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DATA ARTICLE

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The biome inventory – Standardizing global biogeographical land units

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Abstract

Motivation: The subdivision of the Earth's terrestrial surface into different biomes, ecozones, bio-climatic realms or other large ecological land units is an essential reference for global biogeographical and ecological studies. Various classification schemes exist. These differ significantly in terms of the considered criteria for classification and the underlying methodology of class assignments. Evident divergences between global biome concepts are elusive, weakening hereon based analyses and assumptions. Compilation and standardization are essential for obtaining a framework that enables the comparison of different products. To address this need, we created a catalogue of standardized categorial biome maps comprising 31 different global products based on various methodological approaches. These products were processed individually to facilitate their use in large-scale biogeographical and ecological analyses.

Main types of variables contained: We provide a unified RasterStack containing 31 terrestrial biome and land-cover classifications in different layers. Additional ancillary and processing information is allocated.

Spatial location and grain: Global, 10 km × 10 km grain size in equal-area Mollweide projection.

Major taxa and level of measurement: Biomes, ecozones, bio-climatic zones, and ecological land units.

Software format: GeoTiff.

KEYWORDS
biosphere, boreal, climate zones, desert, ecozones, land cover, rain forest, savanna, temperate forest, tundra

1 | INTRODUCTION

Global changes of ecosystems are currently dominated by various anthropogenic drivers such as land use or climate change (Bellard et al., 2012; IPBES, 2019; Sage, 2020). Biota and species communities are globally affected at an unprecedented speed, with severe and partially uncertain consequences for human well-being. The sum of environmental alterations results in substantial modifications of biodiversity patterns, processes, functioning, and in consequence of ecosystem services. This development urges for mitigation and compensations through societal and economic measures and investments (IPBES, 2019; IPCC, 2021), for example via ecological restoration (Strassburg et al., 2020). A commonly implemented measure counteracting environmental alterations and biodiversity decline is the designation of protected areas. However, even these intended arks of biodiversity and refugia for threatened species are no longer safe sites. As protected areas are spatially fixed zones, they experience changes, such as emerging novel climatic conditions within their spatial extent (Hoffmann et al., 2019; Hoffmann & Beierkuhnlein, 2020). Furthermore, alien species cannot be excluded from protected areas but are invading increasingly weakened ecosystems (Liu et al., 2020; Schulze et al., 2018). All these processes should not be seen as the result of local singularities but require a larger spatial and temporal perspective.

Biome classifications are commonly referred to in applied sciences such as conservation ecology (e.g., Hoffmann et al., 2019). Distinct partitioning of the Earth's surface into different categorial classes has immense implications on study results, and thus reflects upon management strategies. However, the conclusions for decision making are dependent on the choice of a particular classification. Consequently, an informed selection of particular biome classifications according to specific research needs is essential to fathom effects of global change, and to obtain a baseline for conservation and restoration actions. The requirement for comprehensive and data-based reference systems describing terrestrial biomes was recently reiterated (GEO ECO, 2020). A variety of such differing biome and land cover classifications is presented and widely used in past and contemporary scientific studies (e.g., Hassani et al., 2020; Hoffmann et al., 2019; Lenzner et al., 2021; Mucina, 2019). Traditional global biome concepts, for example, the traditional approach by Whittaker (1975), are textbook knowledge. Despite initial intentions to form maps based on moving targets of changing climates, correlated with biome patterns, such adaptations are not comprehensive. In previous decades, interactions between climate, soil properties, vegetation structure, and physiology were increasingly considered (e.g., Prentice et al., 1992), even leading towards global and continental vegetation models applied in climate change impact assessments (e.g., Allen et al., 2020; Cramer et al., 2018; Smith et al., 2001). However, these assumed linkages between ecosystem processes and spatial patterns as well as their development need to be validated through ground-truthing and in-situ monitoring.

