Chapter

Implement and Analysis on Current Ecosystem Classification in Western Utah of the United States & Yukon Territory of Canada

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Abstract

The study cases in western Utah of the United States and Yukon Territory of Canada have more natural land and conservative ecosystems in North America. The ecosystem classification of land (ECL) in these two ecoregions had been analyzed and validated through implementation. A full ECL case study was accomplished and examined with eight upper levels of ECOMAP plus ecological site and vegetation stand in Western Utah, the US. Theoretically, applying Köppen climate system classification, Bailey's Domain and Division were applied to the United States, North America, and world continents. However, Canada's continental upper level ecoregion framework defined the ecological Mozaic on a sub-continental scale, representing an area of the hierarchical ecological units characterized by interactive and adjusting abiotic and biotic factors. Using Bailey's Domain as the top level of Canada's territorial ecoregion was recommended. Eight levels of ELCs were established for Yukon Territory, Canada. Thus, the second study case recommends integrating the ecosystem approaches with Bailey's upper level ECL, broad ecosystem classification, and objectively defined ecological site in different countries, or ecoregions. Our study cases had exemplified the implementations with a full ELCs in Bailey's 300 Dry Domain and 100 Polar Domain.

Keywords: Ecosystem Classification of Land (ECL), Ecoregion, Hierarchy, Board Ecosystem, Objective Approach, Ecological Site, Dry Domain, Polar Domain

1. Introduction

The ecosystem classification of land is about the theory and design of the ECL framework and implements and practices in different nations, continents, and global scales. Bailey had made his primary studies and contributions on ecological classification framework and application, representing his scientific collections of mapping on ecosystem classification of land for the United States, North America, and global continents in [1, 2]. The ecological sites were studied and monitored with environmental conditions, biological characters, and ecosystem services [3–6]. Ecologists and geographers had proposed and classified the land into simplified ecosystems where the different plants, animals, and bacteria populations lived together. By processing into different scales, geographers and ecologists designed ECL framework, theory, and applications to depict the ecosystem as systemically organized, nested, and multiple layers in [7–9]. They are so complex and adapted a cycle crossing a threshold from one stable state to another depending on the seasonality, time, landscapes, and disturbances in Refs. [10, 11], which results in the academic argument where to draw a line based on prior selected criteria, how to identify ecological sites and classify the ecoregions in Refs. [1, 3, 8, 12–14]. Afterward, do we achieve our research goal?

From a philosophical perspective, ecological regionalization could be concerned as an objective that has a form with a perceptive logic; at other times, it is an inductive and subjective art that reflects a management consideration, which is dependent on the application of the ecoregion. However, with the ecological regionalization, the contributions of existing ecoregion schemes are inconsistent. In other words, it is getting study complete with errors remaining in [11, 15].

A large amount of vector or raster formats data made the quantitative and spatial analysis more useful and practical in the last two decades. The tree technique was used to explore the analysis of complex ecological data with nonlinear relationships and high-order interaction in 2000 [16]. Many studies and attempts to analyze the complex system of nature as dynamically organized and structured within and across the scales of space and seasonality had assisted ecological researchers to solve population richness and dynamics in [17], vegetation distributions in [18, 19], and ecosystem classification framework in Refs. [1, 2, 9, 14, 20–24]. Understanding how environmental variables influenced the vegetation pattern and distribution and successional order, many research works demonstrated a hierarchical paradigm in Refs. [1, 11, 15, 25].

From 1976 to 1998, Bailey started to identify the ecoregion boundaries and generated the ecoregions of the United States, North America, and the world's continents. He published his research works and had made significant progress in the 1990s. In 1993, Bailey classified the ecoregion into the top three level classes: Domain, Division, and Province. Then, applying the Köppen climate system of classification, he depicted the Domains with the synthetic description of the land surface form, climate, vegetation, soils, and fauna, seeing in [1–3]. Since Federal Geographic Data Committee (FGDC) in the United States accepted the National Hierarchy of Ecological Units (NHEU), ECOMAP in [26] was created with eight levels hierarchical approach to study the ecosystem classification of Land (ECL).

Bailey and Jensen published their work on the design and ecological mapping units with nine levels [27]. The Subregions below the Domain, Division, and Province were divided into Sections, Landtype Association, Landtype, Landtype Phase, and Ecological Site. Thus, NHEU and Bailey had driven a classified Ecosystem Classification of Land into the nested hierarchies at various scales, depending on management needs.

In the global context of ecosystem classification of land, we need to understand the landscape-scale processes more generally. The issue focuses on generalizing ecoregions, the landscape-scale variation, and the combination of abiotic and biotic factors. It had been extended to identify the circumstances in which generalizations can be made, where there are limits, and find a solution in Refs. [9, 10, 14, 24, 28, 29]. It was valuable to examine the hierarchies of ecosystem classification of Land {ECL} globally when we had working experiences and research cooperation that can be related in different countries or continents in Refs. [12, 14, 19, 30]. More recently, the ecosystem services and values have been concerned with the wise use of biodiversity and natural resources [6].

In this chapter, we tried to compare the current two national ecosystem classification frameworks and assess any Domain related issue when it existed. We tried to find suitable abiotic and biotic factors, topographic features, climatic, and ecosystem services to generate deliverable lower-level ecosystem classification when these related research works were reported and published. However, this inconsistency in terminology is often confusing because similar terms may have different meanings or apply to different scales, and different terms may have the same meaning in [15]. Therefore, we will stick to our current references and literature for reviewing and discussing.

