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Review

A Synthesis of Land Use/Land Cover Studies: Definitions, Classification Systems, Meta-Studies, Challenges and Knowledge Gaps on a Global Landscape

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Abstract: Land is a natural resource that humans have utilized for life and various activities. Land use/land cover change (LULCC) has been of great concern to many countries over the years. Some of the main reasons behind LULCC are rapid population growth, migration, and the conversion of rural to urban areas. LULC has a considerable impact on the land-atmosphere/climate interactions. Over the past two decades, numerous studies conducted in LULC have investigated various areas of the field of LULC. However, the assemblage of information is missing for some aspects. Therefore, to provide coherent guidance, a literature review to scrutinize and evaluate many studies in particular topical areas is employed. This research study collected approximately four hundred research articles and investigated five (5) areas of interest, including (1) LULC definitions; (2) classification systems used to classify LULC globally; (3) direct and indirect changes of meta-studies associated with LULC; (4) challenges associated with LULC; and (5) LULC knowledge gaps. The synthesis revealed that LULC definitions carried vital terms, and classification systems for LULC are at the national, regional, and global scales. Most meta-studies for LULC were in the categories of direct and indirect land changes. Additionally, the analysis showed significant areas of LULC challenges were data consistency and quality. The knowledge gaps highlighted a fall in the categories of ecosystem services, forestry, and data/image modeling in LULC. Core findings exhibit common patterns, discrepancies, and relationships from the multiple studies. While literature review as a tool showed similarities among various research studies, our results recommend researchers endeavor to perform further synthesis in the field of LULC to promote our overall understanding, since research investigations will continue in LULC.

Keywords: synthesis of land use/land cover definitions; meta-analysis studies in land use/land cover; challenges and knowledge gaps in land use/land cover assessments; literature review

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1. Introduction

The land is the earth's terrestrial surface (immediately above or below the surface) that is delineable and with attributes [1] and is considered a nexus for environmental challenges [2]. Its characterized by land objects (distinguishing properties) and land key elements [1]. Anandhi et al. (2020) provided a narrow and broad definition of land resources more recently [3]. They broadly defined a land resource to include multiple components such as ecological resources of climate, water, soil, landforms, flora, and fauna, and all the socio-economic systems that interact with agriculture, forestry, and other land uses within some system boundary. Knowledge of land use and land cover is essential for

(1) understanding land development, loss and degradation [4]; (2) food and energy security for the growing population [5]; (3) simulating water and carbon cycles, ecosystem dynamics, and climate change inland surface models [6]; (4) equalizing tax assessment in many states [4]; (5) assessing associated land use related environmental effects and impact on provisioning of ecosystem services (e.g., eutrophication, pollution, biodiversity loss or climate effects) [5]; (6) land management consideration, which account for land cover modifications that influence approximately 71–76% of free range land under land cover conversions [7,8]; (7) change detection analysis (e.g., location where the change occurs, the type of change, and how the change is) [9]; (8) understanding and assessing the effects of landscape changes on the atmosphere, climate and sea level [10,11]; (9) considering the changes of land dynamics, how habitats and biodiversity are impacted [12,13]; (10) use of monitoring tools in policy change, landscape monitoring, and natural resource management within the environment [14]. These contributed to the observation, researching, planning, and implementation of policies that will strike a balance between managing resources on the land, such as agriculture, forestry, and building construction that alters the land surfaces while protecting the environment (ecosystems and wildlife habitat) [15]. (11) Administration of a variety of land conservation programs. The USDA 2019 Economic Research Service report identified the principal need for a better understanding of the drivers that will help with strategic planning and program design. This would considerably improve land conservation programs resulting in billions of dollar savings. Additionally, the United Nations Convention to combat desertification targets land degradation neutrality (LDN), addressing sustainable development goals to strengthen national capacity and quantitatively assess land degradation [16].

Several literature reviews have published investigations in the field of LULC. This study has summarized the review studies since the year 2000. Over the decades, the diverse research literature has defined "Land-use" and "Land-cover" in various ways. Depending on the specific area of interest, they have further broken down each region separately to clarify meaning. Land-use and land-cover can carry separate definitions, where land-use relates to what purpose the land is utilized, e.g., agricultural or recreational use. In contrast, land-cover states specific landscape patterns and characteristics [17]. While the terminologies for LULC may be used interchangeably [18,19], the concept remains the same for any particular region. It focuses on man's utilization in time and space of the various physical, chemical, and cultural factors of the land [20]. A synthesis of LULC definitions fills an apparent gap in the existing literature.

Land-use and land-cover are key physical elements that observe the Earth's surface and answer basic questions: What is this (land-cover)? What is it for (land-use)? [21]. classification systems are required to differentiate between land-use and land-cover. These systems provide the essential functions of tool structuring for classification, naming, and identifying objects on the earth [21]. Classification systems have incorporated mapping and spatial data as an essential function for analysis, and challenges have arrived with these classification system's assessment of land observations. "Continuity in observation" for both fine and coarse resolution satellite data along with in-situ information is an essential issue to addressed [22]. Challenges in LULC have given rise to associated knowledge gaps in data collection, image sampling, naming rules, overlap, and the inclusion of new objects [21]. Finally, a chart summarizes the knowledge gained in this study that will be useful to potential stakeholders working in the field of land use and land cover. Land use and land cover are important aspects of land resources. The general goal of this study is to review land use and land cover literature. Specific objectives are to summarize current knowledge in their definitions, classification systems, meta-studies, challenges, and knowledge gaps while building on past reviews in the field. Finally, this study seeks to systematically interpret and summarize that knowledge for stakeholders who work in land use and land cover.

A literature review was the methodology followed out in this study. It is a procedure used by investigators or researchers to compare the results from various studies. It finds common patterns, accomplishes synthesis, finds discrepancies or relationships using multiple studies [23,24]. This methodology will focus on five areas of interest related to LULC from various articles to give a clear and concise understanding of LULC. The five (5) areas of research interest for this paper are as follows:

1. Land use/land cover definitions and how the various authors define them.
2. The use of land use/land cover classification systems and how they are used by countries, regionally and on a global scale.
3. Land use/land cover meta-analysis studies in the areas of direct and indirect LULC, as well as data and methods of change.
4. Associated challenges correlated to land use/land cover changes.
5. Knowledge gaps and needs associated with land use/land cover change.

2. Methodology

This research project downloaded three hundred and eighty-nine (389) research articles, and one hundred and forty-six (146) were used to present research findings in this study. This research used a systematic meta-analysis framework adopted from Mengist et al. (2020) [25]. This framework takes into consideration protocol (P), search (S), appraisal (A), synthesis (S), analysis (A), and report (R). The methodology used for this research is the PSALSAR framework. Research articles for this study were taken from the year 2000 to 2019 and obtained through search engines accessed during the period 10 January 2020–30 April 2021: Science Direct (https://www.sciencedirect.com/) and Google Scholar (https://scholar.google.com/). There was a specific protocol used for the collection of published articles for the research objectives. According to the aim of this study, articles were downloaded and compiled on the keywords for each research objective. Keywords used in the "search" aspect of the framework are as follows: (1). Land; (2) Land-use/Land-cover; (3) Land classification systems; (4) Land-use/land-cover challenges; (5) Knowledge gaps and needs associated with land-use/land-cover.

These terms were used in the extensive search, appraisal, synthesis, and analysis based on the research questions: (1) How do various authors define land-use and land-cover?; (2) Land use/land cover classification systems used by countries, regionally, and on a global scale; (3) Meta-analysis studies of various LULC investigations for direct and indirect impacts on land use; (4) The associated challenges with LULC; (5) Identification of different LULC knowledge gap areas. The methodology presents a step-by-step process used in the synthesizing of LULC: (1) Definitions; (2) Classification systems used worldwide; (3) Meta-studies of LULC; (4) Challenges related to LULC; (5) Knowledge gaps associated with LULC. This systemic literature review summarizes information, ideas, explanations, and various methods from secondary data (published research articles). This protocol in Table 1 describes the process of acquiring papers to report actual findings. The methodological steps are outlined accordingly and broken down for each research objective.

Table 1. A systematic step by step process to acquire research articles for each objective.

Research Source	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
1. Google Scholar 2. Science Direct	Research articles were downloaded based on scope and keywords.	The articles were selected for specific objectives.	The articles were appraised for a specific objective.	Specific information was used from the appraised articles.	Tables and figures represent research findings.	Result findings are reported and discussed.

2.1. The Steps Used According to the PSALSAR Framework for Collecting and Synthesizing Land Use/Land Cover Definitions for This Literature Review

1. The defined scope and terms "land use and land cover definitions" was used as the keywords as part of the search strategy.
2. A total of thirty-five (35) articles on "land use and land cover definitions" were downloaded based on the terms.

3. "Backward and forward snowball" sampling for a further thirteen (13) research articles based on the terms "land use/land cover definitions".
4. Thirty (30) articles for "land use and land cover definitions" were selected and appraised for information.
5. The definitions were synthesized and placed into a table template, separated into two categories: land use and land cover.
6. The definitions were divided by regions where the specific authors did research.

2.2. The Steps Used According to the PSALSAR Framework for Collecting and Synthesizing Land Use/Land Cover Classification System Used for This Literature Review Worldwide

1. The defined scope and terms "land use and land cover classification systems" was used as the keywords as part of the search strategy.
2. A total of two hundred and thirty-three (233) articles on "land use/land cover classification systems" were downloaded for information.
3. One hundred and seventy-one (171) articles on "land use/land cover classification systems" were selected based on their relevance.
4. Sixty-two (62) articles were reviewed and appraised for "land use/land cover classification systems" information based on classification systems.
5. Twelve (12) articles were synthesized and placed into a table template for "land use/land cover classification systems".
6. The table contains three categories (national, regional, and global) and shows classification systems used by various countries.