Established concepts of biomes and ecozones vary substantially in categorization criteria, the number of mapping units, conformity, spatial coverage, and resolution (Beierkuhnlein & Fischer, 2021). This is a consequence of the application of different underlying methodological approaches and criteria for class definition. Concepts can be categorized according to their methodological origin, which includes partitioning referring to in-situ measurements and remotely-sensed observations, modelling approaches, expert knowledge, review, and combinations of these. In addition, classifications differ according to their specific thematic foci. Considerations based on climatic conditions and seasonality (e.g., Beck et al., 2018), primary vegetation composites either focusing on potential natural (Hengl et al., 2018; Kaplan et al., 2003; Pfadenhauer & Klötzli, 2014; Ramankutty & Foley, 1999) or actual vegetation patterns (Buchhorn et al., 2019; Ellis et al., 2010), the inclusion of geological features (mountain systems, e.g., Pfadenhauer & Klötzli, 2014; barren land, e.g., Defries et al., 2010; Kaplan et al., 2003) or geographical focus, such as the latitudinal arrangement (e.g., moist mid-latitudes, Schultz, 2016), add to variety and disharmony in biome classifications. There is no consistency in the consideration of azonal classes that are not linked to climatic factors, such as inland water bodies, ice shields or emerging urban, and other areas of human dominance. Due to the fact that in large mountain ranges ecosystems of different zonal biomes can be superimposed within a small two-dimensional area, orobiomes have been distinguished as specific cases in several approaches (e.g., Walter & Breckle, 2002).

Certain classifications include transitional zones, called zono-ecotones, in between particular zones (e.g., Walter, 1968; Walter & Box, 1976). Despite these differences, many drivers of alternative biome classifications are interdependent. As an example, climate is controlled by solar radiation, which in turn relies on latitude, continental location, and topography, further defining precipitation regimes. This complexity is reflected in habitat conditions that affect vegetation structures and ecosystems.

While understanding the progression and history of biomes is one way to approach differences in biome classifications (Hunter et al., 2021; Mucina, 2019), we argue that a comparison of classification schemes is helpful to understand where different concepts agree and deviate. Hitherto no comprehensive inventory has been attempted to describe products of different global classifications in a standardized way to facilitate comparisons and ultimately select the most suitable classification system for individual research purposes. Here, we inventory published and commonly used terrestrial biome and land-cover classifications and provide a standardized catalogue for products originating from 31 concepts.

2 | THE SPECTRUM AND USE OF BIOME CLASSIFICATIONS

Biomes as a concept have their roots in the work of Lamarck and Candolle (Lamarck & Candolle, 1805) and von Humboldt and Bonpland (1805), who pointed out that certain regions could be, for example, attributed to large-scale floristic regions. The term 'biome' was introduced in 1916 by Clements (1916). Although today biomes are considered a framework for all biota at large scales and are characterized by a specific set of ecosystems, historically there has been a strong emphasis on vegetation structures (formations). Initially, predominant vegetation structures and plant physiology were seen as the most important features related to average climatic conditions (Walter, 1968; Whittaker, 1975). Even though this connection between climate and vegetation patterns is still the most common approach, additional drivers of global patterns, such as soil types, water availability, and disturbance events, were increasingly considered in the following decades (Mucina, 2019). Given the complexity of extensive natural systems biomes are intended to characterize, it is not surprising that the term is still ambiguous. Even though the continental scale is not clearly defined, there is consensus that the term biome is being used to represent larger spatial units than ecosystems. Nevertheless, the term is avoided when the focus is purely on vegetation and not on entire ecosystems (e.g., Pfadenhauer & Klötzli, 2014).

Interestingly, the diversity of biome classifications is not only a consequence of linear progression with more sophisticated methods and finer grained data but also a result of the differing disciplinary viewpoints and approaches applied to derive such classifications. Early biome classifications were merely built on individual expert knowledge (e.g., Walter, 1968, 1976; Whittaker, 1975), with therefrom resulting discrepancies related to individual viewpoints. At that time, individual ecological experience was difficult to attain on a global scale, and data availability was scarce. Considering the difficult circumstances, under which these early biome concepts were created, they are of high quality and invaluable for science today. To this day, classifications derived from expert knowledge are often cited and used in contemporary biogeographical research (e.g., Dinerstein et al., 2017; Olson et al., 2001).