Two sets of ecoregions data of Western Utah of the United States, Yukon Territory of Canada were analyzed and validated. The Biogeoclimatic Ecosystem Classification (BEC) approach was referred to as an additional assessment in the discussion. Our focus was tried to explore lower level ecosystem classification in the different ecoregions of North America in Refs. [1, 2, 31–39].

2. Methodology and analysis

2.1 The review of upper level ecoregions of the United States

The ecosystem can be a complex system more than we thought, which is changed and varied along with longitude, latitude, and elevation on the earth's surface, and constantly adapted to the slope, aspect, environmental variables in macroscales [1, 2, 7, 9, 15, 17, 24]. Bailey had contributed to the ecological classification framework and application, which represented his scientific collections of mapping on ecosystem classification of the United States (**Figure 1A**).

Theoretically, Bailey's Ecosystem Classification of Land had explained the ecoregions and their nested structures in the upper levels of Domain, Division, and province. However, these advantages had not been fully applied and examined as ECL's bases for Terrestrial Ecozones and Ecoregions of Canada in [31, 36–39], even though technically Bailey's ECL polygons in the upper three levels can be easily retrieved in GIS spatial model in [14] when the ECL project was conducted.

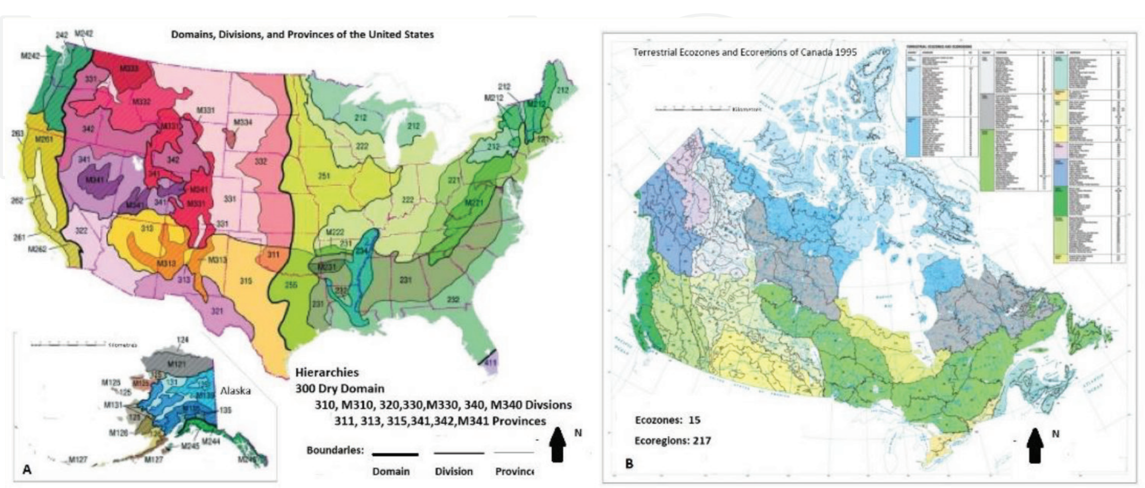

Figure 1.
(A) Upper level ecoregions of the United State. https://www.environment.fhwa.dot.gov/env_topics/ecosystems/veg_mgmt_rpt/images/vegmgmt_ecoregional_approach_fig 03.png (more detail, refer to the web link). (B) Terrestrial ecozones and ecoregions of Canada. Data source: Environment Canada, Terrestrial Ecozones and Ecoregions of Canada 1995. https://mspace.lib.umanitoba.ca/bitstream/handle/1993/24087/cad_map.jpg?sequence=1&isAllowed=y (more detail, refer to the web link).

2.2 Review of upper level generalizations of Canada

The Ecological Framework from Canada Ecological Stratification Working Group in 1996 defined four upper levels of ecosystems as a nested hierarchy. Definitions and the number of map units for the four levels of generalization are outlined in **Table 1** in Ref. [39] and **Figure 1B** and updated by Statistics Canada in 2018.

In brief, Bailey's 100 Polar Domain only included an area with short summer and low temperature throughout the year, which had been divided into three major Divisions, Icecap Division, Tundra Division, and Subarctic Division, furthermore had been recognized and delimited into 13 Provinces (124,125,126, M121, M125, M126, M127,131,135,139, M131, M135, M139). Bailey also extended Humid Temperate Domain (200) to Canadian Territorial and classified Warn Continental Division (210), Hot Continental Division (220), Marine Division (240), Prairie Division (250), and Dry Domain (300) overlaying with Canada subcontinent. However, the Provinces' descriptions had very little content about Canadian Territory (242, 244,245,251, 331, 332, etc.).

Bailey's 100 Polar Domain overlays the area of Canadian eight Ecozones of Arctic Cordillera (covers Ecoregion 1–7), Northern Arctic (Ecoregion 8–31), Southern Arctic (Ecoregion 32–49), Taiga Plains (Ecoregion 50–67), Taiga Shield (Ecoregion 68–86), Boreal Shield (Ecoregion 87–116), Atlantic Maritime (Ecoregion 117–131), Taiga Cordillera (Ecoregion 165–171) in **Figure 1B**. Furthermore, Bailey's 200 Humid Temperate Domain covers the area of Canadian six Ecozones of Mixedwood Plains (covers Ecoregion132–135), Boreal Plains (Ecoregion 136–155), Prairies (Ecoregion 156–164), Boreal Cordillera (Ecoregion 172–183), Pacific Maritime (Ecoregion 184–197), Montane Cordillera (Ecoregion 198–214). In addition, the Prairies in Canada is extended from 200 Humid Temperate Domain to 300 Dry Domain.

