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An International Library for Land Cover Legends: The Land Cover Legend Registry

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Abstract: Information on land cover is vital to numerous United Nations (UN) missions, including achieving the Sustainable Development Goals (SDGs). Because land cover data are developed by a variety of organizations for a range of objectives, they are based on different classification schemes and have discrepancies. In addition, the sustainability for land cover is hampered by limited access to information and documentation. Accordingly, international standards for land cover are developed to improve interoperability between different land cover datasets. However, the use and development of land cover datasets are limited by various factors including availability of properly documented land cover legends in support of different applications including change assessment, comparison, and international reporting. The purpose of this article is to highlight the importance of land cover in achieving several goals and to introduce the first international platform for land cover legend, named Land Cover Legend Registry (LCLR). This registry is a contribution to the international land cover community and the UN in effort to promote and support data harmonization processes and interoperability from local to global level, and vice versa. Users can not only use the registry for preparing consistent datasets, but also contribute to it by providing the latest data to ensure the long-term availability of both updated and existing datasets around the world. Moreover, building on the experience developing land cover legends with different nations, a brief explanation on the preparation of legends is also provided. Additionally, it is more important than ever to develop land cover registers to support the use, expansion, integration, and use uptake of land cover data, particularly for innovative remote sensing, machine learning, and information and communication technologies and techniques that build on existing and national contexts.

Keywords: interoperability; standards; geospatial; semantic ontology; harmonization; classification

Citation: Mushtaq, F.; Henry, M.; O'Brien, C.D.; Di Gregorio, A.; Jalal, R.; Latham, J.; Muchoney, D.; Hill, C.T.; Mosca, N.; Tefera, M.G.; et al. An International Library for Land Cover Legends: The Land Cover Legend Registry. *Land* **2022**, *11*, 1083. https://doi.org/10.3390/land11071083

Academic Editor: Giusppe Pulighe

Received: 31 May 2022
Accepted: 29 June 2022
Published: 14 July 2022

1. Introduction

The critical need for monitoring natural resources has increased over time because of many factors, including rapid growth in population and climate change [1]. The impacts of climate change are not limited to one country and extend beyond national and political administrative boundaries. An assessment presented in the Intergovernmental Panel on Climate Change (IPCC) report suggested that climate change has had severe effects on freshwater, terrestrial, and marine ecosystems, including alterations in seasonal timing with

negative socioeconomic consequences, heat extremes with extinction of local species, forest degradation, hydrological changes, and agricultural productivity stress. This condition exacerbates the global food and water security crisis and obstructs progress toward reaching the SDGs [2].

Land cover information is a critical component in monitoring natural resources and is recognized by the UN as one of the fourteen fundamental data layers [3]. This information is essential to support many mandates of the UN, including the United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD), and United Nations Forum on Forests (UNFF) [4,5], as well as many other national, regional, and/or international initiatives. The land cover information serves as a critical baseline information for land, water, and/or hazard monitoring, including agriculture production [6], rapid crisis impact assessment on agriculture sector [7], food security [8], nutrition, environmental conservation and management, climate science, and many others.

Different organizations create land cover datasets to meet specific user needs utilizing a variety of classification schemes, tools, approaches, and datasets at the global [9–11], regional [12,13], and national levels [14]. Because different land cover classification schemes are used, the interoperability between land cover datasets and their compatibility and comparability are often very limited. Such consistency is required to aggregate and harmonize results to allow cross-comparison and validation for understanding regional and global landscape trends and/or climate changes [15,16], as well as for the sustainability of the land cover monitoring efforts. Several international, regional, and national organizations and agencies have emphasized the vital need for improved, consistent, and harmonized land cover statistics and spatial data from local to global levels to address the environmental and climatic issues at a larger scale.

In this context, geospatial technologies are important in the paradigm shift and transition to climate change initiatives, greener economies, natural resource conservation, sustainable carbon emissions, catastrophe effect assessment and management, and sustainable agriculture production, among other things [17–22]. These technologies play a crucial role in the development of land cover maps and datasets using integrated efficient and cost-effective approaches including remote sensing and machine learning [14]. The use of standardized information is required for the proper processing of data and information to profit from recent technological advancements in geospatial fields.

