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Full Length Research Paper

Managing land use/cover data harmonized to support land administration and environmental applications in Turkey

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Land use / land cover (LULC) data is used in various application domains including land administration and environmental applications. Land cover data presents the physical coverage of the earth's surface while land use data presents its socio-economic functionality. A common definition and classification system is required to combine these data. In this way, according to user requirements in Turkey, coordination of information on the environment (CORINE) database which defines land cover classes in three data-use level was extended by creating a standard definition system at large scaled data use level. Harmonized LULC data model with five levels was produced from national to local level. LULC data at large scaled data use level was produced for Trabzon City to examine the applicability of the proposed model. This LULC data were generalized to other data use levels with the using of the LULC data model. Case studies showed that managing LULC data harmonized are successful to promote the multiple uses of LULC data in various environmental applications effectively.

Key words: Land use, land cover, CORINE database, data model, geographical information systems, remote sensing.

INTRODUCTION

Land can be managed better with information that presents LULC patterns (Slak, 1999). In many cases, the terms as land cover and land use are defined with exchangeable expressions. Land cover refers to the physical material covering the surface of the Earth including vegetation, water, soil and artificial surfaces built by human activities. On the other hand, land use refers to the way and how land is used by humans and their habitat (Ramachandra and Kumar, 2004). Therefore, land use defines territory according to its current and future planned functional dimension, such as agricultural, residential or socio-economic purpose including Indus-trial, commercial and recreational (INSPIRE, 2007; Duhamel, 1995). In other words, land use is characterized by the arrangement and activities people undertake in a certain land cover type (Gregorio and Jansen, 2000). Two land parcels may have similar land cover types, but different land use types and vice versa. For example, two land parcels could be covered by grass as land cover, but one may be used as a sport area, while the other as farming area. In addition, determining LULC types with their spatial and temporal distribution is required for a wide range of studies (Stefanov et al., 2001). The present distribution of LULC data, as well as information on their changing proportions, is needed by decision-makers and data users to determine better land use policy, to project transportation and utility

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demand, to implement national and regional plans effectively, to analyze environmental processes and problems and to make living conditions and standards improved (Campbell, 2007; Reis, 2008; Wu et al., 2006; Singh et al., 2001).

Land cover classification as an abstract representation of the land is defined as the ordering or arrangement of objects into groups or sets on the basis of their relationships (Sokal, 1974). Classification involves definition of land class boundaries clearly and is precisely based upon objective criteria. According to Hierarchical Spatial Reasoning (HSR), spatial borders should be ordered in a hierarchical pattern to simplify complex processes and problems by dividing them into uncomplicated sub-categories. Most LULC classification systems generally start with high-classes and divide them into more detailed sub-classes to help us use LULC data efficiently (Car, 1997; Glasgow, 1995). These classifications are focused on vegetation, or a specific theme such as agriculture or forestry (Anderson et al., 1976; Kuechler and Zonneveld, 1998; Roberts et al., 2003), For example, UNESCO (1973) considers only natural vegetation, not cultivated areas and urban vegetation. Some of them are generally inappropriate for particular purposes such as statistical or rural development needs. Some classification systems do not define classes very well, which result in conflicts to define a clear boundary between two classes and may not be suitable for mapping and change detection purposes (FAO, 1999; Herold et al., 2000). In short, various systems have been developed for a certain purpose, at a certain scale, using a certain data type. A standard classification system that has been accepted inter-nationally does not exist (CEC, 1993). As a result, public institutions in different countries define their own national land cover classification systems. On the other hand, land cover data coming from different countries or in a country needs to be used corporately for joint environ-mental projects and policy aims. With this approach, CORINE program was initiated by European Commission to combine and coordinate the consistency of information about the environment and to monitor how it changes in European Community. But available land cover data at national level is heterogeneous and difficult to obtain in all EU countries (Hall, 2006). Therefore, as a part of CORINE program, the CORINE Land-Cover (CLC) project has continued to provide consistent geographic ("geo-" prefix) information about the land cover of the European Community (EEA, 2000, 2009). Beside this, land use data having a direct link with land cover data are produced for various land administration applications such as zoning plan, cadastre, agriculture, etc. at local level.

LULC data are produced by using land surveying, photogrammetry, remote sensing and Lidar technology.

Although land surveying offers high accuracy, it is costly, labor intensive and time consuming (Huang and Fu, 2002). Photogrammetry with airborne imagery provides adequate information, however data acquisition process is also costly and time consuming at a certain degree. Lidar technology has some advantages over photogrammetry and land surveying. It offers high accuracy, fast acquisition and processing time with minimum human dependence. However, airborne lidar systems are expensive and are currently less available. On the other hand, using remote sensing technology with high resolution satellite data, the lands can be mapped at regular time intervals, with larger ground coverage, sufficient information content, higher resolution, revisit capability of remote sensing satellites and multispectral optical sensors. Thus, satellite imagery provides a good alternative for producing and improving LULC data (Rogana and Chen 2004; Chen and Rau, 1998).

