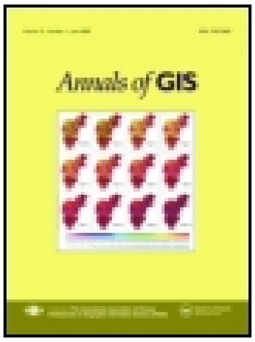

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Analysing the inconsistencies of CORINE status layers (CLC) and layers of changes (CHA) (1990-2018) for a Spanish case study

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ABSTRACT
CORINE Land Cover is one of the most relevant Land Use Cover (LUC) databases in Europe because of its degree of detail and long time series. Although some studies have assessed the uncertainty and inconsistencies of the database for specific years and periods, no work has been found that analyses all the available CORINE time series (1990–2018). In this study, we analyse the inconsistencies of the CORINE time series for a specific Spanish region (Asturias). To this end, we compare and analyse the CORINE status layers (CLC) and the CORINE layers of changes (CHA) for each of the mapped periods: 1990–2000, 2000–2006, 2006–2012, 2012–2018. Results show how CLC and CHA layers provide different information, especially after the change of production of CORINE Spain in 2012. The last two CORINE editions (2012, 2018) show a lot of technical changes that make the use of CLC layers very uncertain. In addition, mixed categories, whose definition is imprecise and, therefore, more uncertain, are behind most of detected change in both types of CORINE layers (CHA, CLC).

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Land use; Land Cover; CORINE Land Cover; uncertainty; time series

1. Introduction

Land Use and Land Cover (LUC) information is of uttermost importance for many studies in different fields, from social to natural sciences (Bontemps et al. 2012; Green et al. 2005). Researchers from these fields demand accurate LUC data at different levels of spatial and thematic detail that are able to characterize regional, national and continental areas, or even the global surface (Giri 2012; Nedd et al. 2021).

The CORINE Land Cover project, hereinafter CORINE, can be considered the most relevant European LUC database because of its history (the project dates back to 1985), comprehensive coverage (up to 38 countries in the last update), method of production (photointerpretation or data generalization) and degree of detail (Minimum Mapping Unit of 25 ha and 5 ha for changes) (Falt'an et al. 2020). Although new, more detailed and accurate LUC products have been recently generated as part of the Copernicus Land Monitoring Service, such as the High Resolution Layers (HRL) or the Urban Atlas, CORINE remains as a valuable and unique source of LUC information because of its rich time series (García-Álvarez et al. 2022).

Despite its utility and wide use, there are few studies analysing the CORINE database, its uncertainties, inconsistencies and limitations. Most of the available studies focus on specific CORINE editions, supplementing the accuracy analyses made by the CORINE production team when validating the dataset. In fact, some of the available analyses come from the validation exercises carried out by the national teams (Aune-Lundberg and Strand 2021, 2010; Caetano, Mata, and Freire 2006; Torma and Harma 2004) and the European Environment Agency (European Environment Agency, 2006). Complementary to those are the analyses that compare for specific years the CORINE agreements and disagreements with global and continental LUC datasets (Bach et al. 2006; Neumann et al. 2007; Perez-Hoyos, Garcia-Haro, and Valcárcel 2014).

For specific countries and areas, there are also academic analyses of the CORINE database, which either evaluate the general accuracy of the dataset for the area or categories of analysis (Mañas et al. 2003; Śleszyński, Gibas, and Sudra 2020), make a fine scale profile of the CORINE classes (Fonte et al. 2020; Gallego 2001) or check the consistency of CORINE with other LUC datasets (Felicísimo and Sánchez Gago 2002). Śleszyński, Gibas, and Sudra (2020) analysed the uncertainty of CORINE built-up areas for Poland. Fonte et al. (2020) assessed the uncertainty of the CORINE classification for a Portuguese city (Coimbra). For Spain, Felicísimo and Sánchez Gago (2002), Catalá Mateo, Bosque

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Sendra, and Plata Rochas (2008), Barreira González, González Cascón, and Bosque Sendra (2012) and Diaz-Pacheco and Gutiérrez (2013) have assessed the CORINE uncertainties and inconsistencies for specific areas and covers. García-Álvarez and Camacho Olmedo (2017) and, later, Martínez-Fernández et al. (2019) have also assessed the consequences of the methodological change in the production of the Spanish CORINE for 2012.

Analyses focusing on the CORINE time series and the changes it maps are usually lacking and, when existing, usually limit to a couple of dates, without exploring the full CORINE time series (Barreira González, González Cascón, and Bosque Sendra 2012; Catalá Mateo, Bosque Sendra, and Plata Rochas 2008; Diaz-Pacheco and Gutiérrez 2013; Teixeira, Marques, and Pontius 2016). The only exceptions are the work presented by García-Álvarez and Camacho Olmedo (2021) and the analysis of Ovejero-Campos et al. (2019). The first provides a general analysis of the CLC dataset for all Europe from 1990 to 2012, including some brief comments on the potential inconsistencies of the changes mapped by the CLC time series. The second analyses the CORINE time series between 1990 and 2012 to evaluate its quality for LUC change analysis in coastal areas. Neither of the two works evaluates the CORINE time series in detail and for general purposes, including both CORINE status layers and layers of changes.

Analysing the changes of CORINE and their inconsistencies is an important task. A lot of people make use of CORINE for land change analysis, but are not aware about the inconsistencies and potential uncertainties of the dataset for this purpose. Although useful, accuracy analyses with ground truth are not enough to check the uncertainties of CORINE for change analysis. Thus, extra analyses on the coherence and inconsistencies of the dataset are required.

Through this paper, we aim to fill the previous research gap by analysing in detail the coherence and inconsistencies of the CORINE Land Cover time series for Spain. We build on the previous work carried out by García-Álvarez and Camacho Olmedo (2017) and Martínez-Fernández et al. (2019), which have assessed in detail the inconsistencies of CORINE for the period 2006–2012, when the method of production of CORINE for Spain changed.

Since 2012, the Spanish CORINE is obtained through generalization of SIOSE (Land Cover and Land Use Information System of Spain), a fine-scale national LUC database. However, the SIOSE method of production has also changed since the 2017 edition (Equipo Técnico Nacional SIOSE 2020), which may have introduced changes in the last CORINE release as well. Thus, through the present paper, we aim to shed light on the uncertainties associated to the last update of CORINE for Spain at the same time that we analyse the full coherence and inconsistencies of the Spanish CORINE time series. To that end, we analyse the CORINE time series for a specific Spanish area (Asturias), which can be considered an illustrative case study because of its size and landscape heterogeneity. By limiting our analysis to a specific area, we aim to provide a better interpretation of the results, closely connected to the real ground and authors' understanding of the analysed landscapes.

In the following lines, we first make a brief introduction to the selected study area (Asturias). Second, we provide a brief presentation of CORINE Land Cover, its history and characteristics. In the third part of the paper, we explain the methods employed in our analysis. Later, the results are presented and discussed. Finally, we provide a brief conclusion.

2. Study area

The Principality of Asturias is one of the 17 Spanish Autonomous Communities, the first level of administrative division in Spain. It is located in North Spain, as part of the Cantabrian Coast (Figure 1). Asturias is a mountainous region made up of a succession of mountain ranges and deep valleys plus a plain coastal surface where most of the activities and infrastructures locate (Cortizo Álvarez et al. 1990). At the centre of the region, in a topographically favourable area, the Asturias Central Area hosts the most relevant urban centres of Asturias as well as most of the population and economic activity (Rodríguez Gutiérrez, Menéndez Fernández, and Blanco Fernández 2009). Most of the artificial uses and covers of the region are placed here and in the coast. On the contrary, the rest of Asturias and, especially, its mountainous areas, are dominated by rural and natural landscapes made up of pastures and forests (Rodríguez Gutiérrez and Menéndez Fernández 2005). Because of the difficult topographic conditions, the agricultural activity of Asturias is mostly driven by extensive livestock farming, with limited surfaces of arable land (Cortizo Álvarez et al. 1990).

3. Materials: corine land cover

In this paper, we analyse the full time series of CORINE status layers (CLC) and layers of changes (CHA) available for Spain: CLC90, CLC00, CHA00 (90–00), CLC06, CHA06 (00–06), CLC12, CHA12 (06–12), CLC18 and CHA18 (12–18).

