ENVIRONMENTAL AND CLIMATE STRESS INDEX

Application for Group Earth Observation—Google Earth Engine

UN environment programme

THE UNIVERSITY of EDINBURGH

EARTH BLOX

EXECUTIVE SUMMARY

THE PROBLEM THAT THE PROJECT ADDRESSES

The global climate is changing rapidly, undermining the security of current and future generations. Climate change and biodiversity collapse mean that the world is facing a double crisis. There is an urgent need to scale up response efforts worldwide. In September 2019, the UN Secretary-General described the climate emergency as the "fight of our lives, and for our lives" and called upon the entire UN system to "ramp up actions and ambition." Indeed, we are already witnessing a world where global climate change and its associated economic and geopolitical transition processes are shaking up societies, generating winners and losers, amplifying inequities and undermining social cohesion.

Climate change increases the importance of sound governance of the environment and natural resources, in both stable and insecure contexts. When natural resources are poorly managed or inequitably shared, resource competition can escalate into tensions, or exacerbate pre-existing conflict dynamics. Population growth and environmental degradation are intensifying competition over scarce resources, such as land and water. Climate change will further increase such competition. Natural resources are likely to become key drivers in a growing number of disputes, with significant consequences for international, regional, and national peace and security.

The United Nations system needs a rapid and accurate way to determine where environmental and climate stresses are converging and contributing to increased risk of maladaptation, fragility, migration, and conflict. Advanced geospatial analytics of Earth Observation data and other thematic data at the global and national level are needed over time and space to help identify and prioritize hotspots as well as programme risk reduction and resilience-building interventions.

HOW THE PROJECT ADDRESSES THE NEED TO IDENTIFY ENVIRONMENTAL AND CLIMATE STRESSES

The project will co-design an environment and climate stress index with end-users using a combination of global public earth observation data, thematic geospatial data and cloud computing. The main goals of such an index are to help end users easily and rapidly understand:

1. where the convergence of environmental stressors is occuring around the planet;
2. how and why the intensity of these "hotspots" is changing over time/space;
3. where these hotspots could interact with other social and economic variables to increase the risk of fragility, social conflict, migration or maladaptation.

The index will allow end users to generate standard and customized analytical products that can be used as an input to conflict and fragility analysis systems as well as multi-hazard risk assessments and early warning platforms. It will use an innovative user-friendly interface (Earth Blox) that allows greater customisation by the user, empowering public sector stakeholders, decision makers and the public to more effectively address environmentally driven challenges and to improve understanding of the natural forces that impact on vulnerable livelihoods.

THE ANTICIPATED IMPACTS

The outputs of the index will be used by over 130 UN country teams in the field to integrate environment and climate stressors into horizon scanning and early warning mechanisms, as well as conflict prevention, risk reduction and resilience-building measures. Ultimately, it will help identify and prioritize areas of interest (hotspots) within ecosystems under threat, and resource-dependent livelihoods that require improved management and restoration in order to reduce risks. The index will feed directly into the UN Common Country Analysis (CCA) processes as well as UN Development Cooperation Frameworks as part of the on-going UN Reform process. It will also be used as an input to the World Bank fragility analysis, the EU Global Conflict Risk Index, and the UN Climate Security Mechanism.

CONTRIBUTION TO GLOBAL GOALS AND GEO

The project concretely contributes to the following global goals and targets:

a) UN Sustainable Development Goals and Targets:

- Goal 1. End poverty in all its forms everywhere. Target 1.5.
- Goal 11. Make cities and human settlements inclusive, safe, and sustainable. Target 11.5.
- Goal 13. Take urgent action to combat climate change and its impacts. Target 13.1, 13.2.
- Goal 15. Promote sustainable use of terrestrial ecosystems. Target 15.1, 15.3.
- Goal 16. Peace, Justice, and Strong Institutions. Target 16.10.

b) Sendai Framework for Disaster Risk Reduction Targets:

- Global Target G: Multi-hazard early warning systems and disaster risk information and assessments. Target G5.

c) Paris Agreement Priority Actions:

- Priority 1. Comprehensive risk assessment and management (in particular in the areas of food production poverty and inequality, deforestation and forest degradation, scarcity of the natural resources).
- Priority 2. Resilience of communities, livelihoods and ecosystems.
- Priority 3. Early warning systems, emergency preparedness.

d) GEO Work Plan 2020-2022 in four ways:

- Human Planet Initiative (HUMAN-PLANET)
- Initiative on Land Degradation Neutrality (GEO LDN)
- Data Access for Risk Management (GEO-DARMA)
- Data Analysis and Integration System (DIAS)

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PROJECT PLAN

1. Introduction

This proposal lays out the rationale and key components for the development of an environmental and climate stress index. The main goals of such an index are to integrate and analyze multiple sources of earth observation and other thematic geospatial data to understand: a) where the convergence of multiple environmental stressors is occurring around the planet; b) how and why the intensity of these "hotspots" is changing over time/space; c) where these hotspots could interact with other social and economic variables to increase the risk of fragility, social conflict, migration or maladaptation.

The outputs and derived analysis of the environment and climate stress index would be fed into global processes and frameworks linked to integrated risk analysis, fragility and resilience assessments, as well as early warning and forecasting systems. By integrating environment and climate stress factors within these broader frameworks, more accurate policies and programmes can be developed for conflict prevention, risk reduction and improved resilience. The project is transdisciplinary in nature by directly bringing together the fields of earth observation, data science and cloud computing; environment, climate change and disaster risk reduction. Moreover, the index itself will inform subsequent analysis and programming conducted by experts in the fields of migration, fragility, peace and security. As the leading global environmental authority, the UN Environment Programme (UNEP) is leading this project given that it is mandated to support states in the implementation of their national environmental policies, collaborating closely with other relevant entities of the United Nations system. UNEP has a particular responsibility to support states in which environmental management is weak, and where climate and environment-related security risks are high.

