Land-use change dynamics at cadastral parcel level in Albania: an object-oriented geo-database approach

Louisa J.M. Jansen [a], Giancarlo Carrai [b], Massimiliano Petri [c]
[a] Land/natural resources consultant, Via Girolamo Dandini 21, 00154 Rome, Italy.
E-mail: louisa.jansen@tin.it, Tel.: +39-065757719.
[b] Managing director, SVALTEC S.r.l., Via del Campofiore 106, 50136 Florence, Italy.
E-mail: gc.carrai@svaltec.it, Tel./Fax: +39-0556236003.
[c] University of Pisa, Department of Civil Engineering, Via Diotisalvi 2, 56126 Pisa, Italy.
E-mail: m.petri@ing.unipi.it, Tel.: +39-050553502, Fax: +39-050553495.

Abstract

A case study in Albania is presented based on the EU Phare Land Use Policy II[1] project results where GIS-oriented instruments and innovative methodologies were implemented to support decision-making for land-use policy and planning. With the aim of improved land-use planning, the change dynamics over the period 1991-2003 were analysed at multiple levels: from cadastral parcel to cadastral zone to commune level.
CASE Visio and ArcInfo UML diagrams were used to organise the objects and feature classes of the Information System according to the European Environmental Agency's INSPIRE initiative. The developed Land-Use Information System for Albania allows the logical and functional hierarchical arrangement of land uses and data harmonisation with other land-use description systems. The Land-Use Change Analyses methodology groups changes into conversions and modifications to underline the change processes. An object-oriented approach has been followed in the change dynamics application and the Knowledge Discovery in Databases process was used to detect a priori unknown relationships.
The preferred land-use change pattern indicates that land users take rational decisions when changing land-use because of low suitability soils or unsuitable soils for that particular use in areas with steep slopes causing erosion and subsequently abandonment. Areas most apt to agriculture, well served with infrastructure and close to urban centres, have overall maintained their production characteristics though at lower levels. In the case of urbanisation in rural areas, green areas around the buildings were maintained for agricultural production for self-sufficiency purposes. These developments are the more surprising in the absence of any regulating plan.

Keywords: land-use change dynamics, Knowledge Discovery in Databases, object-oriented database approach, agriculture, urbanisation.

1. Introduction

In Albania, government distributed the land to the rural households instead of restitution of most of the fertile lands to a small number of families that would have restored the highly unequal pre-reform land distribution [1,2]. The transition from 550 large agricultural cooperatives to 467,000 smallholder farms was associated with the fragmentation of land into 1.5 million parcels that often have limited, or no, access to infrastructure and mechanisation. Most of the agricultural land lies in sloping areas with soils having high erosion risk potentials. Most of the farms are subsistence ones and about 75 % of farm production is home consumed. The lack of information, inadequate extension services, almost no access to bank credits, lack of marketing channels up to difficult access to transport are major constraints for the Albanian farmer. Since about half of the Albanian population is employed in the agricultural sector, a national development priority is a sound land-use policy allocating land to uses that prevent

[1] Two authors worked as consultants in the LUP II project: Giancarlo Carrai was the GIS/IT Manager and Louisa J.M. Jansen the Land Use/Land Evaluation Expert.

degradation and yield high long-term returns. The land users should ensure the long-term quality of land for human use, minimise social conflicts and protect ecosystems. All user categories should have enough land with an infrastructure balanced against environmental threats, at reasonable costs and endowed with a well-defined tenure.

One of the problems of a country in transition like Albania is the passage from the centralised management of land and natural resources into a sustainable decentralised management that takes into account the market-oriented economy. Transition requests a substantial institutional effort with the creation of entities for decentralised planning and management of resources, as well as a significant legal effort in order to formulate a set of laws that regulate the use of resources and empower the created entities. Furthermore, the transition phase presents two important elements that are interlinked: (1) it is necessary for those concerned to understand the instrument of planning not as a means of top-down control up to the level of the individual, but to perceive it as a means to understand the need for change from the bottom to the top thereby finding an equilibrium between the costs/benefits of an intervention in terms of social, economic and environmental impact; and (2) at the same time staff needs to be trained at the various decentralised levels to collect, structure, organise and share data contained in the information system. The aim of establishing such a system is not primarily the visualisation of data (e.g., maps and tables) but the capacity to elaborate these data in order to create information to support decision-making (e.g., analysis of time-series, establishment of relationships between different thematic data layers, development of scenarios). Nowadays with the enormous amounts of data and information at hand and the technological instruments available, the responsibility of a decision maker has increased substantially. It is therefore necessary to consider the impact that a decision may have on future generations. Instruments that support decision-making are needed with powerful models that simulate various scenarios in order to be able to evaluate the effects, risks and advantages of a choice.

The EU Phare Land Use Policy II project (EU Phare AL98-0502) provided GIS-oriented instruments and innovative methodologies to support decision-making for land-use policy and planning to the Ministry of Agriculture and Food in Albania. This paper illustrates the concepts adopted and results obtained for the analysis of land-use change dynamics over the period 1991-2003 at multiple levels: from cadastral parcel to cadastral zone to commune level. Land-use change is one of the main driving forces of (global) environmental change and therefore central to sustainable development [3-6]. Thus analysis of past land uses and the understanding of processes and preferred pathways of change will support informed decision-making for improved, sustainable and environmentally sound land uses in future.

2. Methodology

2.1 The cadastral land parcel as basic unit

For each piece of land, individuals choose a type of use from which they expect to derive the most benefits in the context of their knowledge, the individual's household, the community, the bio-physical environment and the political structure to which the individual may be subject. These choices vary in space and time resulting in a spatial pattern of land uses. In Albania, the smallest spatially explicit land unit that one can define and subject to a particular use coincides with the land parcel unit of the multi-purpose cadastre. This legal unit, at which digital data is available, has been adopted as the basic unit for the data modelling and the land-use change analysis. The use of cadastral information for urban planning is an established practice, whereas the use of the cadastre for rural land-use planning is less common. The analysis at the spatially explicit detailed level may show the variability at the level of each cadastral zone while the aggregated level of commune may show patterns that remain invisible at the detailed scale, and vice versa [7]. The aggregated level of the commune is important in the land-use policy and planning process while the cadastral parcel unit is a level that corresponds with the decisions made by the individual landowner or land user. It should be clear though, that such decisions may be related to the group and its size the individual belongs to [8]. Individuals interact to form groups and organise collective action (e.g., farmer associations).

In general, land registration and the cadastre should be seen as part of the process of natural resources planning and management. They deal with two of the world's major resources, i.e. land and information. Land information is necessary in many central and communal government activities. The registers may be used for land taxation, the rights over public utilities over private land or along public roads for facilities such as electricity and water may need to be protected, infrastructures need to be maintained and/or improved, restrictions may be necessary where misuses occur, etc. The multi-purpose cadastre should therefore be seen as an integral part of the land management system. It is therefore important to establish linkages with a wider range of land-related data, especially those on the environment. In this manner managing land and land information meet [9].

2.2 The geo-database, data model and the object-oriented approach to land-use change dynamics

The geo-database constructed uses CASE Visio and ArcInfo UML diagrams in order to organise the objects and feature classes of the Information System comprising data sets structured according to the European Environmental Agency's INSPIRE (Infrastructure for Spatial Information in Europe) initiative that coordinates and develops agreed rules and standards to facilitate data harmonisation processes and to ease the access to environmental spatial information [10] (Figures 1 and 2).

Insert Figures 2 and 3.

An object-oriented approach has been followed in the developed land-use change application that puts each cadastral parcel unit of 2003 in relation to its parent cadastral parcel unit in 1991 and 1996 of which the land uses are known using the relation: Object.GetParent_ID (byValue). The object-oriented approach in information systems is defined as the "*collection of cooperative objects, treating individual objects as instances of a class within a hierarchy of classes*" [11]. The parent-child relationships created facilitate the analysis of the spatio-temporal dimensions, i.e. area and perimeter over time, because with the usual GIS overlay method one will have dispersion of a class into other classes with no information in the database about the relationships related to this dispersion. The data model considers also the fact that sometimes a cadastral parcel changes land use as a consequence of the construction of a building (e.g., an area with vegetables and fruit tree cultivation in which a residential house has been built) in which case two types of information are stored (e.g., the "garden" representing a kind of peri-urban agriculture and the residential building).

2.3 The Land-Use Information System for Albania

There is significant diversity of opinion about what constitutes a land use because the term land use has different meanings across disciplines and, as a result, implies a set of mostly unidentified characteristics [12]. These different perspectives on land use are, however, all valid. In the context of the project land use is defined as "*the type of human activity taking place at or near the surface*" [13].

The Land-Use Information System for Albania (LUISA) developed allows the logical and functional arrangement of land-uses at different levels of detail, as well as data harmonisation with other land-use description systems in use in the country (e.g., statistical office, cadastre and communes). LUISA has adopted as guiding principles two criteria that are commonly applied in international systems [14-23]: (1) *function* that refers to the economic purpose of the land use and can group many different land-use types in a single category; and (2) *activity* that refers to a process resulting in similar type of products and is used at the lower levels of the hierarchy [24,25]. The adopted concept builds upon and exceeds experiences gained in two case studies [26,27].

LUISA is the result of a participatory process with the key actors in land-use policy and planning and it has been developed in complete synergy with the information system analyst. Categories present in the current version of LUISA represent the key categories of the Albanian law on the land: “Agricultural”, “Forests”, “Pastures and Meadows” and “Non-agricultural” land uses (Figure 3). LUISA contains a hierarchical land-use legend, i.e. a systematic and logically ordered method in which to describe land uses, for the particular purpose of support to land-use planning and policy at different administrative levels and for a particular area, i.e. the pilot areas of the project in Albania. The set of classes in this legend may therefore be only a proportion of what one may actually find in Albania.

Insert Figure 3.

Because of the scale of observation selected, i.e. the cadastral parcel unit, and in order to create in a timely manner a pragmatic land-use database of a manageable size (i.e. the number of records created will also need to be maintained and updated at regular intervals) knowing that the cadastre in Albania contains 1.5 million records, the decision has been made that only one land-use class is attached to each cadastral parcel unit having an average size of less than 1 ha. At aggregated cadastral parcel levels mixed classes can be introduced, but they do not exist at the most detailed level of LUISA.

Harmonisation between data sets is achieved on the condition that the data structure of existing data sets can be integrated in LUISA. Here, problems may arise because it may mean having to compromise and accommodate certain classes in a specific position in the legend structure that is neither the most suitable when considering the concepts adopted nor enhancing the legend’s internal consistency. In addition, the legend structure is linked to a data structure and therefore it is linked to the concepts adopted in the data model. In the context of the data model two issues should be mentioned:

1. The data model developed distinguishes *spatial* features (e.g., land use and soils) from *linear* features (e.g., roads and channels) (see Figure 2). Linear features are however also related to land use because roads form the transport network, whereas channels form the drainage or irrigation network. In the developed data model the linear features have undergone the decomposition of information of the object-oriented database approach meaning that they have been split into several segments (physical segmentation was preferred to the dynamic one because of ease of maintenance in the geo-database and also because segments of channels, for instance, often belong to the landowner); consequently for each identified road or channel segment data are collected that deal with the actual state and maintenance of this road or channel fragment. The advantage of having such segment information is that the user of the data can identify, for example, if anywhere on a road used for transporting agricultural products to the nearby market there is a segment that is in such a worse condition that a vehicle cannot pass. If the road would be a single feature in the database such an analysis would be impossible. The linear features do therefore not appear as land-use features in LUISA but as land cover features.
2. Land-use classes are only coded at the lowest levels of the LUISA legend in order to ensure data collection at the most detailed level in the different communes. Aggregation of the lower level classes will automatically generate higher-level land-use classes.

The three land-use data sets available each represent a critical moment: (1) the 1991 data represent the land uses under the former centralised government; (2) the 1996 data represent the moment when distribution and registration of the land to the family households took place; and (3) the 2003 data represent the actual land uses in the market-oriented economy.

