# TROPICAL RESOURCES

The Bulletin of the Yale Tropical Resources Institute

## Contents

## The Bulletin

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## About TRI

### Mission

The Mission of the Tropical Resources Institute is to support interdisciplinary, problem oriented, and applied research on the most complex challenges confronting the management of tropical resources worldwide. Lasting solutions will be achieved through the integration of social and economic needs with ecological realities, the strengthening of local institutions in collaborative relationships with international networks, the transfer of knowledge and skills among local, national, and international actors, and the training and education of a cadre of future environmental leaders.

The problems surrounding the management of tropical resources are rapidly increasing in complexity, while demands on those resources are expanding exponentially. Emerging structures of global environmental governance and local conflicts over land use require new strategies and leaders who are able to function across a diversity of disciplines and sectors and at multiple scales. The Tropical Resources Institute seeks to train students to be leaders in this new era, leveraging resources, knowledge, and expertise among governments, scientists, NGOs, and communities to provide the information and tools this new generation will require to equitably address the challenges ahead.

### TRI News

*Publications*

We are building a database of all publications resulting from TRI support. If you are a previous TRI Fellow, and published *anything* resulting from your fellowship research (journal article, book, popular press article, webpage, report, …), please let us know at tri@yale.edu.

## The Burch Prize

The William R. Burch Prize is named in honor of the influential founding director of TRI. The $1,000 prize, generously funded by TRI alumni, is awarded annually to the paper written by a TRI Fellow published in *Tropical Resources* that best reflects Bill's visionary interdisciplinary leadership of TRI, as well as the mission of TRI: to support interdisciplinary, problem-oriented student research on the most complex challenges confronting the conservation and management of tropical environments and natural resources worldwide.

## A Word from the Director

In this volume (Vol. 37) of *Tropical Resources*, we present the research of five TRI Fellows who conducted fieldwork in 2017. Their fieldwork was carried out in the tropics of the Americas and Africa, and included floristic surveys, socio-economic impact surveys, and recommendations for ecosystem service valuations.

First, Caroline Hobbs (MEM) describes how to use photographic images to quantify the differences between different colored morphs of a common Hawaiian coral that is being impacted by climate change and changes in light levels. Caroline demonstrated that it is possible to determine morph color from photographic images, thus it is possible to survey large areas of coral and establish the health and likely impact of climate change on coral reefs.

In a second article, Caroline discusses how ecosystem service and natural capital valuations can be improved through the use of better community engagement, and data collection, management, and access, as well as different stakeholder valuation systems. She highlights some NGOs doing interesting work in this area.

Third, Beryl Ajwang' (MEM) delves into the factors affecting how the uptake of pay-as-you-go solar products influences digital financial access in Kenya, where much of the rural population has no access to mains electricity. She discovers some innovative ways that companies and individuals are working to minmize risk and maximize the benefits of both these technologies.

Fourth, Katherine Young (MFS) documents the floristics of *cabrucas*, cacao agroforestry systems in Brazil, that have great potential to act as a reservoir of diversity and may be comparable to secondary forest in terms of their structure and function.

Fifth, Coral Bielecki (MESc) provides a holistic account of the history of Kahoʻolawe, an island of Hawaiʻi that has undergone extreme political, sociological, and ecological change. Coral make recommendations for its full restoration in legal and ecological terms.

Finally, Christopher Martin (MF-MBA) covers the effects of impact investing in reducing deforestation in Acre, Brazil. Is it possible to broaden the economies of rural communities and small-scale landowners to minimize further unsustainable agricultural practices such as slash-and-burn?

In all these studies, TRI Fellows are addressing critical local issues that have global repurcussions for human wellbeing and the environment.

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## TRI Fellows research sites represented in this issue


**Hawaii:** Caroline Hobbs

**Kenya:** Beryl Ajwang'

**Hawaii:** Coral Bielecki

**Brazil:** Kata Young

**Brazil:** Christopher Martin

Hobbs. C. 2018. Quantitative differentiation of color morphology in the colonial coral *Montipora capitata*. *Tropical Resources* **37**, 1–8.

# Quantitative differentiation of color morphology in the colonial coral *Montipora capitata*

*Caroline Hobbs, MEM*[*], *Dennis Conetta*[†], *Carlo Caruso*[‡], *Mariana Rocha de Souza*[‡], *Ruth Gates*[‡]

**Abstract**

Color is an intuitive indicator of phenotype for a biologist or ecologist in their study of species adaptation and evolution, and simultaneously is one of the fastest-learned species identification tools for the citizen scientist. Quantifying color reliably and differentiating between morphs (in a consistent and rigorous manner) strengthens the validity of any scientific experiment or morph identification. Inconsistent identification of color may result in imprecise conclusions within studies and poor linkages amongst studies in a given body of knowledge. In this paper, we look at two subjectively differentiated color morphs of the pacific coral *Montipora capitata* and assess the quantitative difference between those identified as 'Orange' and as 'Brown'. We found that 'Orange' coral morphs occupied significantly different RGB color space than corals qualitatively identified as 'Brown' morphs. The results of this study will directly inform further research on *M. capitata*'s colormorphs and their stress response to light, allowing us to consider separate physiological responses of 'Brown' versus 'Orange' phenotypes.

## Introduction

Throughout their life cycle, biological organisms are exposed to a wide variety of stressors, including external attack (or fear of attack) by predators, herbivores, or disease, a critical lack of resources (e.g., drought or shade), and even excess of a resource or condition (such as temperature or $CO_2$) (Gibson et al. 2011). These stressors can have distinct effects on specific organisms. In particular, because sessile organisms such as plants and corals do not have the immediate option to move away from stressors, they have evolved a range of internal responses to attempt to alleviate or adapt to stress (Menge et al. 1987; Nevo et al. 2001). Corals—marine invertebrates that contain photosynthetic dinoflagellates that live symbiotically within their tissues—appear particularly susceptible to abiotic stressors. These stressors include variation in ocean temperature, light levels, and $CO_2$ concentration, all of which are exacerbated by anthropogenic climate change (Brown et al. 1985). The ability to directly assess coral stress would allow us to estimate the severity of climate change impacts on marine ecosystems.

The overall expression of color in a coral is

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thought to be a combination of protein florescence (determined by genetic make-up) in the coral host and the community composition of functionally diverse dinoflagellates, *Symbiodinium*, present in a coral's tissue at a given time. Distinct color morphs of various coral species have been identified qualitatively and used to study coral's varying epigenetic responses to stressors such as bleaching and disease (Innis et al. 2018, Shore-Maggio et al. 2018). The dominance of a specific clade of *Symbiodinium* found in a coral at a given time (and the consistency of this community make-up over time) may also help us to identify and predict coral colonies' response to environmental changes or stress (Innis et al. 2018). While within-species color morphs are distinct from one another based on their color differences (which may be understood as their phenotypic expression), color change is also a clear indication of a stressor (to which different morphs have been shown to respond differently; Innis et al. 2018, Shore-Maggio et al. 2018). In white band disease, a distinct white band is visible around the coral in contrast to surrounding pigmented tissue (Aronson et al. 2001), while in coral bleaching, tissue changes from deep browns to pale browns and eventually to white in response to heat-induced stress. These color changes are attributed to *Symbiodinium* loss.

Thus, at any given time, coral color and coral color change can be partially attributed to *Symbiodinium* density and partially attributed to the interaction of the dominant clade of *Symbiodinium* and genetic make-up of coral host. With a stronger understanding of color expression and clearer identification of the morphs in question, coastal management and restoration efforts could be finely tailored to aid the health of reef building species like *Montipora capitata*. Further, the study of coral color morph shows great promise in the attempt to better understand coral epigenetics, resilience, and potential for short term adaptation (Putnam et al. 2016). This may include increased accessibility to the citizen scientist and even an easily identifiable measure of ecosystem resilience potential in a reef community.[1]

*Montipora capitata* Dana. (Acroporidae) is a scleractinian Indo-pacific reef-building coral, common in Hawai'i, which exists as two distinct color morphs (Innis et al. 2018, LaJeunesse et al. 2004, Shore-Maggio et al. 2018). These two morphs have been identified clearly but have yet to be quantitatively or consistently characterized. For example, the two morphs are referred to as 'Red' and 'Orange' morphs by Shore-Maggio et al. (2018), and 'Brown' and 'Orange' morphs by Innis et al. (2018), where 'red' and 'brown' probably refer to the same morph. This labeling mismatch may create confusion and highlights the need for a proven, quantitative and consistent, identification system to define the color morphs of *Montipora capitata*. Confirming that the two morphs are reliably different will create a rigorous backing for future study of coral color morphology and for progress made previously with reference to color morphs of *Montipora capitata*.

In this study we attempted to quantitatively differentiate between the two apparent color morphs. Using the imaging software ImageJ (Schneider et al. 2012) we standardized the objective color space (red-green-blue, RGB) to quantify the color of the experimental fragments which were preliminarily identified as 'Brown' or 'Orange' colonies. These experimental fragments were photographed over a ten-week period to track each color morph's response to varying depth (light by proxy) treatments.

[1]Coral color has been used effectively as a key indicator of reef health in citizen science initiatives such as CoralWatch (Fabricius et al. 2011) and has been identified as one of the easiest indicators for the citizen scientist to pick up and relate to (Davis 1977, Benbasat 1985). Understanding the implications of variation in coral color can thus inform the development of citizen science projects in the marine management sphere. This may include developing a measure of or scale for ecosystem resilience based on genetic makeup or potential for adaptation of a community. Coral color data and differentiation can also inform and validate remote sensing monitoring techniques (Leiper et al. 2009), bridging disciplines and improving global coral health data.

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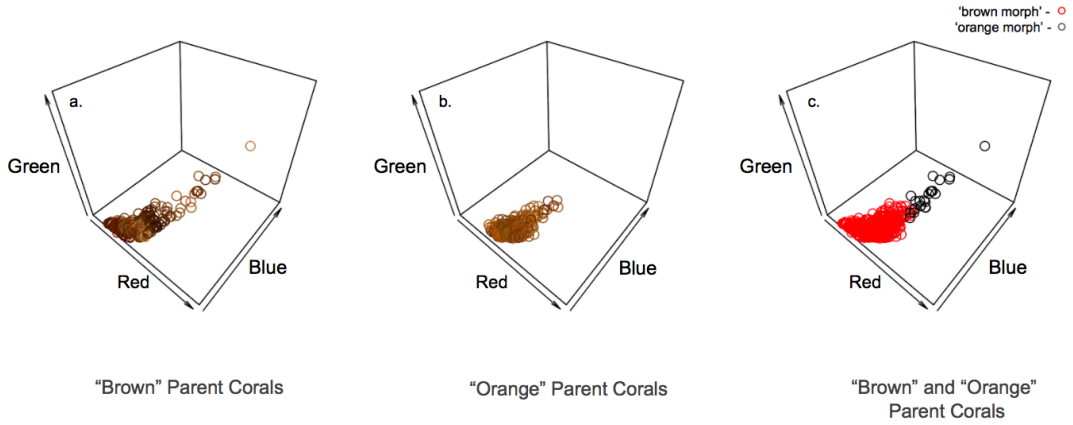


**Fig. 1.** Parent coral color in 3D RGB space. (a). The distribution in 3D RGB color space of 'brown' parent corals (n = 240) at time point = 0. Points are the color of the data they represent and lie in that RGB space. (b). The distribution in 3D RGB color space of 'orange' parent corals (n = 240) at time point = 0. Again, points are the color of the data they represent and lie in that RGB space. (c). The distribution in 3D RGB color space of 'brown' and 'orange' parent corals (n = 240) at time point = 0 represented by red and black points respectively.

## Methods

*Study site*

Kaneohe Bay, Hawai'i (21.4282° N, 157.7919° W) is a eutrophic ecosystem, characterized by patchy reef flats dominated by *Montipora capitata* Dana. (Acroporidae) and *Porites compressa* Dana. (Poritidae) (Cox et al. 2006, Jokiel 1987, Shore-Maggio et al. 2018).

*Sampling*

Thirteen medium sized, plating growth-form *Montipora capitata* parent corals were chosen for this study. These corals were obtained from a floating coral nursery, which consisted of colonies of opportunity that had been rescued from a construction site. The parent colonies collected for this study were kept at a consistent depth of 6 ft. for two weeks before being chosen; six of these were qualitatively identified as 'Brown' morph parent colonies and seven qualitatively identified as 'Orange' morph parent colonies. These 13 parent corals were each cut with a diamond cutter into four pieces and those pieces were glued onto plugs to be placed on crates we created for four treatment groups (all within the nursery): shallow (3 ft. depth), control (6 ft. depth), deep (9 ft. depth), and shade (6 ft. depth shaded by a netted platform). Each of the original 13 parent colonies were photographed such that all four of the fragments that made up each colony were photographed next to a color card, at a fixed depth, with a camera mount we designed and built to minimize color distortion.

*Color data analysis*

We used ImageJ v. 1.51 (Schneider et al. 2012) to extract the RGB color values (Appendix A). Each photograph was color corrected using an ImageJ plug-in which corrected the photo to the true values of black and white using the gray scale on the color card. From each corrected image, we sampled 10 circular regions 175 pixels in diameter and calculated a mean RGB color value for each region. To test that our subjective assignment of 'Brown' versus 'Orange' color morph was consistent with RGB color space, we first plotted each fragment in 3D

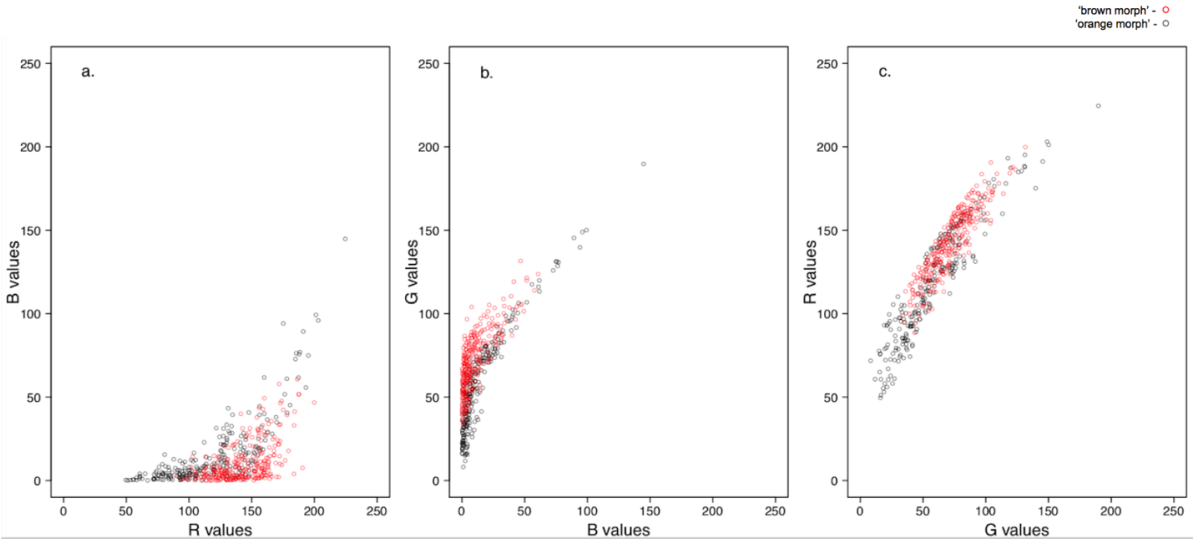


**Fig. 2.** Parent coral color in 2D space. The distribution in 2D color space of 'brown' (n = 28) and 'orange' (n = 24) parent corals at time point = 0, represented by red and black points respectively.

RGB space and then in 2D color space. Then we modeled two of the three colors in turn, for example green as a function of red, then red as a function of blue, then blue as a function of green, using linear mixed effects models. We ran two models for each combination of colors, with and without parent morph color, and compared the two models using ANOVA to test for a significant effect of morph color (Bolker et al. 2009). We have multiple color samples from each coral fragment and have thus set the random effect in all models to be "fragment".

## Results

As we hypothesized, the objective RGB color space showed a clear differentiation between 'Brown' and 'Orange' color morphs (Fig. 1 & 2). Further, in all three tests of one color on another, the model that included parent color was significantly different from the model without parent color. We see this in all three ANOVA models. Models 1 and 2, which look at red and blue values with and without parent coral color accounted for ($\chi^2$ = 28.9, df = 2, n = 240, p < 0.001), models 3 and 4, which look at green and blue values with and without parent coral color accounted for ($\chi^2$ = 162.9, df = 2, n = 240, p < 0.001), and models 5 and 6, which look at green and red values with and without parent coral color accounted for ($\chi^2$ = 213.7, df = 2, n = 240, p < 0.001). These results indicate that the models that included color as a variable were significantly more representative of the data than the models that did not include color. These results support our hypothesis that parent color was objectively different between the two morphs (Table 1).