The 2020-21 Programme of Work commits UNEP to focus on "*integrating best practice environmental approaches into the key risk reduction, response and recovery policies and* frameworks of countries and the international community," with particular attention focused on "understanding and identifying **emerging environmental threats to security, and to supporting partners in the United Nations system who are working to address those threats at both the political and programmatic level**." The Programme of Work highlights "the links between ecosystem approaches to disaster risk reduction and ecosystem-based adaptation and the emerging issue of climate security."

In 2019, the UN Environment Assembly also requested UNEP to develop and prioritize a long-term environmental data strategy by 2025 to enable regular regional and global analysis of the state of and trends in environmental parameters, including geospatial data and statistics aligned to the SDG indicators. This includes the development of a World Environment Situation Room to monitor key environmental and climate risks at a global level as a digital public good. The data strategy should improve the coordination of efforts with the Group on Earth Observations to fully utilize Earth observations as well as with the citizen science community to fill potential data gaps. It should also enable more robust environmental analysis to UN Resident Coordinator offices, as well as to UN Common Country Analyses and UN Development Cooperation Frameworks.

Based on the above, the environment and climate stress index is being built by UNEP's Crisis Management Branch within the Climate Change and Security project. This project aims to address global and trans-regional effects of climate change that may have a potentially destabilizing impact on fragile communities, regions, and states. The project is currently being funded by the EU and the Governments of Norway, Sweden and Finland. The index is being developed in cooperation with the University of Edinburgh, Quosient (EarthBlox), and UNEP's World Environmental Situation Room (see Annex 1).

2. OBJECTIVES, APPLICATIONS AND EXPECTED IMPACT

2.1 Main objective and impact statements

The **objective** of the project is to help decision-makers in the UN system and in vulnerable countries take data-driven measures to reduce risks and build resilience to stresses caused by environmental degradation and climate change that could trigger migration, social conflict, and maladaptation. Ultimately, the project **impact** focuses on preventing fragility, violent conflict and disasters by early identification of converging environmental and climate risks combined with better risk reduction and resilience programming. This will be achieved by state-of-the-art geospatial analysis of earth observation data and other thematic variables into a combined global index that tracks changes in environment and climate stresses over space and time. This index is being designed to achieve three major outcomes as outlined in the following sections.

2.2 Outcome A: Increased use of Earth Observation data and cloud computing in risk assessment and decision-making

Risk assessment and decision-making based on the index will ensure use of the latest earth observation data, gathered, processed and presented transparently through open-source cloud computing. This will be tracked through a number of output indicators including statistics on the share of earth observation data among the climate and environmental stress data layers, their spatial resolution, spatial cover (% of missing data), temporal resolution, temporal cover (% of missing data), and duration since the last releases and updates of the underlying data layers. Transparency is ensured by publishing methods, the index' code, and data used in the construction of the index; using open-access geospatial, environmental datasets, and open source statistical and geospatial software; and lastly, by regularly reporting results and manuals for the index.

- **Outcome indicator A1** assesses the value of earth observation data within the index as a key input to risk assessments by evaluating the identified - and missed - risks compared to: a) other risk assessment tools on the relevant scale that do not, or to a lesser, extent rely on earth observation data; b) On the ground risk information from country offices and interviews with local organisations.
- **Outcome indicator A2** assesses the value of earth observation data within the index as a key input to decision making based on user surveys, and key user interviews.

2.3 Outcome B: Enhanced early warning and predictive analytics

The index will contribute critical insights to enhance existing early warning systems as well as offer key inputs to predictive analytics. The target end-users to reach include state agencies, international organisations (governmental and non-governmental), and academic researchers working on early warning and prediction of adverse socio-economic impacts. A number of output indicators demonstrating the uptake of the index are the number of visitors to the web-platform, number of data downloads, number and types of queries with the web platform, number of use cases in programme and policy reports, number of academic citations of the index that used the index for analytics and predictions, and the number of media and journalist outputs using the index.

- **Outcome indicator B1** will be the change in predictive performance of early warning systems of the targeted tools by incorporating the index.
- **Outcome indicator B2** will be feasibility outcomes of the index' own predictive analytics for adverse societal impacts, such as maladaptation, migration and social conflict.

2.4 Outcome C: Improved programming for risk reduction and resilience

New analytical perspectives provided by the index will improve policy-making and programmatic responses to address the livelihood conditions of people affected by environmental and climate stresses. Targeted end-users include state agencies, environmental and humanitarian aid organisations, and funding bodies for development and aid projects, working on subnational to global scales. A number of output indicators demonstrating the uptake of the index for programming towards risk reduction and resilience include how many of the identified target end-users have used the index for programming tasks, the number of policy reports that uses the index, and the amount of questions the index developers receive on how to use the index and web platform. The satisfaction and usefulness of the tool towards programming priorities and policy development will be qualitatively monitored on the long-term for continuous feedback and improvements, e.g. through surveys and yearly workshops.

- **Outcome indicator C1** will be the amount and intensity of program implementation dedicated to risk reduction and resilience building following the application of the index, measured by the amount of funds dedicated to risk reduction and resilience building through key-user surveys and reporting of risk reduction and resilience building projects.
- **Outcome indicator C2** will be the agreement in spatial allocation of such programming and funds with identified stress and fragility hotspots.
- **Outcome indicator C3** will be the effectiveness of known implemented programmes following the application of the index, which can be monitored with the index itself.