2.4 The Land-Use Change Analyses methodology

LUISA contains many classes and thus will result in numerous possible land-use changes that do not facilitate a meaningful interpretation if not grouped in a functional and systematic manner. The developed Land-Use Change Analyses (LUCA) methodology arranges the potential land-use changes in three main groups per land-use category in order to underline the change processes: (1) land-use *conversion*, i.e. where a certain land use has been changed into a land use that is very different and the change cannot easily be reversed; (2) land-use *modifications*, i.e. changes that are related to one another and where the situation can be reversed; and (3) no changes, i.e. areas that have remained under the same land use. The detailed groupings of land-use changes are shown in Table 1. With the reconstruction of past land-use change dynamics, an insight is gained in the land-use evolution and this can help government when making future projections. The LUCA methodology thus serves as an instrument in the decision-making process.

Insert Table 1, Figures 4 and 5.

In principle, land-use modifications occur within a land-use category and the degree of modification depends on the level of the class (e.g., at Level IV modification is small, at Level III medium and at Level II high) and land-use conversion occurs between land-use categories. The exception is the Non-Agricultural land-use category that contains a larger variety of classes than the other categories; in this category modifications occur within one group (e.g., within “Urban Uses”, within “Transport”, within “Utilities”, etc.) and conversions between groups (e.g., from “Unproductive” to “Urban Uses”, or from “Water Bodies and Waterways” to “Extraction and Mining”). Unlikely changes such as a “Residential area” having changed into “Arable land” have been excluded from the change analysis. Figures 4 and 5 illustrate the functionality of LUISA for the two main types of land-use changes of LUCA.

2.5 Knowledge Discovery in Databases

The Knowledge Discovery in Databases (KDD) process is an iterative procedure of selection, exploration and modelling of large amounts of data that was used to detect a priori unknown relationships in the data. The KDD process comprises [28]:

1. Data cleaning: the first phase in which “noise” is eliminated and the data consistency is checked;
2. Data integration: combination of different data sources and multiple data;
3. Data selection: in this phase from the complete information system only those data sets are selected that are expected to be relevant for the successive phases in relation to the defined objective;
4. Data transformation: in this phase data are transformed and/or consolidated in the format requested by the specific algorithm selected for the successive phase of data mining;
5. Data mining: the most important phase in which through the use of specific algorithms previously unknown patterns are extracted from the data that are channelled into a data model;
6. Pattern evaluation: an interpretation and evaluation of the identified patterns and data model is given in order to create new knowledge;
7. Knowledge presentation: visualisation and representation of the new knowledge to the users (e.g., the decision makers in case of the project).

KDD is a multi-disciplinary field in which concepts of statistics, artificial intelligence, expert systems, neural networks, etc., are combined. The innovative aspect is that KDD, especially the data mining phase, focuses on the enhanced value of the combination of the specific areas that converge in it in order to produce innovative solutions to data analysis and to resolve the inadequacies that each of them may present when used alone. The KDD process has been applied to the analysis of preferred pathways of change in Preza Commune.

The territory of Preza Commune has been divided in cells of 50 by 50m to which a series of attributes are linked from the available data sets and that comprise various data types (e.g., point, line and polygon). Some of the variables linked to each cell are:

- Distance of the cell to the border of the cadastral land parcel in 2003, 1996 and 1991 (3 variables);
- Area of the original cadastral land parcel;
- Land use in 2003, 1996 and 1991 (3 variables);
- For each cell the nearby occurring land uses in 1996 are recorded in a rectangle of 250 by 250m, i.e. a window of 5 by 5 cells, using Model Builder of ArcGIS 9 (13 variables);
- Distance to irrigation channels;

- Distance to river or lake;
- Number of roads that intersect the cell;
- Distance to the nearest road;
- Typology of the road surface of the nearest road (e.g., tar road, dirt road);
- Type of nearest road (e.g., communal, provincial, national);
- Maintenance condition of the nearest road;
- Presence or absence of buildings in the cell;
- Number of buildings in each cell;
- Number of buildings in a range of 500m;
- Drainage class;
- Erosion risk; and
- Slope class.

The above-mentioned variables were used as inputs into the decision tree that belongs to the data mining phase of KDD with the assumption that one of the variables, in this case land use 2003, is dependent on (part of) the other variables. The use of the above-mentioned variables to construct the decision tree is such that one starts at the initial node with all available data, then at each step groups are created on the basis of an explanatory variable, in the successive step each created group will be further subdivided by another explanatory variable and so on until the terminal node. Once a variable has been used it cannot be used in successive steps [29]. From the initial node towards the terminal node a series of decision-rules can be extracted of the type IF-THEN. Each decision-rule is characterised by a weight and a confidence level that measure the frequency and strength of the decision-rule respectively. Decision-rules that are valid for many cells have a major weight, whereas those that repeat themselves always in the same manner have a high confidence level. In the application to Preza commune, the decision-rules with major weights have been chosen first, followed by those with high confidence levels. The method requires several runs in order to create groups that maximise the internal homogeneity and the external heterogeneity. To create the groups at each level of the procedure a function is used as efficiency index that is known as “function segmentation criteria” [30].

3. Results

3.1 The temporal changes at cadastral zone level

Figures 6, 7 and 8 show the different types of land-use changes in the three communes, i.e. Preza, Ana-e-Malit and Pirg in the centre, north and southeast of the country, per cadastral zone in the periods 1991-1996 and 1996-2003. In all three communes the majority of parcels did not undergo any change in both periods (type 1). The main change in land-use concerns a land-use modification and in all three communes it is the Medium-level-modification-in-Agriculture (type 301).

Insert Figures 6, 7 and 8.

Land-use conversions are less frequent but do occur in the period 1991-1996, especially in Ana-e-Malit followed by Pirg and to a much lesser extent Preza (types 6, 7 and 8). Agriculture is converted into Pastures or Non-Agriculture, whereas Forests are converted into Agriculture or Pasture, Pasture is converted into Agriculture and Non-Agriculture is converted into Agriculture.

In the period 1996-2003 the majority of the cadastral parcels remained the same (type 1) but the stack bars in the three figures are a little bit lower than in the previous period. If modifications occurred they were again of the type Medium-level-modification-in-Agriculture (type 301), whereas land-use conversions are very few and of the type Agriculture-to-Pasture or Agriculture-to-NonAgriculture (types 6 and 7). It seems that in this period in particular agricultural lands were converted, whereas overall changes were affecting less parcels. In this period land has been privatised and apparently many new owners did not want or did not have the means to continue agricultural activities.

In all three communes the intensity of changes in the period 1991-1996, so before the land distribution, compared to those occurring in the period 1996-2003 is higher.

3.2 The temporal changes at commune level

The detailed distribution of the actual land uses (LUISA) for the pilot areas of the project is shown in Table 2. It is clear from this table that the communes are predominantly agricultural ones and that "Non-agricultural" land uses are more frequent than either "Forests" or "Pasture and Meadows" land uses.

Figure 9 shows the different types of land-use changes at commune level in the periods 1991-1996 and 1996-2003. There are clearly three major trends in the communes:

1. The majority of parcels did not undergo any land-use change in this period as indicated by the stack bars for land-use change type 1 (No change); whereas in Ana-e-Malit and Pirg the area that is not subject to changes increases in the second period, in Preza it decreases.
2. Medium-level-modification-in-Agriculture (type 301) is the most important land-use change, which means that classes in the "Agricultural" land-use category changed at level III, i.e. from Permanent into Temporary Crop Cultivation or vice versa (as shown in Figure 4). However, the extent of this modification is diminishing in the period 1996-2003 in Ana-e-Malit and Pirg, whereas Preza shows a clear increase.
3. Land-use conversions are much less important in terms of their extent but their impact may be bigger than that of land-use modifications. The most common conversion is Agriculture-to-NonAgriculture, except in Preza in 1991-1996 where Pasture-to-Agriculture conversion is dominant. The second most common conversion is Agriculture-to-Pasture in Preza and Ana-e-Malit in both periods and in Pirg in 1996-2003. In Pirg, NonAgriculture-to-Agriculture conversion is important in the 1991-1996 period.

Insert Table 2 and Figure 9 and 10.

Concerning the most important change, Medium-level-modification-in-Agriculture, more insight is gained when analysing what type of land-use classes result in this type of change. Selection of this change type in the three communes and grouping the class combinations of this change shows that in Preza and Ana-e-Malit in the period 1991-1996 the trend is to go from temporary to permanent crops, whereas in Pirg the trend in the same period is from permanent to temporary crops (Figure 10). In the period 1996-2003, the trend in Ana-e-Malit remains more or less the same. In Preza, however, the majority of changes still concerns the change from temporary to permanent crops though the rate of change is at a lower level than in the previous period, while the change from permanent to temporary crops increases clearly. In the period 1996-2003 the main trend in Pirg remains the change from permanent to temporary cropping but at a lower level than in the previous period and the change to permanent crops increases clearly. In Pirg many terraces with fruit trees, its main crop production system, were destroyed in the 1990s; in Preza and Ana-e-Malit projects are underway to plant useful trees (e.g., fruit trees, olives).

The identified change dynamics have some important repercussions: the permanent cultivation land-use types are usually found in landscape positions where there are slopes where the trees stabilise and protect the environment or they grow on human-made terraces. A further analysis made, combining the land-use change data with a digital terrain model shows that one of the adverse affects of the change from permanent to temporary crops is increased erosion in hilly to sloping areas. Furthermore, there seems to be a shift in agricultural land-uses because area is lost in one place and gained in another so this change affects different parts of the commune territory. From the three-dimensional analysis of where such changes are found it becomes clear that parts of the flat or almost flat areas favourable for agriculture are lost, whereas areas where less or even unfavourable terrain (e.g., steep slopes) conditions exist are gained. The so-called “ecological footprint” of cities includes the consumption of prime agricultural lands, in plains and river valleys, in peri-urban areas that blurs the distinction between cities and countryside [31].

3.3 The spatial distribution of changes

As characteristics vary in space and time, so do land-use choices, resulting in a spatial pattern of land-use types [13]. If one shows the land-use changes not in the format of statistics but as maps, one can easily identify in each commune areas that were more prone to land-use changes than others. Figures 11, 12 and 13 show the distribution of changes over the territory of the commune ranked according to the environmental impact of the change and the fact that the Albanian law protects agricultural land, forests and pastures from other uses. The changes in Preza seem to be divided clearly over the territory: in the left part that consists mainly of hills mostly conversions are found, whereas in the right part that consist of foot slopes and a plain (indicated by the channel system) mostly modifications occur. In Ana-e-Malit modifications occur mainly on the foot slopes and close to the main village of the commune where also the frequency of conversions is highest.
Insert Figures 11, 12 and 13.

The areas were land-use conversions occurred -those changes that cannot be easily reverted- are mainly in the sloping and hilly parts of the communes. In the plains of the communes land-use modifications were dominant, whereas in all three communes the residential areas grew at the cost of neighbouring land uses.

3.4 Preferred pathways of change in Preza Commune

The change dynamics can be related to the landscape position of the cadastral parcel within the terrain and for instance the land suitability for irrigated agriculture as the communes are predominantly agricultural ones as well as a set of variables related to what one finds in or close to the land parcel. The area of Preza Commune that changed in 1991-1996 and/or 1996-2003 has been more closely examined. A first analysis shows that 31% of the area subject to change in Preza commune in either 1991-1996 and/or 1996-2003 falls in the period 1991-1996 (Table 3). The agricultural land subject to modification from Temporary to Permanent Crop Cultivation (15%) concerns flat areas with highly suitable soils (29%) and the rest concerns various types of slope classes with either a very low land suitability or unsuitable for agricultural production. In 1996-2003, 57% of the area is subject to change dynamics (Table 4). The modified agricultural land is subject to either a change from Temporary to Permanent Crop Cultivation (23%) with 41% of such areas being almost flat and having highly suitable soils for agricultural production, or a change from Actually Cultivated Land into Actually Not Cultivated Land (20%), i.e. abandoned or idle, with 91% of such lands having steep slopes and unsuitable for irrigated agricultural crop production. Conversion from Agriculture into Pasture concerns 10% of the area and is found exclusively on steep slopes with unsuitable soils for irrigated agricultural crop production.

Insert Tables 3 and 4.

The data of 1996-2003 for Preza Commune has been used as input into the KDD process in order to identify what variables in the extracted decision-rules are important and lead to specific pathways of change, in addition to the frequency and strength of these decision-rules. The correlation between the land use 2003 data and the simulation result is 0.75. The difference between the average square root of classification (0.149) and average absolute error (0.0444) is low, which means the absence of classification outliers. In addition, the accuracy of prediction for each land-use class is above 0.70 with the exceptions of Services and Industrial Areas because the first class is little present in 1996 and the second even absent at that date (Table 5). Low values for these two classes, however, do not imply that the extracted decision-rules involving these classes are erroneous, but they do indicate that these rules are not easily tested and evaluated. The confusion matrix shows that errors occur in those classes that are most spatially present: Arable Lands and Forests (Table 6). The overall accuracy is 79.9 %.

