PANGEA White Paper Outline

[NASA Tropical Ecology Scoping Solicitation](https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=860588/solicitationId=%7BEB63A640-7CE0-70F6-BE80-C12541C56B5F%7D/viewSolicitationDocument=1/A.4%20Terrestrial%20Ecology%20Amend%2036.pdf)

***From Solicitation:***

The main deliverable will be a scoping report that lays out the scientific issues at stake, the logistical framework, and one or more paths forward toward implementation. Scoping studies will be required to address the following elements:

1. The science questions and issues
2. The current state-of-the-science
3. The potential for a major, significant scientific advancement
4. The central, critical role of NASA remote sensing
5. The essential scientific components of the study and why coordinated teamwork is required in their implementation
6. An overall study design identifying the required observational (e.g., spaceborne, airborne, and/or supporting in situ observations) and analytical (e.g., models, data, and information system) infrastructure
7. The feasibility of the proposed project, both technical and logistical
8. The engagement of the broader research community to seek feedback on the ideas, to assess interest, and to foster diversity and inclusion
9. The disciplinary skills needed to conduct the study and engage potential partners in their planning activities
10. Potential use of results for applications and decision support.

Scoping studies must produce a written report that **provides the scientific rationale and an initial study design concept** for a new field campaign or related team project. While this report need not be lengthy, it **must include a thorough presentation of science questions, goals, and objectives; the underlying rationale in terms of state-of-the-art, relevance, and expected advances; implementation concepts**; and other information to enable NASA to fully evaluate the project.

**[LOGO]**

**The PAN tropical investigation of bioGeochemistry and Ecological Adaptation (PANGEA): A Concise Plan for a NASA-Sponsored Field Campaign**

**Final Report**

**December 2024**

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**Foreword**

NASA’s Research Opportunities in Space and Earth Sciences released in 2022 called for proposals to conduct scoping studies to identify the scientific questions and develop the initial study design and implementation concept for a new NASA Terrestrial Ecology field campaign. In the spring of 2023, NASA selected two projects for funding, including a project entitled: “*A Scoping Study for the NASA Tropical Terrestrial Ecology Campaign”* (NASA Grant 80NSSC23K1019 to the University of California, Los Angeles). This report contains the recommendations from this scoping study, which presents the **PAN tropical investigation of bioGeochemistry and Ecological Adaptation (PANGEA).** NASA outlined ten expectations to be identified for each scoping study:

1. The science questions and issues.
2. The current state-of-the-science.
3. The potential for a major, significant scientific advancement.
4. The central, critical role of NASA remote sensing.
5. The essential scientific components of the study and why coordinated teamwork is required in their implementation.
6. An overall study design identifying the required observational (e.g., spaceborne, airborne, and/or supporting in situ observations) and analytical (e.g., models, data, and information system) infrastructure.
7. The feasibility of the proposed project, both technical and logistical.
8. The engagement of the broader research community to seek feedback on the ideas, to assess interest, and to foster diversity and inclusion.
9. The disciplinary skills needed to conduct the study and engage potential partners in their planning activities.
10. Potential use of results for applications and decision support.

In this white paper, we XXX.

**Acknowledgments**

**Biogeochemical Cycles & Carbon Dynamics:**

**Ecosystem Structure, Function & Biodiversity:**

**Social-Ecological Systems:**

**Climate Feedbacks & Interactions:**

**Community Engagement & Research Applications:**

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## 

## 1. Introduction and Motivation

In recent decades, tropical forest regions have been a strong and persistent carbon sink. As a result of climate change and land-use change, the tropical carbon sink is now fragile, at times reversing to become a source of carbon emissions to the atmosphere in response to extreme events. Critically, tropical forests appear to differ in their sensitivity to extreme events and future climate and land-use change feedbacks. We do not currently know how sensitive tropical forest regions are, how much that sensitivity differs across continents, or the mechanisms that account for those differences.