Early pioneering works in North America evolved from forest and climate classifications and were often climate-driven, referred to in [1, 2, 13, 31, 32]. The use of more holistic classifications was recent from 1980′ to 1990′. The holistic approaches were recognized and considered the importance of a broad range of physical and biotic characteristics for identifying ecosystem regionalization and classification. They recognized that ecosystems of any size or level were not always dominated by one particular factor. In describing the ecoregion framework of Canada in [13], Wiken indicated, "The Ecological land classification is a process of delineating and classifying ecologically distinctive areas of the Earth's surface, which can be viewed as a discrete system that has resulted from the mesh and interplay of the geologic,

Ecozones **15**	Canada Ecozones on a sub-continental scale is defined and represented an area of the earth's surface of large ecological units classified by interactive and adjusting abiotic and biotic factors. Canada is divided into 15 terrestrial Ecozones.
Ecoprovinces **53**	A subdivision of an Ecozone was classified by major assemblages of structural or surface forms, faunal realms, and vegetation, hydrology, soil, and macro climate.
Ecoregions **217**	A subdivision of an Ecoprovince was classified by distinctive regional ecological factors, including climate, physiography, vegetation, soil, water, and fauna.
Ecodistricts **1031**	A subdivision of an ecoregion was classified by a distinctive assemblages of relief, landforms, geology, soil, vegetation, water bodies and fauna.

Note: 217 ecoregions and 1031 ecodistricts were updated from 2018 Canada ecological land classification in [38, 39]. E.g. **11.1.165.0858** *represented ecozone, ecoprovince, ecoregion and ecodistrict coordinately.*

Table 1.
Upper level ecosystem classification of Canada.

landform, soil, vegetative, climatic, wildlife, water, and human factors.". Therefore, land classification can be applied incrementally on a scale-related basis from site-specific to broad ecosystems.

Because of underlying dynamics of the ecosystems, the multiple patterns of correlation among the biotic, abiotic, and human factors produced the complex; these approaches were apt to produce a converging depiction of regions and significant ecosystem boundary overlapping between Canada and the United States in Refs. [1, 34, 35, 38, 39]. Thus, Canada's continental upper level ecoregion framework defined the ecological Mozaic on a sub-continental scale, representing an area of the Earth's ecological units characterized by interactive and adjusting abiotic and biotic factors. It is not possible to equate Canada and US classification systems directly in [31].

2.3 Implement on lower level ecosystem classification in western Utah of the United States

At Domain, Division, and Province levels, Ecoregions of the United States had been examined by Bailey. The first case study we used for the lower level was accomplished with the upper four levels for the project in a 4.5-million-hectare area centered in western Utah of the United States. National Hierarchy of Ecological Unit (NHEU) had been referenced as the coarsest boundaries in Utah, the United States. This study area was on 300 Dry dominant divisions and had bounders intersecting with 340 Temperate Desert Division and M340 Temperate Desert Regime Mountains Divisions. Three interesting provinces are 342 Intermountain Semi-Desert Province, M341 Nevada-Utah Mountains Semi-desert Coniferous Forest Alpine Province, and 341 Intermountain Semi-Desert and Desert Province. In addition, four sections were intersected in the study area: Bonneville Basin Section, Central Great Basin Section and Northeastern Great Basin Section, and Northwestern Basin and Range Section, shown in **Figure 2**, **Table 2** in [14].

"Bolson" is used as a term in the lower level of ecosystem classification, described the terrain, having entire area from surrounding mountains to mountain slopes, reduced with distance from ridgelines, to the centre of either a river valley or terminal lake basins, or reaching nearly all the study area. DEM data (30 m) was used in the model (**Figure 3A** and **B**) and generated 60 bolson segments.

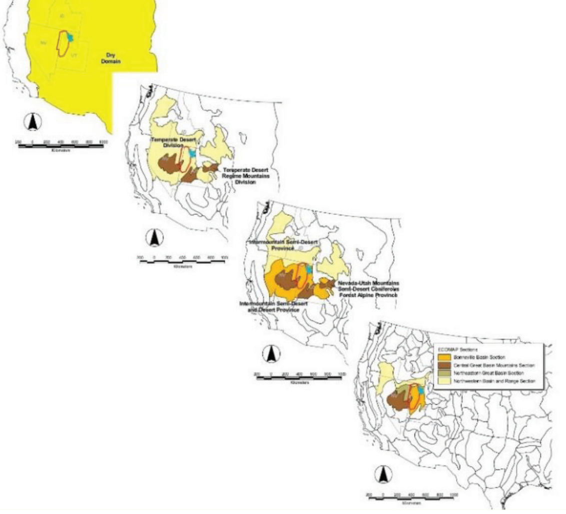

Figure 2.
Upper four levels of ECLs overlaid and intersected in the study area.

Level	ECOMAP name	Example name	Main environmental characters	Scales
1	Domain	300 Dry	Climate/ Köppen Bsk	Ecoregion
2	Division	340 Dry Temperate	Climate	Ecoregion
3	Province	342 Intermountain Semi-Desert	Climate	Ecoregion
4	Section	Central Great Basin	Topography/Terrain	Segment
5	Subsection	Erosional Landscape	Intermediate Scale Terrain Segment	Landscape Mosaic
6	Landtype Association	Hard Erosional Landscape	Macroterrain Units,	Landscape Mosaic
7	Landtype	Eolian Sediments	Mesottrain Units	Landscape Mosaic
8	Landtype Phase	Sedimentary (ridge, slope etc)	Microterrain Units	Zone/Subzone
9	Ecological Site	Desert gravelly Loam	Objectively Defined Land Unit/ Management	Site
10	Vegetation Stand	Sagebrush	Homogeneous Vegetation	Stand

Table 2.
Summaries of the implemented ecosystem classification in western Utah.

