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REPORT

Global Vegetation Project: An Interactive Online Map of Open-Access Vegetation Photos

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Abstract

The Global Vegetation Project (http://gveg.wyobiodiversity.org) is a new initiative to host an online database of open-access, georeferenced vegetation photos. The mission of the Global Vegetation Project is 'to inspire and empower people of all ages to learn about the diversity of vegetation on our planet and to provide educators with a resource for teaching ecology online'. The beta release includes two R-Shiny web applications that allow users to 1) submit photos of plant communities through a user-friendly online portal and 2) explore submissions made by others through an interactive global map. The spatial coordinates of each photo are used to extract information about the location including long-term and recent climate data to create Walter and Leith climate diagrams for each photo. User submitted photos can be filtered by biome, temperature, precipitation, and elevation on the map. The Global Vegetation Project will evolve to match the needs of vegetation scientists and ecology educators. We intend to enhance the educational value of the mapping application by incorporating additional search features, global data layers, and the publication of curricula geared towards primary, secondary, and post-secondary education. We encourage the global community of vegetation scientists to use this resource in their classrooms and to contribute photos of vegetation to grow this valuable resource for the world.

Keywords

community ecology, ecology, geodatabase, global database, gVeg, R-Shiny

Mission and scope

Understanding the structure and dynamics of vegetation on Earth requires international collaboration and data sharing at a global scale. Recently, several biological databases have been made available and are being used to study global biodiversity: sPlot provides a database of vegetation relevés (Bruelheide et al. 2019), the Global Index of Vegetation-Plot Databases (GIVD) provides a metadatabase of vegetation relevés (Dengler et al. 2011), the Global Biodiversity Information Facility provides a database of species occurrences and distributions (https://www.gbif.org) (GBIF 2020) and TRY provides a database of plant traits (Kattge et al. 2020). There are many others. However, despite the importance of digital media in research and education, there was no database of georeferenced global vegetation photos or a map to explore them, until now.

To fill these gaps, we have launched a new initiative called the Global Vegetation Project (http://gveg.wyobiodiversity.org) to host a database of globally-distributed vegetation photos. The Global Vegetation Project is, as far as we know, the first global online repository of open access, georeferenced photos of plant communities. Our mission is 'to inspire and empower people of all ages to learn about the diversity of vegetation on our planet and to provide educators with a resource for teaching online'. This project was inspired by the urgent need for online teaching resources in ecology classrooms and the lack of an open-access central

repository of georeferenced photos which represent all of the major vegetation types across our diverse planet.

We aim to bring the field into the classroom in a previously impossible way, enabling visual and interactive experiences that link vegetation and climate at the global scale. The long-term vision is to curate a global database of vegetation photographs that can be explored interactively through an online map and search interface. Curricula will be developed for a range of educational levels to challenge students to tackle a variety of learning outcomes such as 1) understanding how annual and seasonal climate shapes vegetation composition and physiognomy, 2) identifying examples of functional convergence in different regions of the planet, and 3) hypothesizing how climate change might affect the distribution of vegetation types in the future. In some ways, the project has similarities to iNaturalist (https://www.inaturalist.org/), which has had a powerful impact on ecology education. The difference is that we focus on communities of plants (i.e., vegetation) rather than individual species and our project will directly provide curricular resources for online education.

Accomplishments in the beta release

To date, we have developed two R-Shiny web applications (Chang et al. 2019) hosted on a RStudio Shiny Server. These applications allow users to 1) submit photos of plant communities through a user-friendly online portal and 2) explore submissions made by others through an interactive global map.

We invite vegetation ecologists and community scientists to contribute through a photo submission portal where users upload an image and submit information about their photo (Figure 1). The required information includes the photographer's name, geographical coordinates in decimal degrees, and a short list of dominant plant species. We include optional fields for observation date, email address, place name, landscape naturalness, vegetation type, vegetation classification system, associated publication DOIs, and additional comments. We have imported the Leipzig Catalogue of Vascular Plants (LCVP) as a dropdown to standardize taxon names (Freiberg et al. 2020), but also allow users to provide any species names that they prefer. Rather than requiring users to use one approach to vegetation classification, such as EcoVeg (Faber-Langendoen et al. 2018), we include a dropdown menu with options for a variety of vegetation classification systems (e.g., International Vegetation Classification, International Code of Phytosociological Nomenclature, etc.). If a system is not on our list, users can simply enter the classification system they used to define their vegetation type. We encourage users with large batches of photos to contact us to facilitate batch uploads of photos and metadata. By submitting photos, users agree to provide the Global Vegetation Project a CC-BY-NC-SA 4.0 license and user images will be 'sub-licensed' by us to end-users (e.g., educators) under the same license.