The global carbon cycle and tropical forest function are tightly linked to the water cycle (e.g., rainfall recycling), increasing temperatures and changes in seasonality, the biodiversity that underpins these systems, and feedbacks with the people that live in and depend on these landscapes. A coordinated multiscale campaign is required to advance our understanding of the sensitivity of these systems to future change. This campaign will simultaneously advance global-scale understanding of tropical ecosystem processes, accelerate progress in modeling tropical ecosystems, and in our data-rich era of new dimensionality effectively utilize current and forthcoming satellite missions to diagnose the current state of tropical forests.

### 1.1 Science Questions and Objectives/Issues

As a result of climate change and land-use change, the tropical carbon balance, heretofore mainly a sink, is now often reversing to become a source of carbon emissions to the atmosphere in response to extreme events and trends in climate and land-use change. Critically, the tropics appear to differ in their recent trends in X, sensitivity to extreme events, and future climate and land-use change feedbacks. Understanding long-term tropical carbon flux trends and the resilience of the tropical carbon sink to extreme events has globally important implications and requires an improved understanding of patterns and processes. PANGEA aims to answer the following overarching question:

**How do climate change** **and land-use change interact with the heterogeneous structure, function, and biodiversity of tropical forest biomes to affect the current and future carbon balance of the tropics?**

[1-2 paragraphs in the white paper after this about why this is uniquely suited to satellite remote sensing → the central, critical role of NASA remote sensing]

* Data-rich and model-rich moment
* We now have remote sensing capabilities that allow for more direct measurement of diversity (structural, functional, maybe taxonomic)
* We now have models that represent processes that mediate forest diversity the interactions of structurally heterogeneous forests with climate, land use and biogeochemical cycles
* Also cloud computing / computational resources
* But we can’t use those satellite data effectively without coordinated cal/val measurements
* Cut and paste from ROSES solicitation, and reviewer comments, and slide that emphasizes things from solicitation
* Tropical forests have a major role on global climate and teleconnections with non-tropical climate

More specifically, PANGEA will address:

1. **How does ongoing and projected changing climate impact the resilience of the tropical carbon sink and how does the weakening of the carbon sink feedback on the climate?**

* Changing climate = multi-decadal trends and extreme events with respect to temperatures (thermal tolerance), rainfall regimes (intensity, total precipitation, seasonality), storm frequency and intensity (convective systems), drought intensity and frequency, CO2 fertilization effect
* Emphasis on land-atmosphere interactions
* Link forest carbon stocks and fluxes, but also exchanges at the interface between forest and agricultural systems
* **How does variation in ecosystem structure, ecosystem function, and biodiversity within and among regions in the tropics contribute to differences in the resilience of the carbon sink?**
* Forest structure = Canopy height, vertical height heterogeneity, vertical leaf/plant area density distributions, and biomass
* Forest function = GPP, NPP, woody productivity, respiration, tree mortality, woody residence time, evapotranspiration, sensible heat flux, net radiation, water-use efficiency, carbon-use efficiency, nutrient-use efficiency and nutrient cycling
* Biodiversity = Functional, phylogenetic, and taxonomic (think trait and spectral diversity and phylogenetic diversity likely at the genus and family levels), faunal and floral diversity
* Ecosystem = natural ecosystem, agro-ecosystem, social-ecological system
* **How do current and future land-use change interact with the resilience of the tropical carbon sink to influence climate feedbacks and biogeochemical cycles?**
  + Land-use change = deforestation, degradation, fragmentation, restoration, and regeneration
  + Degradation = selective logging, mining, defaunation, human-ignited fire

### 1.2 PANGEA Science Themes

### 1.3 Role of Remote Sensing Observations

### 1.4 PANGEA Study Domain

## 2. PANGEA Science Themes

### 2.1 Biogeochemical Cycles and Carbon Dynamics

### 2.2 Ecosystem Structure, Function, and Biodiversity

1. What are the patterns of spatial variation in tropical forest structure and function today and what are the mechanisms underlying those patterns?
2. How does tropical forest function vary seasonally and interannually, and how do patterns and mechanisms of temporal variation in forest function differ spatially across the tropics?
3. How does biodiversity influence tropical forest structure and function and their responses to climate variation, disturbance, and global change?