CORINE Land Cover is a European LUC dataset whose production dates back to 1985 (Büttner, Manakos, and

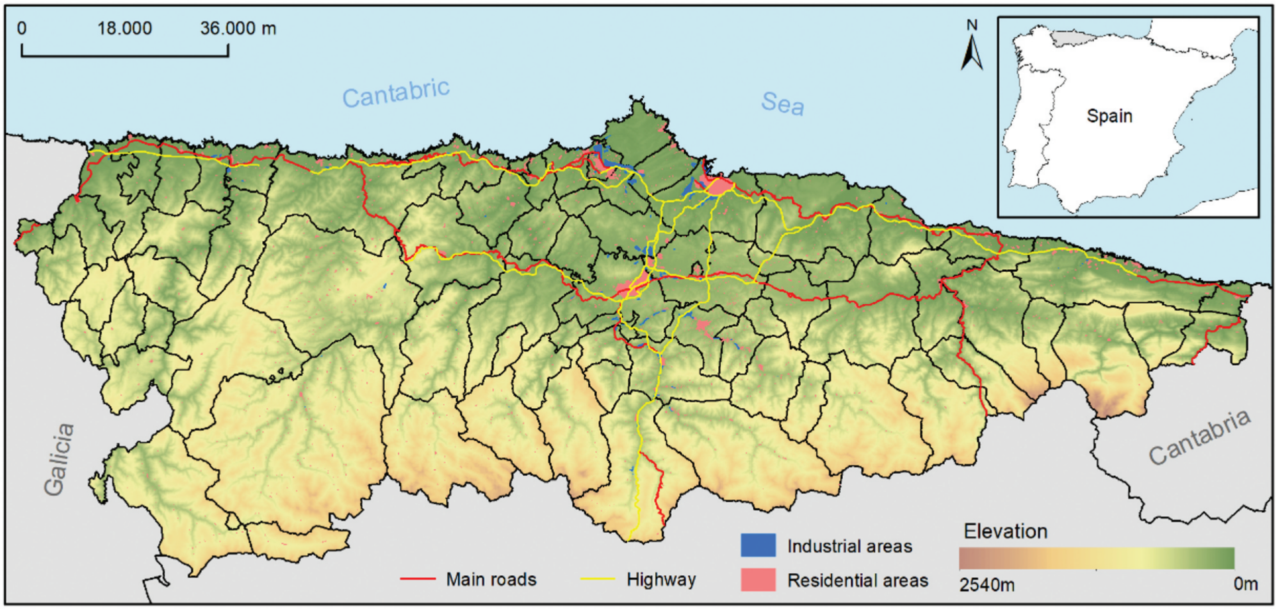

Figure 1. Location map of Asturias.

Braun 2014). Since then, 5 different editions of CORINE have been produced for the reference years 1990, 2000, 2006, 2012 and 2018 (European Environment Agency 2021). New updates of CORINE are expected every 6 years (Büttner, Manakos, and Braun 2014).

CORINE is produced at the national level under the coordination of the EEA, which defines the common characteristics of the dataset and ensures its coherence in border areas (European Environment Agency 2021). Nowadays, the CORINE production takes part of the Copernicus Land Monitoring Service, together with other relevant LUC products at finer (HRL, Urban Atlas, etc.) and coarser (CGLS-LC100) scales (García-Álvarez et al. 2022). A new product based on the CORINE experience and complementary to it is currently being developed. CORINE Land Cover + (CLC+), also called the '2nd generation CORINE Land Cover', will provide a single repository of European and selected national LUC datasets, which will be integrated in a common grid following the EAGLE data model and nomenclature (Probeck et al. 2021). The created grid will be based on a new product (CLC+ Backbone) obtained through Sentinel imagery segmentation and auxiliary data, which will also classify the landscape through a 18-categor y classification scheme (European Environment Agency 2021). The new CLC+ dataset will allow its use for multiple purposes, including the update of the traditional CORINE dataset (CLC legacy).

CORINE maps have been traditionally obtained in vector format through photointerpretation of satellite imagery at 1:100.000 scale (Büttner, Manakos, and Braun 2014). However, in the last two editions, an increasing number of countries, including Spain, obtain CORINE through the generalization of national LUC datasets at finer scales (Hazeu et al. 2016). National datasets provide richer thematic and spatial detail. Then, the generalization process first associates every LUC category to a specific category of the CORINE classification legend, made up of 44 categories. In a second step, small and narrow polygons are removed, split and merged with bigger polygons to meet the 25 ha Minimum Mapping Unit (MMU) and 100 m Minimum Mapping Width (MMW) of CORINE.

Figure 2 shows the historical workflow for CORINE generation in Spain. Independent of the production method, CORINE mapping rules (MMU, MMW and classification legend) have remained the same (European Environment Agency 2021).

In addition to the production of a CORINE status layer (CLC), for each mapped period (90/00, 00/06, 06/12, 12/18) a specific layer of changes (CHA) is obtained. This layer maps all LUC changes over the considered period at the same scale and with a Minimum Mapping Unit of only 5 ha, except for the first period (90/00). Different to the comparison of the status layers, the CORINE layers of changes only map the changes that really happened on the ground, without any technical change due to mapping errors or changes in the method of production.

Since 2000 the CLC layers are obtained from the revision of the previous CLC layer of reference and the

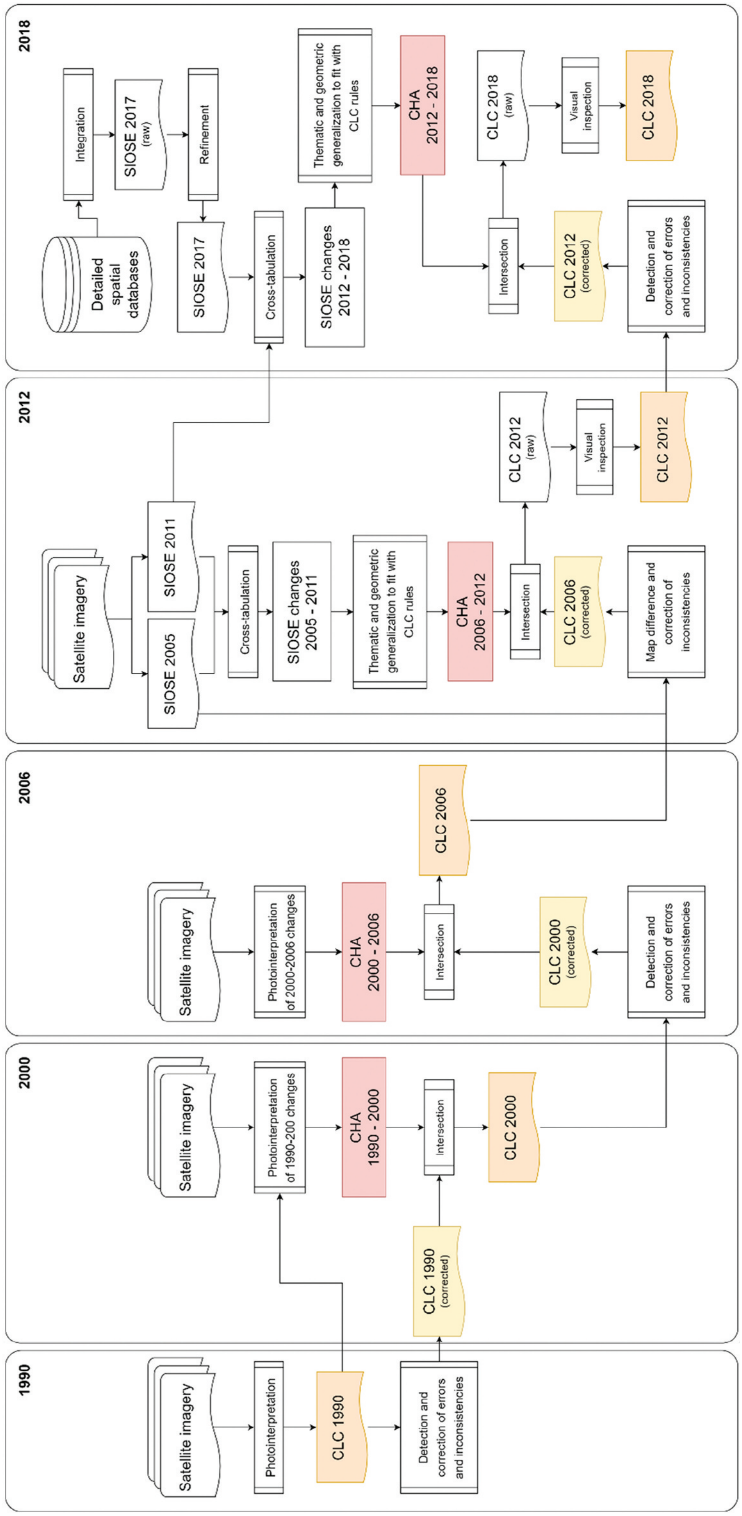

Figure 2. History of the Spanish CORINE production workflow.

superposition of the CHA layer (Figure 2). In this regard, every time a new CLC status layer is produced, the one for the previous year is updated, accounting for the detected errors and inconsistencies. Because of the different mapping rules between CLC and CHA layers, the updated CLC layer with CHA changes is generalized to fit with the CLC MMU rule. That is, polygons smaller than 25 ha are generalized, split and merged to larger polygons.

