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Magical Realism on Cuban Landscapes: A Distant Reading of Regional Development Through Satellite Data

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Magical Realism on Cuban Landscapes: A Distant Reading of Regional Development Through Satellite Data

By

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Committee in charge:

Professor Kristina Hill, Chair
Professor Iryna Dronova
Professor Isha Ray

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Abstract

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Our awareness of detrimental changes to all environmental systems has forced us to project into the uncertain future to determine how to live in the present. The United Nations (UN) is currently holding the global conversation on climate change by incorporating 'sustainability' in poverty reduction goals. After decades of scientists failing to work with other core disciplines to mobilize our society, those outside of the discipline have started to write about the inevitability of societal collapse to express urgency in a way that connects with popular culture (Bendell, 2018). This is a process tracing case study to understand the development trajectories captured in public datasets of the Republic of Cuba since the Special Period began. During this time, the island nation was able to avoid a major collapse and begin to shift towards a circular economy, a central tenet of the UN's Sustainable Development Goals (SDG). A noted weakness of public global development data is the lack of intranational resolution. While satellite imagery has limitations, it can give insight into regional conditions. Assuming unique milieus have produced varying change to the Cuban landscapes across regions, this research attempts to capture that variance using global public datasets. Measuring intranational variance is a key part of the UN's development goals that necessitates data at local scales. The lack of consistently produced global datasets severely constrain the ability to use them for time series analysis or local level adaptation planning. Cuba's ability to educate its citizens makes it possible to examine the role of human capital accumulation on 'sustainable' regional economic adaptation and poverty reduction. The political climate of the country also helps us discuss the balance needed between strong governance and individual freedoms as the nation underwent a multisector decentralization effort.

To my younger self, my current self, and my future self.

May we all be free

Table of Contents

List of Figures

List of Tables

Acknowledgments

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Dissertation Introduction

Colonialism starts at home.

To understand this body of work it is important to consider the epistemologies and title of this dissertation, *Magical Realism on Cuban Landscapes: A Distant Reading of Regional Development Through Satellite Data*. I hold the belief that the separation of the disciplines is detrimental to innovation and a true understanding of the world. Similar to the way Western understanding of the world was held separate and superior to other ways of knowing. In this dissertation I blur the lines between digital humanities, critical geography, political, and environmental science. I must acknowledge Professor Katherine McKittrick whose work defies rigid convention by mixing culture and popular education with rigorous academic work. Magical realism is referenced in the title because Cuba is often discussed in magical terms. When referencing the prominence of classical cars in Havana the world does not speak of the illegal embargo preventing newer cars from being imported or the shortage of gasoline on the island; instead, it is spoken of as the place where time stood still. When the world refers to Cuban agroecology and their political survival despite little ties to the United States, it is described as a miracle, not a challenging decentralization effort marked by struggle and community development.
The literary studies term Distant Reading, coined by Franco Moretti in 2000[1], is used in the title to indicate a lack of closeness, the limits of a small canon, and a need to lose some knowing to understand a whole system. It is also referencing Ted Underwood's work on the genealogy of Distant Reading and its relation to computational literary analysis.[2] Similar to this method in the digital humanities, landscape semiotics through land change science allows us to read landscapes to understand a system, the Republic of Cuba.
This dissertation is formatted in three chapters. The first gives a historical overview of policy changes in Cuba's largest sector, agriculture, after the collapse of the Soviet Union and subsequent economic crisis experienced on the island; known as the Special Period at a Time of Peace. It then links these policy changes to a longitudinal land cover change study that observes the location, direction, and intensity of changes on the island and derives economic meaning from them. The second chapter is more closely linked to the economic trajectory on the island during and after the Special Period. By looking at distribution and direction of nighttime lights, we are able to observe which areas grew or shrunk, and when major trend changes occurred. Chapter two also offers an overview of energy and development

[1] Franco Moretti, "Conjectures on World Literature," *New Left Review* 2, no. 1 (2000): 54–68. In the section titled Distant reading, Moretti writes "If we want to understand the system in its entirety, we must accept losing something."
[2] Ted Underwood, "A Genealogy of Distant Reading," *Digital Humanities Quarterly* 011, no. 2 (June 27, 2017).

policy in Cuba that could explain some of the changes in nighttime lights. Chapter three discusses the political climate the data are collected in, some regional patterns on the island, and limitations of a distant reading of regional, intranational, landscapes using satellite data. A notable limitation to this research as a whole was the lack of funding to do meaningful field work on the island to capture the perspectives of Cubans. While literature review gives us an insight into some of the policy and cultural changes the island underwent through the Special Period, it is a poor substitute for conversations with those who experienced them. Additionally, this field work was hampered by shifting political relations between the U.S. and Cuba after the election of former U.S. president D.J. Trump and the COVID pandemic.

1. A Distant Reading of Changes in Cuban Landscapes (1992-2018)

The Republic of Cuba has experimented with and been transformed by major policy reforms that have shaped the evolution of its landscapes from the 1990s to today. The Geopolitical and socioeconomic dynamics that defined the Special Period set Cuba on a path to adapting its economy. Cuba's pivot from exporting sugar to diversifying productivity is an example of revisioning their production model. Cuba gives insights into alternative scenarios for the distribution of benefits and burdens associated with adapting national economies to surviving climate change. Unique among Latin American & Caribbean contemporaries, Cuba's economic changes have been implemented in pursuit of an integrative, regional approach to managing natural resources. The impact of these socio-economic transformations can be seen in resultant changes in land use and land cover change across Cuba's sugarcane producing regions.

My research here assumes that the dynamics in land cover change function as a proxy for economic activity, as has been shown in other contexts.[3] I use satellite data to quantify & analyze changes in land cover to understand comparative economic resilience across regions impacted by Cuba's pivot away from a sugar-export-based economy. My research analyzes data from two editions of the European Space Agency's Climate Change Initiative annual global land cover maps from 1992-2018 (ESA CCI-LC), which represent the most extensive, standardized, and open data source of its kind. The dataset is able to capture the timing, location, and intensity of land cover changes associated with changes in the Cuban economy. While there was a net growth in forests and economically active landscapes, there is a clear shift in the location of these activities. Especially noticeable is the agricultural retreat from unsustainable soils and the stunted growth in urban areas.

Thesis Q: how much physical change in the environment is captured in the ESA CCI-LC dataset?

- What are the main drivers of land cover change on the island of Cuba?
- What was the magnitude of change that can be observed?
- What direction did the changes take?
- What were the geographic locations of changes?

[3] Chao Chen et al., "Analysis of Regional Economic Development Based on Land Use and Land Cover Change Information Derived from Landsat Imagery," *Scientific Reports* 10, no. 1 (July 29, 2020): 12721, https://doi.org/10.1038/s41598-020-69716-2.

Introduction

As articulated by Turner et al. 2007, landscapes reflect the complex interactions between society, ecology, and institutions.[4] Resilient climate change adaptation will require monitoring of landscape health to account for changes in environmental services, including collapses, and measuring the effectiveness of sustainable development policies.[5] The authoritative nature of such datasets makes it possible to remotely create articulate fictions of national land change. Such distant reading of landscapes can create problematic narratives that obstruct sustainable development.[6] Rather than creating an imaginary explanation of why national level changes happened, this research seeks to understand what trends were captured in this seminal dataset throughout Cuba in light of major policy changes which have defined Cuba's pivot to a more diversified, less export-dependent economy. Landscapes including croplands, mines, urban areas, grasslands, and forests, which are represented in ESA CCI data, have been identified by international research as being critical to tracking development trends resulting from economic policy changes in Cuba.[7] While analysis of the data alone cannot give us insights into local processes, it can show us general regional changes experienced on the island. Using existing data can lower the cost and time spent on research. Despite losing control of data collection and processing methods, researchers can use critical approaches to find new insights at global or local levels. Additionally, countries with less international focus and access to their own satellites can use the data for their own planning and management. Additional data sources are also brought in to corroborate or add to the narrative.

La Llave de América y Perla del Caribe[8]

Located between the North Atlantic Ocean and the Caribbean Sea, the 110,860 Km^2 island is home to just above 11 million people.[9] The World Bank classifies it as an

[4] Billie L. Turner, Eric F. Lambin, and Anette Reenberg, "The Emergence of Land Change Science for Global Environmental Change and Sustainability," *Proceedings of the National Academy of Sciences* 104, no. 52 (2007): 20666–71.
[5] Simon J. Watson et al., "Land-Use Change: Incorporating the Frequency, Sequence, Time Span, and Magnitude of Changes into Ecological Research," *Frontiers in Ecology and the Environment* 12, no. 4 (2014): 241–49.
[6] Eric F. Lambin et al., "The Causes of Land-Use and Land-Cover Change: Moving beyond the Myths," *Global Environmental Change* 11, no. 4 (2001): 261–69.
[7] Juan José Cabello et al., "An Approach to Sustainable Development: The Case of Cuba," *Environment, Development and Sustainability* 14, no. 4 (August 1, 2012): 573–91, https://doi.org/10.1007/s10668-012-9338-8.
[8]During Spanish colonization of the Western Hemisphere Cuba quickly became crucial in transporting stolen precious metals and goods from Spanish colonies to Europe. Its location as a sea 'gate' to the continents made it a useful military and shipping base. The island has undeniable lush beauty, especially when compared to Europe at the time, and is positioned as the largest of the Caribbean islands. These factors gained the island the nickname the key (La Llave) of the Americas and pearl (La Perla) of the Caribbean Antilles. At times the nickname of pearl is also used for Puerto Rico.
[9] Central Intelligence Agency, "The World Factbook 2014-2015" (Government Printing Office, 2015), https://www.cia.gov/library/publications/the-world-factbook/.

