Review papers (including abstracts) identified in the Web of Science database on August 29 and 30, 2018, applying the following categories in the search (see Table 5.1): *(LaU OR LaC OR FoC) AND BpE AND ClV AND (ObD OR MoD) AND NoP* (in alphabetical order)

Bagley, J. E., et al. (2015). "Biophysical impacts of climate-smart agriculture in the Midwest United States." Plant Cell and Environment **38**(9): 1913-1930.

The potential impacts of climate change in the Midwest United States present unprecedented challenges to regional agriculture. In response to these challenges, a variety of climate-smart agricultural methodologies have been proposed to retain or improve crop yields, reduce agricultural greenhouse gas emissions, retain soil quality and increase climate resilience of agricultural systems. One component that is commonly neglected when assessing the environmental impacts of climate-smart agriculture is the biophysical impacts, where changes in ecosystem fluxes and storage of moisture and energy lead to perturbations in local climate and water availability. Using a combination of observational data and an agroecosystem model, a series of climate-smart agricultural scenarios were assessed to determine the biophysical impacts these techniques have in the Midwest United States. The first scenario extended the growing season for existing crops using future temperature and CO2 concentrations. The second scenario examined the biophysical impacts of no-till agriculture and the impacts of annually retaining crop debris. Finally, the third scenario evaluated the potential impacts that the adoption of perennial cultivars had on biophysical quantities. Each of these scenarios was found to have significant biophysical impacts. However, the timing and magnitude of the biophysical impacts differed between scenarios. This study assessed the biophysical impacts of several climate-smart agricultural practices in the Midwest United States. Specifically we investigated the biophysical impacts of adapting crops to extended growing season length, expanding no-till agriculture, and the adoption of perennial cultivars. We found that each of these practices had significant biophysical impacts, but the seasonality and extent of the impacts differed between scenarios.

Chakraborty, S. (2013). "Migrate or evolve: options for plant pathogens under climate change." Global Change Biology **19**(7): 1985-2000.

Findings on climate change influence on plant pathogens are often inconsistent and context dependent. Knowledge of pathogens affecting agricultural crops and natural plant communities remains fragmented along disciplinary lines. By broadening the perspective beyond agriculture, this review integrates cross-disciplinary knowledge to show that at scales relevant to climate change, accelerated evolution and changing geographic distribution will be the main implications for pathogens. New races may evolve rapidly under elevated temperature and CO2, as evolutionary forces act on massive pathogen populations boosted by a combination of increased fecundity and infection cycles under favourable microclimate within enlarged canopy. Changing geographic distribution will bring together diverse lineages/genotypes that do not share common ecological niche, potentially increasing pathogen diversity. However, the uncertainty of model predictions and a lack of synthesis of fragmented knowledge remain as major deficiencies in knowledge. The review contends that the failure to consider scale and human intervention through new technology are major sources of uncertainty. Recognizing that improved biophysical models alone will not reduce uncertainty, it proposes a generic framework to increase focus and outlines ways to integrate biophysical elements and technology change with human intervention scenarios to minimize uncertainty. To synthesize knowledge of pathogen biology and life history, the review borrows the concept of fitness' from population biology as a comprehensive measure of pathogen strengths and vulnerabilities, and explores the implications of pathogen mode of nutrition to fitness and its interactions with plants suffering chronic abiotic stress under climate change. Current and future disease management options can then be judged for their ability to impair pathogenic and saprophytic fitness. The review pinpoints improving confidence in model prediction by minimizing uncertainty, developing management strategies to reduce overall pathogen fitness, and finding new sources of data to trawl for climate signatures on pathogens as important challenges for future research.

Dalal, R. C. and D. E. Allen (2008). "Greenhouse gas fluxes from natural ecosystems." Australian Journal of Botany **56**(5): 369-407.