Each submission is stored within a Microsoft SQL Server relational database and our associated cloud file storage

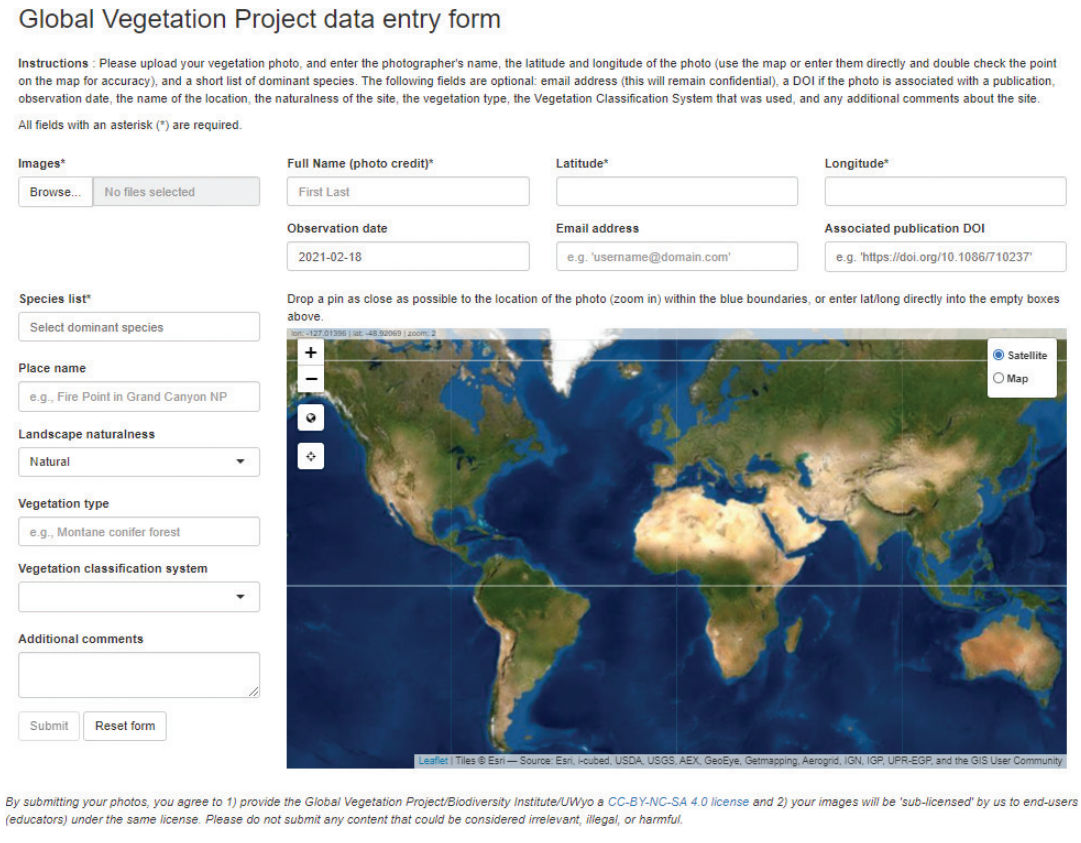

Figure 1. Screen shot of the photo submission application being hosted at http://gveg.wyobiodiversity.org.

server. Image attributes are written to relational tables within the database, with records having the image metadata as well as the cloud storage URL to the image file. These data are backed up nightly to an offsite location and maintained for at least 15 days. The web application programming interface (API) is built upon ASP.NET, and provides multiple end points for data retrieval (https://documenter.getpostman.com/view/11557311/SztD4mhW?version=latest). The API conducts validation of each user submission to ensure minimum data requirements are met. Valid submissions then undergo a second inspection by the maintainers of the Global Vegetation Project to ensure that images are appropriate and to correct identifiable errors. The Advanced Research Computing Center (ARCC) at the University of Wyoming provides robust cyber-infrastructure and security that the Global Vegetation Project uses for its data visualization and storage needs. This includes the open-source software Shiny-Server from RStudio running on a fault tolerant virtual machine, 100 gigabit networking, and S3 storage through the open-source Ceph project.

The location data of each photo is used as a spatial reference to extract a variety of additional information about the photo. We extract historic (1961–2009) and recent (2010–2018) climate data on annual and monthly timescales (Karger et al. 2017; Trabucco and Zomer 2018), elevation (Danielson and Gesch 2011), state/province, and country of origin (Hijmans et al. 2018) as well as biome (Ellis et al. 2010) and ecoregion classifications (Olson et al. 2001; Dinerstein et al. 2017). The interactive map displays this information in a sidebar and as global raster layers (Figure 2). We convert the list of species names provided during submission to species specific hyperlinks that reference occurrence and distribution data on GBIF (GBIF 2020). We apply the R package 'plotbiomes' (Stefan and Levin 2020) to plot the location of the photo on a Whittaker biome diagram defined by mean annual temperature and precipitation (Whittaker 1970). We use the R package 'climatol' (Guijarro 2019) to create Walter and Leith climate diagrams of historic and recent climates for that location (Breckle 2002). Figure 2 illustrates the layout of the online map interface after selecting a photo point. The pop-up to the left of the sidebar contains a thumbnail of the user submitted photo. The sidebar on the right is comprised of three tabs that shows photo metadata (detailed above), climate diagrams, and spatial filters.

