.3%, is conversion into Herbaceous Crops (HC).

TABLE V
Modification and conversion of the vegetated areas subject to change at LCCS domain level[a]

		Area			Area	
LCCS domains	Modifications	Ha	%	Conversions*	Ha	%
Forests	Within FO	10351	3.1	From FO to HC	56977	17.3
	From FO to WL	84390	25.6	From FO to BU	2518	0.8
	From FO to TS	12026	3.7	From FO to BA	3384	1.0
	From FO to GL	25896	7.9			
Woodlands	Within WL	983	0.3	From WL to HC	1161	0.4
	From WL to FO	6621	2.0	From WL to BU	367	0.1
	From WL to TS	8417	2.6	From WL to BA	3457	1.0
	From WL to GL	23717	7.2			
Thickets & Shrublands	Within TS	12683	3.9	From TS to HC	1802	0.5
	From TS to FO	10456	3.2	From TS to BU	663	0.2
	From TS to WL	4281	1.3	From TS to BA	334	0.1
	From TS to GL	6937	2.1			
Grasslands	Within GL	7760	2.4	From GL to HC	397	0.1
	From GL to FO	817	0.2	From GL to BU	742	0.2
	From GL to WL	2223	0.7	From GL to BA	5346	1.6
	From GL to TS	4702	1.4			

[a]For the codes used see Figure 3.

- In the Woodland domain the modification to Grassland (GL) consist of 7.2%.
- In the Thicket and Shrubland (TS) domain the most important change is modification within the domain with 3.9%, followed by modification into Forest with 3.2%.
- In the Grassland domain conversion to Bare Areas (BA) with 1.6% and modification within the domain with 1.4% are the most significant among the changes.

From the above it seems that there is a gradual shift from Forests to Woodlands, Woodlands to Grasslands and Grasslands to Bare Areas. The highest percentages of change are found in the vegetation types were trees were, or still are but to a (much) lesser degree, dominant. In each of these vegetation types especially -but not only!- the tree layer has become less dense with time. Analysis of the semantic aspects of the LCCS parameter options reveals that in all cases the parameter canopy cover of the life form trees has changed either from closed to open, closed to sparse, or from open to sparse. Since the change study is based upon remote sensing no statement can be made about the height and state of the vegetation. A logical explanation would be that these natural resources have been depleted as a result of deforestation (e.g., illegal cutting). Forests also show that a considerable part of them have been converted into agricultural fields, a change with a more permanent character. The Thickets and Shrublands, though, show a different development and sometimes even a return to a tree dominated vegetation type. Human or animal pressure on the environment may sustain certain vegetation types; if this pressure falls away, the vegetation might regenerate.

Analysis of the Broadleaved Forests and Woodlands (Open Forests) at the class level improves the understanding of their change dynamics, especially since Broadleaved Forests change into Broadleaved Woodlands and the latter in turn change into Grasslands. The following classes are involved (note that percentages given concern total change and are not relative to the country territory):

1. "Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice" mixed with "Cultivated areas with herbaceous crops on sloping land" (CXB) with 21.0% (17.1% converted into "Cultivated areas with herbaceous crops on sloping land" (1CS));
2. "Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice" (2BD) with 15.0% (10.0% going to "Broadleaved deciduous open forest (*Quercus* spp. are dominant) usually coppice" (2DO));
3. "Broadleaved deciduous open forest (*Quercus* spp. are dominant) usually coppice" (2DO) with 11.5% (with 3.8 and 2.0% going to "Sparse trees and shrubs with open to closed grass cover and rock outcrops (pastures)" (2SR) and "Sparse trees and shrubs with very open grass cover and rock outcrops (pastures)" (2GR) respectively);
4. "*Fagus silvatica* pure and mixed with coniferous forest" (2FC) with 7.8% (with 3.2% going to "*Fagus silvatica* pure and mixed with coniferous open forest" (2FO)); and

5. “Broadleaved deciduous forest with dominant *Fagus silvatica*” (2FS) with 5.9% (with 3.6% going to “Broadleaved deciduous open forest with *Fagus silvatica* dominating” (2FB)).

