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Experts' Perception of the Key Drivers of Land-Use/Land-Cover Changes in Serbia from 1990 to 2012

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Abstract: Negative trends in land use and land cover changes (LULCCs) are embodied in environmental, economic and social problems, keeping entire societies away from sustainable development goals (SDGs). This recognition incites a need for securing comprehensive and transdiciplinary knowledge on the complex interplay between LULCCs and their drivers. It should inform land use policy makers and produce adequate sustainable social responses. However, fragmentation in both academic and governmental arenas is an important impediment to the needed application of sustainability to land use policy. With this regard, the study offers a transdisciplinary, bottom-up and reproducible framework for understanding key drivers of LULCCs at the national/regional level where sustainable land use policies should be defined. Its main component is the repeated measure ANOVA of the experts' survey data. The analysis allows aggregation of experts' different disciplinary, professional and experiential perceptions and produces comparable results. It is tested in Serbia in three sub-periods during post-socialism. Main results confirm that LULCCs and drivers are complexly intertwined and need to be analysed within a comprehensive and transdisciplinary framework. Furthermore, the study should enable the transdisciplinary discussion, learning and knowledge coproduction that are required to inform land use policy makers about the needed trans-sectoral coproduction of policy responses towards SDGs.

Keywords: land use/land cover change drivers; national/regional level; transdisciplinary research; repeated measure ANOVA; experts' survey; Serbia

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1. Introduction

Land-use and land-cover change (LULCC) is the result of a long-term complex interaction between humans and nature. It has a spatial and a temporal dimension and is determined by the natural, social and economic conditions under which it takes place [1,2]. In the recent period, the negative consequences of LULCCs are intensified and more evident, from the global to the local level. Past interventions to promote sustainable land use have proven to be insufficient to address drivers which include changes in value systems, economic and social trends, technological innovations and political priorities regarding growth, climate change and energy [3]. Recent [4] also argues that better land use governance requires the use of a broader set of public policies to influence land use. In order to understand the complex interplay between LULCCs and drivers (i.e., land dynamics), and provide more sustainable responses, there is an increased demand for more transdisciplinary frameworks for knowledge coproduction that transcend the limits of disciplinary domains [2,5–7].

In this regard, transdisciplinary understandings of land dynamics in a country or a region become even more significant because strategic guidelines towards more sustainable

land use are defined within a land use policy, planning and management on a national or/and regional level (depending on the assembled spatial governance system).

However, in their review article, [8] assert that studies on LULCC drivers are usually focused on one LULCC, only covering a small area (around 75%, considered an area smaller than 1000 km^2). Similarly, after a literature review, [6] found that "transdiciplinarity" has been so far insufficiently elaborated and practiced even though land use science appears to be a designated field for this kind of research.

The present study aims at establishing an evolving methodology for identifying the key drivers of LULCCs and a more transdisciplinary understanding of their interplay at a territorial level (national/regional) that sets its broader context, as well as policy guidelines towards more sustainable land uses. It offers a transparent, bottom-up methodology for aggregating academic and professional perspectives with comparable, empirical results. This type of research has been perceived as exceptionally important in terms of enabling comparative analyses and the standardization of the framework for land system research [5,9,10]. By being tested in a concrete case in Serbia, it also offers an integrated study on its land dynamics, which has been missing so far (see [8]).

With these aims in view, the transdisciplinary drivers—land-use/land-cover change analysis (TDLCA) framework has been constructed as a tool for identifying the key drivers of LULCCs at the national/regional level for three sub-periods. Firstly, recent comprehensive studies focusing on the drivers and LULCCs have been reviewed and a drivers-LULCCs matrix has been constructed. The matrix consists of six major groups of drivers (by [8]) and seven main types of LULCCs (by [11]). Experts' survey questions are based on this matrix. Experts (academics and professionals) have relevant competencies in specific territorial land-use/land-cover research and practice, yet different values, disciplinary backgrounds and experiences. The key importance of the drivers for LULCCs is identified by the repeated measure analysis of variance (ANOVA) [12]. The analysis mitigates possible experts' biases and aggregates their different perceptions [13,14].

The TDLCA framework is tested in Serbia for three sub-periods which marked the country's contextual post-socialism micro-shifts. The experts perceive that the importance of the drivers in Serbia varies depending on the LULCC type and that the key drivers in one sub-period/context may not have the same importance in the other. Standardization with certain adaptability, a bottom-up approach and quantifiable results make the TDLCA framework generally reproducible and comparable. Agreements, as well as disagreements reflected in the statistical results, can be used for opening transdisciplinary discussions about the drivers' importance. Furthermore, the study can be used as an input to the general understanding of land dynamics at lower levels (e.g., as it was used to inform scenario making needed for the local educational project elaboration. The project was presented at the 2021 International Geodesign Collaboration). It also enables the identification of interactions among drivers, which can serve as a more in-depth knowledge needed for preparing models of LULCCs. In general terms, the study aims at encouraging further comparative research towards a more coherent, organized and contextualized transdisciplinary knowledge coproduction on land dynamics and, consequently, more sustainable trans-sectoral coproduction of responses within land use policy making.

2. Materials and Methods

Changes in land use and land cover are the result of complex interactions among numerous drivers operating at various spatial levels. The complexity of the drivers has attracted considerable attention in recent years in a wide range of scholarly disciplines and research fields [15]. Noteworthy contributions to systematizing the knowledge on LULCCs and the division between underlying (factors of change) and proximate drivers, i.e., LULCCs, have been made by [8,16–18].