Besides water vapour, greenhouse gases CO2, CH4, O-3 and N2O contribute similar to 60%, 20%, 10% and 6% to global warming, respectively; minor contribution is made by chlorofluorocarbons and volatile organic compounds (VOC). We present CO2, CH4 and N2O fluxes from natural and relatively unmanaged soil-plant ecosystems (the ecosystems minimally disturbed by direct human or human- induced activities). All natural ecosystems are net sinks for CO2, although tundra and wetlands (including peatlands) are large sources of CH4, whereas significant N2O emissions occur mainly from tropical and temperate forests. Most natural ecosystems decrease net global warming potential (GWP) from - 0.03 +/- 0.35 t CO2-eha(-1) y(-1) (tropical forests) to - 0.90 +/- 0.42 t CO2-e ha(-1) y(-1) (temperate forests) and - 1.18 +/- 0.44 t CO2-e ha(-1) y(-1) (boreal forests), mostly as CO2 sinks in phytobiomass, microbial biomass and soil C. But net GWP contributions from wetlands are very large, which is primarily due to CH4 emissions. Although the tropical forest system provides a large carbon sink, the negligible capacity of tropical forests to reduce GWP is entirely due to N2O emissions, possibly from rapid N mineralisation under favourable temperature and moisture conditions. It is estimated that the natural ecosystems reduce the net atmospheric greenhouse gas (GHG) emissions by 3.55 +/- 0.44 GtCO(2)-ey(-1) or similar to 0.5 ppm(v) CO2-e y(-1), hence, the significant role of natural and relatively unmanaged ecosystems in slowing global warming and climate change. However, the impact of increasing N deposition on natural ecosystems is poorly understood, and further understanding is required regarding the use of drainage as a management tool, to reduce CH4 emissions from wetlands and to increase GHG sink from the restoration of degraded lands, including saline and sodic soils. Data on GHG fluxes from natural and relatively unmanaged ecosystems are further compounded by large spatial and temporal heterogeneity, limited sensitivity of current instruments, few and poor global distribution of monitoring sites and limited capacity of models that could integrate GHG fluxes across ecosystems, atmosphere and oceans and include feedbacks from biophysical variables governing these fluxes.

Devaraju, N., et al. (2015). "Modelling the influence of land-use changes on biophysical and biochemical interactions at regional and global scales." Plant Cell and Environment **38**(9): 1931-1946.

Land-use changes since the start of the industrial era account for nearly one-third of the cumulative anthropogenic CO2 emissions. In addition to the greenhouse effect of CO2 emissions, changes in land use also affect climate via changes in surface physical properties such as albedo, evapotranspiration and roughness length. Recent modelling studies suggest that these biophysical components may be comparable with biochemical effects. In regard to climate change, the effects of these two distinct processes may counterbalance one another both regionally and, possibly, globally. In this article, through hypothetical large-scale deforestation simulations using a global climate model, we contrast the implications of afforestation on ameliorating or enhancing anthropogenic contributions from previously converted (agricultural) land surfaces. Based on our review of past studies on this subject, we conclude that the sum of both biophysical and biochemical effects should be assessed when large-scale afforestation is used for countering global warming, and the net effect on global mean temperature change depends on the location of deforestation/afforestation. Further, although biochemical effects trigger global climate change, biophysical effects often cause strong local and regional climate change. The implication of the biophysical effects for adaptation and mitigation of climate change in agriculture and agroforestry sectors is discussed. center dot Land-use changes affect global and regional climates through both biochemical and biophysical process. center dot Climate effect from biophysical process depends on the location of land-use change. center dot Climate mitigation strategies such as afforestation/reforestation should consider the net effect of biochemical and biophysical processes for effective mitigation. center dot Climate-smart agriculture could use bio-geoengineering techniques that consider plant biophysical characteristics such as reflectivity and water use efficiency.

Dugdale, S. J., et al. (2017). "River temperature modelling: A review of process-based approaches and future directions." Earth-Science Reviews **175**: 97-113.

River temperature has a major influence on biophysical processes in lotic environments. River temperature is expected to increase due to climate change, with potentially adverse consequences for water quality and ecosystems. Consequently, a better understanding of the drivers of river temperature space-time variability is important for developing adaptation strategies. However, existing river temperature archives are often of low resolution or short timespans, and the analysis of patterns or trends can therefore be difficult. In light of these limitations, researchers have increasingly used models to generate river temperature estimates suitable for addressing fundamental and applied questions in river science. Of these models, process-based

approaches are well suited to helping improve knowledge of the mechanisms controlling river temperature, because of their ability to explore the energy (and water) fluxes responsible for temperature patterns. While process-based modelling approaches can often be more data intensive than their statistical counterparts, they offer significant advantages with regard to simulating the impacts of projected land-use or climate change, and can provide valuable insights for informing the development of statistical models at larger scales. However, a wide range of process-based river temperature models exist, and choosing the most appropriate model for a given investigation requires careful consideration. In this paper, we review the foundations of process-based river temperature modelling and critically evaluate the features and functionality of existing models with a view to helping river scientists better understand their utility. In conclusion, we discuss key considerations and limitations of currently available process-based models and advocate directions for future research. We hope that this review will enable river researchers and managers to make informed decisions regarding model selection and spur the continued refinement of process-based temperature models for addressing fundamental and applied questions in the river sciences.