A major challenge in global land area classification consists in balancing between limiting the number of classes without oversimplifying the natural heterogeneity of any ecological unit. The applied criteria for class definition determine boundaries according to the thematic focus. Consequently, careful selection of the criteria used to delineate such large-scale units is essential to create distinct biome maps. A resulting caveat is the delimited set of classification criteria. Nevertheless, this, often hidden, drawback is balanced out by the advantages in terms of practical applicability of maps with clear units and respective ancillary documentation.

In the past, map-based comparisons of global biome concepts were based on visual inspection alone, allowing only vague similarity estimations to be made (Leemans, 1990). Surprisingly, several widely referred to expert-based biome classifications are to date not available as georeferenced products (e.g., Pfadenhauer & Klötzli, 2014; Schmithüsen, 1976; Schultz, 1988, 1995, 2002, 2008, 2016), which restricts their use in geoinformatics and global studies. However, lacking digital availability should no longer be accepted as an argument for ignorance. Overall, past selection biases induced by lacking digital standards are reduced with ongoing technological advances but limitations remain in respect to availability of computing power, which might be required for processing of certain remote sensing derived products and modelled classifications. Nevertheless, such approaches reflect the current-day realities of land surfaces that are strongly modified by humans and thus are valuable for global change analyses.

While historically most expert-based biome classifications exclusively displayed the potential natural vegetation on Earth, and were thus also hypothetical to a certain degree and in addition dependent on a given time and climate, some included landscape elements resulting from anthropogenic activities (e.g., Müller-Hohenstein, 1981). As humans have shaped their environment for 12,000 years or more, the concept of anthromes was introduced to classify terrestrial areas based on the human imprint on nature (Ellis et al., 2010; Ellis & Ramankutty, 2008). While classifications both with and without anthropogenic elements can be justified, they represent different reference systems. For nature conservation, naturalness, and wilderness may be the most important guidelines. For global change impact studies, the human footprint may be more relevant. Obviously, the philosophy and methodology behind different global maps differ considerably. Certain concepts focus on potential global patterns of natural ecosystems and others on the current state of land cover. The continuity of past 'natural' patterns is questionable under contemporary conditions (Chiarucci et al., 2010). Under this perspective, it can be questioned if formerly produced global maps are still valid. Some classifications like, Schultz (1988) have never been significantly updated but are still frequently referred to in geography, pedology, and vegetation sciences (e.g., Amelung et al., 2018; Eitel & Faust, 2013; Pfadenhauer & Klötzli, 2014; Zech et al., 2014). However, modelling the global distribution of potential natural patterns of biomes under current climatic conditions (e.g., Hengl et al., 2018; Higgins et al., 2016) does intrinsically ignore the human sphere, which interacts intensely with natural systems. Consequently, there is no right or wrong, but just different viewpoints and baselines that users need to be aware of. Our work aims to provide an overview and easy access to diverse approaches and classifications.

3 | DATA SOURCES: INVENTORIED BIOME CLASSIFICATIONS

We focused on categorial maps of global terrestrial biome and land-cover classifications. Potential products for consideration were identified based upon a literature review of scientific papers and textbooks. Aiming for maximum comprehensiveness and high inclusiveness, the ultimate criterion for contemplation of individual classifications was the partition of Earth's terrestrial surface following climatic and vegetation characteristics as well as remotely sensed surface properties. The selection was refined in respect to popularity (number of citations or editions), topicality (latest versions of e.g., Köppen-Geiger climate classification) and individuality to yield 31 concepts extracted from 30 sources (Table 1; for an extended version including additional information see Supporting Information Appendix S1). Regarding their methodological genesis, the considered products represent a variety of techniques, comprising climatic and vegetation modelling, earth observation, divisive data clustering, quantitative analysis, review, field study, and expert knowledge. The underlying criteria of class assignment comprise a wide range of climatic, radiative, bio-, geo-, and lithologic as well as vegetative, geographic, geomorphologic, and anthropogenic parameters.