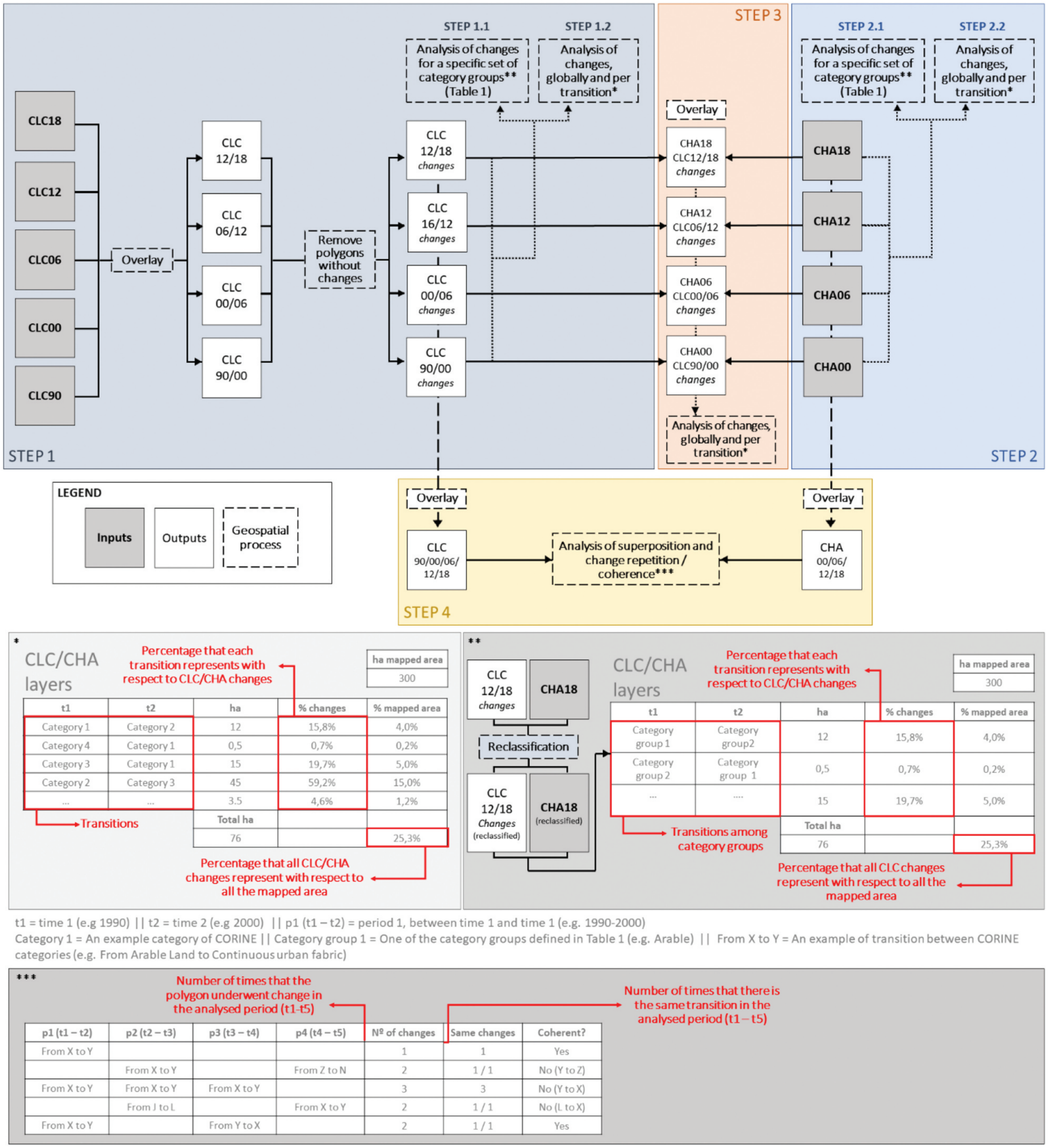

Figure 3. Flowchart of the analysis of CORINE land cover data carried out for this study.

4. Methods

We analysed the changes showed by the CORINE Land Cover database in both the CORINE status layers (CLC) and the CORINE layers of changes (CHA) following the workflow summarized in Figure 3.

First, CLC vector layers were overlayed in pairs, matching the periods for which CHA layers are available: 90/00, 00/06, 06/12 and 12/18 (step 1 in Figure 3). After the layers were overlaid, we separated those polygons that changed between dates from those that did not undergo change. Then, we analysed the polygons that changed globally and per transition (changes between every pair of categories) for each of the three levels of the CORINE classification legend (step 1.1 in Figure 3). That is, we analysed exchanges among the 5 categories of the CORINE level 1 classification legend, exchanges among the 15 categories of the CORINE level 2 classification legend and exchanges among the 44 categories of the CORINE level 3 classification legend. In each case, we calculated the area and proportion of the changes for all Asturias and with respect to the total quantity of detected changes for each period. Changes showed by CHA layers were analysed in the same way (step 2 in Figure 3): globally and per transition for all Asturias and with respect the total quantity of CHA changes for each available period (step 2.1 in Figure 3).

In addition to the change analysis globally and per transition, to help the understanding of the layers' changes, we have grouped the transitions of each CLC and CHA layer in five groups, according to the type of uses or covers involved: mixed covers, moors and heathland, pure forest covers, agricultural covers and artificial surfaces (Table 1) (steps 1.1 and 2.1 in Figure 3). As in the previous analyses per transition, this gives us information of all exchanges between every group of transitions. The transition groups include the most representative covers of LUC change in Asturias and reflect well the different nature and characteristics of the covers involved in the changes.

CHA and CLC change layers were also mutually overlaid in pairs to specifically account for the changing areas that are included in the two layers, globally and per transition (step 3 in Figure 3). We differentiated between those cases where the two layers show the same transitions and those cases where the two layers show different transitions.

Finally, CLC and CHA layers for all available periods (t_1, t_2, t_3, t_4) were independently overlaid (CLC t_{1234} and CHA t_{1234}) (step 4 in Figure 3). This allowed to count the number of times a specific area underwent change in the considered period for each type of layer and the plausibility of the change timeseries in each case. In this regard, when the CLC and CHA layers showed a change from category X to category Y in a period and the next change in a following period transitioned from a different category than Y, this was considered a non-plausible change. Eg, for the same area, a transition from arable land to coniferous forest in the period $t_1 - t_2$ and a transition from moors and heathland to transitional woodland-shrub in the period $t_2 - t_3$ would be considered incoherent or non-plausible. In addition, we counted the number of times the same transition (e.g. from X to Y) happened in the analysed time frame.

5. Results

In the next sections, the results of our analyses are presented. First, we compare the changes mapped by both CLC and CHA layers globally, without distinctions per category (section 4.1). Second, we analyse the plausibility of those changes by focusing on the number of times the same area underwent change in the analysed period (1990–2018) and the coherence between transitions (section 4.2). Finally, we analyse and compare the changes mapped by both CLC and CHA layers at the category level (section 4.3) Full results from section 4.3 are provided as supplementary material to this paper.

5.1 Global patterns of change in CLC and CHA layers

Except for the first editions of CORINE (90, 00), CLC layers always detect more LUC changes than CHA layers (Table 2). This is especially true in the 2012 and 2018 editions of CORINE: whereas CLC layers detect change in 36.5% and 7.9% of the mapped area for 2012 (06/12) and 2018 (12/18) respectively, CHA layers only detect 1.3% and 1.1% of

Table 1. List of land uses and covers according to the level 3 of the CORINE classification scheme for each of the five groups that we have analysed: arable, artificial, forest, mixed covers and moors and heathland.

Category group 1: Arable	Category group 2: Artificial	Category group 3: Forest	Category group 4: Mixed covers	Category group 5: Moors and heathland
Non-irrigated arable land	Continuous urban fabric	Broad-leaved forest	Complex cultivation patterns	Moors and heathland
Permanently irrigated land	Discontinuous urban fabric	Coniferous forest	Land principally occupied by agriculture, with significant areas of natural vegetation	
Rice fields	Industrial or commercial units		Transitional woodland-shrub	
Vineyards	Road and rail networks and associated land		Mixed forest	
Fruit trees and berry plantations	Port areas		Annual crops associated with permanent crops	
Olive groves	Airports		Agro-forestry areas	
Pastures	Mineral extraction sites			
	Dump sites			
	Construction sites			
	Green urban areas			
	Sport and leisure facilities			

change for the same periods. The 2000 edition of CORINE (90/00) is the only one for which the mapped changes by CLC layers are the same than mapped changes by CHA layers.