In this study, LULC data needs of public institutions in Turkey were examined. A standardized LULC data model of Turkey was defined with hierarchical five main categories as sub-classes of first three levels of CORINE land cover classification. To test the proposed model, with the using of geo-information systems (GIS) and remote sensing (RS) techniques, LULC data produced in level-5 was generalized to upper levels. Various land administration applications have been performed to test and to confirm the applicability of this LULC data model, such as urban atlas, land cover map, agricultural ownership analysis and coastal zone management.

METHODS

Background: Producers and users of LULC data in Turkey

According to ministerial reports and the field work executed to the public institutions that produce and use geo-data, public Institutions using LULC data were determined and grouped into five levels; Government, National, Regional, Provincial and Local level as seen on Table 1. These public institutions are listed with administration levels and work discipline in this table. At government level, Ministry of Environment and Forestry and Ministry of Agriculture work with land related activities. At national level, 16 public institutions conduct land cover related projects. General Command of Mapping (HGK), the national mapping agency, is responsible for producing standard topographic maps (STMs) that are used as reference data in various projects done by public institutions (LRCD, 2004). Regional level consists of 11 Regional Directorates, particularly Regional Directorate of Forestry and State Hydraulic Works (DSI) which need LULC data in their thematic projects. Maps with a scale larger than 1:5000 are produced by Directorates of Land Registry and Cadastre (LRCD) and State Provincial Bank in Turkey. Provincial and county level also contains 15 public institutions in all provinces, primarily Provincial Public Administration, Municipalities, Directorate of Forestry Management and Provincial Directorate of Agriculture, which produce and use LULC data.

Table 1. Public Institutions producing and using LULC data in Turkey.

Government	National	Regional	Provincial	County	Work discipline
Ministry of Agriculture	Gen. Dir. of Agricultural Reform				Produces soil and land cover maps for agriculture and land use data of arable lands.
	Gen. Dir. of Agricultural Production				
			Prov. Dir. of Agriculture	County Dir. of Agriculture	
Ministry of Energy and Natural Resources	Gen. Dir. of Mineral Res. and Expl. (MTA)	Regional Dir. of MTA			Produces mining district maps and determining mineral location.
	Gen. Dir. of Electricity Production				
	Gen. Dir. of Electricity Transmission	Group Dir. of Electricity Transmission	Dir. of Turkey Elect. Transmission		
Ministry of Environment and Forestry	Gen. Dir. of Environ. Effect. Eval. and Planning				Responsible for protection and control of flood and soil erosion.
	Gen. Dir. of Natural Cons. and National Parks	Council for Cult. and National Entities			
	Gen. Dir. of State Hydralautic Works (DSI)	Regional Dir. of DSI			
	Gen. Dir. Of Forestry	Regional Dir. of Forestry	Dir. of Forestry Manag.	Sub-Dir. of Forestry	
			Prov. Dir. of Environment and For.		Produces cadastre maps, land use maps, and plans of forests.
Ministry of Transportation	Gen. Dir. of Highways	Regional Dir. of Highways	Dir. of Highways	Sub-Dir. of Highways	
	Gen. Dir. of State Ports Const. (DLH)	Regional Dir. of DLH			Makes construction plans of airports and seaports.
		Regional Dir. of Transportation			Makes infrastructure and construction plans of roads
Ministry of Public Works and Settlement	Gen. Dir. of Land Regist. and Cadastre (LRCD)	Regional Dir. of LRCD	Directorate of Cadastre	Dir. of Land Ownership	Determines land use attribute of land parcels.
	Gen. Dir. of Disaster Works		Prov. Dir. of Public Works and Settlement		Produces coastal area and disaster management plans.
	Gen. Dir. of Provincial Bank	Regional Dir. of Provincial Bank			Supports projects including the production of LULC data.

Table 1. Continued.

Ministry of Interior Works			Provincial Governorship		Responsible for all urbanization and environmental activities, implementing urban plans, and generating land use data, etc.
			Provincial public administration	Municipalities (Metropolitan/City)	
Ministry of Defence	General Command of Mapping (HGK)				
	Turkey Statistics Institute (TUIK)	Regional Dir. of TUIK			