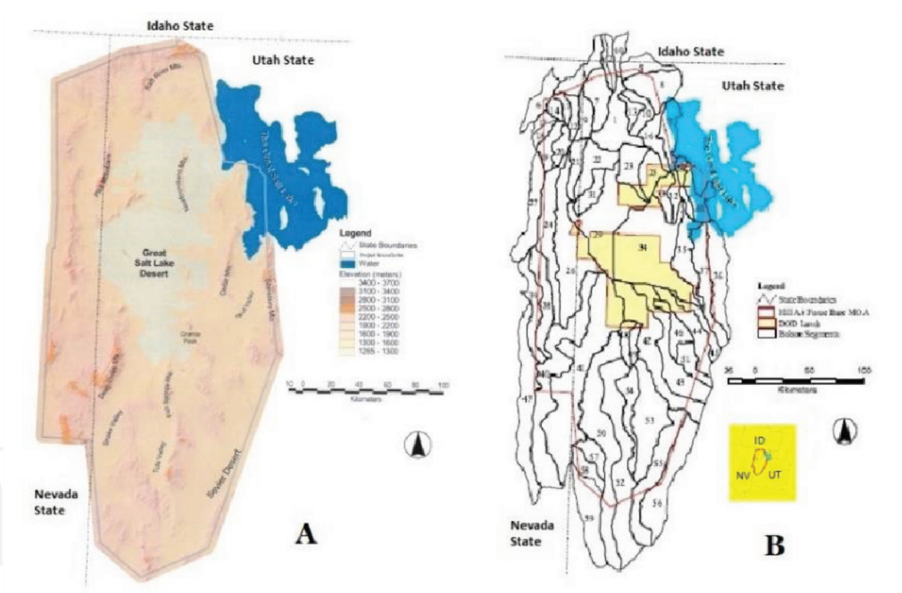

Figure 3.
(A) DEM landscape layout of study area. (B) The 60 bolson segments of the subsection.

2.3.1 Macrotterain units

In the study area, the 60 bolson segments were subdivided into different macroterrain units. The algorithm to determine macroterrain units employed elevation and relative change in apparent elevation (slope) from adjacent 30 m DEM cells. It had classified the cells as upslope of equal or higher slope position. Thus, most "mixed" macroterrain unit cells will have "erosional" cells upslope and "depositional" cells downslope depended on their positions. This principle of "superposition" was enforced by the application of the macroterrain class using watershed functions.

2.3.2 Mestoerrain units

With available data of geologic formation or sediments at 1:50,000 scale, the computer algorism was used to identify and delineate the polygons with name attributes for example the metamorphic or moderately hard sedimentary rock, basalt, alluvium, and eolian sediments. By a rationale based on probability, the exposed bedrock units were identified by steeper slope classes, and the presence of rock outcrop as the mapping units.

2.3.3 Microterrain units

The mesoterrain units were divided into subdivisions called microterrain units. Microterrain units were further nested subdivisions of mesoterrain units, which were based mainly on landforms for the erosion-dominated surfaces and landforms plus soils condition. The protocols repeatedly identified landscape units. And two additional levels below the 8th level (NHEU) were added. The 9th level of Ecological sites (ESs) was designed and implemented by using important data on ESs, nested to ECOMAP; the 10th and finest-grain level of vegetation stands were subdivisions of individual polygons of ESs based on differences in disturbance histories (fire, grazing, and human activities) (**Table 2**). The vegetation stands were studied and described by vegetation characteristics, representing fine-scale variations in regional climate, site-specific moisture, nutrient regimes, and disturbance histories (**Figure 4A** and **B**).

2.4 Implement of lower level terrestrial ecoregion classification in Yukon territory of Canada

The major Canadian publications about territorial ecosystem classification or ecoregion classification were designed and generalized as a hierarchical, nested framework with systematic, nested hierarchical layers in the upper four layers (**Table 1**) in [38, 39].

In second case analysis, we validated the Environment Yukon's data and documental report [40–43] with our field observation. The territory of Yukon

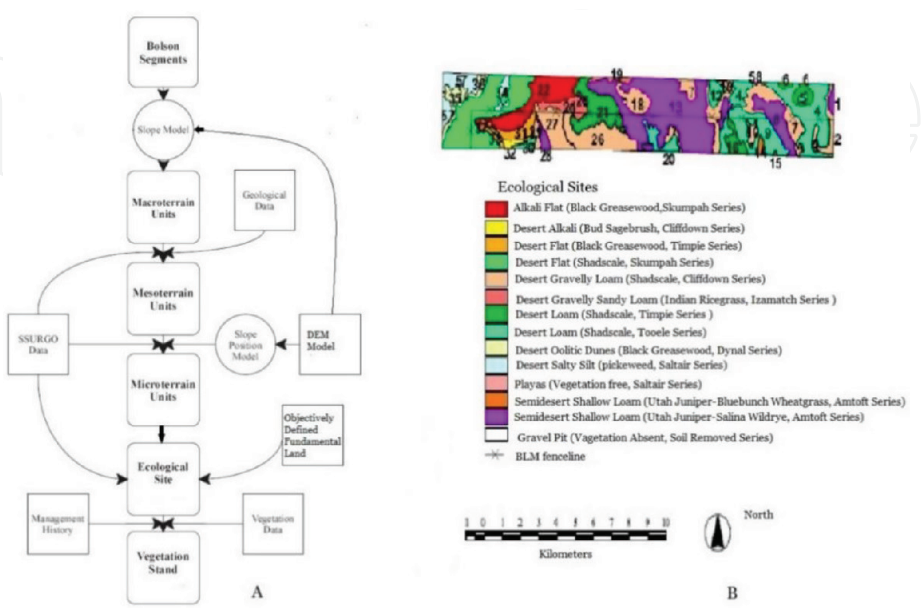

Figure 4.
(A) Flow diagram of ecosystem classification of land from bolson segments to vegetation stands. (B) Map of the ecological sites in sampling area.

is approximately 483,450 km2, about 2.2 times that of Utah State in the US, and intersects with Southern Arctic, Taiga Plain, Taiga Cordillera, Boreal Cordillera, and Pacific Maritime Ecozone. Yukon's 23 Ecoregions **of 32, 51, 53, 66, 166–182,184** were described and reported (**Figure 5A**) in [40]. The Yukon Ecosystem and Landscape Classification Framework in [43] provided a classifying tool and method for mapping and implementing ecosystem classification under the Canada Ecozones and Ecoregions.