Insert Tables 5 and 6.

The extracted decision-rules with relative major weights are:

- The forested areas (for fuel wood/firewood or environmental protection) with relative big land parcels remained unchanged with time.
- Residential areas accessible by asphalt roads remained unchanged with time.
- Olive tree areas with few houses near the land parcel remained unchanged with time.
- Fruit tree areas accessible only by dirt roads in medium-sized land parcels were abandoned.
- Forested areas (for fuel wood/firewood or environmental protection) accessible by asphalt roads with medium to large land parcels were changed into Pastures.
- Arable lands in zones with steep slopes far from roads, in bad conditions and with little maintenance, in zones with medium erosion risk and having land parcels of medium size were abandoned.

3.5 Factors in the decision-making process that drive land management

Land-use change dynamics do not only affect the spatial extent over time as discussed in the previous paragraphs, they significantly affect land management that is driven by changes in decision-making processes. Decision-making is influenced by factors at different levels. Direct causes of land-use change constitute human activities or immediate actions that originate from intended land use and directly affect land cover. Indirect causes are formed by a complex of social, political, economic, demographic, technological, cultural and biophysical variables that constitute initial conditions in the human-environment relations and are structural (or systematic) in nature. Direct causes operate at the level of individual farms, households or communities. Indirect causes may originate from districts or national levels with complex interactions between levels of organisation [29]. Changes in land management are frequently linked to modifications in agricultural land use.

The change in economic system in Albania has forced changes at all levels of organisation. Many land users have a sceptical approach to any form of collective action and at receiving advice from government related services (e.g., farmers are reluctant to organise themselves on a voluntary basis in farmer associations and they hardly use the free agricultural extension services). The general lack of information hampers informed and strategic decision making by the rural households. Economic factors and policies define a range of variables that have a direct impact on the decision making by land users (e.g., taxes, subsidies, credit access, technology, production and transportation costs). Market access is largely conditioned by government investments in transportation infrastructure and is identified as one of the major problems and constraints in the communes (Table 5). Evident from travelling around the country is that the lack of market access in certain areas has greatly influenced the agricultural production, identified as another major problem and constraint. With mainly semi-subsistence farming and no external demand (or the impossibility to answer to any external demand) the agricultural intensity has decreased dramatically. In the pilot areas results from the socio-economic study report that the production of most crops has declined drastically (e.g., wheat by 50 %; tobacco, sunflower, sugar beet and soya by 25-33 %), whereas the area of forage crops (e.g., alfalfa) increased with 17 % and so did livestock production. The only crops experiencing an increase in area and production are vegetables, though mainly used for self-sufficiency purposes. A result of the land distribution was also the changed access to non-land assets such as agricultural equipment. If farmers have no or little access to machinery and labour needs to be executed manually the agricultural production will suffer. Thus the tendency of rural households active in farming is to go towards a mixture of livestock and forage production. Crop types that are in competition with imports from especially EU countries in the internal market lose this competition and as a result of their low quality and the lack of facilities can also not be exported to the external market (e.g., CIS countries). It should therefore not come as a surprise that because of the many difficulties 47 % of the rural households in the pilot communes decided to be active in agriculture only part-time. The low agricultural productivity levels can be seen as an indicator of the non-ability of the land users to adapt to changed circumstances as described by Lambin et al. [6].

Insert Table 7 and Figure 14.

Erosion and land degradation, flooding and sedimentation (especially in the floodplain of Ana-e-Malit) and pollution and solid waste problems mentioned in Table 7 can be seen as other indicators of the fact that in the pilot communes the ability to adapt to changed circumstances is very limited.

Another factor influencing the decision making of the land users is land tenure. Interviews held in the communes showed that many rural households do not consider their land tenure secure due to pressure exerted by pre-reform land owning families. This hampers investments in agriculture and the establishment of a real land market. Each rural household received several parcels of land distributed in the landscape (plain and hills). Figure 14 shows the distribution of farm sizes in the pilot communes from data collected by the project. The internal land fragmentation, i.e. the number of parcels that each land user exploits [32], in the three pilot communes is calculated to be 3.5, 3.8 and 4.8 parcels per household in Preza, Ana-e-Malit and Pirg respectively. So 78 % of households have a farm smaller than 1 Ha distributed over 3 to 5 land parcels. With this fragmented ownership-pattern farming risks may be spread because the farmer employs different activities in each parcel of land (e.g., permanent cultivation and pasture in the hills and crop production in the plains). However, government considers that this situation calls for correction. Correcting land fragmentation is of ongoing importance for constantly adapting farm responses to ever-changing conditions of the world market, agricultural policies or regional economic developments [32]. Graefen [33] confirms that land fragmentation is putting an additional burden on farm management. But the question is if land consolidation is meaningful considering the average farm size of a rural household, i.e. if four parcels of a less than 1 Ha farm are re-allocated one can still not make a decent living. In such cases off-farm income can supplement the revenues from the farm, thus overcoming the farm size restriction. However, small farms may make sense in some labour-abundant agricultural economies in the short run, in the longer run the transition to a modern state means that farm size must be sufficiently large [34].

4. Conclusions and discussion

The temporal and spatial magnitude of change dynamics in the studied pilot areas is limited as most of their territories are not subject to change. Modification is the predominant land-use change type and concerns agricultural lands where temporary crops are replaced by permanent crops or vice versa. In the understanding of the land-use change processes of modification the decision-making processes of the land users play a key role. Development of future trajectories that include intensification of agriculture should consequently include the decision-making processes of these farmers though policies usually address more aggregated levels (e.g., district or national levels). A study carried out at national and district levels may obscure the existing local variability of spatially explicit land-use changes, whereas it may show patterns that at more detailed data levels remain invisible [35]. Understanding land-use change dynamics concerns the quantities of changes, i.e. the amount of area changed and the amounts of inputs used and/or production per unit area gained or lost as a function of management level.

The preferred pattern in Preza Commune seems to indicate that the land users take rational decisions when they change land-use because of soils with low suitability or unsuitable for that particular use in areas with steep slopes and that they seem to abandon steep lands where erosion phenomena manifest themselves. This valuation finds confirmation in the socio-economic evolution of Preza. Before 1991 all areas in the hills with low land suitability for rainfed cropping were cultivated after having been terraced. Historically, agricultural output is mainly increased by bringing more land into production followed by the intensification of production through fertilizer use and/or irrigation. After the privatisation in 1996, the costs of maintenance of these terraced areas and, more important, the division of this area not according to contour lines but perpendicular to the terracing led to the prevalent use of these areas for pasture. The movement of the animals damaged the terracing and initiated a process of accelerated erosion aggravated by run-off. In the social turmoil of rapid urbanisation, the first areas to be abandoned are those with a low agricultural productivity in the hills. Furthermore, the areas most apt to agriculture, well served with infrastructure and close to urban centres have in general maintained their production characteristics. In case urbanisation took place, green areas around the buildings have been maintained for production of fruit and vegetables for self-sufficiency purposes of the family household. This development is the more surprising in the absence of any regulating plan. The analysis in Preza shows clearly that trajectories of land-use change involve both positive and negative human-environment relationships.

ADD STATEMENT ON KDD FINDINGS

Land-use change analyses assist the government in defining those areas where certain land-use processes and patterns are undesired or cause negative environmental impacts that need to be mitigated. Government will be able to formulate and implement suitable measures according to the land-use policies adopted. It will assist in prioritising areas for definition of land-use planning interventions in the three pilot communes and development of sustainable future land-use trajectories. Spatial modelling can thus be instrumental in land-use planning and informed decision-making. In addition, an analysis of change dynamics may not only help to identify vulnerable places but also vulnerable (groups of) people that on their own are incapable to respond in the face of environmental change.

Acknowledgements

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641 Figure 1. The organisation of the data sets of the Land Use Policy II project geo-database according to INSPIRE