Upper Middle-Income country.[10] It has a moderate tropical climate that is enriched by the island's varying soils and topography to create a hotspot for biodiversity.[11] Human uses of the land further add to the heterogeneity of landscapes. While Cuba's agricultural footprint has decreased since the start of the Special Period, it occupies the largest percentage of the island's area, estimated to be 60.3% in 2018 by the CIA World Factbook. The Factbook is uniquely placed in the world to provide consistent and reliable information on all nations recognized by the United States. While not all methods of data creation are described in detail, the CIA is an internationally recognized intelligence agency with credible authority.[12] The 2018 ESA dataset only captured 54.5% as cropland, grasslands, and mosaic croplands, see Figure 1 below. Some variability in estimates is expected as there could be differences in the methods used to compile the estimates and in the auxiliary data used to validate the information. The CIA approximation for forest cover the same year was 27.3% while the CCI dataset estimates 35%, forest cover types.

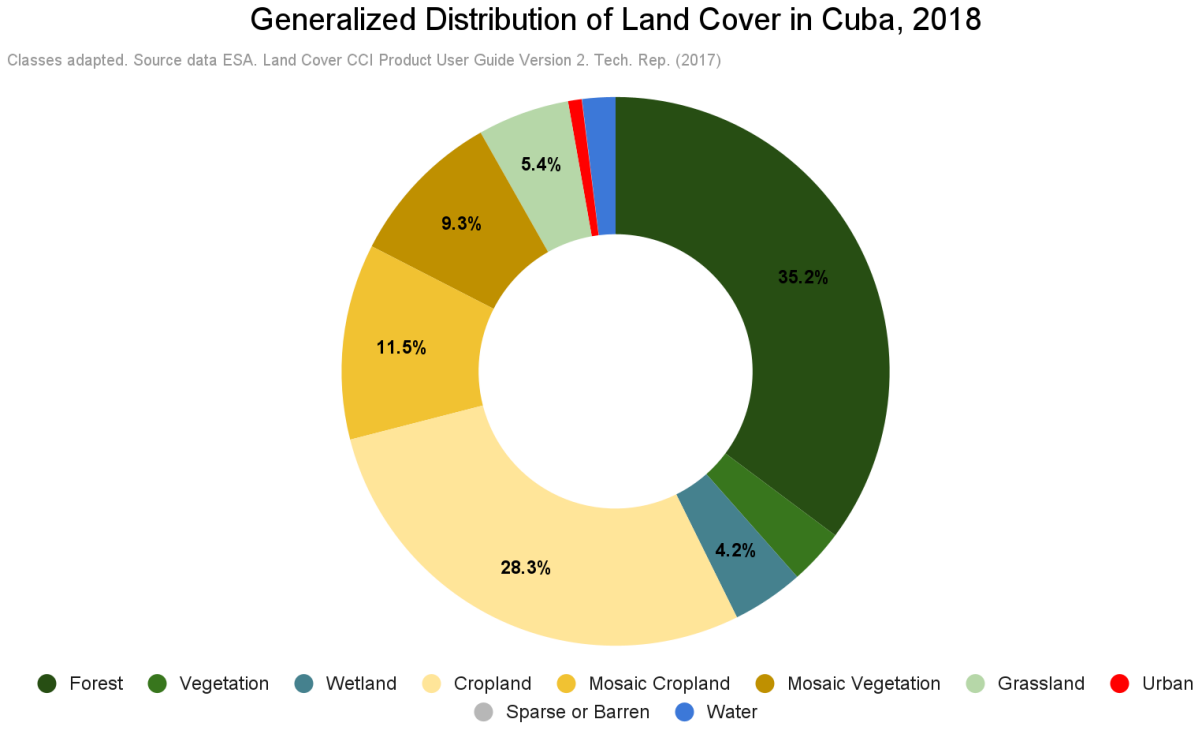

Figure 1 ESA data with generalized cover classes for the Republic of Cuba 2018

[10] World Bank Group Archives, "World Development Indicators (WDI)," 2018, https://datacatalog.worldbank.org/dataset/world-development-indicators.
[11] Jennifer Gebelein, *A Geographic Perspective of Cuban Landscapes*, Landscape Series: V. 15 (Dordrecht; New York: Springer, 2012).
[12] Panagiotis Podiotis, "Towards International Relations Data Science: Mining the CIA World Factbook" (arXiv, October 12, 2020), https://doi.org/10.48550/arXiv.2010.05640.

When comparing the changes over two time periods a difference can be identified in the trends captured. The 1992 Factbook estimates cropland at 52% (this includes Arable land 23%, Permanent crops 6%, meadows and pastures at 23%). Forest and woodland covers are reported with the singular Figure of 17%.[13] For the same year the CCI dataset estimated 56.5% cropland and 34.6% forest, see Figure 2 below. While the estimates are within a reasonable range from each other, the trends they report tell of a different development trajectory. The CIA estimated an increase of almost 16% in croplands and 61% in forests and woodlands while the ESA dataset reports a 3.5% decrease in croplands and a modest 1.7% increase in forest.

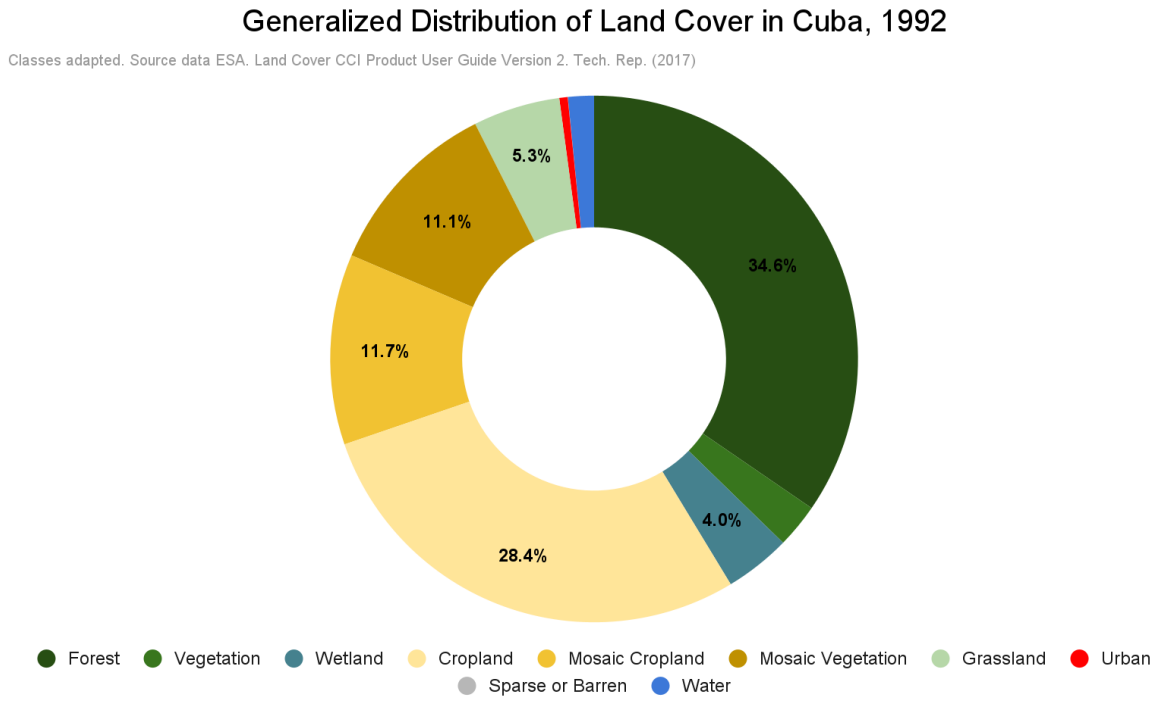

Figure 2 Initial land cover distribution for the Republic of Cuba 1992 (percent of total area)

The CIA does not provide data tables summarizing quantitative details of each State they collect information on. However, through public records, digital libraries and their own archive, previous annual copies of the Factbook can be viewed. The agency uses their own classification system for land cover based on what serves their internal purposes. While this makes it difficult to do long term comparison of changes between datasets, the longevity of the Factbook gives insights into the

[13] United States Central Intelligence Agency, "The 1992 CIA World Factbook," Project Gutenberg, January 1, 1993, https://www.gutenberg.org/ebooks/48/.

island of Cuba years before CCI data is available. The categories reported by the CIA have not been consistent since the Factbook began publishing. To summarize the Factbook, I obtained select information about Cuba from the Hathi Trust Digital Library which makes public editions spanning 1981- 2013.[14] For the 2014-2018 data, I downloaded the data for each year from the CIA archives.[15] Figure 3 below plots the percentage of each reported land cover from 1982-2018.