2.3. The Steps Used According to the PSALSAR Framework for Collecting and Synthesizing Land Use/Land Cover Meta-Analysis Studies for (1) Direct Changes in LULC; (2) Indirect Changes in LULC and; (3) Meta-Studies of Data/Methods

1. The defined scope and terms "land use and land cover meta-analysis" was used as the keywords for the search strategy in the search engines.
2. A total of fifty-five (55) articles were downloaded for information on "land use/land cover meta-analysis".
3. To conduct the "land use/land cover meta-analysis", forty-eight (48) articles were selected and appraised.
4. Three categories: Direct, indirect, and data/methods associated with "land use/land cover meta-analysis" were used to present the papers in figures.

2.4. The Steps Used According to the PSALSAR Framework in Synthesizing Associated Challenges Correlated to Land Use/Land Cover Changes

1. The defined scope and terms "land use and land cover challenges" was used as the keywords as part of the search strategy.
2. A total of thirty-five (35) articles were downloaded on "land use/land cover challenges" for information.
3. Twenty-nine (29) papers were selected and appraised for information related to "land use/land cover challenges".
4. Two categories: Data quality and data consistency on "land use/land cover challenges", were used for the paper and presented in a table.

2.5. The Steps Used According to the PSALSAR Framework in Synthesizing Knowledge Gaps and Needs Associated with Land Use/Land Cover Change

1. The defined scope and terms "land use/land cover knowledge gaps and needs" were used for land use/land cover,
2. A total of thirty-one (31) articles were downloaded on "land use/land cover knowledge gaps and needs" for information,
3. Twenty-seven (27) articles were selected and appraised for information "land use/land cover knowledge gaps and needs",

4. "Land use/land cover knowledge gaps and needs" were identified and placed into four categories related to LULC, namely ecosystem services, forestry, data, and modeling.

3. Results

3.1. Land Use/Land Cover Definitions

The terms "land use" and "land cover" are widely used. Therefore, several definitions are utilized by authors to describe them. This study attempts to analyze the purpose of land-use and land-cover by highlighting the similarities and differences in the diverse descriptions used to explain the terms. The literature review presented various definitions for the terms "land use" and "land cover" from appraised research articles (Table 2). Finally, the "definitions" are illustrated and interpreted in Figure 1 with a paragraph description for potential stakeholders (Figure 1).

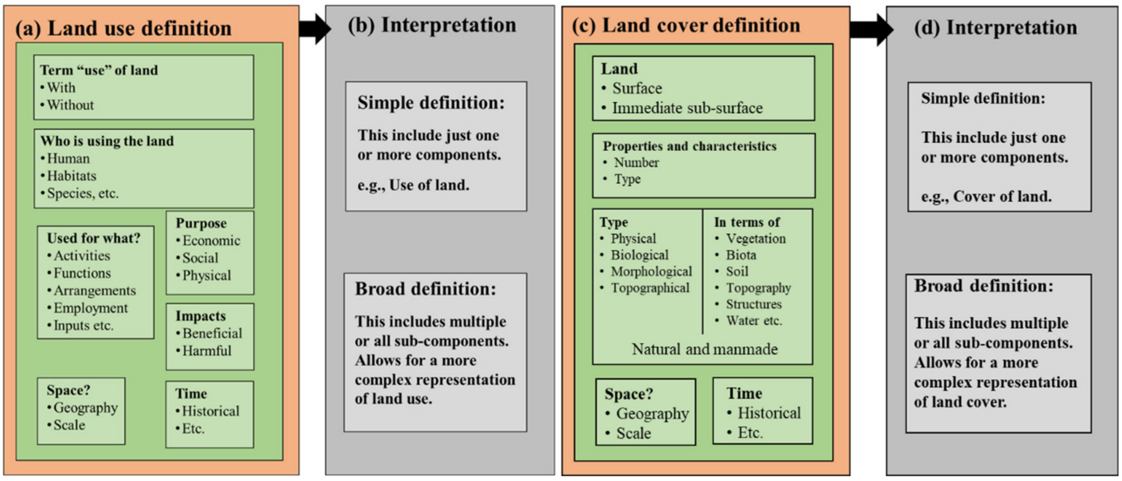

Figure 1. Showing simple and broad definitions of LULC developed and interpreted in this study.

Studies assume these concepts (land use and land cover) to be similar and interchangeable in the literature. Moreover, other concepts regarding land characteristics are defined based on species land class [10]. Other researchers consider them as different concepts [8,26]. The review of thirty (30) definitions revealed variations in the definition/description of land use and land cover (Figure 1). These definitions from different regions worldwide (e.g., North America, European nations, Africa, and Asian countries) showed how the meaning of LULC has similarities based on various authors in different regions worldwide. While exploring the concept of land use, the simplest definition observed coincides with its semantic meaning "What this land is used for?". However, a more complex description can be regarded with the following components:

1. Most of the definitions have the word "use" while describing the term. However, Anderson et al. (1976) defined land use as "Man's activities on land which are directly related to the land" [4], while Sreedhar et al. (2016) describe it as "Human activity or economic functions associated with a specific geography" [20]. These definitions do not have the term "use".
2. Many interpretations focus on who is using the land. The majority of the studies have a human component. Man, human, anthropogenic, land managers are used to describe this component [27]. Other definitions that highlight habitats or species using the land have been described [28,29].
3. Definitions often include the activities or functions related to the use of land. Additionally, terms such as arrangements and inputs have been used in describing this component. Further, the employment of land is used in descriptions by social

scientists [10]. In some cases, this component precisely defines the purpose of these activities, such as economic, social, and physical reasons.

4. Definitions can describe the effect of these activities. Additionally, beneficial or harmful impacts of the changes in the land are included in these interpretations.
5. A few of the definitions have a space component in them. Geographic scales are the terms associated with this component [20,30].
6. A few of the definitions have a time component in them. Terms such as historical are associated with this component [30].

Table 2. Definitions for "*Land use*" and "*Land cover*" from various articles.

S.N.	Land Use	Land Cover	Country	Citation
1	Man's activities on land that are directly related to the ground.	The vegetational and artificial constructions covering the land surface.	USA	[4]
2	Land use denotes the human employment of the land and is primarily studied by social scientists.	Land cover denotes the physical and biotic character of the land surface and is studied mainly by natural scientists.	USA	[10]
3		Land cover, which we define as 'the observed biophysical cover of the earth's surface' is an expression of human activities and, as such, changes with changes in land use and management.	USA	[11]
4	Land use refers to the purposes for which humans exploit the land cover.	The term land cover refers to the attributes of a part of the Earth's land surface and immediate subsurface, including biota, soil, topography, surface and groundwater, and human structures.	Belgium	[12]
5	Land-use areas refer to what this land is used for, such as commercial areas, industrial areas, or residential areas.	Land-cover materials refer to what is actually on the land, such as grass, asphalt, or soil.	USA	[31]
6	Land use is characterized by the arrangements, activities, and inputs people undertake in a certain land cover type to produce, change or maintain it.	Land cover is the observed (bio) physical cover on the earth's surface.	Rome	[32]
7	Land use deals with the socio-economic inputs to land and, thus, describes an activity with an input, a process, and an output.	Land cover is the observed (bio) physical cover on the Earth's surface.	Scotland	[22]
8	Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology, and biodiversity.	Land cover refers to the physical and biological cover over the land's surface, including water, vegetation, bare soil, and artificial structures.	Brazil	[15]
9	Land use is related to important changes in species composition on and around the used area.		United Kingdom	[29]
10	Land use is referred to as man's activities and the various uses which are carried on Land.	Land cover is referred to as natural vegetation, water bodies, rock/soil, artificial cover, and others resulting due to land transformation.	India	[30]
11	Land use is the manner in which human beings employ the land and its resources.	Land cover describes the physical state of the land surface.	Malaysia	[26]
12	Land use is defined as the way or manner in which the land is used or occupied by humans.	Land cover refers to the observed biotic and abiotic assemblage of the earth's surface and immediate subsurface (Meyer and Turner, 1992). *	USA	[33]
13	Land use includes the human activities and management practices for which land is used.	Land cover includes the status of vegetation, bare soil, developed structures (for example, building, roads, and other infrastructure), and water bodies, including wetlands.	Kenya	[34]
14	Land use, in contrast, refers to the purposes for which humans exploit the land cover.	Land cover addresses the layer of soils and biomass, including natural vegetation, crops, and human structures that cover the land surface.	Netherlands	[13]
15	Land use corresponds to the description of the former areas in terms of their socio-economic purpose (the function they serve): areas used for residential, industrial, or commercial purposes, for farming or forestry, for recreational or conservation purposes, etc.	Land cover corresponds to a physical description of Earth, leading to a simple definition: the observed physical cover of Earth's surface.	USA	[21]
16	Land use is characterized by anthropogenic activities to modify, manage and use certain types of land cover.	Land cover describes the physical cover of the Earth's surface, including vegetation, non-vegetation, and man-made features.	Germany	[35]
17	Forest land use is a function of the social and economic purposes for which land is managed.	Forest land cover is a human definition of the biological cover observed on the land (Watson et al., 2000). *	USA	[36]