## Discussion

In this paper we have attempted to quantitatively differentiate between 'Brown' and 'Orange' color morphs of the Pacific reef building coral, *Montipora capitata*. We see that coral color morphs qualitatively selected and observed in the field, can be quantitatively differentiated in RGB space. This process has exemplified a color differentiation methodology which may be utilized broadly (especially in the field of biology), creates a basis for phenotypic comparison within and among corals, and identifies a potential pathway for citizen science to incorporate a measure of reef community resilience.

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**Table 1.** Color Tests: This table presents the linear mixed effects models we ran and compared via ANOVAs. For example, green as a function of red including parent color compared to green as a function of red without accounting for parent color. We found that differentiating between color morphs created a more statistically significant representation of the color data. The random effect in all models was fragment.

| Model | Model Equation | ANOVA |
|---|---|---|
| R ∼ B + Color | B: y = 0.87x + 104.6 O: y = -0.06x + 28.6 | $\chi^2$ = 21.88, df = 2, p < 0.001 |
| R ∼ B | y = 0.085x + 119.9 | |
| B ∼ G + Color | B: y = 0.84x − 31.0 O: y = - 0.14x − 5.916 | $\chi^2$ = 162.98, df = 2, p < 0.001 |
| B ∼ G | y = 0.79x − 36.14 | |
| G ∼ R + Color | B: y = 1.10x − 67.4 O: y = - 0.16x + 11.33 | $\chi^2$ = 213.65, df = 2, p < 0.001 |
| G ∼ R | y = 1.03x − 64.44 | |

Clear differentiation between color morphs within a species creates potential for comparison over time that may help us identify mechanisms behind short-term adaptation to stressors based on coral-*Symbiodinium* partnerships and subsequent color expression. Without a quantitative difference in morphs, the ambiguity of morph identification creates significant margin for error in analysis of color, color change, and therefore also in analysis of phenotypic plasticity and adaptation. This is especially true considering the "shuffling" (Innis et al. 2018) of symbiont communities within a coral which alludes to potential for movement along a spectrum of color expression as the result of *Symbiodinium* community make-up at any given time; This may be both due to the highly diverse morphologies represented across the genus *Symbiodinium* and due to the varying timescales at which *Symbiodinium* community make-up may evolve in a given coral i.e., genetic make-up and potential for adaptation of the coral and symbiont community.

There is a significant amount of error incurred in a number of the aspects (arguably all aspects) of this color differentiation process, which is compounded by error present in areas flawed by inherent human biases. We attempted to minimize error throughout this process but recognize there is always room for improvement minimizing color identification error. We were forced to assign color-morph boundaries more or less arbitrarily. Ideally future methodology can be developed to define standardized and distinct RGB boundaries for categorizing color-morphs. Our hope is that a more rigorous, collaborative, and consistent color differentiation processes/technology will continue to develop within and beyond biology.

There is a communication gap between scientists, managers, and citizens all impacted by and impacting coastal health that creates detrimental inefficiencies in conservation and development efforts. A stronger understanding of coral biology (and subsequently increased potential for improved coastal health) will come from exploration of color morphs and their relationship to changing environments. This exploration cannot be justified without definition and differentiation of color morphs. With the interest around color morph as an indicator of *Symbiodinium* community make up (Innis et al. 2018) and maybe even as an indicator of a colony's ability to adapt to a given environment (Putnam et al. 2016), it is imperative that the language used to address these morphs is consistent and accessible. We have attempted to provide a clearly defined and consistent protocol to allow both the scientist and the citizen scientist to quantitatively differentiate between color morphologies. This protocal is a precursor to specifically identifying and labeling a color morphology.

We hope that with this basis of color differentiation, collaborative and consistent color identifica-

tion processes, which enhance the baseline for epigenetic understanding and improve the effectiveness of marine management strategies, will continue to emerge.

## Acknowledgements

This project was supported by the Tropical Resources Institute at Yale, the Hawai'i Institute of Marine Biology, Northeastern University's Three Seas Program, and the Yale School of Forestry and Environmental Studies. We would like to thank Simon Queenborough, Andrew Muehleisen, Beth Lenz, and Chris Wall for their support and consulting.

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## Appendix A

*Protocol in ImageJ*

Optimizing the Procedure:

1. Open color corrected photo
2. Use the oval function and draw an oval on the fragment
3. Hit Edit» Selection» Specify. Ensure that 'constrain' is on and that width and height are exactly the same. Make a perfect circle
4. Without clicking on the photo again hit Control B and draw a new circle. When done do not click on the photo, but hit Edit» Selection» Specify to make both circles the same dimensions (175 x 175)
5. Go to Image» Overlay» To ROI Manager

a. It will number and highlight both circles

6. Select the circle that the ROI Manager deems as circle #1 in the ROI Manage Tool Bar (on the left hand side) and press Add

a. This will create the same circle and provide a new number to this new circle
b. Click on the number in the middle of the circle and drag the circle to the desired spot on the fragment
c. Repeat step 6a and 6b until you have 10 circles equally distributed (by hand) across the coral

7. Without exiting out of the ROI Manager Tool Bar click on the first circle (either in the ROI Manager Tool Bar or physically click on the circle's number) and hit Plug-ins» Compile and Run

a. Find the RGB_Measure.java file and hit enter
b. Do this for each circle by selecting the number either in the ROI Manager or by selecting the circle by clicking on the number in the circle
c. When all 10 of the circle's data is complete go into the data tool bar and hit Ctrl A to select all and copy and paste it into an excel sheet
d. Repurpose the data accordingly on the excel sheet and clear the data in the data tool bar by not clicking in the data but by going to Edit» Clear with all the data selected (Ctrl A if they happen to deselect)

8. Without exiting ROI Manager, individually slide the circles to the next desired locations and repeat steps 7 and 8 to get all data on one picture (data for each of the fragments in the picture)

9. When you are done gathering the data for one photo hit File» Open Next to keep the circles on the photo and then you can slide them to where you would like and plug through steps 7-8.

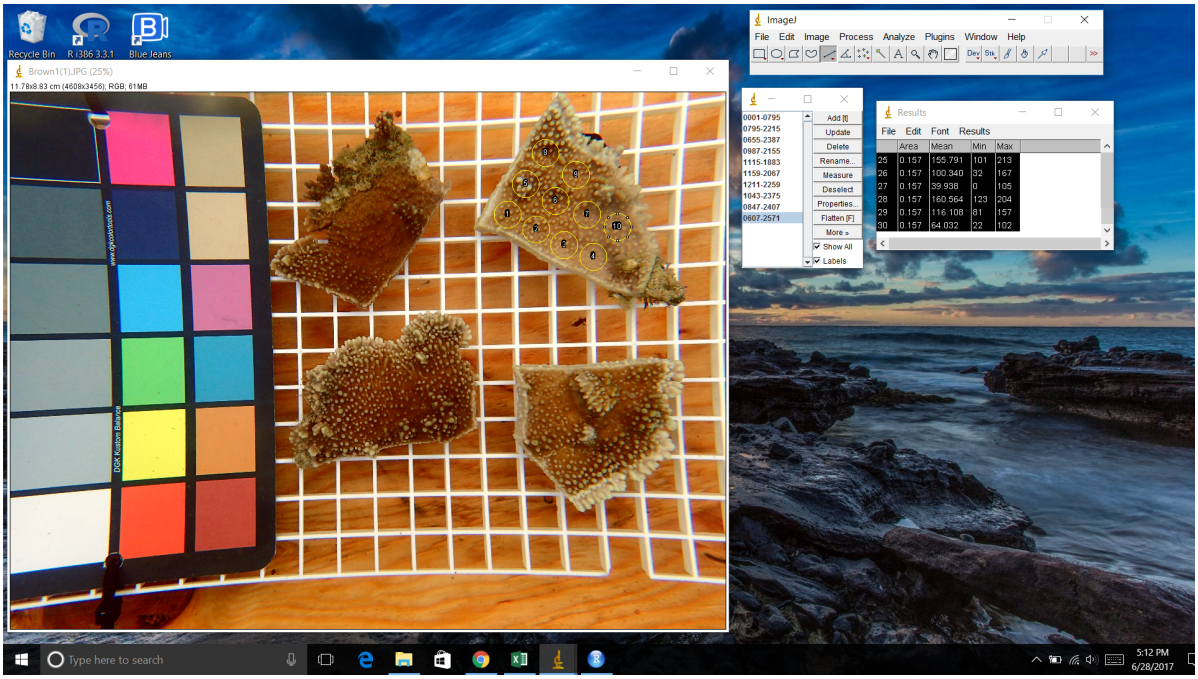


**Fig. 3.** A visual representation of the ImageJ color sampling process, after color correction.

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Hobbs. C. 2018. Inclusionary practices in the seeding and communication of ecosystem service valuations.
*Tropical Resources* **37**, 9–13.

# Inclusionary practices in the seeding and communication of ecosystem service valuations

*Caroline Hobbs, MEM*[*]

Quantitatively valuing natural capital, which can be understood as the valuation of benefits provided by ecosystem function to humans, is increasingly recognized as a powerful decision making tool in political, development, and management planning. Valuations increase the accuracy of cost benefit analyses used to manage and utilize resources for human activities, by creating a basis of comparison that aims to be widely recognized and respected. Furthermore, the research efforts that go into valuing natural capital allow us to better understand natural functioning and the potential for terrestrial, coastal, and aquatic ecosystems to provide resources that support human existence. It is less often that natural capital valuation is appreciated for its potential to shed light on humans' relationship with nature, its layering with and of complex value systems, and its potential to reinforce, separate and connect value across and within networks and communities.

## A History

The relationship between nature and the concept of value are deeply intertwined, and have been indirectly understood in the context of one another for centuries and arguably for all of human existence. Monetization of this value began formally in the 1970s with the framing of ecosystem functions as beneficial services to humans, in order to contribute to conservation efforts (Westman 1977, Ehrlich and Ehrlich 1981, de Groot 1987, Gómez-Baggethun 2010). With the development of global scale valuation methodologies (Costanza 1997) and excitement around the Millennium Ecosystem Assessment (2003), this relationship has evolved into economic valuation systems to inform policy and management (Costanza and Daly 1992, Perrings et al. 1992, Daily 1997). Payments for Ecosystem Services and other market-based instruments, which contribute to the monetization and commodification of ecosystems and their functioning (Sanchez-Azofeifa 2007) are a recent progression of this field. These tools have been a major policy focus in country's commitments to the Paris Agreement in their nationally determined contributions (NDCs) and in their work on the UN Sustainable Development Goals.

The evolution of ecosystem service valuation (ESV) has brought to light two main areas of current contingency. First, in the detachment of large scale of valuation processes from an individual's relationship to and part in nature. Global scale valuations have been argued to detract from potential local scale management benefits, and simultane-

[*]Caroline graduated from Yale F&ES in May with a Masters in Environmental Management focused on Marine Ecology and Environmental Communications. She has worked on coral restoration and community ecology projects with the Central Caribbean Marine Institute and aided in efforts to breed "super corals" at Hawai'i Institute of Marine Biology. On the communications side, Caroline directed finances for the Environmental Film Festival at Yale in 2018 and has worked closely with UN Women and Gender constituency to the UNFCCC and the Greenhouse Gas Management Institute to promote transparency in negotiations and space for standardized carbon accounting at the COP22 and COP23. Caroline hopes to continue her work as a coral biologist and environmental communicator in the experiential education realm aiming to foster inclusivity and space for creative expression in all she does.

ously praised for communicating ESV to audiences previously unreached and for creating a sense of shared responsibility for resource use and natural processes that play out on a global scale. Those directly affected by management decisions informed by ESV have not historically been involved in valuation processes. And the trade-offs and complexity of value systems within a community are rarely appreciated (Tilman et al. 2002, Rodriguez et al. 2006, Raudsepp-Hearne et al. 2010, Ring et al. 2010, Hauck et al. 2013).

Second, the long term socio-psychological implications of our use of market-based mechanisms in addressing issues of resource use and allocation remain unaddressed. Some would argue that market-based approaches to resource management improve overall well-being, while others still argue that these approaches might be to the detriment of the important conceptualization of humans as, not separate from, but a part of the natural systems they live within (Schmitz, 2017). Many have expressed concern that a utilitarian framing of ecosystem service functions and market-based mechanisms for conservation efforts are contributing to a conceptualization and evolution of understanding of nature that will be counterproductive to conservation efforts in the long run (Rees 1998, Martínez-Alier 2002, Robertson 2004, McCauley 2006, Soma 2006, Gómez-Baggethun 2010, Kosoy and Corbera 2010). We see this divergence in the difference in Nationally Determined Contributions to the Paris Agreement in Costa Rica, a leader in institutionalizing these instruments, compared to Bolivia, a leader in opposition to market mechanisms.

Rather than discarding valuation as a tool, there are several ways it could be used to bridge the gaps that have historically polarized it. These concerns may be addressed by a more holistic and intentional valuation process that is standardized yet appropriately scalable, accessible, co-developed, and transparent.

## Natural Capital: A network of value systems

The valuation of natural capital and use of ecosystem service valuations in policy, management, and development decision-making processes is an inspiring intersection of quantitative and qualitative research methods, academic interest, and practical application. The process of natural capital valuation has the potential to bridge local–global gaps and engage communities in an inclusive and equitable manner, contributing to socially sound complex adaptive management practices.

Successful development and execution of natural capital research has many layers:

*1. Seeded by the community that will be affected by the management decision it is informing*

a. Of appropriate scale, and

b. Community-based dialogue being a key precursor to study

A community's sense of efficacy in the development, management, and governing processes of an area increases the likelihood of compliance with management stipulations or regulations imposed on that area, for example, Marine Protected Areas with no-take zones. This layer includes thoughtful consideration of the scale of a project. Smaller or localized scales create more potential for individuals to identify with the project and be included in the valuation. Larger scales can be more effective in communicating to communities indirectly involved but less accurate in the valuation itself. Integrating scales and being explicit and transparent about the scale of a project and the purpose it is informing can bridge scales and increase compliance and impact rates.

*2. Interdisciplinary in nature, and incorporates both quantitative and qualitative research methods*

a. Standardized data collection and presentation.

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Ecosystem service valuations focused solely on monetary value of exported resources are important but cannot wholly represent a community or individual's value system, given the immeasurable significance of a given land area or water body to different stakeholders and people. This does not have to be a barrier to entry for ESV or a discrepancy that de-legitimizes the entirety of ESV for a population. Rather, the profound spiritual, cultural, religious, and inherent significance of a given area should be duly noted and communicated in tandem with an ESV via qualitative research and presentation. A standardized platform for communication of this data (in various formats) is imperative for the adequate representation of ecosystem significance in decision-making processes. A strengthened methodology and platform for sharing and collection of such information would benefit peacebuilding and consensus building in management decision-making.

*3. Effective communication to the affected and target audience/s*

a. Open access data,

b. Transparency in reports by NGOs and presentation of data by governments,

c. Adaptive: feedback channels and potential for improvement/expansion of study.

Effective communication in this case means a platform for information sharing and analysis that is open access. In particular, the platform should be easily accessible to those individuals affected by management decisions that incorporate informartion from this platform. There should be a clear delineation of the information used in decision making processes. Information should be conveyed through verbal, visual, and interactive means. Reports presented by NGOs and governments should link clearly to the research supporting them. Furthermore, this information should be adaptive, which may take the form of feedback channels to allow space for commentary on a study and potential for the study's improvement and expansion. A problem faced by this layer is that the adaptive nature of a study may impair the standardization and clarity of other scales of communication.

*4. Acknowledgement of synergies and trade-offs in how stakeholders value ecosystem services*

a. How individuals' values diverge, and

b. How divergent values of currency and resources affect the equity of trade schemes.

Explicit inclusion of ecosystem services in decision making, reporting, and policy demands careful attention be paid to the synergies and trade-offs experienced by and between stakeholders in their relationships to ecosystem services. A comprehensive exploration, attention to detail and openness to expanding knowledge of these perceptions and dynamics on varying scales (although difficult to pull apart in many cases) can allow policies and communication tools that use ecosystem services to be most effective.