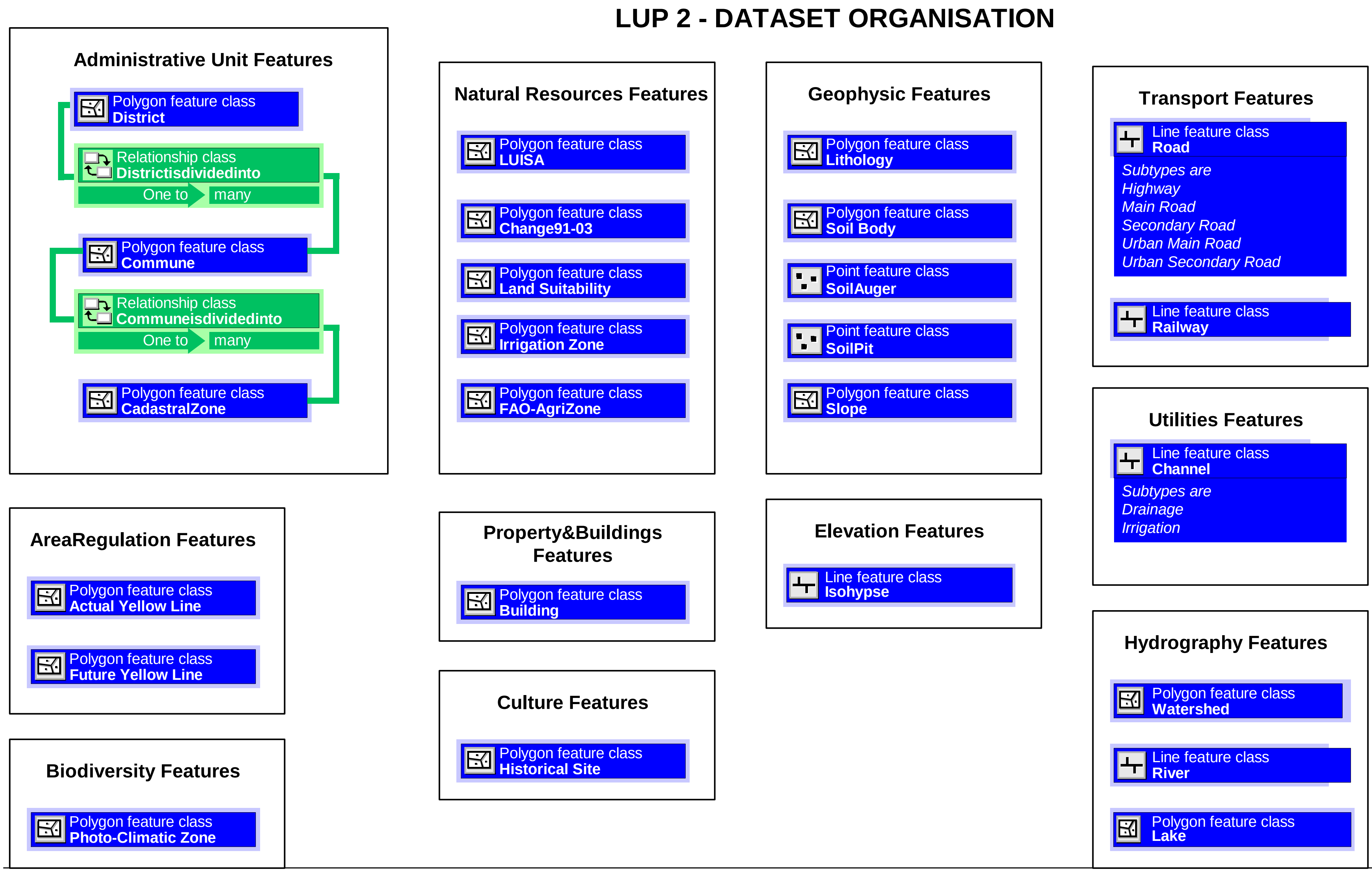


Figure 2. Data model for the Land Use Policy II project geo-database

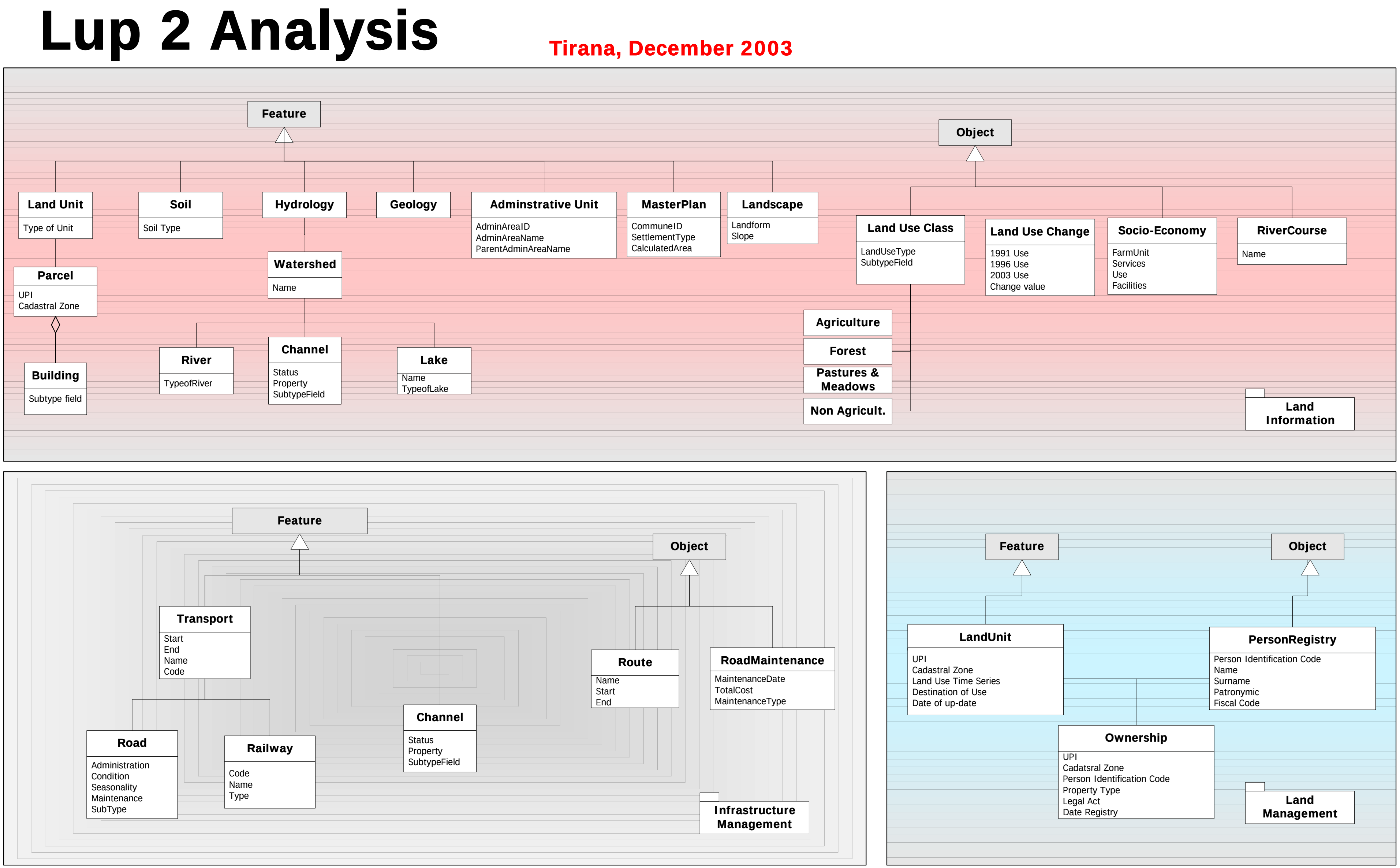


Figure 3. Overview of the LUISA legend with the four main categories “Agricultural”, “Forests”, “Pasture and Meadows” and “Non-agricultural” land uses

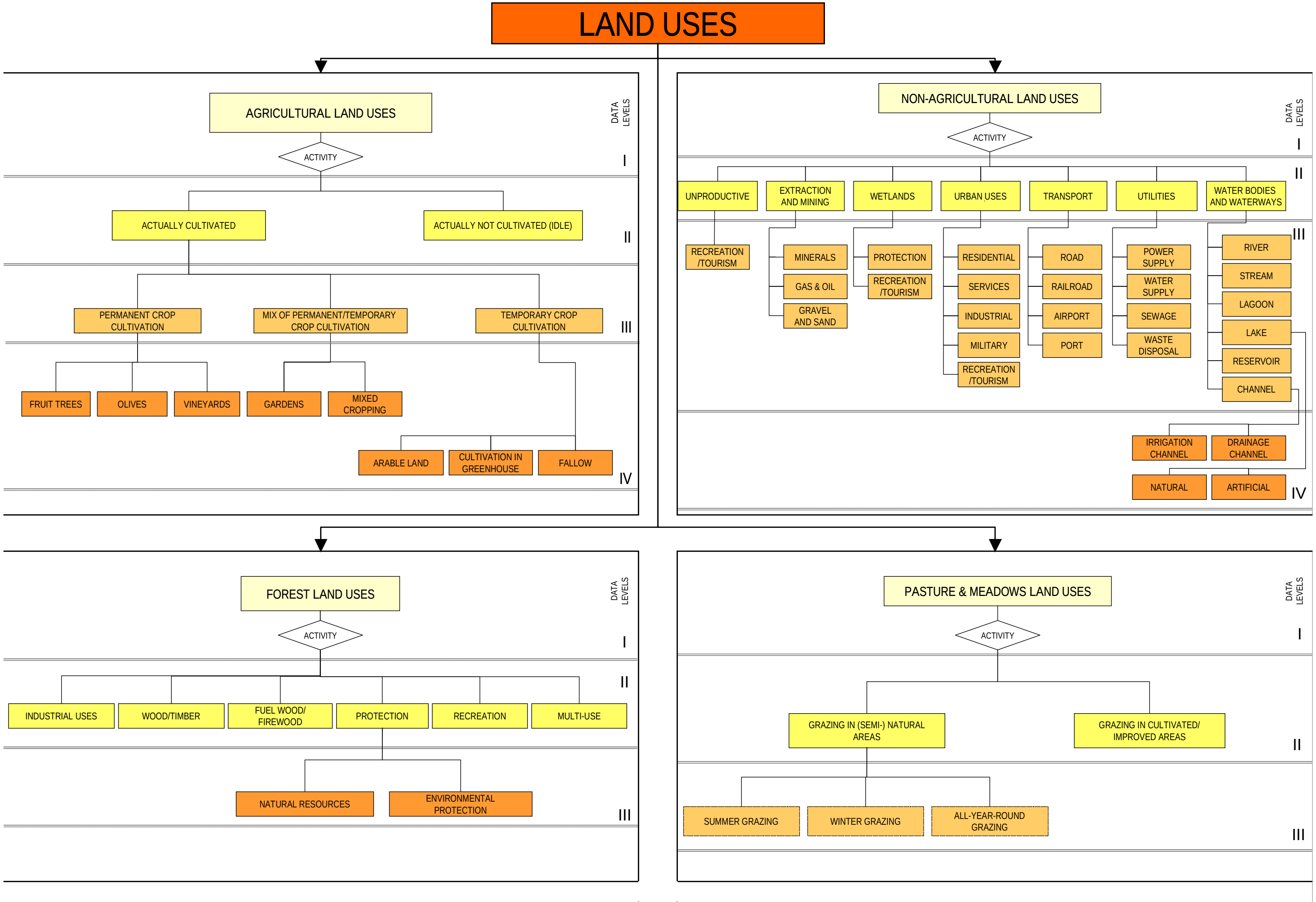
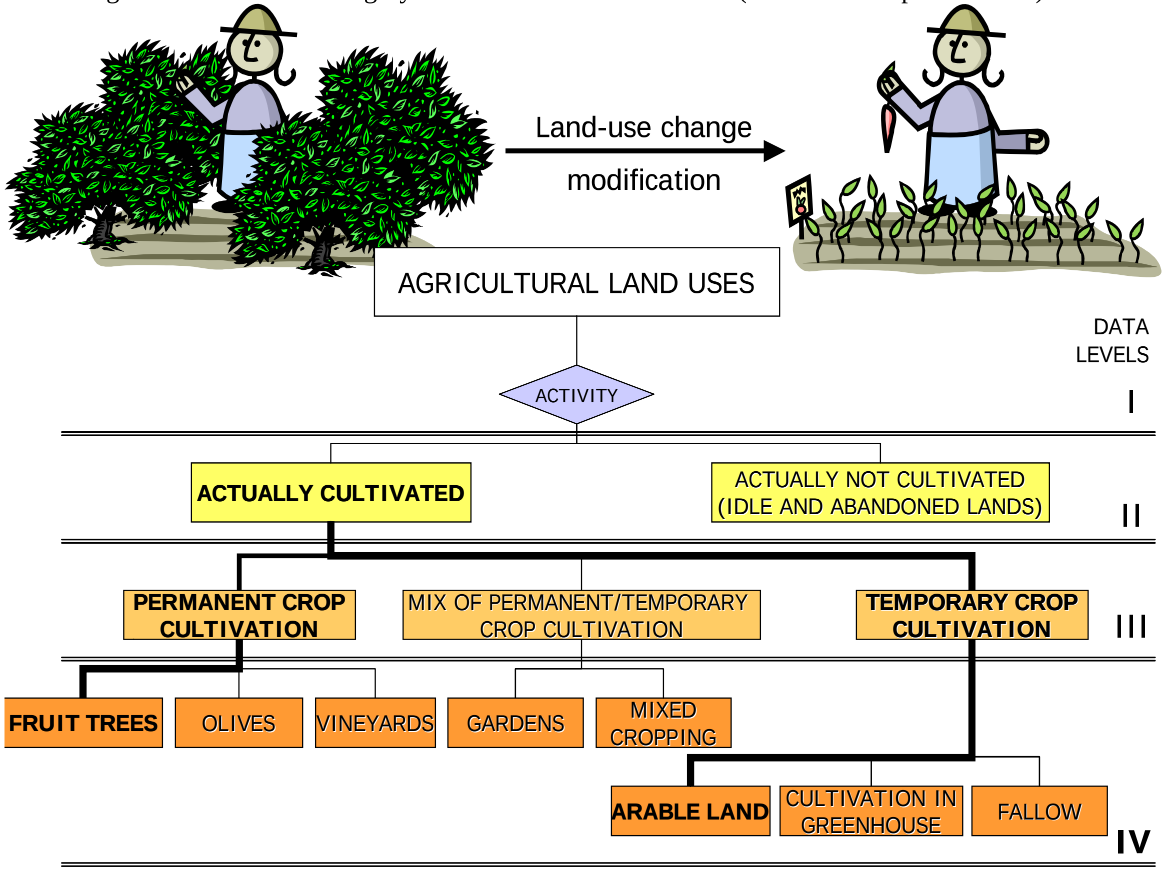


Figure 4. Land-use modification within the Agricultural land-use category from “Fruit trees cultivation” (Permanent crop cultivation) to “Arable land” (Temporary crop cultivation)



650 Figure 5. Land-use conversion from the "Pastures and meadows" to the "Non-agricultural" land-use category, from "Grazing in (semi-) natural areas" into "Residential"