2.5 Contribution to international agreements and GEO workplan

The project will contribute to the following international agreements and to the GEO workplan:

a) UN Sustainable Development Goals and Targets	
Goal 1	End poverty in all its forms everywhere.
Target 1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable.
Target 11.5	By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.
Goal 13	Take urgent action to combat climate change and its impacts.
Target 13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
Target 15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions.
Target 16.10	Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements.
b) Sendai Framework for Disaster Risk Reduction Targets	
Global Target G	Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.
G-5	Number of countries that have accessible, understandable, usable and relevant disaster risk information & assessment available to the people at the national & local levels.
c) Paris Agreement Priority Actions	
Priority 1	Comprehensive risk assessment and management
Priority 2	Resilience of communities, livelihoods and ecosystems.
Priority 3	Early warning systems, emergency preparedness.
d) GEO Work Plan 2020-2022 in four ways	
	Human Planet Initiative (HUMAN-PLANET)
	Initiative on Land Degradation Neutrality (GEO LDN)
	Data Access for Risk Management (GEO-DARMA)
	Data Analysis and Integration System (DIAS)

The project also aims to support the GEO Work Programme by proposing a new GEO Community Activity to bridge a current gap in the services of the Group. Our initiative will provide a unique entry point to the observation of livelihoods and their interdependency with environmental and climate factors which drive their social dynamics.

2.6 Differentiation from other indexes

The environmental and climate stress index differentiates from existing similar indexes in two main ways. First, it is spatially and temporally distributed, aiming to employ the best disaggregated data possible to move beyond standard country-year setting and obtain much more detailed geospatial insights. Secondly, the index innovates by introducing a sustainable livelihoods dimension to understand how environmental degradation and climate change could impact populations in terms of maladaptation, migration, and conflict.
The environmental and climate stress index should address three of the key weaknesses and limitations of other well-known environmental indexes including the Environmental Performance Index (EPI), the Environmental Vulnerability Index (EVI), and the resilience index against food security shocks by FAO.

First, the unit of analysis of these existing products is almost always country-year. Typically, due to ease of data gathering, analysis, and visualisation. Yet, environmental problems are not confined by political borders and range over all spatial scales from very local to global. Hence, country-year is not the most relevant unit of analysis for understanding the convergence of environmental and climate stresses. Clearly, a higher resolution spatial and temporal unit is needed.

Second, existing environmental indexes provide only several snapshots through time. Typically, they are relevant at the moment of their creation and possibly a number of ad-hoc updates in subsequent years. Cross-sectional time-series are uncommon, but essential to support the analysis of trends over time and of relationships with other concepts.

Lastly, most environmental indexes have not tested their relation/relevance to societal fragility or security outcomes. Rather, they are driven by data availability than outcome and purpose. In contrast, the environmental and climate stress index is intended to inform different applications linked to migration, conflict and fragility risk assessment together with measures for risk reduction and resilience building.

3. END-USERS, USER-CENTERED DESIGN AND PILOTS

The environment and climate stress index will support risk analysis and decision-making by a range of different end users. The following sections outline the expressions of interest that have been received from specific end users as well explore other potential users. It also describes the user-centered design approach that will be adopted and the initial pilots.

3.1 Expressions of interest

The following end-users have already been consulted and have expressed substantive interest in using the derived analysis of the environment and climate stress index:

- **Global Conflict Risk Index (GCRI)** managed by the EU Joint Research Center. The index would address the need for a consistent and robust approach for measuring environment and climate stresses within a planned spatialized version of the GCRI.
- **Common Country Assessment (CCA)** process used by all UN country teams (130+). The index would help integrate the convergence of environment and climate stresses into the overarching risk analysis and to inform the design of response programmes. Pilots will include Colombia and Haiti.
- **UN Climate Security Mechanism** jointly managed by UNEP, UNDP and UN DPPA**.** The index would help assess global and regional trends in terms of accumulating environmental and climate stresses as the basis for horizon scanning and early warning.
- **EU-UNEP Climate Change and Security Project:** The Index will help map the convergence of environment and climate change stresses as an input to integrated risk assessment and resilience programming. Pilots will include Sudan and Nepal.
- **Fragility analysis method of the World Bank**: The index would offer a stream of analytics on the environment and climate drivers of fragility and priorities for resilience building. The first pilot will include the Sahel region.
- **World Environment Situation Room:** The index would address the need for an environment and climate security monitoring platform and be used as an input for GEO7.
- **Global Environment Facility (GCF) and Green Climate Fund (GCF):** The index can be used as an evidence-based tool by GEF and the GCF to help map global environmental and climate stress dynamics as the basis for programme prioritization and trend monitoring.

3.2 Other potential end users

In addition to the end users that have already expressed interest, other potential end-users will also be considered. They include:

- **Other analysts, academics, humanitarian actors and peace and security actors –** who can use the index as an input to a larger index or analyses (e.g. Internal displacement monitoring center, OECD multi-dimensional fragility index).
- **Local communities:** As an open product, the index offers local communities the possibility to track changes in environment and climate stresses in order to help prioritize local resource management and restoration efforts. The index offers an

entry-point to build the capacity of local communities worldwide to conduct their analyses and interpret the results to strengthen local practices in climate change adaptation and mitigation, sustainable natural resources management, and developing sustainable livelihoods.

- **Private sector:** The environmental and climate stress index's datasets and derivatives could be used as a business tool to assess potential risks from environment and climate stress to their supply chains, operations, and customers. The index could be aligned with SDG Compass's Inventory of Business Indicators to support private firms to push forward sustainable development practices.

3.3 User-centered design and pilots

The environmental and climate stress index will adopt a user-centered design (UCD) approach. UCD involves end-users throughout the design process via a variety of research and design techniques, to create highly usable and accessible digital products, tailored to the end-users needs and task context.

The project will therefore engage the identified end-users (section 3.1) and a selection of potential users (section 3.2) throughout each of the development stages - from the design of the methodology to the platform prototype to the web interface. To ensure the index suits a wide array of use-cases and end-user requirements, user experiences and needs will be captured by a mix of investigative methods and tools (e.g. surveys, interviews, focus-groups, scenario-based elicitation) and generative ones (e.g. focus-groups, user and expert presentations, panel discussions, brainstorming, world cafe method). Such a co-design process will ensure that the suite of final products are fit for purpose to each specific end-user group, and that the end-user group feels a sense of mutual ownership. Within the user-centered design process, the project will seek to map specific user needs at four main scales and within specific, but diverse, set of pilot countries and regions: local, national, regional and global.