It is key to consider and account for in some way, the difference in value of one dollar in different places in the world. This value discrepancy perpetuates inequality in global trading schemes. Therefore a globally recognized value of a given area disproportionately represents its worth. Addressing this is complicated, but one option is to weigh values based on who will be using a given valuation, who will be importing a resource, and who has rights to the land or water area from which a resource is being extracted.

## Examples

This field is quickly growing, changing, and shows significant promise. Moving forward in the field we need a standardized yet multiplicative framework and flexible platform for valuations that is widely respected and can be easily utilized. This begins with coalition building around valuation. One such example is the ESMERALDA project

(founded in 2015), which "aims to deliver a flexible methodology to provide the building blocks for pan-European and regional assessment of ecosystems and their services." The Ecosystem Service Partnership (2014) is another example, aiming "to enhance communication, coordination and cooperation, and to build a strong network of individuals and organizations working on #ecosystemservices". The Natural Capital Project (2012), a partnership between Stanford University, World Wildlife Fund (WWF), The Nature Conservancy, University of Minnesota, and Chinese Academy of Sciences, is "bringing the values of nature into decision-making". International Spring University began developing Artificial Intelligence for Ecosystem Services (ARIES) in 2007. ARIES "is a networked software technology that redefines ecosystem service assessment and valuation for decision making. Another software that has emerged is InVEST (which has come out of Woods Institute at Stanford and the Natural Capital Project), a program that "is both helping to address challenges and analyzing what impacts and cost-benefits exist for conservation efforts and watershed management." Meanwhile WAVES, Wealth Accounting and the Valuation of Ecosystem Services, a World Bank-led global partnership, "aims to promote sustainable development by ensuring that natural resources are mainstreamed in development planning and national economic accounts".

These programs could be improved by taking a more interdisciplinary approach, using multiple methods of valuation, being explicit about the scale and seeding of valuation projects, and by working to make their systems and data more accessible and easily communicated to divergent stakeholders. Their products and networks stand to benefit by maintaining the key layers outlined above to support holistic valuation processes and open communication. This may take the form of a cooperative effort to standardize and map qualitative valuation components in ARIES. WWF may be interested in co-developing the valuations with communities affected by them (for example, in reports such as *Reviving the Ocean Economy*), communicating their valuations more transparently, and working at more socially appropriate scales with the communities involved in the ecosystem service valuations they present. Similarly to ARIES, InVEST may incorporate qualitative data and make their software open source. Ideally these initiatives and others will evolve progressively together, filling their own niches while making space to cooperate and develop more holistic natural capital valuations that are mutually beneficial across a spectrum of value systems.

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# Energy access and financial inclusion: Are solar PAYG products promoting digital financial access and use among rural households in Kenya? A case study of Kakamega County

*Beryl Ajwang', MEM*[*]

## Abstract

This study evaluates the impact of adoption of Pay-As-You-Go (PAYG) solar products on digital financial access and use among rural households in Kenya. The study was conducted in Kakamega County with 94% of its population considered off-grid and 85% considered rural. A total of 570 households were interviewed and through the use of statistical analysis, including regression analysis and t-tests, the results were analyzed. Findings from the analysis indicate that there is no significant difference in digital finance access and use between households that have adopted PAYG solar products and those that have not. However, households with PAYG products have a higher frequency and level of use of their mobile wallets as compared to households without. The increased frequency and their repayment history increases their eligibility for credit through their mobile accounts. Informal financial groups have a strong impact on the adoption of PAYG solar products as they help in pooling of risks and reducing the marketing costs involved in the sales of these products. Companies, such Green Planet, are leveraging the existing farmer groups run by One-Acre Fund (a social enterprise that work with farmers to provide seeds and fertilizers on credit in the County) to sell their products. PAYG as a business model has the potential to provide financial services to the unbanked if they are able to carefully assess the lending risks involved. However, to remain sustainable they may have to overcome challenges of a shrinking market size due to parallel government electrification programs and uncertainty in policies regarding mobile money transactions.

*Utafiti huu unaangazia athari ya matumizi ya taa za sola ambazo hununuliwa kwa njia ya malipo ya polepole kwenye ufikiaji na matumizi ya fedha za simu vijijini, nchini Kenya. Utafiti huu ulifanyika katika kata ya Kakamega nchini Kenya. Asilimia tisini na nne (94%) ya wakazi wake walichukuliwa kutokuwa na umeme nyumbani na asilimia themanini na tano (85%) walichuliwa kuishi vijijini. Jumla ya nyumba 570 zilitembelewa na wenyeji kuhojiwa. Majibu yalichambuliwa kutumia uchambuzi wa takwimu ikiwa pamoja na* regression *na* t-test. *Matokeo ya uchambuzi yanaonyesha kwamba hakuna tofauti kubwa katika ufikiaji na matumizi ya fedha za simu kati ya nyumba ambazo zinatumia taa za sola za malipo ya polepole na zisizo. Hata hivyo, nyumba zilizo na taa za sola za malipo ya polepole zina kiwango cha juu ya matumizi ya fedha za simu ikilinganishwa na nyumba zisizo. Ongezeko la matumizi ya fedha za simu pamoja na historia yao ya malipo huongeza kiwango cha mikopo kupitia akaunti zao za simu. Zaidi, makundi ya kifedha yasiyo rasmi yanaathiri sana ununuzi na matumizi ya*

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*taa za sola za malipo ya polepole kwa kuwasaidia kuunganisha hatari ilhali wakikupunguza gharama za uuzaji zinazohusika katika mauzo ya bidhaa hizi. Makampuni, kama vile* Green Planet, *wanatumia vikundi vilivyopo vya wakulima vinavyoendesha na shirika la* One-Acre Fund *(ambayo hufanya kazi na wakulima kutoa mbegu na mbolea kwa mkopo katika Kata) ili kuuza bidhaa zao. Ni wazi kwamba makampuni yanayoendesha malipo ya polepole kama mtindo wa biashara yana uwezekano wa kutoa huduma za kifedha kwa wasio na benki iwapo wanaweza kuchunguza kwa makini hatari za mikopo zinazohusika. Hata hivyo, kubaki endelevu lazima makampuni haya yakabiliana na changamoto za soko kupungua kutokana na mipango sambamba ya serikali kusambaza umeme na kutokuwa na uhakika katika sera zinazohusiana na shughuli za fedha za simu.*

## Introduction

Lighting remains one of the leading expenses for households without access to electricity. Globally, it is estimated that households spend 25–30% of their family income on kerosene for lighting and cooking, about US$ 36 billion a year (Pode 2013). In Africa, up to US$ 17 billion is spent on fuel-based lighting sources, with poor households spending 10–15% of their incomes on lighting alone (Lighting Africa 2012). In Kenya, close to 4 million households use kerosene for lighting and spend US$ 2–4 (KES 200–400) per month on kerosene (Lay, 2012) and a total of US$ 157 per year in meeting their energy needs (Bloomberg New Energy Finance 2016).

The massive growth in the solar sector in Kenya has been driven by low electrification rates and the high upfront cost of connection. Considered one of the most mature markets in East Africa, the solar market dates back to the 1980s. The initial solar Photovoltaic (PV) market was dominated by donors such as the World Bank and GEF, who were more interested in the larger applications of PV in schools and communication and did not target households. This disparity resulted in the rise of the private sector, which did eventually steer the market to its present status (Acker 1996). As of 2011, about 320,000 solar home systems had been sold with annual sales of between 20,000–25,000 systems (Lay 2012), bringing the current estimates to a total of 450,000–500,000 installations.

The need to overcome the high upfront cost of solar technologies for modern lighting has seen the emergence of innovative consumer financing models such as the Pay-As-You-Go (PAYG) which operates by extending a credit in form of the solar products to the household and allowing them to pay back over a given period of time. PAYG solar products are replacing kerosene lamps among rural poor households by providing cleaner lighting solutions. Turman-Bryant et al. (2015) posit that PAYG solar products are also promoting digital finance access through the use of mobile wallets among the rural unbanked households. Moreover, they argue that because the asset loans provided through PAYG are of smaller size than was previously possible by formal financial institutions, even low-income households can be reached.

Digital financial access has great benefits to households by allowing them to make and receive payments and access credit without having bank accounts. Further, it increases the incentives to save through default options (World Bank 2016). Studies such as Beck et al. (2007) indicate that the availability of capital allows poor households to realize small business opportunities, which leads to an increase in income, enables them to better absorb shocks such as health issues, allows for household investments in durable goods, home improvements or school fees, and also reduces income inequality.

The use of technology and innovative business models has been considered as a ways to increase financial usage among poor households (World Bank 2014). The PAYG business model leverages the success of mobile money in the country by creating flexibility in payments that favor poor households. This goes above the traditional forms of consumer financing by minimizing transaction costs and accommodating irregular and low incomes.

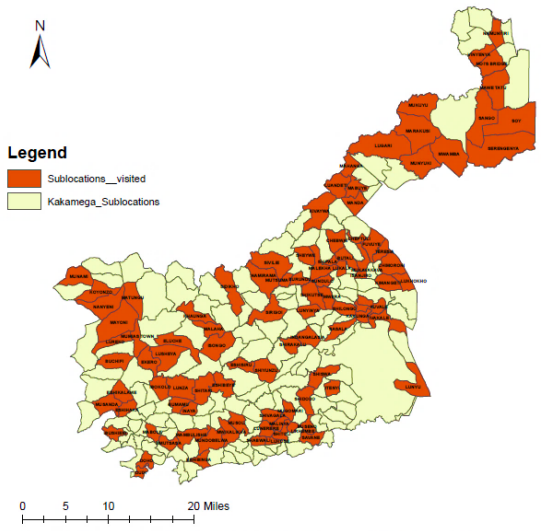


**Fig. 1.** Map of sampled locations in Kakamega County, Kenya.

While previous studies have evaluated the impacts of mobile technology on financial inclusion (Andianaivo 2012, Lundqvist 2014, Olela 2016), this study hopes to contribute to the growing knowledge of how the PAYG business model influences energy access by evaluating the impact of the adoption of PAYG solar products on digital finance access and use among low-income rural households in Kenya. The objectives of the study were to determine (i) the occurrence and use of PAYG solar products in off-grid households, (ii) the factors that determine the adoption of PAYG solar products, and (iii) extent of digital finance usage (e.g., for savings, credits, payments, remittances) among these households.

## Methods

*Understanding PAYG*

Based on the definition by the Global Off-Grid Lighting Association (GOGLA & BNEF 2016) PAYG refers to a variety of technologies, payment rules, ownership and financing structures that allow the end user to pay for solar kits in affordable installments and incorporates a technology enabled mechanism to disable the system if a payment is due. The PAYG products range from the Pico products of less than 10W to solar home systems of about 350W.

The PAYG business model has a growing presence in countries with low electrification rates such as those in Sub-Saharan Africa, and particularly in East Africa. Its success in the region can be attributed to the large presence of off-grid solar products and large off-grid population. Some of the PAYG companies/operators using the PAYG mode in Kenya include; Azuri, Mobisol, M-KOPA, Green Planet, Mibawa, Angaza Design, Divi Power, and BBOxx (GOGLA and BNEF 2016). M-KOPA is the leading PAYG provider with over 500,000 homes connected (M-KOPA 2017)

*Study site*

Kakamega County is located in western Kenya, with a total population of 1,660,651, according the 2009 census (Commission on Revenue Allocation 2013). The main economic activity of the county is agriculture, with the sector employing 756,711 people while only 2,554 people are on wage employment, according to the 2009 census. About 15% of the population is considered urban with the rest residing in rural areas (Kakamega County Government 2013). In terms of energy access, a great percentage of the population still remains unelectrified with only 5.5% using electricity for lighting. Twenty-eight percent of the households use lanterns (paraffin) for lighting and 63.9% tin lamps indicating that about 95% of the population is dependent on kerosene as the main lighting fuel (Kenya National Bureau of Statistics [NBS] 2013)

The poverty incidence in the County is estimated at 49.2%, slightly above the estimated national level of 45.2% (Kenya NBS 2013). About half the population (809,500) live below the poverty line with a poverty gap of 12%, almost equivalent to the national value of 12.6%. The County is considered the leading contributor to the national poverty rate by a factor of 4.8%. The mean monthly expenditure in the county is US$ 52.30 (KES 5,230; 1 US$

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= 100 KES) as compared to the national average of US$ 66.20 (KES 6,620).

*Household surveys*

A total of 570 households out of 325,167 households in Kakamega County were sampled (Figure 1). Respondents were 58% female and 42% male. A clustered random sampling technique was employed to determine the respondents. In this case, the constituencies were identified as sampling blocks. All sublocations within the constituencies were then listed and randomly selected for the survey, using a computer. About 90 sublocations were sampled during the study. Five to six households were randomly selected and interviewed in each sublocation.

*Data analysis*

To determine if there was significant difference in digital access and use between solar users and non-solar users, and PAYG and Non-PAYG users, I used a two-sample t-test.

To evaluate the factors that affect the adoption of solar products in Kakamega county, I used logistic regression. Households were scored as solar (1) or non-solar (0) as the dependent variable. Average income, literacy, location (household category), gender, education, main source of employment, membership in a non-formal/formal financial group, and ownership of mobile phone were the independent variables.

To establish what factors influence access and use of digital finance, I used multiple linear regression. The dependent variable was a continuum from 0 to 10, based on summing the scores for the following variables: active mobile account (0.5), when it was activated (>5 years: 0.5, >3 years: 0.8, $\leq$2 years: 1.0), any family member having an active account (0.5), cell phone ownership (0.5), type of phone (basic: 0.5, feature phone: 0.7, smart phone: 1.0), level of use (basic: 0.5, moderate: 1.0, high: 1.5), frequency of use (daily: 1, $\leq$every two weeks: 0.5, other: 0.3), savings in the mobile account (2), and credit from mobile accounts (2). The independent variables that were considered for the model were lighting source (solar and non-solar), gender (female, male), education (none, primary, secondary, degree/diploma), main source of income (business, agriculture, employment, other), average income (<10K, 10K–40K, 40K–80K, >80K), household head (male, female).

All analysis was done in R and Minitab.

## Results

Fifty-eight percent of the sampled population used solar as the main source of lighting with the rest using electricity, paraffin, or rechargeable battery (Figure 2). The solar products used ranged from small solar lanterns to stand-alone solar home systems (PV). Of the 331 households that used solar for lighting, about 61% obtained their products through PAYG processes, in which they made daily or weekly payments.

Households in the Kakamega County still remain largely outside the banking system. Almost half did not have formal bank accounts at all; of those that did, only 36% had active accounts, while the remainder had dormant or deactivated accounts. One of the main reasons stated for lack of accounts

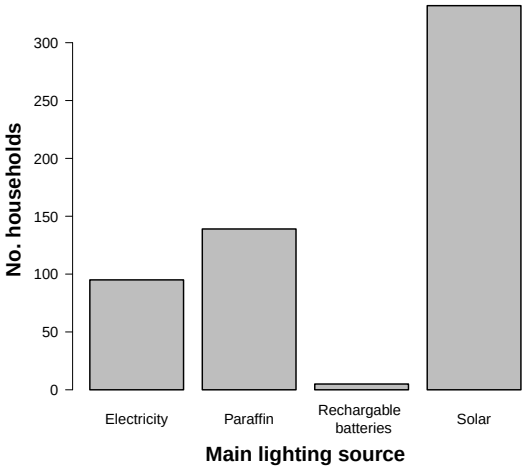


**Fig. 2.** Main lighting source of 570 households in Kakamega County, Kenya, sampled in 2017.

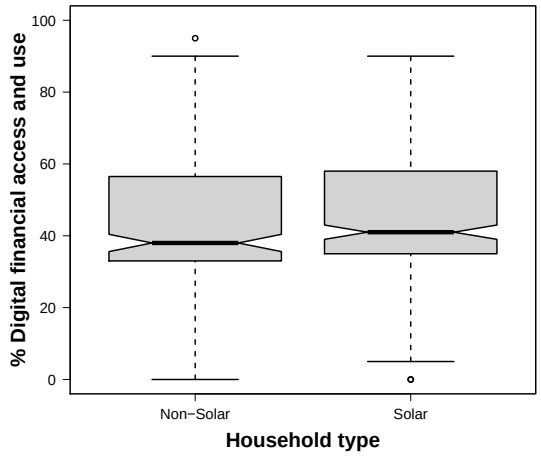


**Fig. 3.** Digital finance and access use between solar and non-solar households in Kakamega County, Kenya.

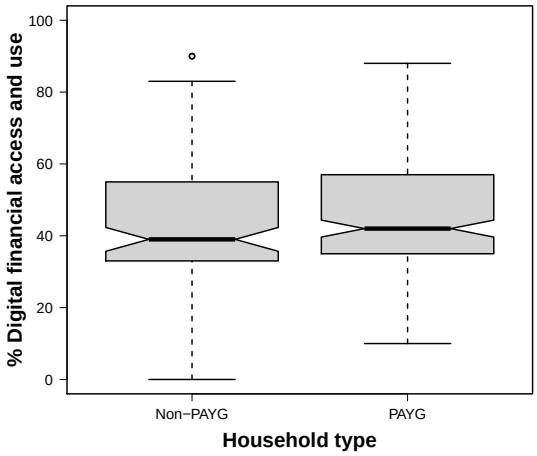


**Fig. 4.** Digital finance and access use between PAYG and non-PAYG households in Kakamega County, Kenya, sampled in 2017. Asterisks indicate outliers in the data.

was low income. Apart from formal banks, many households were also part of informal financial groups, such as the Village Savings Loan Association (VSLA) and the Rotating and Savings and Credit Association (ROSCA), with only 28% of households not part of any such association. In the past six months, at least 68% of households had deposited savings and 44% taken credit. Credit was mostly taken to cover agricultural purchases (fertilizers and seeds) followed by assets, which in this case were the solar lighting products.