To overcome the inconsistencies in generic classification systems, dozens of countries and international organizations have now created land cover datasets using the Food and Agriculture Organization of the United Nations (FAO) Land Cover Classification System (LCCS) based on Land Cover Meta Language (LCML-ISO 19144-2) [14]. In LCML, the land cover classes are defined using a hierarchical structure [16,23]. This system does not intend to alter or replace the previous classification systems. Nonetheless, it provides a consistent framework for the comparison and integration of data for any generic land cover classification [23], building upon the involvement of FAO in several countries. Therefore, these datasets can be used for integration and harmonization processes to analyze the results and changes at the global, regional, and national levels.

The role of the land cover legends is the initial step in the preparation of land cover maps and datasets [15]. For this, proper and complete documentation, as well as information on the land cover classes in a land cover legend, including clear and unique description of the class and/or photo-keys using field photographs and/or satellite imageries, is required. Therefore, to fill the gap, development of land cover registers is needed where information can be stored and be easily accessible to the user.

Development of land cover registers are needed (1) to facilitate the broader use and expansion of the land cover register, (2) to create sustainable ownership and technical capacity to use the register for land cover translation purposes, and (3) to support the migration of the register to incorporate new land cover and land use schemas. Accordingly, the first international platform, named the Land Cover Legend Registry (LCLR), was

developed to support cataloguing land cover legend descriptions based on international standards. The register is meant to host a curated list of legends created at the global, regional, and national levels. Users can easily and freely access and download land cover legends, their datasets, and relevant documents.

The rest of the article is organized as follows. Section 2 reports on a survey of land cover and a few key findings that prompted the development of the LCLR. The focus then shifts to the latter, reporting on some aspects, like standardization, that have influenced its architecture, as well as its place in a growing ecosystem of tools developed by FAO in collaboration with other international institutions. This is followed by a discussion of important aspects that LCLR helps to address, before moving to the conclusions.

2. Land Cover Legend Registry Development

2.1. Land Cover User Need Assessment

The work on the development of the registry was inspired by a survey on the importance of land cover in different domains and applications, including change assessment, comparison, international reporting, and others at different levels. Various organizations contributed to the development of the survey questionnaire, including the FAO; Organization for Economic Co-operation and Development (OECD); United Nations Statistics Division (UNSD); Basque Centre for Climate Change (BC3Research); United States Geological Survey (USGS); National Research Council, Italy (CNR); and University of Southampton (Soton). The main aims of this survey were (1) to assess the user requirement on the use of land cover information in the context of SDGs; (2) to present limitations in the development of land cover; and (3) to contribute to the establishment of international standards, i.e., LCML and others.

Numerous academic, scientific, government, and public sector entities from the national, regional, and international levels participated in the survey, particularly from the environmental, agricultural, and climate sectors. The results revealed that land cover information is very important and is used for all SDGs at different levels and dimensions, particularly for climate action (SDG 13) and life on land (SDG 15) (Figure 1) [24,25]. Moreover, the results indicated that the lack of documentation and information on land cover and unavailability of existing datasets are the main issues in the development of consistent and/or harmonized land cover maps.