The adoption of Earth Blox as the core analysis and visualization platform should enable the stress index to be customized to meet different users' needs through a combination of distinct dashboards and API feeds. Users will also be able to further customize the analysis using the Earth Blox interface. With Earth Blox, users will either make use of predefined workflows that allow easy visualization of the stress index, or design their own modifications based on local conditions or with the inclusion of their own data, or inclusion of Earth observation data sets already available on GEE. The drag-and-drop style interface of Earth Blox ensures that users without coding skills will still be able to fully engage, interrogate and customise the analysis conducted on the platform. To enable full customisation by users we will also develop functionality to upload, download, and store a user's own data. This includes building-in output formats that enable statistical analysis, data download for offline use, and non-standard outputs. This includes constructing capacity for building customised user dashboards.

4. PROJECT APPROACH

4.1 Transdisciplinary approach

The environmental and climate stress index project is characterised by its trans- and interdisciplinary nature. At its current stage, it has already brought together experts and end-users from the fields of earth observation, data science, cloud computing, environmental sciences (including climate change, and disaster risk reduction), and politics (including fragility, peace, and security).

4.2 Features of the index visualization and dashboard

The **visualization** of the index will be shown as a global heatmap, where the convergence of different environment and climate stresses can be easily spotted and monitored. Each pixel will offer a value obtained from the combination of several environmental and climate variables that contribute to the stress in that specific area.

We believe that democratizing the digitalization of our environment is a crucial element to provide capacity of monitoring, evaluation, and analysis to everyone - public and private sectors at every level. The visualization of the index will be produced using EarthBlox. With its unique easy-to-use interface, EarthBlox simplifies access to terabytes of global satellite data. Its technology removes the barriers that hinders data exploitation, in terms of complexity, cost and skill levels required to process satellite and planetary data. Hence, its innovation lies in the complete removal of coding skills, making space data accessible, which is an essential element needed to develop the index.

The index will be accessed through an **web-based interactive dashboard** which will serve to mainstream the monitoring of a wide array of environmental and climate variables allowing non-technical users to quickly evaluate the situation of any given region, a task typically in the hands of environmental and climate experts. A heatmap of the index will be embedded in a web-based dashboard that will support the understanding and interpretation of how livelihood vulnerability is linked to environmental, climate, and other social factors. Therefore, the index will allow the analysis of human resilience to environmental and climate shocks and stresses which, consequently, will assist in the design of evidence-based policies and programmes on risk reduction and resilience building.

The **navigation** of the online tool will be fully interactive, and it will allow data download of the raw and derived environmental and climate variables. The index will also be accessible through an API for advanced users that prefer to use third-party tools such as mapping software QGIS, coding languages Python and R, and statistics packages (STATA). It will also be a flagship application on UNEP's World Environment Situation Room.

4.3 Backend technical requirements, data, and licensing

A) Data Load

Initially, the project will load a set of 87 global public data sets, around 1 TB of data, in seven categories: socio-economic context (17); water (21); land degradation (12); extractives (3); natural hazards (11); climate–historical (8) and climate-projections (15). In total, this represents 25 vector data sets (points, lines and polygons with attributes) and 61 raster data sets (pixels with values). The second set of data sets at the national and sub-national level will be identified and included for each of the pilot countries (Colombia, Haiti, Nepal and Afghanistan), accounting for 1 TB of additional data per country.

During the two-year period of development employing the GEE-GEO license, a more significant number of data sets will be added to the initial collection, as it is expected that novel, original data sets relevant to the index will emerge, and existing datasets will be updated covering more extensive periods of time at higher resolutions. Consequently, up to 5 TB of data is expected to be loaded and used during the development of the project.

From the earth observation data already held in the GEE catalogue, the project would focus on the analysis of Landsat and Sentinel imagery and related secondary data products. It may also attempt to exploit higher resolution imagery provided through a bi-lateral partnership with Planet Labs.

B) Data Licensing

Aligning the project with GEOSS Data Sharing Principles 2016-2025, the index will be shared as open data free of charge and without limitations on use and reuse. Distribution, display, perform, modification and reutilisation of the index will be permitted subjected to attribution. Distribution of modified derivatives of the index shall be subjected to the same licensing terms.

Data obtained from governments and the public sector processed in the index will, ideally, be open for use and reuse. In the case of using data obtained from private-held sources, it will be requested for permission, and for it to be open, at least to the relevant subset employed in the index. User-uploaded data will be licensed as open. Moreover, every employed and shared data set will be coupled with metadata detailing source, methodology, periodicity, contacts, time span, and other attributes.

The above considerations aim to recognize each data contribution to the index, in order to incentivize more contributions and the liberation of spatial data from private-held sources. To ensure that the project complies with all data licenses, and to be accountable and responsive to these, a focal point will be established.

4.4 Tools and software

All analyses will be performed within open access statistical tools to promote transparency and give the possibility to engage many users. The final aim is to visualize and distribute the environmental stress variable within the World Environmental Situation Room (WESR) through the open access geospatial web-platform MapX (Lacroix et al. 2019; UNEP and GRID GENEVA 2019) as well as a standalone website using Earth Blox. GEE will host the back-end platform for the environmental stress index. The novel addition to the front-end will be the use of Earth Blox, a new interface from Quosient that allows the construction of workflows using visual drag-and-drop tools. The reason for incorporating an Earth Blox front-end is because Earth Blox democratises the power of satellite data and intelligence, by leveraging the power of cloud processing without the need for computer coding or high-level Earth-observation expertise. It enables the processing of terabytes of planetary scale geospatial data and the creation and download of actionable insights with unprecedented power and ease. Currently, for most Earth Observation users, a typical supply chain involves a convoluted process of finding and acquiring data from diverse suppliers which then requires further processing and application development using expensive proprietary software or open applications requiring know-how. Earth Blox streamlines this process, by converting months of learning into a 5 minutes solution.