Further classifications that were reviewed but not included in our final catalogue are the International Geosphere-Biosphere Programme (IGBP) Land Cover Classification (Belward, 1996), the Simple Biosphere 2 Model (Sellers et al., 1996), the Vegetation Lifeform (Running et al., 1995), the Global Ecosystems (Olson, 1994a, 1994b), the Biosphere Atmosphere Transfer Scheme (Dickinson et al., 1986), the Simple Biosphere Model (Sellers et al., 1986), and

TABLE 1 Standardized products of all concepts sorted by year of publication or last edition, including the number of different classes and the underlying criteria for class assignment

Publication	Name of classification	Criteria for class assignment	Methodology of class assignment	Layer in RasterStack
Allen et al. (2020)	Global vegetation patterns of the past 140,000 years	Carbon mass, LAI, and plant functional types	Modelling with the global dynamic vegetation Lund-Potsdam-Jena General Ecosystem Simulator	1
Buchhorn et al. (2019)	Dataset of the global component of the Copernicus Land Monitoring Service	Multi-spectral Earth surface reflectance on top of canopies	Supervised classification of satellite imagery data based on external reference datasets and expert opinion	2
Beck et al. (2018)	Present and future Köppen-Geiger climate classification maps at 1-km resolution	Climate (temperature and precipitation)	Application of a slightly adjusted Köppen-Geiger classification based on climatological thresholds following Peel et al. (2007)	3
Hengl et al. (2018)	Global mapping of potential natural vegetation: an assessment of machine learning algorithms for estimating land potential	Potential natural vegetation	Modelling based on several machine learning techniques including neural networks, random forest, gradient boosting, K-nearest neighbour, and Cubist	4
Dinerstein et al. (2017)	An ecoregion-based approach to protecting half the terrestrial realm	Biogeographical zonation and species distribution	Revision of the terrestrial ecoregions of the world by Olson et al. (2001) based on technical advances and expert knowledge	5
Zhang et al. (2017)	A global classification of vegetation based on NDVI, rainfall, and temperature	Climate (temperature and precipitation) and vegetation (NDVI)	Non-hierarchical data clustering based on K-means distances in 14 classes, validation via Kappa statistics	6
Netzel and Stepinski (2016)	On using a clustering approach for global climate classification	Mean monthly climatic conditions including temperature, precipitation, and temperature range	Climate data clustering based on dynamic time warping as a measure for dissimilarity between climate types	7
Netzel and Stepinski (2016)	On using a clustering approach for global climate classification	Mean monthly climatic conditions including temperature, precipitation, and temperature range	Climate data clustering based on Euclidean distance as a measure for dissimilarity between climate types	8
Higgins et al. (2016)	Defining functional biomes and monitoring their change globally	Vegetation parameters including a productivity index, timing of minimum vegetation activity, vegetation height; essential data for the definition of these factors are NDVI, soil moisture, solar radiation, and temperature	Classification of vegetation categories based on multiple predefined parameters of vegetation height, productivity, and plant growth limitations	9
Pfadenhauer and Klötzli (2014)	Earth's vegetation	Life-form and distribution of potential natural dominant vegetation types as defined by local environmental habitat conditions (climate, soil, relief)	Review and modification of global vegetation patterns by Schmithüsen (1976) informed by multiple regional sources	10

(Continues)

TABLE 1 (Continued)