The research and field work focused on displaying and describing bioclimate features such as the horizontal distribution from south to north and vertical distribution from lower to high (**Figure 5B**). The study was characterized the broad areas influenced by similar climates into a hierarchy of bioclimate zone to lower level classification. Thus, Boreal Low (BOL), Boreal High (BOH), Subalpine (SUB), Taiga Wooded (TAW), Taiga Shrub (TAS), Tundra (TUN), Alpine (ALP) were identified as Bioclimate Zones. The broad ecosystem types by slope position and the phases by plant community dominant species were identified in the nested multiple layers and simplified in **Table 3** in Refs. [41–43]. Field survey and road investigation were carried out at the eleven observation points in 2021 summer (**Figure 5B**). The broad ecosystem types were classified by relative moisture regime as dry, moist, and wet, which can be functionally represented and retrieved the relationship by the generalized the Edatopic Grid as **Figure 6**, and using indexes of Hydrodynamic, aquatic and actual moisture, PH, similarly to it in report [43].

A DEM is a derivative product of the CanVec topographic data set. In Yukon, DEM is available for the entire territory. The generalized GIS model in Keno town area was established to generalize the lower level's bioclimate board ecosystem

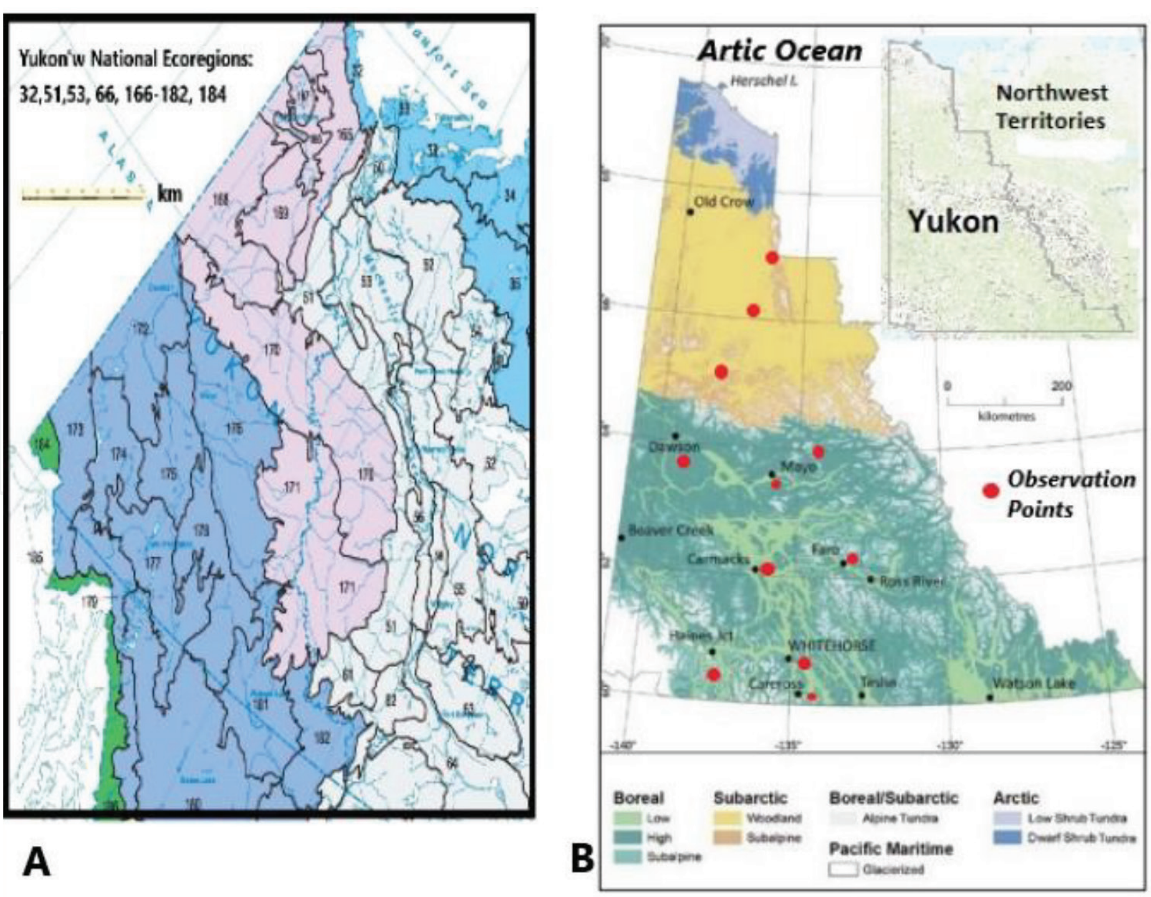

Figure 5.
(A) Yukon ecozones and ecoregions. Data source from Ecological Stratification Working Group and Smith et al. editors [38, 40]. (B) Yukon bioclimate zones, red dot – observation points. Background source from Environment Yukon [43].