Murray, S. J. (2014). "Trends in 20th century global rainfall interception as simulated by a dynamic global vegetation model: implications for global water resources." Ecohydrology **7**(1): 102-114.

The Land-surface Processes and eXchanges Dynamic Global Vegetation Model (LPX-DGVM, one of several developments of the Lund-Potsdam-Jena (LPJ) model) is evaluated in terms of its interception component and used to simulate trends in 20th century global relative throughfall from natural vegetation. Mean global annual runoff is estimated to have been reduced by 16319km(3)year(-1) between 1901 and 2006 as a result of biophysical changes controlling throughfall generation. Widespread decreases in relative throughfall of up to -1% are evident between the periods 1901-1953 and 1954-2006, while changes of up to -15% are shown in parts of North America and East Asia. Areas of simulated decrease in relative throughfall often lie in close proximity to areas of increase, reflecting the effects of vegetation shifts. It is shown that simulated global absolute throughfall has generally increased (because of increasing precipitation) during the studied period, but the curtailing of runoff caused by decreased relative throughfall (as a result of increased fractional plant coverage and possible vegetation shifts) has caused a slight exacerbation of water stress in some regions (including parts of East Asia, North America and the tropics) and increased water supplies in others (for example, other parts of the tropics and northern Russia). This study offers an initial insight into an often overlooked product of climate-induced vegetation changes and attempts to quantify how these responses may contribute to influencing the global freshwater budget and global water resources. Copyright (c) 2012 John Wiley & Sons, Ltd.

Nikolov, N. and K. F. Zeller (2003). "Modeling coupled interactions of carbon, water, and ozone exchange between terrestrial ecosystems and the atmosphere. I: Model description." Environmental Pollution **124**(2): 231-246.

A new biophysical model (FORFLUX) is presented to study the simultaneous exchange of ozone, carbon dioxide, and water vapor between terrestrial ecosystems and the atmosphere. The model mechanistically couples all major processes controlling ecosystem flows trace gases and water implementing recent concepts in plant eco-physiology, micrometeorology, and soil hydrology. FORFLUX consists of four interconnected modules-a leaf photosynthesis model, a canopy flux model, a soil heat-, water- and CO(2)-transport model, and a snow pack model. Photosynthesis, water-vapor flux and ozone uptake at the leaf level are computed by the LEAFC3 sub-model. The canopy module scales leaf responses to a stand level by numerical integration of the LEAFC3 model over canopy leaf area index (LAI). The integration takes into account (1) radiative transfer inside the canopy, (2) variation of foliage photosynthetic capacity with canopy depth, (3) wind speed attenuation throughout the canopy, and (4) rainfall interception by foliage elements. The soil module uses principles of the diffusion theory to predict temperature and moisture dynamics within the soil column, evaporation, and CO(2) efflux from soil. The effect of soil heterogeneity on field-scale fluxes is simulated employing the Bresler-Dagan stochastic concept. The accumulation and melt of snow on the ground is predicted using an explicit energy balance approach. Ozone deposition is modeled as a sum of three fluxes- ozone uptake via plant stomata, deposition to non-transpiring plant surfaces, and ozone flux into the ground. All biophysical interactions are computed hourly while model projections are made at either hourly or daily time step. FORFLUX represents a comprehensive approach to studying ozone deposition and its link to carbon and water cycles in terrestrial ecosystems. (C) 2003 Elsevier Science Ltd. All rights reserved.

Nolan, R. H., et al. (2018). "Safeguarding reforestation efforts against changes in climate and disturbance regimes." Forest Ecology and Management **424**: 458-467.