Most households had acquired their solar products via a top-up loan to the basic agricultural loan offered by One-Acre Fund (a social enterprise that works with farmers to provide seeds and fertilizers on credit), which is headquartered in the County.

The mobile penetration rate in Kakamega County was high. A total of 95% of households had a mobile phone and about 76% had activate mobile accounts for at least 5 years whereas only 2.4% had activated their account less than a year ago.

*Variation in digital finance use and access*

There was minimal variation in digital finance access and use between solar and non-solar households (Figure 3). Similarly, there was no differencein digital finance access and use in solar households between PAYG and non-PAYG (e.g., cash, higher purchase, gift) methods of acquisition (Figure 4).

There was no significant variation in level of access and use of digital finance among the solar and non-solar users (Student's t-test: t = -1.75, df = 438, P = 0.08) and in the level of use and access of digital financial between households that acquired their solar products through PAYG and Non-PAYG (Student's t-test: t = -0.79, df = 186, P = 0.43).

*Factors affecting adoption of solar technologies*

Possession of a phone, average household income, and membership in a financial group were significant predictors of whether a household adopted solar technology (Figure 5).

Households with cell phones were 2.6 times more likely to use solar products compared to those that did not have cell phones. Additionally, households with low average income had a higher likelihood of taking up solar compared to those with higher income. For example, households with incomes of KES 10,000–40,000 were about 2 times

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more likely to adopt solar than households with incomes greater than KES 80,000. Households with membership in financial groups – whether formal or non-formal institutions such as village savings – had double the chance of solar adoption.

*Factors affecting digital finance access and use*

Owning a solar product did not seem to have any significant effect on the access and use of digital finance. Gender, average household income and household main source of income were significant predictors of digital finance access and use among households. Households that had average income levels of KES 10,000-40,000 and those that had business as their main source of income had higher levels of use (Table 1).

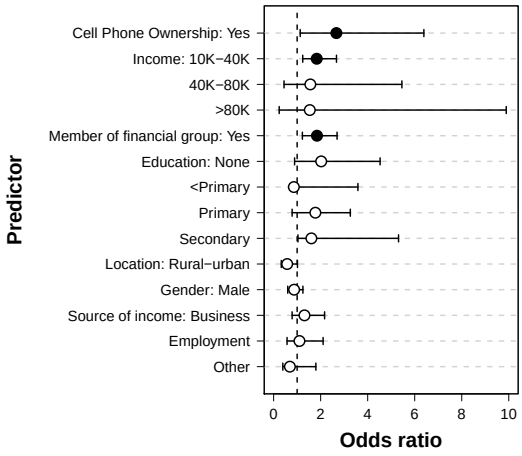


**Fig. 5.** Plot of odds ratios from a logistic regression analysis of household data from Kakamega County, Kenya, sampled in 2017.

## Discussion and conclusion

Digital financial access and use does not seem to vary between households that acquired their solar products though PAYG and those that acquired them through different means such as cash or higher purchase. However, there seems to be a correlation between the frequency and level of use of mobile money and adoption of PAYG. Households with PAYG have increased rate of use as compared to other households. A possible explanation would be that they have to make weekly or monthly payments. This concurs with the ideas posited by Waldron (2016), that the adoption of PAYG solar products become an activation and increases the use of mobile money. Increased frequency of mobile money use can have direct impacts on access to credit. PAYG companies are also using the repayment history of households to give advanced form of credits such as larger solar panels and smartphones. While this study was focused on a country with a well-established mobile money platform, it would be interesting to see the outcomes for countries that are adopting these solar technologies but do not have elaborate mobile money platform as Kenya.

Households indicated willingness to take up different products on a PAYG model ranging from assets such as water pumps, sewing machines, TV, dairy cows to cash for business and educational purposes. This shows that PAYG companies have the potential of diversifying and ensuring sustainability by moving beyond supplying the regular energy products to offering different products such income generating assets, and loans. MKOPA is already adding TV and clean cooking technologies such as LPG. Given that PAYG companies have established relationships and trust with customers and have existing distribution networks, it becomes easier and cheaper to introduce new products and advance loans based on customer re-payment histories. According to Winicieki (2015) as cited by Waldron and Faz (2016), an accurate assessment of the risk of lending by PAYG solar companies while expanding their markets across the country may set them to become the first scalable model for providing asset financing to unbanked customers.

In order to become sustainable, PAYG companies may have to contend with two main challenges. The first would be parallel programs from the government that target rural-electrification such as the Rural Electrification Program and the Last Mile

**Table 1.** Results of multilinear regression analysis of household data from Kakamega county, Kenya, sampled in 2017. $R^2$ = 11.87%.

| Predictor | Reference Category | Coefficient | P |
|---|---|---|---|
| **Household head:** | Female | | 0.093 |
| Male | | 0.492 | |
| **Av. household income:** | 10,000 | | 0.022 |
| 10,000–40,000 | | 0.426 | 0.005 |
| 40,000–80,000 | | 0.771 | 0.119 |
| >80,000 | | 0.958 | 0.200 |
| **Education:** | Degree/Diploma | | 0.058 |
| None | | -0.585 | 0.066 |
| Less than Primary | | -0.172 | 0.637 |
| Primary | | -0.063 | 0.818 |
| Secondary | | 0.126 | 0.653 |
| **Gender:** | Female | | 0.041 |
| Male | | 0.302 | |
| **Main Source of Income:** | Agriculture | | 0.001 |
| Business | | 0.718 | 0.000 |
| Employment | | 0.347 | 0.176 |
| Other | | -0.223 | 0.406 |
| **Main lighting source:** | Non-Solar | | 0.274 |
| Solar | | 0.158 | |
| Constant | | 3.647 | 0.000 |

Connectivity. As demonstrated in their research, Lay, Ondraczek, and Stoever (2013) advance that there is a likelihood that the potential market for solar home systems in off-grid areas would shrink due to grid extension, especially if it is offered at offered on a large scale, predictable and reliable basis. There is also lack of recognition of these products as a means of electrification and hence no direct policy to support this market. There is room for the government to potentially partner with these organizations to offer energy products services to these areas instead of bypassing them. Additionally, as suggested by Lay, Ondraczek, and Stoever (2013) price policies such as subsidies on these products will be beneficial in ensuring the products are competitive enough and affordable to low-income households.

The second challenge would be policy uncertainty in relation to mobile currency regulation and taxes on solar products are at the center of the PAYG business model. Changes in the transaction costs, such as increased exercise duty, have direct impacts on the pricing of products which in turn impacts the purchases and the market size for these companies. In order to address this, the government should ensure that all stakeholders are involved in decision-making for a fair bargain.

Membership in financial groups – whether formal or non-formal institutions such as village savings – seems to be pivotal in the adoption of solar products with households that in groups being twice as likely to adopt than those not in any group. Groups are increasingly becoming a marketing/distribution model for most products that target households at the base of the pyramid-whether

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asset or fiscal. MFIs and PAYG operators are using agents who in the end target groups to reduce the marketing costs and pool risks. The groups provide a financial guarantee that may not be possible with one person and also reduces the default risk. As was observed in Kakamega County, Green Planet Company, which sells the Sun King products is leveraging existing farmer groups run by One-Acre Fund to sell their products.

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# Floristics of cacao agroforestry in the Mata Atlântica of southern Bahia, Brazil

*Katherine J. Young, MFS*[*]


## Abstract

Sustainable land use practices are urgently needed to aid the conservation of biological diversity and natural resources as well as for social and economic development to sustain local communities living within natural or semi-natural ecosystems. *Cabrucas*, a traditional system of agroforestry management for cacao, entails clearing the native forest understory and planting cacao trees under the shade of the forest canopy. In this study, I documented the species richness and diversity of four cabruca stands in southern Bahia, Brazil. Of the 4,435 trees measured in the cabrucas, I found a total of 103 different tree species $\geq$5 cm DBH, in 33 families and 61 genera. Almost a fifth (17%) were neither *Theobroma* nor *Musa* species. Most of these individuals were in the families Leguminosae, Rutaceae, Moraceae, and Meliaceae. Future analyses will assess how similar these cabruca stands are to adjacent secondary forest stands of the same age class to elucidate opportunities for applying forest restoration principles and silvicultural techniques to the management of landscapes dominated by agricultural production.

*Práticas sustentáveis de uso da terra são necessárias e urgentes para apoiar a conservação da diversidade biológica e recursos naturais, bem como para o desenvolvimento social e econômico de comunidades locais que vivem em ecossistemas naturais ou semi-naturais. As* cabrucas *são sistemas tradicionais de manejo agroflorestal para o cacaueiro que envolvem a limpeza do sub-bosque da floresta nativa e o plantio de cacaueiros sob a sombra do dossel da floresta. Neste estudo, foram mensuradas a riqueza e diversidade de espécies de quatro cabrucas no sul da Bahia, Brasil. Das 4.435 árvores medidas nas cabrucas, o estudo revelou um total de 103 diferentes espécies de árvores $\geq$5 cm DAP, em 33 famílias e 61 gêneros. Quase um quinto (17%) de todas as árvores não eram nem* Theobroma *nem* Musa *spp. A maioria desses indivíduos pertencia às famílias Leguminosae, Rutaceae, Moraceae e Meliaceae. Análises futuras avaliarão a similaridade entre áreas de cabruca a fragmentos de florestais secundários adjacentes e de mesma classe etária, a fim de elucidar oportunidades de aplicação de princípios de restauração florestal e técnicas de manejo silviculturais no manejo de paisagens dominados pela produção agrícola.*

*Se necesitan con urgencia prácticas sostenibles de uso de la tierra para ayudar a la conservación de la diversidad biológica y los recursos naturales, así como para desarrollarse social y económicamente y sostener a las comunidades*


[*]Katherine ('Kata') works at the intersection of sustainable agricultural production and ecological restoration of tropical environments, as an international advisor on regenerative agro-ecological land use management and climate change adaptation. Kata has 15 years of professional experience working with multi-stakeholders in vulnerable communities in Latin America, South Asia, and Africa. Her work has been conducted in collaboration with smallholder farmers, farmer field schools, farmer associations and cooperatives, civic and non-profit organizations, private sector actors and corporations, and public sector representatives (local, regional, and national governments, and international-level). In 2017, Kata received a joint Masters in Forest Science from Yale School of Forestry & Environmental Studies and the New York Botanical Garden, Institute of Economic Botany. She holds a B.S. in International Agriculture & Rural Development from Cornell University ('15), with a strong interdisciplinary foundation in international development, soil and agro-ecological management, gender and development sociology, and participatory research and farmer-to-farmer learning modalities. Kata currently resides in Washington, D.C., where she works as a consultant and volunteers as the coordinator for her neighborhood's community garden.

*locales que viven en ecosistemas naturales o seminaturales.* Cabrucas*, un sistema tradicional de manejo agroforestal para el cacao, implica limpiar el sotobosque del bosque nativo y plantar árboles de cacao a la sombra del dosel del bosque. En este estudio, documenté la riqueza de especies y diversidad de cuatro rodales de cabrucas en el sur de Bahía, Brasil. De los 4.435 árboles de medidas en las cabra, encontré un total de 103 diferentes especies de árboles ≥5 cm DAP, de 33 familias y 61 géneros. Casi un quinto parte (17%) de todos los árboles no eran ni* Theobroma *ni* Musa *spp. La mayoría de estos individuos pertenecían a las familias Leguminosae, Rutaceae, Moraceae y Meliaceae. Los análisis futuros evaluarán cuán similares son estos rodales de cabruca a rodales secundarios adyacentes y de la misma clase de edad, para dilucidar las oportunidades para aplicar los principios de restauración forestal y las técnicas de manejo silvícola en la gestión de paisajes dominado por la producción agrícola.*

## Introduction

The Atlantic Forest in Brazil is one of the most biodiverse forests in the world with over 8,000 vascular plant species, approximately 40% of which are endemic to the region (da Silva and Casteleti 2003, Galindo-Leal and Câmara 2003). However, very little of this rich forest remains: just 9% of the original extent of the moist tropical forest in the cacao-growing region of southern Bahia is left. Despite this situation, the area holds more old-growth and secondary forest patches with more endemic species and greater species richness than any other part of the Atlantic Forest, largely as a result of traditional agroforestry management known as cabruca (Alger and Caldas 1994, Thomas et al. 1998, Rambaldi and Oliveira 2003, Rolim and Chiarello 2004). In cabrucas, native overstory tree species are retained for their shade cover while the understory is cleared and replaced with high quality cacao (*Theobroma cacao* L., Malvaceae s.l.). Yet, the future of conserving native species within this unique agroforestry system is uncertain.

As human populations continue to increase locally in the cacao-growing region of Bahia, and world chocolate consumption is expected to grow by 2–3% per year (Lass 2004), the pressure on farmers to intensify cacao production is also likely to increase (Schroth and Harvey 2007). Over the last two decades, farmers have frequently opted to simplify the native shade canopies of cabruca agroforestry systems and replace them with early-successional and/or exotic tree species (Rolim and Chiarello 2004), or opt out of cacao cultivation entirely and convert the cabrucas to other agricultural land uses such as pasture or annual crop production, that are generally less compatible with biodiversity conservation (Schroth and Harvey 2007, Rayner et al. 2011). Sustainable land use practices are urgently needed to facilitate the conservation of biological diversity and natural resources, regenerate degraded agricultural fallows adjacent to native forest stands, while addressing economic pressures faced by local communities.

A driver of the high biodiversity of cabruca systems is the selective management and assisted regeneration of native overstory shade species, and selective plantings of food-bearing species within available niches amongst cacao stems, increasing complexity in vertical structure and compositional diversity (Young 2017). As part of a larger study comparing the structure and composition of cabruca forest to natural forest, I conducted vegetation surveys of four cabruca forests. Here, I document the diversity and floristics of the trees of these cabruca agroforestry systems.

## Methods

*Study site*

I surveyed cabrucas in the tropical moist broadleaf forest zone of southern Bahia, Brazil (approximately 14–15°S and 39°W), at an elevation of 15–150 m asl. Mean annual temperature is 24°C (75.2°F) (Instituto Nacional de Meterologia, Brasil), and average annual precipitation 86.6–209.48 mm, with a distinct 4–5 month rainy season (World Bank 2016). Soils are classified as haplorthox oxisols typically high in iron and with low fertility (Piotto et al. 2009). Serra do Conduru

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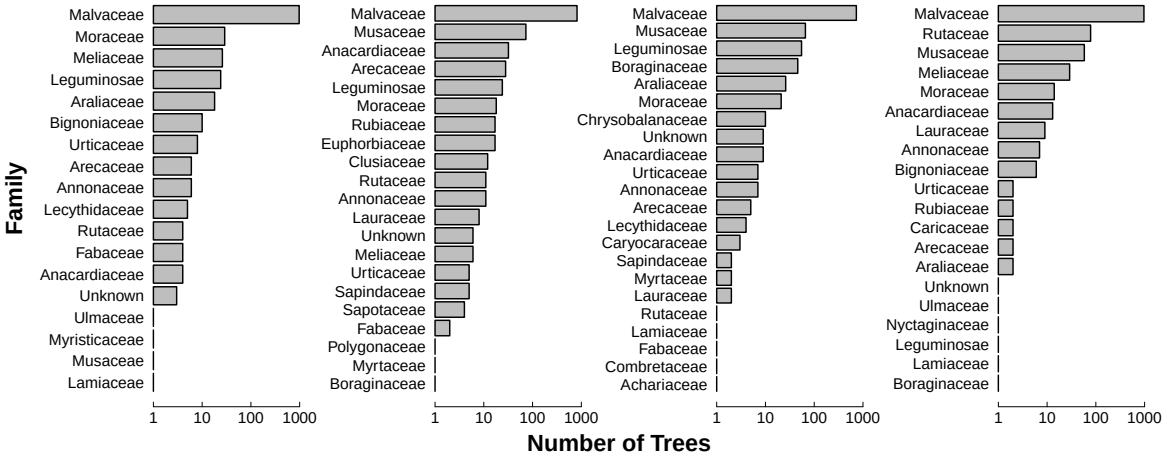


**Fig. 1.** The number of trees in the top 18 families in four cabruca stands in southern Bahia, Brazil. Most Malvacaeae are *Theobroma cacao*; most Musaceae are *Musa* spp.