Publication	Name of classification	Criteria for class assignment	Methodology of class assignment	Layer in RasterStack
Zhang and Yan (2014)	Spatiotemporal change in geographical distribution of global climate types in the context of climate warming	Climate (temperature and precipitation)	Non-hierarchical data clustering based on K-means distances in 14 classes, validation via Kappa statistics	11
Metzger et al. (2013)	A high-resolution bioclimate map of the world: a unifying framework for global biodiversity research and monitoring	42 climatic and physical environmental parameters including temperature, precipitation, evapotranspiration, aridity and humidity indices, solar irradiance, and elevation	Compilation of multiple bio-climatic parameters, collinearity reduction among input parameters based on Pearson correlation, statistical grouping by principal components analysis of the covariance matrix, data clustering by iterative self-organizing data analysis for classification of principal components into homogeneous environmental strata, similarity-based aggregation of strata into global environmental zones based on Euclidean distance, comparison of final classification with multiple global and regional ecosystem concepts by Kappa statistics	12
Food and Agriculture Organization of the United Nations (2012)	Global ecological zones for FAO forest reporting: 2010 update	Bioregionalization, biogeography, biodiversity, and macroecological patterns, vegetation	Delineation of global ecological zones based on a compilation of global and regional ecological and vegetational source maps, revision according to remote sensing observational data and expert consultations for categorization of broad vegetation (forest) types	13
Tateishi et al. (2011, 2014); Kobayashi et al. (2017)	Global Land Cover by national mapping organizations	Earth's spectral surface reflectance	Supervised classification of satellite imagery by MODIS based on multiple remote sensing products for reference as well as specific regional maps and expert opinion, individual unsupervised classification for certain classes, validation with stratified random sampling	14
Defries et al. (2010)	ISLSCP II University of Maryland global land cover classifications, 1992–1993	NDVI, vegetation cover, and canopy height	Resampling of land cover and derived NDVI data from AVHRR with hierarchical classification	15

TABLE 1 (Continued)

Publication	Name of classification	Criteria for class assignment	Methodology of class assignment	Layer in RasterStack
Ellis et al. (2010)	Anthropogenic transformation of the biomes, 1700 to 2000	Human population density and land use	Rule-based model classification according to standardized thresholds	16
European Space Agency (2010)	GlobCover	Earth surface reflectance of solar radiance in 15 spectral bands ranging from 412.5–900 nm in wavelength	Regionally specified classification of high-resolution surface reflectance mosaics, validation informed by expert knowledge	17
Friedl et al. (2010)	MODIS collection 5 global land cover: algorithm refinements and characterization of new datasets	Earth surface reflectance data derived from time series of seven spectral bands provided by MODIS, EVI, remotely sensed land surface temperature, surface albedo	Nested classification of Earth observation data based on ensemble decision trees, cross-validation analysis	18
The Nature Conservancy (2009)	Terrestrial ecoregions of the world	Macro-biogeographical patterns	Compilation of selected global and regional ecozones, alignment and expert informed modification	19
Peel et al. (2007)	Updated world map of the Köppen-Geiger climate classification	Climate (temperature and precipitation)	Classification and spatial interpolation of observational climate records based on predefined thresholds	20
Bartholomé and Belward (2005)	GLC2000: a new approach to global land cover mapping from Earth observation data	Top-of-canopy surface reflectance	Derivation of land cover maps from spectral surface reflectance at four wavelength ranges based on regionally optimized image classification procedure	21
Kaplan et al. (2003)	Climate change and arctic ecosystems: 2. modelling, paleodata-model comparisons, and future projections	Potential natural vegetation and associated phenological, hydrological and biogeochemical characteristics	Coupled biogeographical and biogeochemical distribution modelling of biomes of defined by main potential natural vegetation types	22
Olson et al. (2001)	Terrestrial ecoregions of the world: a new map of life on Earth	Distribution of distinct natural communities prior to human land use change, biogeographical zonation, and species distribution	Review of global and regional biogeographical provinces, hierarchical classification into ecoregions, refinement based on expert consultation, nesting of ecoregions into biomes and biogeographical realms	23
Loveland et al. (2000)	Development of a global land cover characteristics database and IGBP DISCover from 1 km AVHRR data	NDVI	Unsupervised classification and subsequent stratification of monthly NDVI composites provided by AVHRR from 1992–1993 at continental scale	24
Ramankutty and Foley (1999)	Estimating historical changes in global land cover: croplands from 1700 to 1992	Potential natural vegetation	Informed classification of remotely sensed land cover	25

(Continues)

TABLE 1 (Continued)

