FloodAdaptVN

# Thematic Legend Harmonization for Central Vietnam

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Photography by Katharina M. Borgmann, in Vietnam

**Centered on the land-use legend from the Vietnamese Department of Natural Resources and Environment (DONRE), a thematic legend harmonization was formulated for the central Vietnamese province of Thừa Thiên Huế (TTH). This harmonized legend facilitates interoperability between distinct land use and land cover categories, serving as a relevant tool for flood management. It is also conducive to activities focused on the integration of ecosystem-based approaches into flood risk management, thereby promoting adaptive and sustainable urban development in central Vietnam. The harmonization process was executed in three sequential phases. Initially, pertinent land use and land cover products, as well as project perspectives, were identified, and their respective thematic legends were compiled. Subsequently, a land cover classification system was employed to disaggregate the legend classes into discrete building blocks, termed classifiers. Ultimately, common thematic elements were discerned, a conversion table was constructed to align the disparate legends, and a newly harmonized legend was generated.**

Tóm tắt tiếng Việt
Dựa trên huyền thoại về sử dụng đất từ Bộ Tài nguyên và Môi trường Việt Nam (DONRE), một huyền thoại chủ đề được hòa quyện đã được xây dựng cho tỉnh Thừa Thiên Huế (TTH) ở miền Trung Việt Nam. Huyền thoại hòa quyện này giúp tương thích giữa các loại sử dụng đất và phủ đất khác nhau, phục vụ như một công cụ liên quan cho việc quản lý lũ lụt. Nó cũng có lợi cho các hoạt động tập trung vào việc tích hợp các phương pháp dựa trên hệ sinh thái vào quản lý rủi ro lũ lụt, do đó thúc đẩy sự phát triển đô thị linh hoạt và bền vững ở miền Trung Việt Nam. Quá trình hòa quyện được thực hiện trong ba giai đoạn liên tiếp. Ban đầu, các sản phẩm sử dụng đất và phủ đất liên quan, cũng như các quan điểm dự án, đã được xác định và các huyền thoại chủ đề tương ứng của chúng đã được biên soạn. Tiếp theo, một hệ thống phân loại phủ đất đã được sử dụng để phân tách các lớp huyền thoại thành các khối xây dựng riêng biệt, được gọi là bộ phân loại. Cuối cùng, các yếu tố chủ đề chung đã được nhận diện, một bảng chuyển đổi đã được xây dựng để căn chỉnh các huyền thoại khác nhau, và một huyền thoại hòa quyện mới đã được tạo ra.

## Introduction

Accelerating climate change has led to variations in water and temperature regimes worldwide, resulting in increased intensities of calamitous events such as droughts and floods [1]. Vulnerabilities of ecosystems and societies to these events differ by type and vary spatially and temporally. Southeast Asian agglomerations are particularly affected [2]. Driven by rapid economic development, political, economic, and civil society institutions face challenges in adaptation. Adaptation performance and societal resilience against climate change are influenced by experience, implementation capacity, and sustainable planning prospects [3]. Central to successful adaptation activities is the interdependency of various societal actors—politicians, administrators, scientists, and responders—in shaping a joint planning process.

A common understanding of affected assets and land, through a unified nomenclature of information, is essential for constructive communication and collaboration among stakeholders. Definitions of land use (LU) and land cover (LC) and their associated expectations differ depending on perspective. While administrative staff may focus solely on land use, modelers often consider land cover; both perspectives are crucial for calamity management. Land cover refers to the biophysical surface of the Earth, whereas land use pertains to its anthropogenic function [4]. Multiple legends can impede collaborative efforts and erode cohesion. We propose a legend harmonization for projects involving multiple societal actors to facilitate seamless integration of spatially explicit products and perspectives.

This activity falls under the Federal Ministry of Education and Research (BMBF) Sustainable Development of Urban Regions (SURE) umbrella, targeting Southeast Asian agglomerations and covering various challenge-related projects. Specifically, we designed a legend harmonization for the Integrating Ecosystem-based Approaches into Flood Risk Management for Adaptive and Sustainable Urban Development in Central Viet Nam (FloodAdaptVN) project, focusing on the area of interest (AOI) in Thừa Thiên Huế (TTH) province.

Results should be scalable and potentially reproducible in other SURE or related projects.

