ANALYSIS OF FREE AND OPEN LAND COVER MAPS FOR AGRICULTURAL LAND USE PLANNING AT LOCAL LEVEL

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ABSTRACT:

According to the Law on Agricultural Land of the Republic of Srpska, municipalities and cities are obliged to prepare a planning document "Groundwork for Agricultural Land Protection, Use and Restructuring (The groundwork)". Information related to the current state of land cover and land cover use are essential for the groundwork. Such layer was created for the municipality Laktaši in Bosnia and Herzegovina by digitization of land cover features from orthophoto imagery. Even if digitization provides highly reliable data, it is also time-consuming activity, and therefore the evaluation of Corine Land Cover (CLC) for the municipality Laktaši was performed to determine if it is accurate enough to sustain the groundwork for other municipalities. In this paper, using free open source programs, a comparison of two sets of data representing land cover was performed: manually vectorized data with orthophoto images of LC/LU and CLC. Using QGIS, the two datasets were harmonized, and then the error matrix and accuracy indexes were computed by using Python. The obtained results show that the overall accuracy of CLC with respect to LC/LU reference is 70%, but the class related to agricultural areas are overestimated in some locations and underestimated in other locations. After analyzing the results, it was concluded that the CLC in the studied area is not a sufficiently precise GIS basis for agricultural land use planning at the local level. However, it can be a good starting point for making of LC/LU, which would significantly shorten the time of its creating.

1. INTRODUCTION

The area of agricultural land for food production is limited and is constantly decreasing both in the world and in Bosnia and Herzegovina. The loss of land by anthropogenic impact is about 2.5 times greater than the loss of land by natural processes (Lal, 1990). According to the National Action Plan in Bosnia and Herzegovina (BiH), up to 1,600 ha of land are lost annually (NEAP BiH, 2003). Since the exploitation of the land will continue in the future, the main question is how to protect agricultural land from permanent loss, i.e. how to produce sufficient quantities of food in the current conditions, which are additionally aggravated by the evident climate changes, when agricultural areas are constantly decreasing, and the number of people is increasing. The prevention of degradation and sustainably controlled land use should be the most important parts of the land protection policy of every country and the local community. In order for this policy to be implemented properly, relevant indicators of the state of land resources are necessary (Predić et al. 2021). According to the Law on Agricultural Land of the Republic of Srpska (Entity in BIH), municipalities and cities are obliged to prepare a planning document "Groundwork for Agricultural Land Protection, Use and Restructuring (The groundwork)". The Groundwork is made according to the FAO (Food and Agriculture Organization) model which consists of an inventory of land and climate resources, agro-ecological zoning, and economic-ecological zoning. Starting from the existing data (pedology, digital elevation model, and climate data) with GIS modeling new relevant data were created (bonity, agro-ecological zoning, suitability of cultivation, etc.) (Biancalani et al. 2004). It is intended for municipal authorities in decisions making during the process of land use and land protection. The GIS layer of the current condition of land cover and land use (hereinafter LC/LU) is one of the most important GIS layers for creating the Groundwork. It is necessary to make a precise GIS layer on a large scale in order to obtain relevant data on agricultural land and land use. The most precise method of making LC/LU for the Groundwork is manual mapping of LC/LU classes with orthophotos and high-resolution satellite images combined with field verification. The critical point of this method is that it is time-consuming. On the other hand, "free" land cover data is available, such as Corine Land Cover (hereinafter CLC) and OpenStreetMap. In this paper, a comparison of two sets of data representing land cover was performed, using free open source programs: manually vectorized data with an orthophoto image of LC/LU and CLC. The aim of this paper is to determine the relevance of CLC data for the needs of land use planning at the level of administrative units in the Republic of Srpska.

2. DATASETS

2.1 Study area

The Laktaši Municipality occupies the center of the western part of the Republic of Srpska. (Figure 1) The area of the municipality is 38807 hectares with the population of 36848

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citizens. The river Vrbas flows in the middle of its territory and divides it in two parts: Župa part (right bank of the river) and Lijevce-Potkozarje part (left bank of the river). Terrain heights span from 104 m to the 543 m within the study area. The biggest portion (93%) of the terrain is lower then 300 meters. (Predić et al. 2019). Forest is dominating in the eastern, western and southern part, while central and north part are mostly covered by agricultural areas and artificial surfaces (Figure 2). The core of the economy are small/medium companies, agricultural production and spa tourism (Laktaši, 2019).