In order to facilitate the synthesis, enable comparative analyses of case studies all over the world and make general conclusions, many authors call for the standardization of the conceptual framework for the study of the drivers of LULCC [5,9,10]. Furthermore, there

is a growing body of literature promoting the use of combined methodologies in the study of complex interactions within LULCC processes (e.g., [19]).

However, in spite of great interest and profuse research [20], the concept of LULCC drivers has still not reached a standardized framework.

In parallel, calls for a more transdiciplinary land use research have been emerging as a necessary basis for developing theory(ies) of land use [15]. However, according to [6], trandisciplinarity as a concept and approach in land use science has been insufficiently elaborated and practised. Based on a literature review, they found that "transdiciplinarity" is a vaguely defined concept, even though land use science appears to be a designated field for this kind of research. These authors have also found that: there is a theory–practice gap, empirical findings are scarce and dispersed over several disciplines and case studies, perspectives from non-scientific actors are insufficient, the research lacks adequate quality criteria and approaches for the evaluation and its contributions to achieving sustainable land use still remain unclear [6].

On the other hand, social responses to unsustainable complex land dynamics require an improved application of sustainability in policy areas. Transdisciplinary knowledge production in which individuals with different disciplinary, professional and experiential backgrounds combine academic and practice-based knowledge in the shared production, interpretation and ultimate use of scientific knowledge and its products has been perceived as necessary to support social learning and sustainable policy making [7].

The potential of aggregating different knowledge by using the opinions and perceptions of experts has been recognized in social [21], mainly political sciences [14]; however, it has also been used in prominent studies on LULCC (e.g., [9]). References [14,22] state that the knowledge that experts have is already synthesized based on multiple sources of information and methods; it is especially important for exploring topics that might otherwise be difficult to study systematically and which are temporally distant from the domain of the discussed construct.

A standard statistical analysis for comparing two or more repeated measures observed in different time periods is the repeated measure analysis of variance (ANOVA) [12]. When used to process the expert survey data, the repeated measure ANOVA produces an average of the highest values for different variables, mitigates experts' possible cognitive and judgment biases and aggregates their different disciplinary perceptions [13,14].

Based on these findings and assumptions, the TDLCA framework was conceived: find main drivers and LULCCs, interrelate them in a matrix, use the drivers-LULCCs matrix as the basis of the survey, find a relevant sample of experts, conduct the survey and use the repeated measure ANOVA for survey data processing to obtain results.

2.1. The TDLCA Framework

Proximate drivers imply a direct action on a particular stretch of land; they become manifest at a local level and are mainly related and limited to activities such as construction, agriculture or forestry [23]. Reference [11] defines them as processes or trends in LULCC and identify them using the Conversion Table method for processing data generated by CORINE Land Cover. More specifically, the Conversion Table, using the information regarding the land-cover changes on the second level of the CLC nomenclature classes, has translated these changes into seven "land-cover flows" [11] (pp. 23–24). In the subsequent sections, we will address these "flows", i.e., proximate drivers, as "LULCCs": urban sprawl; agricultural intensification; agricultural extensification; afforestation; deforestation; water bodies' construction and management; as well as others.

In the case of European countries, land-cover analysis and the identification of land-cover changes between 1990 and 2012 can be based on the CORINE Land Cover (CLC) for 1990, 2000, 2006 and 2012, and CORINE Land Cover Change (CLCC) databases for three sub-periods: 1990–2000, 2000–2006 and 2006–2012 [24]. The identified five major LULCCs (all aforementioned except the categories of "water bodies' construction and management" and "others" which usually have a lower share in the total body of LULCCs) strongly relate

to the global land-use/land-cover trends identified in the 1982–2016 period by [25], i.e., urbanization, cropland intensification, agricultural expansion, reforestation or afforestation and (tropical) deforestation. This makes the presented classification of LULCCs largely reproducible and comparable.

Underlying drivers determine the context for the relationship between humans and nature. They consist of different social, political, economic, demographic, technological, cultural and biophysical variables, diffusely influence one or more proximate drivers, i.e., LULCCs [10], and appear at multiple territorial levels (global, national, regional and local). The most comprehensive classification has been recently devised by [8], who reviewed 144 studies in order to identify the drivers of landscape change in Europe between 1990 and 2015. They have classified drivers into five major groups: political–institutional, economic, natural–spatial, cultural and technological. Cultural drivers in this classification entail variables relating to demography, such as population size, distribution and age structure. We support the stance of some other authors [10,26] who suggest that these variables be separated from cultural drivers into a distinct, sixth group of demographic drivers. In the following sections, we will refer to underlying drivers as "drivers". These major groups of drivers cover most of the factors that initiate LULCCs and, therefore, they too can take the part of the comprehensive drivers–LULCCs matrix.

The matrix enables the driver–LULCC interrelation, i.e., each driver (political–institutional, economic, natural–spatial, cultural, demographic and technological) is related with each LULCC (Urban sprawl, Agricultural intensification, Agricultural extensification, Afforestation, Deforestation, Water bodies' construction and management). This contributes to the standardized, comprehensive part of the TDLCA framework, but also allows certain adaptability demanded by its testing in a particular case.

In order to interrelate different drivers with a particular LULCC and assess their importance in a large-scale context, land-use/land-cover-specialized experts should be consulted. Following the structure of the drivers–LULCCs matrix, experts' perceptions can be collected in a survey in which multiple individuals can be asked to rate multiple interrelated targets.

