

# CIESIN Capabilities Statement

May 2024

The Center for International Earth Science Information Network (CIESIN) is a research unit of the Columbia Climate School at Columbia University, based at Columbia's Lamont campus in Palisades, New York. CIESIN is a world class data and analysis center focused on geospatial research and applications covering a range of subjects related to the human interactions in the environment. CIESIN has more than 45 professional staff with expertise in a range of natural, social, health, and computer science fields and extensive experience in cross-disciplinary data integration and analysis. As with other units of the Climate School, CIESIN moves beyond the traditional boundaries of academic research and education to support real-world decision making and practical applications. Here we cover CIESIN's data development and research applications (Section 1), its IT infrastructure and data management capabilities (Section 2), and its experience in education and training (Section 3).

## 1. Data Development and Applications

CIESIN's longest running and largest project is the NASA Socioeconomic Data and Applications Center (SEDAC)<sup>1</sup>, which CIESIN has operated for more than 25 years. SEDAC provides unique global and regional data products and services used widely in research, decision making, applications, and education. Data and applications are developed in five major areas: population and settlements; climate mitigation and adaptation; environmental sustainability; natural hazards; and poverty and food security. Currently SEDAC's archive comprises 292 data sets with a total volume of 14 TB. SEDAC data come from three sources: we develop our own data, we archive data generated by other projects at CIESIN, and we curate high value data from third party data developers. SEDAC's flagship data product is the Gridded Population of the World (GPW), which facilitates integration of population data with spatial environmental, hazard, health and other data. A fourth release is available to the public, and a fifth version will be released in 2024. In its management of SEDAC, CIESIN employs best practices in web design, data archiving, metadata, and data documentation (see Section 3 for details).

CIESIN has supported the international work of the Bill & Melinda Gates Foundation for three major projects. CIESIN managed a consortium of partners (UNFPA, WorldPop/Flowminder, and UCLA) for the multi-million dollar Georeferenced Infrastructure and Demographic Data for Development (GRID3) project<sup>2</sup>, which supports the production, collection, storage, and application of geospatial data for informed decision-making in African countries working hand-in-hand with governments and local stakeholders. In 2022 GRID3 spun off into an independent organization, and CIESIN continues support its geospatial work. Through the POPGRID Data Collaborative<sup>3</sup>, CIESIN is leading a consortium of partners working in the field of georeferenced population and settlement data to harmonize and validate data products and services needed by a range of scientific and applied users. CIESIN also had a major role in the Africa Soil Information Service (AfSIS)<sup>4</sup> project (2013-2019), which used innovative data and modeling approaches to capture the previously unmeasured elements of the agriculture and food system that are relevant to building resilience in a way that is cumulative and progressive.

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<sup>1</sup> <http://sedac.ciesin.columbia.edu/>

<sup>2</sup> <http://grid3.org/>

<sup>3</sup> <https://www.popgrid.org/>

<sup>4</sup> <http://africasoils.net/>

CIESIN served as the survey research and data management arm of the Millennium Villages Project<sup>5</sup> (2008-2011), and conducted field surveys for the Haiti Regeneration Initiative and the USAID-funded PREPARED and WA BiCC projects (see below). In addition to field data collection and analysis, CIESIN has conducted desk research on a wide range of topics—e.g., climate change impacts in West Africa, loss and damage from climate change, gender aspects of urbanization, land degradation, and environment and security linkages—for development agencies including USAID, UNEP, UNEP GEF, UNDP, UNFPA, World Bank GFDRR, and many others. In addition, its staff has conducted complex spatial data development tasks and spatial analyses on topics ranging from globally gridded estimation of migration and India’s urbanization to the risks of damage to infrastructure from natural hazards for a range of clients including the UK Government (Foresight Department), the World Bank, and US intelligence agencies.

Three specific thematic areas for data development and applications include climate change, sustainability indicators, and environmental security.

### *Climate Change*

A growing array of CIESIN projects directly or indirectly address issues of relevance to climate change vulnerability, adaptation and resilience – both domestically and internationally. CIESIN projects tackle challenging problems such as assessing patterns of climate vulnerability and societal responses, climate information for adaptation planning, developing integrated indicators and information systems for environmental performance and resource management, and translating research results and data into forms usable by decision makers and the general public. Spatial analysis is core to CIESIN’s project activities. Specific areas of expertise include vulnerability mapping, urban climate risks, and climate change-induced migration.