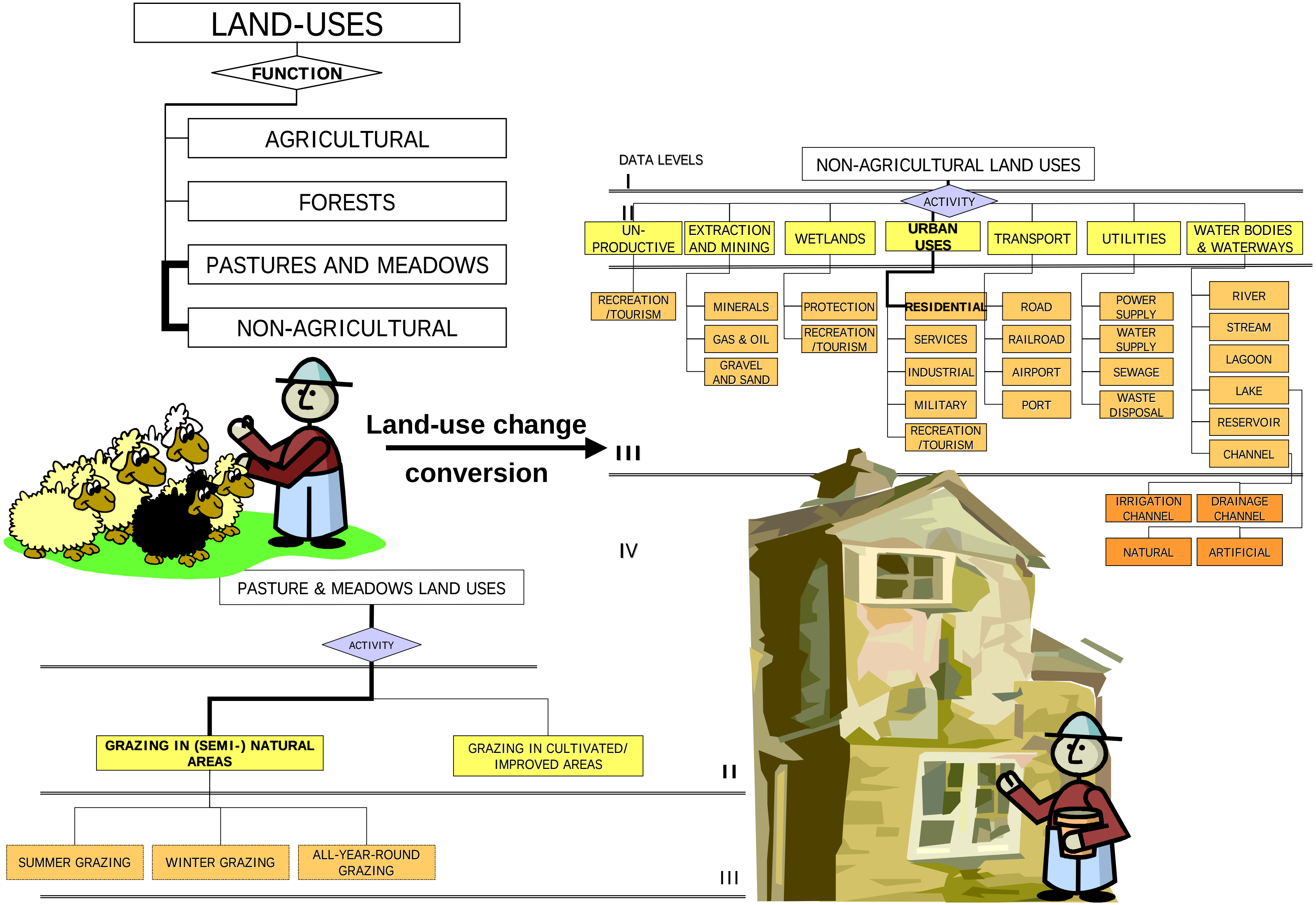


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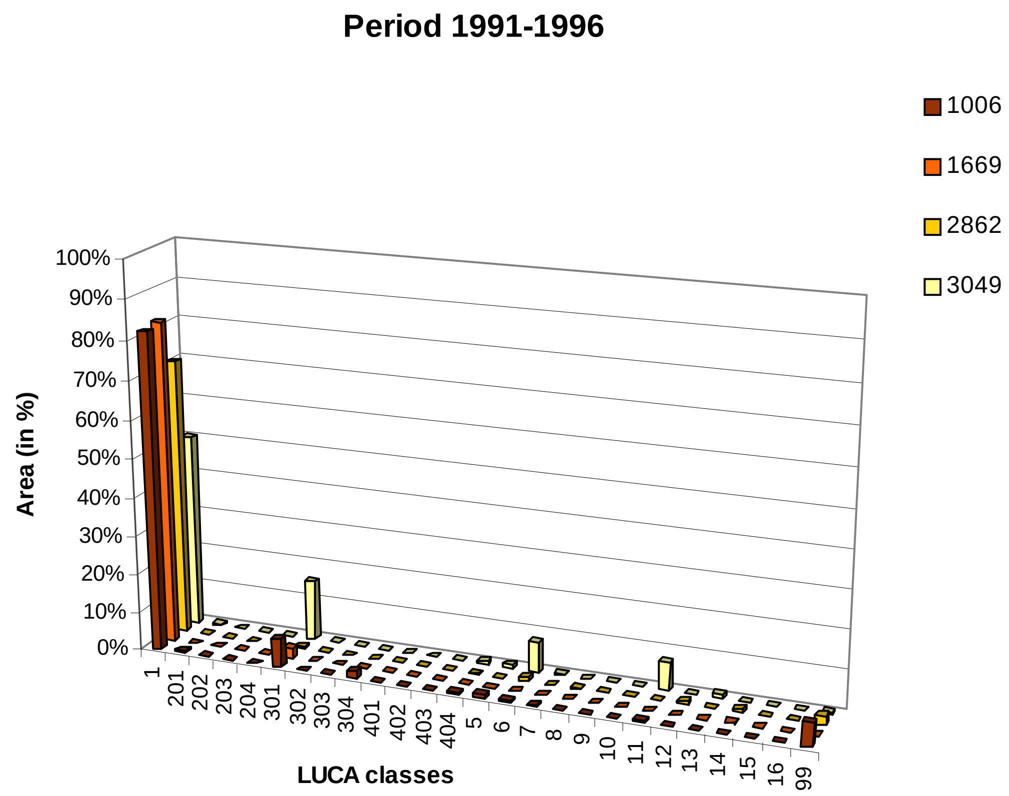
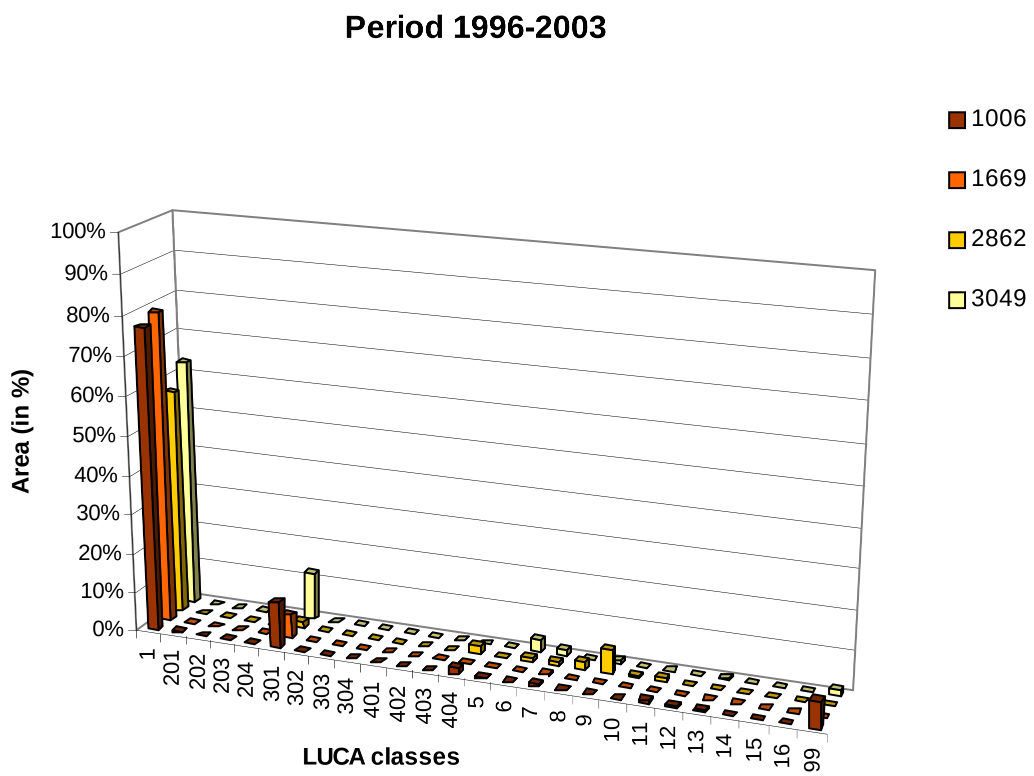
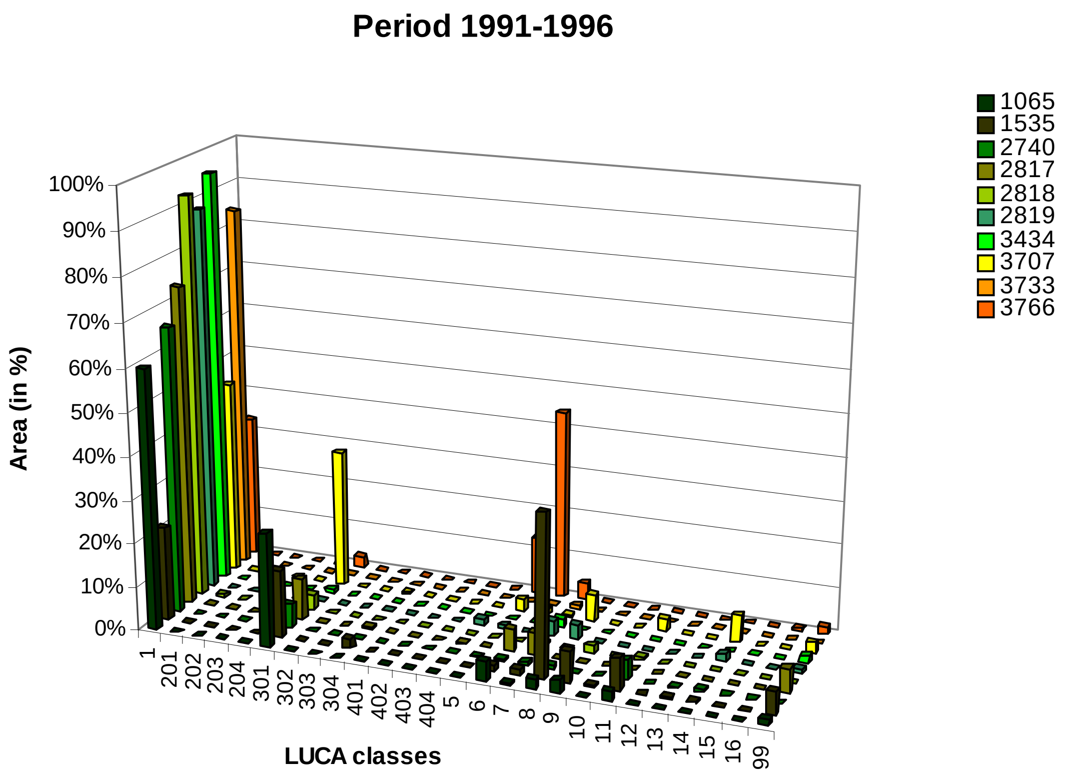
Figure 6. Type of land-use changes in Preza Commune per cadastral zone





655 Figure 7. Type of land-use changes in Ana-e-Malit Commune per cadastral zone



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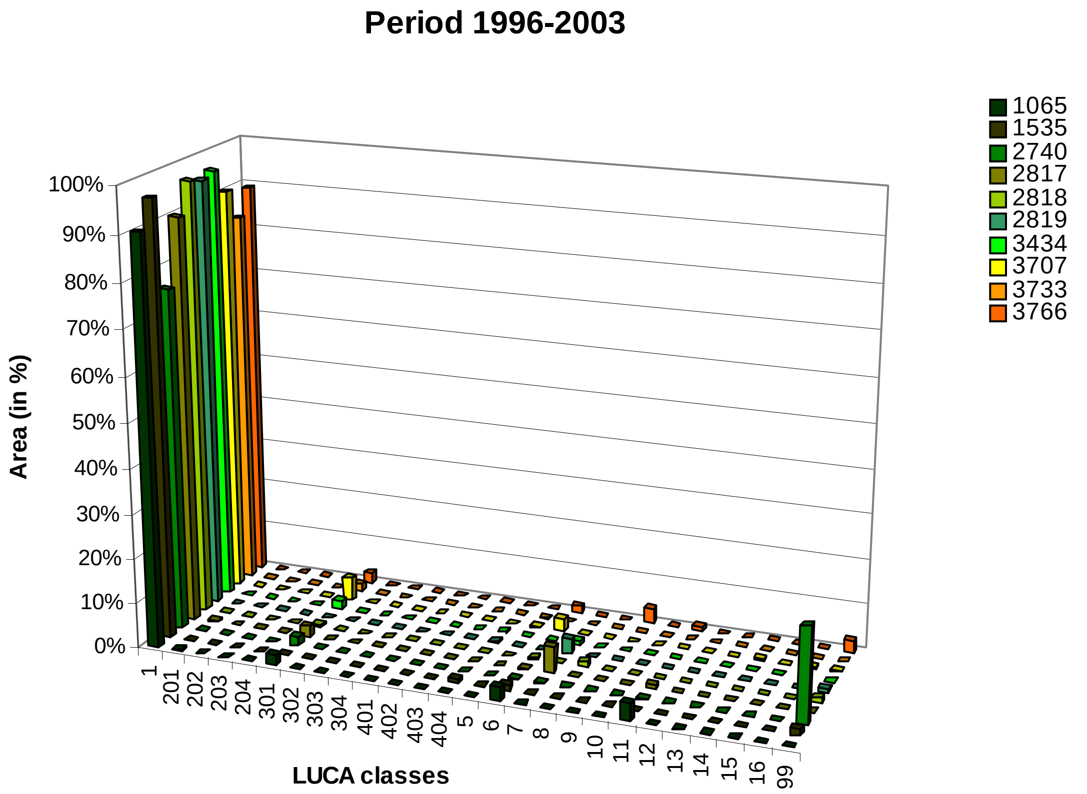