A key component is the Economics of Climate Adaptation (ECA) tool, which combines infrastructural asset groups with Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSP) scenarios to determine asset values impacted by flood events. Assessments aim to capture the diversity of impacts and associated vulnerabilities, an approach termed as multi-risk [5] or multi-vulnerability [6]. The assessment will primarily utilize existing land use maps, infrastructure data, and field survey data.

We accommodated different perspectives by using existing LU data from the Department of National Resources and Environment (DONRE) as the foundational geographic information system (GIS) layer. Classes were tailored to align with existing descriptions in the Vietnamese language for quick adoption into existing planning processes. The ECA tool required refinement of DONRE classes towards detailed building descriptions and assets, including thematic depth for land offering ecosystem services and recreational values linked to green spaces, both natural and artificial. Compatibility with common urban growth and hydrological models was also a requirement. In the context of the spatial and temporal requirements of TTH, two objectives were formulated:

- Identify existing legends suitable for urban growth modeling, hydrological modeling, ecosystem analysis, land use, and infrastructural asset groups
- Harmonize identified legends, prioritizing a Vietnamese-centered perspective

To address these research questions, discussion rounds were set up among the FAVN research consortium to identify legend requirements in alignment with proposed project and research activities. A legend harmonization tool was applied as the methodological device.

## 2. Methods

Here, methods are presented to create a harmonized legend that accommodates economic perspectives on asset value estimations, ecological functions, models, and is centered around a regional used existing legend. A legend is the application of a classification in a specific area to express its thematic attributes [7]. For comparative interrogation the legend of a LULC product has an impact on its accuracy. The most common classification systems are the Anderson Legend [8] and the Intergovernmental Panel on Climate Change (IPCC) Land Use, Land Use Change and Forestry (LULUCF) legend [9]. Classes of legends can be aggregated, split up or extended to offer comparison across different legends, in other words a legend harmonization. An option to identify common thematic denominators of different legends is through the United Nations (UN) Food and Agriculture Organization (FAO) Land Cover Classification System (LCCS). Common in all classification systems is the capability in covering all land surface characteristics within the AOI, meaning no object can remain unclassified. Different geographic scales reveal more or less details of the land surface or its anthropogenic function requiring the legend to adjust using different levels of detail. Thus, major classes can contain subclasses. The Anderson Legend contains 4 Levels of details and within the Remote Sensing science community was the first one widely accepted. LCCS provides essential classifier blocks that can be combined to create any land cover class in explicit thematic detail.

Figure 1 provided an outline of the study. First, a suited Vietnamese legend was identified through bilateral meetings of local stakeholders and review of existing maps. It was mandatory to center the

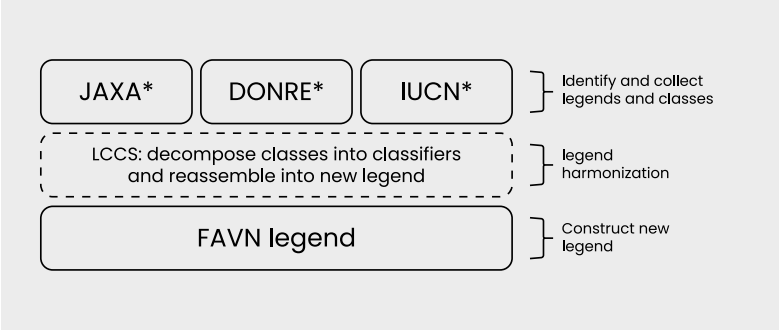


Figure 1: Methodological setup of legend harmonization; *considered legends

legend harmonization around a local used legend to ensure local acceptance. Due to its relevancy within the planning process across Huế province departments, the DONRE legend was chosen. Second, legends were identified to accommodate the research and planning needs of FAVN project. And finally, we identified thematic class overlaps and legend harmonization by using LCCS. The proposed legend was not limiting thematic depths and can be expanded further within a specific class. For instance, the amount of bed for the class medical hospitals can still be added or species can be amended for forest related class as needed. We defined three axioms for the legend harmonization: Vietnamese centered, forward and backward convertibility across legend and scalability.