Publication	Name of classification	Criteria for class assignment	Methodology of class assignment	Layer in RasterStack
Leemans (1990)	Possible changes in natural vegetation patterns due to global warming	Vegetation determined by bio-climatic site conditions (biotemperature, precipitation, potential evapotranspiration ratio)	Application of the Holdridge life zone classification (Holdridge, 1947, 1967) based on spatially interpolated bio-climatic parameters from climate station records	26
Schultz (1988, 1995, 2002, 2008, 2016)	Ecozones of the Earth	Climate (temperature, precipitation, evapotranspiration), vegetation (community composition, phytomass distribution, primary production, growing season), radiation, pedosphere, lithosphere, fauna, human activities (settlement, land use)	Review, evaluation of regional ecological studies, quantitative ecosystem analysis	27
Müller-Hohenstein (1981)	Landscape belts of the Earth	Climate, vegetation, soil	Review and combination of thematic concepts	28
Schmithüsen (1976)	Atlas of biogeography	Climate (temperature, potential evapotranspiration), potential natural vegetation, soil, topography, elevation	Biogeographical analysis	29
Whittaker (1975)	Communities and ecosystems	Climate (temperature, precipitation) and vegetation (plant community distribution)	Biogeographical analysis	30
Walter (1964, 1968); Walter & Breckle (2002); Breckle and Rafiqpoor (2019)	Vegetation and climate	Bio-physical environmental parameters including temperature, precipitation, solar radiation, soil characteristics, flora, and fauna, continentality and maritime influence, snow cover	Classification according to defined thresholds on climatic data, vegetation proxies, and surface cover indices	31

Abbreviations: AVHRR, advanced very high-resolution radiometer; EVI, enhanced vegetation index, FAO, food and agriculture organization of the United Nations; IGBP, international geosphere-biosphere programme; ISLSCP II, international satellite land-surface climatology project, initiative II; LAI, leaf area index; MODIS, moderate resolution imaging spectroradiometer; NDVI, normalized difference vegetation index.

the United States Geological Survey (USGS) Land Use/Land Cover System (Anderson et al., 1976). These are all derived from the Global Land Cover Characterization (GLCC) scheme (USGS EROS, 2018) and were replaced by more up to date products. Furthermore, the Global Land Cover Map 2006 (Iwao et al., 2006) was not included because of the limited number of only six non-specific USGS land-cover classes. A clustering-based classification by Zscheischler et al. (2012) could not be included because underlying spatial data were unavailable.

4 | STANDARDIZATION OF PRODUCTS

Spatial data of the selected classifications were retrieved from original sources depending on their availability. Certain concepts, including Breckle and Rafiqpoor (2019), Schultz (1988, 1995, 2002, 2008, 2016), Pfadenhauer and Klötzli (2014), Müller-Hohenstein (1981), Schmithüsen (1976), and Whittaker (1975), were manually digitized and geo-referenced as Environmental Systems Research Institute, Inc. (ESRI) shapefiles in ArcGIS (ESRI, 2019) based on scans of the latest available map representations extracted from the relevant literature. These classifications and others presented in vector format were transformed to grid data.

A template raster file was created from country polygons (wrld-simpl dataset) (Bivand & Lewin-Koh, 2021) to serve as a reference for grid processing. All concepts were harmonized with this standard format at a spatial resolution of 10 km × 10 km, over a global extent from 180°W to 180°E and 90°N to 90°S and with the coordinate reference system set to equal-area Mollweide projection. Any undefined classes were excluded. The values of all raster cells were transformed to numbers by changing the names of classes, which are commonly character strings, to distinct values (e.g., values '1' and '2' were assigned to 'Tropical rain forest' and 'Savanna', respectively). Classes were sorted according to their centre's latitudinal deviation from the equator in ascending order from 1 until the maximum number of different classes. For example, in the case of a classification with 14 classes, the value '1' was assigned to all cells of the biome with the lowest latitudinal centre, and '14' was set as the cell value for the biome closest to the poles. Inland water bodies, oceanic islands, mountains, and urban areas were defined as azonal classes; thus, consistent values were assigned (inland water bodies = 95, oceanic islands = 96, mountains = 97, urban = 98). All processed classifications were combined into one RasterStack object (Hijmans, 2021) with 31 layers in chronological order from the most