Spatial filters and comparative climate diagrams enhance the education value of the map interface by providing a means for active learning. We give users the option to filter observations by precipitation (mm/yr), temperature (°C), elevation (m), and biome at present and intend to expand these options to include all user inputs from the data entry application. These queries will be invaluable for educators seeking photos for their lectures and the general public who are curious about vegetation in their region. We also provide users the ability to compare climate diagrams based on the most recent decade of data (2010–2018) to historic averages (1961–2009) to demonstrate recent climate change at the location of each photo.

We released the beta version of the Global Vegetation Project in October 2020 and have had 2,011 unique visitors as of February 15, 2021. At present, 240 users have contributed 1,043 photos spread across 14 biomes (100% of terrestrial biomes) and 196 ecoregions (~23% of ecoregions classified in Dinerstein et al. 2017). Users have

Figure 2. Screen shot of the online map application at http://gveg.wyobiodiversity.org illustrating a photo from a tropical lowland evergreen Amazonian forest in Bolivia (photo by Gonzalo Navarro, used with permission) within the pop up feature (on the left) and the photo metadata on right (**A**). Whereas (**B**) illustrates the historic and recent climate of the area in a Walter and Leith climate diagram and its location in a Whittaker biome diagram. Note that users can turn on additional global layers, including mean annual temperature and precipitation, elevation, aridity (MAP:PET ratio), biomes, and ecoregions. For clarity, we do not display the spatial filters tab here.

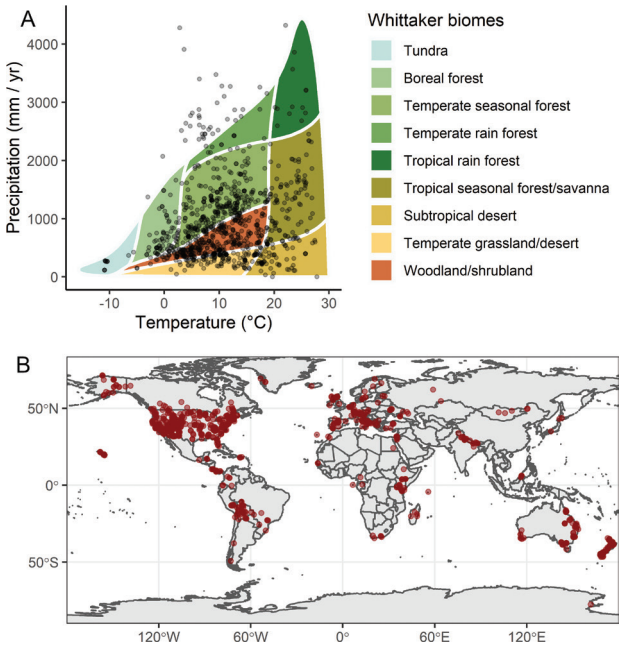

Figure 3. A Location of current photos in the database in a Whittaker biome diagram defined by mean annual temperature and mean annual precipitation. **B** Point locations of current photos.

submitted photos from 64 countries, on every continent, and across a wide range of climate conditions (Figure 3). However, like many ecological surveys, there are apparent gaps in tropical and temperate rain forests, tundra, and hot deserts, representing the extremes in climate space (Figure 3a). We hope that contributions from the global community of vegetation ecologists and community scientists will fill the map with photos (Figure 3b).

Plans for the future

Our goal is to enhance online ecology education and serve the global community of vegetation scientists. The Global Vegetation Project will evolve to match the needs of vegetation scientists and ecology educators. We have several additions in the pipeline to improve the functionality of both applications and we are in discussions with vegetation scientists to meet the needs of the research community.

We have plans to add additional global data layers to the mapping application, such of land cover, disturbance regimes, canopy height, soil properties, and other globally mapped factors that relate to vegetation distributions. We will use these layers in conjunction with preexisting features in educational modules that we will develop for primary, secondary, and post-secondary education levels. These modules will be geared toward teaching concepts such as functional convergence, vegetation-climate relationships, and climate change. We have expanded our database by integrating photos and their metadata from other scientific and open-access databases such as PhenoCam (http://phenocam.us) (Richardson et al. 2018). New features and educational support tools will be released as they are developed through the coming years.

With the help of contributions from a global community, the Global Vegetation Project aims to improve online vegetation science and education. We encourage vegetation scientists to use this resource in their classrooms and to contribute photos of vegetation to grow this valuable resource for the world.

Author contributions

J.R.F., D.H.A., S.A.W., S.E.A., N.W.C., and D.C.L. conceptualized the idea. N.W.C. and S.E.A. developed the geodatabase and web API. J.R.F. developed the R-Shiny apps with contributions from all other authors. J.R.F. and D.C.L. prepared the original draft manuscript. All authors contributed to review and editing. D.C.L. acquired all funding.

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