Examining LULC data use of public institutions in Turkey

This analysis examines the current situation with respect to the existing specifications and LULC data use. Despite the fact that Turkey has achieved some success in standardization of LULC data, there are still different approaches and hierarchical categories in the description of land-cover classes. Standardization problems occur on the use of LULC data since the maps having different scales are produced by different organizations without any coordination among them. These force public institutions to collect land related data by themselves for their thematic needs. LULC data specification can be summarized as below to examine current situation;

i. HGK has conducted STMs and institutional projects to generate LULC data. However, HGK generates and classifies LULC data without considering different user needs (Durduran and Erdi, 2006).
ii. Forest management plans generated by Regional Directorate of Forestry are taken to describe the forest and vegetation areas.
iii. Land use classification methodology implemented by General Directorate of State Hydraulic Works is also taken into account to describe wetlands.
iv. Provincial Public Administration and General Directorate of Forestry also have been conducting projects to produce land-cover data based on CORINE database and methodology (Karagulle and Kenduzler, 2007).
v. Ministry of Agriculture classifies agricultural land into four categories as arable land, land for specific products, orchard and groves and marginal agricultural land (not suitable for agriculture) according to Soil Protection and Land Use Act (No. 5403) (Official Gazette, 2005).
vi. Municipalities work independently without coordination and standard to generate LULC data. Land-use in urban areas must be planned and implemented by considering standard legends of Reconstruction and Development Act (No. 3194) for scales of 1:25000 - 1:5000 (Official Gazette, 1985). Almost all municipalities produce LULC data, create reconstruction plans and build Urban GIS for other mapping, real estate and environment purposes. Land use classification system of Istanbul Metropolitan Municipality provides a five levels hierarchical approach from national to local level.

Directorates of LRCD also record land use data of each land parcel during cadastre; But this effort is far beyond setting standardization.

Determining LULC data needs of public institutions in Turkey

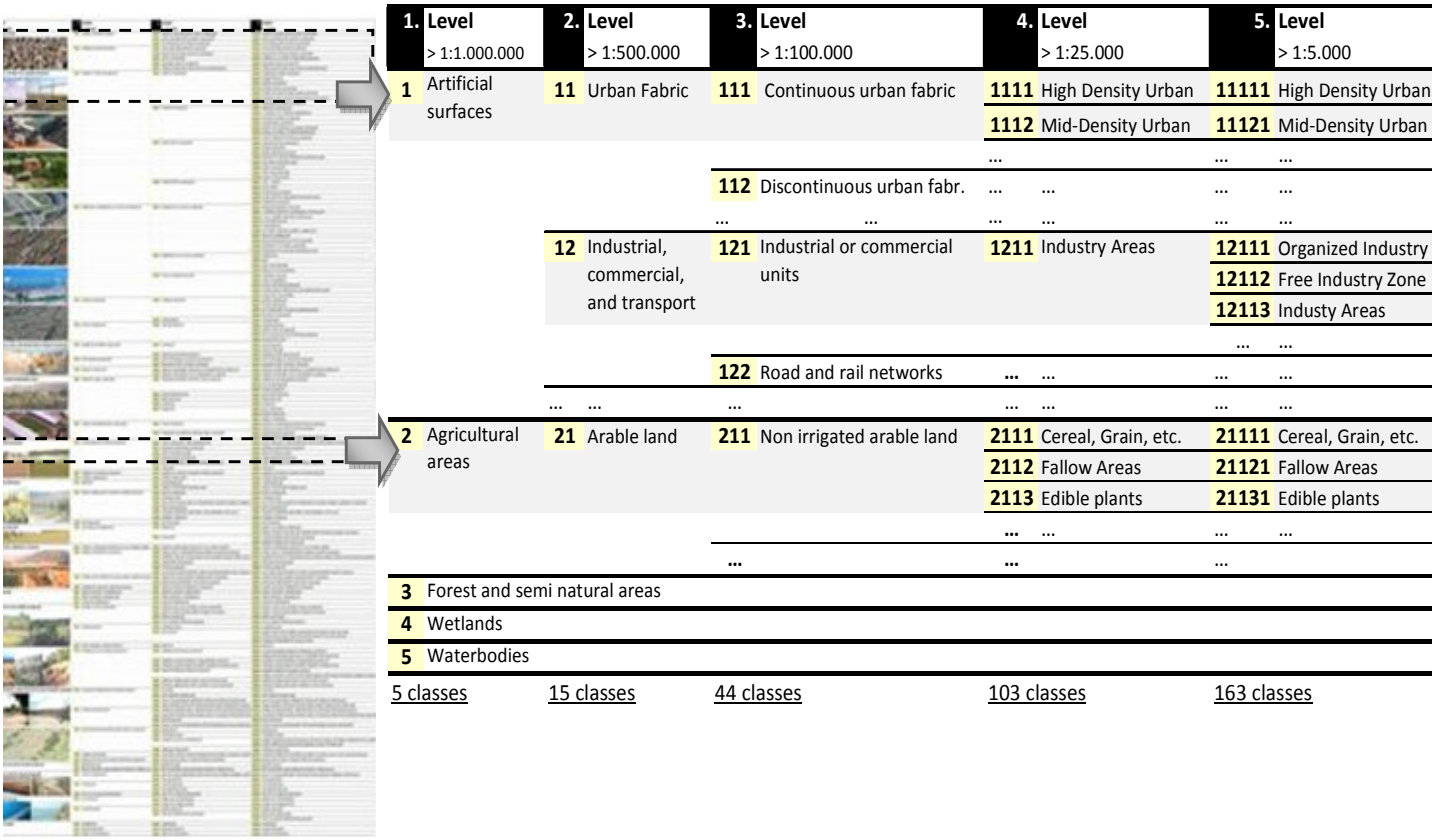
Turkey has centrally management authority and provincial system as a main administrative unit of Turkey (Prime Ministry, 2006). If a geo-database modeled for a particular province works, it should also be applicable from local to national level for all other provinces. Hence, Trabzon, one of the 81 provinces of Turkey, was chosen as a pilot province. In a Field Work, 12 of public institutions that are main LULC data producers/users (bold in Table 1) have been analyzed to examine LULC data needs in their environmental projects and GIS applications. These GIS functions were summarized and combined in a Data/Function matrix. User requirements of these functions were defined as LULC type, the level of detail, relationships between classes, data consistency and the like.