Reforestation schemes, which encompass environmental plantings and natural regeneration of vegetation on cleared land, are increasingly being established for the purposes of mitigating anthropogenic carbon emissions. However, these schemes are themselves at risk from climate change and associated changes in disturbance regimes. Simultaneously, there is increasing pressure on reforested areas to achieve multiple co-benefits, e.g. maximizing carbon storage, ameliorating environmental degradation and promoting biodiversity objectives, all while not adversely affecting community values, such as agricultural production. Here, we review the myriad of biophysical risks posed by climate change to reforested areas while documenting management actions and policies that can enhance both the resistance and resilience of reforested areas to such risks. While it is difficult to buffer vegetation against the direct effects of climate change, such as elevated temperature and changed precipitation patterns, it is possible to manage some of the indirect effects, such as wildfire, drought and insect defoliation. Methods for reducing the vulnerability of reforested areas range from site-specific management actions, particularly around design and location, through to regional and national scale initiatives, such as vulnerability assessments and decision support tools. The complexity of objectives and risks posed to reforested areas means that it is vitally important to evaluate outcomes from across the current estate of reforested areas. However, there is currently no national protocol in place in Australia to track, monitor or evaluate the outcomes of reforestation. Thus, we recommend the establishment of a national framework for analyzing and supporting the growing range of reforestation activities.

Perugini, L., et al. (2017). "Biophysical effects on temperature and precipitation due to land cover change." Environmental Research Letters **12**(5).

Anthropogenic land cover changes (LCC) affect regional and global climate through biophysical variations of the surface energy budget mediated by albedo, evapotranspiration, and roughness. This change in surface energy budget may exacerbate or counteract biogeochemical greenhouse gas effects of LCC, with a large body of emerging assessments being produced, sometimes apparently contradictory. We reviewed the existing scientific literature with the objective to provide an overview of the state-of-the-knowledge of the biophysical LCC climate effects, in support of the assessment of mitigation/adaptation land policies. Out of the published studies that were analyzed, 28 papers fulfilled the eligibility criteria, providing surface air temperature and/or precipitation change with respect to LCC regionally and/or globally. We provide a synthesis of the signal, magnitude and uncertainty of temperature and precipitation changes in response to LCC biophysical effects by climate region (boreal/temperate/tropical) and by key land cover transitions. Model results indicate that a modification of biophysical processes at the land surface has a strong regional climate effect, and non-negligible global impact on temperature. Simulation experiments of large-scale (i.e. complete) regional deforestation lead to a mean reduction in precipitation in all regions, while air surface temperature increases in the tropics and decreases in boreal regions. The net global climate effects of regional deforestation are less certain. There is an overall consensus in the model experiments that the average global biophysical climate response to complete global deforestation is atmospheric cooling and drying. Observed estimates of temperature change following deforestation indicate a smaller effect than model-based regional estimates in boreal regions, comparable results in the tropics, and contrasting results in temperate regions. Regional/local biophysical effects following LCC are important for local climate, water cycle, ecosystems, their productivity and biodiversity, and thus important to consider in the formulation of adaptation policy. However before considering the inclusion of biophysical climate effects of LCC under the UNFCCC, science has to provide robust tools and methods for estimation of both country and global level effects.

Pitman, A. J. (2003). "The evolution of, and revolution in, land surface schemes designed for climate models." International Journal of Climatology **23**(5): 479-510.

The land surface is a key component of climate models. It controls the partitioning of available energy at the surface between sensible and latent heat, and it controls the partitioning of available water between evaporation and runoff. The land surface is also the location of the terrestrial carbon sink. Evidence is increasing that the influence of the land surface is significant on climate and that changes in the land surface can influence regional- to global-scale climate on time scales from days to millennia. Further, there is now a suggestion that the terrestrial carbon sink may decrease as global temperatures increase as a consequence of rising CO2 levels. This paper provides the theoretical background that explains why the land surface should play a central role in climate. It also provides evidence, sourced from climate model experiments, that the land surface is of central importance. This paper then reviews the development of land surface models designed for climate models from the early, very simple models through to recent efforts, which include a coupling of biophysical processes to represent carbon exchange. It is pointed out that significant problems remain to be addressed, including the difficulties in parameterizing hydrological processes, root processes, sub-grid-scale heterogeneity and biogeochemical cycles. It is argued that continued development of land surface models requires more multidisciplinary efforts by scientists with a wide range of skills. However, it is also argued that the framework is now in place within the international community to build and maintain the latest generation of land surface models. Further, there should be considerable optimism that consolidating the recent rapid advances in land surface modelling will enhance our capability to simulate the impacts of land-cover change and the impacts of increasing CO, on the global and regional environment. Copyright (C) 2003 Royal Meteorological Society.