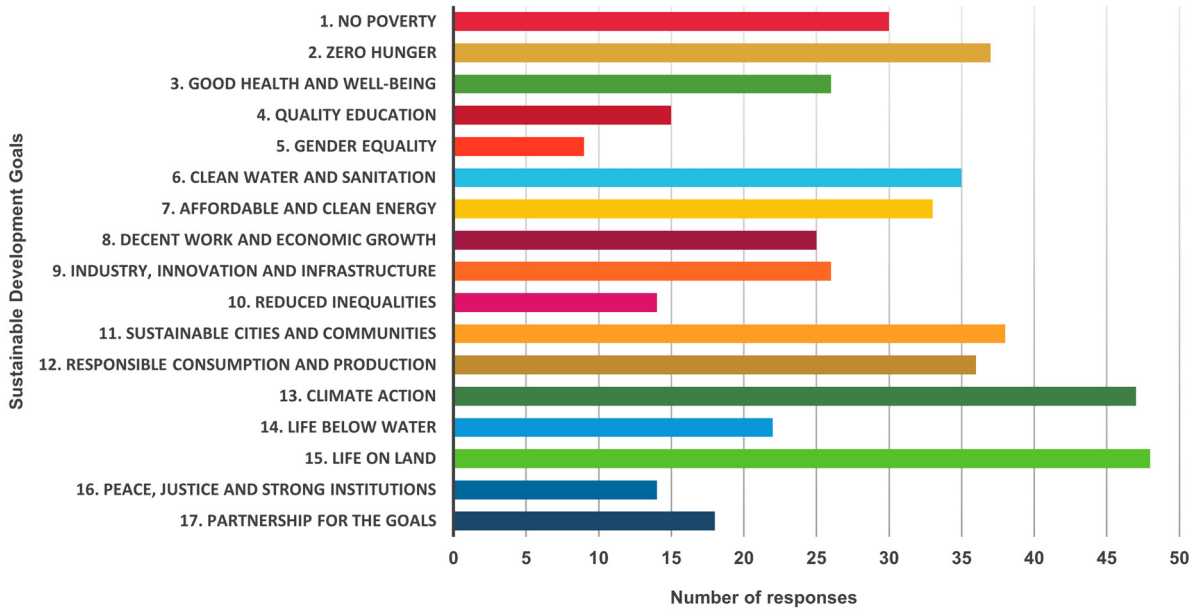


Figure 1. Land cover in the Sustainable Development Goals. Reprinted/adapted with permission from Ref. [25]. 2022, FAO and ISO/TC211 AG13.

2.2. Land Cover Database

A registry database was developed for land cover legends based on the registry concepts that is derived from ISO 19135-1 [26], identified in ISO 19144-1 [27], and makes use of the descriptive metalanguage described in ISO 19144-2. The LCLR was internally developed as a spreadsheet application (i.e., Microsoft EXCEL) and is a flat table linked through a primary key with different sub-registers. After a set of postprocessing, it is presented in a more compelling form. The registry consists of three main parts, i.e., (1) metadata describing the whole register (content), (2) a description of the meaning of each item in the register (content description), and (3) the registered items (categorization) (Figure 2) [28].

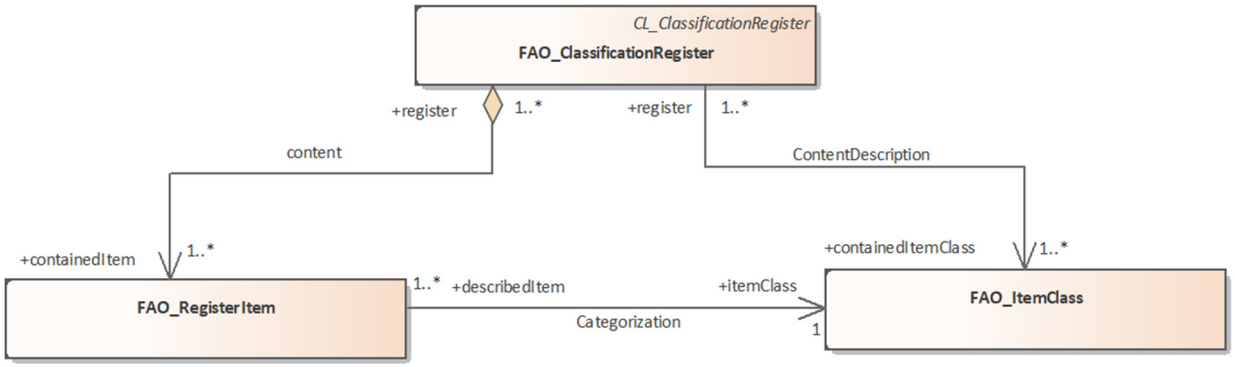


Figure 2. Structure of the land cover legend registry. Reprinted/adapted with permission from Ref. [28]. 2021, FAO, UoS and STIIMA-CNR. * Multiplicity (https://khalilstemmler.com/articles/uml-cheatsheet/, accessed on 15 June 2022): a classification register can have 1 or more register/RegisterItem/ItemClass.

The registry contains information about the land cover legend, land cover legend classes, land cover dataset, and relevant reference documentation. Several of the land cover legends in the database were prepared and translated from the original classification system into ISO 19144-2 standard using LCCS software [29]. Moreover, this database also contains land cover legends in different classification systems but marked as not yet translated. The registry is multilingual to support the adaptability of systems in local and/or national languages for data integration, comparison, and many other purposes.