This "crossed design" offers the greatest leverage in recovering information about the differential application of ratings across experts [14]. Also, the quality of an expert survey largely depends on the experts' attentiveness to the task, the level of relevant knowledge and their understanding of the questions, answer choices and/or the rating scale used in the survey [14]. The repeated measure ANOVA of the survey data can mitigate the possible cognitive and judgment biases of experts [13] and help aggregate their different perceptions (based on their background and experience) on the key importance of various drivers in different types of LULCC within different sub-periods/contexts [14].

2.2. Case Study: Serbia during the 1990–2012 Period

In order to test the TDLCA framework in Serbia during the 1990–2012 period, data from [27], legal and planning documents, academic literature on social transition [28–30] and land-use/land-cover issues in Serbia were consulted (e.g., [31,32]), along with other sources, cited in the following sections.

2.2.1. General Information

The Republic of Serbia is located in South-Eastern Europe. It was one of the constituent parts of the former Socialist Federal Republic of Yugoslavia, a country that tragically disintegrated in the early 1990s. In the post-socialist period, Serbia is designated as one of the Western Balkan countries. From the outward perspective, "Western Balkans" as a region is associated with a very complex historical and transitional processes, as well as slow EU integration. From the inward perspective, in political and institutional, economic, natural and spatial, cultural, demographic and technological terms, Serbia is regionally uneven and divided into a generally more favourable North and less favourable South with a highly centralized capital city—Belgrade.

Furthermore, post-socialism generally implies neoliberal economic restructuring, the legacy of socialism and pre-socialism and the passage of 'transition' [33]. These are reflected in peculiar post-socialist circumstances in Serbia (described in three sub-periods) which set a new context for very complex LULCC-related issues. Namely, built-up land, with or without a building permit, is spreading and occupying fertile land, land affected by floods, erosion and landslides; forest land is spreading into unused agricultural land spontaneously; while agricultural land is either overused or completely abandoned [34]. Land policy and administration are unsynchronized and uncoordinated, due to which the issues of land tenure, use and development are generally unresolved [35,36].

2.2.2. The 1990–2000 Sub-Period

An extremely difficult period marked by civil wars on the territory of the former Yugoslavia, the collapse of the socialist system, the establishment of an autocratic regime, isolation, economic and social decline and impetuous processes. The transition towards a capitalist society, which was also unfolding in the other countries of Central and South-Eastern Europe, was very slow. Additionally burdened by the causes and consequences of the NATO intervention in 1999, the process was postponed until the democratic revolution in 2000.

2.2.3. The 2000–2006 Sub-Period

The democratic revolution at the beginning of the period enabled an accelerated transition towards a capitalist system supported by European and international institutions. This included defining sustainable development in numerous official documents and strategies as one of the most important societal goals. The imperative of rapid change, accompanied by insufficiently built capacities, fostered intensified activities, but also the uncritical adoption of neoliberal mantras, poorly conducted privatization of publicly owned companies, corruption and polarization regarding social values.

2.2.4. The 2006–2012 Sub-Period

The period was marked by the striving to cope with the consequences of previous activities, further aggravated by the independence of Montenegro (from the joint state Serbia and Montenegro, which was not opposed by Serbia), proclaimed in 2006, the unilateral proclamation of independence in Kosovo in 2008 and the Global Economic Crisis in the same year. As it was necessary to reduce the chance of national bankruptcy, the key decisions were increasingly made under the guidance of international financial institutions. Capacity building to attract foreign investment and austerity measures in the public sector boosted economic and social stratification.

3. Results

3.1. The TDLCA Framework Testing in Serbia during the 1990–2012 Period

3.1.1. Identifying the Drivers of Land-Cover Change in Serbia during the Three Sub-Periods

The mentioned classification by [8] as the first element of the framework was slightly modified based on the academic literature and depending on the availability of statistical data and specific conditions in Serbia. More specifically, the set of the distinctive variables of the population were separated from Cultural drivers into a distinct group—Demographic drivers. The data on the prices of agricultural and forest products from the original classification were abstracted within the general assessment of the market and retail growth. "Topography and spatial configuration" were replaced with "relief; current land cover, infrastructure and public services", because we expected it to be readily understood by respondents from Serbia. E-government was added to Technological drivers due to its rising importance regarding land-use management not only in Serbia.

As a result, we have established the following classification of drivers:

- Political–institutional drivers include sectoral policies and strategies relevant to the process and legal documents relevant to the process including property rights, spatial and urban policies and plans;
- Economic drivers include structural economic change, especially in activities relevant to the process, taxes and subsidies, market and retail growth (real-estate, goods and services market);
- Natural–spatial drivers include relief, climate, hydrology, soil characteristics and natural hazards, current land cover, infrastructure and public services;
- Cultural drivers include public attitudes, values and beliefs, individual and household lifestyles and behaviour;
- Demographic drivers include population size and density, age and education structures and migrations;
- Technological drivers include modernization of society, of the land management system and of local community units (e-government).

A literature review, national statistical data and our previous research [31] made it possible to specify the drivers' main features for Serbia in the three sub-periods.

The 1990–2000 Sub-Period

Political–institutional: sectoral policies and laws intended to delay the transition in the context of Yugoslavia's disintegration, wars, centralization and international isolation.

Economic: the international economic sanctions hindered access to markets; sales dropped; production and the growth of services collapsed; grey and black economy grew to an extreme extent, subsidies in all areas were reduced.