Rosenthal, J. K., et al. (2007). "Links between the built environment, climate and population health: Interdisciplinary environmental change research in New York City." Annals Academy of Medicine Singapore **36**(10): 834-846.
Global climate change is expected to pose increasing challenges for cities in the following decades, placing greater stress and impacts on multiple social and biophysical systems, including population health, coastal development, urban infrastructure, energy demand, and water supplies. Simultaneously, a strong global trend towards urbanisation of poverty exists, with increased challenges for urban populations and local governance to protect and sustain the wellbeing of growing cities. In the context of these 2 overarching trends, interdisciplinary research at the city scale is prioritised for understanding the social impacts of climate change and variability and for the evaluation of strategies in the built environment that might serve as adaptive responses to climate change. This article discusses 2 recent initiatives of The Earth Institute at Columbia University (EI) as examples of research that integrates the methods and objectives of several disciplines, including environmental health science and urban planning, to understand the potential public health impacts of global climate change and mitigative measures for the more localised effects of the urban heat island in the New York City metropolitan region. These efforts embody 2 distinct research approaches. The New York Climate & Health Project created a new integrated modeling system to assess the public health impacts of climate and land use change in the metropolitan region. The Cool City Project aims for more applied policy-oriented research that incorporates the local knowledge of community residents to understand the costs and benefits of interventions in the built environment that might serve to mitigate the harmful impacts of climate change and variability, and protect urban populations from health stressors associated with summertime heat. Both types of research are potentially useful for understanding the impacts of environmental change at the urban scale, the policies needed to address these challenges, and to train scholars capable of collaborative approaches across the social and biophysical sciences.

Wentz, E. A., et al. (2014). "Supporting Global Environmental Change Research: A Review of Trends and Knowledge Gaps in Urban Remote Sensing." Remote Sensing **6**(5): 3879-3905.
This paper reviews how remotely sensed data have been used to understand the impact of urbanization on global environmental change. We describe how these studies can support the policy and science communities' increasing need for detailed and up-to-date information on the multiple dimensions of cities, including their social, biological, physical, and infrastructural characteristics. Because the interactions between urban and surrounding areas are complex, a synoptic and spatial view offered from remote sensing is integral to measuring, modeling, and understanding these relationships. Here we focus on three themes in urban remote sensing science: mapping, indices, and modeling. For mapping we describe the data sources, methods, and limitations of mapping urban boundaries, land use and land cover, population, temperature, and air quality. Second, we described how spectral information is manipulated to create comparative biophysical, social, and spatial indices of the urban environment. Finally, we focus how the mapped information and indices are used as inputs or parameters in models that measure changes in climate, hydrology, land use, and economics.

Vereecken, H., et al. (2012). "Characterization of Crop Canopies and Water Stress Related Phenomena using

Microwave Remote Sensing Methods: A Review." Vadose Zone Journal **11**(2).

In this paper we reviewed the use of microwave remote sensing methods for characterizing crop canopies and vegetation water stress related phenomena. Our analysis includes both active and passive systems that are ground-based, airborne, or spaceborne. Most of the published results that have examined crop canopy characterization and water stress have used active microwave systems. In general, quantifying the effect of dynamic vegetation properties, and water stress related processes in particular, on the measured microwave signals can still benefit from improved models and more observational data. Integrated data sets providing information on both soil status and plant status are lacking, which has hampered the development and validation of mathematical models. There is a need to link three-dimensional functional, structural crop models with radiative transfer models to better understand the effect of environmental and related physiological processes on microwave signals and to better quantify the impact of water stress on microwave signals. Such modeling approaches should incorporate both passive and active microwave methods. Studies that combine different sensor technologies that cover the full spectral range from optical to microwave have the potential to move forward our knowledge of the status of crop canopies and particularly water related stress phenomena. Assimilation of remotely sensed properties, such as backscattering coefficient or brightness temperature, in terms of estimating biophysical crop properties using mathematical models is also an unexplored avenue.

Yan, W. Y., et al. (2015). "Urban land cover classification using airborne LiDAR data: A review." Remote Sensing of Environment **158**: 295-310.