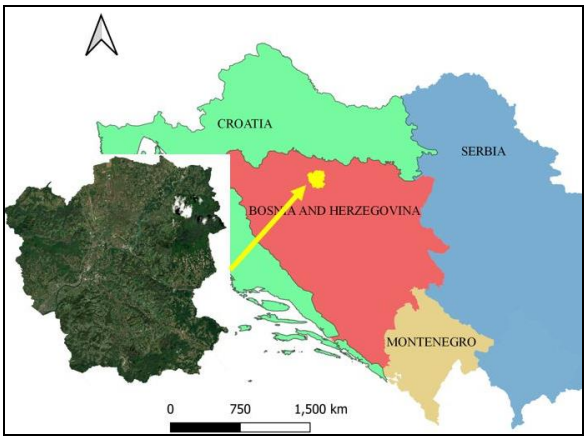

Figure 1. The position of Laktaši municipality

The two sets of data: manually vectorized data with orthophoto images of LC/LU and CLC were compared in this paper. The reason for this comparison is the fact that those ortophoto images dates from 2018, which is the same as baseline year of CLC for BIH.

2.2 LC/LU

LC/LU has been created for the purposes of planning document called "Groundwork for Agricultural Land Protection, Use and Restructuring of the municipality Laktaši". Its creation is based on vectorisation of different proprietary and free data sources: orthophoto images, cadastral and topographic maps. The reached target scale for this "layer"/map was 1:5000 (some parts were mapped at the scale of 1: 2500).

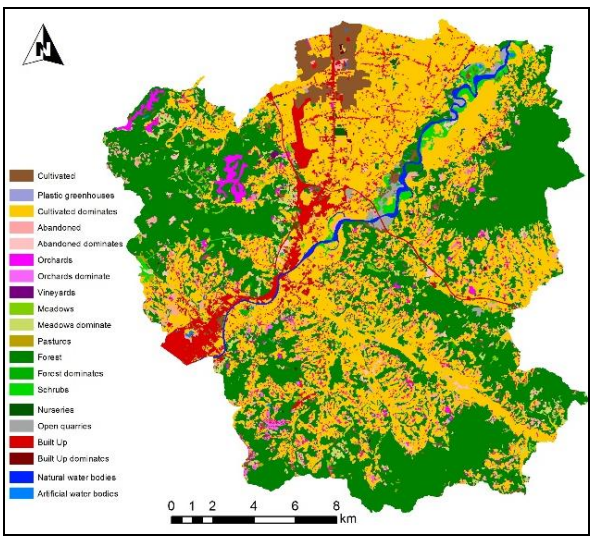

Figure 2. The spatial distribution of classes in LC/LU layer

The Land Cover Classification System, (FAO LCCS, 2000) was used to delineate the polygon, which was modified for the conditions of BIH within the implementation of the project "Inventory of post war situation of land resources in BIH" (FAO, 2002). The modified FAO classification does not consider land cover and land use classes separately, but both classes are combined into unique LC/LU class. The reason for this approach is that the key to drafting the Municipal Groundwork is the allocation (identification) of agricultural land.

In the study area, 9 main LC/LU classes have been recorded, containing 20 (Table 1) out of a total of 36 LC/LU classes (10707 polygons) that are available in the entire Republic of Srpska. In the area of Laktaši Municipality there are 12 (54%) classes that represent agricultural land.

LC/LU Categories	Main classes	Classes	Code
Agricultural	Cultivated	Cultivated	2
		Plastic greenhouses	6
		Cultivated dominates	30
	Abandoned	Abandoned	7
		Abandoned dominates	40
	Permanent crops	Orchards	9
		Vineyards	10
		Nurseries	89
		Orchards dominate	51
	Meadows	Meadows	12
		Meadows dominate	66
	Pastures	Pastures	13
Non-Agricultural	Forest	Forest	17
		Forest dominates	16
		Low vegetation	83
	Bare areas	Open quarries	21
	Built Up	Built Up	22
		Built Up dominates	102
	Water bodies	Water bodies	25
		Artificial water bodies	26

Table 1. The list of the present LC/LU classes within the study area and their classification