Level	Yukon nested ECLs	Classification I	II	III	Equivelent to
1	100 Domain	Domain			Bailey's Top Level
2	12 Ecozone	Boreal Cordilera			Canada's Top level
3	12.2 Ecoprovince	Northern Boreal Cordilera			Bioclimatic Zone
4	12.2.176 Ecoregion	Yukon Plateau-North			Bioclimatic Subzone
5	12.2.176.0898 Ecodistrict	Elsa			Canada ECL's unit
6	Board Ecosystem	H. Wetland	B. Ridge	D. Plains	Bioclimatic/ Slope Position
7	Board Ecosystem Phase	Shrub and salix grasses	Herb	White Spruce	Bioclimatic/ Plants
8	Ecological site/Ecosite	Lodgepole Pine Spruce-Grass-Lichen	Ledium / Salix	Mixedwood/ Boardleaf Forest	Objective or Bioclimatic

Note: bioclimatic Zone: TAW- Taiga Wooded, BOL-Boreal Low, BOH-Boreal High, SUB-Subalpine, TUN- Tundra, ALP- Alpine.
Bioclimatic subzones: Yukon Plateau North, Eagle Plains, North Ogilvie Mountains etc.
Canada ecodistrit can be searched and viewed https://databasin.org/maps/new/#datasets=8dca767690af48e6ae558 1b34612a19d

Table 3.
Yukon's board ecosystem classification and nested lower levels' ECL.

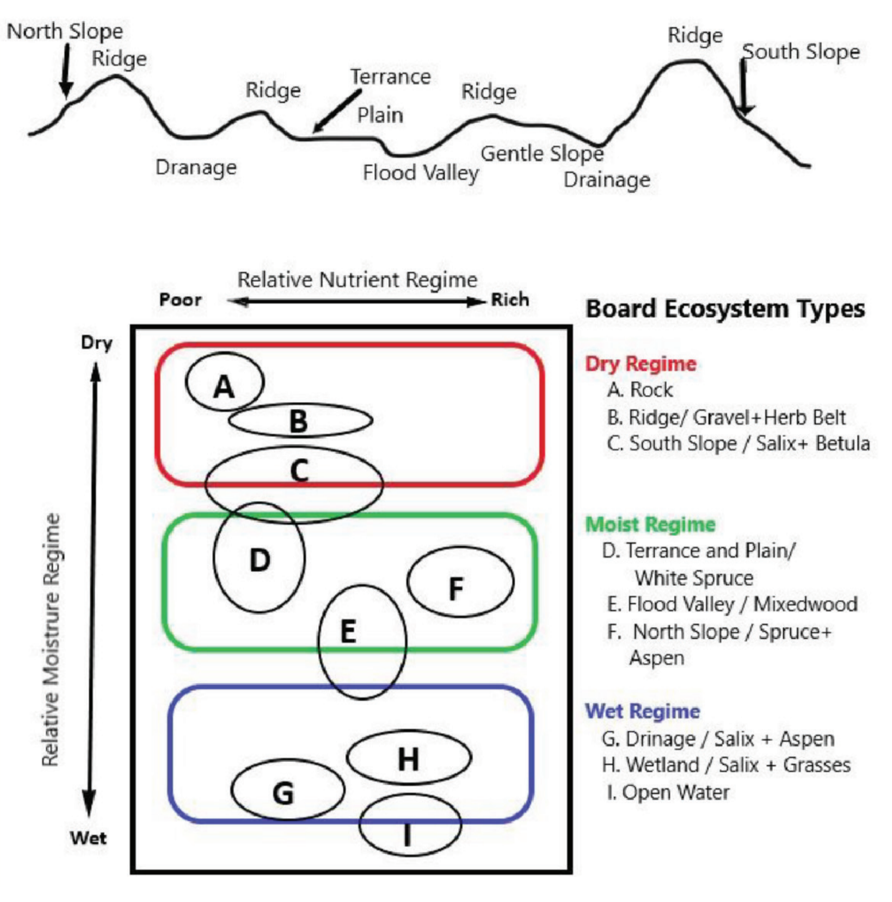

Figure 6.
Broad ecosystem gernerated with edaptopic grid scheme and slope position. The board ecosystem types can be identfied in a lanform position.

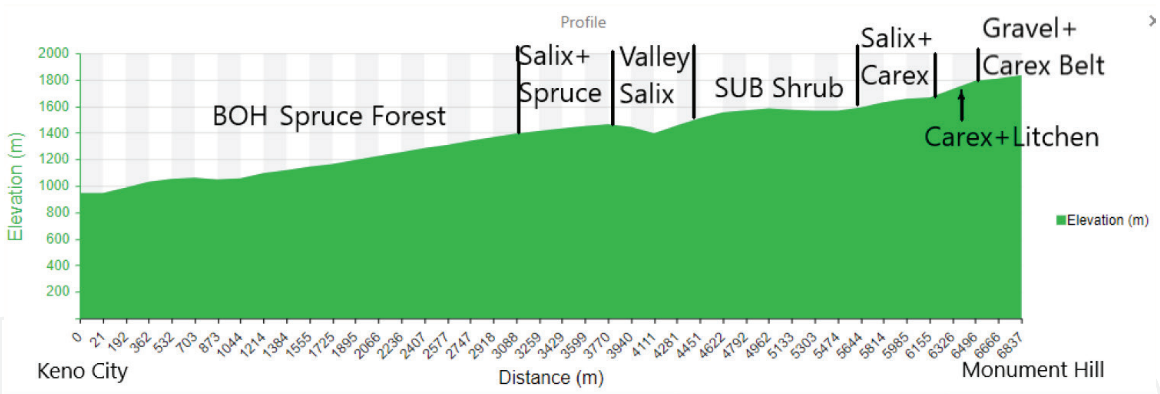

Figure 7.
Vegetation distribution along Keno Hill slope, Yukon.