Table 2. *Cont.*

S.N.	Land Use	Land Cover	Country	Citation
18	Land use normally refers to the arrangements, activities, and inputs people engage in a certain land cover type to produce, change or maintain it (Liang, 2008). *	Land cover is defined as the observed biophysical state of the earth's surface and is largely described by the presence or absence of various vegetation types (Anderson, 2005). *	Germany	[37]
19	Land use is determined by environmental factors such as soil characteristics, climate, topography, vegetation, basic human forces that motivate production, and its responses to environmental changes. (Dinakar S., 2005; Dinakar and Basavarajappa., 2005). *		India	[38]
20	Land use denotes the approach in which land has been used by humans for economic activities. (Mengistu and Salami, 2007; Reis, 2008; Forkuo and Frimpong, 2012; Olokeoguna et al., 2014). *	"In common, land cover is defined as the perceived (bio)-physical cover on the Earth's surface which may include vegetation, man-made features, bare rock, bare soil, and inland water surfaces, etc."	India	[39]
21	"In general, the term "land use" refers to the human activity or economical functions associated with a specific geography."	Land cover as a type of natural features present on the surface of the earth. (Lillesand and Kiefer, 2000). *	India	[20]
22	Land use is more complex. On the one hand, it can be equally approached by natural scientists by analysing the "syndromes of human activities" in the context of biodiversity, hydrology, or biochemistry (Ellis, 2013). *	Land cover describes the directly observable bio-/physical overlay of the Earth's surface (Fisher et al., 2005; Verheye, 2009). *	Germany	[1]
23	Land-use refers to the way in which humans and their habitat have used land, usually with accent on the functional role of land for economic activities (Kumar et al., 2013). *	Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities, e.g., settlements (Kumar et al., 2013). *	India	[28]
24	Land use can be broadly defined as the manner in which the observed biophysical cover is actually used by humans (Cihlar and Jansen, 2001). *	Land cover can be broadly defined as the manner in which the observed biophysical cover is actually used by humans (Di Gregorio, 2005). *	China	[40]
25	Land use is commonly defined as a series of operations on land, carried out by humans, with the intention to obtain products and benefits through using land resources.	Land cover is commonly defined as the vegetation (natural or planted) or man-made constructions (buildings, etc.) which occur on the earth's surface. Water, ice, bare rock, sand, and similar surfaces also count as land cover.	Ethiopia	[8]
26	Land use describes the social, economic, and cultural utility of the land (Turner 1997) and is known to alter how ecosystems function (DeFries, Foley, and Asner 2004). *	Land cover informs the functional relationship between terrain, climate, and soils, providing biophysical insights into the environment and drivers of change.	Canada	[41]
27	land use refers to the conversion or transformation of the land cover into the desired human purposes which are associated with that cover, e.g., cropping, conservation, or settlement.	The formation of a given land cover results complex processes and can be considered as the biophysical state of the earth's surface and immediate subsurface.	Ethiopia	[42]
28		Land cover is a biophysical indicator that refers to both the observed biotic and abiotic assemblage of Earth's surface, including the vegetation and anthropogenic structures covering the land (Hansen and Loveland 2012; Meyer and Turner 1992). *		[43]
29	Land use documents how people are using the land for development, conservation, or mixed uses (NOAA, 2015). *	land cover refers to the physical land type, such as how much of a region is covered by forests, impervious surfaces, agricultural lands, wetlands, and open water (NOAA, 2015). *	Bangladesh	[44]
30	The events that take place in the land represent the current use of the properties such as built-up institutions, shopping centers, parks, and reservoirs are described as land use categories (Fonji and Taff 2014). *	Natural and biological landscapes such as forests, marshlands, grasslands, water lands, and urbanized and built areas denote the land cover.	Germany	[45]

All definitions are direct quotes from research articles. * Multiple authors have similar definitions.

These components in the complex definition establish direct links between land cover and the people's action in their environment on a space and time scale.

While exploring the land cover definitions, most descriptions describe the land surface and immediate sub-surface properties and characteristics. The definitions vary with the number and type of properties and characteristics used in the interpretations. They include the physical, biological, morphological, and topographical cover of land in terms of vegetation, biota, soil, topography, water, structures, etc., which can be anthropogenic or natural. A simple definition of land cover can be its semantic meaning "What's this land cover". A more complex description can have more specific components.

3.2. Land Use/Land Cover Classification System Used Worldwide

3.2.1. Classification Systems

Over the years, the need for structuring information systems on LULC has developed into "classification systems" that are abstract representations of the situation in the field using well-defined diagnostic criteria. Earlier stages it was defined by Sokal in 1984 as: "the ordering or arrangement of objects into groups or sets based on their relationships [46]". Jansen and Gregorio (2002) also described this coordination of objects as: "the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes" [9]. Understanding LULC classification systems have caused researchers to investigate further how they work, and their definitions have broadened. According to Duhamel (2012), classification systems have three main functions of structuring information, facilitating communication and exchange among users of these systems [21]. These are (1) classification (assignment of all objects in a hierarchical series); (2) nomenclature (naming and describing the groups of objects); and (3) identification (allowing to assigning the membership status of individual objects in the classification) [21]. For classification systems to work efficiently, there is a need for land cover maps. Land cover maps are the foundation for accurate extraction of information from land covers to remote sensing modeling [6]. A literature review has shown various studies that provided the accuracies and a comparison of different LULC classification systems [47]. There are several classification systems examined in this study, and they are categorized based on their use as national, regional, and global systems (Table 3).

Table 3. Classification Systems used at National, Regional and Global Scales.

Category	Classification System	Year	Scale	Location	Citation
National	1. National Land Cover Data Classification System	1992; 2006; 2011	1:5000–1:10,000	U.S.A	[48,49]
	2. US National Vegetation Classification Standard	1997			
	National Forest Inventory Land Cover Classification Scheme	1999	1:5000–1:10,000	Canada	[41]
	National Institute of Statistics, Geography and Informatics	1993; 2000	1:25,000	Mexico	[50]
	National Land Use Database (NLUD)	2001	1:100,000	United Kingdom	[51]
	Sistema de Información de Ocupación del Suelo en España (SIOSE)	2000	1:25 000	Spain	[51,52]
	National Land Survey Classification System	1984; 2007	1:100,000–1:125,000	China	[53]
	NRSA LULC Classification System	2007	1:250,000	India	[30]
	South African Standard Land Cover Classification System	1996	1:100,000	South Africa	[49]
	The MapBiomas LULC Classification Scheme	2020	1:125,000	Brazil	[54]
	ALUM Classification System	2005	1:100,000–1:125,000	Australia	[51]
	New Zealand Land use Class.	1984	1:100,000–1:125,000	New Zealand	[51]
Regional	CORINE/Land Cover2006	1985–2018	1:100,000–1:125,000	Europe	[55]
	AFRICOVER Land Cover Classification System	1995–2002	1:100,000–1:125,000	Africa	[11]
	AARS Land Cover Classification	1999	1:100,000–1:125,000	Asia	[49]
	North American Land Change Monitoring System	2005	1:100,000–1:125,000	North America	[49]
Global	Land Cover Classification System (FAO)	1996	1:100,000–1:125,000	FAO	[11]
	USGS Land Use/Land Cover Classification Systems (National)	1972/1976	1:100,000–1:125,000	USGS	[4,49]
	International Geosphere-Biosphere Programme-Data and Information System	1996	1:100,000–1:125,000	IGBP	[49]

3.2.2. National Classification System

Classification systems at the national level assist policymakers, leading to the sustainable development of land resources [56]. National classification systems use land cover maps from remote sensing data to model, monitor, and understand landscape changes [6]. Table 3 shows how some countries have specific national classification systems for LULC at lower spatial scales. These classification systems describe the structure and relationship of various land objects [57]. To understand this process, land cover products that aggregate maps and multiple datasets are used for different land cover projects. For example, technological advances have used remote sensing. Wulder et al. (2018) showed "Land Cover 2.0" to be a great tool that emerged in that it enabled free and open access to data; it is high performing, accurate, and rapidly developed data processing and analysis capabilities [41]. This system is user-friendly and efficient in generating land object data for classification systems, and it's used widely for various LULC model projects.

On the national scale, many countries have developed classification systems. Table 3 shows countries with LULC classification systems for the identification of land cover objects. Notable examples of the national classification system are found in the North American region, which has employed consecutive land cover classification data for the past decade. The National Land Cover Database (NLCD) contains classifications for the United States for 1992, 2001, 2006, 2011, and 2016 [48,58]. There are many different sources of information on existing land use and land cover and the various changes occurring over time in the United States of America, including the U.S. Geological Survey (USGS) Land Cover Trends (LCT), National Land Cover Database (NLCD), North American Forest Dynamics (NAFD), Monitoring Trends in Burn Severity (MTBS), Protected Areas Database (PADUS), and North American Forest Age [59].

While Canada has its land cover classification system (National Forest Inventory Land Cover Classification Scheme), most land classifications use the NLCD. While countries like Mexico have the Instituto Nacional de Estadística y Geografía (INEGI) Uso del Suelo y Vegetación land cover product (INEGI, 2014) contains consistent classifications over Mexico for years 1985, 1993, 2002, 2007, and 2011 [59].

Table 3 shows national classification systems used by countries with significant land development and changing landscapes pushed by population density. The synthesis indicates that various literature resources have identified these different classification systems at the national level, their scale of use, and year of development. Due to the small-scale ranges, these systems update readily with changing land covers by human activities and are utilized locally. The use of accurate land cover maps identifies land classes and objects, classifying at the sub-national scales, division, district, sub-district, county, city, and municipality levels [60]. While classification at the local level is for the observation of land objects, the result is for advancement and documentation of changing land covers. The literature review has shown that many researchers use remotely-sensed information for land cover classification. The typical practice involves using raw numerical data or calibrated reflectance from other land cover studies [61]. This information from national land cover classification (detected land classes and objects) is adapted for regional and global classifications.