2.3. Land Cover Legends

The land cover legends provided in land cover legend registry are at the global, regional, national, and sub-national levels. Legends are available in different formats that are used worldwide. The different legend file formats are CSV, LCCS, EAPX, HTM, and XSD, and are devised to be used under different software and platforms. Furthermore, the land cover legends in the registry were created to account for a variety of scenarios, including the following:

1. Country- or region-specific legend available and translated to LCML, e.g., non-irrigated arable land [30] translated into LCML using LCCS version three (LCCS3) software. This class was translated as "herbaceous growth forms" with the characteristics "cultivated and managed" and "rainfed". With an "optional" presence type of the LCML element "woody growth form" defined by a standard characteristic as "Orchard and other Plantation" (Figure 3);
2. Land cover legend available and translated from version 2 to version 3 using LCCS3 software, e.g., tree crop class from Himalaya land cover legend [31] (Figure 4);
3. A new legend prepared using LCCS3, e.g., "evergreen hill forest" class [32] (Figure 5).

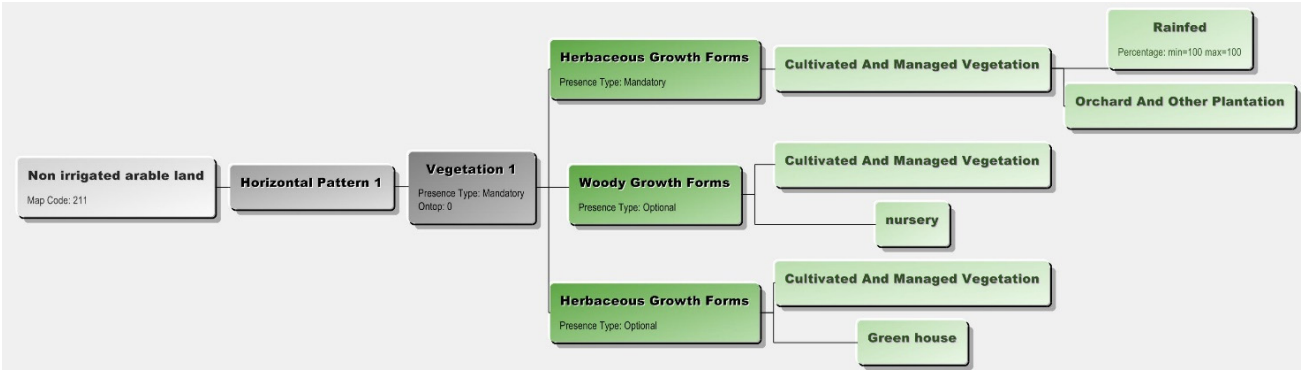
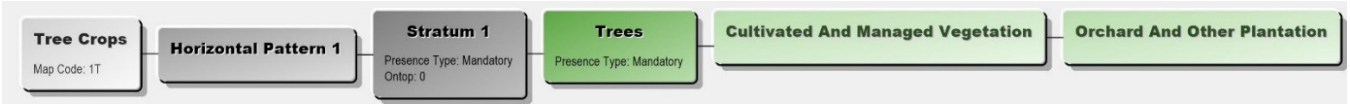


Figure 3. Non-irrigated arable land class in CORINE land cover legend using the LCCS3 tool.

Table	Structural Domains LCC Code	Mode	Level	Classifiers	User's Label	Land Cover Class Name	Map Code	User's Description
1	Cultivated and Managed Terrestrial Area(s)							
1	10001-W8	0	1	A1-W8	Tree Crop	Tree Crop(s) Crop cover Orchard(s)	1T	Tree Crop

(**A**)



(**B**)

Figure 4. Himalaya land cover legend. (**A**) Land cover class ''tree crop" using LCCS2 and (**B**) land cover class ''tree crop" using LCCS3.

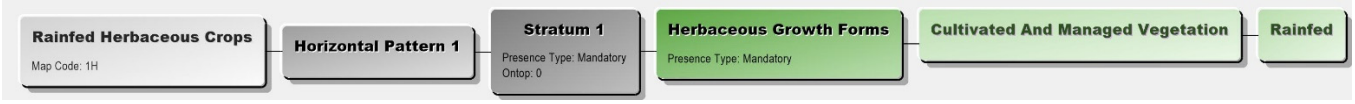


Figure 5. Rainfed herbaceous cropland class using the LCCS3 tool.