CIESIN has worked as subcontractors with Tetra Tech on a number of USAID-funded projects related to climate variability and change, including the African and Latin American Resilience to Climate Change (ARCC)<sup>6</sup> (2012-2017), Planning for Resilience in East Africa through Policy, Adaptation, Research and Economic Development (PREPARED) (2013-2018), West Africa Biodiversity and Climate Change (WA BiCC)<sup>7</sup> (2016-2021), the Climate Adaptation Support Activity (CASA) (2023-present), and the SERVIR West Africa Hub (2017-present). Under these projects CIESIN has led field-based vulnerability assessments, conducted climate analyses and vulnerability mapping, developed strategies for the use of climate data and information for adaptation planning, and developed data management approaches. Most of these activities have resulted in published reports (and two journal articles) as well as training of staff of a number of local and regional partners.

CIESIN has multiple projects related to risk, resilience, and early warning systems. CIESIN conducted risk and exposure mapping for the World Bank’s Natural Disasters Hotspots project in 2005, and more recently in collaboration with ImageCAT under contract to NASA and the World Bank. This work entails understanding and quantifying the exposure of populations and assets to various natural disasters. And through the International Committee on New Integrated Climate Change Assessment Scenarios (ICONICS), CIESIN is contributing to understand how early warning systems can take a more systemic approach to risk.

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<sup>5</sup> XXX MVP project

<sup>6</sup> <http://www.ciesin.columbia.edu/publications.html> (see Reports section for 2014)

<sup>7</sup> <http://www.ciesin.columbia.edu/wa-bicc/>

From 2017-2021, CIESIN led a consortium of research groups, including the Potsdam Institute for Climate Impact Research (PIK) and the CUNY Institute for Demographic Research (CIDR), to model the potential effects of climate change on population distribution and migration up to 2050 incorporating climate impacts. This work was in support of The World Bank flagship reports *Groundswell: Preparing for Internal Climate Migration* (2018)<sup>8</sup> and *Groundswell Part 2: Acting on Internal Climate Migration* (2021), as well as a series of reports for *Groundswell Africa*. The model was further modified in work with the Global Centre on Climate Mobility (GCCM) on the Africa Climate Mobility Initiative (funded by the Robert Bosch Foundation), which resulted in the *African Shifts* report and *Voices from the Frontline* award-winning website (2022).<sup>9</sup> Work with the GCCM has continued in 2023-2024 under the Greater Caribbean Climate Mobility Initiative (funded by UNOPS), resulting in a comprehensive literature review and new model based on a Computable General Equilibrium (CGE) approach developed by the Luxembourg Institute for Socioeconomic Research (LISER).

CIESIN also has a number of projects at the state and local level in New York. With funding from the New York State Energy Research & Development Authority (NYSERDA), CIESIN assessed the scale of potential flooding in New York State under different sea level rise and storm scenarios via a building-level flood impact assessment using a flood damage model. This follows on prior work to develop a flood assessment mapping tool for the lower Hudson Valley region.<sup>10</sup> CIESIN worked with the Nature Conservancy to implement a physical habitat model of the Hudson River floor and conduct a comprehensive ecological assessment to characterize the habitat units. CIESIN has also collaborated with Brooklyn College and partners of the Science and Resilience Institute at Jamaica Bay to develop an integrated data management system to assess spatial and temporal patterns of water quality in Jamaica Bay. A sub-contract from the Stevens Institute of Technology (SIT) on a grant funded by the National Oceanic and Atmospheric Administration supported development for a flood, sea level rise, and adaptation mapping tool for Jamaica Bay, New York, called AdaptMap.<sup>11</sup>

### *Sustainability Indicators*

Since the early 2000s CIESIN has collaborated with the Yale Center for Environmental Law and Policy on a two global, country-level comparative indices, the Environmental Sustainability Index (ESI) and the Environmental Performance Index (EPI).<sup>12</sup> The biennial EPI evaluates approximately 180 countries in areas related to environmental health, ecosystem vitality, and climate mitigation using an innovative array of indicators. The EPI has had an important demonstration effect, being emulated by a number of global index efforts, and a number of indicators have been adopted for use by the US Agency for International Development and the UN Sustainable Development Goals (SDGs).