When delineating agricultural areas, the smallest mapped area for the class "cultivated" is 0.5 ha, for the class "permanent crops" 0.1 ha, and for the class "plastic greenhouses" 0.01 ha. Due to the demand for high resolution LC/LU map as the final product, our task was mapping of clear LC/LU classes (cultivated, orchard, meadow, pasture, greenhouse, forest, built-up areas). LC/LU classes, containing "dominate" within their nomenclature, are representing greater mapped areas where the delineation of individual "clear" classes (meadow, cultivated, forest) is irrational due to fragmentation. In these cases, the class whose area is covering more than 50% will be assigned to the mapped polygon (e.g. cultivated dominates, built up dominates, meadows dominates, etc.) (Table 1). The goal of delimitation of LC/LU classes on a large scale is to keep such polygons (with term "dominates") as small as possible, but it is impossible to avoid them due to the fragmented land in the Republic of Srpska. The characteristic of the rural area is the existence of forest between which there are cultivated and smaller orchards, i.e., agricultural areas that are less than 0.5 ha.

In that case, one polygon was mapped, which unites the forest with agricultural areas. The polygon is coded with the LC/LU class "forest dominates", for example the primary LC/LU is forest with 60%, and the secondary LC/LU is cultivated with 40%. This class ratios are stored in attribute table of LC/LU shape file. In this way, later data processing (polygon area) enables to calculate the actual areas of agricultural land by LC/LU classes that can be compared with "cadastral classes". (Predić et al. 2021).

2.3 CLC

Label 1	Label 2	Label 3	Code
ARTIFICIAL S.	Urban fabric	Discontinuous urban fabric	112
	Industrial, commercial and transport units	Industrial or commercial units	121
		Road and rail networks and associated land	122
		Airports	124
	Mine, dump and construction sites	Mineral extraction sites	131
	Artificial, non-agricultural vegetated areas	Sport and leisure facilities	142
AGRICULTURAL A.	Arable land	Non-irrigated arable land	211
	Permanent crops	Fruit trees and berry plantations	222
	Pastures	Pastures	231
	Heterogeneous agricultural land	Complex cultivation patterns	242
		Land principally occupied by agriculture, with significant areas of natural vegetation	243
FOREST SNA.	Forests	Broad-leaved forest	311
		Coniferous forest	312
		Mixed forest	313
	Shrub and/or herbaceous vegetation associations	Transitional woodland-shrub	324
WATER B.	Inland waters	Water courses	511

Table 2. The list of the present CLC classes within the study area and their codes

CLC is the product provided by Copernicus - European Union's Earth Observation Programme. It is freely and openly accessible to the users, through the Copernicus Land Monitoring Service (EEA, 2021). The first version dates back to the 1990. Since that period, 4 updated versions have been published until now. The CLC2018, the edition of CLC for 2018, has been used for this research. This inventory represents the update of CLC2012 (CLC edition for 2012). It is based on Sentinel-2 and Landsat-8 satellite data, with geometric accuracy better than 100 m. The minimal mapping unit is 25 ha, while the minimal mapping width is 100m. The number of countries involved in this product is 39 (EEA, 2019). One of them is the Bosnia and Herzegovina. According to CLC2018_BA (CLC2018 for Bosnia and Herzegovina) final report all changes greater than 5ha, were mapped. Besides mentioned sources, the auxiliary data were used (orthophoto images for certain municipalities, topographic maps, Google Earth, etc.). The Land Cover in the Bosnia and Herzegovina is expressed by 35 out of 44 classes of the CLC nomenclature. In the municipality of Laktaši, 16 out of those 35 classes are present (177 polygons).