3.2.3. Regional Classification Systems

Regional classification systems are sometimes known as continental classification systems, and they are used at large scales (from 1:250,000 to 1:100,000) compared to those used at national levels [62]. As shown in Table 3, they would periodically involve multiple countries or overlapping landscapes, depending on project type. Large projects employ continental classification systems. For example, while the services of other LULC classification systems are used locally, the CORINE (Coordination of Information on the Environment) classification system is used as a system to classify significant areas in Europe [49]. Eurostat was developed at the early stages in the European Union as a LULC statistical system [63]. There has been significant land development through decision-making for most European countries. The AFRICOVER Land Cover Classification System (LCCS) developed by the Food and Agricultural Organization (FAO), classified twenty-one African countries [49]. There is also the AARS land cover classification that develops land products for Asia [64]. Similarly, the North American Land Change Monitoring System covers the North American region, including Canada, the United States, and Mexico. This system provided continental information and met the need for country-specific monitoring programs with improved land cover maps for accurate databases [65].

Regional land classification systems are employed for continental landscape monitoring. Regions, such as North and South America, Asia, Africa, and Europe, did initial work for general land classification. However, with multiple accurate land products, land maps, and numerous land features, objects, and legends, more countries have developed a localized classification system for land objects for decision-making related to land management, monitoring, and ecosystem preservation. The key to many regional classification systems is land-cover products. While many land products may not accurately update changing land covers [66], these land products are used at the local and regional levels for classifying and decision making. Numerous LULC methods have been used at the local and regional levels to develop and amend various landscape policies, safeguarding ecosystems and biodiversity [67]. These regional classification systems update land characteristics and are also pivotal in regional decision-making from these landscape surveys.

3.2.4. Global Classification System

Global LULC classification systems have been around since the 1980s. As shown in Table 3, international organizations developed such systems for use worldwide. These include The Food and Agricultural Organization (FAO), which created the Land Cover Classification System (LCCS); The CORINE Land Cover (CLC) of the European Union and classification system designed by the International Geosphere-Biosphere Programme (IGBP) [1]. The MODIS Land Cover, GlobCover, or Global Land Cover [1], are examples. Others include UMD land-cover product, Globeland-30, Corine-2012, GlobeCover-2009, and Global Historical Land-Cover Change [62,68]. Once these land-cover products are validated, they provide accurate information and datasets related to land cover classes, objects, and features for global use in LULC classification systems. Classified land products lead to enhanced decision-making related to landscape management, monitoring, and change.

The FAO LCCS, a land-cover classification system, is used regionally and globally [32]. According to Keil (2016), the LCCS is a standardized multi-purpose system usable for any land cover condition independent of collection method and hierarchy [1]. The LCCS is a hierarchical classification scheme. Its classification focuses on specific classes, containing twenty-three (23) exclusive categories, divided into three layers with dimensions for land use, land cover, and surface hydrology [69]. The LCCS system is widely used as a global classification system and using various datasets from various sources. However, the Global Land Cover Network (GLCN) (http://www.fao.org/geonetwork/srv/en/main.home (accessed on 17 September 2021)) is one of the primary dataset sources used by LCCS created by the FAO [70]. There are other global land-cover dataset maps used as part of land classification, and these are as follows: (1) International Geosphere-Biosphere Project (IGBP), http://www.igbp.net/ (accessed on 17 September 2021); (2) University of Maryland (UMD) https://geog.umd.edu/research/landingtopic/land-cover-land-use-change (accessed on 17 September 2021) [71]; (3) Global Land Cover 2000 (GLC2000) https://ec.europa.eu/jrc/en/scientific-tool/global-land-cover (accessed on 17 September 2021), and (4) Moderate Resolution Imaging Spectroradiometer (MODIS) https://modis.gsfc.nasa.gov/data/ (accessed on 17 September 2021) [72].

3.3. Synthesis of Meta-Analysis Studies in LULC

Land use and land cover changes have been investigated extensively over the years. These research studies have been linked to the landscape's various changes from human modification to the earth's surface. Meta-analysis is a valuable technique that employs a combination of peer-reviewed studies to determine relationships [73]. Research studies have used meta-analysis to synthesize studies that show direct impacts on the changes in LULC. The focus of the analysis is on specific sites and landscapes [47]. Most peer reviews concentrated on deforestation and reforestation studies [74–76], while some meta-studies have focused on the indirect effects of LULCC [77–79]. The analysis of such studies addressed categories of direct and indirect LULCC, then further subcategorized into specific areas of interest (Figure 2). A further category was added to show meta-studies of data and method changes in LULCC. The information for these studies was also placed into a diagram (Figure 3) between the years 2000 and 2020, showing how the meta-analysis studies have developed over the years. More peer reviews in the area of LULC analyzed by this method provided qualitative and quantitative results from published research studies.

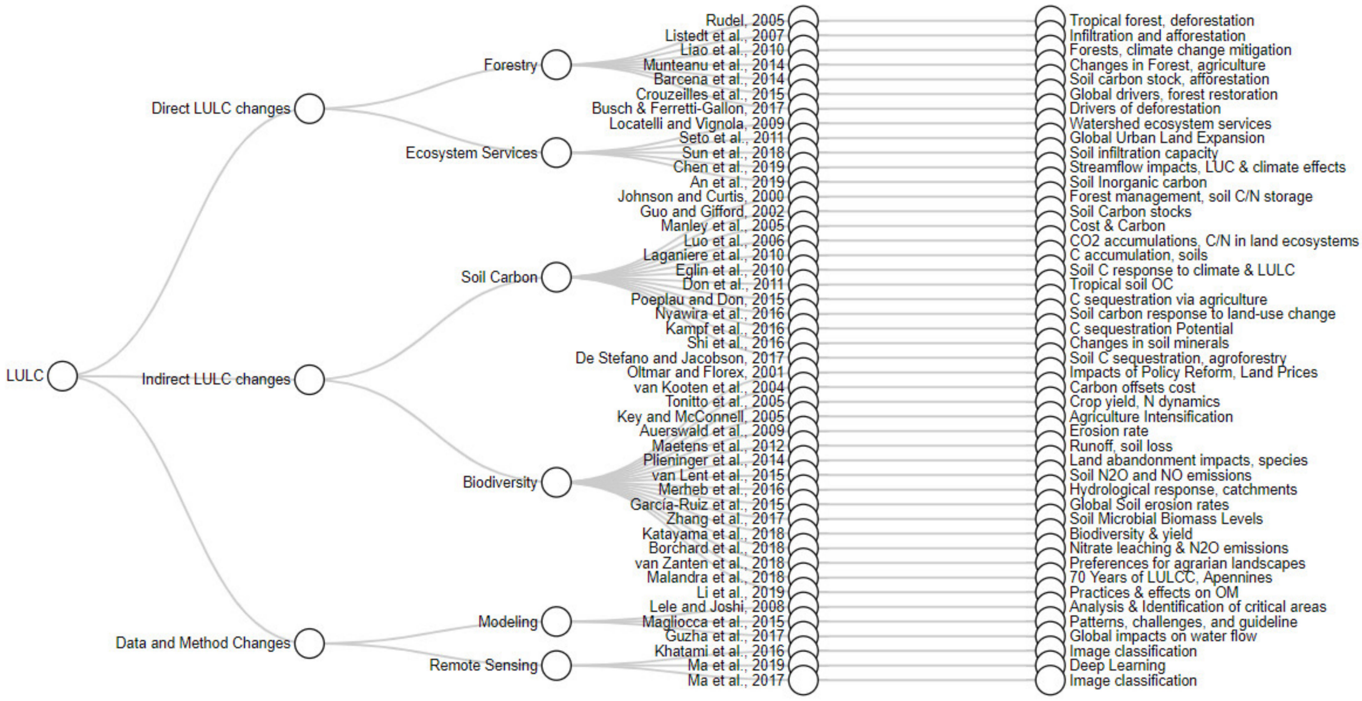

Figure 2. Diagram showing meta-studies divided based on categories.

3.3.1. Meta-Analysis Related to Direct Changes in LULC (Forest)

Land use has essential impacts on forests, the use of forest products, and changes in forest cover. These changes appear primarily in the United States but also occur globally [34]. In the context of LULC forestry and forestry cover, meta-studies look at the public response concerned with deforestation and the implementation of policies that have slowed down deforestation of some protected areas [76].

The meta-analysis allows a researcher to test specific hypotheses about the effect of a treatment by considering research information from various studies in the past in a particular topical area. This approach and technique are utilized for medical research [80,81]. LULC in forestry is unique and appropriate for meta-analysis studies. While other studies focus on agents of deforestation, for example, growing population, new settlements, roads, even topography, and other general factors that affect forest loss [82]. A meta-analysis is a valuable tool for understanding how LULC changes in forestry are changing [83]. Some case studies looked at the forest and agricultural land change [74], while others have looked at forest restoration, attributing it to the enhancement of 15–84% of biodiversity and 36–77% of vegetation structure compared to other ecosystems that are showing signs of degradation [75]. It is also helpful to identify the various services the forest may provide, specifically the storage of carbon, biodiversity for habitat, disease suppression, water filtration, storm mitigation, food, medicines, recreation, timber, and non-timber products [75].

