A Hierarchical Analysis On Ecosystem Classification of Land

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Research Article

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Abstract

Background: The ecosystem classification of land (ECL) has been studied for a couple of decades, from the beginning of the perfect organism system “top-down” approach to a reversed “bottom-up” approach, defining micro-ecological unit. After reviewing two study cases of the ecosystem classification of land, the ecosystem classification framework implements in different ecoregions were examined and analyzed.

Results: Theoretically, Bailey’s upper levels ECL (1995) was applied to the United States, and world continents. China's Eco-geographic classification was most likely fitted into Bailey’s Ecosystem Classification regime. With a binary decision tree analysis, it demonstrated that the top-level, Domain has an empty entity between the US and China ecoregion framework. Based on the biogeoclimate condition, vegetation distribution, landform, and plant species feature, classified HIIC1 into two subsections (labeled as *i, ii*), and delineated *iia* of QiLian Mountain East Alpine Shrub and Alpine Tundra ecozone into *iia-1* and *iia-2* zone.

Conclusions: 1) The Plateau Domain 500 should be added into the top-level Bailey’s ecoregion framework, coordinately it includes HI and HII Divisions, and humid, dub-humid, semiarid, and arid provinces. 2) Two case comparisons recommend using a practical approach, objectively defined ecosystem classification for the lower-level ECLs in matter of time and project cost.

Instruction

The ecological classification and units had been studied and monitored on the states of neighbors with relations of environmental conditions, biological characters, and ecosystem services (Walfram, 2002; Clark and Carpenter et al., 2001; Wallace 2007). Ecologists had proposed and classified the land into simplified ecosystems such as rainforest, forest, tundra, and desert, savanna, where the different plants, animals, and bacteria populations were living together. By looking into different scales, geographers and ecologists found out and depicted the ecosystem as systemically organized, nested, and multiple layers (O’Neil and DeAngells et al, 1986; Bailey, 1983, 1986, 1995). They considered the ecosystem as complex and unstable depending on the seasonality, time, and landscapes (Hutchinson and Mcintyre et al., 2005), and classified the land into hierarchy ecosystem units (Bailey, 1995, 1996). Based on prior selected criteria, identifying ecological boundaries and classifying the land into the ecoregions (Creque and Bassett et al., 1999; Bailey, 1983, 1986; Wiken 1986; Ecological Stratification Working Group, 1996; West and Dougher et al., 2005; Albert and Lapin et al., 2015) presented a long historic battle and academic progress in last 30 years.

The large amount of data stored in the computer system in digital or raster formats made quantitative analyzing and spatial analyzing more useful and practical in the last two decades. De’ath and Fabricius in 2000 used the tree technique to explore the analysis of complex ecological data with nonlinear relationships and high-order interaction. Traditionally, when the classification and regression trees (CARTs), artificial neural networks (ANNs), evolutionary algorithm (EAs), and generalized linear models

(GLMs) were used, the environmental variables such as mean monthly air temperature, precipitation, distribution area, Slop, and elevation became very significant to predict the species richness and community dynamics. Many studies and attempts to analyze the complex system of the land as dynamically organized and structured across the scales of space had assisted ecological researchers to solve population richness and dynamics (Allen and Angeler et al., 2014), vegetation distributions (Hou, 1983; Zhang and Zhou, 1992) and ecosystem classification framework (Bailey, 1995, 1996; Cleland and Avers et al., 1997; Wu and Yang et al. 2003; Altert et al., 2015; Brodrick and Davis et al., 2019).

Bailey started to identify and delineate the boundaries and the ecoregions of the United States, North America, and the world's continents from 1976 to 1998. His works were published and had made significant progress in the 1990s. In 1993, his work divided the ecoregion into the top three level classes as Domain, Division, and province. At the Domain level, applying the Köppen climate system of classification, Bailey (1983, 1995, and 1996) depicted the Domains with the synthetic description of the land surface form, climate, vegetation, soils, and fauna.

Since Federal Geographic Data Committee (FGDC) in the United States accepted the National Hierarchy of Ecological Units (NHEU), ECOMAP (1993) was created with 8 levels hierarchical approach to study the ecosystem classification of land (ECL). The subregions below the Domain, Division, and Province were divided into the section and subsection, landtype association, landtype, and landtype phase. Thus, NHEU had a classified Ecosystem Classification of Land into the 8 levels' nested hierarchies.

Chinese geographers and ecologists started to measure and study geographic regionalization and broad scale of ecological units, and had developed quantitative analysis methods for studying regional ecosystems (Zheng, 1999; Wu et al., 2003). Detailed vegetation map, soil type map and grassland map, ecosystem services had been used for the ecoregion studies at the national scale (Hou, 1983; Fu, 2001; Yue and Fan et al., 2006). The remote sensing and Geographic Information System (GIS), and modeling had been applied to study the ecosystem services, landscape, ecoregion classification, and delineation boundaries (Zhang and Xia et al., 2016; Zhang and Lu et al., 2017; Zhou and Fan et al., 2020; Wang and Cheng et al, 2020).

The decision tree method, a top-down approach with origins in the field of statistical technique, is recognized as holding great promise for the advancement of understanding and prediction about ecological phenomena. This modeling technique is flexible to handle complex problems with multiple interacting elements and typically practical approaches, e.g., generalized linear models, no-linear models, for classifying ecosystems (De'ath et al., 2000; Olden and Lawler et al., 2008; Allen et al., 2014). Debeljak and Džerosk (2011), Yates and Bouchet et al. (2018), Berhane and Lane et al. (2018) used the decision tree algorism to study the ecosystem complexity and nested multiple layers. This method was used to help actualize both categorical and continuous dependent variables under a supervised learning process for comparing the ecosystem classification between the United States and China. The algorism splits the selected classes into two or more homogeneous sets based on the most significant attributes, or charters making the groups as distinct as possible.

In the global context of ecosystem classification of land should be able to understand the landscape-scale processes in a more general way. The issue is not whether we can generalize about landscape-scale variation, and combination of abiotic and biotic factors, but to identify the circumstances in which generalizations can be made, and where there are limits, and find a solution (Hutchinson et al., 2005; West et al., 2005; Olden et al., 2008; Albert et al., 2015; Bridrick et al., 2019; Hornsmann and Pesch et al., 2008). It was further examination to the hierarchies of ecosystem classification when the working experiences and research cooperation can be reached in different continent regions.