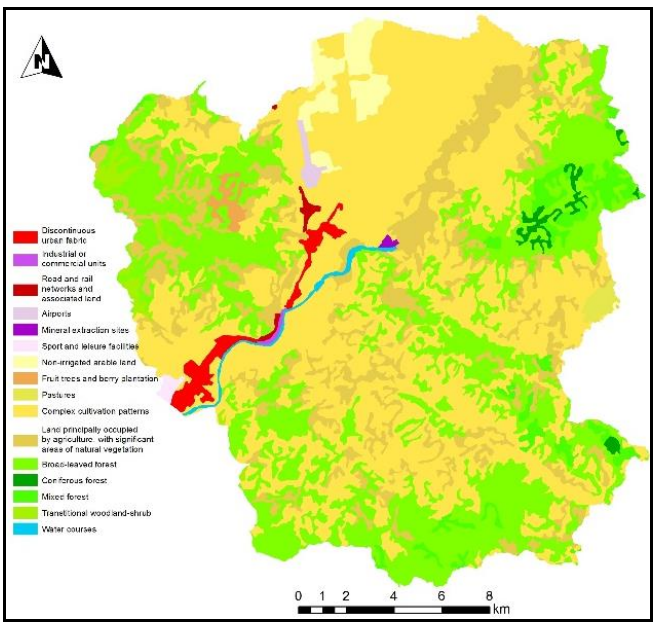

Figure 3. The spatial distribution of classes in CLC layer

2.4 Vector of Laktaši municipality

The vector layer of Laktaši municipality, representing its boundary, has been provided by the Republic administration for geodetic and property affairs of the Republic of Srpska.

3. METHODOLOGY

The following text describes the procedure of data analysis: synchronization of LC/LU and CLC classifications, data processing and output metrics.

3.1 The synchronization of LC/LU-CLC classifications

The first phase of the comparison is the synchronization of LC/LU and CLC classifications. Both the LC/LU and the CLC classifications consist of classes divided into three levels. The main difference between LC/LU and CLC is that the LC/LU classification is primarily intended for the detailed identification of agricultural land. The LC/LU nomenclature is dominated by

classes that represent agricultural land both in terms of land cover and in terms of use (20 out of a total of 36 classes).

Unlike the CLC classification, which discusses artificial surfaces in great detail and has 11 classes in the third level (111 Continuous urban fabric, etc., 121 Industrial or commercial units etc., 142 Sport and leisure facilities), LC/LU classification has only 2 classes for artificial surfaces: Built up and Built up dominates. In this class, the minimum mapped area is 0.025 ha because it is necessary to accurately separate land areas that are temporarily or permanently lost for agriculture purposes.

Regardless of the above differences, it is possible to synchronize LC/LU and CLC classifications through third level classes.

The assignment of LC/LU classes' codes to the CLC classes' codes was the aim of the synchronization (Table 3). Since their native classifications are different, it was mandatory to analyze deeply each class in both data sets in order to avoid mismatching.
The minus (–) sign in the Table 3 occurred stands when CLC did not have corresponding class of LC/LU within the study area. This fact is going to be analyses and explained in Paragraph 4.2.
In the study area, the CLC classification did not recognize 11 classes of LC/LU, of which 8 classes are precisely characterized agricultural areas (greenhouses, vineyards, nurseries, meadows, etc.).

LC/LU Code	CLC Code
2	211
6	-
7	-
9	222
10	-
12	-
13	231
16	311, 312, 313
17	324
21	131
22	121, 122, 124, 142
25	511
26	
30	243
40	-
51	-
66	-
83	-
89	-
102	112

Table 3. The pairing of classes for LC/LU and CLC

3.2 Data processing

The workflow applied for data processing is shown in the Figure 4. The CLC data were reprojected at the first step of the processing. The initial CLC layer was defined by European Terrestrial Reference System 1989 (ETRS89) datum and Lambertian Azimuthal Equal Area (LAEA) projection (EPSG 3035) (EEA, 2021) It has been converted to MGI 1901/Balkans zone 6 (EPSG 3908). After that, CLC layer was clipped by the mask layer representing Laktaši municipality. Afterwards, the union of LC/LU and CLC has been done. The new vector layer, containing 14044 polygons, came out as the result. Each of these polygons contained values for LC/LU and CLC class (within two separate columns in attribute table). The value of the area has been calculated, for each polygon, and added to the attribute table of the "Union" layer. Until this step, the processing has been performed using QGIS. The following processing steps were done using Python (Spider environment). The .dbf file of "Union" was imported using pandas and Dbf5 libraries. The resulted data frame was constructed in following way. Each row was representing a polygon, while columns were representing LC/LU, CLC, and area, respectively. The synchronization has been committed according to the Table 3. Once more, this step was mandatory in order to apply the same classification nomenclature for both datasets and to perform the comparison of two land cover maps.