2.4. Land Cover Legend Registry Platform

The open-source LCLR platform is an online library for land cover legend and relevant products. This platform is available on the FAO Hand-In-Hand geospatial platform [33] and data can be downloaded directly in different formats. Meta data for this registry are available on the FAO CKAN [34]. The datasets on the LCLR platform are updated weekly. A user can download land cover legends in provided file formats, i.e., LCCS, CSV, EAPX, HTM, XSD, and so on. Land cover classes are prepared based on Unified Modeling Language (UML) and are available in JPEG format for download. Relevant land cover datasets are available in raster and/or vector format. All reference data for relevant land cover legends are available in PDF format. A list of land cover legends that are currently available on this platform is provided in Figure 6.

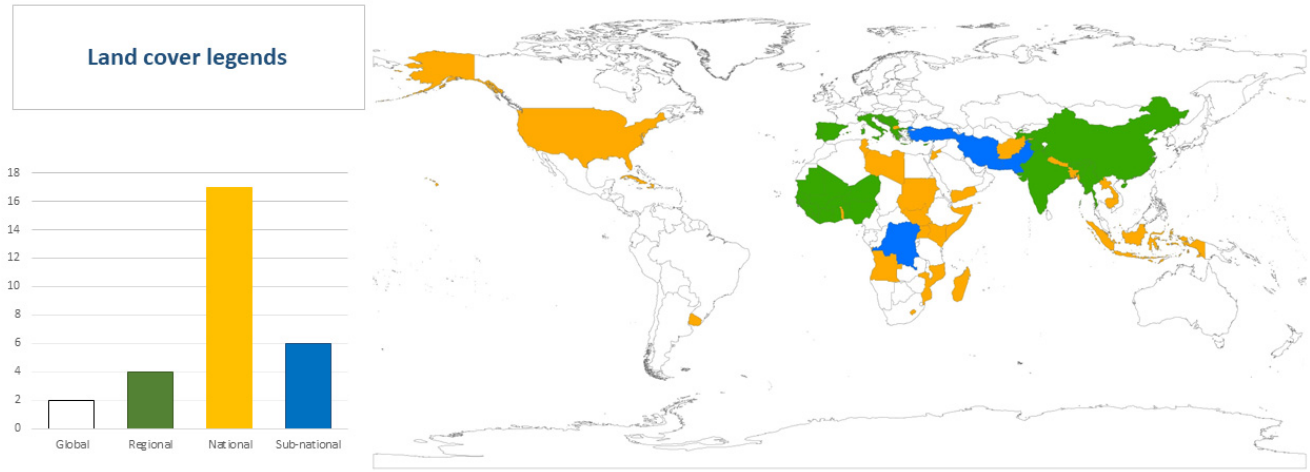


Figure 6. Status of land cover legends in the land cover legend registry platform using the LCCS3 tool.

2.5. Connectivity to Other Platforms

The Land Cover Legend Registry (LCLR) platform has the potential to link to the cloud computing platforms including System for Earth Observation Data Access, Processing, and Analysis for Land Monitoring (SEPAL) [35] and Google Earth Engine (GEE), as well as other desktop software like Enterprise Architect and many others. For example, the land cover legend in CSV format after downloading from the LCLR platform can be directly uploaded into the SEPAL platform to classify the satellite images for land cover preparation (Figure 7) using machine learning techniques including random forest (RF), support vector machine (SVM), and others.