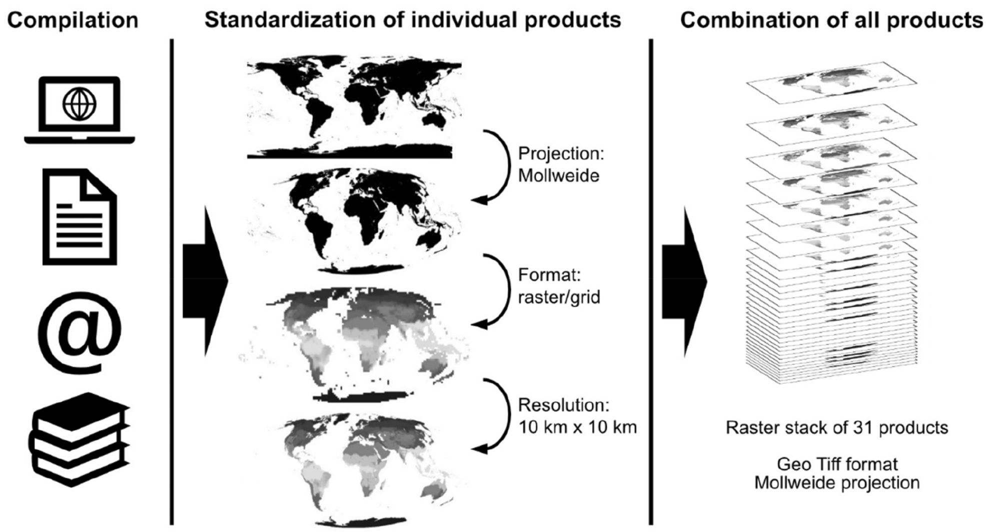

FIGURE 1 Schematic figure of the methodological procedure. Concepts were compiled from different sources, including scientific literature and textbooks (left). All individual products were aligned in terms of their coordinate reference system, data format, and spatial resolution (middle). Finally, all products were stored in a RasterStack object (right).