Even despite the big difference in the quantity of detected changes, CLC layers do not even account for all changes mapped in the CHA layers. In 2012 and 2018, around a quarter of the mapped changes by CHA layers are not considered as changing areas in CLC layers (Table 2). In addition, when both layers consider change, that change is sometimes differently interpreted by each layer: in 2012 half of the changing areas mapped by both CLC and CHA layers showed a different transition of change in each case. In 2018, this happened the 25% of the times.

Whereas CHA layers show a similar trend of changes for all periods, except for the first one (90–00), four years longer in time with respect to the others, there are important differences in the number of changes detected by CLC layers in each period (Figure 4). In 2000 (90/00), CLC and CHA layers map the same change according to the same transitions (Table 2). In 2006 (00/06), CLC layers detect more changes than CHA layers, although the difference is not very relevant. However, in the last two editions of CORINE and, above all, in 2012, there is a huge difference between the quantity of change mapped by CLC and CHA layers (Figure 4).

5.2 *Frequency and coherence of changes in CLC and CHA layers*

In most of the cases, either in CLC or CHA layers, changes only happen once in the same area in all the analysed period (90–18) (Figure 5). Nevertheless, the number of areas undergoing two different transitions in the considered period (90–18) is very relevant: 22% in CLC and 14.5% in CHA (Table 3). For all periods, CLC layers map change in 41% of the mapped area and CHA layers only in 5% of the mapped area.

The areas that undergo three or the maximum of possible changes (4), although they exist, are quantitatively of little relevance (Table 3). In CLC layers, most of the areas that change in more than one period undergo those changes in the last editions of CORINE (2012, 2018). Seventy per cent of the areas undergoing two transitions experiment these changes in the periods 06/12 and 12/18. On the contrary, for CHA layers, almost 50% of the areas undergoing two transitions experiment those changes in the periods 90/00 and 00/06.

CLC layers always show coherent transitions (Table 4): if an area changes two times, the category to which the transition took place in the first period is always the category from which the transition takes place in the next period. However, that is not the case of CHA layers. In these layers, for example, we have found polygons that changed from pastures (2000) to continuous urban fabric (2006) and again changed in 2006 from pastures to construction sites in 2012. That is, the polygon that was pastures in 2000 was again pastures in a CHA layer in 2006, but urban fabric in another CHA layer, which makes no sense. Nonetheless, the areas that show these incoherencies only represent 2% (1279 ha) of the mapped changes in CHA layers.

There are important differences among years. Whereas the non-coherent transitions between CHA00 and CHA06 layers only cover 73.5 ha, for the following periods the areas affected are much bigger: 750.8 ha when comparing CHA12 and CHA06 layers and 454.6 ha when comparing CHA18 and CHA12 layers (Table 4). On the other hand, the proportion of changes, either in CLC or CHA layers, which are mapped following the same transition for more than one time point in the analysed period (90–18) is insignificant: 1% (668.9 ha) of all mapped changes in CHA and 0,1% (662.5 ha) in CLC (Table 5).

Table 2. Percent of detected changes, regarding the total mapped area, by the CORINE status layers (CLC) and the CORINE layers of changes (CHA). We differentiate between changes mapped in a layer, but not in the other (Only CLC, Only CHA) and areas that are mapped as change in the two layers (Both CLC&Cha). Among the last ones, we differentiate between those cases where the two layers describe the change through the same or different transitions.

		12/18	06/12	00/06	90/00
CLC	Total	7.9%	36.5%	1.6%	2.3%
	Only CLC	7.1%	35.6%	0.5%	0.0%
CHA	Total	1.1%	1.3%	1.2%	2.3%
	Only CHA	0.3%	0.3%	0.1%	0.0%
Both (CLC&CHA)	Total	0.8%	1.0%	1.1%	2.3%
	Same transitions	0.6%	0.4%	1.0%	2.3%
	Different transitions	0.2%	0.5%	0.1%	0.0%

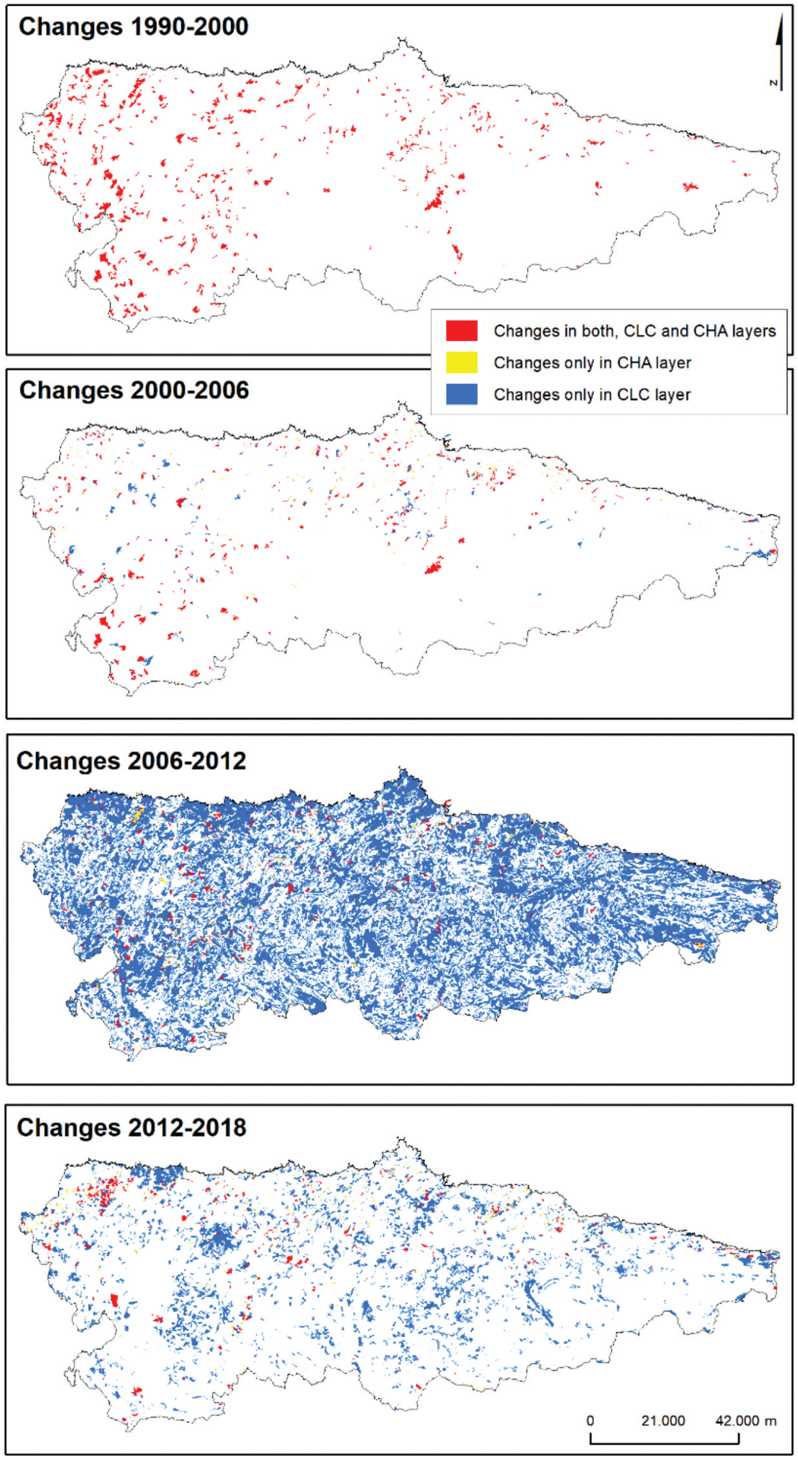

Figure 4. Location of changing areas in CLC and CHA layers and both of them for each mapped period.