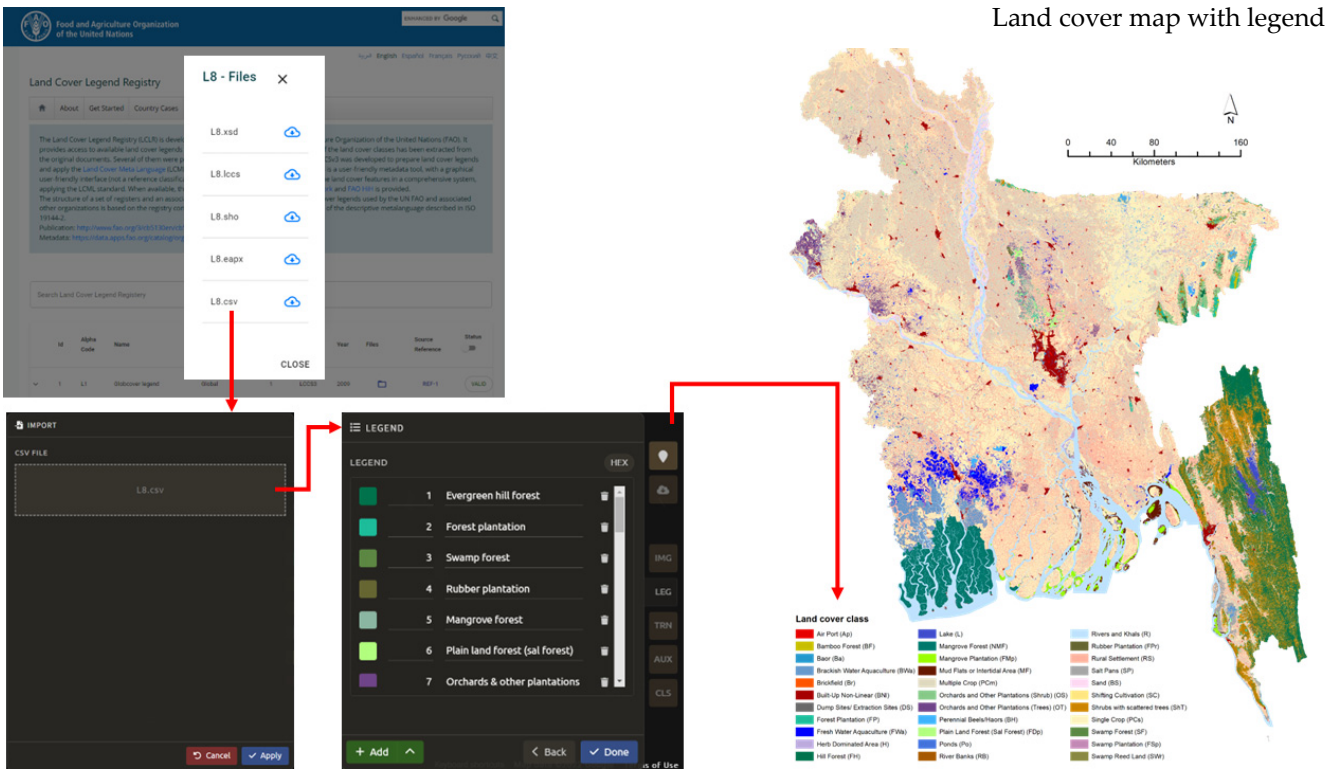


Figure 7. Land cover legend registry connectivity to SEPAL for land cover mapping.

2.6. Availability of Land Cover Datasets in the Registry

The availability of land cover datasets is as important as the development of datasets. There are several organizations and countries that have developed and are developing land cover datasets for different purposes and using different approaches and supporting documents. In most cases, land cover legends have limited documentation and the land cover legend registry provides only land cover legends that have been prepared using LCCS3. For example, the national land cover map for Bangladesh 2015 was prepared based on the LCML using the LCCS3 tool [34,36]. This interoperable system and the land cover dataset are used for a variety of applications including national forest resources assessment, estimation of REDD+ activity data, integration of biophysical and socioeconomic information, and semantic similarity assessment [14]. The land cover legend for Bangladesh is available in the registry along with a dataset and reference document. Moreover, land cover maps for Jordan [37], Afghanistan [38], and many others are also available in the registry. Therefore, a user can access existing and latest land cover datasets using this registry and can further use it for their purpose.

3. Discussion

3.1. Land Cover Data for All

Although there are several global and regional products and platforms that provide land cover products, accessibility in a user-friendly manner is always a hurdle. There is no platform that can provide updated information on existing land cover legends at the global, regional, national, or local levels. The LCLR, as an online library for land cover legend, aims at closing this gap by ensuring its wider use and accessibility by anyone around the world. This registry is based on international standards that are widely recognized by land cover experts. LCLR has potential to be used by the land cover community for different purposes and sectors including agriculture and food security monitoring, land and water resources assessment, environmental accounting, land use planning, and emergency reporting. Furthermore, there is potential for the scientific community to contribute to improve land cover at local to international level by following LCML and contributing to using or providing new legends and datasets to LCLR.

3.2. Semantic Interoperability and Comparison

Because traditional land cover legends contain symbols that are symbolic, brief, and vague, determining land cover similarity has always been difficult. The inconsistency of classification systems continues to hinder how the world is represented and managed, despite the advancements in geospatial technology that give access to new images, tools, and methods. In order to normalize geographic representation of our surroundings, nomenclatures have been developed over time [30,39], but they have not addressed the issue of sufficient representation of land cover semantic meaning.