The error matrix was created independently of existing Python tools and libraries. Prior to that, the reclassification was performed for the reason to allow easier creation and manipulation within the error matrix. A unique number between 0 and n-1 (where n is the total number of classes after synchronization) was assigned to each separate class. According to that rule values for LC/LU and CLC were substituted. In case of LC/LU that number was representing the column of error matrix (Figure 4). On the contrary, the assigned reclassification number was representing the row in the error matrix in the case of CLC. The value of a cell in the error matrix represent sum of the area of all polygons that have class of LC/LU as the heading row in which the cell is, and the class of CLC as the heading column in which the cell is. Given that the error matrix is computed from vector of polygons, its values represent the area of each class of LC/LU shared with each class of CLC. It is a bit different than typical error matrices that represent count of pixels of the land cover map (raster) that are in agreement or disagreement with points or pixels of reference data.

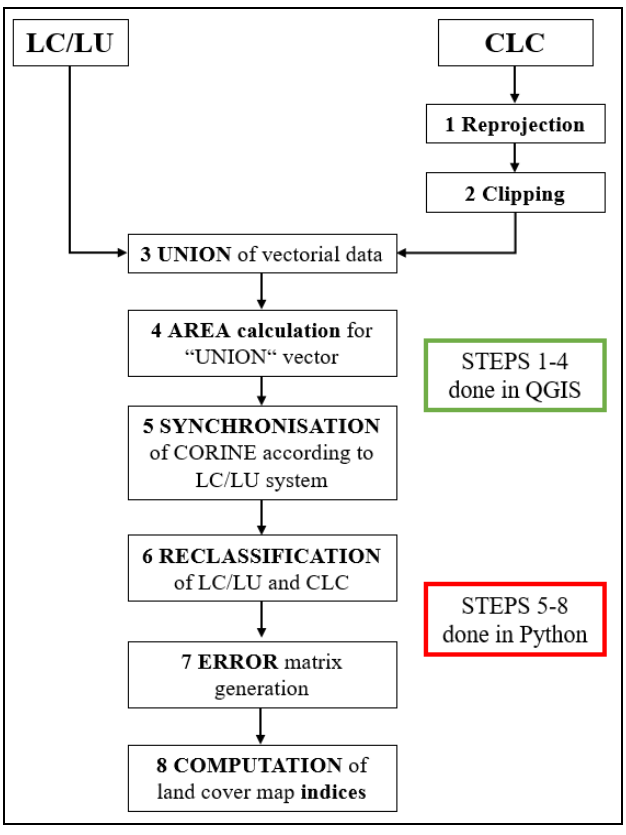

Figure 4. The complete workflow of data processing

3.3 Accuracy indexes and analyses

The main metrics/outcomes of this work are: Overall accuracy (OA), Producer's accuracy (PA) and User's accuracy (UA).

OA is an index, representing the coherency in the classification between two land cover maps. From computational point of view, it is the ratio between the total area where both land cover maps have the same classes and the area of the Laktaši municipality (area of interest). Regarding the error matrix, OA is the sum of diagonal elements divided by the sum of all elements.

Producer's accuracy of a class represents the ratio of correctly classified area and the total area of that class in the reference data (LC/LU data). Regarding the error matrix, it is calculated as division of diagonal element (representing a certain class) and the sum of elements in the column where the mentioned element exists. This index is a measure of omission error, i.e. it is the measure that relates to probability of a reference sample unit's being correctly classified. (Story & Conglaton, 1986)

UA represents the ratio between the total area correctly classified and the sum of area representing that class within the examined dataset (CLC data). Regarding the error matrix, it is calculated as division of diagonal element (representing a certain class) and the sum of elements in the row where the mentioned element exists. (Story & Conglaton, 1986)Prior to indices computation, we were interested to compare the areas for the first and second level of classes, before proceeding to the evaluation of indices for the individual classes.

4. RESULTS AND DISCUSSION

The mentioned indices (Paragraph 3.3) will be presented and discussed in following text. Surely, the focus will be on agricultural classes.

4.1 Comparison of aggregated classes

The comparison has been done for three macro classes: agricultural-land, non-agricultural land and forest.