5.3 Patterns of change in CLC and CHA layers at the category level

When analysing the transitions mapped by each type of layer in detail, we can see how the exchanges among forest and semi-natural areas are in almost all periods and layers (CLC, CHA) the most relevant change in quantity (Tables 6 and 7). These exchanges always represent above 70% of the mapped change in all CHA layers (Table 7). In 2012 and 2018 CLC layers, they represent a smaller proportion because of the important number

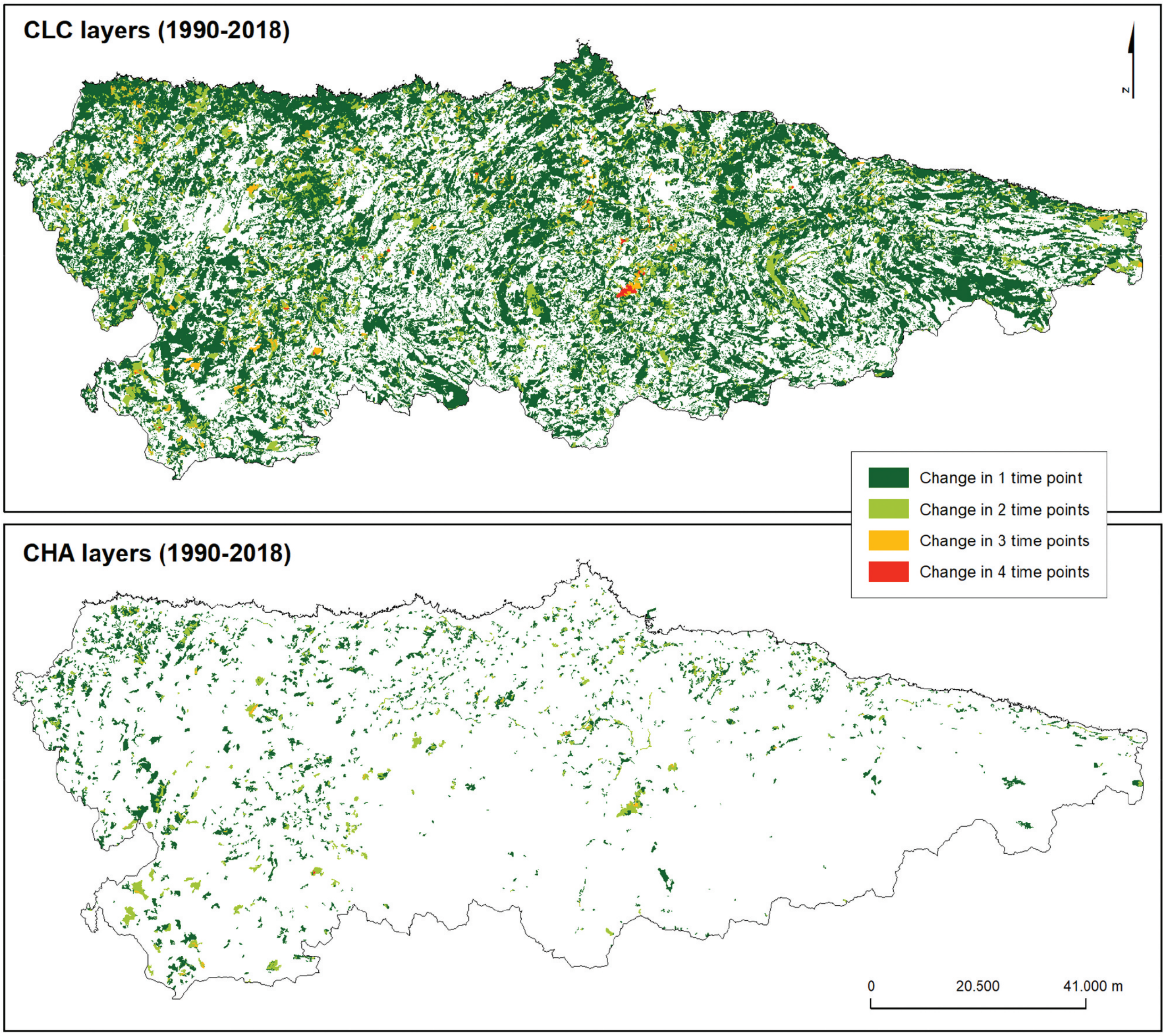

Figure 5. Areas of change of Asturias, according to the number of times they undergo change (from 1 time period to a maximum of 4 time periods) in both CORINE status layers (CLC) and CORINE layers of changes (CHA).

Table 3. Areas that underwent change in the CORINE status layers (CLC) and the CORINE layers of changes (CHA) classified according the number of times they undergo any change, from 1 (one time period out of 4) to 4 (changes in all time periods). The last row summarizes the size of all areas that undergo any change in the analysed period (1990–2018) and their proportion with respect to the total mapped area.

	CHA		CLC	
	ha	% total changes	ha	% total changes
1 time period	48746.3	84.0%	459614.2	76.9%
2 time periods	13920.0	14.5%	79586.6	22.0%
3 time periods	674.7	1.3%	7129.6	1.1%
4 time periods	29.4	0.1%	782.0	0.0%
		% total Asturias		**% total Asturias**
All periods	63370.5	4.8%	547112.4	41.1%

Table 4. Non-coherent transitions in the CORINE status layers (CLC) and the CORINE layers of changes (CHA) according to the period in which the incoherence is found: incoherence in the changes between the years 1990, 2000 and 2006 (90-00-06); incoherence in the changes between the years 2000, 2006 and 2012 (00-06-12); and incoherence in the changes between the years 2006, 2012 and 2018 (6 December 2018). For each period, the table indicates the number of polygons with incoherent changes, their area in hectares and the proportion that area represents regarding the total area of changes mapped in each type of layer.

	CHA			CLC		
Period	Nº polygons	ha	% Total CHA	Nº polygons	ha	% Total CLC
90-00-06	145	73.5	0.1%	0	0	0
00-06-12	303	750.8	1.2%	0	0	0
6 December 2018	179	454.6	0.7%	0	0	0

Table 5. Polygons that present the same transition for more than one period, indicating the number of times they experience this: from 1 to a maximum of 4 times. The table shows, for each layer (CORINE status layers – CLC, CORINE layers of changes -CHA) the number of polygons involved, their area in hectares and the proportion that area represents regarding the total area of changes mapped in each type of layer.

	CHA			CLC		
Nº of times	Nº polygons	ha	% Total CHA	Nº polygons	ha	% Total CLC
1	262	653.3	1.03%	104	662.5	0.12%
2	0	0	0	0	0	0
3	8	15.6	0.02%	0	0	0
4	0	0	0	0	0	0

Table 6. Percent of detected changes, regarding the total of mapped changes and the total mapped area, by the CORINE status layers (CLC) and the CORINE layers of changes (CHA). We differentiate the changes according to the categories that take part of the change: mixed categories, moors and heathland, forest categories, agricultural categories and artificial surfaces (see Table 1).

	CLC (% changes)				CHA (% changes)			
	12/18	06/12	00/06	90/00	12/18	06/12	00/06	90/00
Mixed	66.5%	48.2%	41.5%	51.5%	70.3%	43.3%	34.6%	51.5%
Moors and heathland	22.0%	40.0%	38.4%	46.2%	21.6%	38.4%	33.2%	46.2%
Forest	31.7%	38.8%	42.4%	38.6%	67.7%	35.3%	32.2%	38.6%
Agricultural	52.2%	36.2%	14.6%	12.9%	6.9%	10.2%	11.6%	12.9%
Artificial	7.1%	3.2%	23.0%	15.7%	7.3%	18.9%	23.1%	15.6%
	CLC (% mapped area)				CHA (% mapped area)			
	12/18	06/12	00/06	90/00	12/18	06/12	00/06	90/00
Mixed	5.3%	17.6%	0.7%	1.2%	0.8%	0.6%	0.4%	1.2%
Moors and heathland	1.7%	14.6%	0.6%	1.1%	0.2%	0.5%	0.4%	1.1%
Forest	2.5%	14.2%	0.7%	0.9%	0.8%	0.5%	0.4%	0.9%
Agricultural	4.1%	13.2%	0.2%	0.3%	0.1%	0.1%	0.1%	0.3%
Artificial	0.6%	1.2%	0.4%	0.4%	0.1%	0.2%	0.3%	0.4%

of changes among agricultural areas. The exchanges among forest and semi-natural areas are usually from and to a couple categories: moors and heathland and transitional woodland-shrub (Table 8).

In 2012 and 2018, the exchanges among agricultural areas are one of the biggest changes detected by CLC layers (Table 7). These exchanges do not represent significant proportions in any CHA layers, neither in the previous editions of CORINE (1990–2006). In CLC layers, changes in agricultural areas represent a proportion of the mapped changes which is 7 (2018) and 3 (2012) times bigger than the proportion that the same type of changes represent in CHA layers and 3–4 times bigger than the same transitions in previous editions of CORINE (Table 7). The most important exchanges of agricultural covers mapped by CLC layers in 2012 and 2018 are the transitions from and to heterogeneous agricultural areas (that is, mixed covers), which in many cases are not even mapped at any extent in CHA layers (Table 8).

Changes of agricultural and forest and semi-natural covers are mostly driven by the dynamism of mixed categories. In this regard, the most relevant mapped transitions in any period in either CLC and CHA layers are from or to a mixed category (Table 6). Transitional woodland-shrub is the forest and semi-natural mixed cover accounting for all these changes. Among agricultural covers, complex cultivation patterns and land

Table 7. Main transitions at the Level 1 (L1) of the Corine Land Cover classification for the CORINE status layers (CLC) and the CORINE layers of changes (CHA) for each mapped period (12/18, 06/12, 00/06, 90–00). We indicate the percentage that each transition represents with respect to the total of mapped changes in CLC (CLC %) and CHA layers (CHA %) as well as the ratio between the area of mapped changes by CLC and CHA layers (CLC/CHA) and by CHA and CLC layers (CHA/CLC). A CLC/CHA value of 757 means that the area of the considered transition in CLC layers is 757 times the area of the considered transition in CHA layers. Colors identify transitions of different nature: exchanges among agricultural areas, exchanges among forest and semi-natural areas, exchanges among agricultural and forest and semi-natural areas, exchanges among or with artificial covers, etc. The table in full is provided as supplementary material to this paper.