### 2.1. Legends and requirements

Legends and their associated requirements are articulated in the subsequent section. The foremost requirement was to harmonize the new legend with the existing DONRE legend [10]. A secondary emphasis was placed on accommodating ECA asset estimations, which required intricate descriptions of urban functionalities. While the majority of these functionalities were already encapsulated by the DONRE legend, specific augmentations were made, notably in categories such as land designated for traffic infrastructure and residential zones (Table 1). For the delineation of ecosystems, the International Union for Conservation of Nature (IUCN) legend was employed [11], [12]. The Slope-Land-Cover-Excluded-Urban-Transportation-Hillshade (SLEUTH) model was utilized for FAVN's urban growth modeling activities. This model integrates historical Land Use and Land Cover (LULC) data, topographical elements, and infrastructure parameters to generate spatially explicit urban growth simulations. It functions as a cellular automaton, utilizing a predefined set of growth parameters and associated rules [13]. Due to SLEUTH's limited requirement for land cover classes and its lack of specificity for urban land use functionalities, the Japan Aerospace Exploration Agency (JAXA) legend was selected for its robustness and compatibility with extant LULC products [14]. This JAXA legend was also considered appropriate for the hydrological modeling component.

### 2.2. Legend harmonization

Legend harmonization was conducted using the LCCS3 tool, version 1.8.3, sourced from the Food and Agriculture Organization (FAO). Given the tool's orientation toward Land Cover (LC), thematic gaps related to Land Use (LU) were addressed through expert consultation and by extending definitions where required. LCCS serves as a reference classification system and provides avenues to specialized expertise. Classes within LCCS are decomposed into independent diagnostic criteria, termed classifiers. These classifiers are selectable from a comprehensive array of options. Any existing legend can be translated into LCCS by employing these classifiers as foundational elements to construct classes. The comparison of legends translated into LCCS facilitates the identification of common thematic denominators across different legends. The LCCS user interface is organized into categories related to vegetation characteristics, abiotic surfaces, and land cover class attributes. Classes are structured through horizontal strata, organized as branches akin to a decision tree. Thematic detail is represented through dichotomous pathways, leading from specific criteria (e.g., herbaceous growth forms) to more general criteria (e.g., presence or absence of vegetation).

## 3. Results

Figure 2 illustrates a representative example of classes decomposed into classifiers and their thematic overlap. Displayed are the classes "rice paddies" from the IUCN legend and "other cropland" from the JAXA legend. The classes exhibit significant overlap, with the exception of the blue water classifier unique to the IUCN's rice paddies category. Consequently, the IUCN class could be considered a subclass of the JAXA class, and their common thematic denominator is represented by boxes of identical color. This analytical process was replicated for all classes and legends to identify thematic overlaps, substrates, and potential aggregations. The outcome of this exercise is presented in Table 1, where the FAVN legend is displayed.