### 2.3 Climate Interactions and Feedbacks

### 2.4 Social-Ecological Systems

ONE-SENTENCE SUMMARY OF WHAT THIS SCIENCE THEME DOES

[*this could be a modification of the 'overarching' question: “How do climate change, tropical forest heterogeneity, and human activities and governance interact to impact food, water, energy, and livelihood security?”*]

CONTEXT

**Paragraph 1:** Description / definition of social-ecological systems in the tropics, highlighting that humans are part of the ecological systems [Oliver Coomes?]

* integrated system comprising ecosystems and human societies with complex and interdependent relationships
* recognizing that human activities impact ecological processes and, conversely, ecological changes affect human well-being
* Mention the term co-benefits and that interconnectedness and interdependencies exist from which multiple benefits to nature and societies emerge (see also [Levis et al, 2024, NatEcoEvo](https://www.nature.com/articles/s41559-024-02356-1))

**Paragraph 2:** Describe feedbacks and their importance [Maria Santos]

* Feedbacks between human and natural systems are critical for understanding the dynamics of SES, can be positive or negative and influence the resilience, stability, and sustainability of these systems
* Can be complex and occur across scales (e.g., (inter)national policy and local action)
* Examples for positive and negative feedbacks

**Paragraph 3:** Demonstrate the relevance of better understanding SES (for NASA, and in general)

LITERATURE REVIEW

* To provide appropriate literature background for the context sections
* And to demonstrate that the questions we ask are relevant, and have not been answered before (i.e., showcasing the literature gaps)

SCIENCE QUESTIONS

1. How do human activities\* and socio-economic conditions impact forest structure and composition, and how does this affect the provisioning of and access to social-ecological co-benefits at multiple scales?
2. What is the geographic distribution and variability of forest-friendly economic activities\* and how do they covary with tropical forest [net primary] productivity, ecosystem function, biodiversity, and livelihoods?
3. How do differences in the history of human activities affect forest recovery and the restoration of social-ecological co-benefits?
4. How do varying tropical forest land-atmosphere interactions affect water availability and food security, human health, and cultural practices, including Indigenous Peoples and Local Communities?

WHAT ARE THE ADVANTAGES / KNOWLEDGE / OUTPUTS OF ANSWERING THE QUESTIONS ABOVE

APPROACH/METHODS

Remote sensing [Maria Santos]

* Detection of LULCC
* Identification of crop types
* Identification of agroforestry systems

Field data

* Using qualitative methods like interviews and focus groups to complement remote sensing data ,
* Governance [MVE]
* Economics
* Perceptions & culture [Ale Echeverri Ochoa?]

**GLOSSARY**

***Co-benefits*** = Joint positive contributions of biodiversity and cultural diversity for humans and other species. These contributions are associated with the concepts of nature’s contributions to people and people’s contributions to nature. → From: Levis et al, 2024, “Contributions of human cultures to biodiversity and ecosystem conservation”, Nature Ecology & Evolution, <https://doi.org/10.1038/s41559-024-02356-1>

***Human activities =*** formal, informal, and illegal economic, subsistence, and development practices by humans that lead to the exploitation, alteration, and degradation of forest ecosystems, including logging, construction of infrastructure, agriculture, livestock rearing, fire, mining, hunting and wildlife exploitation, charcoal production

***Vulnerable communities*** = communities that are most likely to experience the adverse effects of climate change and environmental degradation, including indigenous peoples, low-income communities, and those reliant on natural resources for their livelihoods. → From: United Nations Framework Convention on Climate Change (UNFCCC). (2020). *"Vulnerable communities"*.