CLC transition		CLC %	CHA transition		CHA %	CLC/CHA	CHA/CLC
12/18							
Agricultural	Agricultural	41.1%	Agricultural	Agricultural	0.4%	758	0
Forest and semi natural	Forest and semi natural	32.8%	Forest and semi natural	Forest and semi natural	87.8%	3	0
Forest and semi natural	Agricultural	12.0%	Forest and semi natural	Agricultural	4.5%	19	0
Artificial	Artificial	1.2%	Artificial	Artificial	4.7%	2	1
06/12							
Forest and semi natural	Forest and semi natural	50.8%	Forest and semi natural	Forest and semi natural	74.3%	19	0
Agricultural	Agricultural	23.5%	Agricultural	Agricultural	2.6%	255	0
Agricultural	Forest and semi natural	14.1%	Agricultural	Forest and semi natural	0.8%	530	0
Forest and semi natural	Agricultural	7.9%	Forest and semi natural	Agricultural	3.2%	71	0
Artificial	Artificial	1.1%	Artificial	Artificial	5.6%	5	0
Agricultural	Artificial	1.0%	Agricultural	Artificial	6.0%	5	0
Forest and semi natural	Artificial	0.3%	Forest and semi natural	Artificial	4.5%	2	1
00/06							
Forest and semi natural	Forest and semi natural	66.7%	Forest and semi natural	Forest and semi natural	70.0%	1	1
Agricultural	Artificial	9.1%	Agricultural	Artificial	7.9%	2	1
Forest and semi natural	Agricultural	6.4%	Forest and semi natural	Agricultural	4.0%	2	0
Artificial	Forest and semi natural	5.5%	Artificial	Forest and semi natural	7.4%	1	1
Artificial	Artificial	5.1%	Artificial	Artificial	3.3%	2	0
Agricultural	Agricultural	0.6%					
90/00							
Forest and semi natural	Forest and semi natural	72.7%	Forest and semi natural	Forest and semi natural	72.7%	1	1
Forest and semi natural	Agricultural	8.4%	Forest and semi natural	Agricultural	8.4%	1	1
Agricultural	Artificial	6.8%	Agricultural	Artificial	6.8%	1	1
Forest and semi natural	Artificial	5.2%	Forest and semi natural	Artificial	5.2%	1	1
Artificial	Artificial	2.4%	Artificial	Artificial	2.4%	1	1
Agricultural	Agricultural	1.1%	Agricultural	Agricultural	1.1%	1	1

principally occupied by agriculture are the two categories accounting for all this change (Table 8).

Among artificial areas, mines, dump and construction sites are the covers that usually account for most of the mapped changes (Table 8). In the 2000 and 2006 editions of CORINE, changes in artificial areas represent an important part of the mapped changes in both CLC and CHA layers (Table 6). In 2018, the artificial surfaces only represent a small proportion of all changes (7%) in both layers. In 2012, whereas changes in artificial areas represent 18,9% of all CHA changes, they only represent the 3,2% of all CLC changes (Table 6). In area (ha), the differences are not that noticeable. However, when analysing the specific transitions mapped by each layer, we can appreciate how CHA transitions from and to mine, dump and construction sites are 2–5 times bigger than the same transitions in CLC layers (Table 8).

Similar to the artificial areas case in 2012, forest covers (coniferous, broad-leaved forest) account for 67.7% of the CHA change in 2018 and only 31.7% in CLC (Table 4). However, CLC layers also map at a similar extent (area) the transitions in which forest covers are involved. Thus, this difference in proportion is not caused by many features mapped in CHA layers and not mapped in CLC layers, but because of mapping some specific transitions in CLC layers that are of little relevance or do not even exist in CHA layers.

6. Discussion

The results prove how CLC and CHA layers provide very different information for Land Use Cover Change (LUCC) analysis. This difference is especially noticeable since 2012, after the change of production of CORINE Spain, which has introduced important limitations in the use of the CORINE temporal series. In all cases, mixed categories account for most of the mapped change, which may introduce new uncertainties in our studies because of the flexible nature of these

Table 8. Main transitions at the levels 2 and 3 (L2-L3) of the Corine Land Cover classification for the CORINE status layers (CLC) and the CORINE layers of changes (CHA) for each mapped period (12/18, 06/12, 00/06, 90–00). We indicate the percentage that each transition represents with respect to the total of mapped changes in CLC (CLC %) and CHA layers (CHA %) as well as the ratio between the area of mapped changes by CLC and CHA layers (CLC/CHA) and by CHA and CLC layers (CHA/CLC). A CLC/CHA value of 757 means that the area of the considered transition in CLC layers is 757 times the area of the considered transition in CHA layers. Colors identify transitions of different nature: exchanges among agricultural areas, exchanges among forest and semi-natural areas, exchanges among agricultural and forest and semi-natural areas, exchanges among or with artificial covers, etc. The table in full is provided as supplementary material to this paper.

CLC transition		CLC %	CHA transition		CHA %	CLC/CHA	CHA/CLC
12/18							
Pastures	Heterogeneous agricultural	**28.3%**					
Arable land	Heterogeneous agricultural	**3.8%**					
Heterogeneous agricultural	Arable land	**3.7%**					
Broad-leaved forest	Woodland-shrub	**5.7%**	Moors and heathland	Woodland-shrub	**0.8%**	52	0
Moors and heathland	Woodland-shrub	**3.8%**					
Broad-leaved forest	Coniferous forest	**3.6%**					
Moors and heathland	Broad-leaved forest	**2.9%**					
Broad-leaved forest	Moors and heathland	**2.8%**					
Coniferous forest	Woodland-shrub	**2.0%**	Broad-leaved forest	Woodland-shrub	**41.0%**	0	3
Coniferous forest	Woodland-shrub	**2.0%**	Coniferous forest	Woodland-shrub	**16.2%**	1	1
Burnt areas	Moors and heathland	**1.3%**	Burnt areas	Moors and heathland	**11.1%**	1	1
Woodland-shrub	Broad-leaved forest	**0.5%**	Woodland-shrub	Broad-leaved forest	**6.4%**	1	2
Forests	Heterogeneous agricultural	**4.2%**					
Scrub/herbaceous vegetation	Pastures	**3.2%**	Scrub/herbaceous vegetation	Pastures	**4.3%**	5	0
Scrub/herbaceous vegetation	Heterogeneous agricultural	**2.2%**					
Mine, dump, construction	Industrial, commercial, transport	**0.5%**	Mine. dump. construction	Industrial. commercial. transport	**4.3%**	1	1
06/12							
Woodland-shrub	Moors and heathland	**9.0%**	Woodland-shrub	Moors and heathland	**0.5%**	467	0
Broad-leaved forest	Moors and heathland	**7.1%**	Broad-leaved forest	Moors and heathland	**0.2%**	1007	0
Moors and heathland	Broad-leaved forest	**4.6%**	Moors and heathland	Broad-leaved forest	**0.1%**	1969	0
Moors and heathland	Burnt areas	**0.0%**	Moors and heathland	Burnt areas	**13.4%**	0	12
Broad-leaved forest	Woodland-shrub	**0.6%**	Broad-leaved forest	Woodland-shrub	**10.8%**	1	1
Moors and heathland	Sparsely vegetated areas	**0.3%**	Moors and heathland	Sparsely vegetated areas	**8.6%**	1	1
Woodland-shrub	Coniferous forest	**0.6%**	Woodland-shrub	Coniferous forest	**5.8%**	3	0
Woodland-shrub	Mixed forest	**0.4%**	Woodland-shrub	Mixed forest	**4.1%**	3	0
Pastures	Arable land	**8.2%**	Pastures	Arable land	**1.1%**	203	0
Pastures	Heterogeneous agricultural	**6.2%**	Pastures	Heterogeneous agricultural	**0.2%**	730	0
Heterogeneous agricultural	Arable land	**5.1%**	Heterogeneous agricultural	Arable land	**0.0%**	27429	0
Heterogeneous agricultural	Pastures	**3.6%**					
Heterogeneous agricultural	Forests	**4.4%**	Heterogeneous agricultural	Forests	**0.3%**	366	0
Pastures	Forests	**4.2%**	Pastures	Forests	**0.1%**	1656	0
Heterogeneous agricultural	Scrub/herbaceous vegetation	**2.9%**	Heterogeneous agricultural	Scrub/herbaceous vegetation	**0.1%**	598	0
Pastures	Scrub/herbaceous vegetation	**2.7%**	Pastures	Scrub/herbaceous vegetation	**0.1%**	627	0
Mine, dump, construction	Industrial, commercial, transport	**0.0%**	Mine. dump. construction	Industrial. commercial. transport	**2.6%**	0	4
Pastures	Mine, dump, construction	**0.0%**	Pastures	Mine. dump. construction	**2.4%**	0	2
Scrub/herbaceous vegetation	Mine, dump, construction	**0.0%**	Scrub/herbaceous vegetation	Mine. dump. construction	**1.9%**	0	2
Forests	Mine, dump, construction	**0.0%**	Forests	Mine. dump. construction	**1.8%**	0	2
Mine, dump, construction	Urban fabric	**0.0%**	Mine. dump. construction	Urban fabric	**1.6%**	0	5
00/06							
Burnt areas	Moors and heathland	**16.0%**	Burnt areas	Moors and heathland	**21.6%**	1	1
Broad-leaved forest	Woodland-shrub	**8.6%**	Broad-leaved forest	Woodland-shrub	**15.3%**	1	1
Coniferous forest	Woodland-shrub	**7.0%**	Coniferous forest	Woodland-shrub	**10.0%**	1	1
Woodland-shrub	Broad-leaved forest	**5.9%**	Woodland-shrub	Broad-leaved forest	**4.1%**	2	1
Moors and heathland	Woodland-shrub	**5.2%**	Moors and heathland	Woodland-shrub	**1.7%**	4	0
Broad-leaved forest	Moors and heathland	**3.6%**					
Coniferous forest	Moors and heathland	**3.0%**					
Pastures	Urban fabric	**3.3%**	Pastures	Urban fabric	**0.9%**	5	0
Pastures	Mine, dump, construction	**2.2%**	Pastures	Mine. dump. construction	**4.0%**	1	1
Pastures	Industrial, commercial, transport	**2.0%**					
Mine, dump, construction	Scrub/herbaceous vegetation	**5.2%**	Mine. dump. construction	Scrub/herbaceous vegetation	**7.3%**	1	1

