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Author: Cohn, Avery

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Leveraging Climate Regulation by Ecosystems for Agriculture to Promote Ecosystem Stewardship

Avery Cohn[1]

Abstract

One in every five patches of tropical forest near agriculture in Brazil appears to contribute more to agricultural production by preventing crop-killing extreme heat exposure than it could produce if it were converted to cropland itself. In this commentary, I refer to this and other forms of climate regulation by ecosystems and beneficial for agriculture as E4A. E4A is a readily employable and largely untapped concept for protecting and restoring tropical ecosystems. The promise of E4A lies in demonstrating sizeable production-protection synergies relevant for critical actors. Using a consultative research process, I gauged the current and future status of E4A science and action in tropical land use decision-making. Stakeholders flagged unmet demand for E4A in support of decisions tied to numerous regulatory, governance, and business processes. Results from a complementary literature review revealed gaps in research, advocacy, and entrepreneurship. I close by discussing opportunities to relieve E4A pain points to catalyze tropical ecosystem stewardship.

Keywords

climate regulation, ecosystem services, cobenefits, climate change adaptation, forest conservation

Introduction

Interventions to protect and restore tropical ecosystems must better engage local and agricultural actors (Cohn & Rourke, 2011; Rueda, Garrett, & Lambin, 2017). I propose to increase tropical ecosystem stewardship by these strategic actors by spotlighting an underemphasized environmental service—climate regulation by ecosystems for neighboring agriculture (E4A).

The promise of E4A for ecosystem stewardship lies in demonstrating sizeable, able to be monetized production-protection synergies relevant for critical actors. E4A values ecosystems for many actors who determine ecosystem conversion including investors, local governments, and agribusinesses. E4A also creates a shared agenda for agriculture and conservation by showing that production depends on protection. I led a recent analysis showing that E4A can substantially realign the economics of tropical land use. In Brazil, roughly one in every five locations of tropical forest near agriculture appears to contribute more to agricultural production by preventing crop-killing extreme heat exposure to crops within 25 km than it could produce if it were converted to cropland itself (Cohn & Soares Filho, 2017). We also found the net present value of standing forests for climate regulation exceeded the carbon value of tropical forests in greater than 30% of locations. Combined, carbon value and climate regulation value were worth more than the market price for Brazilian cropland in just under 50% of locations. Carbon and agricultural extreme heat regulation are just two of many values to society from forest ecosystem services. Their sum is a lower bound estimate of the value of ecosystems for society and an even lower bound for the able-to-be-monetized value of ecosystems. Forests supply myriad other sources of value for local to regional natural resource economies (Carrasco, Nghiem, Sunderland, & Koh, 2014; Carpenter et al., 2009;

[1]Tufts University, Medford, MA, USA

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Corresponding Author:
Avery Cohn, Tufts University, 160 Packard Ave, Medford, MA 02155-5815, USA.
Email: avery.cohn@tufts.edu

Garibaldi et al., 2016; Maas, Clough, & Tscharntke, 2013; Stickler et al., 2013).

Quantifying E4A Means Linking Research Frontiers in Climate Modeling and Crop Modeling

The value of E4A information stems from avoiding losses to agriculture from the protection and restoration of ecosystems (Figure 1). The scientific foundation of E4A depends on synthesis of the study of the response of climate to ecosystem conversion with the study of the response of crops to climate. Both components must also weigh the changing influence of greenhouse gas-driven climate change on agriculture and ecosystems.

Regional Climate Modeling

In the tropics, climate change from global greenhouse gas emissions can be rivaled by a second type of climate change from disruptions to energy and water cycling caused by ecosystem conversion (Ellison et al., 2017; Silvério et al., 2015). This latter type of climate change, known as geophysical climate change, accrues at spatial scales from the agricultural plot (Frey et al., 2016) to the planet (Nobre et al., 2016). In regions of high ecosystem conversion intensity, a series of recent findings show that already-occurred amounts of geophysical climate change have in some locations and for some climate metrics exceeded the amount of global climate change projected by end of century under the highest emissions widely modeled scenario (Cohn, Bhattarai, Duncan, & Jeffries, 2017). The two types of climate change can also often combine (Lawrence & Vandecar, 2015) to worsen departures from today's climate (Bagley, Desai, Harding, Snyder, & Foley, 2014).