In this paper, we tried to compare the United States' and China's ecosystem classification frameworks and solve any Domain related issue. Two sets of study data between Western Utah of the United States and Qinghai-Tibet Plateau of China were examined in the upper levels, and discussed how to approach a deliverable lower-level ecosystem classification when time and project budget limited.

Methodology And Analysis

The Review of Two Cases of Upper-Level Ecosystem Classification of Land

1. Upper-Level Ecoregions between the United States and China

The ecosystem can be a complex system, which is changed and varied along with longitude, latitude, and elevation on the earth surface, and always adapted to the slop, and aspect and environmental variables in macroscales (Allen et al., 2014; Brodrick et al., 2019). Bailey (1995, 1996) had made his contributions on mapping the ecoregions of the United States, North America, and world continents. Theoretically, Bailey's Ecosystem Classification had explained the ecoregions and their nested structures in the upper levels of Domain, Division, and Province.

Zheng (1999) and Wu et al. (2003) compared the ecosystem classification between China and the United States. Since they used the temperatures, water conditions, and landforms for the upper level of ECLs, there were similarities between these two ECLs. However, there were some failures to match each level class among the top three levels. At the top levels, China ECLs mainly used the accumulated temperature and the days of great than 10^0C,and next level used aridity to classify as humid, dub-humid, semiarid, and arid (Labeled as A, B, C, D separately) and used landform types to classify plain, mountain and hills (Labeled as 1, 2, 3…etc.).

China's ecological geographic ecoregions had been classified and named (Table 1). For example, IIB1 for the CentralSonhLiao Plain, IIB3 for Piedmont Plain & Hills of Sanhe, HIB for High Plateau of Golog_ Nagqu, HIIA/B for High Mountains and Gorges of W. Sichuan and E. Xizang, etc.

Relatively, China's Eco-geographic classification is mostly fitted into Bailey's Ecosystem Classification regime, and represents the top level of Eco-geographic regions for their scientific needs. Zheng (1999) and Wu et al. (2003) had provided the theory analysis and delineated the boundaries for 11 eco-geographic zones. The HI and HII eco-geographic zone in China did not properly fit into any domain developed by Bailey. Bailey (1995, 1996) initially had put HI and HII area into his framework as M310 Tropical /subtropical Steppe Regime Mountains, and M320 Tropical /subtropical Desert Regime Mountain. Thus, Zheng and Wu et al. left an empty entity for the Domain to which HI and HII eco-geographic zones should have belonged.

Table 1
Upper Level Ecoregions of China and Bailey’s ECL

Bailey’s ECL	**Domain**	**Division**	**Province**	**China eco-geographic regions**
US and China	200 Humid Temperate Domain	230 Subtropical Division	M230 Subtropical Regime Mountains	VI.South Subtropical Zone
		250 Prairie Division	M250 Prairie Regime Mountains	I.Cold Temperate Zone
	300 Dry Domain	310 Tropical /subtropical Steppe Regime Division	M310 Tropical /subtropical Steppe Regime Mountains	V.Middle Subtropical Zone
		320 Tropical /subtropical Desert Division	M320 Tropical /subtropical Desert Regime Mountain	IV.North Subtropical Zone
		330 Temperate Stepper Division	M330 Temperate Steppe Regime Mountain	II.Medium Temperte Zone
		340 Temperate Desert Division	M340 Temperate Desert Regime Mountains	III.Warm Temperate Zone
	400 Humid Tropical Domain	410 Savana Domain	M410 Savana Regime Mountains	VII.Marginal Tropical Zone
		420 Rainforest Division	M420 Rainforest Regime Mountains	VIII.Middle Tropical Zone IX.Equator Tropical Zone
	500 Plateau Domain	510 Plateau Sub-Polar Division	Provinces of HIA Humid HIB Semi-humid HIC Semiarid HID Arid	HI.Plateau Sub-Polar Zone

Bailey's ECL	Domain	Division	Province	China eco-geographic regions
		520 Plateau Temperate Division	Provinces of HIIA Humid HIIB Semi-humid HIIC Semiarid HIID Arid	HII. Plateau Temperate Zone

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The Domain Plateau was predicted by a binary domain decision tree in Fig. 1, and it was comparable with Domain Arctic and Domain Tropic. This Domain classification solved the problems about the tropical and subtropical regions have sub-polar and temperate zones in the high elevation plateau and mountains regimes. The HI and HII eco-geographic zones were delineated (Zheng 1999) and named as the Plateau Sub-polar Division and Plateau Temperate Division separately. The HI was classified with further lower level provinces of HIB: Hilly Plateau of Golog-Nagqu Sub-humid Province, HIC: Plateau with Broad Valley Semiarid Province, HID: Kunlun Mountains & Plateau Arid Province. The HII was classified with further lower level provinces of HIIA/B: High Mountains of Gorges of W. Sichuan and E. Xizang Humid & Semi-humid Province, HIIC: Plateau & Mountains Semiarid Province (E. of Qinghai, Qilian Mountains, and S. Xizang), HIID: Qaidam Basin and N. Slopes of Kunlun Mountains and Ngari Mountains Arid Province in the Table 1.

Based on Bailey's (1995), the next level classification is the Section based on mesoscale of landforms such as basin, watershed, and mountain terrain shape, pattern, geologic substratum, and geologic structure and scales. China's ECLs used the plains, hills, and mountains to classify, or equivalent to Bailey's Sections, which are being named with numeric numbers 1,2, and 3 such as HIB1, HIC1, HIC2, HID1, and HIIA/B1, HIIC1, HIIC2, HIID1, HIID2, HIID3. Theoretically, the predicted HI and HII with A, B, C, D, and intermediate types A/B can exist in the system in the Table 1.