***Forest-friendly activities*** = economic activities that utilize forest resources in a way that preserves the forest's ecological integrity and supports the sustainable livelihoods of local communities → From: IUCN. (2021). *"Forest Conservation and Sustainable Use"*

***Vulnerability*** = the propensity of social and ecological systems and their practices to be adversely affected by changes, encompassing their sensitivity to such changes and their ability to adapt. → Adapted From: FAO. (2013). *"Community-Based Forest Management and Vulnerability to Climate Change"*

***Livelihood security*** = sustainable, adequate access to resources to meet basic needs and rights. These include adequate food, health, shelter, minimal levels of income, basic education and community participation. The ability to meet some of these needs is tightly linked to the resilience of the ecological systems that provide these needs. *→ adapted from: Frankenberger, Timothy R. and M. K. Mccaston. “The household livelihood security concept.” Food, nutrition and agriculture (1998): 30-35.*

Methods: network analysis, social capital, modeling (biophysical models)

### 2.5 Potential use of results for Earth Science to Action

* Use an example pyramid of PANGEA -> ES2A
  + use ES2A language
* In ABOVE referred to as "applications and decision support"
* Use the information we gathered during the DC workshop session on flows of information
* Draw upon lessons learned from ABOVE (Debjani Singh, Libby Larson, Kimberly Minor). Divide all the user cases into different stakeholder group. These groups will have different needs and how we will address these needs. Maybe have 4-5.
* Sort potential partners into groups
* Visualization of partners and different types of uses

## 3. Research Strategy and Study Design

### 3.1 Overall Design / Approach

### 3.2 Candidate Study Sites / Regions

### 3.3 Modeling and Integrative Analyses

### 3.4 Remote Sensing Observations

* boots -> towers -> drone -> aircraft - diagram
* get specific about satellites and how they'd be used
  + not just a list of sensors
* mention - also using sensors from partner agencies
  + ESA, JAXA, ISRO

### 3.5 Field Observations, Studies, Experiments

### 3.6 Technical and Logistical Feasibility / Issues

## 4. Organization and Management

### 4.1 Scientific Leadership

### 4.2 Project Organization

### 4.3 Field Operations

### 4.4 Data Management and Sharing

* DAACS, tropical DAACs, data sovereignty, cloud computing - access for partners (Centers for Excellence & trainings)
* highlight working with existing training programs (specify)
  + if don't exist - describe those and how PANGEA could implement

### 4.5 Timetable

## 5. Community Engagement

### 5.1 Community Engagement Methods during the PANGEA Scoping Campaign

The Community Engagement and Research Applications Working Group engaged with over 500 individuals from X number of countries across five continents during the PANGEA Scoping Campaign through (A) an international working group, (B) short information sharing events, (C) multi-day consultative workshops, and (D) bilateral meetings with potential partners.

(A) The Community Engagement and Research Applications (CERA) working group (1) was comprised primarily of students, researchers and professors from academic institutions, practitioners from non-governmental and intergovernmental organizations, and some private sector representatives. Similar to the other PANGEA working groups, CERA membership was open and advertised online, at PANGEA events, and within “word of mouth.” In total, approximately 100 individuals signed up to the CERA working group and participated in one or more of the 12 CERA meetings conducted online and/or contributed to the team’s collaborative documents. Many members also participated in CERA-relevant sessions at the PANGEA multi-day workshops in Cameroon, US, Brazil and Peru.

(B) The PANGEA Leadership Team engaged with X NUMBER OF PEOPLE through twelve information sharing events conducted on five continents. These events include 1-2 hour presentation and discussion sessions at international academic conferences (e.g. American Geophysical Union Town Hall, USA, December 2023; Ecological Society of America webinar, March 2024; European Geosciences Union presentation, Austria, April 2024), regional events (e.g. Smithsonian Tropical Research Institute, Barro Colorado Island 100th Anniversary Symposium presentation, Panama, June 2024; Congo Basin Forest Partnership 20th Meeting of the Parties presentation, June, 2024), and special meetings organized by the PANGEA community (e.g. Africa women’s session, April 2024; Meeting with Indigenous Communities in Panama, April 2024).