Natural–spatial: reduced production and exploitation of resources led to a relative improvement of soil and hydrological features; neglected and underdeveloped infrastructure and public services. The percentage of the first-level CLC classes in total area from 1990 to 2000: artificial surfaces from 3.18% to 3.31%; agricultural areas from 57.09% to 57.19%; forest and seminatural areas from 38.37% to 38.08%; wetlands from 0.27% to 0.30%; water bodies from 1.09% to 1.12%.

Demographic: population of 7,822,795/population density 88.53 people per km^2; average age 37.1; 40% with completed secondary education, 5.06% with higher education. Intensive emigration to developed countries and immigration of Serbian and other refugees from war-affected areas of ex-Yugoslavia.

Cultural: relative domination of non-civic attitudes, values and beliefs regarding ethnic tolerance, inter-confessional harmony, human equality, tolerance of sexual minorities and the rule of law. Traditional, agricultural and patriarchal lifestyles in rural communities in contrast to the lifestyles in urban communities. Behaviours focused on self-actualization and health, environmental, social and economic rights and responsibilities were largely marginalized. Consumerism was limited due to the poor offer of products and services and low income.

Technological: stagnating technological modernization and the emerging uptake of information technology (IT) among individual users and institutions; delays in maintaining and improving the land-management system; e-government did not exist.

The 2000–2006 Sub-Period

Political–institutional: abrupt transition towards capitalism, democratization and decentralization supported by the international and EU community. Intensified development of strategies, plans and laws aimed at the accession to the EU and fostering reforms with a special focus on spatial interventions and regulation.

Economic: access to new markets and sales growth due to the lifting of the economic sanctions; intensification and relative diversification of space-consuming, low-productivity and income-creating activities. Controversial privatization of state-owned factories and further growth of the services sector; initial steps in establishing systems for tax collection and subsidy assignment, especially for new jobs.

Natural–spatial: intensified degradation processes and the pollution of natural resources due to increased production; the reconstruction and moderate development of infrastructure and public services. Intensified pressure on agriculture and forest land use, especially in the close vicinity of urban areas. Percentage of the first-level CLC classes in the total area from 2000–2006: artificial surfaces from 3.31% to 3.63%; agricultural areas from 57.19% to 55.63%; forest and seminatural areas from 38.08% to 39.25%; wetlands from 0.30% to 0.33%; water bodies from 1.12% to 1.16%.

Demographic: population of 7,498,001/population density 84.85 people per km^2; average age 40.2; 41.19% with completed secondary education, 6.62% with higher education. Significantly decreased intensity of migrations, except for internal migrations from rural to urban settlements and from small urban settlements to major urban centres.

Cultural: democratic change in 2000, accompanied with lingering crisis and corruption; four distinct social groups subscribed to different ratios of civic and non-civic attitudes, values and beliefs: hard liberals, soft liberals, ultra-nationalists and a growing apolitical group. The differences between the rich minority and the poor majority were more obvious. The same applies to the differences between rural, traditional and patriarchal and relatively modernized municipalities. Behaviours related to the mentioned rights and responsibilities were promoted. Consumerism was invigorated due to a better offer of products and services, higher incomes and availability of loans.

Technological: sporadic and moderate technological modernization in the economy. Increasingly massive implementation of IT in governance; land-management system was relatively improved due to various international projects and donations.

The 2006–2012 Sub-Period

Political–institutional: intensified development of strategies, plans and laws aimed at the accession to the EU and national spatial interventions, and diminished effects of regulation, democratization and decentralization. The implementation of austerity measures in the public sector after the 2008 Global Economic Crisis.

Economic: increased production and the further growth of the services sector; intensified market expansion and sales growth; stricter tax collection and the diversification of subsidy opportunities, accompanied with significantly reduced funding allocated for subsidies after the 2008 Global Economic Crisis.

Natural–spatial: intensified degradation processes and pollution, accompanied with the negative impact of global climate changes and increased natural hazard risk, especially flood risk; focus was on infrastructure development, with moderate results, while the public service development was affected by austerity measures. Intensified problems related to over- or under-used and polluted land. Percentage of the first-level CLC classes in the total area from 2006–2012: artificial surfaces from 3.63% to 3.67%; agricultural areas from 55.63% to 55.68%; forest and seminatural areas from 39.25% to 39.27%; wetlands from 0.33% to 0.33%; the share of water bodies has not changed (1.16%).

Demographic: population of 7,186,862/population density 81.33 people per km^2; average age 42.2; 48.93% with completed secondary education, 10.59% with higher education. Low birth rates and re-intensified emigration, especially brain drain towards major urban areas in the country and to developed countries.

Cultural: lingering and poor transition resulted in the growing apolitical group, while hard liberals and ultra-nationalists experienced further polarization. The urban–rural and rich–poor polarization in terms of lifestyle was intensified. Further promotion of tolerance and rights and responsibilities was undermined by the 'delegitimization' of the EU integration. Relatively increased consumerism.

Technological: modernization in industry and further growth and improvement of IT application were increasingly dependent on the recognition of benefits and the availability of economic resources; establishment of a hybrid land-management system in terms of technological improvements (in some areas, the system was highly developed, whereas, in

others, it was neglected and outdated); improving infrastructure towards developing the e-government.

3.1.2. Identified LULCCs in Serbia for Three Sub-Periods

The land-cover analysis and the identification of LULCCs in Serbia between 1990 and 2012 were based on the CORINE Land Cover (CLC) for 1990, 2000, 2006 and 2012 and CORINE Land Cover Change (CLCC) databases for Serbia for the three sub-periods (1990–2000, 2000–2006 and 2006–2012). They were processed using the ArcGIS Desktop 10.5 software package. In the territory of Serbia, 29 CLC land-cover classes were identified for the 1990–2012 period.