The Analysis of Three Cases of Lower-Level Ecosystem Classification of Land

1. The Study on Lower-Level Ecosystem Classification in United States

Ecoregions of the United States had been examined by Bailey (1995,1996) in great detail at Domain, division, and Province. The first case study used for lower-level was accomplished with upper 4 levels for the project in a 4.5-million-hectare area centered in western of ECOMAP (1993). National Hierarchy of Ecological Unit (NHEU) had been set up to present as the coarsest boundaries Utah, the United States. This project started in 1995, and conducted out in a team works. It stressed one of 300 Dry dominant; Divisions area had bounders intersecting with 340 Temperate Desert Division and M340 Temperate Desert Regime Mountains Divisions; three provinces are interesting with study area, 342 Intermountain Semi-Desert Province, M341 Nevada-Utah Mountains Semi-desert Coniferous Forest Alpine Province, and 341 Intermountain Semi-Desert and Desert Province. The study area is intersecting with 4 sections, Bonneville Basin Section, Central Great Basin Section and Northeastern Great Basin Section, and Northwestern Basin and Range Section. In the Table 2, 8 levels' ECOMAP Units were applied to the study area as the outline of ecosystem classification, and the rules and ecological features for the ECL model (Fig. 3A).

Table 2
Summary of the bases of ecosystem classification layers for the Hill AFB project

Level	ECOMAP Name	Example name	Main Environmental Characters	Data Source & methods	Scales
1	Domain	300 Dry	Climate	Köppen Bsk	Ecoregion
2	Division	340 Dry Temperate	Climate	Bsk	Ecoregion
3	Province	342 Intermountain Semi-Desert	Climate	Bsk	Ecoregion
4	Section	Central Great basin	Topography	Terrain	Segment
5	Subsection	Erosional landscape, East slope of grassy Mountains	Intermediate scale terrain segment	Terrain segment	Landscape mosaic
6	Landtype Association	Moderately hard sedimentary erosional landscape	Macroterrain Units,	Erosional, depositional landscape	Landscape mosaic
7	Landtype	Alluvium, eolian sediments	Mesottrain units	Soil type of rock, sedimentary, lake, glacial, volcanic	Landscape mosaic
8	Landtype Phases	Moderately hard sedimentary (ridge, middle, foot slope)	Microterrain units	Landform (side, toe, foot, bottom) and moisture regime	Ecozone/zone
9	Ecological Sites	Desert Loam	Objectively defined land unit	Evaluation and management	Sites
10	Vegetation Stands	Desert Loam	Homogeneous vegetation	Vegetation association	Stands
Note: Ecoregion, Ecozone means the classification classes had both biotic and abiotic features					

“Bolson” is subsection and used as a special term in the lower level of ecosystem classification, described the terrain. DEM data (30m) was used in the model and generated 60 bolson segments (Fig. 2B). In the study area, the macrotterain, mesoterrain, microterrain units were generated in the model with algorisms to identify and delineate their boundaries. The protocols (Fig. 3A) were used to identify landscape units between ladtype association, landtype, and lantype phase one step at a time seperately. The ecological sites (ESs), the 9th level, was designed to overcome the using important data on ESs, nested to ECOMAP; vegetation stands (VSs), the 10th and finest-grain level were subdivisions of individual polygons of ESs (Fig. 3B) based on differences in disturbance histories that have led to differing current vegetation structure and composition. The vegetation stands were defined and described in terms of vegetation characteristics that represent fine-scale variations in regional climate, site-specific moisture, nutrient regimes, and disturbance histories (fire, grazing and human activities).

2. The Study on Lower-Level of Ecosystem Classification of Land in China

In our second study case, Qinghai province is located western China, and the northeast part of Qinghai-Tibet Plateau. The latitude is from 31039’N to 39011’N, and the longitude is from 89025’E to 103004’E. From south to north, there is almost a span of 8 degrees that equates to 800 km, and from east to west, there is a span of more than 14 degrees that equates to 1200 km (Zhou and Wang et al., 1987). The total area of Qinghai province is 720,000 km2.

Qinghai province is far away from the east-south coast of Mainland China, where the summer monsoon comes from the Pacific Ocean and brings the rainfall to the China continent. The warm and wet air mass only reaches the southeast province boundary and leaves the west part of the area dry in summer and cold in the winter. Geographically, Qinghai province is located in the subtropical and warm-temperate climate zone. However, the average elevation of the province is increased over 3000 m above sea level and the subtropical zone’s evergreen broad-leaved forest and warm-temperate zone’s deciduous broad-leaved forest are total disappeared and replaced by the alpine shrub, alpine tundra, alpine steppe, and alpine desert vegetation. The annual average temperature in the coldest month is under − 6.5^{O}C in the whole province, and the annual average temperature in the warmest month is under 10^{O}C in higher mountain region (> 3500m), 10^{O}C-15^{O}C for the valleys and mountain slop (2700 m -3500 m), above 15^{O}C in east agriculture region and west desert basin. The rainfall is in the summer season during June, July, and August, taking by 80–90% of annual total precipitation. Qilian Mountain ridge is divided north border from Gansu Province. Qaidam bison located in the northwest of the province, basin valley elevation is about 2600 m, the north border with Altyn-Tagh mountain range. Southern Qinghai Plateau is named for the southern area of Golog Mountains and Qinghai South Mountains, and the northern area of Tangula Mountains, which form major higher plateau in Qinghai (Fig. 4 (a)).

The Qinghai province is within the 500 Plateau Domain as we examined and defined, intersected with the HI, Plateau Sub-polar Division and HII, Plateau temperate Division (Fig. 3 (b)). The Qinghai province region is intersecting with 5 Sections in Table 3.

Table 3
Biogeoclimatic Framework and lower-levels' ECLs in the North East Qinghai Province in China

HIC1: Plateau with Broad Valley Semiarid Section **i QingNan Plateau cold temperate coniferous forest, alpine shrub, alpine tundra Subsection**
HIIC1: Plateau & Mountains Semiarid Section (E. of Qinghai, Qilian Mountains) i. Qinghai East-North Alpine Tundra Subsection and QingNan Plateau West Steppe Subsection i a QingHai East-North temperate Steppe ecozone ia-1 HuangShui River watershed Forest, Temperate Steppe zone ii QiLian Mountain East Alpine Shrub and Alpine Tundra subsection iia QiLian Mountain East Alpine Shrub and Alpine Tundra ecozone iia-1 Da-Tong River-Black River Alpine Shrub, Alpine Tundra zone iia-2 Lake Around Alpine Shrub, Alpine Tundra zone
HIID 1, 2: Qaidam Basin and N. Slopes of Kunlun Mountains, and Ngari Mountains Arid Section
HIB1 Hilly Plateau of Golog-Nagqu Sub-humid Section
HID1: Kunlun Mountains & Plateau Arid Section

With considering the upper levels' ecosystem classification in China, the lower-levels' ecosystem classification in Qinghai province was conducted and classified, showing at Table 3 and Fig. 5. Based on the biogeoclimate condition, vegetation distribution, landform, and plant species feature, three level biogeoclimate classifications under Section were created, for example top layers i., ii., and 3 lower-levels' hierarchies of Subsection, Ecozone, and zone when applying ECOMAP classification framework.