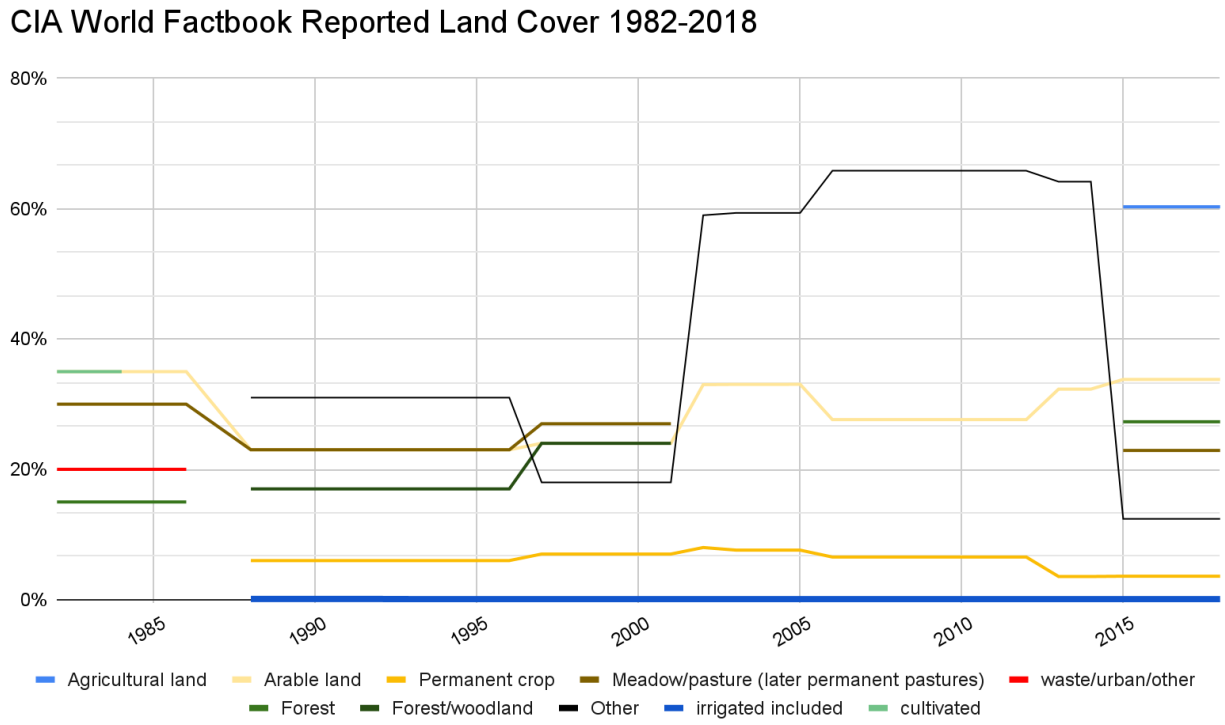

Figure 3 Longitudinal land cover trends in Cuba as captured by the CIA (vertical axis shows percentages of the total area).

Some of the trends evident in the data are:

- Irrigated land area had a slightly negative trend with a 21.5% reduction.
- Forests a generally positive trend of 15% in 1982 to 27.3% in 2018, an 82% increase.
- Pastures reported a 23.7% decrease from 30% to 22.9%, with a boost from 1997-2001 up to 27% of Cuban land.

[14] "Catalog Record: The World Factbook | HathiTrust Digital Library," accessed March 3, 2023, https://catalog.hathitrust.org/Record/000532922.
[15] "The World Factbook Archives - The World Factbook," accessed September 13, 2022, https://www.cia.gov/the-world-factbook/about/archives/.

- Total Arable land and Permanent crops were also reported to have a negative trend. The latter showed a 40% reduction from 6% of land cover in 1988 to 3.6% in 2018, with a high of 8% in 2002 and a low of 3.55% 2013-2014.

The Arable land category tells the longest story, having been reported from 1982 - 2018. It shows the crash from the Soviet era (35% of land cover from 1982-1986) to the special period (23% in 1988 to 1996 and only 24% from 1997-2001) to the reanimation of the economy (fluctuating between 33% to 27% from 2002-2018). The CIA only reported urbanized land cover from 1982-1986 and it was combined with 'Waste' and 'Other' classes, switching to reporting only 'Other' in 1987. The reporting of agricultural, pasture, and forested lands have also changed. Arable land estimates have always been reported. The Cultivated class was only reported until 1984, Agricultural land only since 2015, and Permanent crops and Proportion irrigated only since 1988. Irrigated land was once reported as a percentage but in 1993 changed to reporting as an absolute area in total square kilometers. Forest switched to Forest and Woodland from 1988-2001, when its reporting was aggregated into Other until 2015 when the Forest class reemerged.

These kinds of changes make temporal analysis more difficult and introduce a lack of clarity. The reporting classes the CIA has chosen to obscure some important land uses in the 'Other' category, such as urbanization. It also cannot be discerned how much land is managed under environmental conservation measures, something Cuba has been praised for. In total, the Republic of Cuba protects twenty percent of its territory comprising coastal waters, forests, and other vegetative land covers through a variety of special management zones and reserves.[16] Considering the ecological collapse experienced in parts of the Gulf of Mexico, Cuba is an outlier in the region for the way it is seemingly decoupling human development from unsustainable exploitation of natural resources. It is in effect contributing to sustaining a critical international ecosystem while being isolated from it. The CIA Factbook, while an intensive standardized report on most nations, fails to report intranational information, as do most international institutions.

'Tuyo es el poder, tuyo es el espacio en el papel'[17]

Cuba has recently experienced several major policy changes that have contributed to the dynamic nature of its land development. These were precipitated by the

[16] Gillian L Galford et al., "Cuban Land Use and Conservation, from Rainforests to Coral Reefs," *Bulletin of Marine Science*, 2018, https://doi.org/10.5343/bms.2017.1026.

[17] La Polla Records, *Criticos*, Album, Salve (Song 8: Cultural Rock Records SL/La Polla Records, 1984). This is a quote from the song translates to *yours is the power, yours is the space on the paper*. This is the title chosen for the policy section of this dissertation to reflect the almost absolute power the Cuban government has over what is written about them within Cuba.

collapse of the Soviet trade bloc, the Council for Mutual Economic Assistance (COMECON), that led to economic contraction and realignment between 1989 and 1991.[18] As a result, Cuba entered what is known as El Periodo Especial en Tiempos de Paz.[19] To make up for lost subsidies and trade from COMECON, Cuba opened various sectors of its economy to Foreign Direct Investment including: energy, mining, utilities, and tourism. The shift in types of goods exported can be seen in Figure 4 below. National changes to agricultural production were also necessary when the trade bloc collapsed, taking away a benevolent sugar market and subsidized intermediary products required for industrial sugar production. To reduce the government's monopoly over production and capital, policies were passed to legalize micro-capitalism through small entrepreneurial activities.[20] Modifications to laws regulating property ownership gave more agency to individuals also took place.[21] These began in the 1990's and have had several amendments in the two decades since.[22] The activities that produce the primary crop of Cuba, sugarcane, have also been undergoing massive restructuring since 2002, when the Tarea Álvaro Reynoso shut down almost half of existing sugar mills.[23] Land cover is intimately tied to human production schemes. The economic shocks experienced by Cuba were intensely felt throughout the island. Cuban landscapes offer an excellent opportunity to test whether satellite data can adequately capture the imprint of such changes.

[18] Archibald R. M. Ritter, "Entrepreneurship, Microenterprise, and Public Policy in Cuba: Promotion, Containment, or Asphyxiation?," *Journal of Interamerican Studies and World Affairs* 40, no. 2 (ed 1998): 63–94, https://doi.org/10.2307/166374.
[19] English translation: The Special Period at a Time of Peace
[20] Archibald R. M. Ritter and Ted A. Henken, *Entrepreneurial Cuba: The Changing Policy Landscape* (Boulder, Colorado; London, [England]: First Forum Press, 2015., 2015).
[21] Renee Monzon, "Introducing Private-Property Rights to Cuba: How Cuba's New Constitution Paves the Way for Economic Growth," *Case Western Reserve Journal of International Law* 52, no. 1/2 (Spring 2020): 629–68.
[22] Violaine Jolivet and Mateo Alba-Carmichael, "Reinvesting in Havana: Housing Commodification and Gentrification in the Central Neighbourhoods of a Socialist City in the Global South," *International Journal of Cuban Studies*, December 1, 2021, https://doi.org/10.13169/intejcubastud.13.2.0248; Anicia García Álvarez and Betsy Anaya Cruz, "El Modelo Agropecuario y Su Vínculo Con El Acceso a Los Alimentos: La Experiencia Cubana (1959–2019) The Agricultural Model and Food Access: The Cuban Experience (1959–2019)," *International Journal of Cuban Studies*, July 1, 2020, https://doi.org/10.13169/intejcubastud.12.1.0076.
[23] José Alvarez, "The Current Restructuring of Cuba's Sugar Agroindustry," *University of Florida, Food and Resource Economics Department IFAS Extension*, no. FE472 (January 2004): 9.