The only other significant change dynamic at class level is the conversion from “Cultivated areas with herbaceous crops on level land” (1CU) to “Built-up areas” (5UR), comprising 3.3 % of total change, where cultivated fields have been replaced by constructions. This is an important change as in case 1 above the cultivated areas on slopes are increasing, whereas the cultivated field areas on level land are decreasing. This means that especially in the sloping and hilly areas of Albania particular land-cover/use types have changed in favour of cultivated areas. At the same time this may mean that this change occurred where less favourable environmental conditions exist (e.g., shallow soils, steep(er) slopes, difficult access, etc.) and where environmental effects may be detrimental (e.g., land degradation and soil erosion).

But if certain classes lost area to change, other classes can be attributed large parts of the areas subject to change. Such classes are:

- “Cultivated areas with herbaceous crops on sloping land” (1CS) with 18.3% (17.1% coming from “Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice” mixed with “Cultivated areas with herbaceous crops on sloping land” (CXB));
- “Broadleaved deciduous open forest (*Quercus* spp. are dominant) usually coppice” (2DO) with 14.1% (10% coming from “Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice” (2BD));
- “Sparse trees and shrubs with open to closed grass cover and rock outcrops (pastures)” (2SR) with 12.4% (3.8% from “Broadleaved deciduous open forest (*Quercus* spp. are dominant) usually coppice” (2DO));
- “Maquis and garigue (incl. low Med. macchia)” (2MG) with 8.5%;
- “Sparse trees and shrubs with very open grass cover and rock outcrops (pastures)” (2GR) with 8.2%;
- “Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice” (2BD) with 6.4% (2.8% from “Mediterranean macchia/Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice” (MXB) and 1.9% from “Broadleaved deciduous open forest (*Quercus* spp. are dominant) usually coppice” (2DO));
- “Broadleaved deciduous open forest with *Fagus silvatica* dominating” (2FB) with 6.4% (3.6% from “Broadleaved deciduous forest with dominant *Fagus silvatica*” (2FS)); and
- “Built-up areas” (5UR) with 6.0% (3.3% from “Cultivated areas with herbaceous crops on level land” (1CU)).

A number of figures illustrate where the main land-cover/use changes are found in Albania. The Figures 4–6 show the spatial distribution of the three main changes