Using DEM data and spatial analysis model (Zhang and Peterman et al., 2008), the lowest level of the ecological sites were classified, which was based on vegetation type, slope or aspect position (Fig. 5A).

By using objectively defined algorism, the ecological sites map in the area of Haibei Alpine Meadow Ecosystem Station was generated. The map scales was changed from 1:3,000,000 (Subsection, ecozone, and zone) to 1:50,000 in mapping Ecological Sites. With the development in the GIS spatial analysis model (Zhang et al., 2008), the Normalised temperature surface was generalized and integrated in the Vegetation Dynamic Simulation Model (VDMS). We simulated the alpine tundra vegetation dynamics in response to global warming with scenarios of global annual mean temperature increase of 1^{o} to $3^{o}C$. Since the study area was with the features of the plain, lower hills, and glacier mountains, the ecological sites showed the relation with elevation, slope, aspect, temperature, and water condition (Table 4) (Zhang et al 2008). This approach had been demonstrated, and applicable to the entire region of Qinghai-Tibet Plateau in China (Zhang and Sun et al., 2010) in the simulation of alpine tundra dynamics in response to the global warming.

Table 4
Haibei Ecological Sites' Soil Temperature, Soil Potential, aspect, and elevation range

Ecological Sites	**N0. Of Layers**	**Slope**	**Elevation range m**	**Soil temp 10 cm**	**Soil potential (Centibar) 10 cm**	**Coverage %**
Wet Potentilla	2	NE 15º-NW 40º	3200–3450	11.17	-13.97	70–80
Dry Potentilla	2	SW 10º-25º	3300–3650	10.40	-20.00	80–90
Typical Kobresia	1	Flat	3200–3250	12.40	-12.10	90–95
Dry Kobresia	1	SE20º-SW40º	3200–3300	15.15	-21.00	80–90
Wet Kobresia	1	SW30º-W 0º	3200–3350	11.20	-18.00	80–85
Riverside Blusmus	1	Flat	3100–3140	13.50	0.00	90–95
Riverside Kobresian	1	Flat	3100–3200	9.80	-4.00	90–95

Results

Bailey's (1995) M310, M320 as Mountain Regimes of Tropic and Subtropical Division had left an empty entry for Qinghai-Tibet region in the world ecoregion scale. The United State and China continents have similar latitude ranges, except for having the highest plateau in the southwestern part of China. The binary decision tree analysis had approved that 500 Plateau Domain should be added to Bailey's Ecosystem Classification of Land. The description of the 500 Plateau Domain should have HI and HII's characteristics (Zheng, 1999; Wu et al., 2003) and Climatic Tundra features (Bailey, 1995; Belda and Holtanova et al., 2014).

Based on the biogeoclimate condition, vegetation distribution, landform, and plant species feature, classified HIIC1 into two subsections (labeled as *i, ii*), and delineated *iia* of QiLian Mountain East Alpine Shrub and Alpine Tundra ecozone into *iia-1* and *iia-2* zone. Likewise, *ia-1*, HuangShui River watershed Forest, Temperate Steppe zone was classified under *ia* of QingHai East-North temperate Steppe ecorzone (Fig. 5).

The project in a dry domain area in western Utah of the United States, with 10 level classification would be more theoretical than practical. However, using objectively defined algorism, it had demonstrated that the development in the GIS spatial analysis model (Zhang et al., 2008) had significance valuable for conducting global warming research.

Discussions And Conclusions

By reviewing the upper level of ECLs in the United States, and China, we realized that ecosystem classification of land was very special methodology to explore and classify the ecoregions in different continents. Climatologists used relatively or multiple years' annual climate conditions to demonstrate the uniform climatic classifications and applied them to ecological regionalization study. The differences of the geology and geomorphology on the earth caused uncertain changes within Domain, Division, Province, and Section, where we had to solve the issues in the next levels' classification (Cleland et al., 1997; Creque et al., 1999; West et al., 2005; Grods and Francis et al., 2012). Bailey classified upper-level Ecosystem Classification of Land (Domain, Division, and Province) based on climate classification (Bailey 1983, 1995, 1996). ECOMAP, defined by the National Hierarchy of Ecological Unit (NHEU, 1993), had been set up to present as the "top-down" approach of Ecosystem Classification of Land in the United States. Theoretically, Western Utah's project had proved it was a cost matter and time consuming through a full ECL's field survey and an intensive classification processing.

ECOMAP (1993) is a top-down regionalization that is hierarchically nested and explicitly geographic area. While hierarchical structures allow related land classification units to be used at scales appropriate to various needs, from national to local, a consequence of the top-down, nested hierarchically that dominates the NHEU is that perimeter of outer polygons created at lower levels have to be vertically integrated with the delineation of polygons occurring at upper levels. One consequence of this "top-down" process is that if the lowest levels are produced independently of higher levels, one should logically readjust (merge from the "bottom-up") the congruent polygon boundaries involved in all affected polygons created at higher levels when we understood and considered the content of whole (Bailey, 1983; West et al., 2005). In other words, we dissected wholes into parts on the basis of differences so that classes and units are arrived at by subdivision.

A top-down approach described by Rowe 1961, separated the ecosystem into components like organisms. We have simply pointed out that following a top-down nested hierarchy to its finest subdivisions counters common sense and practicality. Thus, a terrestrial ecosystem is a volume of earth space with organic contents, separated from its neighbors by reasonable divisions in the empirical continua of biota, soil, and physiography. However, ECL framework could be changed when selecting different biotic and abiotic criteria in two different continents or countries.

Practically, the lower-level study case in QingHai province of China study had performed more time saving and cost less, in which using biogeoclimatic classification, GIS technology and Spatial Analysis Model produced the objectively defined ecological sites and map. Plant ecologists had used their sophistical experiences (Hou,1983; Grods et al., 2012; Baldwin and Chapman et al., 2019) to develop the vegetation classification and ecoregion map with a nested structure on biogeoclimatic principles. The map products were produced from regional to local scales, and represented high relations among the long-term climate condition, climax vegetation, and dominant plant species. 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 (Mackenzie and Klassen, 2009; McLennan and Mackenzie et al., 2018), and displayed the site conditions in the edatopic grid with a relationship between soil nutrient regime and soil moisture regime as well (Environment Yukon, 2016).