Earth Blox already has functionality for API links to GEE and other data repositories, but there are some custom-built functions for the stress index that need to be executed on the server. An element of code-optimisation for better automation and statistics gathering will also be carried out. Identifying and executing the stress indicators into data analysis elements of Earth Blox to allow metric extraction, exporting of GeoTIFFs, and interaction with other data layers hosted on the server, is also a task that needs completed. The front-end functionality will be developed using Vue.js and Firebase Hosting. As with any website, a top priority is ensuring that it contains high level security features and ensures full GDPR compliance. This will include implementing data privacy impact assessment, data privacy policy and OWASP Application Security Verification Assessment.

5. WORK PACKAGES AND OUTPUTS

5.1 Work Package 1: Project management (UNEP)

The implementation of this project will be coordinated and led by UNEP's Crisis Management Branch (CMB) within the approved Climate Change and Security Project (co-funded by EU, Finland, Norway and Sweden). The project team will be offered in-kind by UNEP. It will consist of: a) project Manager (25% FTE CMB, Geneva), responsible for directing and supervising the project's execution and team management. This also includes liaison with donors, evaluation and quality assurance of project outputs, provision of substantive technical inputs and budget coordination; b) junior climate change and security analyst (25% FTE CMB, Geneva): provide strategic advice, technical guidance and inputs on environment and climate security risk analysis methodology and potential applications; c) Data scientist (50% FTE CMB, Stockholm): to daily coordinate the development of the environmental stress index methodology and implementation together with all partners. Advice, guidance and views will also be sought from other relevant divisions of UNEP, such as the Science Division, the World Environment Situation Room implementation team and the relevant Regional Offices.

5.2 Work Package 2: User-centered design process (UNEP)

A user-centered, task-oriented, evaluation-driven design process will be set up to ensure usability, accessibility, and satisfaction in the interaction of end-users with the index and the platform. To ensure the financial sustainability of the Earth Blox platform, web interface and front end, different business models will be presented and discussed with end users at various stages of development. The users will also be involved and engaged throughout all stages of the development of the index by a variety of research and design techniques to capture user experiences and needs. A clear understanding of the user tasks and use contexts (challenges, goals, limitations) will be developed, which will be further specified into use cases and scenarios. From the use cases, a set of functional requirements and objectives for the index will be formulated, as well as inspiration and ideas will be gathered for the design and implementation. The implementation and design phases will generate test cases for intermediate evaluation. Identified key end-users feedback and an external audit will evaluate a prototype and a later version of the index, before the official launch. The above steps of a user-centered co-design will be iterated until the evaluation results are satisfactory. After the launch of the index, long-term monitoring of the use and user-satisfaction of the tool will ensure its long-term relevance.

For each of the above steps, a mix of investigative methods and tools (e.g. surveys, interviews, focus-groups, scenario-based elicitation) and generative ones (e.g. focus-groups, user and expert presentations, panel discussions, brainstorming, world cafe method) will be applied. Two workshops are planned in the initial phases of the development of the environmental stress index (Q2 and Q3 2020), for end-user consultation and co-design. A third workshop with experts and key end-users will evaluate the prototype and provide feedback for improvements before the launch.

5.3 Work Package 3: Scientific design of index (University of Edinburgh)

Steps of the scientific design of the index that will be tackled from the user-centered design process includes: developing a working definition of environmental stress, a theoretical framework for integrating different aspects of environmental stress, and a data aggregation process. Definitions, frameworks, and methodologies for the environmental stress index have been reviewed for relevance and usability (see Appendix 2 and 3).

The collaborative tools and processes, described in work package 2, will ensure an iterative process from end-product needs to scientific grounding within established theories and methods, and back. The working definition for environmental stress is needed to build an applicable theoretical framework and, subsequently, to support the selection of methods and tools. At the same time, the applicability of the index depends on end-user needs for data analysis and visualisations. Therefore, the scientific design of the index will iteratively assess the compatibility of definition, framework, and methods with end-user needs, and thereby strengthen both applicability and scientific grounding.

Climate and environmental stresses are scale and ecosystem-specific. Region-specific responses to disturbances can be taken into account in the index by determining the appropriate spatial boundaries to deal with environmental stresses. This will likewise be defined by a balance of end-user needs and scientific grounding. One useful possibility is the ecoregions concept/boundaries by Bryce, Omernik, and Larsen (1999) that “serve as an ecological context for interpreting research and assessment analyses, and provide the largest relatively homogeneous areas in which to extrapolate results”.

5.4 Work Package 4: Data inventory and management (Quosient)

Once the scientific index is designed, data will be inventoried along with specific restrictions on sharing and use. The selected and analysis-ready datasets will be uploaded to GEE, or relevant APIs accessed. This will form the basis to develop the index workflows for work plan optimisation and prioritisation. At this point, potential synergies with the Edinburgh International Data Facility will also be explored. Variable and data selection will follow the well-defined framework for environmental stress (work package 3), including the identification of sub-indicators. Datasets for each sub-indicator need to respect eight criteria regarding: purpose, scientific rigour, measurability, analysis-readiness, ease of understanding, ease of application, relevant time and spatial scale, and relevant time and spatial coverage. The index will incorporate internationally agreed environmental indicators as much as possible, such as the global indicators for the Sustainable Development Goals as adopted by the UN General Assembly. This ensures coherence with other UN products and projects, as well as support for consistent data availability at least until 2030.

5.5 Work Package 5: Algorithm implementation (University of Edinburgh)

The spatial data layers will be aggregated into the index based on ten-step methodology (work package 3), as decided on and adapted by the user-design process (work package 2). The index will be available on different spatial scales by aggregating data with the highest resolution possible. As a first step, the aggregated environmental stress index will be simply overlayed with socio-economic data to identify co-incidence of environmental stress hotspots with population layers and socio-economically fragile conditions, such as inequality, dependence on the natural environment for livelihoods, level of education, migration. That way, the amount of people directly affected by the environmental stress can be identified, as well as their vulnerability towards environmental stress.