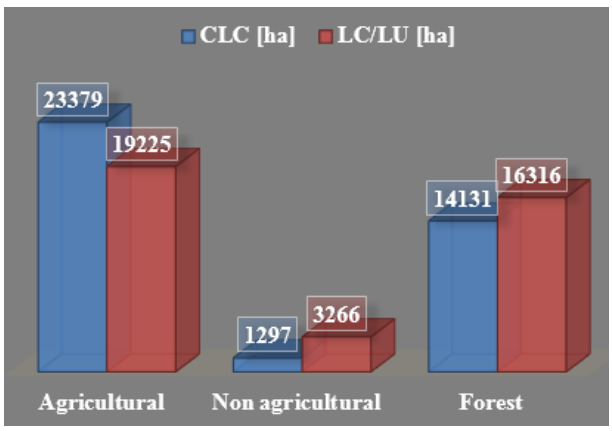

Figure 5. The comparison between 3 macro classes

The Figure 5 clearly shows how CLC disagrees regarding LC/LU, i.e. how big is the difference between macro classes. For instance, CLC has excessive 4154 ha of agricultural area in comparison to LC/LU (ground truth/reference data). Those differences are not negligible.

4.2 Overall accuracy – OA

The computed value of OA is 0.71 (71%). The spatial distribution of the coherency between LC/LU and CLC is shown by the Figure 6. Deeper analysis, on the class level, will show which classes are recognized better with CLC and which one are making biggest "confusion".

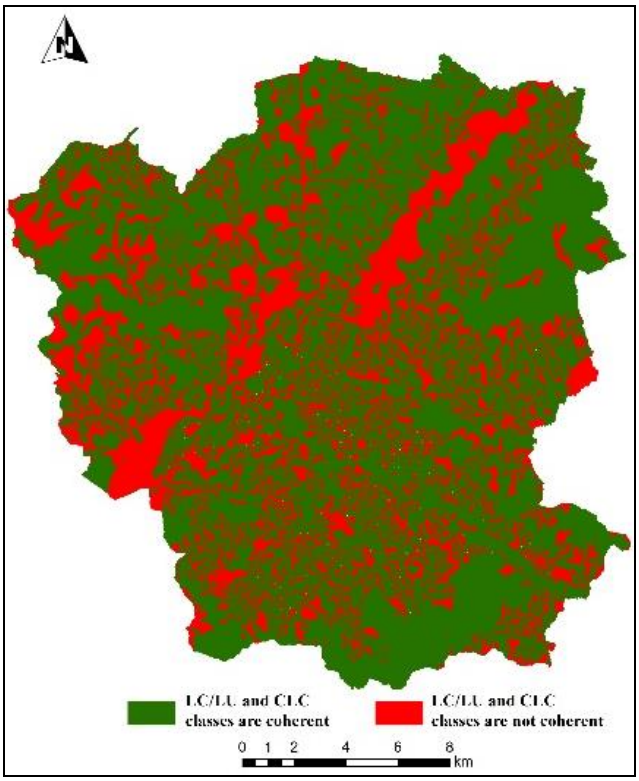

Figure 6. The spatial distribution of coherency between LC/LU and CLC

4.3 Producer's accuracy (PA) and User's accuracy (UA) and discussion

The Table 4 represents values of Producer's accuracy and the disagreement regarding their spatially corresponding classes in CLC. Zero values for PA occurred for two reasons. The first one is the fact that certain classes are not recognized within CLC at all. The second one is the complete mismatch of classes in two data sets. However, the majority of mismatched agricultural classes have been substituted with class cultivated dominates, which can be defined as positive outcome considering the macro levels (previously described in Paragraph 4.1). Certainly, mismatching is something that is considered wrong of the detailed class scale/level. The main reason for such a difference is the variation in minimal mapping unit for two datasets. It can be seen that PA of is high for Cultivated dominates, and to some extent for Forest class, while for many classes it is low which indicates underestimation of such classes.

Although the overall accuracy is 70%, the class-level results are showing that during the creation of CLC layers, a significant part of non-agricultural areas was marked as agricultural classes (Figure 5). The more detailed analyses show (Table 5) that 19.4% LC/LU forest class and 62.2% LC/LU class built up, in CLC were mapped as cultivated dominates class. From the

above example, in the studied area, a significantly larger area of agricultural land was present in CLC with respect to the actual state.