State Park has an overall topography of undulating to rolling (10–30% slope; Piotto et al. 2009).

The cabruca sites are located within or adjacent to Serra do Conduru State Park: three to the east of the park (near Serra Grande) and one to the north of the park (15km outside of Itacaré). Cabruca sites had a minimum of 20 ha of managed cacao cultivation, ≥40 yrs of cacao cultivation following clearing native forest for cacao cultivation, and similar site topography and soil to minimize site heterogeneity

*Sampling design*

At each of the four cabruca sites I established three 0.5 ha fixed area plots (total sampling area 6 ha). Cabruca plots were located in the center of at least two hectares of contiguous cacao cultivation to minimize edge effects, with 20m between each plot. Within each plot we established ten parallel transects (10m x 50m) along either N-S or E-W coordinates to minimize heterogeneity of spacing density that occurs on steep slope inclinations. The first transect of each plot was placed 10m from the corner of the plot. Within each transect I identified and measured all woody trees ≥5cm diameter at breast height (DBH, measured using a calibrated diameter tape (cm) at approximately 1.37m above ground level). To account for the consistent presence of bananas and plantains (*Musa* spp.) in these agroforests, I also included monocots, *Musa* spp., and members of the Palmaceae family ≥5cm DBH. Unknown species were flagged, and leaf samples were collected, dried, and mounted as herbarium vouchers at Instituto Floresta Viva for later identification.

## Results

*Structure*

I recorded a total of 4,435 trees in the four cabruca sites in a total of 6 ha. Mean density (±SD) per 0.5 ha plot was 740±85 trees ≥5 cm DBH $ha^{-1}$ (range = 624–902). Over all trees, mean DBH was 15.5±15.8 cm (1–308 cm).

Within each site, however, most trees were *Theobroma cacao* (3,483) or *Musa* (198). Excluding these stems, the total number of trees was 754, mean density per plot was 126±35 (80–174), and mean DBH was 36.1±30 (4.5–308.0).

*Floristics*

Within all the cabruca plots, I documented a total of 33 families, 61 genera, and 103 species. Nineteen individual trees remained unidentified to family, 18

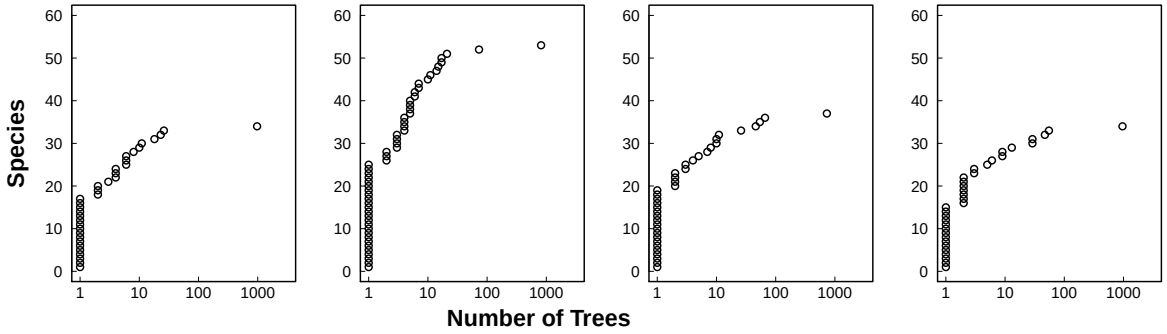


**Fig. 2.** Dominance-diversity curves for four cabruca stands in southern Bahia, Brazil. Each point is a species. Most species had very few individuals; *Theobroma cacao* and *Musa* were the two most abundant. Note the log scale on the x-axis.

to genus, and 346 to species. The mean number of families per plot was 14 (range = 9–19); the mean number of genera per plot was 18 (10–25); and the mean number of species was 20 (10–29).

Over all plots, the most common families, excluding *Theobroma* (Malvaceae) and Musaceae, were Leguminosae (104 trees), Rutaceae (94), Moraceae (82) and Meliaceae (61) (Fig. 1). A total of five families had only one individual and 17 families had 10 or more stems.

Over all plots, the most common genera were *Citrus* (94), *Erythrina* (65), *Cedrela* (61), and *Artocarpus* (54). A total of 14 genera were represented by a single individual, and 22 genera had 10 or more stems.

Over all plots, the most common identified species were *Cedrela atlantica* (61), *Artocarpus heterophyllus* (54), *Cordia trichotoma* (48), and *Citrus tangerina* (48). A total of 54 species were present as a single stem; 22 species had 10 or more stems (Fig. 2).

A constrained correspondence analysis of the families in each plot showed that sites grouped together (Fig. 3). The first axis explained 29% of the variation, and the second axis 22%. It is clear that the families with single species are driving the separation of sites in this analysis.

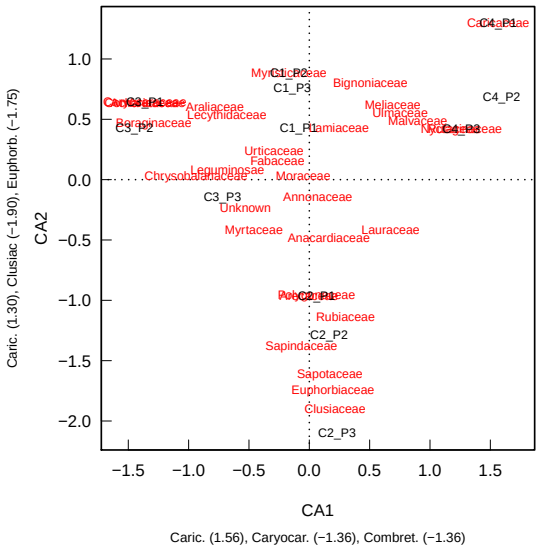


**Fig. 3.** Biplot of a community correspondence analysis of four cabruca stands in southern Bahia, Brazil. Three plots (P) were located in each of four stands (C).

## Discussion

The goal of this study was to provide a baseline ecological analysis to test the underlining "mimicry" principle behind agroforestry design and management, and quantify the similarities in structural and compositional traits between a typical multi-strata cabruca cacao agroforest and an adjacent native secondary forest. In 6 ha of cabruca agroforestry plots, I found a high diversity of non-*Theobroma* species,

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with 33 different families and 103 different species. This richness is comparable to other cabruca systems. For example, Sambuichi and Haridasan (2007) found 180 tree species and Lobão and Valeri (2009) 101 tree species in other studies from Bahia.

Despite the high abundance of *Theobroma cacao* and *Musa*, the floristics of these cabruca systems reflected the general patterns found in the Atlantic Forest, with high abundance of Leguminosae, Moraceae, Meliaceae, among others (Oliveira-Filho and Fontes 2000). However, whether these agroforestry systems "mimic" natural forests remains to be seen. Cabrucas, rather, may be simplified in structure and floristic composition as compared to secondary forests. However, there is ample growing space available in the understory, subcanopy, and canopy to increase agrobiodiversity by selecting and planting native ethnobotanically valuable species in available vertical gaps in the strata (Young 2017). Thus, these agroforests could be managed like secondary forests following assisted natural regeneration and successional forest stand dynamics to improve vertical assemblages of multi-functional species at each stratum. These forest would then better incorporate native ecological principles into agroforestry design and management.

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Bielecki, C.R. 2018. Meeting Kanaloa halfway: A more than human history Kahoʻolawe, Hawaiʻi. *Tropical Resources* **37**, 29–37.

# Meeting Kanaloa halfway: A more than human history Kahoʻolawe, Hawaiʻi

*Coral R. Bielecki, MESc*[*]

**Abstract**

A posthumanist story of Kanaloa-Kahoʻolawe demonstrating the agency of materiality with major implications on how environmental law might be practiced in the U.S.

The Kahoʻolawe Island Reserve encompasses a 45-square mile island in Hawaiʻi that has been devastated by napalm, mock atomic warheads, bombs, rockets, ungulates, and the mismanagement of biological resources. Fifty years of use (1941–1994) by the U.S. military as a weapons testing range resulted in this place, also called Kanaloa-Kahoʻolawe, becoming the most heavily bombed place in the Pacific. The island's history is rooted in the sacred, and despite the forces of degradation and profound socio-political changes in Hawaii, the island continues to be a revered place of learning and healing for the local community. Thousands have risked bodily harm to engage with the restorative project which regards the island as very much alive. While we understand socio-ecological systems as complex, subjective, and lively sites of knowledge production, little attention has been paid to the agency of nonhuman biota. Even less attention has been given to understanding the ways in which landscapes or islands exert their power. This is a more than human history of Kanaloa-Kahoʻolawe in the Hawaiian archipelago, illuminating how nonhumans entangle with the social world and co-produce knowledge. This work invites you to reconsider the iterative engagement humans have with our environment and consider how meaning takes shape and matter comes to matter. My discussions of time-space relations are an effort to reframe nature – culture relations and help us make sense of how an island is alive. This story navigates the biocultural terrain of matter and meaning, the self and the universe, human and nature on Kahoʻolawe island. How we reimagine Kanaloa-Kahoʻolawe presents new political, legal, ecological, and ideological challenges, as well as opportunities. In particular, I describe how recognizing the agency of Kanaloa-Kahoʻolawe could have positive legal implications for its restoration.

## Introduction

Intimate understanding arises from meaningful engagements. My relationships with the winds, waters, plant life, earth forms, people, and animals of Hawaiʻi have been formative in my journey as a *haumāna*[1] of the environment and politics. I have developed senses, or habits of discernment, about human and nonhuman entanglements, and have found myself delighting in familial faces of plants and responding to the wisdom residing in stone. I

[*]Coral is a researcher, writer, and active community member. She shares, "wherever we focus our attention and efforts says something profound about our priorities and the kind of legacy we want to build. As such, I carefully consider the power of my work and enjoy the process as an avenue for personal growth. My hope is that these practices bring me closer to comprehending the infinite truths of the universe." In 2018, she was awarded the Strachan Donnelley Award for her combination of research in Hawaiʻi and leadership that exceptionally blended the humanities with ecology and evolutionary biology in order to promote long-term health, social justice, and sustainability. Bielecki's current roles include liaison, grant writer, and co-coordinator for the growing Yale University and Rwanda strategic partnership on sustainable development.

[1]Student

am of Hawaiʻi more than just by being born there. Such subtle sensitivities to and intimate relationships with Hawaiian places can be difficult to communicate to academia, though they are legitimate ways of knowing. My aim in mentioning this intimacy is to acknowledge how I am implicated within this work, rather than assert any personal claims, including to some notion of objective knowledge or socio-political right.

It is with great love that I share a story of Kanaloa-Kahoʻolawe in which I challenge our supposition of the inertness of matter and recognize the power of this special island in Hawaiʻi. Legitimizing the agency of Kanaloa-Kahoʻolawe has major implications for how the island might be restored, and I describe some of those possibilities—primarily, legal personhood for Kanaloa-Kahoʻolawe would expand State liability for restoration. I utilize the tools of interdisciplinary theory to bring Kanaloa-Kahoʻolawe into appearance and nuanced approaches to knowing the roles humans and nonhumans do and can play in environmental "problems." In this creative work, I draw on insights from quantum physics, post-structuralist theory, Hawaiian cosmology, international law, and the practices of history-making—relying heavily upon enthnographic fieldwork I conducted in my community in Hawaiʻi and Karen Barad's book on material performativity, *Meeting the Universe Halfway*.

## Theoretical background

The universe is not made up of matter, but is made in the process of mattering (Barad 2007). All of existence is essentially entangled in pulsating waves of energy. In the dark ages of our universe, gravity magnified slight fluctuations in the density of energy. The densest of these associations enfolded into the first stars and galaxies, and created spaces that allowed the dawn of early light to blaze into existence. The universe also includes its unseen[2] and non-mattering[3] spaces. Gravitational interactions continually create forces that pull energy into patterns. This is similar to water moving downhill, displaying the coherence of smooth laminar flows and sometimes turbulent effects brought about by the dynamics of adhesion and tortuosity[4]. The enchanting relationship of matter and energy is simplified and symbolized in the famous equation $E = mc^2$, whereby we can understand mass ($m$) and energy ($E$) as two different aspects of the same underlying physical phenomena ($c$ represents a constant number, referred to as the speed of light[5]).

Though we often imagine the universe as an assemblage of things, when we fully consider the implications of Einstein's theories of matter, we may recognize the restlessness of the universe. We have the opportunity to de-"thing" the universe—that is, to transform our understanding of innately-separate components interacting into a recognition of the holistic dynamisms of universal intra-relations. The universe is a phenomenon. The very

[2]Astronomers have established that dark matter dominates the Universe, but they still don't understand its identity, primarily because it doesn't interact with light, and therefore, cannot be seen.

[3]For example, antimatter has been predicted in the combination of the abstract theories of relativity and quantum mechanics, found experimentally, and is implicated in common medical imaging practices (positron emission tomography). Laurent Canetti et al. 2012. Matter and antimatter in the universe. *New J. Phys.* 14. DOI: 10.1088/1367-2630/14/9/095012

[4]Tortuosity (geometrical, electrical, diffusional, hydraulic) describes the energetic efficiency of a non-equilibrium thermodynamic flow process which accounts for relationships between the dynamic porous media (e.g., ice, snow, rocks) and its underlying geometry and topology of pore spaces. (Clennell 1997) See also, Requarth, Tim (11 January 2016) Our chemical eden. *AEON magazine*. Found at: https://aeon.co/essays/why-life-is-not-a-thing-but-a-restless-manner-of-being.

[5]Note: I would argue that the constant c is not fundamental in a physical sense, but reflects only an approximate description of our discernment of the materializing of light in a particular context. That is, the speed of light does not mean the speed of one photon, but the consistent production or "springing up" of quantitatively determining/determined phenomena. This cosmic speed limit is only constant in that the value of 299,792,458 m/s is produced in the particular intra-actions of vacuums and other measuring (demarcating or "cutting") agential apparatuses (such as someone situated in a particular intra-relationship with the measured phenomenon (i.e., right next to it)).

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believable and practical notion of matter results from the nesting of phenomena within phenomena within phenomena ad nauseaum. The material stuff of our lives emerges as a consequence of socio-physical demarcation and enactment of boundaries (Barad 2007, Swimme and Tucker 2011). Our belief in individual entities (alive or otherwise) with pre-existing definite edges and distinct determinate properties does not represent the way the universe actually exists. Relations of interior-exteriority, a "this" separate than a "that," are co-produced. While we give a tremendous amount of power to the social world to represent and create, the material world critically participates in determining our realities, too (Barad 2003). Consider, for example, as theories of quantum physics suggest, that particles remain in a ghostly state of being everywhere and nowhere at once until a measurement occurs which materializes them in place[6]. Distinctions between particles are determined by their performance and our measurement of them—it is a result of entanglement of material and immaterial forces (i.e., energy, quantum forces, scientific discourse, technologies, cameras, and the human body, etc.). The rich diversity of our universe is the result of agentive markings and making of space and time (Barad 2007).

A number of stories have talked about how bodies come to matter and are excluded from mattering in the different productive practices of phenomena (see Michel Foucault's (1982, 1990, 2012) modes of producing human subjects, Neil Smith's (1996) production of nature, and Judith Butler's ideas on gender performativity (Butler 2011)). However, even when these discussions challenge the notion of a pre-existing other, the suppositions of a Democritus atomistic world persist. Atomism, or the separateness of reality, and therefore also the separateness of the social and material, makes possible the inquiry of which representations are real. However, these cosmological assumptions stubbornly recapitulate divides that we seek to undo, such as the colonizer-colonized or nature-culture dichotomies. Through the theory of agential realism, however, Karen Barad (2003, 2007) invites us to stop attempting to determine whether Snowdrop or Kitty[7] is to blame, and step into the diffractive world of intra-actions within the looking glass[8].