classification. Predictive ecosystem mapping relayed on digital elevation models (DEM) to represent landform slope and aspect conditions. These conditions provided and informed soil moisture, a primary determinant of ecosystem pattern. A demonstration was the slope survey completed near Keno city up to Monument hill (**Figure 7**). Subalpine shrub appeared above elevation 1530 m, and Salix + Carex shrub grasses from 1600 m to 1730 m. Homogenous Carex + Litchen alpine vegetation located at 1780 m become biological indicator where was near the ice valley or cold environment. Gravels + Carex + gravels belt located at 1825 m indicated that the seasonal frozen condition was occurred constantly.

3. Discussion

By analyzing the upper level of ECLs in the United States and Canada, we realized that the ecosystem classification of land was a special methodology to explore and classify the ecoregions in the different countries. Bailey classified upper-level Ecosystem Classification of Land (Domain, Division, and Province), in which Domain was based on Köppen climate system classification [1–3]. Bailey, in Ref. [34], indicated that the differences in the climatic regime distinguish the natural ecosystems. The principle is that climate, as a source of energy and moisture, acts as the primary control for the ecosystem. Whether or not using Bailey's Domain as the top level of Canada's territorial Domain remained a further comparison between the United States and Canada. At least, the upper four levels' ecosystem classification and detail descriptions of Canada (see **Table 1**) would be the best fulfillment and data source. Technically, the vector and raster data can be retrieved and integrated into GIS software [14, 44–46].

The Ecological Framework of Canada in Refs. [37–39] used different classification schemes and presented the upper four levels of ecosystem classification with features of hierarchy structure in a subcontinent scale. Canada's top-level fifteen Ecozones have overlaid and intersected with Bailey's 100 Polar Domain, 200 Humid Temperate Domain, and 300 Dry Domain. For instance, Bailey's 100 Polar Domain overlays the area of Canadian eight Ecozones, Bailey's 200 Humid Temperate Domain covers the area of Canadian six Ecozones. In addition, the Prairies in Canada is extended from 200 Humid Temperate Domain to 300 Dry Domain in the US.

ECOMAP defined by the National Hierarchy of Ecological Unit (NHEU), had presented the "top-down" approach of Ecosystem Classification of Land in the United States. Western Utah's project had proved that it was a cost matter through a complete ECL's field survey. Another consequence of the strictly top-down nested hierarchical design of ECOMAP is that progressively smaller and unique polygons are created for each level. In other words, the ECOMAP process applied so far prevents one from easily relating features at one location to those within other landform units or bolson segments. Thus, ECOMAP is a top-down regionalization with hierarchically nested features for an explicitly geographic area. At the same time, these futures allow the ecosystem classification units to be used for various needs, from local to national. These features in the NHEU are the perimeters of outer polygons created at lower levels have to be vertically integrated with the delineation of polygons occurring at upper levels.

The limitation is for this "top-down" process; if the lowest levels are produced independently from higher levels, we still cannot answer whether the similarity of the same label polygon or unit is the same until a field survey is conducted or references available.

Much information for local managers and management companies, not all information very useful for Ecological land of classification. We did not expect any ecological research had funding to complete for mapping as to details. The project in a dry domain area with a 10 level classification would be more theoretical than practical management.

While network linked rather than nested hierarchically could be employed, we propose a simpler, more straightforward solution. Our actions were carried out a complete hierarchical land classification from a top-down approach. Ideally, we treated the ecosystem like an "organism" and separated it into components, following a top-down nested hierarchy to its finest subdivisions, and countered in common sense and practicality. Thus, a terrestrial ecosystem is considered as a volume of earth space with organic contents. We separated it from its neighbors by reasonable divisions by the empirical observation and knowledge in climatology, geography, ecology, soil, and physiography in [47–51].

While it is recognized that the National Ecological Framework with the terrestrial ecoregions in **Table 1** is a referential part of the Yukon ELC Framework, maintaining these layers for Yukon as attributive layers and data in the GIS model that is recommended in [40–43]. Specially, using 100 Domain as a top level ELC. Canada's Ecozone was considered as second level ELC. Canada's Ecoprovince in Yukon Territory was equivalent to the Bioclimate Zone, and Ecoregion was equivalent to the Bioclimate Subzones. Canada's Ecodistrict was established and can be used as identical fifth ELC layer. The sixth and seventh ELCs were related to Bioclimatic Board Ecosystem in terms of slope position and plant population important index. Canada's eight ELC was objectively defined Ecological Site or bioclimatic Ecosite. Thus, we established a complete ELC in Yukon Territory (**Table 3**).

The management approach and applications for the broad ecosystem classification and mapping are listed in **Table 4**.

Mapping level and scales	Applications	Context
Bioclimate (1:100,000 to 1,000,000)	Climate Change Studies	Plant species shifting and community succession
Board Ecosystem 1:50,000 1:250,000	Regional land use planning	Land use changes and management policy
Local Ecosystems 1:10,000 to 1:50,000	Environmental Impact assessments	Land Degradation, recovery and restoration
Varies	Ecosystem Services	Ecosystem Assessment, Supporting, provisional, regulating and cultural services

Table 4.
Broad ecosystem classification mapping and applications.