After the CLC database had been created, the Conversion Table devised by [11] was applied. Six major LULCCs were identified in Serbia in three sub-periods. The category "other changes" was not taken into consideration in the land-cover flow context, similar to the "no change" category, which entails the changes observed among the third level of CLC classes within each second-level CLC class [11].

The numeric values and share of six types of LULCC in total LULCCs in Serbia in the three sub-periods is given in Table 1.

Table 1. The share of individual LULLC change in total change in Serbia in the three sub-periods.

Land Use/Land Cover Changes	Change Area According to Process in the 1990–2000 Period		Change Area According to Process in the 2000–2006 Period		Change Area According to Process in the 2006–2012 Period	
	ha	%	ha	%	ha	%
Urban sprawl	3978.44	4.97	4298.02	12.34	4173.01	11.14
Agricultural intensification	5548.19	6.93	6143.12	17.64	3353.46	8.95
Agricultural extensification	15,220.65	19.02	1871.61	5.37	4307.78	11.50
Aforestation	29,226.28	36.52	9050.75	25.99	10,598.41	28.29
Deforestation	16,144.37	20.17	9645.26	27.70	11,036.70	29.46
Water bodies' construction and management	1572.39	1.96	1627.28	4.67	1146.73	3.06

3.1.3. Assessing the Importance of Drivers for Each LULCC

The assessment of the drivers' importance in each LULCC in Serbia in the 1990–2012 period was performed using the expert survey method.

In order to ensure the satisfactory quality of the expert survey in this study, the following procedure was applied: the survey was based on a list of six major groups of drivers associated with the six processes of LULCC in Serbia; the importance of the drivers was assessed for the three sub-periods. The rating was based on a scale ranging from 0 (no influence) to 10 (the greatest impact). Due to the complexity of the topic and the desire to decrease the random error in the survey, the option "I cannot say" was added to the answer choices, as well as the possibility to make comments [37] for the cases where experts perceived some incoherence with the task they should perform.

The "crossed design" of the survey was chosen in order to reflect the drivers-LULCCs matrix. Subsequently, we identified the target units which included the drivers, the sub-periods and the six types of LULCCs previously identified in Serbia. Since the aggregate error is reduced when a wider range of individuals with different perspectives and knowledge on the target unit contribute to the aggregate [14], we considered a specific "pool of experts". A more detailed description of the process of selecting and communicating with experts is given in the Supplementary Materials.

In total, 17 experts were contacted and 13 assessments were received, while two were excluded due to the insufficient information provided. Out of 11 assessments that were analysed, 8 were from academics (three spatial planners, one geographer, two forest engineers, one economist and one land surveyor all with highest competence in land change issues) and 3 from the invited professionals. The mean (M) age of our respondents was 42.08 (ages ranged from 35 to 54), and Sd (standard deviation) was 6.65. More information about how the survey was conducted can be found in Supplementary Materials.

Finally, descriptive statistics was used to determine the mean values, i.e., the importance of the various drivers of LULCCs in Serbia in the three sub-periods. The process is explained in the following sections.

3.1.4. Identifying the Key Drivers of LULCCs

The data collected in the expert survey were processed by the repeated measure ANOVA conducted using the software package IBM SPSS Statistics 20. We used means and standard deviations as descriptive statistics to present the importance of the various drivers of LULCCs in Serbia in the three sub-periods (Table 2). The three-factorial analysis of variance for repeated measures was used to test the effects of the LULCC type, the driver type and the sub-period on the experts' assessment of drivers' importance. Since the experts were of different ages, we also performed a three-factorial analysis of covariance for repeated measures, adding expert's age as a covariate (Tables 3 and 4).

Perceived Importance of Drivers for Each Type of LULCC

The experts' assessment of the drivers' importance in relation to a LULCC and sub-periods in Serbia showed that some experts did not assess the importance of all drivers for the given sub-periods. Comments were not added, except in the case of water bodies' construction and management. Namely, two experts commented that the area affected by this LULCC was larger than the spatial distribution shown by the CLCC dataset. The mean values for the perceived importance of various drivers are shown in Table 2.

Table 2. Drivers' mean values and standard errors.