The agential realist ontology proposed in Meeting the Universe Halfway (Barad 2007) is not merely a Nietzschean rejection of an objective reality; neither does it argue that separateness is a mere illusion of interpretation. "We" are not reducible to a fundamental sameness, real or imagined. Rather, "we" are made meaningful in the ways we enact our differences. Matter is materialized and made meaningful (for instance, as a body) through performed inclusions and exclusions (Haraway 1988, Barad 2007). Objects are boundary projects because they don't exist as such objects prior to mapping. However, "boundaries shift from within; boundaries are very tricky. What boundaries provisionally contain remains generative, productive of meanings and bodies" (Haraway 1991). What is more, history matters very much—history helps us understand how matter materializes as it does from a theoretical field of infinite potentialities. For example, an oil droplet bouncing along the surface of a liquid gently sloshes the liquid with every bounce while ripples from previous bounces (referred to as pilot waves) affect its course. As such, through history we contemplate how particular intra-actions, specifically particular inclusions and exclusions, limit possibilities.

[6] The theory that particles play out all possible realities simultaneously is known as the "Copenhagen interpretation," named after the hometown of Danish physicist Niels Bohr, one architect of this theory.

[7] That is, the social or the material

[8] The first chapter of Lewis Carroll's *Through the Looking Glass* opens with Alice (from *Alice in Wonderland*) speculating which of her two kittens was to blame for mischief: "One thing was certain, that the white kitten (Snowball) had had nothing to do with it:—it was the black kitten's (Kitty's) fault entirely."

## Kanaloa-Kahoʻolawe

In the eminent Hawaiian creation legend, the Kumulipo, in order to bring sufficient light and space for life to flourish, Earth Mother Wakea and Sky Father Papa separate from each other. During this early emergence of the cosmic web, the god Kanaloa takes form and a time of light and man (ao) is distinguished from the great darkness of spirit (pō). This prayer of the universe's development and Hawaiian genealogy tells us that from within the stretching transformation of pō, Kanaloa births into a hot-striking octopus; his tentacle is cut and ao begins. Kanaloa also materializes into an island, Kahoʻolawe. As Kanaloa is a common ancestor to coral reefs, whales, and man, the Kanaloa-Kahoʻolawe assemblage is embodied in the ocean, the origin of all life of earth, and in the great darkness of the universe. Kanaloa-Kahoʻolawe is an agentive physical apparatus of an elemental god from which life on earth evolved; Kanaloa is a creator not separate from his creations.

Kanaloa-Kahoʻolawe was initially a place laden with powerful prohibitions. Though it was one of the first islands in the archipelago to be seen by man, Kahoʻolawe was the last to be colonized in Hawaiʻi. Kanaloa's existence in this material body excluded it from use for profane activities for hundreds of years. The island's physicality does not represent itself as isolated, desolated, insignificant, or abandoned place (as the first and persistent non-Hawaiian stories describe it to be); rather, Kanaloa persists in the enactment of a physical body. The power of this conspicuous demonstration of self is realized in part through hōʻailona[9]. The kapu[10] of Kanaloa-Kahoʻolawe underscores the respect Hawaiians have for Kanaloa's autonomy. Through renegotiation, the island eventually came to house fishing villages, small agricultural plots, and excellent adze quarries managed by the aboriginal people of Hawaiʻi. Thousands of archaeological features[11] tell us stories about the development of calendars and maps, communing of subjects, gatherings of families, healing of disease, transmission of knowledge, and continuity of purposeful work on the island for over sixty generations (Kanakaʻole Kanahele et al. 2009).

Temporality has a strong role within both historical studies (Partner 1986, Eley 2005, Bloch 1977, Stone 1987) and physics (treated variably as the absolute background or dynamically, as in special relativity, or more recently as a phenomenon of entanglement (Moreva et al. 2014)[12]). Suitably, I want to clarify an essential subtlety about how time is engaged in this moʻolelo[13]. Quantum entanglement, agential realism, and Hawaiian cosmologies treat time not as an external parameter, or succession of metered moments. Instead, time is produced—be it through the agential cuts of Papa and Wakea, in the self-referencing enfolding of Kanaloa materializing, or the rendering of differences.

[9] Hōʻailona can be defined as a symbol, sign, marker, or omen; and refer to physical and metaphysical communications to guide decisions, understandings, and actions.

[10] Kapu, often referred to as a system of taboo, is a prohibition, or a special privilege or exemption based on relational sanctity or power.

[11] Over 500 archaeological or historic sites and nearly 3,000 features have been inventoried on Kahoʻolawe over the last four decades, documenting fishing shrines, dryland agricultural plots, dwellings, medicine grinding stones, petroglyphs, patterns of cupules ground into the surface of flat stones, large arrangements of stone with astronomically significant placement, amongst many others. In 1981, the entire island of Kahoʻolawe was added to the National Register of Historic Places and given the name of the Kahoʻolawe Archaeological District.

[12] A unified theory of everything continues to elude physicists as they seek to reconcile the apparent incompatibilities of quantum mechanics (conditions of the very small world of particles) and general relativity (conditions of the very large world of planets and black holes) created by the "problem of time." The Wheeler-DeWitt equation managed to quantize general relativity, but excluded time in order to do so. The quantum phenomenon of time entanglement is regarded as the closest approach to a unifying theory of time.

[13] Literally "a succession of words," or story.

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O ke au i kahuli wela ka honua
O ke au i kahuli lole ka lani
O ke au i kukaʻiaka ka la
E **hoʻomalamalama** i ka malama
O ke an i makaliʻi ka po
O ka **walewale** hoʻokumu honua ia
O ke kumu o ka lipo
O ke kumu o ka po i po ai
O ka **lipolipo**, o ka lipolipo
O ka lipo o ka la, o ka lipo o ka po
Po wale ho-i

–Prologue of the Kumulipo from Beckwith 1981, emphasis added.

The various English translations of this prologue imply and entangle spatial concepts, degrees of shade, and time variability in describing the establishment of night from "the source of deepest darkness, of the depth of darkness, of the darkness of the sun, in the depth of night" (Beckwith 1981). Night is, and so night was born. Hoʻomalamalama (illuminations) is juxtaposed in relation to deepest darkness (of the depth of darkness, lipo; of the darkness within a cavern, lipolipo) evokes a sense of the ocean's gradation from shore into deep water (Beckwith 1981, Keaulana 2013). Out of the amorphous slime (walewale) of the deepest ocean, life emerges distinguished and continually engaged. Kanaloa remains mostly in the darkness and supports the whole continuum of light-dark along the length of his body. Each new epoch of time, each wā, is marked by an action, or birthed distinctions such as the emergence of ocean and land creatures. Time is not just relative, it is relational. Boundaries, too, are enacted—they are not abstract delineations in space, but specific material demarcations of space (Barad 2007). Hence, both time and space are intra-actively produced (Barad 2007).

Kanaloa-Kahoʻolawe's history is temporal not in the sense that it tells about particular changes over evenly spaced increments of time in a linear fashion; rather, Kanaloa-Kahoʻolawe's story and the ways in which the island comes to matter is re(con)figured in the very making and marking of time. The Hawaiian "map of the body" is a function of time (Keʻeolani, unpublished data)[14]. The human body, for example, is characterized by three zones, or three piko[15], that represent the beginning of time, the present, and forever into the future. Similar to the ways DNA materializes the knowledge of experience and determines possibilities, or the way in which rings in a tree mark the mattering of the past and come into mattering, so too, the corpus of Kanaloa-Kahoʻolawe embodies the past, present, and the future (Barad 2007). Kahoʻolawe is considered the piko of Hawaiʻi, and Kanaloa connects all of the Pacific.

Kanaloa-Kahoʻolawe is not located within a naturally bounded body. However, in privileging representation over performance (Turnbull 2002), we can spatialize Kanaloa within the Euclidian space of a gridded map. In doing so, we create a fetishizing apparatus of a "nature separate than humans;" we create an apparatus of "land;" we fissure the holistic dynamisms of ʻāina[16]—which is the Hawaiian inclusive concept of nature of which humans are a part. In this "overthrow of diffusionism by localism" (Turnbull 2002), these apparatuses enable particular divisions of labor. The fixing and regulating of space enables particular kinds of hierarchies between humans and islands, and between the islands themselves. This positioning of the island is heavily dependent on the material contingencies of international politics, since such dynamics are in-

[14]Kekoʻolani, A. (2004) Nāʻau Poi: Spiritual Food for Cultural Enlightenment. Masters thesis dissertation. Pacific Islands Studies, University of Hawaiʻi http://hdl.handle.net/10125/21175.

[15]There are many understandings of piko. The most salient are its references to the navel or umbilical cord, or figuratively as a blood relative or genitals. Piko also refers to a summit or crest; the crown of the head; end of a rope; border of land; center; the connection of a stem to the leaf (commonly, of taro); the bottom round of a carrying net (kōkō). A piko is emblematic of connections between ancestors and descendants, and the past and future. The piko is also regarded with importance and respect.

[16]Literally translates as "that which feeds," suggesting the significant role of ʻāina in the constitution of human bodies.

strumental in decisions regarding the positioning of resources.

During the morning of December 7, 1941, the Imperial Japanese Navy Air Service launched an attack against U.S. property on Oʻahu island while Hawaiʻi was under the control of a territorial government. The surprise attack, like a drop of ink in a glass of water, punctuated and then permeated the United States with fear. The attack led to three years of very severe military governmental control, declared as martial law, and compelled the United States' entry into World War II. Immediately, the U.S. Navy removed public access from Kahoʻolawe and began using it as a bombing and weapons testing range. An executive order signed by U.S. President Eisenhower in 1953 then reserved the entire island of Kahoʻolawe for the use of the United States and placed the island under the jurisdiction of the Secretary of the Navy[17]. Although Kahoʻolawe has been regarded as the "last bastion for dwellers of the spirit world," (KICC 1993) 50 years of assault by napalm, mock atomic warheads, bombs, and rockets transformed Kahoʻolawe into the most bombed island in the Pacific (KICC 1993).

For decades, red plumes of dust flared forth from Kahoʻolawe island. The denuding of Kanaloa into bloody rivers of eroding soil, the appearance of Kanaloa in dreams, imperatives of aloha ʻāina[18], daring protests, "illegal" occupation of the island, and legal action ("Aluli et al. v. Brown" 1977) eventually resulted in some success for the recognition of Kahoʻolawe as unique. In 1994, the U.S. Navy acknowledged in written terms that Kahoʻolawe rightfully belongs to the Kingdom of Hawaiʻi and military use of the island was finally halted (August 1992, KIRC 2017, PKO 2016). Over $400 million was then spent attempting to de-dud the island. The U.S. Navy removed 10 million pounds of ordnance in 10 years, and then declared the project satisfactorily completed in 2004 when the Congressionally-mandated time frame and money ran out. While just over 75% of the surface of the island was cleared of ordnance, tons of munitions remain lodged in the earth — only nine percent of Kahoʻolawe has been cleared to a depth of four feet. Today the Kahoʻolawe Island Reserve Commission (KIRC), representing the State of Hawaii, manages Kanaloa-Kahoʻolawe within a trust for the promised future return of a restored island to the sovereign Kingdom of Hawaiʻi. The Commission subsequently depleted a $44 million federal trust fund with its restoration activities since the state gained trusteeship of the island.

Trusts are legal devices that are intended to assure that property (in this case, Kanaloa-Kahoʻolawe) is made productive for the trust's beneficiaries (in this case, the governing body of the Kingdom of Hawaiʻi and her subjects). In the international context, the State of Hawaii must execute the trust following customary law and upholding the laws of the Kingdom of Hawaiʻi. While, the KIRC's stated mission is to implement the vision of Kanaloa restored and the people of Hawaiʻi caring for the land "in a manner which recognizes the island and ocean of Kanaloa as a living spiritual entity" (KIRC 2017a), the island has not been significantly restored. The task of restoring such a heavily bombed island is formidable. Paul Hi-

[17]The authority of that decision relied upon The Hawaiian Organic Act, Pub.L. 56–339, 31 Stat. 141, enacted April 30, 1900. This was enacted by the United States Congress to establish a new Constitution and U.S. Territorial government after the Kingdom had been under the control of a hostile foreign provisional government declared "the Republic of Hawaii."

[18]Often literally translated as "love of the land", aloha ʻāina is a central Hawaiian value and concept that characterizes the intimate, related and loving, relationships of nature, and which serves as the basis for human's responsibility for understanding, respecting, and caring for the world of which we are a part.

[19]Hardpan is a dense layer of soil largely impervious to water impeding drainage and restricting the growth of plant roots. Hardpan can be broken up mechanically (digging or plowing) or through the use of soil amendments to varying degrees of success, often unpredictably. Extensive areas of Kahoʻolawe island are seemingly intractable hardpan, created from years of severe erosion of the uppermost layer of soil, and the particular structure of Kahoʻolawe's mostly clay (oxisol) soils. Digging and plowing solutions are restricted by the risk posed from unexploded ordnance.

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gashino, restoration manager of KIRC, once rhetorically asked me, "what do you restore hardpan[19] to?"

Having demonstrated the customary understanding of Kanaloa's agency, the substantive work of my Master thesis[20] charts a path for mediation, arbitration, and legal action to officially recognize the personhood of Kanaloa. That is, granting rights to the environment itself. This would not grant Kanaloa-Kahoʻolawe all the rights of a human in an unrestricted manner, but provide a way of ensuring that access to judicial remedy is available in order to address harms and breaches of trust. In this particular instance, personhood would also explicitly expand the trust's beneficiaries to include Kanaloa-Kahoʻolawe, then allowing direct harms (e.g., the persistence of live ammunition; lack of a comprehensive soil erosion management plan; the severance of an ancient cloud bridge between Ulupalakua, Maui and Kahoʻolawe which brought life-giving naulu rains; etc.) to be considered as breaches of trust. As it stands, the State of Hawaii has only been held responsible for maintaining public trusts for five purposes[21] as defined in the Hawaiian Homes Commission Act, 1920[22].

Rights of nature are not rights to anything in particular, but generally a means to enable nature to have a legal hearing. Legal personhood for Kanaloa would grant the right to a representative of Kanaloa, like a Kingdom subject, to seek remedies for corporeal damages in a U.S. court of law. Oftentimes, the inability to establish a right of action like this is the most consequential hurdle in lawsuits that seek to protect nature and obtain remedy for environmental damages.

## Conclusion

Justice is not a solution, but a process requiring the recognition and assumption of responsibility for the ways in which we materialize what comes to matter and not matter (Barad 2007). I agree with Barad (2007) and others that we cannot respond to the other as if the other is radically outside of one's self, but rather that we have mutually constituted our differences from radically different positions of power. Our practices matter, as the world is materialized differently through them. A number of obstacles to justice (e.g., threat of violence, uneven political power, rhetorical weapons) have characterized the Kingdom of Hawaiʻi's and her subjects' relationships with the United States at local and international levels. And, until restitutio in integrum of the Kingdom is complete, it is assumed the legal system of the State of Hawaii principally provides de facto for the legal protection of rights, including those guaranteed under international law[23], even as Hawaiʻi remains in a state of war under U.S. occupation[24] (Sai 2008). While justice for Hawai-

[20] Master of Environmental Sciences (MESc), Yale University, School of Forestry & Environmental Studies, 2018

[21] for 1) public schools; 2) betterment of the condition of native Hawaiians as defined in the HHCA; 3) farming; 4) homeownership; and 5) public use.

[22] The Admissions Act further states that any other object besides the five purposes shall constitute a breach of trust for which suit may be brought by the United States.

[23] Customary international laws regarding the duty of an occupying State to administer the laws of the occupied State are codified in Article 43 of the 1899 Hague Convention, II.

[24] Proceedings to establish an International Commission of Inquiry under Part III of the 1907 Hague Convention for the Pacific Settlement of International Disputes stemming from the Larsen v. Hawaiian Kingdom arbitration held under the auspices of the Permanent Court of Arbitration (1999-2001) were initiated under a Special Agreement dated January 19, 2017. The title for these proceedings is "Incidents of War Crimes in the Hawaiian Islands—The Larsen Case." The matter of Hawaiʻi being in a state of war is partly the subject of the fact-finding proceedings of International Commission of Inquiry: Incidents of War Crimes in the Hawaiian Islands–The Larsen Case. See: http://hawaiiankingdom.org and Sai, D. K. (2008). A slippery path towards Hawaiian indigeneity: An analysis and comparison between Hawaiian state sovereignty and Hawaiian indigeneity and its use and practice in Hawai'i today. JL & Soc. Challenges, 10, 68.