(C) The PANGEA Leadership Team organized four, multi-day regional scoping workshops that included sessions focused on community engagement best practices and regional demand and preferences for research applications. PANGEA Scoping workshops include a 3-day event in Yaoundé, Cameroon in February 2024; a 3-day event in Washington, DC in April 2024; a 4-day event in Manaus, Brazil in May 2024; and a 2-day event in Peru. All events were organized in close collaboration with local PANGEA partners.

(D) The PANGEA Leadership Team and CERA working group members conducted bilateral meetings with 33 potential PANGEA partners, including. Many (ADD EXACT NUMBER HERE) have shared letters of support to confirm their interest in collaborating on the PANGEA program (if funded).

1. AndesFlux (research initiative conducted by institutions in the US, Canada, Germany, and Peru)
2. ASCEND
3. Australia
4. BELOW
5. Congo Basin Initiative
6. CBSI
7. CIAT - Alliance Bioversity International (International Center for Tropical Agriculture + Bioversity)
8. European Space Agency (ESA)
9. ESDT
10. Food and Agriculture Organization of the United Nations
11. FLUXNET
12. Global Alliance of Territorial Communities (GATC)
13. GeoTrees
14. IITA
15. IREES
16. MapBiomas
17. NASA ARID
18. NASA Biodiversity and Ecological Conservation (BDEC)
19. NASA Earth Science to Action (ES2A)
20. NASA Harvest
21. NASA Hydrology
22. NASA Jet Propulsion Lab / AfriSAR
23. NASA Land Cover Land Use Change (LCLUC)
24. NASA Large-scale Biosphere-Atmosphere Experiment in Amazonia (LBA)
25. NASA SERVIR
26. NASA Soil Moisture Active Passive (SMAP)
27. Observatoire National sur les Changements Climatiques (ONACC)
28. Penn State University
29. Poverty Action Lab at MIT
30. SilvaLab
31. Smithsonian
32. Sylvera
33. US Agency for International Development (USAID)
34. US Department of Energy (US DOE)
35. University of California Santa Cruz
36. United Nations Framework Convention on Climate Change
37. Woodwell
38. World Resources Institute

#### 5.1.1 PANGEA Partners

* *Categorize potential PANGEA partners according to specific user groups*
* *Map geographically and thematically potential partners*

#### 5.1.2 Limitations

* *Proactively discuss limitations in our engagement methods.*
* *Identify the gaps and explain why certain groups were under-represented groups in our consultative process (e.g. private sector, government esp in Africa, IPLC logistical challenge + ethical concerns). Explain how the funded PANGEA program could address these gaps.*

### 5.2 Community Engagement for the PANGEA Program

* General principals (CARE & FAIR, FPIC, Stephanie Caroll)
* PANGEA Engagement goals
* Overall strategy
* Description of PANGEA-relevant communities and specific engagement considerations.
* Mention that the list below is non-exhaustive, but the overall strategy will provide a framework for also all engaging other under-represented communities

#### 5.2.1 Indigenous Peoples and local communities

* [Draft being co-written (in multiple languages) can be found here](https://drive.google.com/drive/u/1/folders/1Gw5jlwLzT7Z_KHRGMwto6nnl4nSpxRIX)

#### 5.2.2 Scientific Institutions

* Including universities, colleges, local and regional research institutions
* Local and international students
* Researchers
* Professors

#### 5.2.3 Government agencies

* Policymakers
* Administrators
* At national and sub-national levels

#### 5.2.4 Non-governmental organizations

* International
* Local

#### 5.2.5 Intergovernmental organizations

#### 5.2.6 Private sector

* Big data companies
* Forest development companies
* Agribusiness
* Energy companies
* Investors (e.g. Africa Nature Investors, Terratai, etc.)