Post project, as a future step, more advanced techniques will be assessed on how statistical and machine learning algorithms could be used to explore complex, direct and indirect, effects of environmental stress on societal outcomes, both positive, such as cooperation or innovation, or negative, such as maladaptation, migration or conflict. Different model/algorithm types will be tested for their relevance, including logistic regression, neural networks, random forest models, ensemble models, etc. Thereby, the complex interactions of environmental stress with socio-economic conditions will be captured to support integrated risk analysis, fragility and resilience assessments, and conflict early warning.

5.6 Work Package 6: User interface and user experience (Quosient)

This work package focuses on the development of front-end functionalities and compliant connections to back end. Work packages 2 and 3 will inform the development of project-specific Earth Blox blocks, toolboxes, and custom-made workflows based on the stress indicator algorithms, matching user needs. Our end-users will be segmented based on similarity of needs, and 4 workflows will be customised to meet those specific contexts and needs.

User experience includes back-end functionality to throttle user quotas to enable usage controls and allow for fair usage and ensure efficient API links accessing GEE and other relevant data repositories as identified in WP3&4, such as the Edinburgh International Data Facility (that will host workspaces and sandpits for academic research and prototyping). Additional outputs will include the conversion of code from WP5 as custom-built functions executable on the server and code-optimisation for automation and statistics gathering (for simulation during testing).

Functionalities to upload, download, and store user-generated data will be built to be incorporated into the platform, and, in formats that enable statistical analysis, data download for offline use, as well as non-standard outputs. Further security features for GDPR compliance will be needed, as well as data privacy impact assessment, data privacy policy and OWASP Application Security Verification Assessment.

The lead output from this work package is the creation of a suite of user Interface (UI) and Experience (UX) Activities, and dashboard functionality: (a) Develop and optimise user interface; involving working directly with a designer to map out the users journey and interaction; (b) Develop alignment and consistency (look and feel across UX) improving ease of use; (c) Implement user preferences and settings page; (d) Identify long term financial sustainability of the web interface, including identifying/designing suitable billing protocols and processes.

5.7 Work Package 7: Platform launch / Go live (UNEP)

This includes the development of a launch strategy to position and brand the index, how it offers a solution for non-technical users to rapidly visualize, analyze, and understand where and how environmental and climate stressors can impact livelihoods. A series of live and online events will be organised to publicly launch the web platform and begin the on-boarding process. The successful launch of the platform, together with the follow-up activities, of the index are expected to result in its recognition and adoption by the end-users identified in sections 3.1 and 3.2. Formal links will be made to the UN SDGs framework targets, the Sendai Framework for Disaster Risk Reduction targets, and the Paris Agreement actions.

Before the launch, a marketing campaign will be developed and implemented to reach out and promote the index through different channels, and to familiarize all crucial actors with the index's web-based platform. The set of launch activities are conceptualized to ensure that users learn about the index and take full advantage of its features to streamline environmental and climate change analysis to support better policy and programme recommendations, as well as advance scientific research.

Capacity building components are also planned. Within this work package, a set of training modules will be developed and delivered directly to end-users, covering different features of the index depending on specific user needs, such as: navigation on the dashboard, identification and analysis of stress hotspots, explanation of the methodology of aggregation and algorithms, sources and licensing of data, or utilization of the API in third-party software. These activities are expected to be delivered during, and after the launch of the platform; and will be built on the results of work package 2, taking into account the requirements and feedback of end-users.

6. TIMELINE AND WORKPLAN

	2020			2021				2022
Work Packages	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
1. Project management	x	x	x	x	x	x	x	x
2. User-centered design process	x		x	x	x			x
3. Scientific design of index	x	x						
4. Data inventory and management		x	x	x				
5. Algorithm implementation			x	x	x			
6. User interface / user experience	x		x		x	x		
7. Platform launch / Go live					x	x		

7. BUDGET

Secured budget (UNEP):	USD	340,000
In-kind staff support (UNEP):	USD	100,000
Quosient (required):	USD	250,000
University of Edinburgh (required):	USD	250,000
Remaining budget to mobilize:	USD	500,000

ANNEXES

A.1. Project partners

United Nations Environment Programme

UNEP's Crisis Management Branch (CMB) seeks to minimize the environmental threats to human well-being from the environmental causes and consequences of disasters and conflicts. Since the start of the new millennium, natural hazards and major conflicts have directly affected some two billion people. Not only do these tragic events destroy lives and infrastructure, they also fundamentally undermine human security and tear apart the fabric of sustainable development. By addressing environmental degradation and resource management, UNEP is working to build more resilient and peaceful societies.

UNEP CMB has responded to crisis situations since 1999 in over 40 countries, delivering over USD 250 millions of high-quality environmental expertise and projects to national governments and partners in the UN family. The Branch conducts field-based assessments works to reduce the risk of disaster, and promotes environmental cooperation for peacebuilding, among other activities.

The branch is coordinated from Geneva, Switzerland, and counts with 120 staff and experts involved in conflict and disaster management across the organization. It has established partnerships with a wide range of international and national actors, including: National governments, the European Union, the World Bank, the UN system, academic and research institutions, and major non-governmental organizations.

This project will also connect to UNEP's World Environment Situation Room - a one stop shop to access the best available open-source environmental datasets on a single authoritative and non-commercial platform backed by the neutrality of the UN. UNEP was requested by the UN Environmental Assembly to develop this capacity as part of a new mandate to promote the use, sharing and application of Environmental Data.