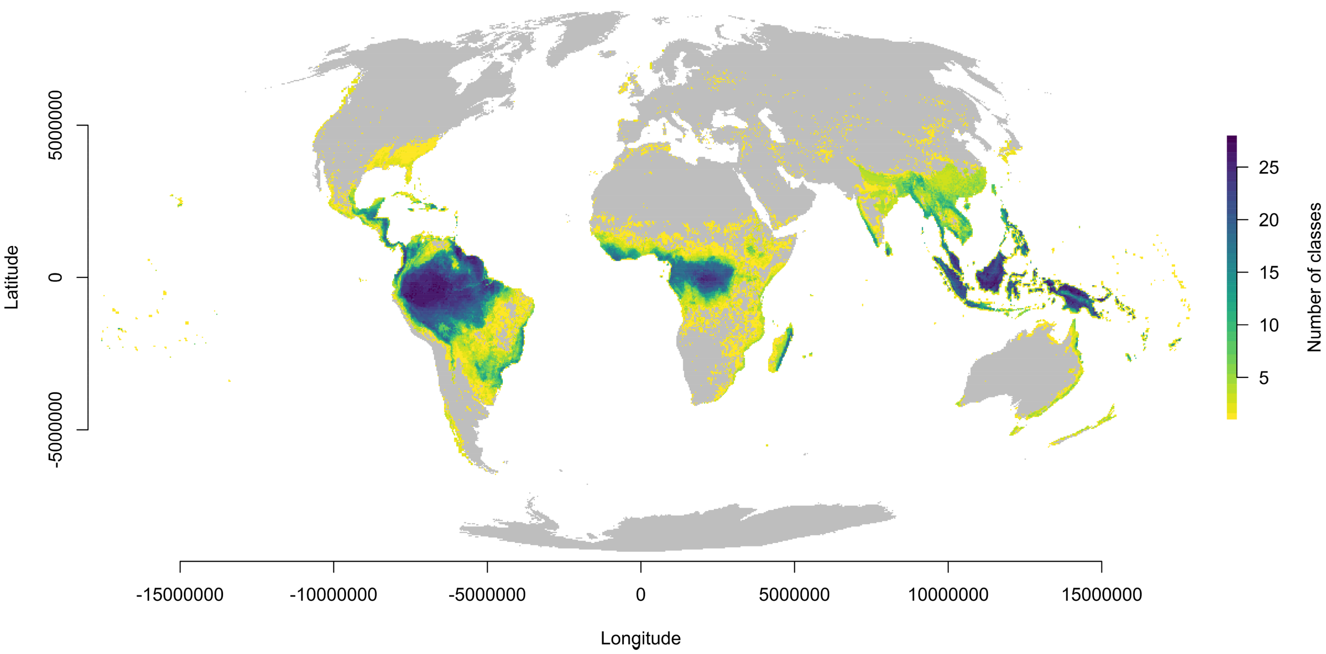

FIGURE 2 Overlay from all 31 classifications of those particular classes located closest to the equator by their latitudinal centre. The colour gradient from yellow to dark blue indicates the frequency of overlapping classes. Note that the total maximum value of overlapping classes was 29 and not 31. This shows that there is no total agreement at any spatial point of all classifications included. This underlines the variance that exists among global biome and land cover concepts. The geographic projection of this map display is set to equal-area Mollweide projection.

recent to the oldest classification (Supporting Information Appendix S2). The methodological procedure is illustrated in Figure 1. To visualize the divergence of products from individual classifications, the spatial overlap of the classes with the lowest latitudinal centres of each biome classification was plotted by frequency in one combined map (Figure 2).

Legends of all maps were harmonized for consistency. They are provided in an ancillary text file in the same order as in the RasterStack (Supporting Information Appendix S3). Maps including legends of all processed concepts are furthermore presented (Supporting Information Appendix S4). We also supply exemplary R code and show how the biome catalogue RasterStack can be opened (Supporting Information Appendix S5).

All spatial data manipulations and displays were performed with the R software environment for statistical computation (R Core Team, 2021) utilizing the 'raster' (Hijmans, 2021), 'rgdal' (Bivand et al., 2021), 'maptools' (Bivand & Lewin-Koh, 2021), 'viridis' (Garnier et al., 2021), and 'terra' (Hijmans, 2022) packages. The code is provided in the Supporting Information (Appendix S5).

5 | DATA STRUCTURE

The final biome catalogue consists of one raster stack object (RasterStack) in GeoTiff format. Each considered classification is represented by one layer of 1,800 rows, 3,600 columns and 6,480,000 cells at a spatial resolution of 10 km × 10 km in *x*- and *y*-dimensions, with global extent in equal-area Mollweide projection. The classifications are sorted chronologically by their year of publication or latest edition, equal to the order in Table 1. For example, the classification by Allen et al. (2020) is at the first position (layer 1), and the concept originating back to 1964 by Walter (1964) (subsequentially updated multiple times, e.g., Walter, 1970; Breckle & Rafiqpoor, 2019) is placed last in the stack (layer 31). Full legend information, including the publication, position in the raster stack, class names, and associated grid values, is provided in Supporting Information Appendix S3.

AUTHOR CONTRIBUTIONS

JCF, AW, and CB conceptualized the study. JCF developed the methodology and compiled, processed, and formatted the data. JCF and AW created the figures. JCF, AW, and CB wrote and edited the manuscript.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

The biome inventory is openly available as a RasterStack object in GeoTiff format with associated legend information contained in a separate text file that can be accessed on Dryad under the following link: https://datadryad.org/stash/landing/show?id=doi%3A10.5061%2Fdryad.hqbzkh1jm. All other supplementary material can be accessed as Supporting Information in the online version of this article.

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BIOSKETCHES

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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