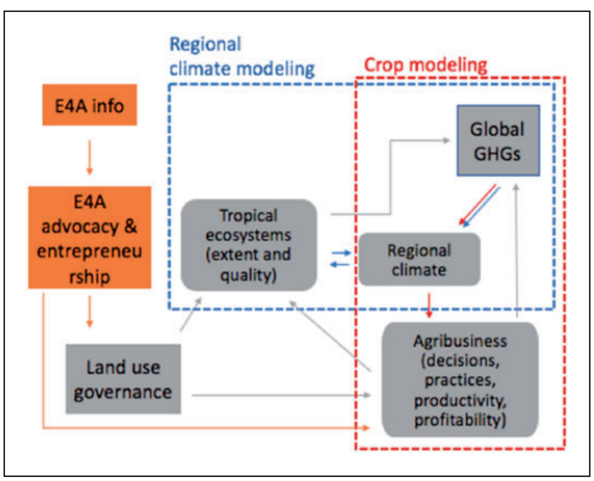

Figure 1. Information on climate regulation services from tropical ecosystems for agriculture (E4A) can promote ecosystem stewardship. The schematic theorizes how E4A can fuel a set of advocacy and entrepreneurship activities that increase the ambition for tropical ecosystem conservation in an existing set of land use governance and business activities. The provision of E4A information stems from fusion of regional climate modeling and crop modeling.

Crop Modeling

Extreme heat, extreme precipitation, delayed rainy season onset, and vapor pressure deficit (Lawrence & Vandecar, 2015) are several climate changes caused by ecosystem conversion, worsened by global climate change and threatening tropical frontier agriculture (Cohn, VanWey, Spera, & Mustard, 2016; Pires et al., 2016). Research on risks posed by climate change to tropical crop productivity is rapidly advancing—enabling more precise estimates of the economic costs of climate change for frontier agriculture and the attribution of a share of these costs to ecosystem conversion.

E4A: Transforming the meaning of ecosystems for agriculture

E4A can transform how agribusiness actors engage in climate and ecosystem governance. First, E4A shows tropical ecosystem stewardship to be a source of locally valuable public and private goods. Farmers neighboring a protected area might benefit from climate regulation. Both a farmer and their neighbors might benefit from stewardship of on-farm ecosystem patches. In this way, climate regulation is a type of local incentive for or co-benefit[1] from ecosystem stewardship. Generally, environmental governance (including both forest and climate governance) has not widely explored spotlighting or internalize such incentives (Green, 2015). A second transformational dimension of E4A is its potential to shift conceptions of deforestation risk to include not only reputation and regulation risk but also operations risk. This shift can engage and enroll a wider and more influential set of agricultural decision-makers in tropical ecosystem protection. Third, E4A also links forest conservation with climate impact risk; reframing climate impact risk from strictly *force majeure* (Giannakis & Papadopoulos, 2016) to a type of risk that can be mitigated with local land management. Fourth, perhaps the shift can enlist agritech precision agriculture efforts for the tropical ecosystem protection agenda. Tens of billions of dollars are invested annually in research, development, and information systems for closing yield gaps within farms and even within fields. Finally, ecosystem driven climate change and E4A from ecosystem protection are contemporary observable realities. By contrast, greenhouse gas-driven climate change and especially the benefits of reduced emissions are, respectively, not easily discernible and anticipated to be indiscernible for at least a decade. Getting agricultural actors focused on E4A can be a gateway to deepening climate engagement and ambition in the sector.

Targeting E4A to Decision Processes

Advocacy and entrepreneurship addressing E4A needs scientific evidence that is: (a) tailored to specific leverage or pain points in contemporary decision processes; and (b) built on a foundation of generalizable systems research (and the datasets underlying it) into the climate, land and ecosystem components of E4A (see Figure 2 for a schematic).

I used an exploratory set of research[2] activities with E4A stakeholders to identify priority decision processes for E4A information. Processes identified comprise non-state market-driven governance, land use regulation, and investment and entrepreneurship in tropical agriculture. Informants mentioned numerous decision processes. These included:

- agricultural sustainability standards such as the Roundtable on Responsible Soybeans, the Soybean Moratorium, and the Cattle Agreement (Nepstad, Boyd, Stickler, Bezerra, & Azevedo, 2013; Gibbs et al., 2016)
- climate insurance take up and insurability (Barnett & Mahul, 2007)
- conversion of cattle pasture to mechanized agriculture (Cohn, Gil, Berger, Pellegrina, & Toledo, 2016)
- predictability of agricultural loan defaults (Miranda & Gonzalez-Vega, 2011)
- the Brazilian Forest Code (Soares-Filho et al., 2016)
- region to national scale agriculture production forecasting (Verdin, Funk, Senay, & Choularton, 2005)
- investment in agricultural and commercial forestry land and infrastructure (Lambin & Meyfroidt, 2011)
- viability of multiple crop per season agricultural systems in a changing climate (Cohn et al., 2016; Pires et al., 2016)
- regional to national land use zoning (Fischer et al., 2008)
- agriculture and energy infrastructure siting (Elliott et al., 2014; Stickler et al., 2013)
- payment for ecosystem services schemes (Bernard, de Groot, & Campos, 2009)
- integration of forestry with crop and livestock systems (Gil, Siebold, & Berger, 2015)
- cattle ranching intensification (Cohn, Bowman, Zilberman, & O'Neill, 2011; Cohn et al., 2014)
- program evaluation of agricultural technology adoption interventions (Burke & Lobell, 2017)
- protected areas siting (Polasky et al., 2008)
- tropical agritech business development
- targeted credit for ''low carbon agriculture'' (Newton et al., 2016)
- adoption of mechanized agriculture (Cohn et al., 2016)
- supply chain climate risk reduction (Stanny & Ely, 2008)