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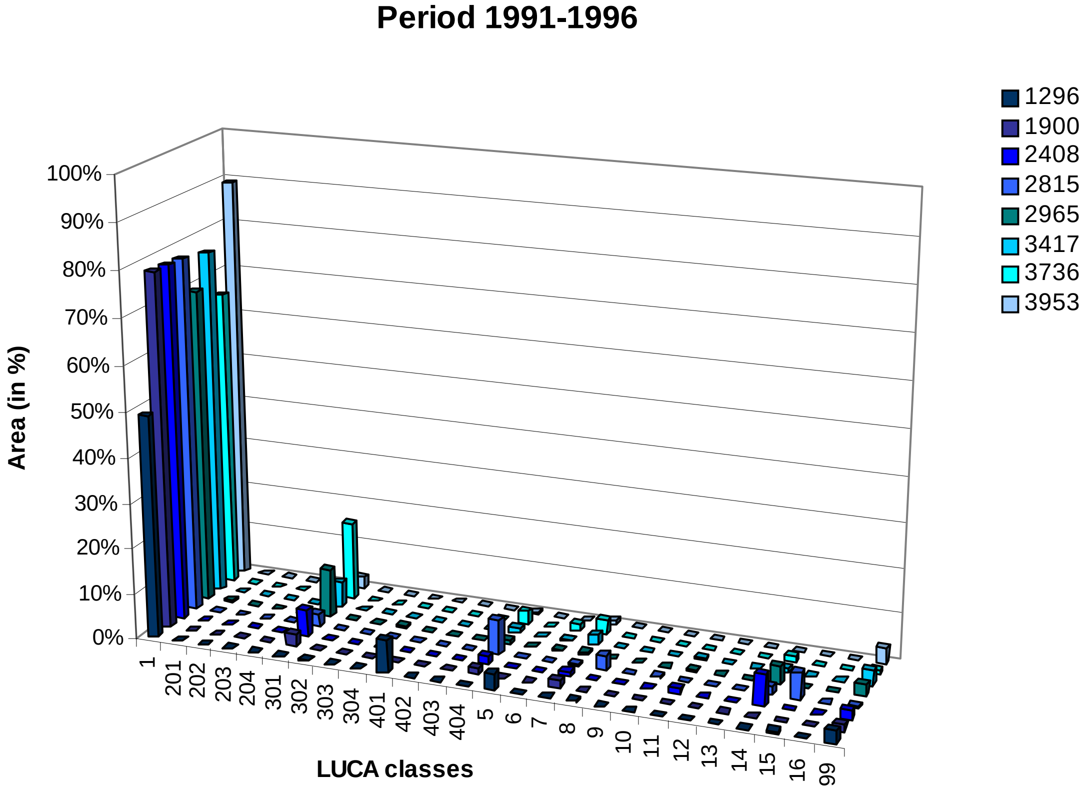
Figure 8. Type of land-use changes in Pirg Commune per cadastral zone



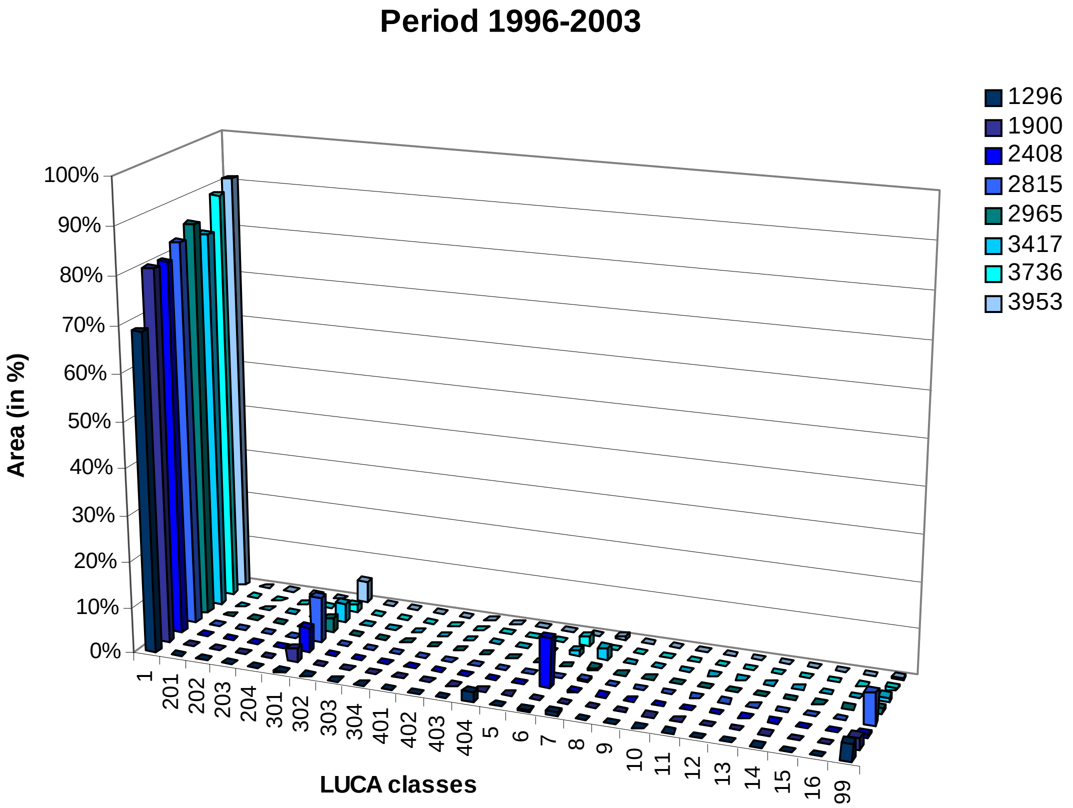


Figure 9. Type of land-use changes in Preza, Ana-e-Malit and Pirg at commune level

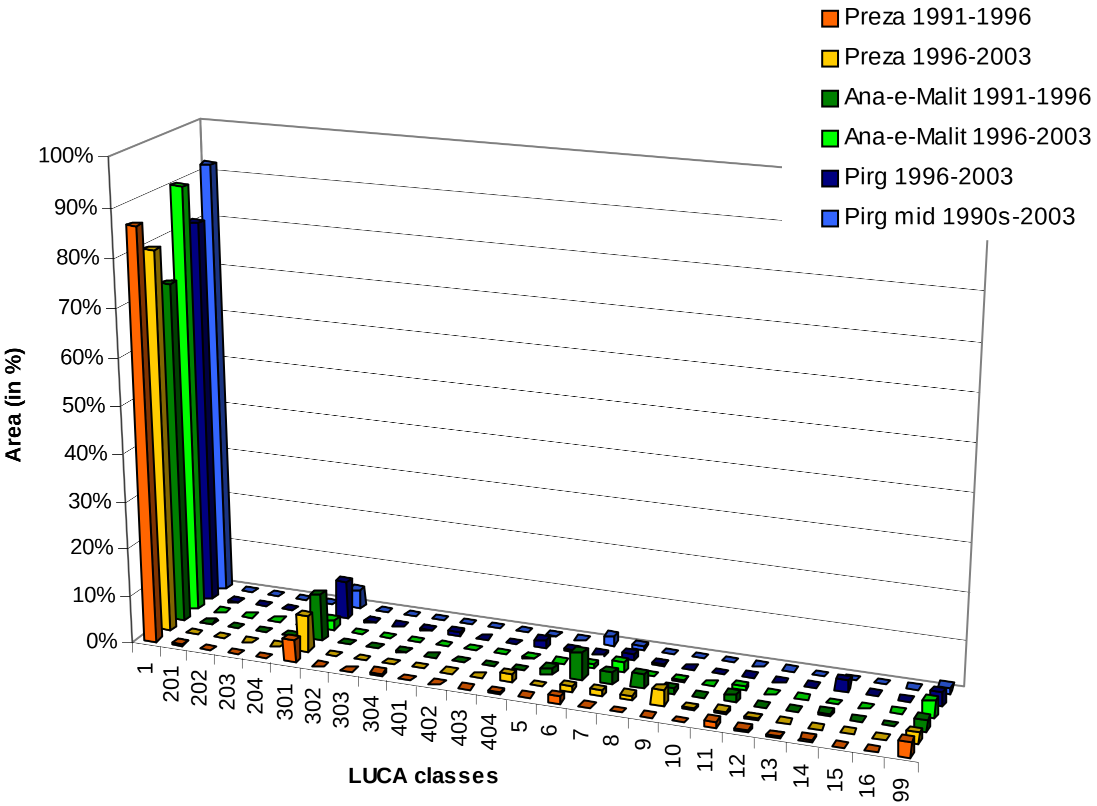


Figure 10. Detailed analysis of the LUCA change type 301- Medium-level-modification-in-Agriculture

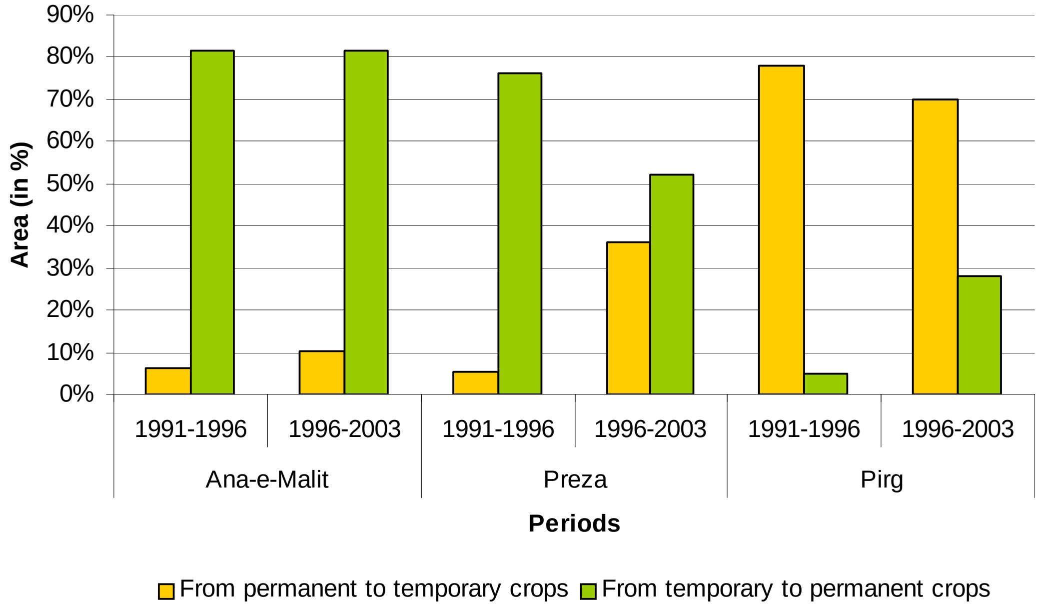


Figure 11. Distribution of land-use changes in the commune of Preza in the period 1991-2003