categories and the difficulty to define them with precision. In the next sections, we independently address each of these issues.

6.1 The difference between CLC and CHA layers

Our results prove how LUC change analysis from CLC and CHA layers may end in very different results and conclusions. In our study case, the only exception to that general rule were the CLC layers for the two first years that CORINE is available (1990, 2000). Changes from the comparison of CLC layers for these years are the same than the changes mapped by the CHA layer for that period. This is explained by the specificity of the first CORINE update. The first CHA layer was obtained in some countries from the intersection of CLC90 and CLC00, after the revision of the first layer (Büttner, Manakos, and Braun 2014; European Environment Agency 2021). Thence, there are not differences between CLC and CHA changes as both were obtained in the same way. Nonetheless, this means that CHA90 does not fit the 5 ha MMU of CHA layers.

Since 2006, the 'change mapping first' approach has been the compulsory method established by the EEA for updating CORINE (Büttner and Kosztra 2011): changes are first obtained by photointerpretation or generalization of finer databases and the new CLC layer is later obtained through the combination of the previous CLC layer, once the detected errors and inconsistencies have been corrected, and the new layer of changes. Then, the obtained CLC layer is generalized to fit the MMU of CLC layers (25 ha). This explains the differences between CLC and CHA layers in the 2006 edition. Although there are some differences in the information that they show, the pattern and sizes of the changes measured by both types of layers is very similar. Therefore, disagreements can be attributed to the generalization process.

Opposite to the previous differences, CLC and CHA layers in 2012 and 2018 show very different transitions and sizes of changes. In addition, a relevant part of the changes mapped by CHA layers in those years are not included or are coded differently in CLC layers. In this regard, in 2012 more than half of the change mapped in the CHA layers is wrongly represented or not represented in the CLC layer. These disagreements cannot be explained by the generalization carried out when producing the CLC layers, that is, by the different layers' scale and resolutions. It can only be explained by the variations in the method of production of the Spanish CORINE, which affected not only to the areas that underwent change, but to all the mapped landscape (section 6.2).

The EEA and the CORINE production teams advise to use the CHA layers of CORINE for LUC change analysis as CLC layers include technical changes caused by the correction of detected errors or variations in the method of production (European Environment Agency 2021). Despite these official recommendations, it is still common the use of the last ones for LUC change analysis (Fernández Nogueira 2021; Gemitzi et al. 2021; Hewitt and Escobar 2011; Rusu et al. 2020).

As the first editions of CORINE (up to 2006) did not show big differences between using one or the other layers for LUC change analysis, users were not faced with the same uncertainties than they find now. This may explain why the use of CLC layers to assess LUC changes has remained a common practice over time. In addition, no other common LUC dataset is made up of status layers and layers of changes (García-Álvarez et al. 2022). Then, users are not familiar with this distinction and tend to use the status layers as the reference to obtain LUC changes.

Users require more and better information regarding the correct use of CORINE database. Although the EEA and the Copernicus programme already provide relevant documentation, the national authorities in charge of CORINE production and distribution, such as the Instituto Geográfico Nacional (IGN) in Spain, supply very limited information on the database and do not warn about all these issues. In this regard, the Spanish IGN does not even provide with the last release of CORINE the most updated product manual (European Environment Agency 2021), where all these issues are addressed in detail.

Many users still require a coherent time series of CLC layers. In many cases, the CLC time series is used as an auxiliary layer for different mapping methodologies or as a required input for different spatial analyses (Burkhard et al. 2012; Goerlich and Cantarino 2013; Kucsicsa et al. 2019). Other users demand to study LUC change for larger periods than the ones between CORINE editions. The EEA has recently developed a coherent time series of raster CLC layers to fit these user needs: the CLC accounting layers (European Environment Agency 2021). They are obtained by backdating the last CLC layer (2018) with the information provided by the CHA layers.

The CLC accounting layers present a triple limitation. First, they are only produced in raster format at 100 m, which may not fit the requirements of all the CORINE user community. Although it would require more time and resources, the development of a similar product in vector format, the traditional one in which CORINE is distributed, could better satisfy the needs of users and favour the correct use of the dataset. Second, CLC accounting layers present MMU inconsistencies, with many patches below the 25 ha threshold (European

Environment Agency 2021). This is of little relevance for many users of CORINE, but could be relevant for those users interested in knowing the distribution of land uses and covers through time, which need coherent measurement rules across the different years. Finally, when there are incoherencies between CHA layers, these are translated to CLC accounting layers as well. The CORINE production team has already tested a method to correct this inconsistencies, although it has not been approved and applied yet (European Environment Agency 2021). Nonetheless, previous experiences to correct these errors in the two first CHA layers show the path to follow, which does not demand a lot of effort nor time (Maucha, Büttner, and Pataki 2011). In this regard, as our study showed, the number of changes that present these inconsistencies is very low, only affecting a very small proportion of the detected changes in CHA layers. It would only require a small investment to correct these errors in the original CHA layers, avoiding these sources of uncertainty for any user of the CORINE database.

6.2 The changes in the method of production of CORINE Spain and their effects

Since 2012, CORINE has been produced in Spain from the generalization of the national LUC database of reference: SIOSE (Hazeu et al. 2016). Before, it was manually obtained through photointerpretation of satellite imagery. This variation caused a lot of changes in the CORINE dataset for Spain, as studied in detail by García-Álvarez and Camacho Olmedo (2017) and Martínez-Fernández et al. (2019). Their studies show how the Spanish landscapes are differently conceptualized in terms of covers and uses in the CORINEs before and after 2012, which explains the important differences between CLC and CHA layers for the period 2006–2012 that we have detected.

Our analysis showed how, different to previous editions, agricultural areas and, specifically, heterogeneous agricultural areas have gained more relevance in recent CORINE editions of Spain. In addition to this allocation disagreement, the details of the dataset did also vary, with the new CORINEs showing more complex polygons, which do not always comply with the CORINE MMU and MMW rules (García-Álvarez and Camacho Olmedo 2017). Some inconsistencies in the landscape conceptualization have been also detected, such as the interpretation as urban fabric of areas made up of a mixture of not related artificial covers.

The change of methodology of CORINE in Spain affected the production of both CLC and CHA layers, although the studies previously cited have only focused on the former ones. CHA layers are also obtained through the generalization of SIOSE changes (European Environment Agency 2021). In this regard, if there are important differences in the complexity and conceptualization of the CLC layers before and after the methodology change, it is expected that the changes showed by CHA layers will be affected by these methodological differences as well. Our analysis proved how the number of non-coherent transition between CHA layers before and after the CORINE 2012 edition is up to 10 times bigger than between CHA layers prior to the methodology change. Thence, a detailed analysis of the effects of the methodology change of CORINE on the mapping of areas of change is required. It would allow to understand the potential uncertainties and inconsistencies of other products, such as the CLC accounting layers. Thus, even if CHA layers do not include technical changes, the transitions and categories that transition may be differently interpreted in one and other year, which makes the inter-year comparison inconsistent and uncertain.