LULC data needs based on the Field Work were combined with LULC data use and existing specifications. As a result of this analysis and user requirements, 163 land use classes were determined and listed at large scaled data use level. Then, these classes were categorized into 5 LULC groups including artificial surfaces, agricultural areas, forest areas, wetlands and water bodies.

Designing and proposing LULC data model for Turkey

A LULC data model was designed that enables hierarchical classification of LULC classes in view of data use levels. The name of this model is “Turkish National Geo-Data Exchange Model for Land Surface” (abbreviated as UVDM: AR in Turkish). UVDM: AR includes LULC classification comprising 5 levels as seen on Figure 1 (Aydinoglu, 2009).

The first, second and third level classification of UVDM:AR is based on CLC methodology that describes how land cover classes should be defined with their geometry, attributes and topological rules. The methodology includes nomenclature, definition of spatial unit, scale of data use level, process of image interpretation in



1. Level > 1:1.000.000	2. Level > 1:500.000	3. Level > 1:100.000	4. Level > 1:25.000	5. Level > 1:5.000
1 Artificial surfaces	11 Urban Fabric	111 Continuous urban fabric	1111 High Density Urban	11111 High Density Urban
			1112 Mid-Density Urban	11121 Mid-Density Urban
			...	... ...
		112 Discontinuous urban fabr.	... ...	... ...
		... ...	... ...	... ...
	12 Industrial, commercial, and transport	121 Industrial or commercial units	1211 Industry Areas	12111 Organized Industry
				12112 Free Industry Zone
				12113 Industy Areas
				... ...
		122 Road and rail networks	... ...	... ...
	... ...	...	... ...	... ...
2 Agricultural areas	21 Arable land	211 Non irrigated arable land	2111 Cereal, Grain, etc.	21111 Cereal, Grain, etc.
			2112 Fallow Areas	21121 Fallow Areas
			2113 Edible plants	21131 Edible plants
			... ...	... ...
		...	...	...
3 Forest and semi natural areas				
4 Wetlands				
5 Waterbodies				
5 classes	15 classes	44 classes	103 classes	163 classes

Figure 1. UVDM: AR LULC Classification.

creation and use of data (EEA, 2000). The spatial unit corresponds to a homogeneous area that represents a land cover class such as water, forest, etc. The spatial units, with area restriction as to data use level, can be distinguishable from other surrounding spatial units without overlapping areas unit (EEA, 2009). UVDM: AR LULC data levels are described as below;

UVDM: AR Level-1 consists of 5 main LULC classes described with integers between 1 and 5 to represent land covers at ≤ 1:500.000 scales. For example, “Artificial surfaces” is described by “1”.

UVDM: AR Level-2 contains 15 LULC classes to be used at map scales between 1:100.000 and 1:500.000. These categories are described with two digit integers such that the digit to the left represents the land-cover type at upper level (Level-1), whereas the digit to the right describes the land-cover type at the second level. For example, “12” represent “Industrial, Commercial and Transport units”, which is a sub-class of “artificial surfaces” represented with “1” at level-1.

UVDM: AR Level-3 consists of 44 LULC classes to be used at applications using maps at a scale of ≥ 1:100.000 and ≤ 1:25.000. In this level, the categories are described with three digit numbers as the subcategories at level-2. For example, *“Industrial or commercial units”* is represented with “121”, which means that this land cover is sub-class of the unit represented with “12” at level-2. In fact, these classes are not only categories of different land covers, but also categories of different land uses.