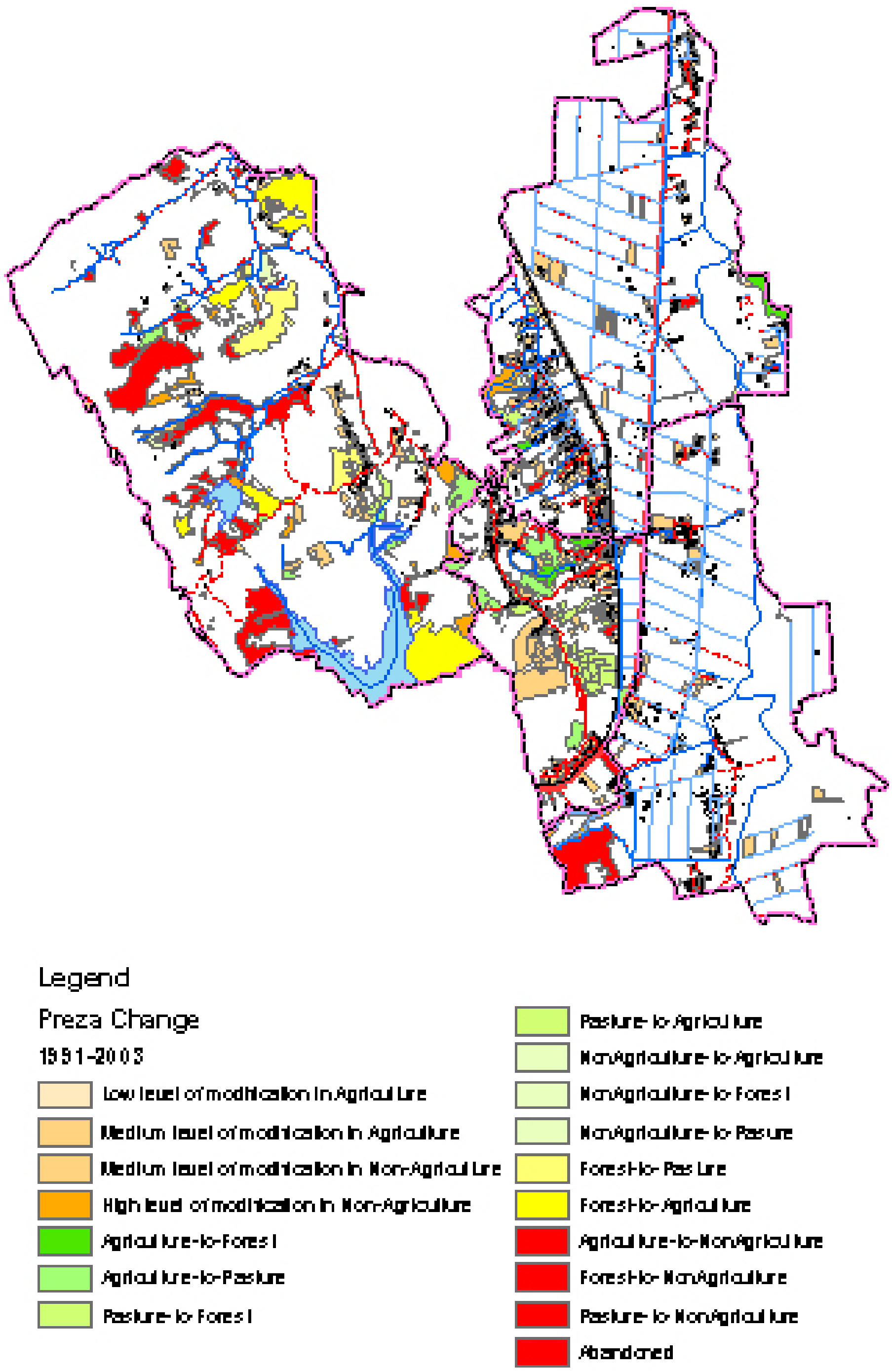


Figure 12. Distribution of land-use changes in the commune of Ana-e-Malit in the period 1991-2003

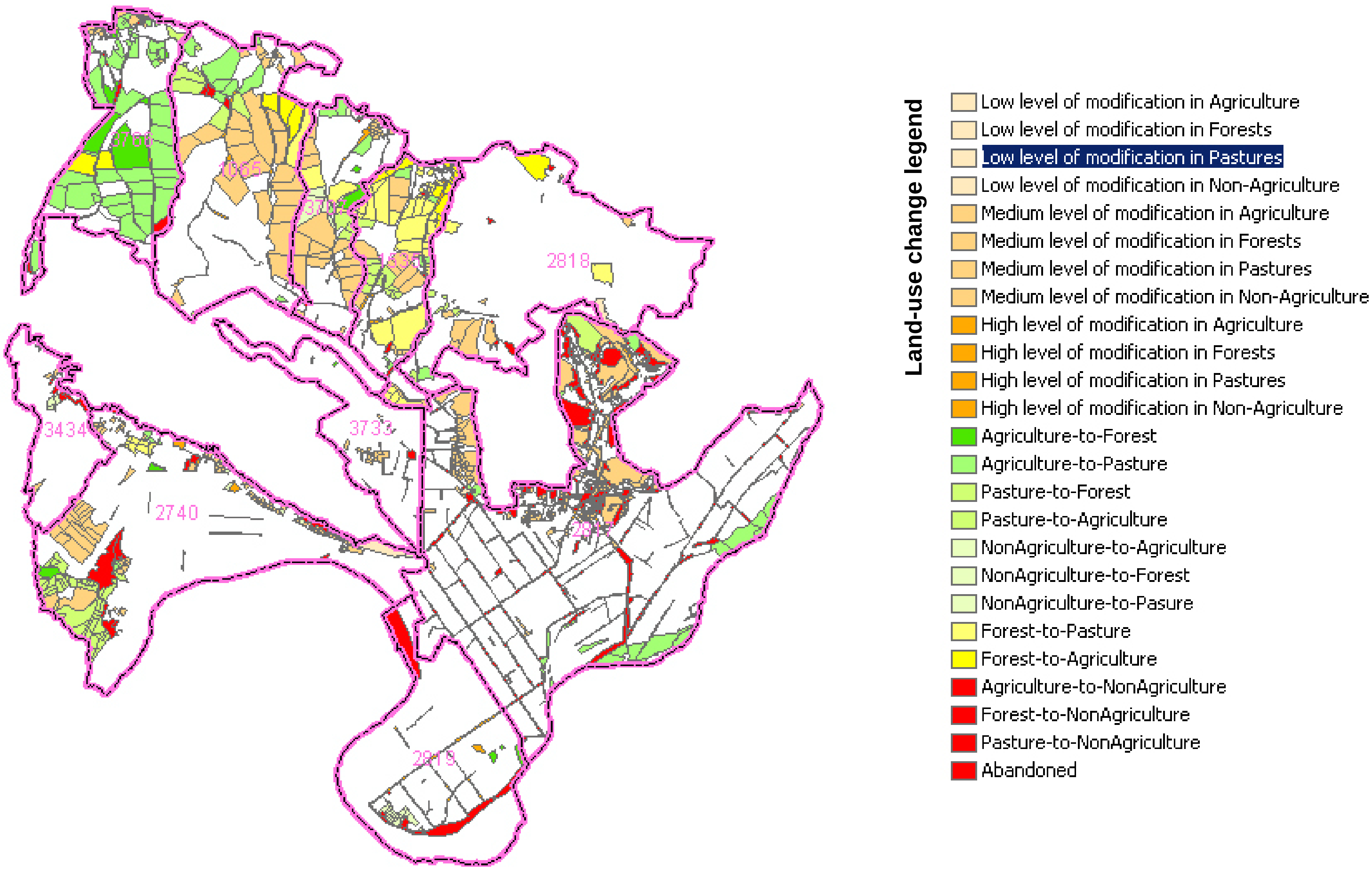


Figure 13. Distribution of land-use changes in the commune of Pirg in the period 1991-2003

Figure 14. Farm size in the pilot communes

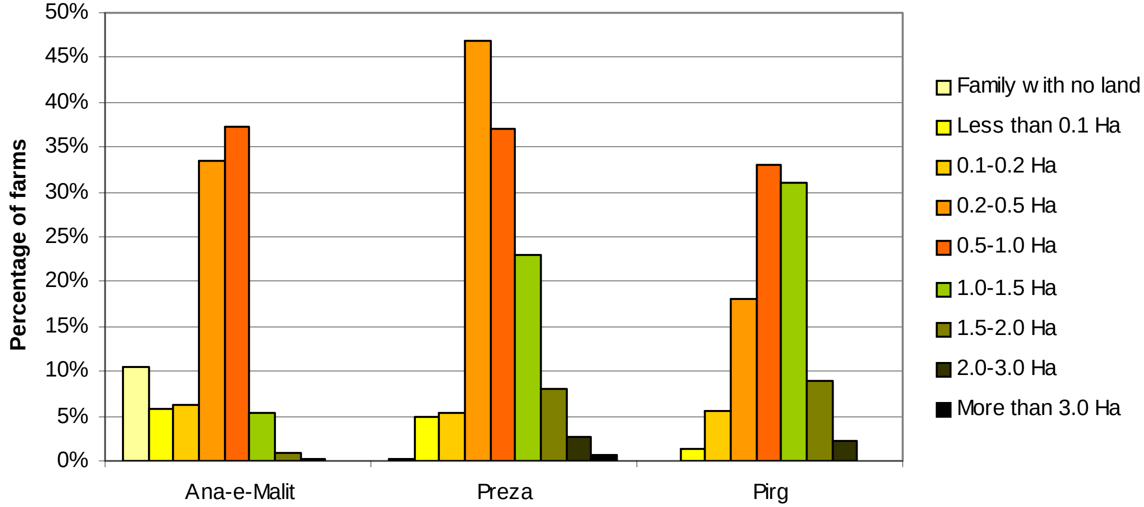


Table 1. The LUCA land-use change types

Type of LUCA land-use change			Code
No change		Correspondence	1
Modifications	Low level	Low level modification in Agriculture	201
		Low level modification in Forests	202
		Low level modification in Pastures	203
		Low level modification in Non-Agriculture	204
	Medium level	Medium level modification in Agriculture	301
		Medium level modification in Forests	302
		Medium level modification in Pastures	303
		Medium level modification in Non-Agriculture	304
	High level	High level modification in Agriculture	401
		High level modification in Forests	402
		High level modification in Pastures	403
		High level modification in Non-Agriculture	404
Conversions		Agriculture-to-Forest	5
		Agriculture-to-Pasture	6
		Agriculture-to-NonAgriculture	7
		Forest-to-Pasture	8
		Forest-to- Agriculture	9
		Forest-to-NonAgriculture	10
		Pasture-to-Agriculture	11
		Pasture-to-Forest	12
		Pasture-to-NonAgriculture	13
		NonAgriculture-to-Agriculture	14
		NonAgriculture-to-Forest	15
		NonAgriculture-to-Pasture	16
No correspondence			99

Table 2. Distribution of the actual land uses according to the LUISA methodology in Preza, Ana-e-Malit and Pirg Communes

Land-use category	LUISA Code	LUISA Class name	Preza[a] Ha	Preza[a] %	Ana-e-Malit Ha	Ana-e-Malit %	Pirg[b] Ha	Pirg[b] %
	0	Missing data	3.0	0.1	0.1	0.0	7.7	0.4
Agricultural land uses	1	Fruit trees	40.3	1.6	162.9	4.9	94.4	4.4
	2	Olives	210.8	8.3	387.4	11.5	0.6	0.0
	3	Vineyards	6.9	0.3	5.9	0.2	21.2	1.0
	4	Gardens	152.2	6.0	31.0	0.9	129.3	6.0
	6	Arable lands	945.5	37.1	1787.8	53.3	1489.8	69.3
	8	Fallow lands	245.8	9.6	-	-	-	-
	9	Actually not cultivated (idle and abandoned) lands	106.7	4.2	-	-	1.2	0.1
Forests land uses	33	Forests for fuel wood/firewood	123.2	4.8	-	-	-	-
	35	Forests for environmental protection	170.0	6.7	147.8	4.4	23.6	1.1
	36	Forests for recreation	0.1	0.0	-	-	-	-
Pasture and meadows land uses	51	Grazing in (semi-) natural areas	178.3	7.0	369.9	11.0	57.9	2.7
	55	Grazing in cultivated/improved areas	1.8	0.1	-	-	0.0	0.0
Non-agricultural land uses	61	Recreation/tourism in unproductive areas	103.3	4.0	62.2	1.9	88.8	4.1
	91	Residential area	1.6	0.1	0.9	0.0	0.1	0.0
	92	Services	10.2	0.4	74.4	2.2	20.8	1.0
	93	Industrial area	3.9	0.2	0.0	0.0	0.3	0.0
	111	Road	92.0	3.6	126.6	3.8	89.2	4.1
	112	Railroad	5.5	0.2	-	-	-	-
	131	River	45.1	1.8	94.3	2.8	6.1	0.3
	132	Stream	32.9	1.3	64.3	1.9	38.3	1.8
	135	Artificial lake	-	-	-	-	0.4	0.0
	136	Water reservoir	41.4	1.6	0.0	0.0	3.0	0.1
	137	Irrigation channel	3.5	0.1	0.3	0.0	27.0	1.3
	138	Drainage channel	27.4	1.1	40.6	1.2	50.9	2.4
		TOTAL	2551.9	100.0	3356.5	100.0	2150.3	100.0

[a] There is an area of 0.4Ha (0.0%) without Unique Parcel Identifier codes in the cadastral data that consequently could not be used for land-use data collection.
[b] The data for three cadastral zones of this commune are missing.