[25] I.e., the statutes (of any form) laid down by a legislature, court, or other human institution—as opposed to natural law, which are understood as inherent rights (often as ordained by God, some other higher power, or logic/reason).

ians is both a philosophical and legal matter, it can be materialized through the apparatus of positive law[25] (Hazard Jr 2001) (e.g., the trust) and remedied through equity (Perelman 2012). This particular trust provides momentous opportunities.

I ka ʻōlelo ke ola, i ka ʻōlelo ka make. In words is the power of life, in words is the power of death.

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*kanaloa-kahoʻolawe*. Edith Kanakaʻole Foundation.

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# Can impact investing in tropical forests improve rural livelihoods and reduce deforestation pressure? An assessment of two case studies in Acre, Brazil

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**Abstract**

Acre Aves and Dom Porquito are animal protein production companies in the state of Acre Brazil. They both received impact investments from Kaeté Investimentos, a São Paulo-based impact investment manager focused on the Brazilian Amazon. Acre Aves and Dom Porquito employ an impact-mode that integrates rural landowners into their supply chains, with the intent of increasing rural incomes and reducing deforestation pressure. Initial results suggest that both companies have strong social impact, as producers integrated into company supply chains were found to have increased overall quality of life, increased income/purchasing power, and more financial stability. Results suggest Acre Aves and Dom Porquito have moderate and weak environmental impacts, respectively. Although the companies' producers reduced the use of unsustainable slash-and-burn agriculture, they were also found to have increased the size of their cattle herds. The results challenge the assumption that intensification of productive activities provides a solution to reduce deforestation in the Amazon. However, they also suggest the model employed by Acre Aves and Dom Porquito provides a sustainable alternative to the Brazilian Amazon's cattle-based economy.

*Acre Aves e Dom Porquito são empresas de produção de proteína animal no estado do Acre Brasil. Ambos receberam investimentos de impacto da Kaeté Investimentos, uma gestora de investimentos de impacto com sede em São Paulo, focada na Amazônia brasileira. Acre Aves e Dom Porquito empregam um modo de impacto que integra os proprietários rurais em suas cadeias de fornecimento, com a intenção de aumentar a renda rural e reduzir a pressão de desmatamento. Os resultados iniciais sugerem que ambas as empresas têm um forte impacto social, uma vez que os produtores integrados nas cadeias de fornecimento da empresa apresentaram maior qualidade de vida, aumento da renda/poder de compra e mais estabilidade financeira. Os resultados sugerem que o Acre Aves e Dom Porquito têm impactos ambientais moderados e fracos, respectivamente. Embora os produtores das empresas tenham reduzido o uso de agricultura insustentável de derrubada e queimada, eles também aumentaram o tamanho de seus rebanhos bovinos. Os resultados desafiam a suposição de que a intensificação das atividades produtivas fornece uma solução para reduzir o desmatamento na Amazônia. No entanto, eles também sugerem que o modelo empregado pelo Acre Aves e Dom Porquito fornece uma alternativa sustentável para a economia baseada na pecuária da Amazônia brasileira.*

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## Introduction

The world's tropical forests provide vitally important ecosystem services including climatic regulation, biodiversity maintenance, and hydrologic cycle regulation, among others (Bonan 2008). However, tropical forests continue to face significant pressure and threats of deforestation and/or degradation (Sloan and Sayer 2015), and suffer losses in area of approximately 6.8 million hectares annually (FAO and JRC 2012).

While most biodiversity conservation strategies prioritize deforestation reduction (Nepstad et al. 2009, Soares-Filho et al. 2006, CBD 2018), there exists a significant gap in the funding needed and the funding available for conservation around the world. While global annual funding for conservation is estimated to be approximately $50bn (Parker et al. 2012), the need is estimated to be between $300–$400bn (Huwyler et al. 2014). Many point to market-based strategies such as impact investing as a means to address this gap. Impact investing is investing in companies, projects, and funds with the objective of generating positive social and/or environmental outcomes alongside financial gains (GIIN 2018). It may help to solve pressing conservation challenges by attracting new sources of financing, while also providing returns to investors (Clark 2007, Huwyler et al. 2014, NatureVest & Eko Asset Management Partners 2014). However, the field of impact investing is still incipient, and more research is needed to evaluate the potential conservation benefits it may offer.

The rise of impact investing in recent years has failed to provide many relevant examples in regions dominated by tropical forests. However, one noteworthy exception is the Amazonian Sustainable Enterprise Investment Fund (FIP Amazônia). FIP Amazônia is a private equity fund 80% capitalized by the Brazilian National Development Bank and managed by São-Paulo based investment manager Kaeté Investimentos (Kaeté). As the world's only fund 100% dedicated to impact investing in the Amazon, FIP Amazônia stood out as an ideal partner for research focused on impact investing in tropical forests. FIP Amazônia has focused the majority of its investments in the state of Acre in northwestern Brazil, as the state government's pro-sustainable development platform has led to an environment relatively rich in sustainable enterprise (Rêgo 2015).

The state of Acre (Figure 1) has a population of slightly over 800,000 and a land mass of about 1.16 million km² (O Governo do Estado do Acre 2018). Acre is a relatively poor state, with its annual per-capita GDP of R$12,690 (about US$3600) ranking number 19 of Brazil's 27 states (Chepkemoi 2017). It does not have the best conditions for agriculture or cattle ranching, particularly due to its predominantly highly-weathered, acidic ultisols (Watling et al. 2017). Such soils are largely lacking in plant nutrients, and farmers must typically rely on slash-and-burn agriculture (Sanchez et al. 1982), making larger scale sustainable agricultural management more challenging. Since the state's pro-environmental government came to power in 1999, deforestation fell from 547 $km^2\ yr^{-1}$ in 2000 to 264 $km^2\ yr^{-1}$ in 2015 (O Governo do Estado do Acre 2018). Furthermore, Protected Areas cover 45.84% of the state's land mass and forest cover remains high at 83% (O Governo do Estado do Acre 2018).

The two investments assessed for the present study were made in animal protein-production companies Acre Aves (AA) and Dom Porquito (DP), which began operations in Acre in 2009 and 2016, respectively. AA produces chicken and DP produces pork, and both integrate low-income, and small- and medium-sized rural landowners into their supply chains. Both companies are public-private initiatives (AA is also partially owned by a cooperative representing the rural community). Start-up costs were funded by the government of Acre and local entrepreneurs. Furthermore, the state government invested heavily in developing the state's productive base. It partially financed the barns used by producers to fatten chickens and pigs in AA and DP's supply chains, and provided access to lines of credit for the producers to take out low

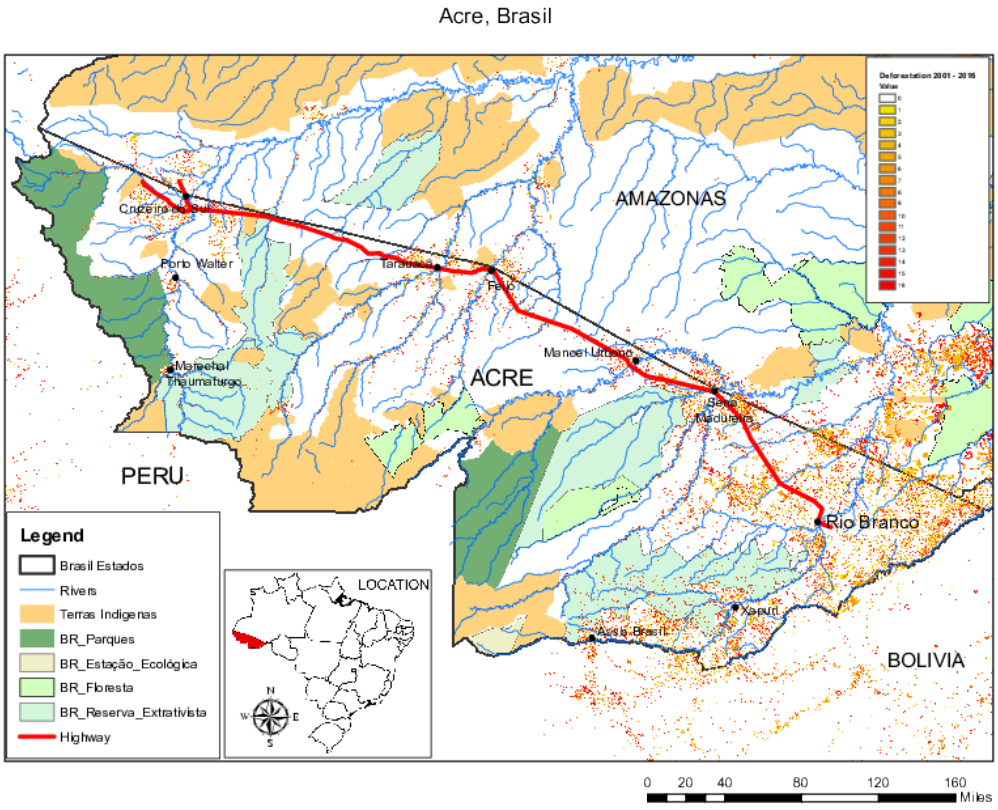


**Fig. 1.** Location of the state of Acre in Brazil.

interest rate loans to finance the remaining portion. In the case of AA, many producers chose to take out additional loans within several years of starting to raise chickens to build newer and larger barns to expand their production.

A description of the supply chain model employed by AA functions is as follows:

- AA produces chicks in a state-of-the-art incubation facility that it built, owns, and manages.
- AA distributes chicks to approximately 45 "integrated producers," rural landowners under contract to raise chickens for AA.
- The rural producers raise the chickens in highly efficient, self-contained chicken barns. AA provides the producers with all the necessary medication and chicken feed (all of which is produced in AA's feed mill), as well as technical assistance.
- After 45 days, the chickens have an average weight of about 2.3 kilograms. AA collects them from the producers and slaughters and processes them in its slaughterhouse, before bringing them to market.
- As mentioned above, the producers are known as integrated producers. They do not pay for the chicks, feed, medication, technical assistance, or transport. Likewise, AA does not purchase the fattened chickens, but compensates the integrated producers for their services and for the use of their chicken

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barn. Compensation varies based on how well the producers are able to fatten the chickens. The higher the average weight of the chickens, and the higher the number of chickens that survived, the better compensation the producers receive[1].

The theory of change behind this model rests on the fact that it provides rural landowners with an intensive production system requiring a small land area. This is meant to replace extensive, low-intensity production systems requiring large area, such as cattle ranching, which is responsible for 4/5 of Amazon deforestation (Nepstad et al. 2009). This is meant to drive positive social impact by increasing and diversifying income for rural landowners. In turn, this should reduce deforestation pressure from rural landowners, who should be able to increase their income through expansion of intensive animal barns instead of extensive pasture, driving positive environmental impacts.

The goal of this research was to assess this theory of change by measuring the environmental and social performance of AA and DP's supply chains. More broadly, there have been few instances of impact investing in tropical forests, and even less research carried out on the subject. This research attempts to shed light on the potential benefits impact investing may hold for tropical forest conservation by observing results from the concrete examples seen in these two companies.

## Materials and methods

*Choice of impact investment company*

As described in the introduction, there are few impact investments that have been made in the Amazon basin or in other tropical forests. FIP Amazônia was chosen to be the subject of the research because it is the only investment fund fully dedicated to impact investing in the Amazon. Of the four major investments made to date, three were made in the state of Acre, which made Acre the obvious research site choice. One of the three investments was made in Peixes da Amazônia, a fish company that employs a similar model to AA and DP. It was excluded from the present study for various reasons, including that a lack of working capital has kept the company at a near "pre-operational" level and its producers do not interact as consistently with the company and are not fully integrated into its supply chain.

*Data collection and interviews*

Research and data collection was carried out in Brazil in September–November of 2017. The first and preliminary phase took place in Kaeté's São Paulo headquarters, and consisted of secondary research and semi-structured interviews of Kaeté staff. The purpose of this phase was to gain familiarity with Kaeté's investment model and investments in AA and DP. The second phase took place in the state of Acre. Several weeks were spent gaining familiarity with Acre and its sustainable development agenda, by speaking with NGO staff and government employees and participant observation of several sustainable enterprises. Next, a better understanding of AA and DP was developed by speaking with executives and staff as well as participant observation of all company processing facilities. Finally, the bulk of data collection occurred via semi-structured interviews of AA and DP integrated producers.

Interviewee selection was randomized; a list of all producers was obtained, each producer was assigned a number, and a random number generator was used to select about 40% of all producers as interviewees, allowing room for unreachable or unwilling producers, with the goal of interviewing about 1/3 of all producers. In some instances, producers that were not chosen for interviews were interviewed either: a) to ensure a representative sam-

[1]For simplicity's sake, the AA operation is described. DP employs essentially the same model, except it includes approximately 25 integrated producers, who fatten pigs over the course of about 105 days until an average weight of 105 kilograms.

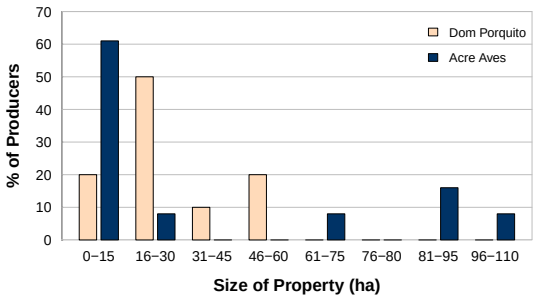


**Fig. 2.** Property size of the interviewed farmers working with Acre Aves (n = 13) or Dom Porquito (n = 10).

ple in terms of geography and socioeconomic status; or b) simplify logistics when a chosen producer was particularly difficult to be reached. Interviews were continued until data saturation had been reached (when it seemed that the variety in responses had been captured and additional interviews were no longer yielding new information).

Semi-structured interviews were designed with the intent of understanding how producers' lives had changed since they began working with AA or DP. Interviews typically lasted between 40 and 60 minutes, and were carried out following the Yale Human Research Protection Program guidelines. Before starting the interview, the research purpose was explained and producers were asked for verbal consent to participate. Producers were assured that responses would be reported anonymously, and their participation would not present them with any potential risks.

The interview questionnaire had four distinct sections. The first focused on relevant background information. This included characteristics and history of the property, such as size, forested area, registration in the Rural Environmental Registry (Cadastro Ambiental Rural, part of Brazil's Forest Code), and how the producer obtained the property. This section also observed the origin of the producer's partnership with AA or DP. The second was mainly oriented towards understanding environmental impact through questions related to productive economic activities, land use and income sources. The third section focused on social impact, with questions related to income level, financial stability, satisfaction with working with AA or DP, and overall quality of life.

*Data analysis*

Based on analysis of the data collected in the semi-structured interviews, social and environmental impact ratings were made for each company. Ratings ranged from Weak to Moderate to Strong. They were based on the analysis of specific indicators discussed in the Results. The social impact rating was most reliant on the self-reported ratings of overall quality of life, income level/purchasing power, and financial stability. The environmental impact rating was most reliant on the number of household engaged in slash-and-burn agriculture and the size of the herd for cattle ranching.

## Results

A total of 29% (13 of 45) of AA producers were interviewed, and 42% (10 of 24) of DP producers were interviewed. 62% of AA producers had properties up to 15 hectares (ha) in size and an average property size of 34 ha, while 70% of DP producers had properties up to 30 ha in size and an average property size of 27 ha (Figure 2).

The relatively small scale of the companies' current supply chains resulted in a relatively small data set, which does not allow for quantitative cause and effect statements to be made with respect to the companies' operations and observed differences in the lives of integrated producers. Accordingly, the data cannot prove or disprove the assumptions made in the impact model employed by AA and DP. However, the results demonstrate significant trends associated with the model, which can be used to support or oppose its underlying assumptions (see Table 1 for summary results).