Ecologists have been studying different computational models in ecological classification such as LeNet, AlexNet, VGG models, residual neural network, and inception models (De'ath et al., 2000; Olden et al., 2008; Brodrick et al., 2019). The biggest challenge lies in the need for a large training dataset to achieve high accuracy. Algorithms are trained by examples and the machine can only detect what criteria have been previously shown and selected. Implementing algorithms provided useful methods to analyze nonlinear data with complex interactions, and can therefore be useful for ecological studies and ecosystem classification. Moreover, they can achieve great accuracy when choosing various tools for identification and classification tasks. Achieving better and unbiased ecological predictions is more feasible now. This is benefited from the availability of ecological data that has increased dramatically. Contribution for increasing data availability is extensively related to using GIS and remote sensing, and large international research networks (Iwao and Nishida et al., 2011; Silver and Carroll, 2013; Zhang and Xia et al., 2016). Furthermore, a fundamental change in research culture is towards making ecological data accessible publically. All of these developments are important factors behind the development in ecology.

With further understanding the ecosystem classification approaches and enhancing ecological modeling experiences (West et al., 2005; Mackenzie et al., 2009; Zhang et al., 2008, 2010; Zhang and Xia, 2016; Zhang and Lu et al., 2017), an objectively defined ecosystem classification can be integrated by using computer algorithm to develop efficient tools and affordable applications without losing hierarchical structure feature. Likewise, our two case studies of ECLs had used the upper level Domain, Division, Province and Section digital format data, and carried out a deliverable application associated with a scaled lower level ECLs such as ecological sites. The objectively defined algorism and analysis generated internal function outputs in the algorism. The slope model, landform model were running based on objective needs, and vegetation, soil, and geology data could be considered as attribute data sources depended in the project.

Ecosystem regionalization is a scale-based approach to classifying land surface, combined with regional and continental data on climate, geomorphology, landform, lithology, and characteristic flora and fauna. Also, we should have understood more on taking geology, landform, soils, vegetation, and climate into account to determine their biogeographical regions in different scales and ecosystem levels, while the boundaries of these ecoregions are still being studying and delineated in a global-wide scheme.

Declarations

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Authors' contributions

Author has contributed a lot to this manuscript, and approved the final manuscript.

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Ethics approval and consent to participate

Author confirmed that there is no ethical conflict

Consent for publication

Author has read the manuscript carefully and agreed to submit for publication.

Competing interests

Author declares that there are no competing interests.

Terminology

Macroecosystem: Groups of spatially related ecosystems can be considered as higher order and commonly greater size, defined by Bailey 1983

Ecoregion: First proposed in 1962 by the Canadian forest researcher Orie Loucks (1962). In 1967 Growley mapped the ecoregions of Canada based on macrofeatures of the climate and vegetation. Bailey mapped the ecoregions of the Unite States in 1976, revised in 1995, and 1996.

Ecological sites: Defined as the fundamental land for evaluation of rangeland condition and trend (Creque et al., 1999), and provide basic information for natural resource planning and management. Ecological site maps may be used for activities such as delineating ecosystems, assessing resources, conducting environmental analyses, and managing and monitoring natural resources (Cleland et al., 1997).

Objectively defined algorism: Features whose values are taken from a defined set of values. For instance, Temperature in set of climate data, aspect and slope always taken from landform.

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Figures

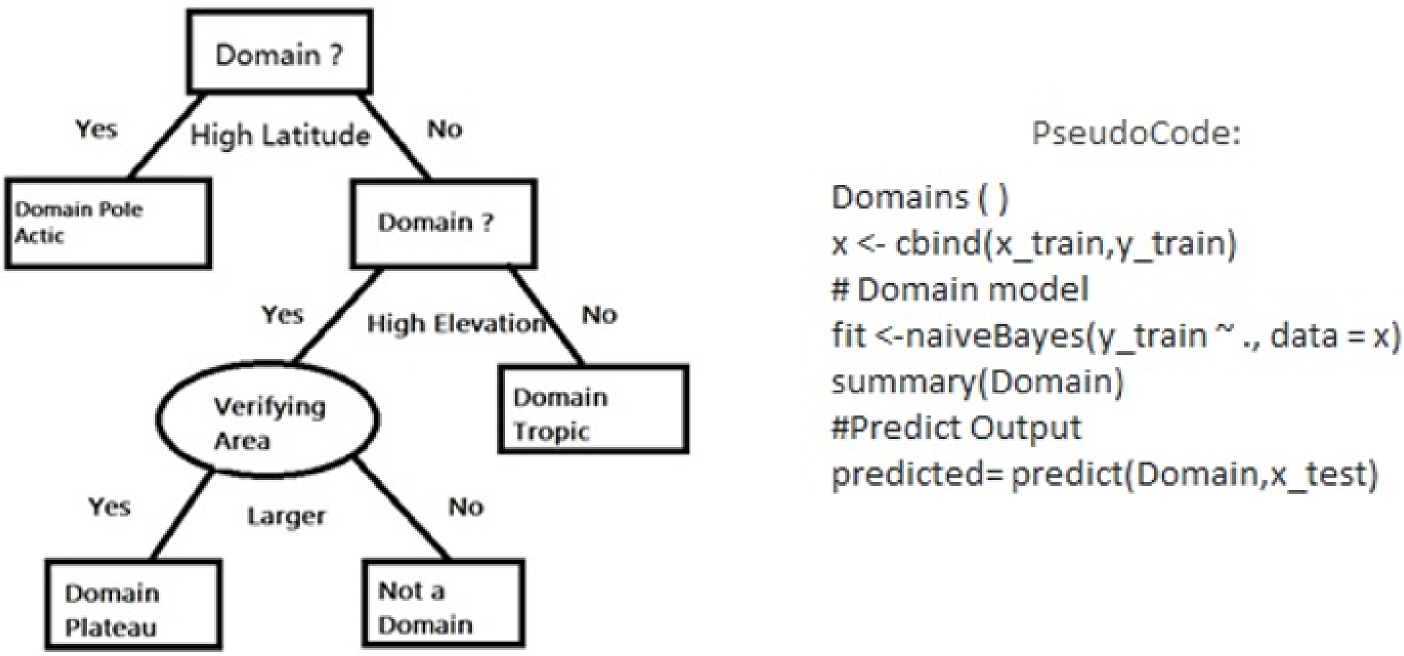
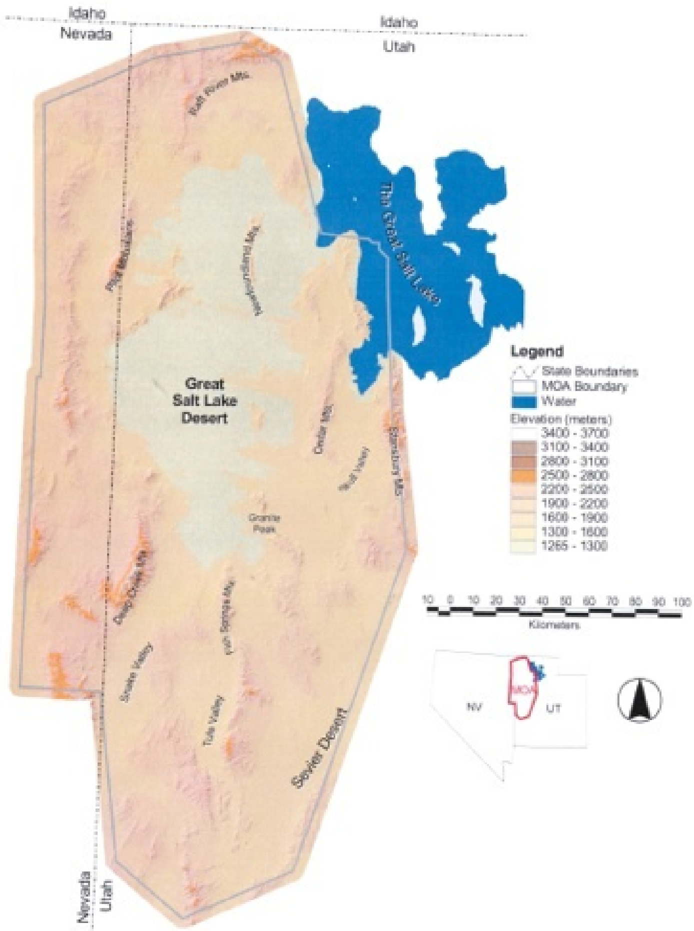