University of Edinburgh

The School of GeoSciences is the largest and most successful interdisciplinary grouping of geoscientists and geographers in the UK, with a growing and cosmopolitan academic and research staff of more than 300 academic and research staff; more than 100 non-academic staff; around 470 postgraduates (half of whom are on taught masters courses), and over 1,100 undergraduates. The school investigates what shapes our world and the environments in which we live, in order to understand the interactions between Earth's geology, atmosphere, oceans, biosphere and human responses and roles. In the UK REF it was top-ranked for Research Power in 'Earth Systems and Environmental Sciences'. We are ranked 12th and 22nd in the 2016 World QS subject rankings for 'Geography and Area Studies' and 'Earth and Marine Sciences'; increased research grant income at over 9%/annum over the past six years to £17.8M/annum; and achieved an Overall Satisfaction rate of 88% in the 2016 National Student Survey.

University of Edinburgh also hosts world class facilities for the analysis of satellite data, including a number of High-Performance Computers on site (HECTor, Archer, Eddie), local linux clusters with the School of GeoSciences and the Edinburgh International Data Facility. Additionally, the University's innovation hub for Data Science and Artificial Intelligence is the Bayes Centre that acts as the central focus of space data research. The technical strengths brought together in Bayes build on world-leading academic excellence in the mathematical, computational, engineering, geosciences and space data analytics in the University's College of Science and Engineering.

Edinburgh has a concentration of expertise in remote sensing technology and applications, and in environment measurements, monitoring and modelling within a development context. We are one of the core funded institutions in the UK National Centre for Earth Observation. We have close links with the UK Space Agency and European Space Agency, including funded research contracts, and serve on advisory groups. We have extensive experience and institutional knowledge of field work in tropical countries over the past five decades. The University of Edinburgh is also active in the fields of sensor development and testing, hosting the NERC Field Spectroscopy Facility and the NERC Airborne Geosciences Facility, and has the ability to test and use sensors on its own piloted plane as well as various UAV platforms.

The School and the wider University through the Bayes Centre is developing its space research-based capabilities and working with key commercial partners to ensure that our research is close to market and relevant to current developments. Edinburgh also hosts one of the sites for the Alan Turing Institute, who we will include as data researcher partners.

Quosient

Quosient is a start-up from the University of Edinburgh that builds and delivers Earth Blox, a brand-new interface for allowing easy access to large Earth Observation data sets. The novelty of Earth Blox is its ability to allow non-coders access to the kind of processing and analysis of EO data that is usually limited to users who can write code and take advantage of the likes of Earth Engine. It is led by Dr Geneveive Patenaude (PhD Oxon, MBA) who brings together an award-winning team with 15-years of successfully working together, evidenced by a strong track record in Earth-observation commercialisation (two trading and successful companies, Ecometrica Ltd. and Carbomap Ltd.). Quosient's contribution is backed by a series of awards and accolades, including a Royal Society of Edinburgh Enterprise Fellowship (Patenaude, 04/19-04/20), selection for the highly competitive IUK Follow-on-Fund (5/12/19-04/03/20) and selection to pitch at EIE 2020: Engage Invest Exploit (23/4/20).

A.2. Additional information on definitions, framework and methods

Among reviewed existing definitions, Fränzle's (2006) definition seems most applicable as a starting point: “Stress is the state of a biotic or abiotic system under the conditions of a ‘force’ applied, strain is the response to the stress, i.e., its expression before damage occurs, while damage is the result of too high a stress that can no longer be compensated for.” In relation to (and to clearly differentiate from) widely applied, related concepts such as environmental vulnerability, risk, and resilience, environmental stress can be seen as a pressure that puts a vulnerable system at risk for harm or loss, while the level of resilience defines the ability to adapt to or recover from the stress.

Besides adhering to the original physical terminology of stress and strain/response, this definition allows for integration with the DPSIR framework (drivers, pressures, state, impact and response model of intervention). Within this theoretical framework, environmental stress corresponds to the pressures or the states, accumulated over five environmental themes: air, biodiversity, oceans and coasts, land and soils, and freshwater.

A ten-step methodology has been developed for composite indicators by the OECD and Joint Research Centre (JRC) of the European Commission (EC) (OECD and EC JRC 2008), which is very suitable for the construction of environmental stress index. In general, composite indicators are used to summarise multidimensional issues to support decision-making. They are a quantitative tool that provides the big picture (aggregated trends over space and time), an analysis-based narrative, and often rankings of performance on a multidimensional complex issue. They are also used for analytic purposes. Disaggregated subparts of the index can also be used as separate indicators of specific types of environmental stress (e.g. stresses on fresh water vs. forests). To reduce the potential misinterpretation and miscommunication of the environmental stress index, transparency is key. This includes giving full transparency to the texts, methods and tools, codes, and data used in the construction of the index, using open-access geospatial, environmental datasets, and open source statistical and geospatial software.

A.3. Indicator and data selection

The selection of data sets will be made depending on the precise development of the cumulative environmental and climate stress index, which is aimed to be aligned with the pressures or responses of the DPSIR framework. An initial collection of 87 layers has been already curated based on a seven-criteria method, which in summary evaluate datasets on their relevance, scientific validity, measurability, ease of understanding, availability and affordability, relevant time and spatial scale, and sufficient coverage in time and space. Depending on the precise development of the environmental stress framework (for example the pressures or the responses of the DPSIR framework), we will search open datasets for each sub-indicator. To decide which data to include per sub-indicator (Annex 2), datasets are evaluated based on the following seven criteria:

1. Measures relevant objectives/content (salience): follow the a priori defined purpose, definition, and framework of environmental stress.
2. Scientifically valid, objective, verifiable and credible: published/reviewed scientifically to ensure that a rigorous review process has taken place, the clear and transparent data acquisition method.
3. Measurable: quantitatively or qualitatively.
4. Easily understood by the layperson and the professional.
5. Easily applied and affordable: inexpensive to measure or readily available.
6. Reflect time and spatial scale relevant to the issue: raw data inputs should be as disaggregated as much as possible in space and time so that the variable can be useful in various types and scales of analyses.
    a. Disaggregated over time means regular time slices (updates/monitoring) of the data at least once a year.
    b. Spatially disaggregated means into statistical subunits around or smaller than city level, or geospatial raster data, preferable raster cells if 0.5° by 0.5°.
7. 7.Sufficient coverage in time and space: the data will be global coverage, as well as time series covering no less than 10 years.