In addition, CIESIN led a NASA Research Opportunities in Space and Earth Science (ROSES) grant from 2010-2012 that focused on the use of satellite remote sensing in environmental indicator development, and has continued that work under the auspices of the NASA SEDAC.<sup>13</sup> CIESIN's reputation in indicator development led to projects with the Global Environmental Facility (GEF) to develop indicators related to

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<sup>8</sup> <https://openknowledge.worldbank.org/handle/10986/29461>; <https://doi.org/10.7927/c5kq-fb78> for the data.

<sup>9</sup> <https://africa.climatemobility.org/>

<sup>10</sup> <http://www.ciesin.columbia.edu/hudson-river-flood-map/>

<sup>11</sup> <http://adaptmap.info/>

<sup>12</sup> <http://epi.yale.edu>

<sup>13</sup> <https://sedac.ciesin.columbia.edu/data/collection/sdei>

land degradation (the KM:Land project from 2007-2008) and transboundary waters (the Transboundary Waters Assessment Project from 2014-2016).

### *Environment & Security*

CIESIN's experience in environmental security research dates back to the 1990s, starting with the early incarnations of the State Failure Task Force. Through the Skoll Global Threats initiative (2010-2011), CIESIN reviewed climate and security assessments developed in 2008 by the National Intelligence Council to explain why they failed to predict the climate and security crises. In two projects with ISciences LLC, CIESIN contributed to assessments of environmental security outcomes in the Sahel and a review of land degradation mapping approaches for the Scitor project (2012-2013), and CIESIN helped to develop an analytical data platform to support environmental security research for the Data Analytics and Tools for Ecoscurity (DANTE) project (2019-2022), funded by the US Army Corps of Engineers. In 2022 CIESIN started work on a three year comparative research project on the drivers of south-north migration in Central America and West Africa<sup>14</sup> funded by DOD Minerva, in collaboration with scientists at Oregon State.

## **2. IT Infrastructure and Data Management**

CIESIN maintains a state-of-the-art computing infrastructure, drawing on both project and internal resources to refresh hardware regularly; assess, test, and implement new software solutions, both open-source and commercial; and provide staff training to ensure efficient and reliable development, operations, and support services. Its core computing infrastructure consists of a suite of web, application, mapping, and database servers. CIESIN has over 100 terabytes of on-line storage and an offsite backup facility. It operates a secure computing environment with a firewall and standard anti-virus packages. Staff have access to a range of geospatial processing (ArcGIS, QGIS) and statistical software packages (Python, SPSS, R, STATA). CIESIN also has access to a high performance computing cluster at Columbia University.

An experienced team of geospatial data analysts and software engineers develops custom tools and resources, taking advantage of open standards when available, and supports innovative research and applications in response to user needs. CIESIN is a pioneer in web mapping that is compliant with Open Geospatial Consortium (OGC) standards, and runs several web mapping tools, including the POPGRID Viewer,<sup>15</sup> The Natural Hazards Mapper,<sup>16</sup> the Population Estimation Service,<sup>17</sup> and the SEDAC four-panel viewer.<sup>18</sup>

CIESIN staff members are experts in the total life cycle of data management. CIESIN is a University member of the Open Geospatial Consortium (OGC) and the Council of Data Facilities (CDF). CIESIN staff members are active in many different data-oriented organizations such as CoreTrustSeal, the Group on Earth Observations (GEO), the IPCC Task Group on Data Support for Climate Impact Assessments (TG-DATA), the International Science Council's World Data System and Committee on Data (CODATA), the Research Data Alliance, and the United Nations Group of Experts on Global Geospatial Information Management (UN-GGIM). CIESIN maintains the University's site license for geospatial software from Esri, and has long-

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<sup>14</sup> <https://maps.ceoas.oregonstate.edu/habitability/migration/>

<sup>15</sup> <https://sedac.ciesin.columbia.edu/mapping/popgrid/>

<sup>16</sup> <https://sedac.ciesin.columbia.edu/mapping/hazards/>

<sup>17</sup> <https://sedac.ciesin.columbia.edu/mapping/popest/pes-v3/>

<sup>18</sup> <https://sedac.ciesin.columbia.edu/mapping/viewer/>

standing partnerships with other private sector organizations including Google, ImageCat, ISciences, and StormCenter Communications.