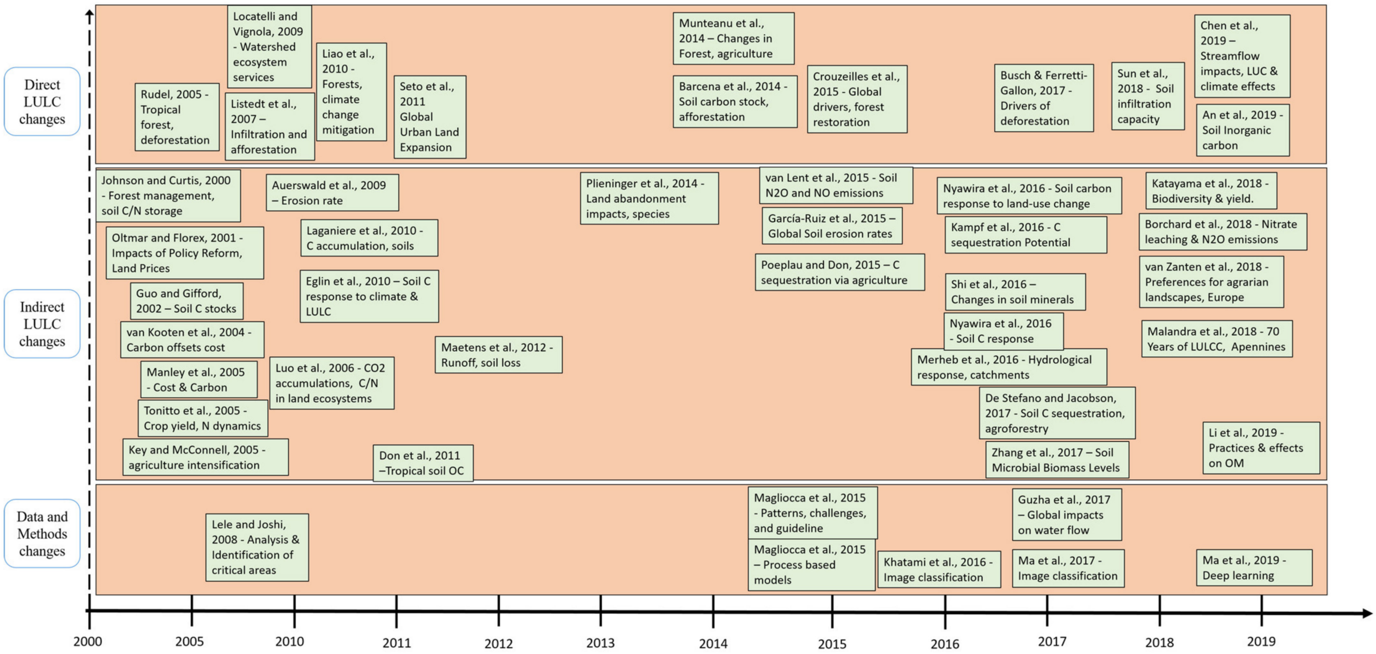

Figure 3. Diagram showing meta-studies timeline of articles.

The literature review showed meta-analysis studies focused exclusively on specific services that afforestation has benefited soil [84]. Various studies, including their respective experiments and statistical software, have shown that water infiltration increased due to afforestation [81]. Our synthesis revealed similar meta-analysis work by another researcher, offering a different meta-analytical approach to determine land use and climate effects on streamflow and infiltration [84]. Some studies focused on land use capacity and its impacts on soil infiltration [85]. Some others investigated the potential of soil carbon stock, the effects after reforestation, and the abilities to perform carbon sequestration [86]. Additional studies showed differing results between the carbon sequestration in a natural forest against a plantation-type forest. The meta-analysis technique showed the differences based on stand age, stand types, tree species, and origin of the plantation [87]. Some studies look at various factors that make up a forest, including investigations within watersheds, focusing on tropical forest services, and comparing hydrological flows between plantation and natural forests [88].

3.3.2. Meta-Analysis Related to Indirect Changes in LULC (Climate Change)

Various landscape projects utilize land use/land cover meta-analysis, significant catalysts of soil-carbon changes in recent decades center around land-use changes. A notable example would be replacing natural forest and vegetation for cropland and urban areas, leading to soil carbon loss. However, the reverse can lead to soil carbon being replenished [89,90]. Older meta-analyses focus on forest soil being a sink for Carbon (C) and Nitrogen (N). Johnson and Curtis (2001) conducted a meta-analysis on various management techniques and determined the mean response of forest soil C and N [91]. This method is adaptable for quantitative analysis of studies with multiple experiments for soil investigations [91]. In contrast, Luo et al. (2006) showed patterns among various studies due to C and N processes within the soil interaction with plants in response to high carbon dioxide [92]. Soil N_2O and NO emissions and their effects on the level of greenhouse gases in the atmosphere have been reviewed and synthesized from multiple studies from land-use changes in tropical and sub-tropical areas [93]. Meta-analysis identified interactions at the soil level to lower some of these emissions into the atmosphere [79]. Synthesizing is the appropriate approach for studies that seek an understanding of forestry-based projects and how researchers can select specific topics for a particular research area. Researchers would have compiled studies on the costs of sequestering carbon in terrestrial ecosystems by activities within the forests [94]. While another study focused on the forests' ability to accumulate carbon, their analysis examines the various experimental techniques used to determine carbon content among studies, thus drawing rational conclusions [95].

While many land-use change projects are formed after deforestation or in cooperation with reforestation practices, some land use characteristics such as agriculture have been responsible for carbon loss from the soil by converting forest and grasslands to arable lands. This depleted soil carbon and biomass have potentially seen carbon emissions into the atmosphere from the biosphere due to intensified agricultural activities [96]. Meta-analyses studies focus on the microbial biomass levels at various land-use sites and their effects on the ecosystems [97]. Soil provides significant storage for carbon. As such, depleted soil from agricultural enterprises can remove soil carbon by destroying primary forests, releasing soil carbon that results in higher CO_2 in the atmosphere [98]. These depleted soil can take atmospheric carbon to replenish what they would have lost [99,100]. There are numerous strategies to sequester atmospheric carbon into the soil through agricultural measures. These include reduced tillage intensity, increasing residue inputs from higher yields, eliminating summer fallows, nutrient and manure management, and restoring permanent grasslands or forests [100,101].

While replanting forest has been a sure way of carbon sequestration, the meta-analysis of various studies has shown numerous ways of soil loss. The investigation of soil loss shows a positive correlation with annual rainfall, plot runoff, and annual runoff coefficient [102]. This used investigative approaches of the effect at the subcontinental scale based on various environmental conditions. Land-use changes have significant impacts on soil degradation. While studies have shown the effects of land-use change through research, a meta-analysis methodology shows studies on specific areas. Shi et al. (2016) conducted a global meta-analysis across broad climatic zones using one hundred and thirty-nine (139) papers that investigated the changes in soil carbon, nitrogen, phosphorus, sulfur, and their stoichiometry in the soils of planted forest investigation [103]. Other meta-analyses on carbon stocks and sequestration investigated soil organic carbon in cultivated soils using cover crops [104]. They quantified soil organic carbon changes accumulation as a response to the use of cover crops. In comparison, researchers use meta-analysis to investigate the effects of agroforestry systems on carbon stocks [24]. Another meta-analysis may look at carbon stock based on land-use changes in a general sense [89]. Meta-analysis can analyze case studies on historical and future global soil carbon response to land-use change [105].

Land-use change meta-analyses have documented research in the area of soil erosion studies globally. Some studies meta-analytically investigated the rate of sheet and rill erosion in Germany [106]. Comparatively, others used meta-analysis to investigate soil infiltration rate effects in China from comparisons of various studies from LULC changes [85]. The use of soil erosion studies to understand the rates of erosion from global sites showed the estimation method for erosion rates and the rationale for improving the practices and theory on soil erosion studies [107]. Land use meta-analysis studies have been centered around agriculture, from investigations into an intensification of agriculture and global changes [78]. Meta-analysis investigations on crop yield and nitrogen dynamics, using cover crops in fertilizer-intensive cropping systems [108]. This methodology has also been applied in no-till cultivation operations, focusing on cost and carbon benefits [109]. The impact of agricultural policy reform on land prices shows quantitative analysis as a focal area [77] and their effects on plant density on a global scale [110], as well as their concentration of dissolved organic matter impacts as a result of land management [111]. This method has contributed to land-use science and its effects on a global scale. Using case studies and other literature as exploratory focal points for identifying impacts of land use/land cover change on climate change, scientific references of anthropogenic effects on the biosphere have shifted to a new geological epoch [112].

Meta-analytical approaches have informed other researchers' use of multiple studies to observe land-use change, anthropogenic activities, and the impacts on climate change within a particular region. Zanten et al. (2014) conducted a meta-analysis study to examine generic preferences of particular landscape attribute across Europe [113]. The assessment conveyed responses from the general public on their willingness to pay for goods and services provided by the environment. In contrast, another study used meta-analysis to investigated land abandonment effects on plants species richness and animal abundance. The results showed the impacts on the biodiversity of the Mediterranean Basin, specifically on arable land, pastures, agroforestry systems, and other permanent crops [114]. Another looked at biodiversity measures under various land covers, assessing different land-use types [115].

Furthermore, this methodology identified objectives and models adopted in the hydrological response attribute of Mediterranean catchment areas [116]. The use of meta-analysis to show the various impacts of land-use changes on the environment compares and shows similarities in specific areas, but it can be used as a guide for multiple researchers, whether regionally or globally, to synthesize, contrast, and show correlations in specific topical areas, perform quality checks, combine and aggregate information from various studies, and then provide estimates of the average magnitudes on particular topics [90].