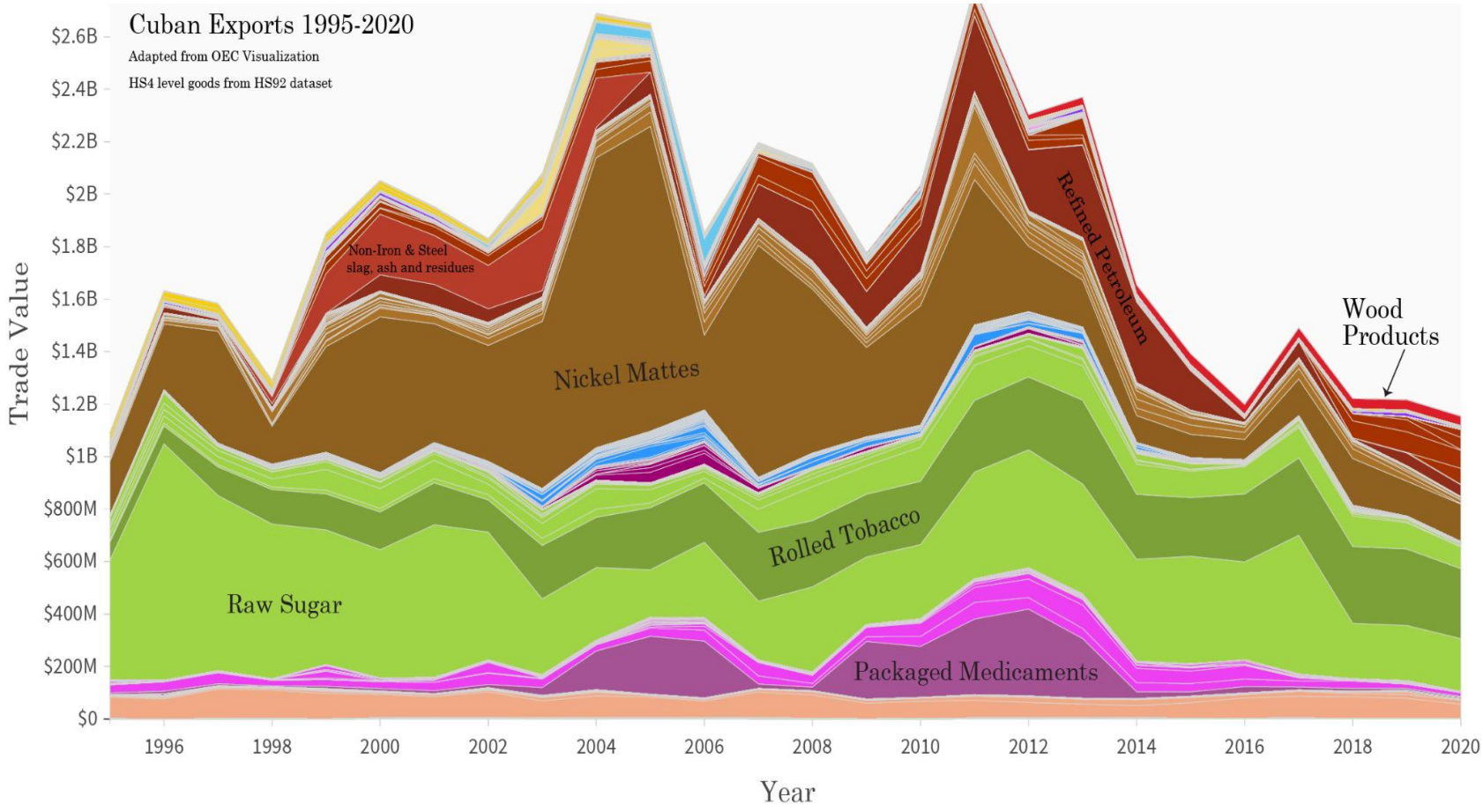

Figure 4 Primary exports of Cuba over a 25-year period shows a decreasing role in sugar while nickel mining increases. Wood products show more prominence after 2012. Medicaments seem to play an intermittent role.

Sustainable Development in Cuba

Cuba's trajectory after the Soviet period is widely recognized as having taken a more sustainable route than other Latin American and Caribbean (LAC) countries and even improved on its own previous schema.[24] This has largely been interpreted as a necessary tactic to adapt to limited access to industrial resources from lack of trade partners, a lack of valued goods to trade, a need to recover deteriorated soils, and the U.S. embargo. While other LAC countries could continue to produce low value agricultural exports under the leadership of foreign companies, Cuba had to shift production to meet local needs with limited imports.

A major change in the way Cuba's environment is managed came with the establishment of the Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA)[25] in 1994, and the approval of a National Environmental Strategy in 1997.[26] Changes to the management of resources played an important role in Cuba's economic restructuring. These ministries created an interface between the government, international stakeholders, and local actors to engage with the environment. Since the creation of CITMA, efforts to manage lands were consolidated and reorganized. While the first national park was created in 1930, the movement that currently protects around 20% of the island's terrestrial and marine territories, Sistema Nacional de Áreas Protegidas de Cuba (SNAP), was not created until the second half of the 90's.[27] The system used was based on an international classification structure created by the International Union for the Conservation of Nature (IUCN).[28] The eight designations for protected areas of interests based on their perceived biological value derive from: high biological diversity, presence of endemic species, unique landscapes, and interest in preserving cultural significance.

A regional approach was also employed in efforts to rebuild soil damaged through colonial and Soviet agricultural practices. Centuries of monocultural production resulted in topsoil erosion, nutrient depletion, and increased salinity. Local actors working with technical support from national entities used diverse, localized strategies which included composting, crop rotation, cover crops and the

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[24] Jennifer Gebelein, "Governmental Organization and Control Over Environmental Policies," *A Geographic Perspective of Cuban Landscapes*, Landscape Series. 15, 2011, 31, https://doi.org/10.1007/978-94-007-2406-8_3.
[25] English Translation: Ministry of Science, Technology and Environment
[26] Daniel Whittle and Orlando Rey Santos, "Protecting Cuba's Environment: Efforts to Design and Implement Effective Environmental Laws and Policies in Cuba," *Cuban Studies* 37 (2006): 73.
[27] Reinaldo Estrada Estrada, *The National System of Marine Protected Areas in Cuba* (National Center for Protected Areas, 2004).
[28] R. Estrada and A. Perera, "Determining Significance of Protected Areas in Cuba," *Intern. J. Wilderness* 4, no. 2 (1998): 13–16. This publication describes each category in great detail. At the time of its publication there were eight designations and levels of protection.

revegetation of previously cultivated land.[29] Regional approaches allowed for increased participation in decision making and knowledge production, encouraging people to grow food while helping the environment recover.[30]

Agriculture- 'Ojalá que llueva café'[31]

The agricultural sector represents 4% of Cuba's GDP, occupies approximately 60% of the island's surface area, and employs 18% of the labor force.[32] Between 1999-2007 cultivated land decreased 17%, mostly impacting sugarcane crops. One government estimated a decrease of 8.5% in non-sugarcane cultivated land from 2007 to 2016.[33] This period of change played an important role in the re-contextualization of Cuban agriculture. Overtaxed with responding to post Soviet changes, the Cuban government with Decree Law No. 142 of 1993 restructured the agricultural sector.

The near collapse of the central government forced them to distribute power to regional and local stakeholders. This was done by dissolving many large, State-run farms and distributing the land to locally controlled, regionally connected cooperatives, Unidades Básicas de Producción Cooperativa (UBPCs). From 1993-1997 UBPCs made up 42% of the agricultural sector, 33% in State hands and 25% in private farms.[34] By 2007, the area of privately held land increased by 257.3% and State administered agricultural land decreased by 34.5%.[35] Forced to alter their agricultural production methods away from the industrialized Soviet model, Cuba turned to agroecology to adapt production without imported intermediary products.[36] Cuba also chose a regional approach to their agricultural extension education programs, encouraging place specific solutions with transdisciplinary epistemologies that integrated culture through ecosemiotics.[37]

Further reforms in 2007 integrated the Ministry of Sugar into the Ministry of Agriculture, symbolically and structurally removing the national focus on sugar

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[29] Peter Michael Rosset et al., "The Campesino to Campesino Agroecology Movement of ANAP in Cuba: Social Process Methodology in the Construction of Sustainable Peasant Agriculture and Food Sovereignty," *Journal of Peasant Studies* 38, no. 1 (January 2011): 161–91, https://doi.org/10.1080/03066150.2010.538584.
[30] Julia Wright, *Sustainable Agriculture and Food Security in an Era of Oil Scarcity: Lessons from Cuba* (London; Sterling, VA: Earthscan, 2009., 2009).
[31] Café Tacvba, *Ojalá Que Llueva Café*, Album, Tiempo Transcurrido (Song 6: Warner Music México, S.A. de C.V., 2001).
[32] Central Intelligence Agency, "The World Factbook 2014-2015."
[33] Mario A Gonzalez-Corzo, "Agricultural Reforms, Land Distribution, and Non-Sugar Agricultural Production in Cuba," 2019, 8.
[34] Carmen G Gonzalez, "Seasons of Resistance: Sustainable Agriculture and Food Security in Cuba," Tulane Environmental Law Journal, 2007, 48.
[35] Febles-González et al., "Cuban Agricultural Policy in the Last 25 Years. From Conventional to Organic Agriculture."
[36] Colin Crawford, "Necessity Makes the Frog Jump: Land-Use Planning and Urban Agriculture in Cuba," *Tulane Environmental Law Journal*, no. Special Issue (2002): 733.
[37] Oscar L Parrado Alvarez et al., "Epistemological Fundamentals of Education in Agriculture in Cuba," 2018, https://doi.org/10.13140/rg.2.2.26258.96963.