Class	PA for CLC	Number of disagreed classes	CLC Class with highest portion of omission error
Cultivated	0.63	8	Cultivated Dominates 0.28
Cultivated dominates	0.93	9	Forest 0.04
Plastic greenhouses	0	2	Cultivated dominates 0.99
Abandoned	0	10	Forest 0.22
Abandoned dominates	0	9	Cultivated dominates 0.64
Orchards	0.26	8	Cultivated dominates 0.66
Vineyards	0	2	Cultivated dominates 0.98
Orchards dominate	0	4	Cultivated dominates 0.88
Nurseries	0	1	Cultivated dominates 1
Meadows	0	6	Cultivated dominates 0.67
Meadows dominate	0	8	Cultivated dominates 0.83
Pastures	0	3	Forest 0.46
Forests	0.76	9	Cultivated dominates 0.19
Forest dominate	0	3	Cultivated dominates 0.77
Low vegetation	0.03	6	Cultivated dominates 0.81
Open quarries	0.06	5	Cultivated dominates 0.86
Built Up	0.14	9	Cultivated dominates 0.62
Built Up Dominates	0	3	Cultivated dominates 0.99
Water bodies	0.29	5	Cultivated dominates 0.64
Artificial water bodies	0	5	Cultivated dominates 0.58

Table 4. PA for classes

Since plastic greenhouses, abandoned, abandoned dominates, vineyards, orchards, nurseries, meadows, meadows dominate, forest dominate and artificial water bodies do not exist in CLC classification within study area, thus their UA is not shown in Table 6.

For classes pastures and built up dominates the value of UA is zero. It means that the commission error is 100% for this two classes. Considering values for other classes, it is noticeable that the highest values of UA are computed for Forests and Built Up (Non agricultural). The omission error (converted in surface area) just for Cultivated and Orchards (agricultural classes) is 350 ha, which is significant area considering the total surface area of Laktaši municipality.

LC/LU		CLC	
Class	ha	ha (%)	Class
Forest	15853,3	12125 (76,4 %)	Forest
		3078.6 (19.4%)	Cultivated dominates
		569.2 (3.6%)	Low vegetation
		52 (0.3%)	Orchard
		14.4 (0.1%)	Pastures
		6.5 (0.04%)	Water bodies
		5.7 (0.04%)	Built Up
		1 (0,01%)	Built Up Dominates
		0,8 (0.01%)	Cultivated
		0.02 (0.0002%)	Open quarries
Built Up	2584.1	368.2 (14%)	Built Up
		1607.5 (62.2%)	Cultivated dominates
		506.6 (19.6%)	Built Up Dominates
		54.1 (2.1%)	Forest
		33 (1.3%)	Cultivated
		9.7 (0.38%)	Water bodies
		1.4 (0.05%)	Orchard
		1.4 (0.05%)	Low vegetation
		1.1 (0.04%)	Open quarries
		1.05 (0.04%)	Pastures

Table 5. Detailed coherency and mismatching for Forest and Built Up classes

Class	UA for CLC
Cultivated	0.73
Cultivated dominates	0.64
Orchards	0.74
Pastures	0
Forests	0.91
Low vegetation	0.02
Open quarries	0.57
Built Up	0.84
Built Up Dominates	0
Water bodies	0.69

Table 6. UA for classes

5. CONCLUSION

Prevention of degradation and sustainable controlled land use should be the most important parts of every state's policy. In order for this policy to be implemented in a quality manner at all levels of government, relevant indicators of the state of land resources are necessary.

Data on land cover and land use are subject to relatively rapid changes that occur both by human influence and natural processes. LC/LU is the most important GIS basis in the process of inventory of land resources and the process of planning the use of agricultural land. LC/LU for the municipal level should be made in a high resolution (equivalent to 1:5000 or better). The LC/LU nomenclature is dominated by classes that represent agricultural land both in terms of land cover and in terms of land use. While delineating agricultural areas, the smallest mapped area is 0.5 ha. CLC as free and open data source is

characterized by the minimal mapping unit of 25 ha, and the minimal mapping width of 100m.

Even though the overall accuracy is 70%, the agricultural classes, which are of primary interest for this work, were overestimated in CLC on behalf of non-agricultural classes. Also, significant portion of agricultural land is mapped as built up and forest by CLC. It means that the CLC, in the studied area, is not a sufficiently precise GIS basis for agricultural land use planning at the local level. However, it can be a good starting point for making of LC/LU, which would significantly shorten the time of its creating.

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