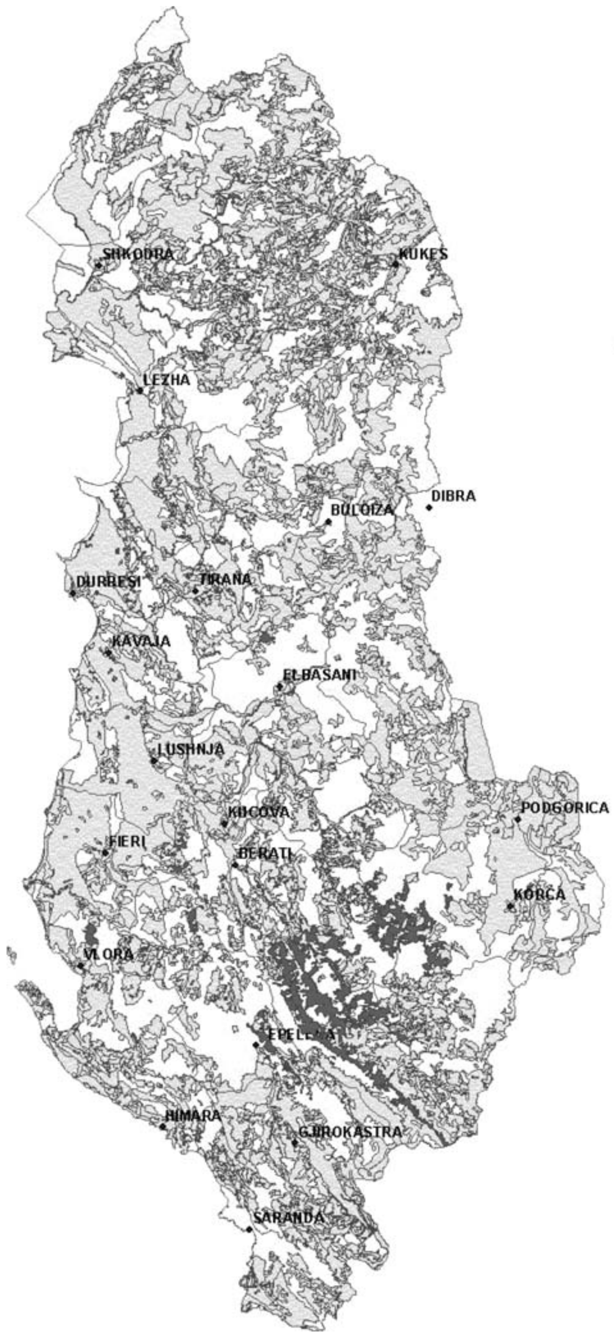

Figure 4. Spatial distribution of the change “Broadleaved deciduous (open) forest, usually coppice” mixed with “Cultivated areas with herbaceous crops on sloping land” into “Cultivated areas with herbaceous crops on sloping land”(dark colour).

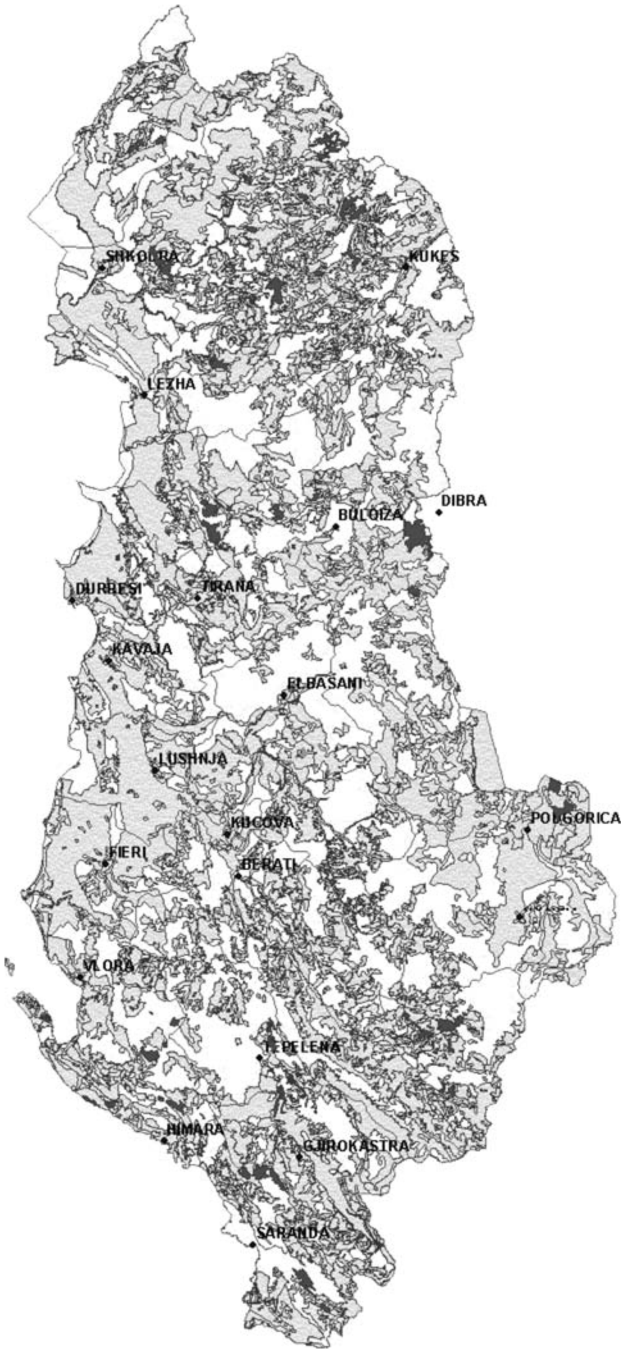

Figure 5. Spatial distribution of the change "Broadleaved deciduous forest" to "Broadleaved deciduous open forest" (dark colour).