D	SP	US		AI		AE		A		Df		WB	
		Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
PI	SP1	4.1111	0.24	2.7778	0.28	3.4444	0.44	4.4444	0.15	3	0.51	4	0.76
	SP2	5.6667	0.19	3.4444	0.19	3.6667	0.58	5.4444	0.34	3.3333	0.54	4.8333	0.74
	SP3	6.1111	0.29	4	0.59	3.8889	0.68	5.4444	0.40	3.4444	0.59	5.3333	0.88
E	SP1	2.7778	0.15	3.3333	0.19	3.6667	0.19	2.4444	0.24	2.4444	0.29	1.6667	0.33
	SP2	5.6667	0.33	5.3333	0.25	5.3333	0.10	3.3333	0.38	3.3333	0.38	2.4433	0.22
	SP3	5.8889	0.29	5.6667	0.19	5.8889	0.19	3.4444	0.43	3.3333	0.38	2.8867	0.24
NS	SP1	3	0.54	4.1111	0.34	3.3333	0.17	2.5556	0.15	3.5556	0.55	7	0.87
	SP2	3.8889	0.43	4.4444	0.19	3.8889	0.29	3	0.25	4	0.59	7.8867	0.82
	SP3	4.1111	0.48	4.4444	0.24	4.2222	0.45	3	0.25	4.2222	0.53	7.3333	1.09
Dm	SP1	2.8889	0.19	5.2222	0.19	5.2222	0.31	2.8889	0.53	3.2222	0.22	3.6667	1.01
	SP2	3.1111	0.20	5.6667	0.42	5.1111	0.44	3.1111	0.56	3.3333	0.35	4.3333	1.01
	SP3	3.5556	0.06	5.6667	0.19	5.3333	0.33	3.1111	0.56	3.5556	0.19	4.3333	1.01
C	SP1	2.6667	0.25	4.3333	0.29	5.2222	0.20	3.4444	0.24	5.3333	0.84	4.5533	1.30
	SP2	2.6667	0.19	4.3333	0.19	4.7778	0.39	3.5556	0.29	5.5556	0.87	4.7767	1.31
	SP3	2.2222	0.06	4.2222	0.24	5	0.35	3.6667	0.35	5.7778	0.78	4.7767	1.31
T	SP1	1.6667	0.19	3.2222	0.19	3.4444	0.06	2.1111	0.22	2.6667	0.25	3.11	0.45
	SP2	3.2222	0.20	5	0.25	5.1111	0.06	3.1111	0.31	3.3333	0.44	5.22	0.66
	SP3	4.4444	0.19	5.6667	0.10	5.5556	0.19	3.6667	0.38	3.4444	0.43	6.3333	0.88

D—Driver; PI—Political and institutional; E—economic; NS—natural and spatial; Dm—demographic; C—cultural; T—technological; SP—sub-period; SP1—the 1990–2000 period; SP2—the 2000–2006 period; SP3—the 2006–2012 period; US—urban sprawl; AI—agricultural intensification; AE—agricultural extensification; A—afforestation; Df—deforestation; WB—water bodies' construction & management; SE—standard error.

Table 3. Effects of the change, the driver type and the sub-period on experts' assessment.

	df1	df2	F	p	η^2
land-use/land-cover change	5	10	1.668	0.230	0.455
Driver	5	10	0.092	0.992	0.044
Sub-period	2	4	39.883	0.002	0.952
land-use/land-cover change * driver	25	50	2.107	0.012	0.513
land-use/land-cover change * sub-period	10	20	2.134	0.072	0.516
land-use/land-cover driver * sub-period	10	20	8.049	0.000	0.801
land-use/land-cover change * driver * sub-period	50	100	1.612	0.022	0.446

df1—degrees of freedom factor 1; df2—degrees of freedom factor 2; F—main effect, p—probability value, η^2—*eta-squared* as a common estimate of the effect size.

Table 4. The effects of the LULCC, driver, sub-period and expert's age on the experts' assessment.

	df1	df2	F	p	η^2
LULCC	5	5	0.748	0.621	0.428
LULCC * age	5	5	0.708	0.643	0.415
Driver	5	5	0.650	0.676	0.394
Driver * age	5	5	0.649	0.676	0.394
Period	2	2	0.126	0.888	0.112
Period * age	2	2	0.894	0.528	0.472
LULCC * driver	25	25	0.923	0.578	0.480
LULCC * driver * age	25	25	0.918	0.584	0.479
LULCC * period	10	10	0.836	0.609	0.455
LULCC * period * age	10	10	0.958	0.526	0.489
Driver * period	10	10	0.414	0.910	0.293
Driver * period * age	10	10	0.674	0.728	0.403
LULCC * driver * period	50	50	2.374	0.001	0.704
LULCC * driver * period * age	50	50	2.660	0.000	0.727

df1—degrees of freedom factor 1; df2—degrees of freedom factor 2; F—main effect, p—probability value, η^2—*eta-squared* as a common estimate of the effect size.

Identified Key Importance of Drivers

We used the three-factorial analysis of variance for repeated measures in order to test the effects of the LULCC type, the driver types and the sub-period on the experts' assessment of drivers' importance (Table 3). The results show statistically significant main effects of sub-periods, and the interactions of LULCCs and drivers, LULCC drivers and sub-periods, as well as the interaction of all three factors (LULCC, driver and sub-period).

Since the experts were of different ages, we also performed a three-factorial analysis of covariance for repeated measures, adding expert's age as a covariate. This time, the analysis showed that only the interactions of three factors (LULCC type, driver type and period), as well as their interaction with age (Table 4), were significant.

As the interaction of all three factors was significant, after controlling for age, we performed post-hoc LSD tests to determine which differences contributed to this interaction. Of course, LSD tests were performed while we controlled for age. Statistically significant differences determined by these tests are shown in Tables 5 and 6.

Table 5. LSD post-hoc tests between driver types for sub-periods and land-use/land-cover change (LULCC) types.