Practically, the lower level cases of Canada territorial Ecosystem Classification had preferred more practice and objective. The researchers can use GIS technology and Spatial Analysis Modeling to efficiently produce the different maps for the landowner, management companies, and government agencies. In addition, plant ecologists had sophistical experiences in [18, 30, 33, 44, 52–57] to develop the vegetation classification and ecoregion map with a nested structure using biogeoclimatic principles. The map products were delivered by the scaled-based ecosystem classification and represented them with a high relation among the long-term climate condition, climax vegetation, and dominant plant species.

In addition to Bioclimatic Board Ecosystem Classification, Biogeoclimatic Ecosystem Classification (BEC) approach was often demonstrated as a quick approach and identified as an ecological framework for vegetation classification, mapping, and monitoring vegetation dynamics in [33, 44, 53–55, 58]. BEC approach has been used in many provinces in Canada, and the association-based ecological units of BEC are the fundamental units, for example, that the boreal vegetation association was integrated for its boundary justification. Also, the BEC approach delineated ecologically equivalent climatic regions and displayed the site conditions in the Edatopic Grid with a relationship between soil nutrient regime and soil moisture regime in [53, 54].

Ecologists studied different computational models in ecological classification such as LeNet, AlexNet, VGG models, residual neural network, and inception models in Refs. [16, 17, 24, 28]. The biggest challenge was faced in the need for an extensive training dataset to achieve high accuracy. Examples trained algorithms and the machine can only detect what criteria have been previously shown and selected. Deep learning, or machine learning algorithms, was going on method for analyzing nonlinear data with complex interactions. Moreover, they can achieve remarkable accuracy for identification and classification tasks. As a result, achieving proper ecological predictions is more feasible now. Increasing data availability is highly related to using GIS, remote sensing, and international research networks in Refs. [45, 46, 56, 57]. Furthermore, a fundamental change in research culture is towards making ecological data open access publically. All of these developments are important factors behind deep learning and development in ecology.

With further understanding, the ecosystem classification approaches and ecological modeling experiences in [14, 44, 46, 56, 57, 59] and objectively defined

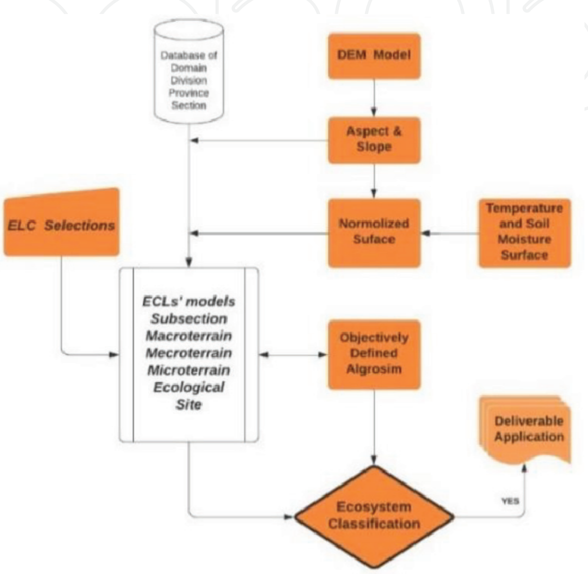

Figure 8.
Objectively defined ecosystem classification.

ecosystem classification can be integrated by using a computer algorithm to develop efficient tools and affordable applications (**Figure 8**) without losing hierarchical structure feature in [30]. The ECL menu had input data function by getting upper-level Domain, Division, Province, and Section digital format data, and carried out a deliverable application associated with a scaled lower level ECLs. The objective analysis generated internal function outputs and combined them in the Deep Learning Algorism. The slope model, landform model, was running based on objective needs; vegetation, soil, and geology data could be considered attribute data sources depending on the study area.

We did not discuss landscape-scale changes and boundary issues that influenced ecosystem classification, which authors already presented in Refs. [1, 2, 11, 15, 25, 31, 48, 49]. Second study case demonstrated that a full ECL generally included three components: Bailey's upper level ECL, Broad Ecosystem classification, and bottom level Ecological site. With assessment, justification, and testing, we completed a full Ecosystem Classification in a Yukon ecoregion.

Why do we use western Utah's ECL to compare with Yukon's? The direct reason is that these two ecoregions had fewer human activities and had more broad original nature ecosystems in North America. In the meantime, the climate conditions are between a Dry Domain and a Polar Domain in these two ecoregions. Our study cases led the research and study with a complete ELC in Bailey's 300 Dry Domain and 100 Polar Domain.

4. Conclusions

Canada's continental upper level ecoregion framework defined the ecological Mozaic on a sub-continental scale, representing an area of the earth's ecological units characterized by interactive and adjusting abiotic and biotic factors. Therefore, using Bailey's Domain as the top level of Canada's territorial ecoregion was recommended. Similarly, many users suggested that they examined the popularity and characteristics in a study area linked to the continental and global scales in [1, 8, 59–62] whenever necessary and integrated to delineate and identify the regional ecosystem. Ecological regionalization is an abstraction from global to a local site-level, contributing to understanding nature and providing differentiated guidance to sustainable environmental management. It recommended that using the global ecoregion scheme offers the guidelines for biodiversity conservation, but it still faces obstacles in improving ecosystem services and substantial uses. We had reviewed and analyzed the regionalization process, implements in two ecoregions, and some practices. With the critical consideration of ecosystem services, global environmental change and human activities should be followed in functionalized ecological regionalization. Ecosystem regionalization is a scale-based approach to classifying land surfaces, combined with regional and continental data. We should have understood more about taking geology, landform, soils, vegetation, and climate into account to classify the regionalization in different scales and ecosystem levels for a global-wide scheme when the ecosystem studies and services have grown in the research, publication and practice.

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Authors' contributions

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Conflict of interest

Authors declare that there are no competing interests.

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