production. New agricultural tax systems, increased prices for products, micro-credit lending, usufruct farming[38], and the authorization of direct sales of some products outside of State operated stores have contributed to changes in the sector.[39] Recent evaluations of the trade deficit estimate Cuba imported two billion dollars of food annually between 2014-2016.[40] Since 2008, policies to encourage usufruct farming were the most significant in changing Cuba's agricultural sector. These policies allowed the transfer of inactive State controlled land to individuals and cooperatives.[41] They also provided loans and grants to non-State producers, allowing for the purchase of necessary products such as seeds and irrigation equipment while leaving decision making at the hands of local actors.[42]

Food sovereignty was a necessary strategy to adapt to economic changes during the special period.[43] Diversification of crops to meet national food demands, as well as the establishment of urban farms, were critical parts of the adjustment.[44] Early policies targeted increasing food production in rural and urban areas. Reforms in 1994, for example, created the Urban Agriculture Department within the Ministry of Agriculture and allowed for direct sale of produce from gardens to Cubans.[45] Further updates to the agricultural sector in 2002, 2007, and 2012 allowed for local decision-making power on what is grown, price of items, and expanded the markets producers could directly sell to.[46] Blue et al. attributed improved innovation and adaptation toward food sovereignty to a diversity of economic regimes within the island, capitalist and socialist. Specifically, hybrid forms of property in contexts

[38] Usufruct comes from the Latin Usus and Fructus. In Cuba is refers to the use of state land by individuals or groups to use (Usus) it and benefit from the fruits (Fructus) of their labor. A description of other uses around the world can be found on Wikipedia at https://en.wikipedia.org/wiki/Usufruct

[39] Mario A. Gonzalez-Corzo, "Transition or Survival? An Analysis of Cuba's Post -Soviet Economic Reforms" (Ph.D., United States -- New Jersey, Rutgers The State University of New Jersey - Newark), accessed July 25, 2022, https://www.proquest.com/docview/305284571/abstract/8C0B93DF83164CC7PQ/1.

[40] Armando Nova González and Galia Figueroa Alfonso, "Recent Transformations in Cuban Agricultural Policy and Impacts on Markets and Production," *Elem Sci Anth* 6, no. 1 (December 10, 2018): 78, https://doi.org/10.1525/elementa.323.

[41] Carmelo Mesa-Lago and Mario A. González-Corzo, "Agrarian Reform and Usufruct Farming in Socialist Cuba," *Journal of Economic Policy Reform* 24, no. 2 (April 3, 2021): 119–33, https://doi.org/10.1080/17487870.2019.1683010.

[42] Mario González-Corzo, "USUFRUCT FARMING IN CUBA: RECENT DEVELOPMENTS AND FUTURE PROSPECTS," 2017, 6.

[43] Sarah A. Blue et al., "Food Sovereignty and Property in Cuba and the United States," *The Journal of Peasant Studies* 0, no. 0 (July 8, 2021): 1–18, https://doi.org/10.1080/03066150.2021.1912026; John Connell et al., "Food Security and Sovereignty in Small Island Developing States: Contemporary Crises and Challenges," in *Food Security in Small Island States*, ed. John Connell and Kristen Lowitt (Singapore: Springer, 2020), 1–23, https://doi.org/10.1007/978-981-13-8256-7_1; Juan Alberto Simón Reardon and Reinaldo Alemán Pérez, "Agroecology and the Development of Indicators of Food Sovereignty in Cuban Food Systems," *Journal of Sustainable Agriculture* 34, no. 8 (October 27, 2010): 907–22, https://doi.org/10.1080/10440046.2010.519205.

[44] Miguel A. Altieri and Victor Manuel Toledo, "The Agroecological Revolution in Latin America: Rescuing Nature, Ensuring Food Sovereignty and Empowering Peasants," *Journal of Peasant Studies* 38, no. 3 (July 2011): 587–612, https://doi.org/10.1080/03066150.2011.582947; Miguel A Altieri, Fernando R Funes-Monzote, and Paulo Petersen, "Agroecologically Efficient Agricultural Systems for Smallholder Farmers: Contributions to Food Sovereignty," *Agronomy for Sustainable Development*, no. 1 (2012): 1.

[45] Mario A Gonzalez-Corzo and Orlando Justo, "Private Self-Employment under Reform Socialism in Cuba," *Journal of Private Enterprise*, no. 32: 2 (2017): 45.

[46] Ingrid Hanon, "Cuba, Agriculture and Socialist Renewal," *International Journal of Cuban Studies* 12, no. 2 (2020): 196–227.

with exclusionary privatization and racialization (most regimes with a history of colonization) allowed for a reconfiguring of social relations with land and production.

García Álvarez and Anaya Cruz compiled data from the Cuban government to demonstrate the simultaneous continued dependence on food imports (around 50% or more depending on the year) and significant increases in the internal production of foodstuffs from 1989 levels.[47] While 2005 stands out as a year of high production, only fruits and tubers had relative stability after initial growth during the Special Period (see Figure 5 below). Rice production has remained relatively the same since 1989. While vegetables have significantly increased, they have not recovered to 2001 levels of production. Legumes and corn have increased significantly but with high production variability during the 1989-2017 period covered in this data.

[47] Álvarez and Cruz, "El Modelo Agropecuario y Su Vínculo Con El Acceso a Los Alimentos." See Figure 3 and 4 on page 93 of their paper

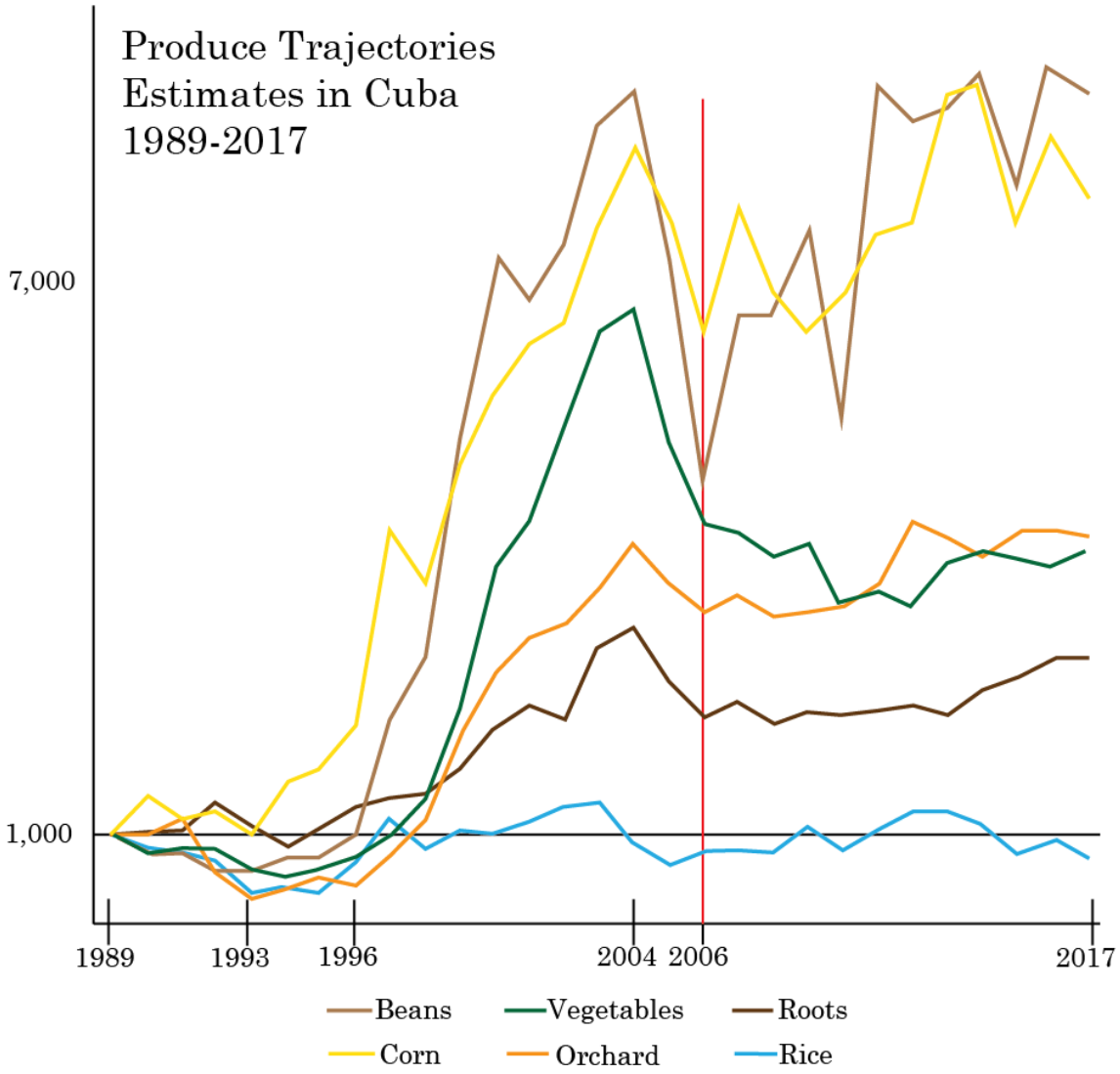

Figure 5 Trends in produce production since the Special Period began. The red vertical line indicates a large drop in production after a series of storms.