3.3.3. Meta-Analysis Related to Data and Methods

According to our research findings, meta-analysis is considered a method of analysis in land-use change [117]. Various research can provide different explanatory interpretations and for land-use change. Analytical differences analysis is dependent on data use. For example, one can use spatial units such as pixel images and political units or inform individual decision-making [118,119]. Remote imaging and maps of land-use changes have equipped researchers to identify, summarize, develop, and document the use of various factors of object-based land-cover image classification with the help of meta-analysis [73]. Their results provided instructions on the use of these classifiers for land cover mapping, whereas another researcher used meta-analysis to provide systematic guidance classification process performance, using research literature to inform supervised per-pixel classification over fifteen years [47]. Meta-analysis has been used to quantify how researchers used various studies, showing LULCC impacts through hydrological influxes on discharge, surface runoff, and low flow in the East African Region [120]. Other researchers have used the meta-analytical approach to research forest cover maps from various data sets over a long period throughout various studies, observation deforestation rate and forest cover change through comparison of land cover images [121]. Conducting meta-analysis at the remote sensing level has been observed over several years to develop land cover models, to analyze unrealized synergies between land change meta-studies and the evaluation, framework, and designs of land change models [117]. Additionally, they navigated data types and relevant research questions for land-use change data, using the typological synthesis approach.

3.4. *Land Use/Land Cover Associated Challenges*

Land use and land cover change remain an urgent environmental challenge related to sustainable management of the earth's surface [120,122]. Anthropogenic activities on a global, regional, and local scale have seen significant landscape changes, land degradation, ecosystem changes, and a shift in the biodiversity of numerous areas that were once forest. These economic and environmental changes to the landscape have characterized LULC changes that provide livelihood (e.g., urban settlements and agriculture enterprises) for persons occupying these land spaces. The last two decades have seen significant encounters of humans and changing land surfaces, and these changes accelerated due to socioeconomic and biophysical drivers from anthropogenic activities [123,124]. Generalized knowledge on the impacts of local, regional, and global land change continues to be an essential challenge of land use science [121,125,126]. Some of the leading documented challenges identified in LULCC are logging, fires, drainage, forest cover change, and other changes to wetlands that degrade soils in cropland areas. Additionally, alterations in these land's volume and beneficial capacity could result in these changes [60,125]. This research investigated LULC change for two areas using meta-analysis, there are "data quality and data consistency". These categories were chosen since they were so familiar in relation to LULC remote sensing and modeling. Significant challenges determined from research in Table 4 have been identified based on specific research articles in the literature review. A word cloud is used in Figure 4 to identify the crucial challenges determined in the research papers, and they are associated with the challenges in landscape monitoring.

Table 4. Showing significant challenges and recommendations.

Category	Major Challenges Highlighted	Recommendation	Citation
Data Quality	• Incomplete data coverage, • Various changes in definitions of categories, • Different methods used by source agencies, • Various data age, • Incompatible classification systems.	The correct classification and standardization of land objects and features.	[4]
	• The difference in datasets for biogeography of contrasting regions.	Measure and determine the impacts of land-use changes on land quality and biogeography.	[29,126]
	• No concept application at the landscape level, • Inappropriate data for quantification.	Engaging frameworks and methods with the use of classification systems to track ecosystem goods and services	[127]
	• Unrecorded and undocumented information.	The classification, quantification, and validation of ecosystem services for past land-use data.	[128,129]
	• Incorrect data, • Use of wrong classification system, • Use of the insufficient resolution.	The use of land cover polygons and valuations in dollars/hectare/year to show the total value of ecosystem services.	[130]
	• The lack of reliable or comprehensive data, • There are different levels of resolution and quality of datasets.	Good data pools are needed to analyzes dynamics between ecosystem services.	[131]
	• Few data sets are designed to provide very similar atmospheres over crops and forests.	Test how models capture LULCC impacts on weather.	[132]
	• Absent of comprehensive knowledge base for datasets associated with remote-sensing.	Correct data must be used at the right time for policy change and decision making (e.g., climate change)	[133]
	• Difficulty in mapping global land -use, • The need for local-based data from local-based study areas are required for producing, • No accurate LULC datasets.	There are databases worldwide that offer free access to current and past information on LULC changes globally.	[40]
	Very High Resolution (VHR) images to develop national, regional, or global maps have proven to be challenging: • The high cost associated with VHR imagery, • Their low spatial extent (a few hundreds of km^2) (Gibbs et al., 2007), • Low availability due to their low temporal resolution and lack of global coverage (Pangra et al., 2015), • The variation of radiometric properties among sensors, • The influence of acquisition conditions (i.e., Sun-scene-sensor angles) (Anser et al., 2003; Barbier et al., 2011; Bastin et al., 2014; Ryan et al., 2016), • Classic atmospheric perturbations (e.g., cloud, fires) (Pangra et al., 2015).	"Collect Earth" as a free search engine for past and present LULC change information can be used for many investigations.It's readily updated and accurate with data at multiple scales.	[134]
	• Time series data (various image composite for land cover mapping); • Movement of algorithms from a research to operational phase (such as data handling and processing).	Progressive work over the years in technology and data availability has seen advance/updated algorithms used for time series data.	[135]

Table 4. *Cont.*

Category	Major Challenges Highlighted	Recommendation	Citation
Data Consistency	• Low accuracy and quality of assessment, • Challenges obtaining national land cover maps for distinctive timestamps.	Accurately mapping global land cover maps.	[136]
	• The challenge of representing decision-making mechanisms in models to show land change.	Model coupling—focused on representing human decision-making, the coupling between human and environmental systems.	[137]
	• Inconsistent global maps.	Mapping projects use accuracy assessment as a tool to accept land cover components.	[36]
	• Discrepancies between maps, • Different features and maps, • Comparison between maps from the same source, • Difference between product features in the same year.	Data consistency is essential when given the capacity to produce maps that have acquired data from a single sensor.	[138]
	• Comparison of different legend information from various classification schemes, • Inconsistencies for land class definitions, • Errors arising from different methods of data collection, • Incomplete compilation of remotely-sensed datasets.	Validation efforts are needed to assess precise accuracy at the regional and global scales for LULC classification.	[133]
	• Large data volume, • Unavailable data in certain seasons, • Challenges obtaining cloud-free images, • Technical difficulties in Landsat satellites, • Revisiting the cycle of the Landsat model, making it more difficult to trust.	The Landsat model needs a continued upgrade.	[139]

Figure 4. Showing significant challenges associated with Land-use and Land-cover.

3.4.1. Data Quality

The diverse challenges associated with LULCC impact assessment are centered around data quality and consistency. Some conference presentations have shown a need for land classification standardization of land feathers [4]. However, some of the challenges are incomplete data coverage, change in definitions of categories, changes in methods used by source agencies, varying age of data, and incompatible classification systems by agencies. Researchers need to measure and determine the impacts of land-use changes on land quality and biogeography. The life cycle impact assessment (LCIA) is a method developed to undertake such a task. As such, it has provided accurate data regarding land quality changes [29]. However, challenges are present in extricating changes and the quality of biogeography of contrasting regions. Therefore, additional maps and images should distinguish other land feathers, such as varying vegetation, soil types, and climates [29,126]. Various studies have shown engaging frameworks and methods using classification systems to track ecosystem goods and services [43]. At the same time, there is an urgency to centralize and determine land, ecosystem, biodiversity quality, and climate changes under one approach, a significant restriction to ecosystem goods and services would be the application of concepts at the landscape level as a result of inappropriate data for quantification [127]. Quantifying ecosystem services for past land use, one of the severe challenges is understanding what occurred in the past related to land use for a particular area. The information might be known but not documented, characteristics such as land cover practices or specific resources from the land. The information may be passed on orally by indigenous dwellers from generation to generation [128,129].

The use of land cover polygons and valuations in dollars/hectare/year shows the total value of ecosystem services given the land cover type. However, the challenge is that the data for the particular area must be correct, and using the right classification system at a suitable resolution is essential [130]. A central challenge in the earth systems and resources is sustainable land management. There's a high demand for the supply of food and other resources for a growing human population. However, land management has potential negative impacts on the environment and ecosystem globally. Effects are observed in global climate change, the loss of biodiversity, pollution of soil, water, and the atmosphere [15]. The management of ecosystem services in agricultural landscapes is challenging, specifically in agro-ecological conditions and topographic areas; thus, ecosystem services must be assessed by various approaches that provide multi-temporal information at a national level [131]. The only regions globally that are not directly affected or have evaded large-scale land alteration with limited LULC changes are Antarctica, boreal/tundra areas in Siberia, parts of the Amazon, and parts of the Congo [132]. Other regions have been affected globally. Therefore, LULC change impacts must be made locally, with a literature review to understand the effects on a regional and global scale [132]. However, there are some challenges to using Geographic Information System (GIS) data. Researchers must have a comprehensive knowledge base of the datasets for remote sensing. Correct data must be used at the right time for policy change and decision-making, especially in climate change, monitoring deforestation, urban landscape planning, and policy changes by governmental offices [133].

Various research models have been developed to study LULCC, specifically in urban land use and ecosystem services. The model InVEST Framework observes the sensitivity of ecosystem services through spatial resolution from input data [140]. The data models conceptual approaches of the scale dependence of different ecosystem services, the model compares spatial patterns and measured future ecosystem services in a particular area [140]. In contrast, other research findings used meta-analysis to quantify LULC change impacts through hydrological influxes on discharge, surface runoff, and low flow in the East African Region [120]. While global land use may be difficult to map, data from local-based study areas are required to produce accurate LULC datasets. There is a need for datasets to provide information on LULC changes and the human impact [40]. Technological advances for LULC mapping and remote sensing have seen some of the previous challenges annulled. There are databases worldwide that offer free access to current and past information on LULC changes globally. "Collect Earth" has been identified as a free search engine for past and present LULC change information, developed by the Food and Agriculture Organization (FAO) [134]. Collect Earth provides satellite imagery of high spatial and temporal resolution (e.g., Google Earth) and uses archived images with multiple resolutions to enable land monitoring suitability. The need for accurate and up-to-date data is essential to understand changes in LULC monitoring. This will alleviate most of the challenges of understanding continuous differences and help researchers and decision-makers monitor change, observe trends, and efficiently manage land resources.