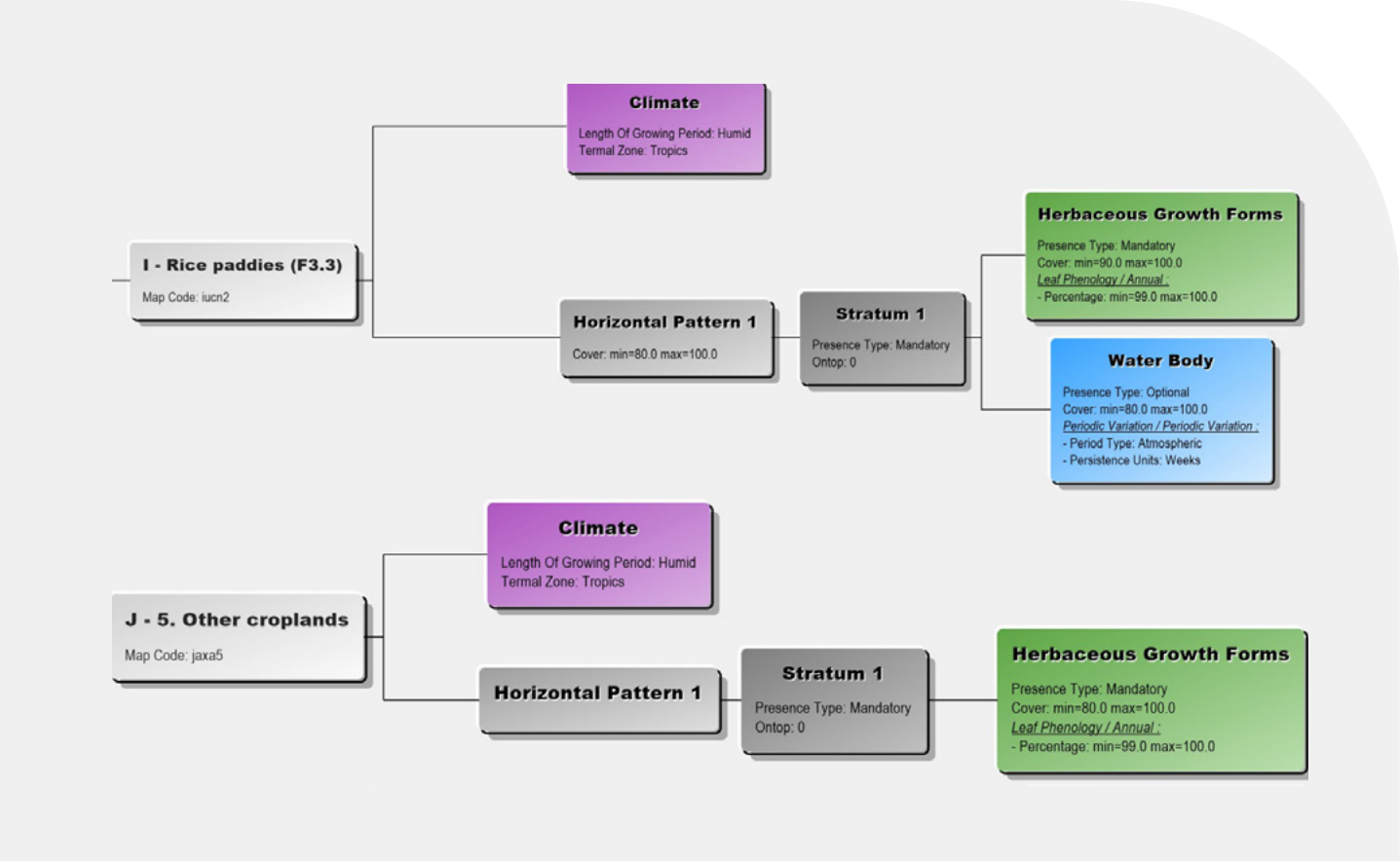


Figure 2: Dichotomous classification scheme example of LCCS3

## 4. Discussion and Conclusions

This study underscores the significance of adeptly managing landscape heterogeneity for the comparative amalgamation of multiple perspectives and disparate legend systems. It also addresses the challenges of handling sites characterized by multiple classification schemes. The study thus facilitates international information fluidity while maintaining a Vietnamese-centric focus for the project. Given the absence of a unified Land Use (LU) classification system, we sought to bridge this gap through Land Cover (LC) classifications and call upon the research community to further address this issue. Problematic classes identified in the study were those that are highly mixed (e.g., land designated for other natural, non-agricultural purposes), which may be overlooked in practical project work but expose existing limitations.

Long-term, computationally intensive activities, such as modeling, necessitate a stable legend within ongoing project activities. Conversely, more exploratory research activities, like Economic Cost of Adaptation (ECA), may require a legend with a degree of flexibility for potential alterations based on outcomes. To meet these varied requirements, we provided a legend harmonization that accommodates both pre-existing classes and a recommended harmonized legend. Interchangeability between these legends is facilitated by our thematic legend conversion table. Consequently, each class can be linked to an existing or incorporated legend system, making our harmonized legend a thematic compilation and conversion hub that ensures interoperability.