Increasing meat production was a goal early in the Cuban revolution. Initially grasslands for grazing were not prioritized; at the end of the 1980's 97% of animal feed was imported.[48] Grazing animals unsuccessfully competed against sugarcane through the Soviet period as existing grasslands were converted for/to cultivation. Similarly, the dairy sector was promoted after 1960 led to investments in livestock sciences, selective breeding programs, and intensive industrial ranching to increase milk production which could be touted as a huge accomplishment by a developing country with a socialist system. In the 80's Cuba was the 6th largest producer of milk in Latin America and the first in the Caribbean.[49] Like other sectors in the Cuban economy, the Special Period saw a reduction in milk production. With large State run farms broken up for smaller cooperatives or individuals, access to feed, supplies, and equipment is highly variable. Since the beginning of the COVID-19 pandemic and the decrease in tourism the island has struggled to import enough dairy to meet demand and internal production has been decreasing since 1990.[50] Dairy consumption on the island was introduced during the colonial period and its continuation despite issues in producing and transporting it on a tropical island is a sign of the importance of culture in what is deemed success or failure in adaptation.

According to the government data compiled by García Ávarez and Anaya Cruz, production with livestock has not seen the same growth as produce, see Figure 6 below. Production of food with livestock has decreased from 1989 levels, except for pork meat. With milk, beef, and chicken production struggled to recover from the 1989-1992 crash. Pork is the only livestock with significant increases in production from 1989 levels. Notably this dataset does not include seafood that can be fished from the coast of Cuba or farmed inland.

[48] Isela Ponce Palma et al., "Historical Changes in the Process of Agricultural Development in Cuba," *Journal of Cleaner Production* 96 (June 2015): 77–84, https://doi.org/10.1016/j.jclepro.2013.11.078.
[49] Reinaldo Funes-Monzote, "The Rise and Fall of Dairy Cows in Socialist Cuba," *Global Environment* 9, no. 2 (2016): 342–75.
[50] Mary Beth Sheridan, "In Cuba, a Frantic Search for Milk," *Washington Post*, May 21, 2022, https://www.washingtonpost.com/world/interactive/2022/cuba-economy-milk-shortage/.

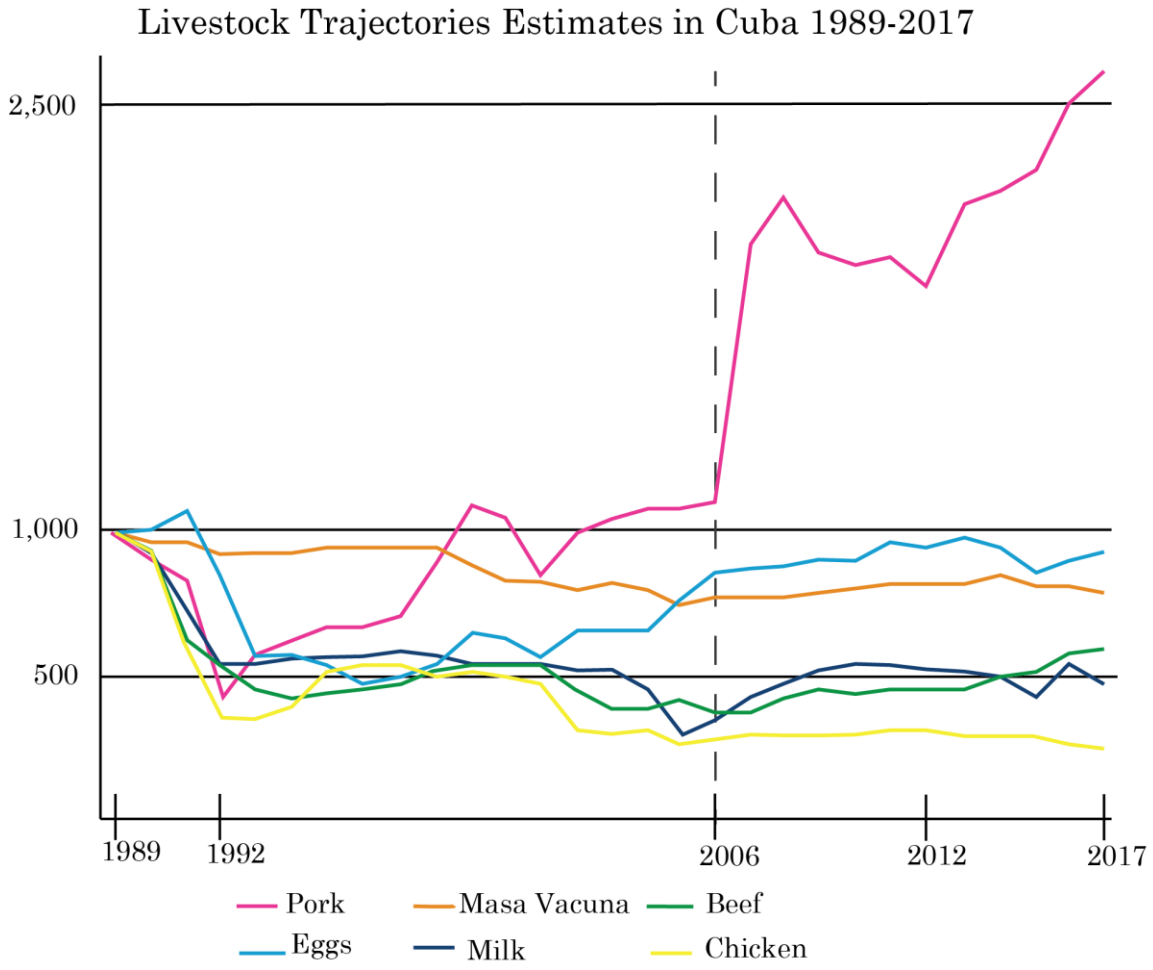

Figure 6 Livestock production trends in Cuba since the Special Period began. The black dashed line indicates changes in production after a series of bad storms. For pork production the steep increase came after policy changes in 2007.

Some issues with the operationalization of food sovereignty programs are related, but not limited to, infrastructure and technology scarcity in Cuba. Mainly, refrigerated trucks, reliable roads, and railroad systems needed to transport what is grown on the island throughout the population; combined with a lack of access to the intermediary products need to turn raw products into longer lasting processed foodstuff. The literature also identifies an elevated cost of food relative to family income; with food costs taking up 42-50% of their spending.[51] A lag is evident in raw product processing for secondary, higher added value, products with longer shelf lives.[52] González-Corzo also identified the deterioration of national infrastructure as a factor impacting both State and non-State producers. The food production graphs created by García Ávarez and Anaya Cruz show a high variability in production. Without going into specific products and varying year-to-year conditions for production it is safe to assume that high production variability makes it hard to predict an outlook for the next year of production. This likely also resulted in dietary changes unless the products were imported. The 2003-2005 period stands out as shifting production from beans, vegetables, and corn to pork.

Sugarcane Hegemony

Since colonial times sugarcane cultivation in Cuba has gone through various periods of expansion and contraction as global sugar markets and technologies have shifted in favor of or against Cuban exports.[53] Figure 7 was vectorized and adapted from Scarpaci & Portela 2009. Immediately after the 1959 revolution, efforts to diversify away from sugarcane production were initiated, only to be undermined by the promise of sugar trade with the Soviet Union as Cuba faced a financial crisis from its revolutionary evolution.

[51] Álvarez and Cruz, "El Modelo Agropecuario y Su Vínculo Con El Acceso a Los Alimentos."
[52] Elisa Botella Rodríguez, "Políticas agrarias, Seguridad Alimentaria y Nutricional y Soberanía Alimentaria: luces y sombras del caso cubano (1990-2015)," *Mundo Agrario* 19, no. 42 (December 7, 2018): e096, https://doi.org/10.24215/15155994e096.
[53] Joseph L. Scarpaci and Armando H. Portela, *Cuban Landscapes: Heritage, Memory, and Place* (Guilford Press, 2009).