Given the global nature of the index, one challenge will be addressing the availability of national data or unique national methodologies for assessing environmental stresses. It would be impossible to develop a globally consistent index on the basis of heterogeneous national-level methodologies. The index requires open access, geospatial, global environmental datasets (that need to be checked for scientific soundness). The index will incorporate internationally agreed environmental indicators as much as possible, such as the global indicators for the Sustainable Development Goals as adopted by the UN General Assembly (A/RES/71/313) (IAEG-SDGs 2017). This ensures coherence with other UN products and projects, as well as support for consistent data availability at least until 2030.

Table 1. Potential set of indicators classified within five environmental themes: air, biodiversity, oceans and coasts, land and soils, and freshwater.

Pressures	State
Atmosphere	
Emissions • CO, NMVOC, NO_x, NH_3, SO_2, BC, OC, Sand and Dust, CH_4, CO_2, N_2O, ODS, POPs, Hg, Pb*	**Atmospheric composition and climate** • Air pollution (including Ground-level O_3 and Particulate matter), • Climate change, • Stratospheric O_3 depletion (UV radiation), • Persistent Bioaccumulative Toxins
Biodiversity	
• Habitat conversion (habitat stress: loss, alteration (land-use change) and fragmentation), • Exploitation (unsustainable use/overexploitation in e.g. fishing, logging, overgrazing, poaching), • Climate change (atmospheric warming and extreme events), • Pollution, • Species introductions (invasive species)	• Genetic diversity (largely unmeasured) • Species diversity • Ecosystems diversity
Oceans and Coast	
Sector actions in • Shipping • Ports • Extractive Industry (Offshore hydrocarbon industries, other marine-based energy industries, marine-based mining) • Tourism • Capture Fisheries • Agriculture • Aquaculture • Coastal development	• Coral reefs (bleaching of tropical coral reefs) • Fishing • Debris entering the marine environment • **Extras:** mercury, sand mining, deep sea mining and ocean noise • Note on UNEP's GEO-6: The First Global Integrated Marine Assessment (A/RES/70/235; Inniss and Simcock eds. 2016) and reports of the Intergovernmental Panel on Climate Change (IPCC 2013) have provided recent comprehensive reviews of the state of the ocean. Therefore, three topics have been selected here
Land and Soil	
Land-use dynamics • Land cover change • Agricultural dynamics • Forest dynamics (de and reforestation) • Urban expansion • Land quality dynamics • Land degradation and crop production • Desertification • Soil salinization • Permafrost thawing	• Not specifically mentioned. Not very well distinguished for this theme in UNEP GEO-6 what they understand as environmental pressure vs. state
Freshwater	
Climate change • Changes in precipitation patterns • Use of freshwater and related ecosystems	**Water quantity** • Rainfall and freshwater sources (surface and ground water) • Water withdrawals: surface and ground water • Glacial retreat • Water scarcity **Water quality** • Pathogens (water-borne diseases) • Nutrients • Sediments • Organic pollutants • Heavy metals • Salinity • Contaminants of emerging concern: • Groundwater pollution from oil and gas fracking activities • Lake acidification • Thermal pollution and radionuclides

A.4. Entry-point for mapping environmental security hotspots

Policymakers, practitioners, and academia regard the rapid advance in computing technology, earth observation, and data science as an opportunity to map environmental security hotspots. The environmental and climate stress index may be an entry-point to advance the mapping of these security hotspots and, even the prediction of social fragilities and conflict risks associated with environmental and climate stress. This feature, aimed to digest the advanced interpretation of interconnected issues for non-expert users, would be used to develop a new early-warning system to prevent emerging conflict and escalation driven by livelihood loss due to environmental degradation and climate change. Given the rising pressure on decision-makers to be transparent and accountable, environmental security hotspots mapping becomes essential to prioritisation of policy development and programme design.

However, violent conflict is rarely, if ever, driven only by deficient natural resources management, environmental degradation or climate changes causes. Hence, conflict risk can not be forecasted solely on environmental or climate variables. A first step is to indicate **current environmental security hotspots** by **overlaying** the mapping of environmental stresses with demographic and socio-economic data layers. That way, the index can provide early warning when environmental stresses, population centres, and socio-economic vulnerable situations coincide.

For **near-future forecasts** of **environmental security hotspots**, it is necessary to include a set of historical, social, economic, and political factors and theories. Even with the most complete data and advanced models, conflict - similarly to other social dynamics - is difficult to predict. Models designed to forecast conflict typically underperform because some social variables to be used as predictors are complicated to observe or measure, or to a lack of georeferenced, long time-series. Considering that the index will be a global tool, aiming to forecast this in a spatial and temporal manner at a global-level is even more complicated due that most fragility variables used to predict conflict risks are heavily location-specific. One solution to address such complexity is to implement machine learning to process any non-linear, interactive, and context-specific dynamics.

For **long-term future scenarios of environmental security**, ideally, the index will display the change of conflict risk based on forecasted cumulative environmental and climate stress scenarios. The index's hotspot mapping can serve to illustrate the potential shift in conflict risk through the implementation of new environmental policies and programmes by comparing scenarios. Therefore, trying to solve the complexity of predicting environmental and climate-driven conflict risks using machine learning is a promising avenue to be explored, primarily, for its potential to support policy development and programme design. In this view, it is to highlight that experts at the UN Climate Security Mechanism, UN Country Teams, UN Resident Coordinators, World Environment Situation Room, and the World Bank, as European think tanks have already expressed their interest in using an environmental-security hotspot-mapping tool for their work.

UN
environment
programme