Figure 6. Spatial distribution of the changes “Broadleaved deciduous open forest” into “Sparse trees and shrubs with open to closed grass cover and rock outcrops” and into “Sparse trees and shrubs with very open grass cover and rock outcrops” (dark colour).

at class level with the areas where the change in class occurs in dark colour and with all polygons subject to change shown in light grey (they do not concern the total area of change but polygons where the boundaries and/or label changed). Figure 4 shows the change "Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice" mixed with "Cultivated areas with herbaceous crops on sloping land" (CXB) converted into "Cultivated areas with herbaceous crops on sloping land" (1CS) that occurs mainly in part of the south of the territory. Figure 5 shows the change "Broadleaved deciduous forest (*Quercus* spp. and/or *Ostrya* spp. are dominant) usually coppice" (2BD) into "Broadleaved deciduous open forest (*Quercus* spp. are dominant) usually coppice" (2DO) that occurs mainly in the north and south, whereas Figure 6 shows two related change types "Broadleaved deciduous open forest (*Quercus* spp. are dominant) usually coppice" (2DO) into "Sparse trees and shrubs with open to closed grass cover and rock outcrops (pastures)" (2SR) and "Sparse trees and shrubs with very open grass cover and rock outcrops (pastures)" (2GR) respectively that occur mainly in the south. From these figures as well as further analysis of where certain change types are found, it seems that changes are regional in their occurrence. The class "Broadleaved deciduous open forest" is in the south subject to two types of changes: in part it occurs where before the forest canopy cover was closed and in part it is transformed into Grasslands.

It is not sufficient to look at the area subject to change dynamics alone. The changes should also be analysed in relation to the presence of a land-cover/use type in the country territory. Figure 7 shows the land-cover groups or domains in 1991 and 2001. From this figure it becomes clear that Albania is dominated by Broadleaved Forests, Herbaceous Crops and Grasslands. Changes in any of these land-cover/use types may have replications to the full area covered by these land-cover/use types. In fact from the analysis of the area subject to change it has become

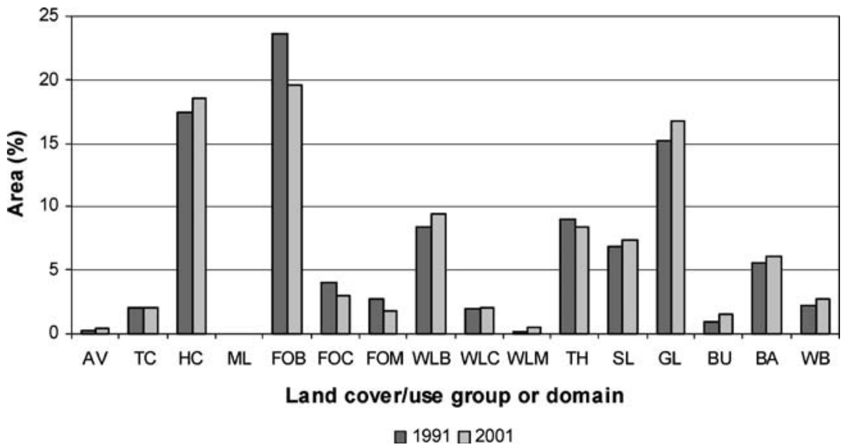

Figure 7. Changes in spatial extent of the LCCS domains. For explanation of the codes see Figure 3.

clear that all these land-cover groups or domains are indeed subject to significant change dynamics.

However, the change dynamics of the individual land-cover/use group or domains becomes clearer when one calculates their absolute increase or decrease over the period 1991–2001 irrespective of how much of the country territory they occupy as is illustrated in Figure 8a. The percentages of absolute increase or decrease are much more pronounced. Forests decrease most, followed by Thickets that decrease at a lower rate; Built-up Areas clearly increase followed by Woodlands and Grasslands, but the latter two at a much lesser magnitude. Figure 8a shows clearly that urbanisation is one of the main land-cover/use changes in the country though the area subject to this change is relatively small. However, if cultivated land with