3.4.2. Data Consistency

Progressive work over the years in technology and data availability has seen its challenges related to data quality. The challenges related to time series data (various image composite for land cover mapping) and challenges involved in the movement of algorithms from research to operational phase (such as data handling and processing) are mostly user-based [135]. There have been various efforts to map global land cover maps [141]. There are still existing challenges regarding the accuracy and quality of assessment, and developing countries face challenges in obtaining national land cover maps for unique timestamps [136].

A major challenge identified in the literature review was representing decision-making in these models as a mechanism by which land changes. Research has focused on human decision-making, namely the coupling between human and environmental systems while answering questions associated with ecological sustainability challenges through model coupling [137]. Mapping projects use accuracy assessment as a tool to accept land cover components. However, the challenges associated with global maps related to data quality are imperative for successful projects [36]. Data consistency is essential when given the capacity to produce maps that have acquired data from a single sensor [138]. While this is an advantage, it poses various challenges (e.g., in previous studies, Bontemps and others compared the GlobCover 2005 and 2009 maps features discrepancies between products).

Various studies have identified land cover classifications with multiple challenges related to mapping, inconsistent class definitions, descriptions in data collection for land characteristics, legends, objects, and other errors with various systems [133]. The use of Landsat data poses some significant challenges, including (1) large data volume in comparison to coarse spatial resolution data, (2) data inconsistency among changing seasons, (3) land images are challenging to obtain as a result of the sixteen-day cycle of Landsat satellites, and (4) there's a great concern for the Landsat satellites that need maintenance. Such technical issues can delay land cover data if not addressed within a timely manner [139]. Another challenge associated with LULC classification systems data is their ability not to be user-friendly. Some databases have unvalidated data or confusion among datasets; in other occurrences, the data are not broken down by specific classes or objects, making it difficult for researchers to understand the best fit for their projects [11]. The challenges described and summarized critical areas of importance in LULCC. While this meta-analysis focused on secondary data from other research articles, it shows essential areas of existing challenges, observed gaps, and even trends among similar research topics, implying that such recognized challenges must be addressed for LULCC.

3.5. Land Use/Land Cover Knowledge Gaps

Land use and land cover have encountered various challenges based on numerous studies. A literature review can determine many knowledge gaps associated with LULCC. Multiple studies have identified specific needs for particular research areas within this discipline to work efficiently. According to Mengist et al. (2020), an accurate meta-analysis with minimal errors can contribute reliable conclusions for a particular area of interest, which leads to the decision-making process [25]. The knowledge gaps for this section separated specific needs into four categories (ecosystem services, forestry, data modeling, and hydrology). Knowledge gaps identified from the literature review were presented in a word cloud showed in Figure 5. The more prominent words indicate how often particular knowledge gaps were highlighted from the synthesis and their importance to land use and land cover.

3.5.1. Ecosystem Services

Initial examination of LULC impacts on ecosystem services has given rise to the need for assessments on severe LULCC within various ecological systems. A valuable tool of assessment identifies the spatiotemporal approach [131]. Ecosystem services would need internationally accepted land cover classification systems with consistent time-series maps, considering their validation and accuracy to identify land characteristics (e.g., distinguish between cropland, fallow, barren, and wasteland) [142]. While there are various areas of ecosystem services, researchers recommend intermittent surveying and mapping of these services provided to monitor their quality, which helps with the overall management and control of ecosystems [143].

Figure 5. Showing knowledge gaps associated with Land-use and Land-cover.

3.5.2. Forestry

The need in any forestry system fall into either land degradation, deforestation, or restoration of forest lands. While many forested areas have converted to urban and agricultural areas, the meta-analysis for this study has focused on areas within a forest system with identified knowledge gaps in various literature. There is a need for land use planning and reforestation of barren regions, such as degraded lands, hillsides, and the expansion of cultivated land for sustainable resource management [42]. Another knowledge gap has been understanding environmental changes in the forest and predicting climate-induced changes in mature trees [144]. Some authors have identified specific areas of interest. For example, Kayet et al. (2016) undertook research on land surface temperature (LST) and described knowledge gaps related to LST being affected on hilltops, highlighting the evaluation of impacts along with policy changes [145]. Other researchers have focused on analyzing LULC classifications systems, specifically on land products such as map accuracy for these systems to function [36].

3.5.3. Data/Images/Modeling

The meta-analysis also focused on studies in the area of data, image, and modeling. Our analysis identified studies that stressed the need for research in land cover change, with a focus on modeling future spatial patterns [146]. Meanwhile, another focused on spatial data modeling of classification systems, emphasizing areas of need such as accuracy, changing land monitoring, and current [134]. In contrast, another researcher focused on validating of data and models for unexplained points in data [147]. While most of these knowledge gaps are addressed with the multiple studies on LULC data, images, and modeling, research studies have described the need for user-friendly images with high resolution for LULC classification. This contributes to decision-making for urban planners [148]. Another research has focused on land surface climate-change models and their simulation at different scales [149] and provides information for changing landscapes and human impacts [40]. While technological advances have seen data, images, and modeling improvements, their practical use is encouraged for further advancements. This helps to optimize model ensembles, compare images of a given area and identify erroneous output data; validation and accuracy are critical factors for transparent LULC classification of objects and classes [150]. Satellite images need to be preprocessed and accurate, which helps with information advancement, accuracy, reliability, and appropriate estimates of LULCC at the global level [139].

The synthesis identified the following needs related to data, images, and modeling:

1. The general need for:
   - Accurate statistical testing;
   - Identical land-cover configurations;
   - Reduction of model uncertainty;
   - Clear experimental protocols [151].
2. Systematic monitoring and management of land use systems [38].
3. Automating image classification processes for accessible data and processing results in a shorter time [35].
4. The assessment of the performance and sensitivities in LULC classification algorithms [111].
5. Improve accuracy, eliminate uncertainties and discrepancies in the spatio-temporal changes [60].
6. Consistency and comparability of different land cover maps, understanding their suitability and limitations for specific applications [152].
7. Detailed datasets for environmental change studies, resource management, climate modeling, and sustainable development of terrestrial land cover are needed [62].
8. Available data for modeling the advancement and collection of new datasets are needed [8].

3.5.4. Hydrology

The meta-analysis focused on the effect of LULCC on hydrology, with a specific interest in groundwater flow and management. The need for further studies of LULCC assessment impacts on groundwater fluxes is paramount since water management is essential [120]. Researchers are concerned with accurate references of existing information related to landscape changes. There is a need for the assessment and harmonization of information [153]. The measurement of land quality impact indicators by various units to measure pathways affected is also essential for water assessment [29].

4. Discussion

4.1. Land Use and Land Cover Definition

The extent to which "Land-use and Land-cover" definitions differ among research articles has changed over the decades. The direct descriptions for each have been used directly by authors to show differences [8]. There are some uncertainties related to the understanding of each term for definitive use [51]. Researchers have stated that definitions can be contingent on the sector based on their description [154]. This research investigation shows the author's intention as being simple, clear, and concise, where "Land use" is defined base on the activities done by human intervention and "Land cover" corresponds to the physical structures that may occupy the land. This research focused on the synthesis of research journal articles that defined "Land-use and Land-cover". Showing similarities based on keywords used (land use/land cover) and how each research journal interpreted these terms while synthesizing these definitions from the meta-analysis resulted in a general description used for each term. The definitions were placed into a table format to show from researchers (Table 2) and interpreted into a form that researchers can use to define "land use" and "land cover" based on the attributes each term represents (Figure 1).

This synthesis found various similarities as it relates to multiple articles using "land use" as part of the definition to define "Land use" and "cover of land" for the description of "Land cover". Limitations related to this literature review identified research articles collectively defining these terms together, conferring broad base definitions to explain the terms holistically or in contrast to each other [26,41]. Other reports have shown definitions to overlap [155], even established that the purpose for each term is not absolute [51]. This was identified from research findings related to definitions by particular region and research year. The use of a standard and straightforward explanation for "Land-use and Land-cover" should always be clear for readers to understand the dynamics of each description. Hence, the findings from this research propose that definitions for each term should be direct, suitable, and relevant for clear understanding, separated to show a disparity between each term and transparent as it relates to their concepts. Inferences such as "use of land" and "cover of land" will continue to be part of the definitions for both "Land use" and "Land cover". Further, researchers will curtail these definitions to suit specific land management projects types or for decision making.

4.2. Land Use and Land Cover Classification System

The use of "Land-use and Land-cover" classification systems has contributed to the awareness of land-use/land-cover objects by country, continent, and global scale. Countless research articles have shown remote sensing of land images and objects (e.g., forest, cropland, urban areas), land cover mapping databases, and empirical datasets to develop classifications for particular regions. "land use and land cover" classification systems give a spatial analysis of objects for specific landscapes [156], the monitoring of land change from temporal and spatial scales [157], and clear insight on land cover dynamics related to land resources and ecosystem services [158]. This research synthesized articles representing classification systems using the key terms "Land-use and Land-cover" and "classification system and scheme". These classification systems were recognized based on their use by country, regionally, and globally. Yang et al. (2017) have identified a solid base for our research findings on classification systems used globally [49]. Remote sensing technology for LULC mapping across a range of spatial scales has guided many nations to establish land cover mapping and monitoring programs that use moderate resolution satellite data [43]. These LULC information sources have been vital for various disciplines (e.g., urban planning, forestry, etc.) and regularly updated for land monitoring. Remote sensing technological advances have led to a more accurate assessment from LULC classification systems and model simulations. This aids in improved monitoring, observation, and analysis of land used and alteration by anthropogenic activities [34].