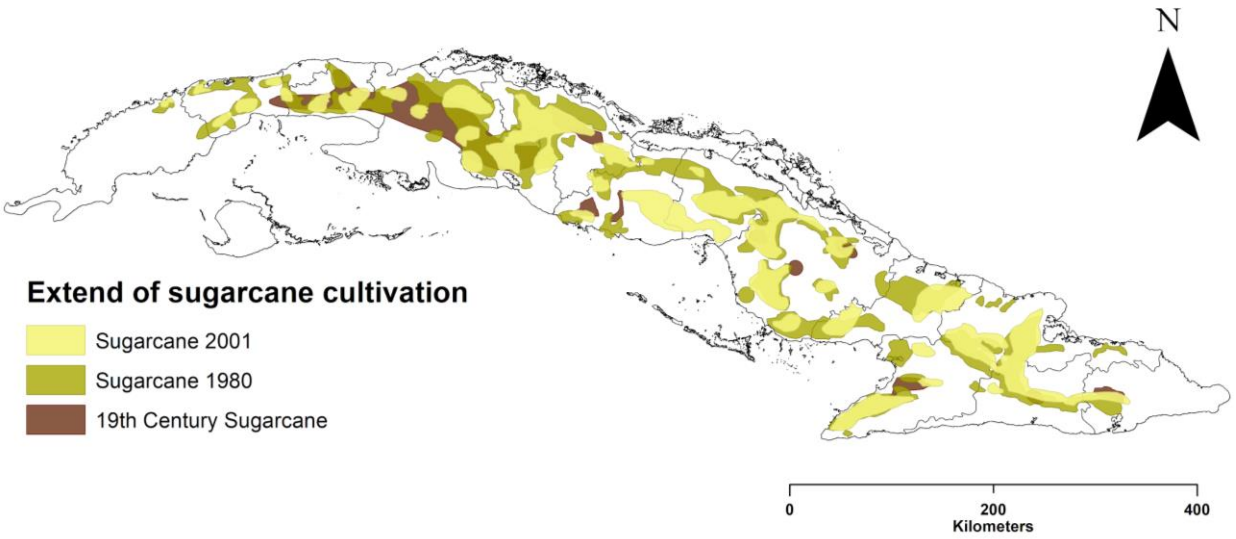

Figure 7 Historical expansion of Sugarcane Cultivation in Cuba

At the peak of Cuba's trade with the Soviet Union an expansion craze, fueled by the false promise of the Green Revolution, pushed cultivation into areas largely unsuited for intense sugarcane production into the 1980's. **S**ugarcane cultivation took up 51.6% of cropland in 1959, rising to 75% in the early 1980's and 82% of their total exports.[54] Hanon and others have remarked on the negative impact that centralized planning had on the autonomy of workers, ultimately leading to inefficiencies and lack of worker engagement.[55] The industrial, capital intensive nature of Soviet agriculture proved to be both socially and ecologically unsustainable.[56] The cultivation and processing of sugarcane over such vast areas was only made possible by encroaching on land less than suitable for growing by supplementing natural resources with agrochemical contaminants. Without the ability to import fuel to run agricultural machinery and intermediate products necessary for industrial agriculture, the Special Period proved detrimental to the sugar industry in Cuba. Considering the extensive area sugarcane covers on the island, the presence of Cropland cover in Cuba is not directly related to the amount of foodstuff being cultivated in a sustainable manner since the majority of crop cover is industrial sugarcane not nutrient food. Measuring the changes in cropland after the collapse of the Soviet Union is a measure of human agricultural activity on the land. Considering the severe economic collapse Cuba went through after 1989, it is also a sign of stability, change, or recovery of economic activity. Sugarcane

[54] Hanon, "Cuba, Agriculture and Socialist Renewal"; Ingrid Hanon, "Moishe Postone, the Mode of Production of Capital and Cuban Agriculture," *Capitalism Nature Socialism*, 2021, 1–19.
[55] Juan Carlos Albizu-Campos Espiñeira, "¿Es El Descenso de La Actividad Económica de La Población Un Fenomeno Temporal En Cuba? Is the Decline in the Economic Activity of the Population a Temporary Phenomenon in Cuba?," *International Journal of Cuban Studies*, July 1, 2020, https://doi.org/10.13169/intejcubastud.12.1.0053; José Luis Martín Romero, "La Cultura Del Trabajo Y La Reestructuración De La Agroindustria Azucarera.," 2003, 18.
[56] Sergio Diaz-Briquets and Jorge F. Pérez-López, *Conquering Nature : The Environmental Legacy of Socialism in Cuba*, Pitt Latin American Series (Pittsburgh, Pa. : University of Pittsburgh Press, 2000).

production continues to be a major activity in almost all provinces in Cuba, led by local cooperatives and advised by Regional Agricultural Extension officers. Further reductions in cultivated area are expected after 2021 with the passage of a policy to further actualize, i.e. modernize, the Cuban Economy.

The Observatory of Economic Complexity (OEC) began as a master's thesis project; proving the important role educational institutions play.[57] Under a Creative Commons CC0 public domain license, the OEC allows its visualizations to be used for all purposes that do not yield a direct profit. The dataset is a crucial publicly available communication tool for understanding the world economy. Yet there are limitations; the graphics are rendered in a style and color that is generally displeasing and exported files are hard to read without the interactive widgets of the website. Their labeling schema and color coding by region obscures the major change in trade partners Cuba had during this time period. Figure 8 below is an adapted visualization from the site that shows the changes in Cuban sugar trade partners. A shift is evident from Russia to China as the main recipient of Cuban sugar between 2002 and 2004. European and Asian countries buy the majority of the sugar, with some short-term partnerships with Canada, Egypt, Peru and Trinidad and Tobago. Overall, there is a decreasing trend in the amount of sugar Cuba is exporting. Sugar cultivation and processing on the island has decreased, impacting all provinces but particularly central ones like Matanzas and Villa Clara where only 29% and 39%, respectively, of sugar mills were kept open after the 2002 restructuring.[58] Chapter three in this dissertation provides a deeper dive into the regional differences of this economic adjustment.

[57] "About the Site | OEC," OEC - The Observatory of Economic Complexity, accessed March 6, 2023, https://oec.world/en/resources/about. AJG Simoes, CA Hidalgo. The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence. (2011)

[58] Jorge F. Pérez-López, "The Restructuring of the Cuban Sugar Agroindustry: A Progress Report," *Cuba in Transition* 26 (2018): 49–57.

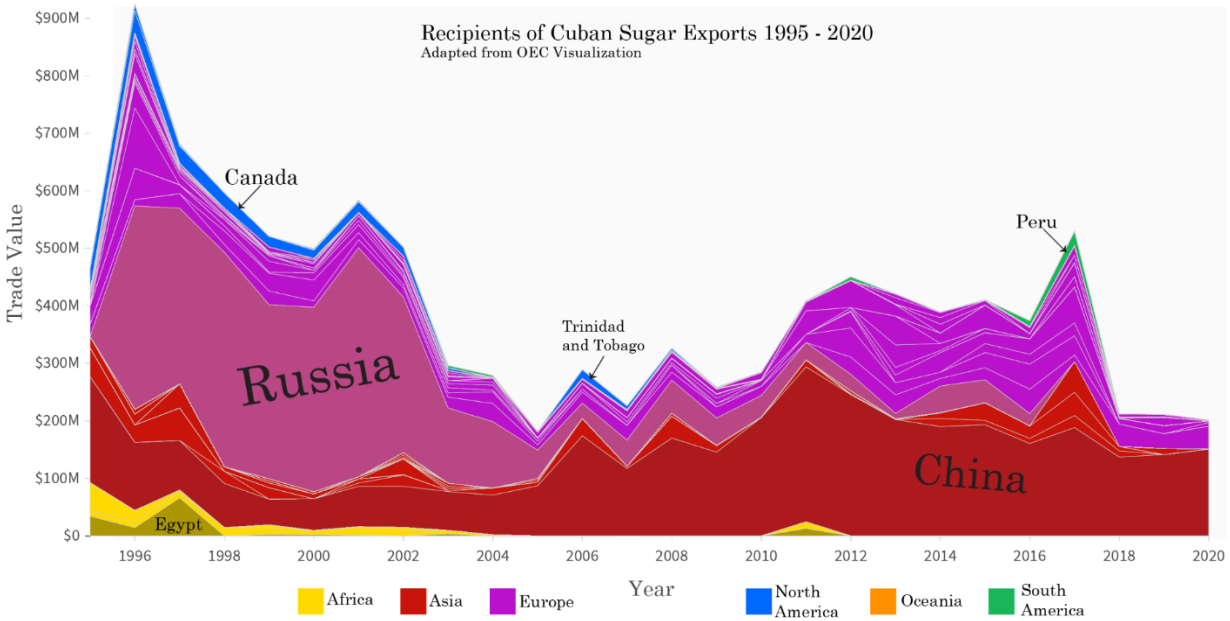

Figure 8 Cuba's main recipients of Sugar exports

Forestry

Prior to the Cuban revolution, exploitative development had left only 14% of Cuba's original forests intact. Forests have been estimated to originally have occupied around 72% of the island by area.[59] A recent study found that Cuba had the second largest regrowth rate in the world, as forest cover increased by 39% over 20 years.[60] The study used global forest mapping data to account for the growth of forests.[61] The authors found that most of the net gain occurred in the general matrix of the country, with a slight net loss within designated protected lands. They noted that the dataset is of tree cover and that losses from natural or human forces cannot be distinguished.

As in agriculture, national strategies guide research & development in the forestry sector. A lack of investment in infrastructure to develop higher value-added products has kept exports low. In total, the sector has contributed an average of 2.8% to the national GDP between 2000 and 2011.[62] The FAO published national statistics for the globe of the economic contribution the sector had from 1990-2011.