| Generalized FAVN class - EN | Generalized FAVN class - VN | DONRE classes - EN | DONRE classes - VN | IUCN classes | JAXA classes |
|---|---|---|---|---|---|
| 1. Land for rice | Đất chuyên trồng lúa | Land for rice crop (all seasons); Land for remaining rice crop (Rice combines with other crops); Land for terrace rice | Đất chuyên trồng lúa nước; Đất trồng lúa nước còn lại; Đất lúa nương | Rice paddies | Rice paddies |
| 2. Land for other crops | Đất trồng cây nông nghiệp khác | Land for other annual crops; Upland land for other annual crops; Land for perennial crops; Other agricultural land | Đất bằng trồng cây hàng năm khác; Đất nương rẫy trồng cây hàng năm khác; Đất trồng cây lâu năm; Đất nông nghiệp khác | Cropland; Sown pastures & fields; Derived semi-natural pastures and old fields | Woody crops; Other croplands; In-house crops; Grassland/ Herbaceous vegetation |
| 3. Land for plantation forest | Đất rừng đồn điền | Land for production forests | Đất rừng sản xuất | Plantations | Plantation land |
| 4. Land for evergreen forest | Đất rừng thường xanh | Protective forest | Đất rừng phòng hộ | Tropical/Subtropical lowland rainforests; Tropical/Subtropical dry forests and thickets; Tropical/ Subtropical montane rainforests; Warm temperate laurophyll forests | Deciduous broadleaf forest; Evergreen needle-leaf forest; Evergreen broadleaf forest |
| 5. Land for special-use forest | Đất rừng đặc dụng | Land for special-use forest | Đất rừng đặc dụng | Tropical flooded forests and peat forests; Tropical/ Subtropical lowland rainforests | Mangrove; Bamboo area |
| 6. Land for quaculture | Đất nuôi trồng thủy sản | Aquaculture land | Đất nuôi trồng thủy sản | Freshwater aquafarms | Aquaculture |
| 7. Land for salt-making | Đất làm muối | Land for salt-making | Đất làm muối | Coastal saltmarshes and reedbeds | Inland wetland |
| 8. Land for residential areas | Đất ở | Rural residential land; Urban residential land | Đất ở tại nông thôn; Đất ở tại đô thị | Urban & Industrial | High developed area; Low developed area |
| 8.1. Single family house | Nhà cho một gia đình | | | | |
| 8.2. Multi family house - apartment building | Nhà nhiều gia đình và nhà chung cư | | | | |
| 8.3. Villa | Biệt thự | | | | |
| 8.4. Irregular/ informal house | Nhà không chính thức | | | | |

| Generalized FAVN class - EN | Generalized FAVN class - VN | DONRE classes - EN | DONRE classes - VN | IUCN classes | JAXA classes |
|---|---|---|---|---|---|
| 9. Land for governmental and military infrastructure | Đất cho cơ quan nhà nước và quân đội | Land for state-run offices/ buildings; Land for non-business organizations; Land for building cultural facilities; Land for social service facilities; Land for foreign/ diplomatic facilities; Land for other facilities; Land for national defense; Land for national security; Land for post and tele-communicaiton facilities | Đất xây dựng trụ sở cơ quan; Đất xây dựng trụ sở của tổ chức sự nghiệp; Đất xây dựng cơ sở văn hóa; Đất xây dựng cơ sở dịch vụ xã hội; Đất xây dựng cơ sở ngoại giao; Đất xây dựng công trình sự nghiệp khác; Đất quốc phòng; Đất an ninh; Đất công trình bưu chính, viễn thông | Urban & Industrial | High developed area; Low developed area |
| 10. Land for healthcare facilities | Đất cho cơ sở y tế | Land for healthcare facilities; | Đất xây dựng cơ sở y tế | Urban & Industrial | High developed area; Low developed area |
| 10.1. Medical hospital | Bệnh viện y tế | | | | |
| 10.2. General practitioner | Phòng khám chuyên khoa | | | | |
| 10.3. Pharmacy | Nhà thuốc tây | | | | |
| 11. Land for education, research facilities | Đất cho cơ sở nghiên cứu, giáo dục và đào tạo | Land for education and training facilities | Đất xây dựng cơ sở giáo dục và đào tạo; Đất xây dựng cơ sở khoa học và công nghệ | Urban & Industrial | High developed area; Low developed area |
| 11.1. Primary/ secondary school | Trường tiểu học, trung học cơ sở | | | | |
| 11.2. Highschool | Trường trung học phổ thông | | | | |
| 11.3. University | Trường đại học | | | | |
| 11.4. Research center | Trung tâm nghiên cứu | | | | |
| 12. Land for sport activities | Đất cho cơ sở thể dục thể thao | Land for sport facilities | Đất xây dựng cơ sở thể dục thể thao | Urban & Industrial; Derived semi-natural pastures and old fields | Scrub/Shrub |
| 13. Land for industry | Đất cho khu công nghiệp | Land for industrial parks; Land for industrial processing zone; Land for industrial clusters; Land for non-agricultural production facilities | Đất khu công nghiệp; Đất khu chế xuất; Đất cụm công nghiệp; Đất cơ sở sản xuất phi nông nghiệp | Urban & Industrial | High developed area; Low developed area |