Level-4 and Level-5 LULC classes were defined and classified as the sub-categories of level-3 CLC classification with hierarchically coded attribute values. 163 LULC classes in level-5 and 103 LULC classes in level-4 were determined through negotiations with various public institutions.

UVDM: AR Level-4 contains 103 LULC classes are used at a scale of ≥ 1:25.000. These categories are described with four digit integers such that the first three digits to the left represent upper level (Level-3), whereas the digit to the right describes the land use type at the second level. For example, “1211” represent “*Industry Areas*”, which is a sub-class of the unit represented with “121” at level-3.

UVDM: AR Level-5 with 163 LULC classes are used at a scale of ≥ 1:5.000. In this level, the classes are defined with five digit numbers as the children of classes at level-4. For example, “*Organized Industry Areas*” represented with “12111” means that this LULC is a sub-class of the unit represented with “1211” at level-4.

APPLICATION

To test the usability and the performance of the proposed LULC data model, with the using of LULC Level-5 classification, 1:5000 scaled land use map of Trabzon city was produced from topographic maps, Quick Bird

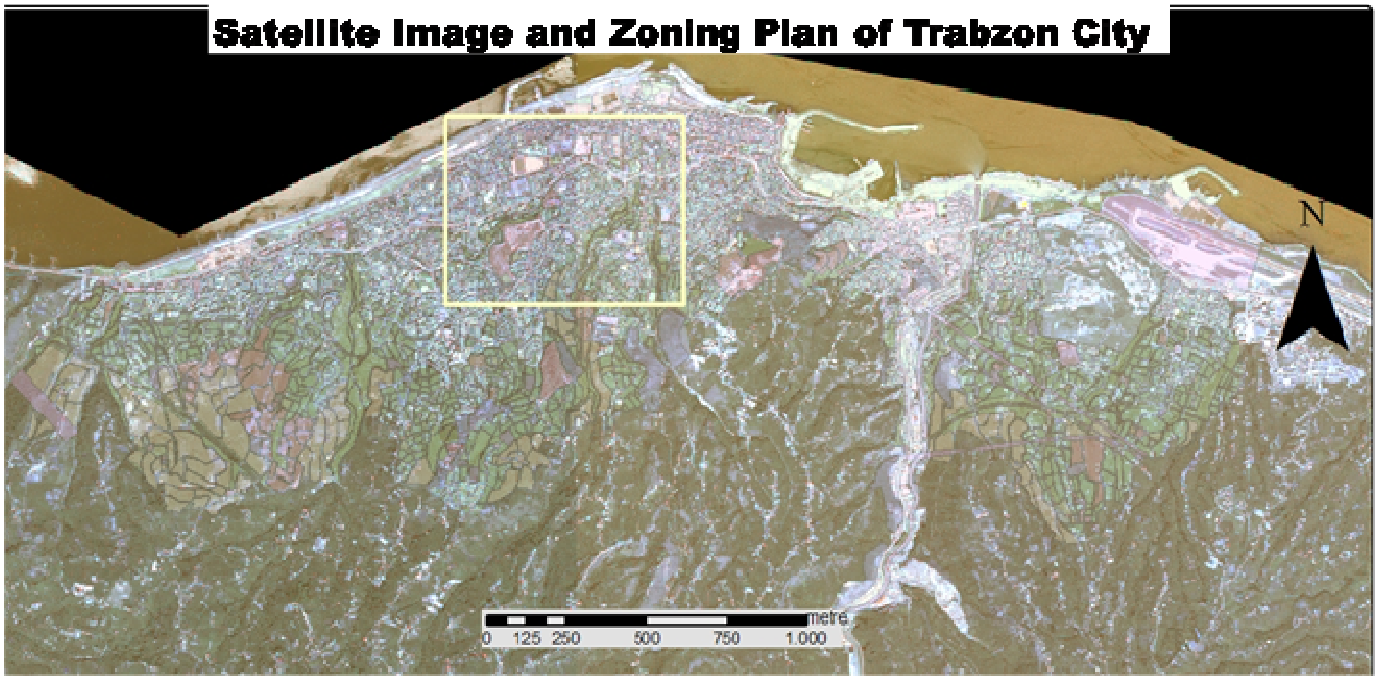


Figure 2. Quick Bird multispectral image of Trabzon city.

multispectral image and in situ data. This LULC Level-5 map on Figure 3 was produced for a part of Trabzon city as displayed on Figure 2 with yellow rectangle.

As a case study, this land use map was used to produce LULC data at other levels and to confirm the usability of the data in various urban and rural applications. Generalization process between LULC levels was done with the using of hierarchic LULC codes and minimum area rule. ArcGIS generalization and editing tools were used to generalize level-5 LULC data to higher levels in view of user needs. The minimum area that is defined at LULC levels is determined according to detectable map area (5 x 5 mm) at the smallest scale of LULC level. For example, the smallest area at level 5 is calculated 650 m^2 with 1:5000. As seen on Figure 3, LULC classes that are larger than 650 m^2 at level-5 is generalized to level-4 with a minimum area of 15.6 da and then generalized to level-3 with a minimum area of 25 ha. LULC classes at level-3 is generalized to level-2 and then generalized to level-1.