The last edition of CORINE (2018) followed in Spain the same methodology than the 2012 edition. However, our results proved that important differences remain between the changes showed by CLC and CHA layers for that year. This may be caused by the change in the method of production of SIOSE (Delgado Hernández et al. 2017). Since 2017, SIOSE has been rebranded as SIOSE Alta Resolución (AR) (SIOSE High Resolution) and is being produced at very detailed scales and with finer MMU and MMW through the integration of national and regional spatial databases, such as the Spanish cadastre, the information collected as part of the Common Agricultural Policy (CAP) campaigns, LiDAR data or the Spanish forest map (Equipo Técnico Nacional SIOSE 2020). Before, SIOSE was obtained from manual photointerpretation of aerial imagery (Valcárcel Sanz and Castaño Fernández 2012). As far as SIOSE editions before and after 2017 have been obtained following different methods, there will be important differences among them, which will be also translated to the updating workflow of CORINE.

Although not that relevant and massive as in 2012, CLC layers between 2018 and 2012 show important areas of disagreement (up to 7% of the mapped surface) that cannot be attributed to LUC changes. Most of this disagreement is between agricultural areas and usually involve mixed agricultural covers, such as complex cultivation patterns and land principally occupied by agriculture, with significant areas of natural vegetation. This is a common feature of the technical changes between 2012 and 2006 caused by the CORINE methodology change (García-Álvarez and Camacho Olmedo 2017). In both cases we find a lot of technical changes that involve agricultural covers. However, changes and exchanges from, to and among agricultural covers are usually irrelevant in the Asturian landscapes, as reflected by the CHA layers.

Methodological changes are common to most of the available LUC datasets providing a timeseries of LUC maps (García-Álvarez et al. 2022). In the case of LUC datasets obtained through automatic or semi-automatic classification of remote sensing imagery, the use of imagery from different sensors or sources or taken at different points in time, as well as the use of different classification algorithms, explains most of the technical changes when studying LUC change from maps obtained at different times. Although different strategies have been studied and proposed to fix this problem, it remains one of the most relevant challenges in LUC mapping (Bontemps et al. 2012; Grekousis, Mountrakis, and Kavouras 2015).

In the last update of MODIS Land Cover, a hidden Markov model was introduced to achieve better consistency through the LUC maps for the different years (Sulla-Menashe et al. 2019). However, the dataset's developers still do not recommend its use for LUC change analysis because of the uncertainties that may arise when using the dataset for this purpose. LC-CCI maps are one of the few available LUC products that provide a consistent series of LUC maps that allow LUC change analysis (García-Álvarez et al. 2022). This was achieved through a change mapping approach that only focused on a few classes, avoiding uncertainties coming from the spectral confusion among categories as well as from exchanges among categories of similar nature (e.g. exchanges among different arable categories) (ESA 2017). Notwithstanding, some uncertainties are still present when using this map, which could be comparable to the uncertainties of CHA layers. Thus, the uncertainties and inconsistencies of CORINE are common to most of the available LUC maps, whose limitations are even bigger than the ones we have checked for CORINE.

Semi-automatic approaches for CORINE production are becoming more common across the different European countries, although the traditional photointerpretation remains the norm (European Environment Agency 2021). When making these methodological changes, official documentation on the new methods that have been implemented and their consequences on the database should be provided. Four years after the first studies showing the consequences of the new production method in the Spanish CORINE were published, official documentation about this methodological change is very scarce and only available at the European level (European Environment Agency 2021). For Spain, the IGN, in charge of producing CORINE and carrying out its generalization from SIOSE, has not produced any documentation on the change of methodology and its consequences, which makes the understanding of the database's uncertainty and inconsistencies harder for any interested user. For the least release of CORINE (2018), no information is available at any level explaining the technical changes between CLC layers from 2018 and 2012.

Semi-automated methodologies for change mapping may introduce important changes in the key deliverables of the CORINE time series and cannot be totally suitable for LUCC mapping. In this regard, the last CORINE user manual points out how the delineation and interpretation of LUC changes require local knowledge and a degree of abstraction that is difficult to achieve through semi-automated approaches (European Environment Agency 2021). The Portuguese experience, based on the automatic detection of changes for further manual photointerpretation, may be a balanced solution to update CORINE ensuring its historical coherence and consistency.

6.3 The problem of mixed categories

In almost all editions of CORINE, our results proved how mixed categories were involved in most of the change mapped by CHA and CLC layers. In CHA layers and the first two CLC layers (90, 00) most of this dynamism was driven by the changes among natural vegetated areas and by changes from and to transitional woodland/shrub. Moors and heathland, a category whose definition is similarly imprecise, was also one of the main drivers of the mapped LUC change in all CORINE editions. In the two last editions of CORINE, CLC layers showed a lot of changes where heterogeneous agricultural areas categories (complex cultivation patterns and land principally occupied by agriculture) are involved, which can be attributed to technical changes because of the different method of production of CORINE (see previous section).

Maucha, Büttner, and Pataki (2011) analysed the inconsistencies between CHA00 and CHA06 layers for all Europe. Mixed categories and, specifically, transitional woodland/shrub and complex cultivation patterns were found to be behind most of the checked inconsistencies. Although this may be caused by the important dynamism of the areas mapped under these categories, there may be a correlation between the use of mixed categories and the higher uncertainty of the mapping process. In fact, part of the inconsistencies detected by Maucha, Büttner, and Pataki (2011) were attributed to the subjectivity when mapping and differentiating these categories from other ones. The results of our study and, specifically, the categories involved in the technical changes detected in the 2012 and 2018 editions of CORINE point out in this direction.

The better characterization of the areas assigned to mixed categories could be a solution to this problem. In this regard, a survey carried out by the EEA among the CORINE participating countries revealed an interest of several countries to subdivide mixed categories such as complex cultivation patterns, land principally occupied by agriculture and transitional woodland/shrub (European Environment Agency 2021). The subdivision of the last category was the one that attracted more interest among the countries that were consulted. The detailed information provided by national LUC datasets, like SIOSE, could be useful when carrying out this task. Nonetheless, the generation of the new CLC+ may already give an answer to this problem. It will provide LUC information at finer spatial and thematic scales that the current CORINE (Kleeschulte et al. 2017).

On the other hand, when obtaining CORINE through semi-automated methods, like in the 2012 and 2018 editions, more attention should be paid to the uncertainty attached to the mapping of mixed categories. In this regard, these categories refer to abstract associations of elements that usually operate at specific scales. For CORINE, mixed categories easy to delineate and understand at that scale can refer to a different landscape conceptualization at finer scales like SIOSE. It is the so-called individualistic fallacy problem (Cao et al. 1997). Now, when CORINE is generalized from a very high detailed LUC database (SIOSE Alta Resolución), the problem can be bigger and the obtained result more uncertain, as revealed in our case by the size of the transitions involving mixed agricultural categories since CORINE has been obtained from SIOSE in 2012.

7. Conclusions

The use of the CORINE's time series comes with important limitations and uncertainties that not all users know. CORINE status layers (CLC) and CORINE layers of changes (CHA) show different information, which cannot be only attributed to the different scale of the two products. CLC layers include a lot of inconsistencies and technical changes that hamper their comparison to analyse LUC change through time. CHA layers only present small inconsistencies, which could be easily addressed through a specific analysis, as already carried out in the initial editions of CORINE. The production of a consistent series of CLC vector layers through backdating, following the approach used in the generation of the CLC accounting layers, could be a solution to avoid the current inconsistencies of the CLC layers timeseries.

Most of the changes in CLC and CHA layers are driven by mixed categories, which have flexible meanings and are not easy to understand. By splitting them in more-precise categories or through the provision of more specific definitions, we could avoid some of these uncertainties. Nonetheless, when obtained through semi-automatic mapping approaches, specific attention should be paid to the delineation of these mixed categories, which cannot be correctly mapped following these approaches.

In Spain, the change of production of CORINE since 2012 has meant a lot of changes in the database that require further analysis, especially regarding its impact on the production of CHA layers. The recent change in the production methodology of the national database SIOSE in 2017 has also had an impact in the last edition of CORINE, which requires attention. In addition to the implementation of new methods and strategies to deal with some of the detected uncertainties and inconsistencies, we also require more and better information. In this regard, we have identified a general lack of transparency and detailed information on the uncertainties and changes of the method of production of CORINE in Spain.

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Data availability statement

The data that support the findings of this study are available in Copernicus Land Monitoring Service at https://land.copernicus.eu/pan-european/corine-land-cover.

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