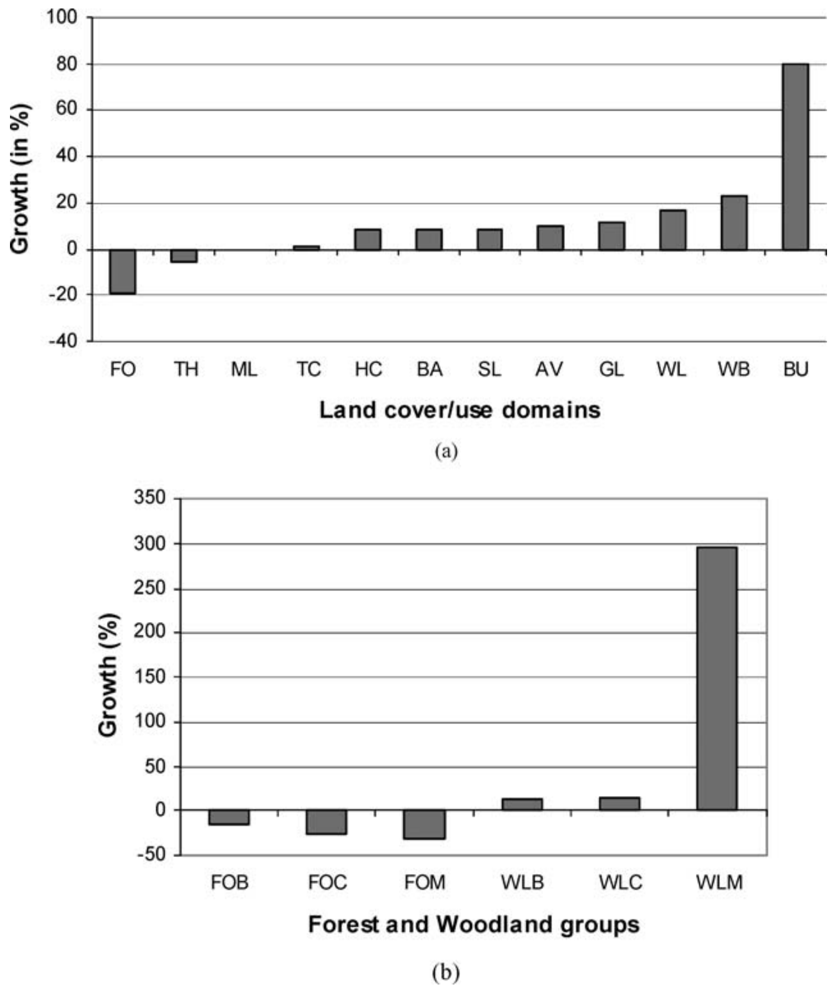

Figure 8. Absolute changes in spatial extent of the LCCS domains (A) and the Forest and Woodland groups in particular (B). For the codes used see Figure 3.

high crop production capacities is lost, these area losses may have relatively important consequences for the total agricultural crop production. The increase in Water Bodies, due to the class Artificial Water Bodies, is neglected in this interpretation as the water levels in the reservoirs depend more on meteorological factors and/or water uses than on change. Many irrigation systems are malfunctioning or have even broken down after the change in economy, thus the amounts of water used have diminished. This change seems more related to the change in agricultural practises than to any real land-cover change, but likely it has greatly influenced the agricultural production of irrigated crops.

Since the better understanding of the change dynamics concerns in particular the Forests and Woodlands, a closer analysis is made. The growth percentages of these land-cover/use domains, as shown in Figure 8A, may hide individual differences at group level. Figure 8b shows that the Forests groups are subject to a decrease in the range of 16 to 32% with the Mixed Forests occupying only a small part of the country territory but suffering relative greater losses than the Coniferous and Broadleaved Forests respectively. The Broadleaved and Coniferous Woodlands show an increase around 13% while the Mixed Woodlands show an enormous increase of 295%. However, the spatial extent of Broadleaved Woodlands is many times that of Mixed Woodlands (270,444 Ha versus 15,797 Ha; see also Figure 7). Figures 8a and b show that the change dynamics may have a greater effect on relative minor land covers/uses in the country territory and consequently may indicate priority areas for the sustainable management of those land-cover/use types that show an unwanted development and where policy interventions may be required (e.g., land cover/use with a great risk to disappear or growth rates with environmental implications).