The literature review identified, collected, evaluated, and review various research articles that give specific information on each classification system related to (1) the year established; (2) the country, region, or global use; and (3) the scale of use. The synthesis provided information on classification systems, with a direct approach to LULC changes, whether hierarchical or used based on their ease of access, spatial scale, and user-friendly qualities. It identified the ability for classification systems suited for a country as against continental use. The synthesis identified key challenges and limitations related to gathering information for each classification system. Contingent on the region of use, classifications are either "scheme" or "system". This is highly dependent on their temporal scale of use, type of projects, meeting requirements, and bypass limitations [11]. This synthesis showed similarities of particular classification systems among research articles used in this study. While many classification systems are associated with their country of origin, the literature review shows that researchers favor particular ones. Primarily, they are chosen based on their constant upgrades, accuracy, validation, and fitness of use.

4.3. Land Use and Land Cover Meta-Analysis

This research took an analysis of various "Land-use and Land-cover" meta-studies as a means to investigate (1) direct changes, (2) indirect changes, (3) data and method changes of LULC. These meta-studies were identified based on each category and placed into a tree diagram (Figure 2), further breaking down each to show how each category's meta-studies were synthesized. Meta-studies used meta-analysis to congregate various data sources, methods, and ideas to advance a missing knowledge base for a particular study area [119]. This study used a literature review to show the various meta-analysis studies for LULC. A total of fifty-five (55) articles were downloaded and sorted, forty-eight (48) were appraised and used to build the analysis tree (Figure 2). A timestamp for the appraised articles presented in Figure 3 is for the years 2000 to 2019. They were compiled on their synergistic efforts in LULC studies, their effects on direct and indirect landscape changes and their affiliation to land use/land cover remote sensing and modeling.

This research showed how various meta-analyses for each category used different protocols for information collection and synthesis. This research identifies LULC meta-studies in areas of direct land influence (e.g., forest related and for ecosystem services) and indirect land influences (e.g., biodiversity and carbon sequestration). While researchers focused on LULC modeling and dataset imagery [119], this research used narrow criteria to identify ideal meta-studies for this category. Therefore, there were few meta-studies. However, it would be advisable to adopt different measures, focusing on future research objectives related to modeling and remote sensing. The benefits of this analysis will help in understanding the various complexities for synthesizing meta-studies in LULCC. A literature review of meta-studies can provide inferences for researchers determining research journals as "best use" for particular interest categories. This analysis shows how studies in LULC were more fitted to direct and indirect land use and land cover. Most studies complied information for decision-making for land management, ecosystem services, and biodiversity. The next step relates to meta-studies used as a premise to understand land monitoring for various ecosystems. The information is regularly updated with more research conducted in these areas internationally and at the local level. Further synthesis revealed meta-studies that identified necessary action for specific land projects, leading to proper decision-making and, in some cases, policy modification or changes.

4.4. Land Use and Land Cover Challenges

Research findings have identified several challenges related to "Land-use and Land-cover", some were minor, while others were crucial. The literature review identified significant articles that comprise LULC challenges; the PSALSAR framework characterized the challenges into two categories for LULC, namely (1) data quality and (2) data consistency (Table 4). The focus of this synthesis considered remote sensing and imaging in LULC. Our investigation identified some keywords associated with data quality and consistency to develop a word cloud (Figure 4), where significant challenges for each category were highlighted and deemed necessary. There were limitations since our synthesis was category-specific and focused on challenges related to data quality and consistency. However, these categories identified are significant in the field of LULC [119].

The importance of data value and verification for GIS has increased with the development of satellite data for land-cover mapping [159]. As a result, large amounts of data are required for global land-cover mapping [160]. This research highlighted significant challenges related to data accuracy and consistency. The analysis, classification, and description of valid data are essential. Therefore, the focus on data processing, validation, verification, access, and accuracy are vital to address major challenges in LULC changes. This information can determine how LULC projects form conclusions and make decisions. While some of the challenges identified in this study are continuously being addressed, research synthesis describes and determines which challenges are still primary concerns. The idea is to highlight significant problems and encourage researchers to approach continued technological advancement in such areas. Comparable findings reported by Verburg et al. (2011) support that the purpose of LULC challenges is to see them dissolved over time [13].

4.5. Land Use and Land Cover Knowledge Gaps

The combination of Land use/Land cover challenges and knowledge gaps correlates to each other. While many knowledge gaps associated with remote sensing studies are related to LULC [161,162], further LULC investigations have various knowledge gaps. Related to the importance of our studies, we identified significant articles in four categories and created a word cloud (Figure 5) based on the critical knowledge gaps for "land Use and land Cover". Our synthesis found most knowledge gaps corresponded to the category of remote sensing, specifically for data, imaging, and modeling. The information identified specific knowledge gaps that were time-sensitive and relevant. Our finding highlights many knowledge gaps to be data-related: Verification/validation of data, data quality, data harmonization, data gaps, data inconsistency, and the uncertainties associated with data were the major knowledge gaps from our analysis. Our findings revealed that there was no single approach to addressing the knowledge gaps identified. There need for comparison and assessment of updated data to improve data quality is paramount to enhance information for LULC projects [13].

Each category gives information on knowledge gaps and the importance of them being addressed critically. The results indicate that some knowledge gaps will be addressed over time. However, this accomplishment will occur with ongoing investigations in LULC [62]. Research findings did not specify a single path to address the knowledge gaps. The consensus was clear that if researchers did not focus on them, they would continue to cause significant consequences in LULC investigations for global change [144]. Consequently, the significant gaps identified have provided areas of analysis that represent the challenges in this field. Data quality, availability, and harmonization emerged from our synthesis as direct reasons for the LULC challenges. This literature review presented the necessary information that requires focus and assessment for LULC research.

5. Conclusions

The primary objective of the present work was to present five critical areas of LULC in the form of a literature review. Enormous work on LULC has been executed over the decades in numerous topical areas by multiple researchers over time. The PSALSAR framework for this systemic review will support scientific and straightforward synthesis. This synthesis has proven to be a method to synthesize, organize, and present LULC information and make inferences related to specific areas of interest. Our study showed a systemic approach to how secondary information on LULC is presented so researchers can interpret and make assumptions. Figure 6 shows a step-by-step process of our research procedure, as well as how secondary information from research articles was collected, appraised, and presented on the five topical areas of our research interest. This flowchart provides a holistic view of how research articles were used to answer questions in each specific category.

Our research findings recommend understanding various land use/land cover areas. A literature review helps synthesize, compare, and present information among multiple studies. Our bias related to articles selected was based on the keywords for each to keep our research concise. We would recommend using more keywords for LULC studies to get a broader range of articles for analysis. Future research for LULC studies should focus on remote sensing, land-cover monitoring, and their effects on ecosystem services. We recommend a research procedure presented in Figure 6. This will aid the researcher in analyzing the information required for new LULC initiatives accurately. This methodology can find similarities for missing knowledge in LULC studies, giving researchers a base method to apply detailed synthesis. The identification and assortment of summarized knowledge in particular LULC research areas are vital. Thus, using this methodological framework, LULC investigations will report findings accurately and provide inputs for environmental monitoring.

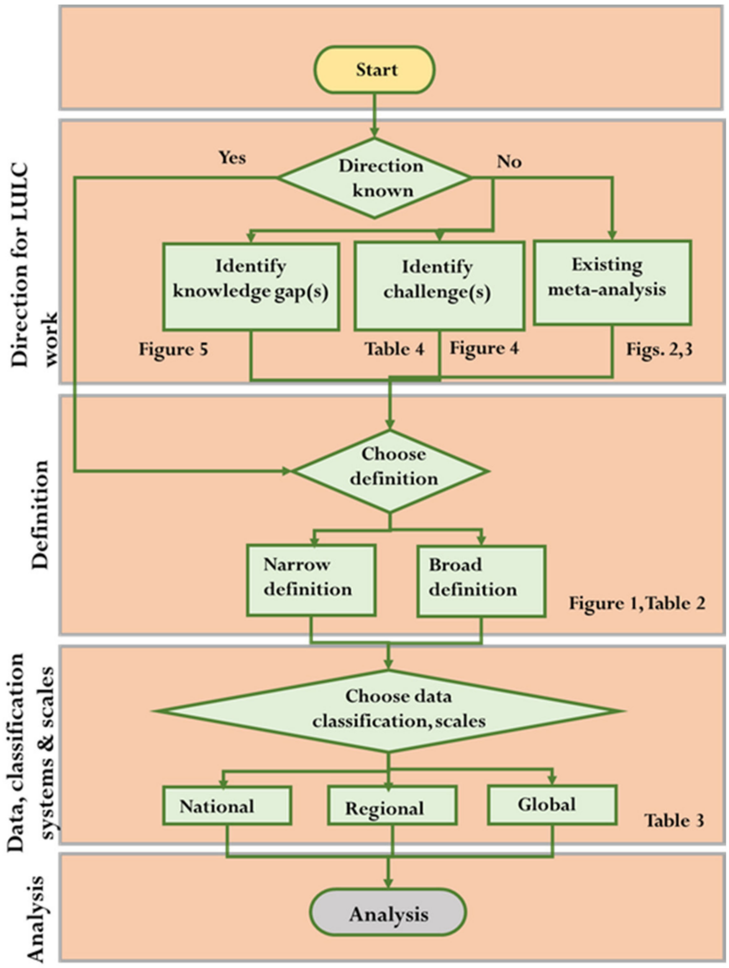

Figure 6. Flowchart of the synthesized research process, the procedure developed for a continuous flow of information from information acquisition to analysis.

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