LULC data includes the functionality of the lands such as industrial, commercial and residential areas. And, these can be used in various urban applications. For example, level-4 LULC data on Figure 3 was extracted and used as a base layer of Trabzon Web Urban Atlas application on Figure 4.

In addition to this, land cover map of East Blacksea region of Turkey was produced with supervised classification technique on Landsat image. These land cover classes are based on Level-3 LULC classification and CLC Methodology. As seen on Figure 5, various environmental applications can be produced and combined with harmonized LULC classification at different levels.

With the LULC data model, land use maps were produced for Ministry of Agriculture. The aim of this map is to control the compatibility of farmer registration declarations with geo-data. In this way, Agricultural areas were checked with cadastral parcels for Isiklar City (Figure 6-a) and Bengisu Village (Figure 6-b). Besides, some environmental applications were produced and shared with the using of LULC data model.

DISCUSSION

It can be noticed easily in the GIS projects implemented by Ministry of Environment and Forestry, Ministry of Agriculture and other public institutions that there is no coordination between public institutions in production of LULC data. As well as LULC data procuders, national data providers such as HGK and LRCD have defined LULC data standards based on their institutional requirements. Therefore, production of LULC data results in duplication of efforts to acquire the same data, which hinders data sharing.

Turkey National GIS initiatives should put geo-data policies into practice to share geo-data effectively and