4.2. Analysis of changes at district level

The land-cover/use change dynamics at district level have been analysed in order to examine local variability and an overview is provided of the most significant changes (Figure 9). The percentages provided are related to total change within the district and not to the district territory. As expected the most significant change dynamics at national level are also found at district level: changes related to the depletion of natural resources, in particular deforestation, such as the change from Broadleaved Forests into Broadleaved Woodlands (FOB to WLB), or into Grasslands (FOB to GL), or into Herbaceous Crops (FOB to HC), and the change from Broadleaved Woodlands into Grasslands (WLB to GL). But also the change from Coniferous Forests into Grasslands (FOC to GL) is important at district level.

Furthermore, the change related to urbanisation is found, i.e. from Cultivated Areas into Built-up Areas (HC to BU), in those regions where large urban centres are found: the Durres-Kavaja-Tirana triangle, which is the economic centre of the country, but also around Lushnja, Fier and Kucova.

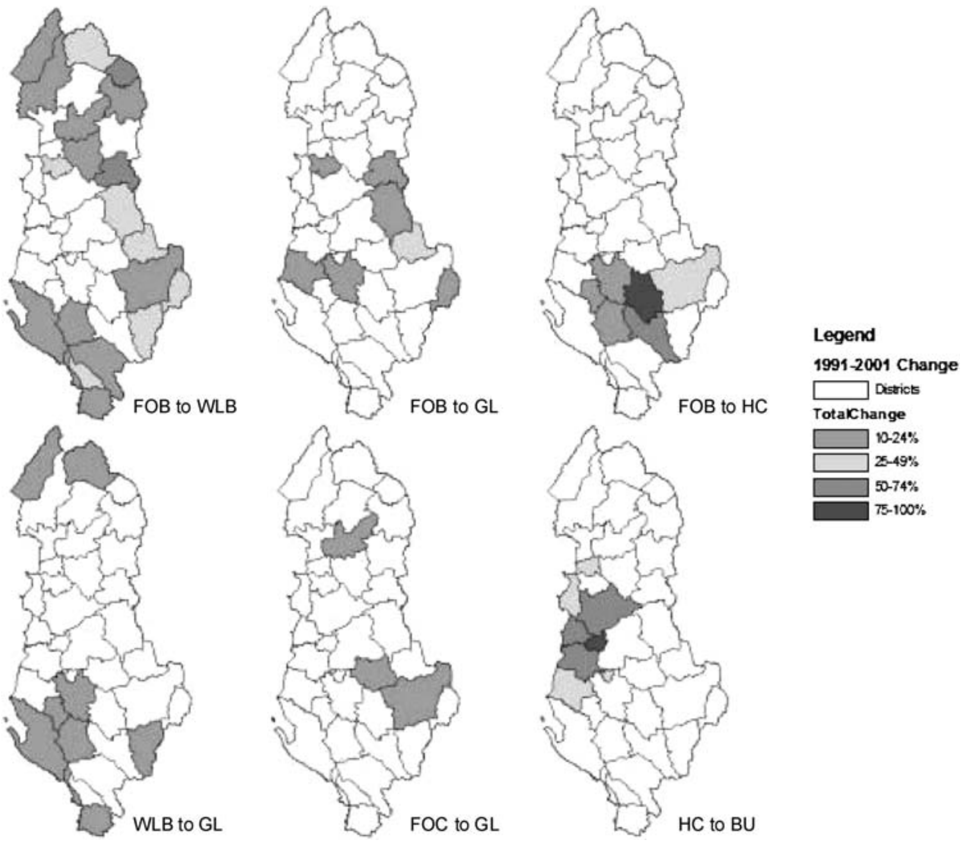

Figure 9. Overview of the most important change dynamics at district level (percentages refer to total change within the district).