CIESIN has built upon project activities and relationships to develop a versatile, robust, and secure IT infrastructure that supports both internal staff and project needs and more than 100,000 external users on an ongoing basis. This infrastructure meets the high security standards imposed by NASA and the University, and supports the stringent requirements for a trustworthy digital repository established by CoreTrustSeal. CIESIN has capabilities to manage both large volume data, e.g., produced by satellite missions or social media, and smaller, more complex data types, including human subjects data and information, across the full data lifecycle. CIESIN has also developed innovative data access, visualization, and analysis tools, including both web interfaces and mobile apps, and supports a range of open standards for data access and interoperability.

Our ongoing and planned infrastructure investments will contribute to the continued development of state of the art computing infrastructure and information systems development activities in the following major areas: Virtualization and Cloud Computing; Cyber Security; Geospatial and Big Data Processing; and Data Systems and Applications Development.

#### *Virtualization and Cloud Computing*

CIESIN has been working with virtualization technologies for more than ten years. Our current computing infrastructure is completely virtualized, including our server and virtual desktop infrastructure (VDI). We can provision server and workstation resources with enhanced graphic processing unit (GPU) capabilities within minutes for project needs and manage them centrally. This helped CIESIN to maintain uninterrupted access to all of its computing resources for all staff working remotely during the COVID pandemic and even during power outages to CIESIN's offices at the Lamont Campus. To achieve this, we deployed a variety of VMware technologies and built up significant knowledge and expertise.

Similarly, CIESIN works with cloud technologies, mainly Amazon Web Services (AWS), to implement components of its infrastructure and system components in the commercial cloud. This includes back up archiving of SEDAC's data archive, the development of a cloud-based disaster recovery site, and development of a cloud-based ArcGIS enterprise system for geospatial web services.

#### *Cyber Security*

Cyber security is critical for protecting computing assets and data. Proactively mitigating vulnerabilities and reducing risks are a requirement, not an option. CIESIN's NASA-funded SEDAC project has to comply with NASA and National Institute of Standards and Technology (NIST) standards for IT security. To be compliant, CIESIN has developed a comprehensive IT security plans, policies, and procedures and implemented them utilizing state-of-the-art security technologies including a comprehensive gateway firewall with capabilities to mitigate a multitude of vulnerabilities and attacks, a cloud-based security and event management solution based on monitoring the firewall traffic, and centrally managed endpoint security for workstations. CIESIN has received excellent scores on NASA security audits. We also developed a secure system for handling protected human subjects research data, which was reviewed and approved by Columbia University IT (CUIT). Through these activities, CIESIN has gained significant expertise in implementing cyber security at various levels, from physical controls to network to servers to workstations, using current security technologies and tools.

### *Geospatial Big Data Processing*

Geospatial data and data science methods are playing increasingly vital roles in scientific data development and applications, especially in interdisciplinary research efforts that require data integration across the natural, social, health, and engineering sciences. CIESIN has longstanding experience with geospatial data processing and geospatial web services, including management of the campus-wide site license for the suite of Esri ArcGIS software and support for the Remote Sensing and Visualization (RSV) lab. CIESIN has developed a virtual GIS lab for CU courses by provisioning VMs for CU students.

CIESIN has a set of high-end data processing servers with GPU capabilities that support commercial (Esri ArcGIS Pro and ENVI) and open source (R, Python, QGIS and GRASS) software. These servers enable integrated analysis of big data including data streams from mobile devices and social media like Twitter using the latest data science techniques and machine learning. SEDAC is establishing a GitHub instance where code will be published (currently it is password protected). We are also implementing an ArcGIS Enterprise platform for publishing geospatial web and data services in collaboration with other NASA data centers.