*Social impacts*

*Overall quality of life*—The vast majority of AA and DP producers reported that they had experienced

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**Table 1.** Summary of results from interviews with producers working with Acre Aves (n = 13) or Dom Porquito (n = 10) in Acre, Brazil. *Notes*: [1]Results suggest that these investments would not have been possible without having become an integrated producer. [2]Results suggest reliance on agriculture and daily contracting are unstable and result in high income volatility.

| **Impact** | **Acre Aves** | | **Dom Porquito** | |
|---|---|---|---|---|
| | Rating | Specific Indicators | Rating | Specific Indicators |
| **Social:** | Strong | *Overall quality of life:*<br>100% reported moderate/significant improvement<br>*Income/purchasing power:*[1]<br>62% made at least 3 significant investments<br>92% made at least 2 significant investments<br>*Financial stability:*[2]<br>92% previously reliant on agriculture<br>46% previously reliant on daily contracting | Strong | *Overall quality of life:*<br>80% reported moderate/significant improvement<br>*Income/purchasing power:*[1]<br>40% made at least 3 significant investments<br>50% made at least 2 significant investments<br>*Financial stability:*[2]<br>80% previously reliant on agriculture<br>80% previously reliant on daily contracting |
| **Env.:** | Moderate | *Slash-and-burn agriculture:*<br>92% of those previously reliant on agriculture stopped<br>*Cattle ranching:*<br>43% increased herd size | Weak | *Slash-and-burn agriculture:*<br>86% of those previously reliant on agriculture stopped<br>*Cattle ranching:*<br>60% increased herd size |

an overall improvement to quality of life, with 100% of AA producers and 80% of DP producers interviewed reporting a moderate or significant improvement (Figure 3). Many producers described a shorter and less physically taxing work day as compared to their previous form of income. For example, many producers used to rely predominantly on unmechanized agriculture, which required long hours working in the hot sun, versus fewer hours per day tending to the animals in the shade of the barn. Another common benefit reported was the ability to work at home and remain close to family, as many producers used to spend long stretches (up to 20 days per month) away working as daily contractors on large ranches. However, a small number of producers reported worsened quality of life, citing things such as bad odor from the barn, the lack of days off (as the animals require daily attention), company delays in delivering new stocks of animals, and the burden of debt that came with the installation of the barns for most producers.

*Income level*—Due to the complexity of measuring rural household incomes (see Discussion), a direct estimate of change in household income was not assessed for all producers. However, all producers of both AA and DP who could give an estimate of monthly income reported increases, some of which were modest while others were up to 300%. Although the accuracy of these numbers is questionable, they suggest that average income lev-

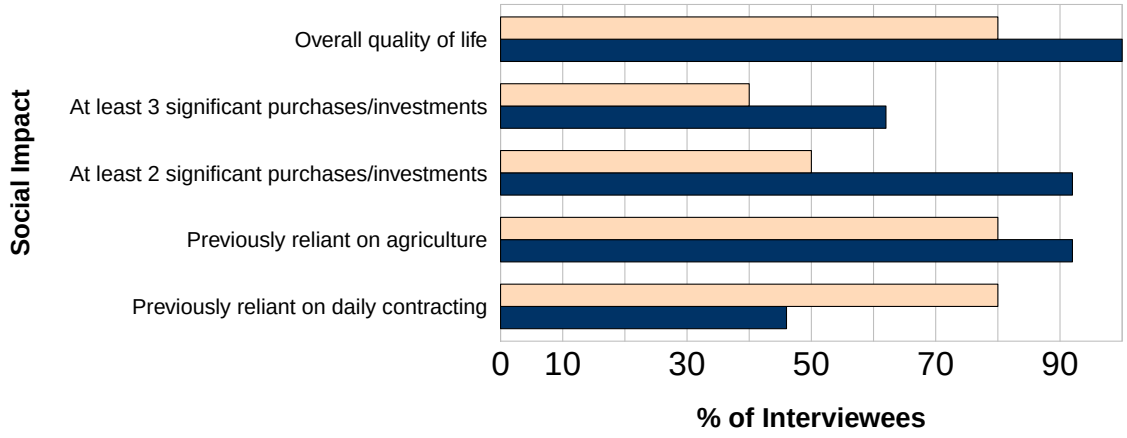


**Fig. 3.** Social impact of Acre Aves and Dom Porquito on a sample of their integrated producers located in Acre, Brazil.

els did rise.

Many producers reported that previously they never had spare money beyond what was needed for basic essentials. The majority reported having made significant purchases or investments on their property (such as buying a new car, building a new house, installing a new well, etc) since becoming integrated producers (Figure 3). 62% of AA producers and 40% of DP producers reported making at least three such investments since becoming integrated producers. Furthermore, 92% of AA producers and 50% of DP producers made at least two such investments. These figures suggest a strong trend of increasing purchasing power after entering AA's or DP's supply chain, particularly among AA producers.

*Stability of income*—All but one producer interviewed reported reliance on a variety of income sources both previously and after beginning to work with AA or DP. According to the interview results and observation, it is very uncommon for producers to rely on only one economic activity. Furthermore, most integrated producers had previously been reliant on agriculture and daily contracting, which are both highly unstable income sources that lead to significant income volatility, unlike working with AA or DP (see Discussion). Of the AA producers interviewed, 92% reported previous reliance on agriculture and 46% reported previous reliance on daily contracting on other ranches. 80% of DP producers previously relied on agriculture and 80% also relied on daily contracting. Thus, there is a clear trend of increased financial stability associated with becoming an integrated producer.

*Environmental impacts*

*Forest conversion for agriculture*—As stated above, the majority of producers previously relied heavily on agriculture as a source of income prior to working with AA or DP. All but one producer used unmechanized agriculture, which necessitates the clearing of forests for additional pasture ever two to three years, as previous pasture becomes degraded due to the region's poor soils. Of the 92% of AA producers who previously practiced unmechanized agriculture, 92% stopped either prior to or upon becoming integrated producers (Figure 4). Of the 70% of DP Producers who previously practiced unmechanized agriculture, 86% stopped. Furthermore, several producers commented one of the additional benefits of working with AA and DP being that the work did not require the clearing of forests, as was

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previously needed in order to survive.

*Forest conversion pressure from cattle ranching*—A total of 46% of AA producers and 70% of DP producers reported previous reliance on cattle ranching. As income levels of integrated producers rose, many chose to invest in their cattle herd. 43% of AA producers and 60% of DP producers expanded the size of their cattle herd since the start of their work with AA and DP, potentially contributing to continued degradation of cleared pastures and increasing pressure for further conversion of the region's forests to pasture (Figure 4). Many producers reported that they had started selling more cattle each year than previously, suggesting that the increased income from becoming integrated producers had allowed them to make their cattle ranching operation more profitable.

*Financial Performance*

A brief commentary on the financial performance of the enterprises is warranted, as it provides insight into the long-term sustainability of the companies as well as their associated social and environmental impacts. Based on conversations with Kaeté staff, it appears as though both companies are performing below expectations. The processing facilities of both companies are operating at very low capacity utilization, thus generating low return on asset values. DP's slaughterhouse is currently operating at about 11% of its maximum capacity, while AA is operating at about 48% of its maximum capacity. There are two main issues contributing to these bottlenecks. First, the companies lack the working capital needed to increase operations to a level that is efficient given the large scale of the production facilities. Second, the underlying productive base supplying the slaughterhouses is not large enough: the piglet production center needs to be enlarged, and more barns to raise both chickens and pigs are needed, but there has been difficulty attracting investors to invest in these earlier stages of the supply chain.

## Discussion

As an initial study observing the results of two impact investments in the Brazilian Amazon, valuable takeaways can be distilled from the results. This is especially true because to the author's knowledge, there have been no peer-reviewed studies examining the effects of impact investing in tropical forest regions. Observed results suggest the AA and DP are achieving strong social impact. While positive environmental impacts are evident, they are more tenuous.

The social impact of both AA and DP was rated as Strong. The majority of integrated producers reported better quality of life and higher income. Many significantly improved their living conditions and homes, and were able to make significant investments on their property. While the results do not demonstrate a direct causal link between becoming an integrated producer and increased purchasing power, they suggest that becoming integrated within AA or DP allows rural producers to make investments that would not otherwise be possible. Furthermore, many interviewees expressed a desire to expand their production systems for further improvement. The AA/DP model also allowed households to increase their degree of financial stability by reducing month-to-month variation in income. The model is not meant to be a standalone income source, but one that provides a stable, base level of income that is complemented by other productive activities. Most producers reported a previous reliance on agriculture and daily contracting, which are both unstable and volatile. Income from agriculture depends heavily on the weather and market prices, and many producers reported either past production losses due to bad weather and/or difficulty selling produce in the market. Daily contracting is perhaps even more unstable an income source, with the majority of producers reporting high variability in the amount of daily contracting work they can find each month. On the other hand, becoming an integrated producer of AA or DP provides a stable and predictable income source that

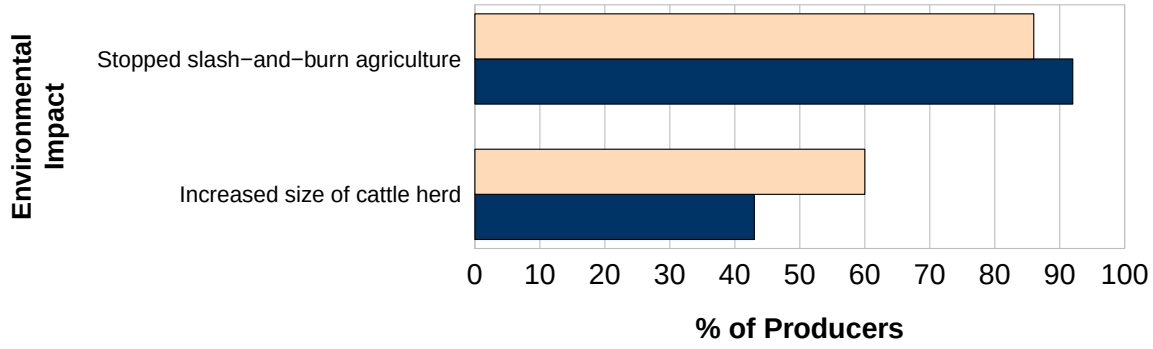


**Fig. 4.** Environmental impact of Acre Aves and Dom Porquito on a sample of their integrated producers located in Acre, Brazil.

can serve as a core component of household income, allowing more unpredictable activities to provide complementary income. Thus, it is evident that becoming an integrated producer was also important in increasing the month-to-month financial stability of integrated producers.

The environmental impact of AA was rated as Moderate, while the environmental impact of DP was rated as Weak. A very strong trend was observed between becoming an integrated producer and reduced deforestation associated with unmechanized agriculture, which contributed positively to the environmental impact rating. However, this was reduced by another strong trend observed between becoming an integrated producer and increasing the size of one's cattle herd. This is a particularly interesting point, because cattle ranching is associated with the majority of deforestation in the Amazon (Nepstad et al. 2009), and increases in herd sizes represent a negative environmental impact. However, in this case it also represents a positive social impact. In Acre, cattle are one of the safest investments small and medium landowners can make, primarily because they are extremely liquid because of the region's strong cattle market. This suggests that in sustainable development, oftentimes tradeoffs must be made between social and environmental progress, and win-win outcomes cannot always be achieved.

There are several additional points that are relevant to the environmental impact of AA and DP, that call into question the assumptions underlying the impact model. Based on interview results and observation, in recent years the government has significantly ramped up enforcement of Brazil's Forest Code and other environmental regulations. Many producers reported that clearing additional forest on their lands was no longer possible for any rural land owners in the region because of increased governmental monitoring and enforcement in the form of fines. This suggests that AA and DP integrated producers may have been forced to stop clearing their lands of forests either way. Second, while some interviewees did have large areas of forest cover remaining on their properties, many had very small areas of forest remaining. Thus, the potential for continued deforestation on those properties is minimal, which makes assessing the model's impact on deforestation more challenging.

It is worth mentioning that the ratings explained above are not indicative of the scale of impacts realized. AA only has 45 integrated producers and DP only has 24. Thus, the direct impacts of the companies' supply chains are relatively limited, reaching under 70 rural landowners who typically have properties under 50 hectares in area. The in-

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vestments made to achieve this impact are large but not exceedingly so: AA has received total equity investments of US$10 million, while DP has received US$25 million. However, these numbers do not include the separate investments made by the government in partially financing the barns for producers. Furthermore, the scale of impact could be greatly increased (about two times for AA and nine times for DP, considering unused capacity in the slaughterhouses) if additional investments are made and the companies are able to operate efficiently.

As discussed in the Introduction, the majority of Amazon deforestation is driven by cattle ranching (Nepstad et al. 2009). In recent years, a large part of international conservation efforts have focused on reducing further deforestation from cattle ranching by intensifying production on existing pasture. The assumption underlying these actions is similar to the assumption underlying AA's and DP's environmental impact model. That is, that intensifying production on lands that have already been deforested will reduce deforestation pressure on remaining forests. The results on this study show that in the case of AA and DP, this link may not be as strong as was assumed. Although this study doesn't disprove this assumption, it does demonstrate that such assumptions regarding the relationship between intensification of production and reduced deforestation merit further qualification and analysis, especially given the large amount of the scarce financing for conservation that is being poured into this area.

While the results yielded significant trends and clear takeaways, the analysis undertaken presented significant intricacies that require further investigation than was allowed for in this project. The complexities of rural household incomes are not insignificant, and demand a more in-depth analysis with a larger sample size to achieve results that are accurate as well as quantifiable. Furthermore, AA and, especially, DP are still relatively young companies, and have not reached a point of equilibrium or long-term stability. Many of the integrated producers are also still paying off loans that were used to finance a portion of the barns installed on their property. Although these loans place a heavy burden on the producers, all producers were confident in their ability to meet the ongoing requirements of their loans and fully pay them off within several years. Once those loans are paid off, a more comprehensive assessment of the effects of their work with AA or DP will be possible. Lastly, an in-depth analysis of the financial performance of the companies would be an ideal addition to this study, to truly gauge how sustainable the business models are and how sustainable the impacts will be in the future.

Despite these limitations, this study suggests that impact investing can be an effective solution for sustainable development in tropical forest environments. The results indicate a strong positive trend between inclusive supply chain and increased financial security and quality of life for rural populations in Acre. While the environmental outcomes were not as clear, the results do suggest a positive trend between inclusive supply chains and reduced deforestation through the reduction of unsustainable slash-and-burn agriculture. However, by increasing rural incomes and giving landowners access to more resources which can be used for unsustainable economic activities, the AA/DP model may also indirectly promote deforestation. The same thing might be said of other conservation efforts in the Amazon attempting to intensify economic activity to reduce deforestation.

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## Announcing the 2018 TRI Fellows

*TRI Endowment Fellowship*: The TRI Endowment Fellowships are designed to support Masters and Doctoral students who conduct independent research in tropical countries. This year, 36 students received TRI Endowment Fellowships. The 2018 recipients and the locations of their research are listed below, and you can follow their exploits on the TRI website: http://tri.yale.edu.

| Fellow | Program | Location |
|---|---|---|
| Indra Acharja | MFS | Bhutan |
| Claire Boardman | MEM | New Zealand |
| Melaina Dyck | MESc | Peru |
| Erica Engstrom | MEM | Tanzania |
| Yufang Gao | PhD | China |
| Javier GonzalezRiviero | MEM | DR Congo |
| Sally Goodman | MESc | Kenya |
| Mickhale Green | MEM | Brazil |
| Akielly Hu | BA | Ecuador |
| AJ Hudson | MESc | India |
| Vanessa Koh | PhD | Singapore, Myanmar, Malaysia, Cambodia |
| Thomas Launer | MF | Rwanda |
| Tak Lun (Andy) Lee | MESc | South Africa |
| Chris Lewis | MEM | Rwanda |
| Bethany Linton | MESc | Uganda |
| Nick Lo | MESC | Myanmar |
| Renata Lozano Giral | MEM | Myanmar |
| Peter Ludwig | MESc | Indonesia |
| Brurce Mecca | MESc | Indonesia |
| Andrew Muehleisen | PhD | Panama |
| Jared Naimark | MESc | Myanmar |
| Sarah Omusula | MESc | Kenya |
| Zander Pellegrino | MESc | Egypt |
| Paul Rink | MEM | Peru, Indonesia |
| Ki'ila Salas | MF | Belize |
| Sara Santiago | MF | Puerto Rico, Cuba |
| Emily Sigman | GlobalAffairs-FES | Ethiopia |
| Evan Singer | MESc | Vietnam |
| Abby Snyder | MEM | Togo |
| Megan Sullivan | PhD | Gabon |
| Caroline Tasirin | MESc | Indonesia |
| Ben Williamson | MEM | Ghana |
| David Woodbury | MFS | Indonesia |
| Sneha Pandey | MEM | Rwanda |