Figure 1

Binary domain decision tree and algorism



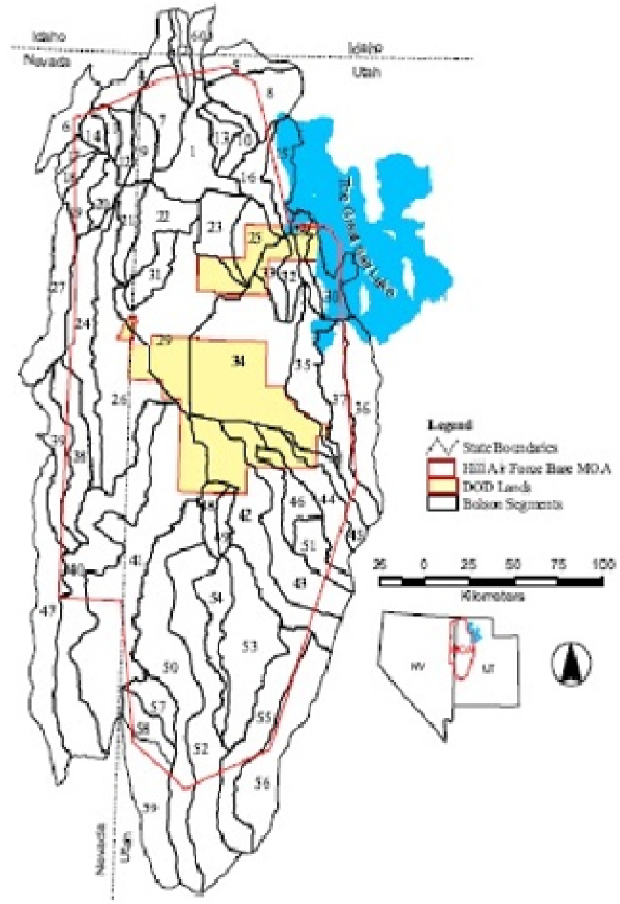


Figure 2

A DEM landscape layout of study area B First layer of lower-level subsection of the study area