#### 5.2.7 Women

* Address gender balance overall. Highlight specific efforts PANGEA could take to address this and key performance indicators we’ll track over time.
* Gender-responsive vs gender transformative (is 9 years enough to transform a system?) acknowledge that we may not transform the system in 6-9 years, but describe the type of impact PANGEA would like to achieve

#### 5.2.8 Donor community

* Public (USAID, Sida, NORAD, etc.)
* Private (e.g. Bezos)

### 5.4 Disciplinary skills needed

### 5.5 Field Infrastructure

### 5.6 Suborbital Platforms and Sensors

### 5.7 Satellite Data Availability, Access, and/or Purchase

### 5.8 International and Other Agreements

#### 5.8.1. NASA airborne campaign Indigenous agreements, permissions, and treaties (KEEP this section)

* Indigenous land and sovereign territories.
* [Draft being co-written (in multiple languages) can be found here](https://drive.google.com/drive/u/1/folders/1Gw5jlwLzT7Z_KHRGMwto6nnl4nSpxRIX)

### 5.9 Training and Education

* Address capacity building

### 5.10 Cost Estimates

## 6. Issues to be Resolved

## 7. References

## 8. Figure and Photograph and Credits

## 9. List of Acronyms

## 10. Appendices

### A - Planned and Ongoing Research and Monitoring Activities

### B - Summary of Level II and III Ecoregions in PANGEA Study Region

### C – Summary of Airborne and Spaceborne Remote Sensing Systems for PANGEA

### D - Summary of PANGEA Participants

## Detailed overview of PANGEA Community Engagement Activities

1. Community Engagement and Research Applications working group meetings online
   * February 13th
   * March 14th
   * March 21st
   * March 28th
   * April 3rd
   * May 15th
   * June 7th
   * June 27th
   * July 11th
   * July 25th
   * August 8th
   * August 22nd
2. Short (1-2 hour) information sharing meetings
   * Kick-off webinar, November 2023
   * American Geophysical Union (AGU) Town Hall, San Francisco, California, December 2023
   * Ecological Society of America (ESA) webinar, March, 2024
   * Information sharing (hybrid) meeting with Indigenous Communities in Panama, April 2024
   * Africa regional women’s session, online, April 2024
   * European Geosciences Union (EGU) presentation, Vienna, Austria, April 2024
   * Smithsonian Tropical Research Institute, Barro Colorado Island 100th Anniversary Symposium presentation, Panama, June 2024
   * Congo Basin Forest Partnership (CBFP) 20th Meeting of the Parties presentation, June, 2024
   * Congo Basin Institute, presentation, July, 2024
   * Ecological Society of America (ESA) update webinar, August, 2024
   * NASA Biological Diversity and Ecological Conservation meeting in Maryland, May, 2024
   * Association for Tropical Biology and Conservation (ATBC), Kigali, Rwanda, July 2024
3. Multi-day workshops
   * Africa Regional Consultation 3-day workshop, Yaoundé, Cameroon, February 2024
   * PANGEA Scoping 3-day workshop, Washington, DC, April 2024
   * Amazon Climate 4-day workshop, Manaus, Brazil, May 2024
   * PANGEA/Governors' Climate & Forests Task Force (GCFTF) Americans regional 2-day workshop in Lima, Peru, June 2024
   * Asia Regional Consultation X # of days? workshop, LOCATION?, July, 2024
4. Bilateral meetings with potential partners

### E - Letters of Support

1. PennState University, USA  
   Department of Meteorology and Atmospheric Science  
   <https://www.met.psu.edu/>
2. National University of Piura, PERU  
   Agronomy Department  
   <https://www.gob.pe/unp>