LULCC	Sub-Period	(I) Driver	(J) Driver	Mean Difference (I−J)	SE	*p*
US	1990–2000	PI	C	1.444 *	0.059	0.026
			T	2.444	0.212	0.055
	2000–2006	PI	T	2.444 *	0.130	0.034
		E	C	3.000 *	0.153	0.033
			T	2.444 *	0.106	0.028
AI	1990–2000	C	T	1.111 *	0.059	0.034
AE	1990–2000	E	C	−1.556 *	0.024	0.010
		NS	C	−1.889 *	0.047	0.016
A	1990–2000	PI	T	2.333 *	0.118	0.032
	2000–2006	PI	E	2.111 *	0.142	0.043
			C	1.889 *	0.142	0.048
	2006–2012	PI	E	2.000 *	0.153	0.049
			C	1.778 *	0.130	0.046
Df	2000–2006	NS	C	−1.556 *	0.083	0.034
	2006–2012	NS	C	−1.556 *	0.083	0.034
WB	2000–2006	NS	Dm	3.553	0.309	0.055
		Dm	T	−0.887	0.080	0.057
		C	T	−0.443 *	0.022	0.032

I and J stand for different types of variables; SE—standard error of mean difference; p is a primary value used to quantify the statistical significance of the results of a hypothesis test; * indicates statistically significant differences i.e., the value of $p \leq 0.05$; PI—Political-institutional; E—economic; NS—natural-spatial; Dm—demographic; C- cultural; T—technological; SP—sub-period; SP1—the 1990–2000 period; SP2—the 2000–2006 period; SP3—the 2006–2012 period; US—urban sprawl; AI—agricultural intensification; AE—agricultural extensification; A—afforestation; Df—deforestation; WB—water bodies' construction & management.

Table 6. LSD post-hoc tests between sub-periods, for different driver and change types.

LULCC	Driver	(I) Sub-Period	(J) Sub-Period	Mean Difference (I−J)	SE	*p*
Urban sprawl	Economic	1990–2000	2000–2006	−2.889 *	0.094	0.021
		2006–2012	1990–2000	3.111 *	0.165	0.034
	Technological	2006–2012	2000–2006	1.222 *	0.012	0.006
Agricultural intensification	Natural and spatial	2006–2012	1990–2000	0.889 *	0.059	0.042
	Technological	1990–2000	2000–2006	−1.667	0.153	0.058
Water bodies'c&m	Political and institutional	2006–2012	1990–2000	1.333 *	0.035	0.017

I and J stand for different types of variables; SE—standard error of mean difference; *p* is a primary value used to quantify the statistical significance of the results of a hypothesis test; * indicates statistically significant differences i.e., the value of $p \leq 0.05$.

4. Discussion

Before providing a more focused analysis, it should be highlighted that, as shown in the identified drivers for three periods in Serbia, the importance of the international level (i.e., isolation, economic sanctions, support in the transition period, the 2008 Global Economic Crisis) was relevant for setting the overall context in Serbia and, in our opinion, it should be considered in this kind of study.

The use of the drivers-LULCCs matrix with the aforementioned modifications of the detailed list of drivers was justified in the case of Serbia.

According to the assessment of the drivers' main features, 1990–2000 can be described as a sub-period/context of regression, 2000–2006 as a period of progression and 2006–2012 as a period/context of stagnation.

The results for LULCCs in Serbia for the entire period show a decline in agricultural areas, while other land-use/land-cover classes, especially forest and artificial areas, show some growth (Table 1).

The expert survey provided important results. Statistically significant differences (Table 5) show significant main effects of sub-periods, but also significant interactions of LULCC types and driver types, driver types and sub-periods, as well as the interaction of all three factors (LULCC type, driver type and sub-period). In this regard, the results on mean values and statistical significance acquired by the LSD tests and presented in Tables 5 and 6 will be contextualized and discussed in the following section.

4.1. Drivers' Key Importance in Relation to LULCCs

4.1.1. Urban Sprawl

The key drivers for this process in the first two sub-periods, as perceived by experts (Tables 5 and 6), were political–institutional. These drivers were perceived by experts as more important than cultural and technological during regression and more important than technological during progression. While the economic drivers were perceived as the second most important, the statistically significant difference shows that they were perceived as more important than cultural and technological during progression. The experts also perceived the economic drivers of urban sprawl as more important in the last two sub-periods than in the period of regression (Table 6). This can be associated to the intensification of economic activities after the international economic sanctions and the need for their localization. The perceived importance of the technological drivers increased in the last sub-period, even though it was a period of stagnation in other aspects (Table 6).

Accordingly, experts perceived political–institutional and economic drivers to be the key drivers for urban sprawl in Serbia during regression. This can be associated with the role of urban and regional land use planning in enabling urban development and lignite extraction. The latter was intensified in Central Serbia throughout the study period due to the closed access to the coal basins located in the AP Kosovo and Metohija during the 1990s.

4.1.2. Agricultural Intensification

Experts perceived cultural drivers as more important than technological drivers during regression (Table 5). Also, the progression period was perceived as more important for the natural–spatial driver than the regression period, while for the technological driver, progression was perceived as more important than the regression period (Table 2). We can say that, during regression, cultural drivers were perceived as the key drivers for agricultural intensification, but also that the importance of natural and spatial and technological drivers was increasing over time.

4.1.3. Agricultural Extensification

The experts perceived cultural drivers as more important than natural and spatial drivers during regression. This is the only case where statistical significance was established (Table 5).

This implies that experts took into account a more complex interaction between different drivers in the last two sub-periods as relevant while assessing their importance for agricultural LULCCs. It may be speculated that their assessment of drivers' importance was related to the traditional role of agricultural production (cultural) during the regression, which made it possible to satisfy the households' needs for food and ensure an income when the industry collapsed. However, in the last two sub-periods, the experts assigned a greater importance to the (economic) decisions of individual owners, fertile land, better accessibility (natural and spatial), expansion of market for some agricultural products, (economic) and (technological) development in both land management and agricultural production.