### *Data Systems and Applications Development*

CIESIN's mission is not just to support scientific research and science users, but also to address practical decision making and societal benefits. However, decision makers and other users have requirements for data systems and applications that extend beyond what scientists typically provide, for example, with respect to clarity and simplicity, reliability and continuity (both short and long term), traceability and accountability, security, and support for users. Users need to have trust not only in the scientific quality of data, but also in their ability to access and use the data and applications in their own decision making processes and decision support systems.

CIESIN was a pioneer in developing and providing access to interactive data and mapping tools via the Internet. We continue to implement innovative approaches to data creation, access, visualization, and analysis across distributed data systems and diverse application areas. This includes producing user-focused decision-support tools and information resources, and developing interdisciplinary data and information resources to address challenging problems such as climate change, disaster risk management, and global-scale pandemics.

CIESIN has long experience in the full stack systems and applications design and development including database design and management (Oracle, MySQL, Postgres/PostGIS), application servers (Tomcat), content management systems (Drupal), web and mapping applications development, and mobile applications (iOS and Android) development. Our developers are proficient in C/C++, Java, PHP, Python, R, ReactJS, AngularJS, and Objective C. This has enabled CIESIN to develop many innovative online applications in support of SEDAC and other projects. In addition, CIESIN has extensive experience in testing, sustaining, operating, monitoring, upgrading, and retiring applications and services in the long run, taking into account rapidly evolving technologies and platforms, threats and vulnerabilities, user needs and expectations, and legal and regulatory environments. CIESIN has also worked closely with external partners to develop and reliably maintain open, interoperable data services that the partners incorporate into their own decision support systems and interfaces. Users are likely to increasingly expect seamless interoperability and integration across different user platforms and cloud environments.

Rapid advances in Internet technology have enabled the increased use of data over the Internet, a need has arisen in the scientific community for more sophisticated technologies for exploring data and visualizing it online through the creation of more complex, customized maps and graphs. CIESIN addresses this need by publishing most of our data via a suite of online mapping services—Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS)—enabling users to integrate, visualize, and analyze SEDAC data layers along with data layers from similar online services. The WMS, WFS, and WCS are Open Geospatial Consortium (OGC) standards that enable a simple HTTP interface for requesting geo-referenced map images and data over the Internet from one or more distributed geospatial data sources. CIESIN also exposes online data and analysis services via RESTful Application Programming Interfaces (APIs). These services all correspond to the diverse data collections and data sets disseminated via our Web site, thus enabling more comprehensive exploration and customization of an extensive collection of data. Map Services via SEDAC allow users to accomplish a wide variety of functions, ranging from simple visualizations to advanced analysis.<sup>19</sup>

### **3. Education, Capacity Building and Training**

CIESIN staff teach in academic programs of the School of Arts and Sciences, The Climate School, the School for Professional Studies (SPS), the School of Engineering, and the School for International and Public Affairs (SIPA). Most of the curricula were developed by CIESIN staff, and courses developed by CIESIN staff often have waiting lists. CIESIN also provides training and technical support services around the world. CIESIN has conducted technical training sessions in data management, development and analysis under the ARCC, PREPARED, SERVIR and GRID3 projects and has helped to lead multiple NASA Advanced Remote Sensing of the Environment Trainings (ARSET). This includes week-long bespoke training programs requested by specific clients. Under the NASA Transition to Open Science (TOPS) program CIESIN is developing educational modules in open science approaches to human-environment research questions as part of its Science Core Heuristics for Open Science Outcomes in Learning (SCHOOL) project. SCHOOL is also working with the CODATA and RDA's Data Science Institutes to develop a training program in Open Source tools for early career environmental justice researchers in 2025.

CIESIN has contributed to bilingual education in Colombia through the NASA Human Planet project, and is active in the K-12 educational sphere, including participation in Earth Institute Live (EI Live)<sup>20</sup>, an online series for K–12 students and educators. Coordinated by the Education and Outreach Office of the Lamont Doherty Earth Observatory (LDEO), live video lessons were led by experts in a broad variety of scientific disciplines across the EI. CIESIN has also contributed to training programs led by the Climate School's International Research Institute for Climate and Society.

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<sup>19</sup> <https://sedac.ciesin.columbia.edu/maps/services>

<sup>20</sup> <https://www.ldeo.columbia.edu/news-events/earth-institute-goes-live-video-series-k12-students-and-educators>