| Generalized FAVN class - EN | Generalized FAVN class - VN | DONRE classes - EN | DONRE classes - VN | IUCN classes | JAXA classes |
|---|---|---|---|---|---|
| 14. Land for commercial services | Đất thương mại dịch vụ | Land for commerce and services | Đất thương mại, dịch vụ | Urban & Industrial | High developed area; Low developed area |
| 15. Land for mineral activities | Đất cho hoạt động khoáng sản | Land for mining activities; Land for construction materials and ceramics | Đất sử dụng cho hoạt động khoáng sản; Đất sản xuất vật liệu xây dựng, làm đồ gốm | Urban & Industrial | Barren land |
| 16. Land for traffic infrastructure | Đất giao thông | Traffic land | Đất giao thông | Urban & Industrial | High developed area; Low developed area |
| 16.1. Primary road | Đường chính | | | | |
| 16.2. Secondary road | Đường phụ | | | | |
| 16.3. Tertiary road | Đường làng | | | | |
| 16.4. Highway | Đường cao tốc | | | | |
| 16.5. Bridges | Cầu | | | | |
| 16.6. Airport | Sân bay | | | | |
| 16.7.Transportation hub | Trạm phương tiện di chuyển | | | | |
| 17. Land for energy facilities | Đất cho công trình năng lượng | Land for energy facilities | Đất công trình năng lượng | Urban & Industrial | High developed area; Low developed area |
| 17.1. Petrol station | Trạm xăng dầu | | | | |
| 17.2. Power plant | Nhà máy điện | | | | |
| 17.3. Power line | Đường điện cao thế | | | | |
| 17.4. Electric substation | Trạm điện cao thế | | | | |
| 18. Land for general public use | Đất cho sinh hoạt và dịch vụ cộng đồng | Land for community services; Land for public entertainment and recreation; Land for landfill and treatment facilities; Land for other public facilities | Đất sinh hoạt cộng đồng; Đất khu vui chơi, giải trí công cộng; Đất bãi thải, xử lý chất thải; Đất công trình công cộng khác | Urban & Industrial | High developed area; Low developed area |
| 18.1. Land for public use general | Đất cho dịch vụ cộng đồng | | | | |
| 18.2. Land for fire station | Đất cho trạm chữa cháy | | | | |

| Generalized FAVN class - EN | Generalized FAVN class - VN | DONRE classes - EN | DONRE classes - VN | IUCN classes | JAXA classes |
|---|---|---|---|---|---|
| 19. Land for market | Đất chợ | Market land | Đất chợ | Urban & Industrial | High developed area; Low developed area |
| 20. Land with historical and cultural sites | Đất có di tích lịch sử - văn hóa | Historical and cultural sites; Scenic land/ tourism sites; Land for religious facilities; Land for believe bases; Land for cemeteries, graveyards, funeral homes, crematoriums | Đất có di tích lịch sử - văn hóa; Đất danh lam thắng cảnh; Đất cơ sở tôn giáo; Đất cơ sở tín ngưỡng; Đất làm nghĩa trang, nghĩa địa, nhà tang lễ, nhà hỏa táng | Urban & Industrial | High developed area; Low developed area |
| 21. Land with semi-natural water surface | Đất có mặt nước bán tự nhiên | Land for rivers, streams and canals; Irrigation landland | Đất sông, ngòi, kênh, rạch, suối; Đất thủy lợi | Canals, ditches and drains; Seasonal upland streams; Seasonal lowland rivers | Open water |
| 22. Land with natural water surface | Đất có mặt nước tự nhiên | Land for water surface | Đất có mặt nước chuyên dụng | Ephemeral freshwater lakes; Constructed lacustrine wetlands; Seasonal floodplain marshes; Permanently open riverine estuaries & bays; Intermittently closed & open lakes & lagoons; Rocky Shorelines; Muddy Shorelines; Sandy Shorelines; Artificial shorelines | Open water |
| 23. Barren land | Đất bằng chưa sử dụng | Unused flat land; Unused mountain land; Rocky mountains without forests | Đất bằng chưa sử dụng; Đất đồi núi chưa sử dụng; Núi đá không có rừng cây | | Barren land |
| 24. Land for other natural non-agricultural purposes | Đất phi nông nghiệp khác | Land for other natural non-agricultural purposes | Đất phi nông nghiệp khác | Pyric tussock savannas; Coastal shrublands and grasslands | |