In this context, under ISO TC211, 19,144 series comprise the set of standards that are meta languages for addressing different classification systems and approaches. For example, ISO 19144-2 (LCML) on land cover provides a common reference structure for comparison and integration of different data. It is not intended to replace any classification system. The translation of classification systems from national systems can support data integration as integration of data is required to address regional and worldwide requirements.

Classes that are coded using the LCML syntax can be easily used for land cover similarity assessment analysis. Exploiting the intrinsic modularity of the LCML standard, the similarity between land cover classes can be assessed quantitatively [15]. For instance, hosted in the Bangladesh Forest Information System (BFIS) geoportal, an object-based methodology is operationalized to make an automatic similarity assessment between LCML-derived classes present in different databases. Therefore, using LCLR, a user can use the LCML syntax-based legend information and compare the results with original datasets and/or new datasets.

3.3. Connectivity, Multi-Languages, and Multiple Formats

Land cover legend data are available in different file formats and in different languages from where a user can download data directly from the platform under the 'file section' and can be used in various platforms and tools, cloud computing, as well as desktop software, e.g., SEPAL platform, Enterprise Architect (EA), and so on. Legends in different languages make the comparability at national context more understandable. This registry has the potential to add more languages and file formats in the future. A user can use and contribute to the registry by providing legends in local language and different file formats.

3.4. Sustainability of the Registry—Future Aspect

There has been tremendous work on the development of land cover classification schemes, tools, and methods to support the land resource monitoring and to develop efficient and consistent land cover maps all around the world. The development of registers, in this context, can contribute to the international community by providing the latest existing land cover legends. For this, the first international register based on international standards has been developed [28]. In order to sustain the registry, a user can contribute by providing land cover legend using the LCCS3 tool, as described in Section 2. Moreover, a user can also provide a land cover legend in local classification schemes that can be translated using LCCS3 and will be accessible through this platform.

For the sustainability of land cover registers, existing and/or new, there is a need to develop a global register that incorporates all of the existing register to ensure the data availability to users.

4. Conclusions

Consistency in land cover datasets at national level is crucial to many applications that can be used and integrated in the analysis of local to global issues and trends. Land cover registers can fill the gaps, including limitations in data sharing and accessibility to the user. LCLR is the first international online catalogue that provides complete information on land cover legend at different levels. The registry supports multiple languages and multiple formats and is easily adaptable from local to global systems. The development of this registry is the first step towards harmonizing the different schemes using LCML and providing a platform that can facilitate end users at its best in the most common ways. It aims to support various international initiatives like ISOTC211 AG13, the FAO Hand in Hand (HIH) initiative, Global Agro Ecological Zoning (GAEZ) [40], WaPOR [41], SEPAL, and so on by providing the LCML-based land cover legend.

Using LCLR, a user can not only access a land cover legend with a proper description but can also contribute to populating the registry to ensure the sustainability of the system by engaging land cover community all around the world. They can also support the process of data transparency, consistency, and comparability through efficient ways. Moreover, this LCLR can contribute to development of harmonized land cover legends and datasets at various levels including global. Also, there is a possibility in the future to develop a registry for land cover or land use using multi-model database management system that can incorporate all existing and/or new registers with a sustainable framework and ownership.

Author Contributions: Data curation, F.M., M.H., A.D.G. and E.T.; Formal analysis, F.M., N.M. and E.T.; Funding acquisition, M.H.; Investigation, F.M., M.H., A.D.G. and E.T.; Methodology, M.H., A.D.G., C.D.O. and J.L.; Project administration, M.H.; Resources, G.F. and J.L.; Software, M.G.T., K.M., Z.C. and N.M.; Supervision, M.H., A.D.G. and C.D.O.; Validation, M.H., A.D.G. and C.D.O.; Visualization, F.M., N.M. and M.G.T.; Writing—original draft, F.M., M.H., A.D.G. and C.D.O.; Writing—review and editing, F.M., M.H., C.D.O., A.D.G., R.J., J.L., D.M., N.M., C.T.H., M.G.T., K.M., G.F., A.G., E.T. and Z.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. The APC was funded by FAO.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All the land cover legend can be downloaded from https://www.fao.org/hih-geospatial-platform/en/resources/land-cover-legend-registry/ (accessed 15 June 2022).

Acknowledgments: The authors would like to thank the anonymous reviewers for the comments that helped improve the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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