Table 3. Distribution of the change dynamics in Preza Commune over the slope classes with their land suitability for small-scale irrigated cropping (LS) in the period 1991-1996

	LUCA change type	Slope < 3%			3%<Slope<12%			12%<Slope<25%			Slope >25%		
		Area	%	LS[a]	Area	%	LS	Area	%	LS	Area	%	LS
1	No change	52.8	22.7	S1	13.1	5.6	S3	17.7	7.6	N	149.0	64.0	N
201	Low level modification in Agriculture	0	0.0		0.4	11.8	S3	1.6	48.1	N	1.3	40.1	N
202	Low level modification in Forests	0	0.0		0	0.0		0	0.0		0	0.0	
203	Low level modification in Pastures	0	0.0		0	0.0		0	0.0		0	0.0	
204	Low level modification in Non-Agriculture	0	0.0		0	0.0		0	0.0		0	0.0	
301	Medium level modification in Agriculture	26.1	28.5	S1	12.8	14.0	S3	21.3	23.3	N	31.2	34.1	N
302	Medium level modification in Forests	0	0.0		0	0.0		0	0.0		0	0.0	
303	Medium level modification in Pastures	0	0.0		0	0.0		0	0.0		0	0.0	
304	Medium level modification in Non-Agriculture	10.8	100.0	S2	0	0.0		0	0.0		0	0.0	
401	High level modification in Agriculture	0	0.0		0	0.0		0	0.0		0	0.0	
402	High level modification in Forests	0	0.0		0	0.0		0	0.0		0	0.0	
403	High level modification in Pastures	0	0.0		0	0.0		0	0.0		0	0.0	
404	High level modification in Non-Agriculture	3.7	68.4	S1	1.0	18.0		0.7	13.6	S3	0	0.0	
5	Agriculture-to-Forest	4.2	69.7	S1	0	0.4	S1	0	0.0		1.8	29.9	N
6	Agriculture-to-Pasture	0.3	1.4	S1	0	0.0		0.4	2.0	N	19.8	96.6	N
7	Agriculture-to-NonAgriculture	0.6	38.4	S1	0.4	26.9	S2	0.3	21.2	S3	0.2	13.5	N
8	Forest-to-Pasture	1.0	30.4	S3	0.2	7.0	S3	0	0.0		2.0	62.6	N
9	Forest-to- Agriculture	0	0.0		0	0.0		0	0.0		0	0.0	
10	Forest-to-NonAgriculture	0	0.0		0	0.0		0	0.0		0	0.0	
11	Pasture-to-Agriculture	1.0	4.5	S3	1.0	4.7	S3	4.6	21.0	S3	15.2	69.8	N
12	Pasture-to-Forest	0	0.0		0	0.0		0	0.0		8.4	100.0	N
13	Pasture-to-NonAgriculture	0.1	4.9	N	0.3	8.9	S3	0.6	21.3	S3	2.0	64.8	S3
14	NonAgriculture-to-Agriculture	0.3	3.4	S1	0	0.0		1.6	17.6	S3	7.1	79.0	N
15	NonAgriculture-to-Forest	0	0.0		0	0.0		0	0.0		0	0.0	
16	NonAgriculture-to-Pasture	0	0.0		0	0.0		0	0.0		0.2	100.0	N
20	Abandoned	0	0.0		0	0.0		0	0.0		0	0.0	
88	Code not existent in LUISA	13.5	10.8	N	13.4	10.7	N	6.6	5.3	S3	91.8	73.2	N
99	No correspondence	24.1	43.1	S2	2.4	4.3	S3	1.8	3.3	S3	27.6	49.4	N
	Total area per slope category[b]	138.5	23.1		45.0	7.5		57.4	9.6		357.7	59.7	

[a] According to the FAO Framework for Land Evaluation (FAO, 1976): S1=highly suitable, S2=suitable with minor restrictions, S3=suitable with major restrictions, N=not suitable for small-scale irrigated cropping.

[b] Only the area that is subject to change in 1991-1996 and/or 1996-2003 has been examined.

Table 4. Distribution of the change dynamics in Preza Commune over the slope classes with their land suitability for small-scale irrigated (LS) in the period 1996-2003

	LUCA change type	Slope < 3%			3%<Slope<12%			12%<Slope<25%			Slope >25%		
		Area	%	LS[a]	Area	%	LS	Area	%	LS	Area	%	LS
1	No change	22.9	29.2	S1	3.5	4.5	N	5.6	7.1	N	46.5	59.2	N
201	Low level modification in Agriculture	0	0.0		0	0.0		0.8	83.1	S3	0.2	16.9	N
202	Low level modification in Forests	0	0.0		0	0.0		0	0.0		0	0.0	
203	Low level modification in Pastures	0	0.0		0	0.0		0	0.0		0	0.0	
204	Low level modification in Non-Agriculture	0	0.0		0	0.0		0	0.0		0	0.0	
301	Medium level modification in Agriculture	57.3	41.1	S1	21.3	15.3	S3	30.8	22.1	S3	30.0	21.5	N
302	Medium level modification in Forests	0	0.0		0	0.0		0	0.0		0	0.0	
303	Medium level modification in Pastures	0	0.0		0	0.0		0	0.0		0	0.0	
304	Medium level modification in Non-Agriculture	0	0.0		0	0.0		0	0.0		0	0.0	
401	High level modification in Agriculture	0	0.0		0	0.0		0	0.0		0	0.0	
402	High level modification in Forests	0	0.0		0	0.0		0	0.0		0	0.0	
403	High level modification in Pastures	0	0.0		0	0.0		0	0.0		0	0.0	
404	High level modification in Non-Agriculture	1.3	3.9	S1	0	0.0		0.3	0.8	N	30.7	95.2	N
5	Agriculture-to-Forest	0	0.0		0	0.0		0.8	39.0	N	1.3	61.0	N
6	Agriculture-to-Pasture	1.9	9.7	N	2.0	10.1	S3	0.5	2.7	S3	15.4	77.5	N
7	Agriculture-to-NonAgriculture	7.1	35.7	S1	0.5	2.6	S3	3.6	18.4	N	8.6	43.3	N
8	Forest-to-Pasture	0	0.1	S1	0	0.1	S1	0	0.0		20.9	99.7	N
9	Forest-to- Agriculture	0	0.0		0	0.0		0	0.0		59.3	100.0	N
10	Forest-to-NonAgriculture	0	0.0		0	0.0		0	0.0		4.6	100.0	N
11	Pasture-to-Agriculture	0.4	3.3	N	0.5	3.6	S2	0.3	2.7	N	11.9	90.4	N
12	Pasture-to-Forest	0.5	18.9	N	0	0.0		0.5	16.5	N	1.8	64.5	N
13	Pasture-to-NonAgriculture	0.2	5.9	N	0	0.0		1.2	42.9	N	1.5	51.2	N
14	NonAgriculture-to-Agriculture	0	0.0		0	0.0		0.1	36.1	N	0.2	63.9	N
15	NonAgriculture-to-Forest	1.2	100.0	N	0	0.0		0	0.0		0	0.0	
16	NonAgriculture-to-Pasture	0.1	100.0	N	0	0.0		0	0.0		0	0.0	
20	Abandoned	3.3	3.7	S3	1.8	2.0	N	3.1	3.5	N	81.1	90.8	N
88	Code not existent in LUISA	13.4	19.2	N	12.4	17.8	N	6.8	9.7	N	37.2	53.3	N
99	No correspondence	28.8	70.5	S1	3.0	7.2	S3	2.8	6.9	S3	6.3	15.4	N
	Total area per slope category[b]	138.5	23.1		45.0	7.5		57.4	9.6		357.7	59.7	

[a] According to the FAO Framework for Land Evaluation (FAO, 1976): S1=highly suitable, S2=suitable with minor restrictions, S3=suitable with major restrictions, N=not suitable for small-scale irrigated cropping.

[b] Only the area that is subject to change in 1991-1996 and/or 1996-2003 has been examined.

Table 5. Detailed accuracy by class

Class	TP rate	FP rate	Precision	Recall	F-measure
Arable lands	0.874	0.111	0.783	0.874	0.826
Fruit trees	0.652	0.002	0.808	0.652	0.721
Meadows/pastures	0.735	0.014	0.833	0.735	0.781
Olive Trees	0.858	0.019	0.806	0.858	0.831
Recreation	0.686	0.007	0.780	0.686	0.730
Residence	0.669	0.034	0.747	0.669	0.706
Services	0.303	0.002	0.556	0.303	0.392
Transport	0.655	0.007	0.659	0.655	0.657
Uncultivated areas	0.755	0.033	0.784	0.755	0.769
Unknown	0.681	0.004	0.702	0.681	0.692
Vineyards	0.850	0.002	0.798	0.850	0.824
Water	0.887	0.003	0.907	0.887	0.897
Wood	0.893	0.013	0.904	0.893	0.898
Industrial areas	0	0	0	0	0

Table 6. Confusion matrix of the predicted land use 2003 against the LUISA 2003 data

Classified as:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	Users' accuracy
a = Arable lands	**2938**	2	16	24	17	145	5	15	159	17	7	7	11	0	87.4%
b = Fruit trees	21	**101**	4	4	1	3	0	0	19	1	0	1	0	0	65.2%
c = Meadows/pastures	81	1	**673**	46	6	17	0	10	39	2	0	1	40	0	73.5%
d = Olive trees	9	2	37	**763**	9	31	0	6	10	1	0	2	19	0	85.8%
e = Recreation	13	1	2	24	**269**	9	2	14	32	2	0	9	15	0	68.6%
f = Residence	371	0	14	15	2	**944**	4	12	24	2	9	0	14	0	66.9%
g = Services	17	0	1	8	0	16	**20**	2	0	0	0	0	2	0	30.3%
h = Transport	20	0	6	7	1	21	1	**135**	6	5	2	0	2	0	65.5%
i = Uncultivated areas	194	17	33	30	28	29	0	4	**1104**	5	0	5	14	0	75.5%
j = Unknown	15	0	3	11	0	4	3	2	3	**92**	0	0	2	0	68.1%
k = Vineyards	5	0	5	0	0	3	0	0	0	1	**91**	1	1	0	85.0%
l = Water	19	0	0	2	0	5	0	2	6	2	0	**282**	0	0	88.7%
m = Wood	48	1	14	13	12	28	1	3	6	1	5	3	**1126**	0	89.3%
n = Industrial areas	0	0	0	0	9	0	0	0	0	0	0	0	0	**0**	0.0%
Producers' accuracy	78.3%	80.8%	83.3%	80.6%	76.0%	75.2%	55.6%	65.9%	78.4%	70.2%	79.8%	90.7%	90.4%	78.3%	**79.9%**

Table 7. Main problems and constraints in the pilot areas as identified by the communes and LUP II project

Constraints and problems	Preza	Ana-e-Malit	Pirg
Agricultural production	xxx	xx	xxx
Marketing	xx	xxx	xxx
Land tenure (security and size)	xx	xx	xx
Settlement and peri-urban development	xxx	x	xx
Erosion and land degradation	xx	x	xxx
Flooding and sedimentation	x	xxx	x
Pollution and solid waste	xxx	xx	xx

xxx - very serious; xx - serious problem; x - moderately serious