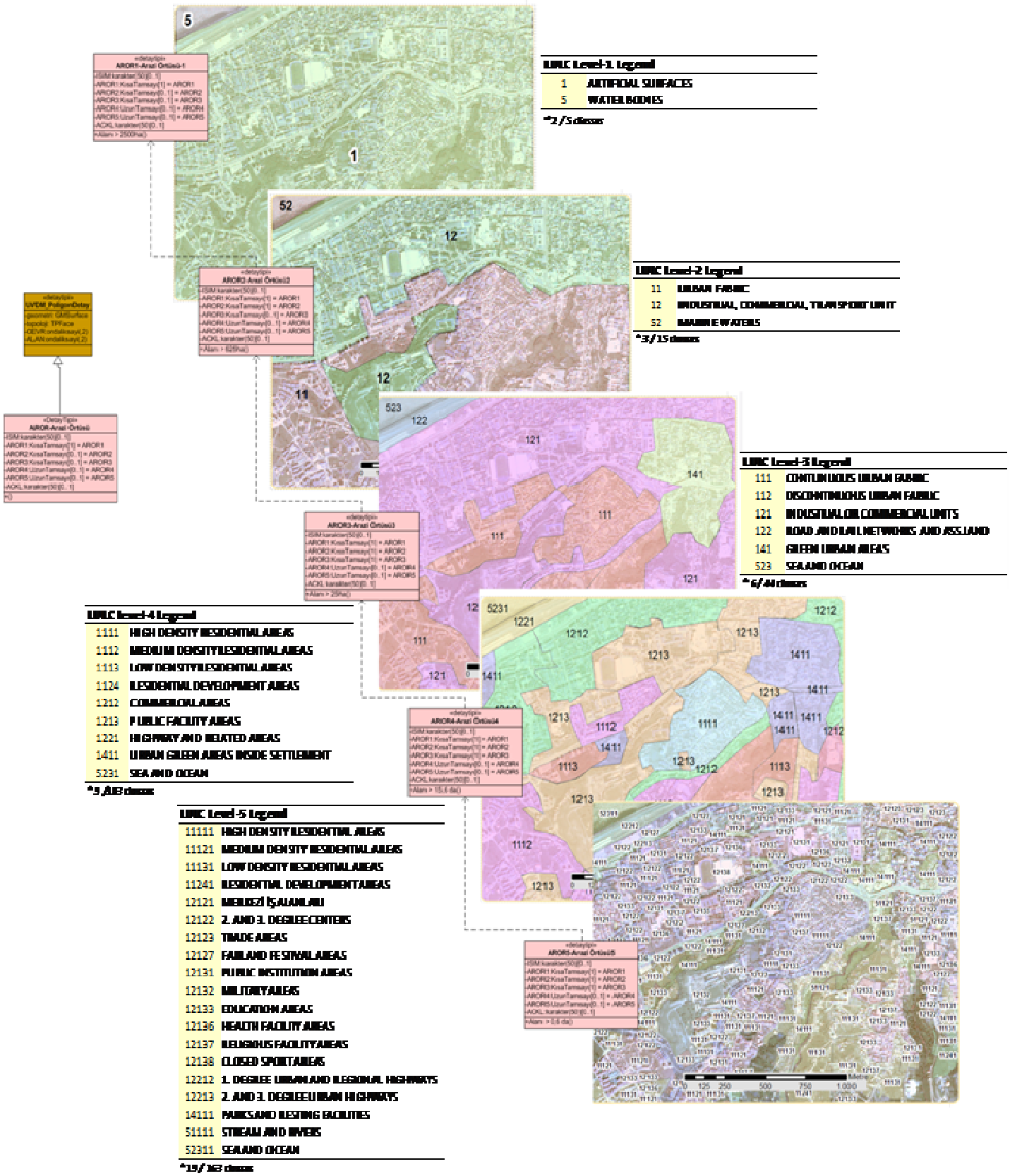


Figure 3. Generalization example of LULC data between different levels.

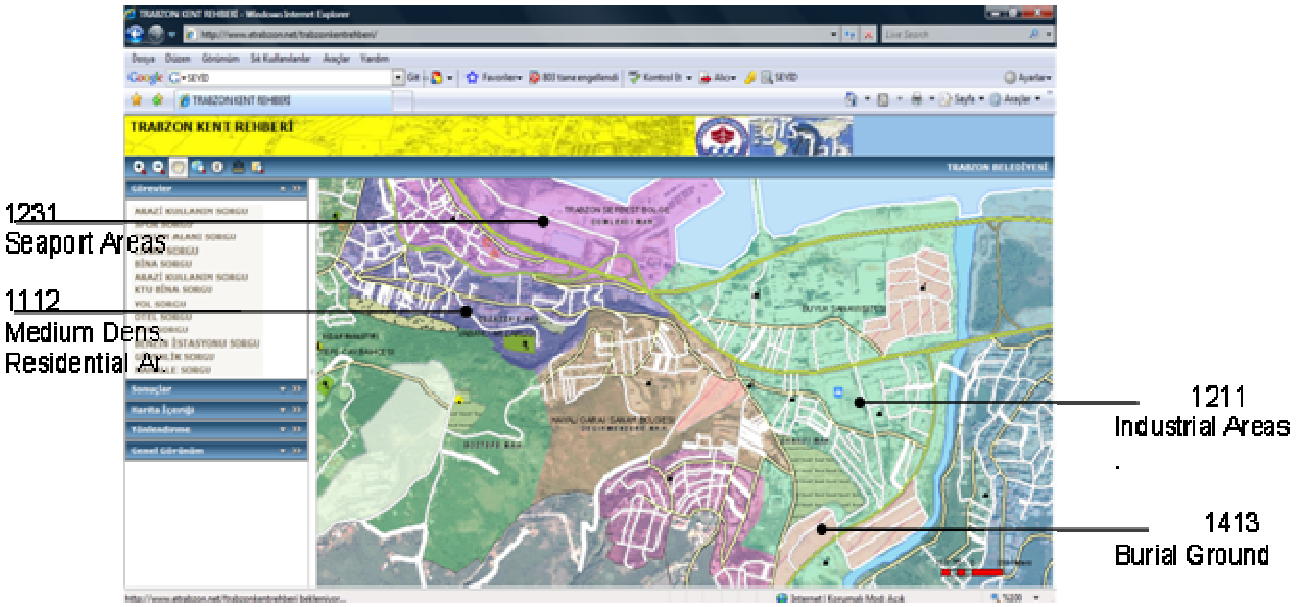
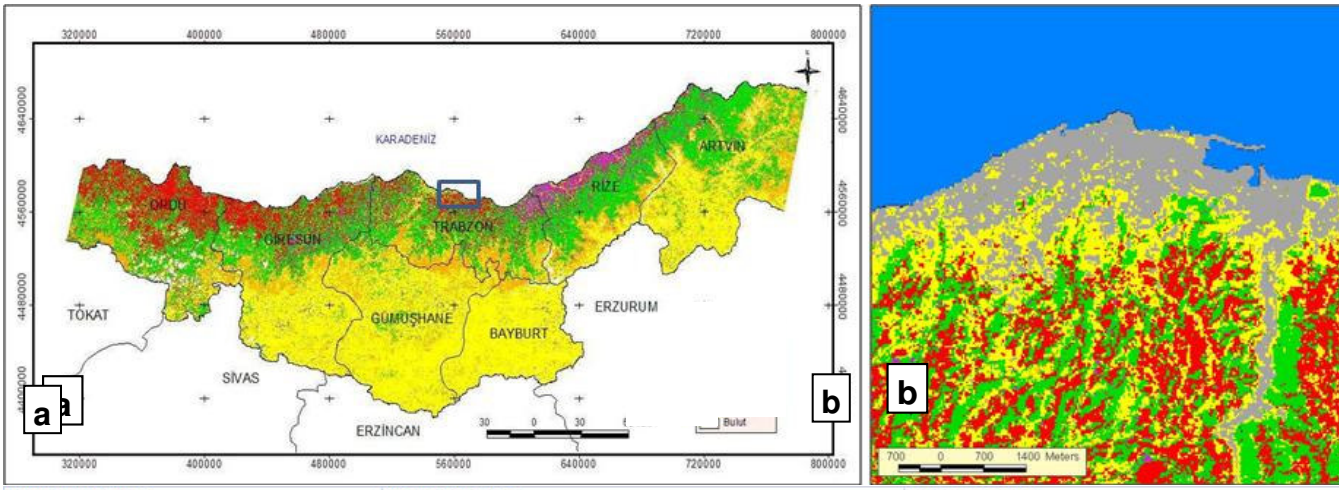