In several districts the most important change dynamic does not correspond to a change that is particularly pronounced at national level. Examples are the change from Broadleaved Forests into Shrublands in Shkoder (30%) and from Mixed Forests into Mixed Woodlands in Diber and Kukes (both 35%). These two changes once again illustrate deforestation. Furthermore, there is the change from Shrublands into Grasslands in Kukove (50%) that may be related to pasture and, finally, the change from Thickets into Broadleaved Forests in Elbasan and Gramsh (48 and 50% respectively) where the tree canopy cover increases substantially.

Modifications within the Broadleaved Forests are important in Has, Librazhd and Tropoje (21, 17 and 11% respectively), within the Grasslands in Durres and Devoll (28 and 31% respectively) and within Shrublands in Fier (25%).

These districts, all of them close together in a specific part of the country, could approach one another when designing and implementing policies and plans for natural resources management. Neighbouring districts that may have experienced, or are experiencing, the same type of change to a lesser degree could learn from such experiences. A decentralised approach seems justified by the data of the study, especially as the Albanian government is transferring the responsibility for forest areas.

5. Conclusions and Discussion

The spatio-temporal and semantic aspects of land-cover/use dynamics in the period 1991–2001 have been analysed for the first time for the whole of Albania through an analysis of spatially explicit data collected through remotely sensed data interpretation and field validation. This analysis has confirmed the major trends of natural resources depletion, in particular deforestation, and urbanisation while at the same time showing that trends are location specific in the country.

The analysis of underlying causes of the observed changes in Albania is limited by the scarce or unavailable spatially explicit data. As a result of not being able to perform a quantitative driver analysis, the interpretation of underlying causes is mostly speculative or based upon other studies.

The transformation of the Albanian forestry sector from the centrally planned and state-implemented model to a market-oriented economy has required major changes in the legal, regulatory and management framework for the sector. Policy failure seems to be one of the essential underlying causes for the widespread natural resources depletion (e.g., corruption, weak or no law enforcement) though policy reforms are progressing and operational and management capacities are being strengthened with international assistance programs (REC for Central and Eastern Europe, 2000; SDC/FAO/World Bank/Ministero degli Affari Esteri, 2003). However, the conditions of the forests as measured by the forest inventory of the ANFI project give reason for concern. The changes in structure of the forests (e.g., from closed forests to more open forests and from high forests to coppice to shrubs) and the unbalanced age class distribution indicate over-utilisation of the forest resources thus jeopardising the sustainability. Albania is one of few European countries where forest resources declined in recent decades, in particular during the transition period, as reported by UN-ECE (2001) and the Forestry Project (SDC/FAO/World Bank/Ministero degli Affari Esteri, 2003). According to The State of Environment Report almost 30% of the forests and about 50% of the pastures were turned into cultivated areas between 1960 and 1980 showing that forest and pasture resources in the past have been sacrificed to economic development based on intensive agriculture (UNEP, 1999). Government has put less and less fuel wood for sale on the market in the 1990s and as a result, given the lack of alternatives for energy supply and the widespread rural poverty, induced the rural population to cut illegally (UNEP, 1999; UN-ECE, 2001).

Furthermore, a notable increase in pasture activities has taken place and the increased grazing intensity has caused other forms of natural resources depletion, namely deterioration of the productive capabilities of pastoral areas and environmental degradation (e.g., as a result of low vegetation cover and the trampling of animals the increased manifestation of run-off and soil erosion) and consequently a demand for new pastoral areas. The special study on grazing impact on wooded lands carried out in the context of the ANFI project reports that pastures and meadows have a poor range condition and the stocking rates are four times the grazing capacity, having thus not only implications for the pastures but also for animal productivity (Agrotec S.p.A., 2003c). Important in this context is also the increased cropping of alfalfa for periods of up to five years on the same plot and the increased use of cultivated areas for grazing. This may alleviate in part the pressure on the pastures.