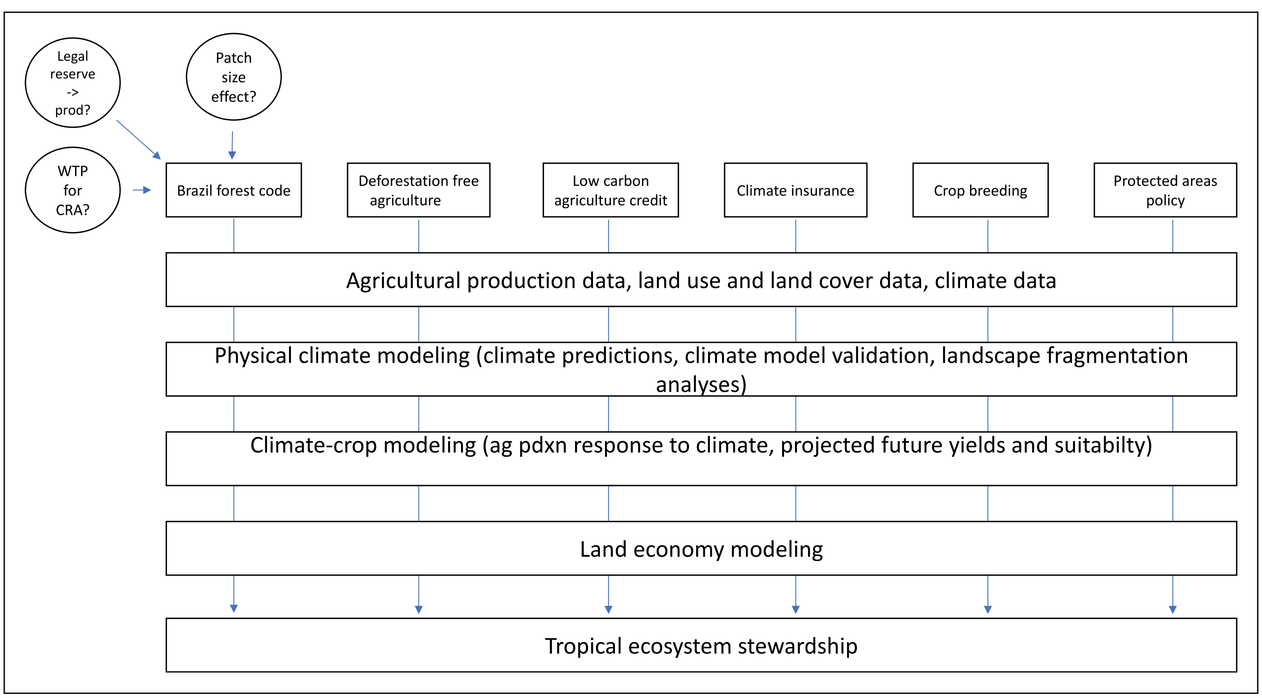

Figure 2. Tailored research questions rest on generalizable E4A evidence and models.

The list of decision processes extended beyond forest governance and included a number of themes related to climate mitigation, impacts, and adaptation.

Brazilian Forest Code: How Tailoring E4A Research Makes It Actionable

Within each decision process, respondents stressed how actionable research would need to support discrete decisions. For example, the Brazilian Forest Code entails multiple research questions that can be shaped by E4A-relevant data and evidence including: (a) how much would a given amount of forest reserve increase agricultural productivity? (b) how much does E4A change with patch size? (c) How much more should a producer be willing to pay to maintain on farm forest versus acquire tradeable forest certificates? (d) How should Questions 1 to 3 influence land or agricultural investment decisions? (e) How should Questions 1 to 3 influence lobbying for Forest Code stringency and revisions? (f) How should Questions 1 to 3 affect advocacy strategies seeking to raise Forest Code ambition?

Cross Cutting Demand for Data and Evidence

A set of foundational types of E4A spatial datasets and evidence categories emerged as relevant for many of the decision analyses detailed. The dataset types include most previously identified as germane for terrestrial conservation decision support (Chaplin-Kramer et al., 2015) but also include climate datasets. Notably, limits to *in situ*

Table 1. Relevance of E4A Information and Data.