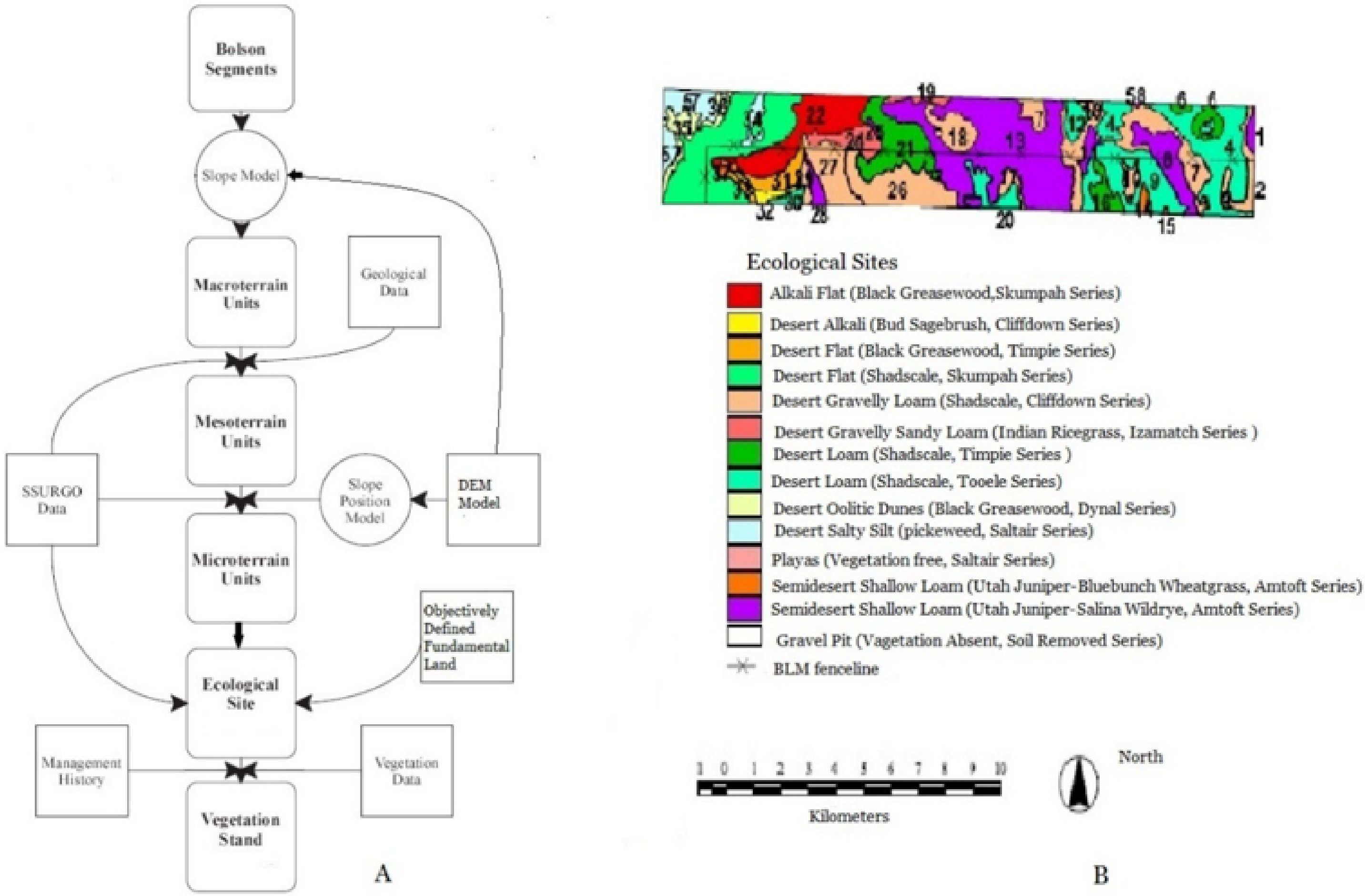


Figure 3

A Flow diagram of Ecosystem Classification of Land from Bolson Segments to Vegetation Stands B Map of the ecological sites in project sampling strip area

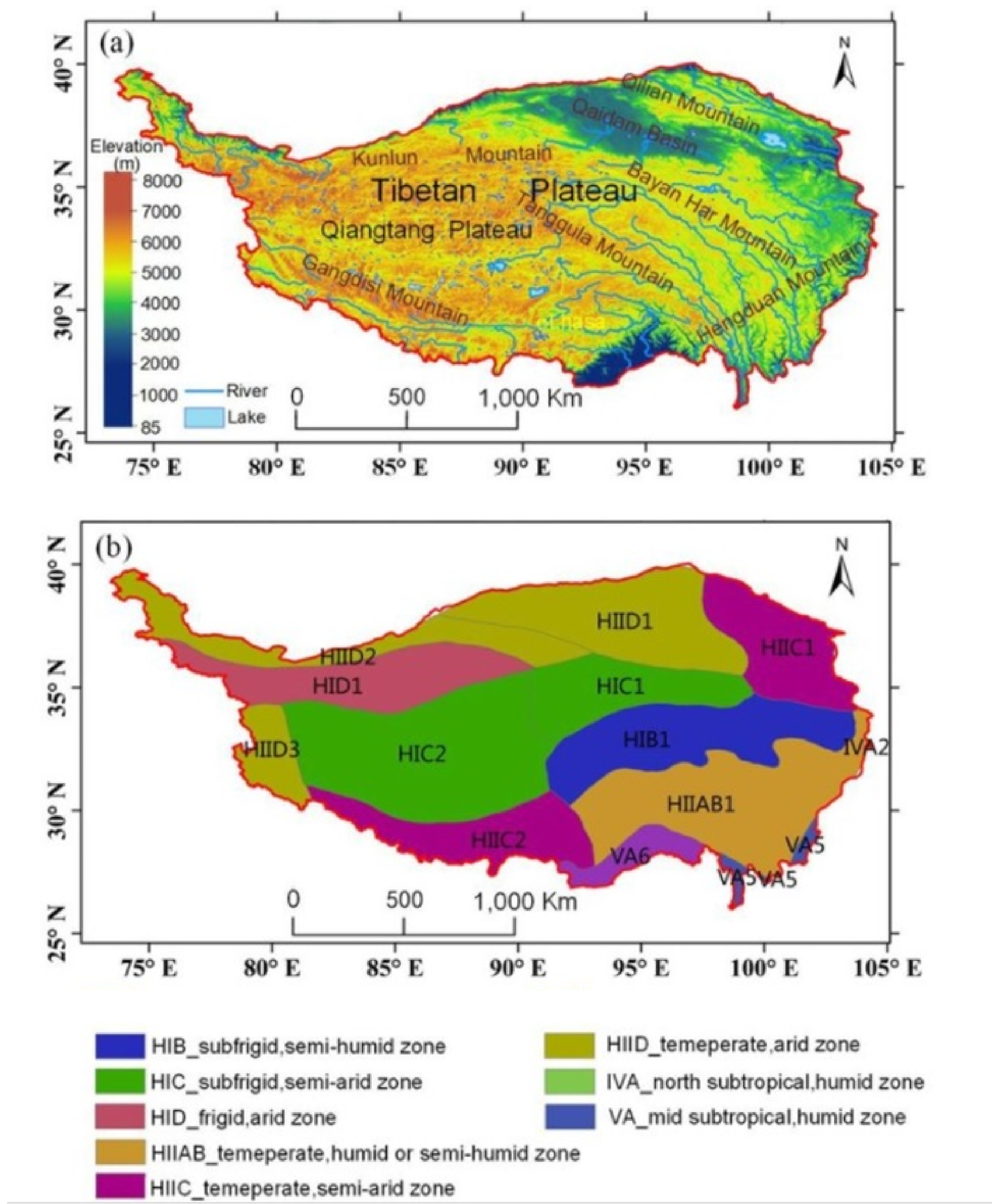


Figure 4

Ecoregion map of Qinghai-Tibet Plateau Data source: https://doi.org/10.1371/journal.pone.0234848.g001