Distribution of land cover has a profound impact on the climate and environment; mapping the land cover patterns from global, regional to local scales are important for scientists and authorities to yield better monitoring of the changing world. Satellite remote sensing has been demonstrated as an efficient tool to monitor the land cover patterns for a large spatial extent. Nevertheless, the demand on land cover maps at a finer scale (especially in urban areas) has been raised with evidence by numerous biophysical and socio-economic studies. This paper reviews the small-footprint LiDAR sensor one of the latest high resolution airborne remote sensing technologies, and its application on urban land cover classification. While most of the early researches focus on the analysis of geometric components of 3D LiDAR data point clouds, there has been an increasing interest in investigating the use of intensity data, waveform data and multi-sensor data to facilitate land cover classification and object recognition in urban environment. In this paper, the advancement of airborne LiDAR technology, including data configuration, feature spaces, classification techniques, and radiometric calibration/correction is reviewed and discussed. The review mainly focuses on the LiDAR studies conducted during the last decade with an emphasis on identification of the approach, analysis of pros and cons, investigating the overall accuracy of the technology, and how the classification results can serve as an input for different urban environmental analyses. Finally, several promising directions for future LiDAR research are highlighted, in hope that it will pave the way for the applications of urban environmental modeling and assessment at a finer scale and a greater extent (C) 2014 Elsevier Inc. All rights reserved.

Yebra, M., et al. (2013). "A global review of remote sensing of live fuel moisture content for fire danger assessment: Moving towards operational products." Remote Sensing of Environment **136**: 455-468.

One of the primary variables affecting ignition and spread of wildfire is fuel moisture content (FMC). Live FMC (LFMC) is responsive to long term climate and plant adaptations to drought, requiring remote sensing for monitoring of spatial and temporal variations in LFMC. Liquid water has strong absorption features in the near- and shortwave-infrared spectral regions, which provide a physical basis for direct estimation of LFMC. Complexity introduced by biophysical and biochemical properties at leaf and canopy scales presents theoretical and methodological problems that must be addressed before remote sensing can be used for operational monitoring of LFMC. The objective of this paper is to review the use of remotely sensed data for estimating LFMC, with particular concern towards the operational use of LFMC products for fire risk assessment. Relationships between LFMC and fire behavior have been found in fuel ignition experiments and at landscape scales, but the complexity of fire interactions with fuel structure has prevented linking LFMC to fire behavior at intermediate scales. Changes in LFMC have both direct (liquid water absorption) and indirect (pigment and structural changes) impacts on spectral reflectance. The literature is dominated by studies that have used statistical (empirical) and physical model-based methods applied to coarse resolution data covering the visible, near infrared, and/or shortwave infrared regions of the spectrum. Empirical relationships often have the drawback of being site-specific, while the selection and parameterization of physically-based algorithms are far more complex. Challenges remain in quantifying error of remote sensing-based LFMC estimations and linking LFMC to fire behavior and risk. The review concludes with a list of priority areas where advancement is needed to transition remote sensing of LFMC to operational use. (C) 2013 Elsevier Inc. All rights reserved.

Zhou, X. H., et al. (2013). "An imperative need for global change research in tropical forests." Tree Physiology **33**(9): 903-912.

Tropical forests play a crucial role in regulating regional and global climate dynamics, and model projections suggest that rapid climate change may result in forest dieback or savannization. However, these predictions are largely based on results from leaf-level studies. How tropical forests respond and feedback to climate change is largely unknown at the ecosystem level. Several complementary approaches have been used to evaluate the effects of climate change on tropical forests, but the results are conflicting, largely due to confounding effects of multiple factors. Although altered precipitation and nitrogen deposition experiments have been conducted in tropical forests, large-scale warming and elevated carbon dioxide (CO2) manipulations are completely lacking, leaving many hypotheses and model predictions untested. Ecosystem-scale experiments to manipulate temperature and CO2 concentration individually or in combination are thus urgently needed to examine their main and interactive effects on tropical forests. Such experiments will provide indispensable data and help gain essential knowledge on biogeochemical, hydrological and biophysical responses and feedbacks of tropical forests to climate change. These datasets can also inform regional and global models for predicting future states of tropical forests and climate systems. The success of such large-scale experiments in natural tropical forests will require an international framework to coordinate collaboration so as to meet the challenges in cost, technological infrastructure and scientific endeavor.