4.1.4. Afforestation

The political–institutional drivers were perceived as more important than the technological driver during regression and as more important than the economic and cultural

drivers in the last two sub-periods (Table 5). Political–institutional drivers are perceived as the key driver for afforestation in Serbia during regression.

4.1.5. Deforestation

The experts perceived cultural drivers as the key drivers for deforestation (more important than the natural and spatial driver) during the progression and stagnation periods (Table 1). It may be speculated that experts perceived deforestation as a process correlated to the cultural values unfavourable for the safeguarding of forest land, which also implies the widespread and recognized problem of illegal wood cutting.

4.2. Water Bodies' Construction and Management

The experts perceived natural and spatial drivers as the key drivers; they were followed by technological and cultural drivers only during progression (Table 5). The stagnation period was perceived as more important than the regression period for political–institutional drivers (Table 6). Their assessment could indicate a more complex interaction of several drivers of water bodies' construction and management. Namely, this LULCC is perceived as the part of the infrastructure development which is assigned to the natural and spatial drivers; however, it is initiated by political–institutional factors (e.g., planning documentation for water accumulations or fish farming). Moreover, water bodies' construction and management is facilitated by technological progress.

General Observations

The results show that the perceived importance of the key drivers varied over time. More precisely, for urban sprawl, the perceived importance of economic and technological drivers increased over time, similar to the importance of natural and spatial and technological drivers for agricultural intensification. For water bodies' construction and management, it is only possible to observe a significant increase in the perceived importance of political–institutional drivers over time.

The perceived importance of political–institutional, natural and spatial, economic and technological drivers increased significantly between the first and the second sub-period. This could be explained by the democratic revolution/the beginning of the transition and lifting the economic sanctions in 2000, which intensified political, institutional and economic activities, as well as infrastructural renewal and construction, technological transfer and IT development.

During the stagnation period, even with the relative political–institutional and economic slowdown, the perceived importance of political–institutional and economic drivers was similar to the progression period. At the same time, the perceived importance of the technological drivers increased significantly, at least for some LULCCs, because of the global trend in technological, especially IT, modernization and development.

According to the results, political–institutional drivers were often perceived by experts as the key drivers for urban sprawl and afforestation. Cultural drivers were often perceived as the key drivers for agricultural intensification, agricultural extensification and deforestation. The experts perceived the natural and spatial drivers as the key drivers for water bodies' construction and management. However, these regularities were observed only in some sub-periods. The only drivers to which the experts assigned the key importance for the entire period (1990–2012) were the political–institutional drivers in the case of afforestation.

The study in general shows that, as the processes within different drivers intensified, their perceived importance increased. In line with this, while the perceived importance of demographic and cultural drivers stagnated, the perceived importance of political–institutional, natural and spatial (mostly infrastructural accessibility), economic and technological drivers was more dynamic and changing in accordance with the context.

In this regard, the perceived high importance of political–institutional (intensified governing processes), economic (intensified localization of activities) and technological

(intensified modernization) drivers of LULCCs in the last two sub-periods and their correlation with negative trends in LULCCs in Serbia requires more political, scientific and professional attention. More importantly, for the possible application of sustainability to the land use policy in the future it is important to have a more in-depth understanding of how intensified and interrelated activities in a context marked by unsuccessful social modernization and democratization, and poor land management produced negative LULCCs. This kept the society away from sustainable development, even though it was an official societal goal in Serbia in the 2000–2012 period.

5. Conclusions

The improved understandings of the complex interplay between drivers and LULCCs should, in turn, foster a better understanding of the set of public policies that need to be interrelated in order to incite changes in value systems, economic and social trends, technological innovations and political priorities regarding growth, climate change and energy [3]. This should result in a better applicability of sustainability to land use policy.

With this regard, the TDLCA presents an evolving, comprehensive, bottom-up, transparent, reproducible and comparable framework. It is able to aggregate different disciplinary perspectives about past land dynamics, mainly at the levels where the application of sustainability to land use policy making should be fostered. Before presenting possible strengths of the TDLCA framework application and recommendations for its further improvement, one of its main difficulties should be pointed out. Namely, securing a sample with an adequate disciplinary representation of academics and professionals within a small community and with regard to their willingness to respond to a relatively complex survey was challenging.

However, once the sample was secured, the constructed TDLCA framework showed a sufficient capacity to identify the key drivers of LULCCs in Serbia between 1990 and 2012 and to offer results that can fill the gaps in the national land use research. The results show that the perceived importance of some drivers in Serbia depended not only on the sub-period/context and LULCC, but that the drivers also diffusely affected one or more LULCCs.

Furthermore, the study can be used as an input to the general understanding of land dynamics at lower levels. It also enables the identification of interactions among drivers needed for preparing scenarios and models of LULCCs. The revealed agreements and disagreements among different disciplinary perspectives about the past interplay between LULCCs and their drivers should incite transdisciplinary discussion, further research and knowledge coproduction. It should subsequently incite interrelation of correspondent policy arenas and enable trans-sectoral coproduction of responses. For example, if there is a perceived key importance of cultural drivers for deforestation, then education policies and those related to the forest land use need to produce a trans-sectoral response towards reducing unsustainable practices of deforestation.

Generally, in the current state marked by poor transdiciplinarity in land use science and poor application of sustainability to land use policy, the TDLCA framework offers a new perspective of how more trandisciplinary and trans-sectoral knowledge could be coproduced towards more sustainable land use policy making. Its possible contribution to this aim, however, requires further evolution, implementation and monitoring, and should be addressed in the future research.

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