Figure 4. Trabzon Web Urban Atlas with LULC base data.



LULC LEVEL-1		LULC LEVEL-2		LULC LEVEL-3	
1	ARTIFICIAL SURFACES	11	URBAN FABRIC	...	
		12	INDUSTRIAL, COMMERCIAL, AND TRANSPORTATION	...	
2	AGRICULTURAL AREAS	21	ARABLE LAND	212	PERMANENTLY IRRIGATED LAND
		22	PERMANENT CROPS	222	FRUIT TREES AND BERRY PLANTATION
		23	PASTURES	231	PASTURES
3	FOREST AND SEMI NATURAL AREAS	31	FORESTS	311	BROAD-LEAVED FOREST
				312	CONIFEROUS FOREST
		33	OPEN SPACES WITH LITTLE OR NO VEGETATION	332	BARE ROCKS
				333	SPARTELY VEGETATED AREAS
5	WATER BODIES	51	INLAND WATERS	511	WATER COURSES
				512	WATER BODIES
		52	MARINE WATERS	523	SEA AND OCEAN

Figure 5. (a) Land Cover Map of East-BlackSea region, (b) Closer view of the area and LULC legend.

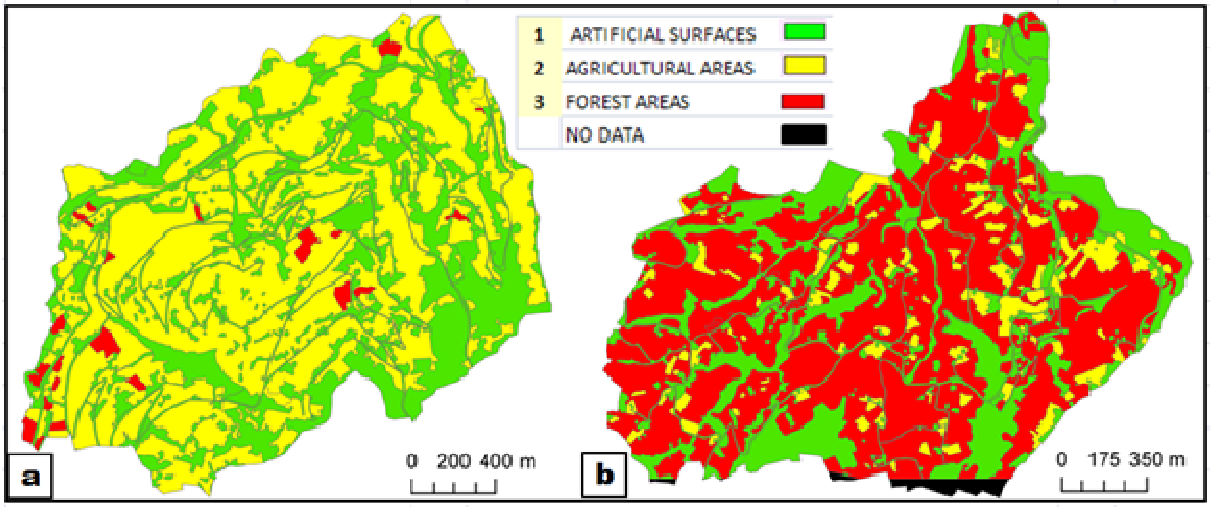


Figure 6. LULC Map of (a) Isiklar City and (b) Bengisu Village.

propose conceptual model components to develop standards of geo-data themes including LULC. Proposed LULC data model should be accepted and developed as a part of National GIS standards to solve standardization problems in Turkey. LULC data acquisition methodology should be developed for data producers. Case studies show that LULC data can be acquired from other data levels by certain generalization rules, since proposed data model is based on hierarchical classification of LULC classes in five major levels. In this way, LULC data can be shared between LULC data users. Multiple uses of LULC data is possible without time and effort losses in various environmental and land administration applications.

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