Data/relationship	Description
Past climate trends	Many decisions such as land investments for crops, agricultural infrastructure siting, and decisions to comply with forest reserve policies depend on assumptions about agricultural productivity derived from historical data under historical climate conditions. These decisions would likely be altered by robust information on climate trends and their spatial variation. Such efforts should focus on trends in not only widely used climate metrics (e.g., mean temperature) but also climate metrics known to be of relevance for tropical agriculture (e.g., rainy season onset date, Pires et al., 2016, dry spells in the rainy season, de Carvalho, Assad, Evangelista, & da Silveira Pinto, 2013, drought variability, Duffy, Brando, Asner, & Field, 2015, and extreme heat exposure, Schlenker & Roberts, 2009.
Temperature and precipitation data	Much of the tropics has an extremely low density of weather stations (Fick & Hijmans, 2017) and in many regions, density is declining (Wohl et al., 2012). New datasets that examine biases in weather data and quantify data selection uncertainty at the scale of kilometers are beginning to appear and must be translated to the agricultural community.
Climate projections (given combination of ecosystem loss and GHGs)	A new set of global climate modeling experiments activities are underway, designed to disentangle climate forcing from GHGs and changes in local and regional climates stemming from land use activities (Eyring et al., 2016). Emulation (Castruccio et al., 2014) of the results of these experiments would enable crop and economic modeling exploring the range of possible climate outcomes from changes in land use and land cover.
Agricultural productivity	Across much of the tropics, coarse scale and inaccurate crop yield data has hampered yield gap analysis and stymied interventions to close yield gaps (Burke & Lobell, 2017). New spatially explicit yield datasets, including a soybean yield dataset for Brazil (Jeffries & Cohn, 2017), are enabling decision-makers to benchmark yield, yield variability, and yield trends within counties and even within rural properties.
Lost ecosystem services from landscape fragmentation	Climate benefits from ecosystems for agriculture depend on ecosystem health which in turn often depends on ecosystem patch size and connectivity (Chaplin-Kramer et al., 2015). These data can modulate the incentives for patchiness that climate regulation service modeling might otherwise suggest.
Climate model validation	The stakeholder consultation revealed that numerous agribusiness stakeholders and climate modeling experts raise credibility concerns regarding land use and land cover change climate model experiments. Empirical validation boosts credibility of results.
Agricultural production response to climate	Scholarly research into agricultural production response to climate in tropical agricultural frontiers is growing but still limited (Cohn et al., 2016; Pires et al., 2016). Issues include identification of critical response, temperature response thresholds and the geographic and management specificity of crop response to climate shocks.

Note. This table summarizes results of stakeholder consultations and a literature review on, respectively, the demand for and supply of E4A information.

data of all germane types at the tropical agriculture-forest frontier means a heavier reliance on remote sensing-derived climate, agricultural production, and land cover data. Evidence categories include all causal relationships depicted by arrows in Figure 1.[3] Table 1 contains a discussion of the state of science and information for these datasets and evidence categories, given the information demands detailed in the consultative research. In sum, much data and evidence needed for decision support is readily available in some critical ecosystems of the tropics. However, even in these critical regions, basic research opportunities exist to close data and information gaps of immediate relevance for ecosystem protection.

Concluding Remarks

Agricultural productivity gains from climate regulation by ecosystems can increase support for ecosystem stewardship. A recently completed expert consultation revealed numerous decision processes in which such information could help to justify agricultural decisions and practices that help to steward tropical ecosystems. Engagement should take many forms including actionable research tailored to decision processes, decision support systems, advocacy, entrepreneurial efforts and targeted investment. The science of E4A is rapidly developing and stands ready to support numerous decision processes. Science advocacy and science-industry engagements will also help to grow actionable research.

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Notes

1. Here, I define local co-benefits as local co-benefits net of local co-costs. For more, see Ürge-Vorsatz, Herrero, Dubash, and Lecocq (2014).
2. Research was performed over the period of September 2014 to March 2017. It included focus groups with farmers in Brazil on constraints to technology adoption, a workshop on supply chain climate risk with agribusiness stakeholders, consultations with Indian and Brazilian agribusiness representatives concerning climate risk, interviews with agritech professionals in Boston and San Francisco on the climate risk-precision agriculture nexus, a consultation with professionals working on agricultural development in multilaterals on the climate risk-sustainable intensification nexus, and a series of conversations with tropical forest conservation advocates on the climate risk-tropical deforestation nexus.
3. Blue arrows show primary relationship of focus for climate modeling and brick red arrows show primary relationships for crop modeling.

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