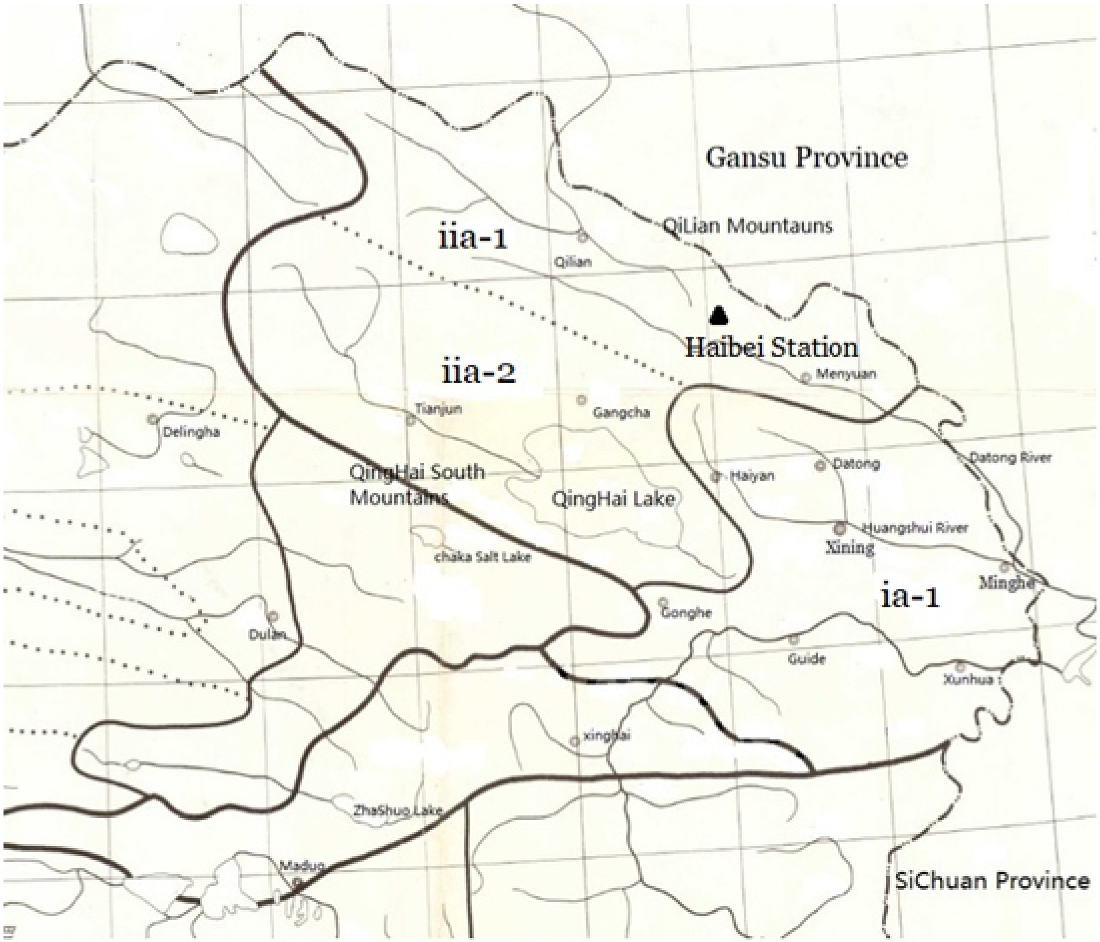


Figure 5

Biogeoclimatic ecoregions in the North Eastern Qinghai Province in China

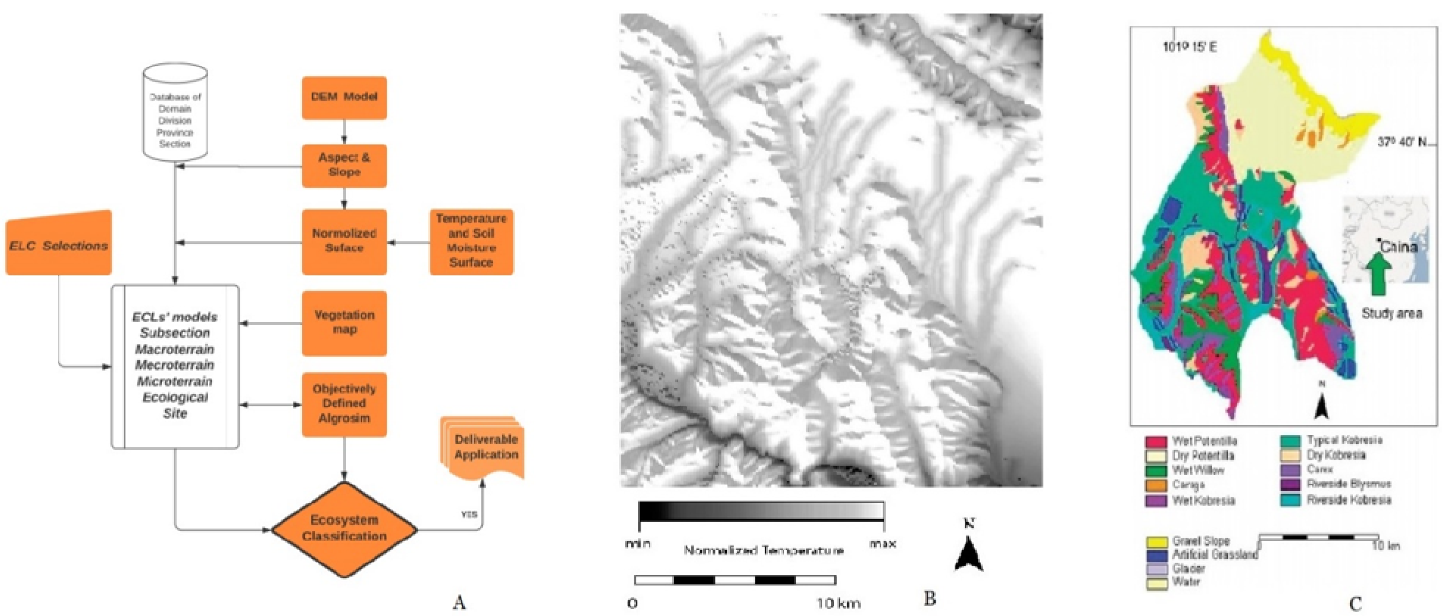


Figure 6

A Objectively defined Ecosystem Classification B Normalised temperature surface (generated)) and soil moisture surface (applicable) C Haibai Alpine Tundra Ecosystem Station’s Ecological Sites