Though the ANFI project confirmed and quantified the poor state of forests and pastures in Albania, this pessimistic situation also provides opportunities. The young stage of forests can be taken as starting point for increasing carbon stocks in Albanian forests through sustainable forest use. Also degraded lands and abandoned cultivated areas form potential areas for afforestation and reforestation. Although Albania adopted the United Nations Framework Convention on Climate Change in 1995, it did ratify the Kyoto Protocol only on the 1st of April 2005. Ratification is a necessary step to enter into the emission trading schemes, including carbon credits, generated by afforestation and reforestation programmes. If these activities are conducted on the basis of synergies among environmental principles, i.e. biodiversity conservation, combating land degradation and carbon sequestration, these may contribute to develop win-win opportunities between environmental protection and conservation, sustainable development and economic growth.

Urbanisation occupies only a small area in the country but changes in spatial extent of built-up areas *per se* do not appear to be central to this type of land-cover/use change. It is a misconception to think that a change can be ignored if the area involved is only small. The importance of urbanisation lies in the fact that it changes urban-rural linkages (Lambin *et al.*, 2001). Consumption expectations in urban centres are higher and will have an impact on areas much bigger than the cities themselves and located at distance (e.g., fuel wood that will need to be brought from the forested areas).

With the present data on land-cover/use dynamics no statements can be made as to the state of land-cover/use classes because the tool of remote sensing is not sufficient. For the (Semi-) Natural Vegetation classes one should consider that factors such as plant species composition (pastures), plant height or wood volumes (forestry) very likely have changed over time. Nothing can be said in the executed change analysis about the state of vegetation types (e.g., degenerated or not, decrease in tree height or not, deterioration in species composition or not, etc.), the state of cultivated fields (e.g., in active use, fallow or abandoned), or the state of urbanisation (e.g., increase in the number of floors of buildings, decrease in the number of habitants per house, etc.) because these features cannot be derived from satellite remote sensing. However, the forest inventory and grazing impact studies carried out in the context of the ANFI project have provided information on the current state of forests and pastures that can be used for monitoring purposes.

Privatisation of agricultural land has changed agricultural production considerably. Changes in the intensity of use, (mal-) functioning of irrigation systems and land fragmentation should be considered when analysing changes at the level of land-use. However, these factors cannot be measured with remote sensing. Combination of the present study results with socio-economic data may provide more conclusive evidence.

Land-cover/use changes do not always occur in a progressive or gradual manner, but they may show periods of rapid and abrupt change followed either by a quick recovery of ecosystems or a non-equilibrium trajectory (Lambin *et al.*, 2003). In the present study only two years are available: 1991 describing the land-cover/use situation under the centralised government and 2001 in a market-oriented economy. The mid 1990s are not represented but stand for the moment in which the land was distributed to rural households and registration as private property took place. It would have been interesting to see how the change dynamics evolved before and after registration as a study at detailed level indicates (Jansen *et al.*, 2005).

Considering the above-described limitations of remote sensing for analysis of land-cover/use dynamics, one could state that the present results are more likely an underestimation of change than an overestimation. If more land-use aspects and information would be integrated into the study, the area subject to change would be likely to be more extensive.

The establishment of permanent forest inventory plots by the ANFI project together with the remote sensing based national inventory of land-cover/use types provides DGFP and DSFD with the technical capability to continue state-of-the-art forest and pasture resources assessments and monitoring programs. The applied inventorying system allows replication of measurements and observations both in the field and through remote sensing. The results show that it is not only important to monitor the extent of natural resources areas but also the quality of these resources. This monitoring should be executed at regular intervals, which hitherto has not been the case. The monitoring system should have a national and a district component as the first is the level at which policies are formulated and the latter is the level at which management takes place and laws should be enforced. Collaboration with the National Environmental Monitoring Program of the Ministry of Environment should be strengthened in order to apply international monitoring methodologies and to enhance the use of limited monitoring equipment. The monitoring and information flow, however, should be focussed on the production of elements for decision making in natural resources management. People's participation in this democratic dialogue should be promoted by increasing the influence of civil society in the decision-making processes.

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Note

1. The authors worked as consultants in the ANFI project: Louisa J.M. Jansen as Remote Sensing and Land Cover/Use Expert, Giancarlo Carrai as GIS Expert, Luca Morandini as EDP Expert, Paolo O. Cerutti and Andrea Spisni as Remote Sensing and Image Interpretation Experts.

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