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[59] Reinaldo Funes Monzote, *From Rainforest to Cane Field in Cuba: An Environmental History since 1492* (Univ of North Carolina Press, 2009); Sergio Díaz-Briquets, "Forestry Policies of Cuba's Socialist Government: An Appraisal," *Cuba in Transition* 6 (1996): 425–37.
[60] Fernando Goulart et al., "Conservation Lessons from Cuba: Connecting Science and Policy," *Biological Conservation* 217 (January 1, 2018): 280–88, https://doi.org/10.1016/j.biocon.2017.10.033.
[61] M. C. Hansen et al., "High-Resolution Global Maps of 21st-Century Forest Cover Change (V2016," *Science* 342, no. 6160 (November 15, 2013): 850–53, https://doi.org/10.1126/science.1244693.
[62] Yerenis Torres Cala et al., "El Proceso de Innovación En El Sector Forestal Cubano y Su Contribución a La Economía Nacional," *Revista Cubana de Ciencias Forestales* 6, no. 2 (August 2018): 146–61.

Notably, Cuba is not listed in the first annex where references used for each country are listed; leaving us to speculate the data may come from international organizations like the UN and World Bank. Their report shows production has not met internal demand as seen in Figure 9 below. Plotted alongside employment in the sector we see that 2001 was the most productive year followed by 2006. Shifts in Forest cover is expected to follow a reforestation trend in the ESA dataset. Like in other studies it would be hard to distinguish between natural forest loss and human driven deforestation for economic gain.

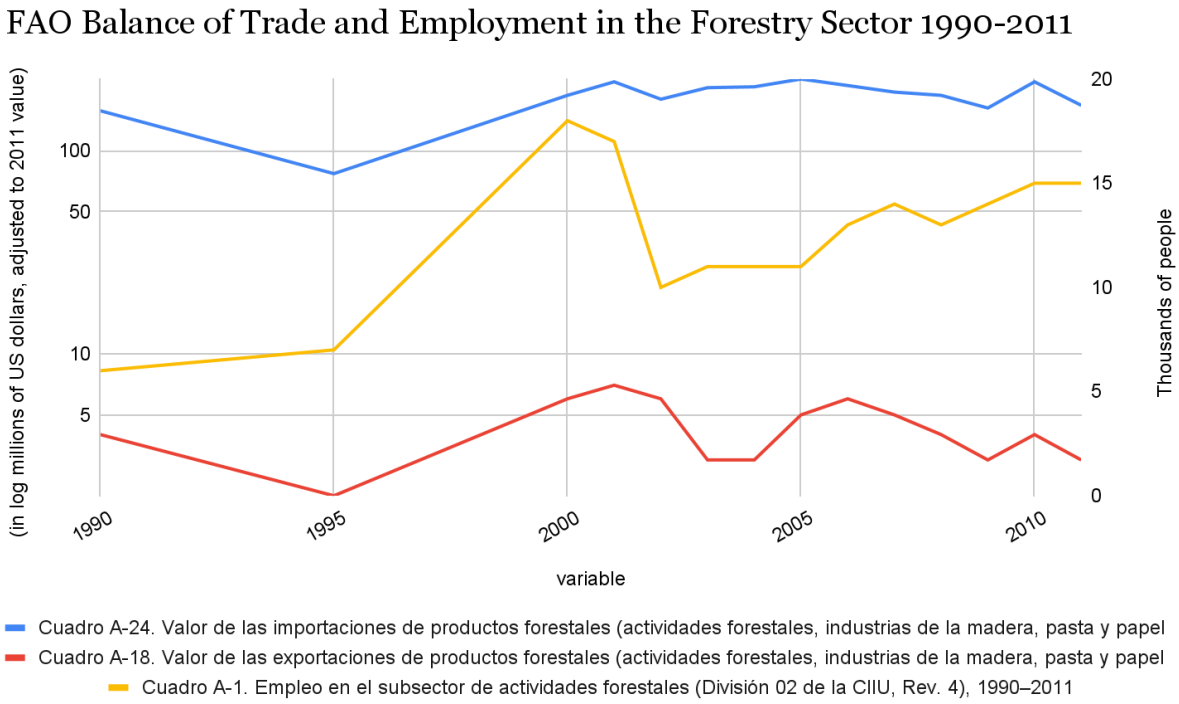

Figure 9 Impact of forestry balance of trade on sector employment.

Housing and Construction

Among the many vestiges of asymmetric colonial development that still plague Cuba, the shortage of adequate housing has yet to be resolved by the socialist government. During colonial and pre-revolution periods, inadequate housing was a result of labor exploitation and human rights abuses that privileged the upper classes with quality construction. Like other colonies, Cuba suffered from Urban Primacy of the capital city. Similar to the proportion of 50 years ago, around 19% of the population live in the capital Havana, with around 76.8% living in areas

recognized as 'urban'.[63] The remaining quarter of the national population living in rural areas must contend with an aging railroad system, limited road network, and few ports and airports serving the areas.

Housing and other construction after 1959 was driven by Cuban ideology focused on rural development and Soviet technology. Prefabricated high density apartment buildings along with concrete schools and health clinics were built in rural towns and small cities. A neglect of existing pre-revolution housing in large cities and insufficient maintenance of Soviet housing projects followed these policies, contributing to housing shortages during and after the Special Period.[64] The embargo and collapse of major trade partners has significantly constrained access to global markets for construction materials. Goods that do make it into the island were not typically sold in stores, and until recently were only available through State agencies for State construction projects.

The Cuban diaspora is responsible for an injection of cash and materials that allows some Cubans to buy, repair, or build housing for locals and tourists.[65] Reforms and guidelines for housing development changed throughout the Special Period to allow transfer of property (2011), access to the private sale of construction materials, private construction workers, welfare subsidies for construction, and the legalization of some self-built houses (2017). Piecemeal programs address one-time issues as they come up from natural disasters and economic shifts rather than a coherent national housing policy.[66] Notably, Cuba experiments with community architect programs to improve accessibility to refurbishing the housing stock.[67] Earlier reforms during the Special Period aimed at reducing the attractiveness of Havana and other large cities and controlling internal migration.[68]

Natural disasters exacerbate the housing crisis. For example in 2008 the municipality of Los Palacios had 77% of its housing stock damaged, 46% completely destroyed.[69] As described in the literature, most construction happened as redevelopment of existing urbanized areas or as infill that took advantage of

[63] Seyed J Faraji et al., "Urban Primacy in Urban System of Developing Countries; Its Causes and Consequences" 6, no. 1 (2016): 13.
[64] Sergio Díaz-Briquets, "RECOGNIZING THE OBVIOUS WHILE MUDDLING THE WATERS: CUBA'S HOUSING SECTOR REFORMS," 2017, 12.
[65] Jolivet and Alba-Carmichael, "Reinvesting in Havana: Housing Commodification and Gentrification in the Central Neighborhoods of a Socialist City in the Global South." International Journal of Cuban Studies 2021
[66] Thomas D Boswell, "Characteristics and Processes of Urbanization in the Caribbean," 1991, 36.
[67] Arturo Valladares, "The Community Architect Program: Implementing Participation-in-Design to Improve Housing Conditions in Cuba," *Habitat International* 38 (April 1, 2013): 18–24, https://doi.org/10.1016/j.habitatint.2012.09.004.
[68] G Edward Ebanks, "Urbanization in Cuba," *PSC Discussion Papers Series* 12, no. 10 (1998): 18.
[69] Sergio Díaz-Briquets, "THE ENDURING CUBAN HOUSING CRISIS: THE IMPACT OF HURRICANES," 2009, 13.

existing utility networks.[70] As a result of the trends mentioned, Cuba's Urban land cover is not expected to have a large increase in the time period captured by the ESA dataset.

Foreign Direct Investment (FDI)

"*Desde hace tiempo*
me has vendido un sueño
me has contado una historia falsa"[71]

Tourism

During the two decades following the revolution, little to no investments were made in tourism infrastructure. Tourism on the island was limited to internal travel and visits from nationals of friendly countries. It was not until 1976 that the socialist government created the Instituto Nacional de Turismo (INTUR) and 1987 when Cubanacan was formed, the main State corporation that engages with foreign tourism. Economic development and improving the balance of payments through tourism started at the end of the 1980's and continued as a strategy into the Special Period.[72]

The Republic of Cuba is currently further expanding its tourism sector. It will undoubtedly experience changes in the level of sustainability the island practices.[73] A growing tourism sector has changed the way the island economy manages land use and international relations. By 1996 tourism, not agriculture, was already the country's main source of revenue, changing the location of economic activity and related land uses.[74] Tourism activity accounted for 41% of foreign exchange earnings in 2000.[75] The CIA estimated the service sector employs 72% of the labor force in 2016.[76] Foreign tourism also funded the maintenance and re-use of existing housing, especially in places with historical tourism.[77] Tourism exists in already developed land where housing existed and was adapted for visitors or in foreign funded, resort style developments segregated from other land uses and Cubans. One of the most

[70] National Report, "Cuba Informe Nacional hacia Hábitat III," Text, Instituto Nacional de Ordenamiento Territorial y Urbanismo (ETECSA S.A., November 3, 2017), https://www.ipf.gob.cu/es/content/cuba-informe-nacional-hacia-h%C3%A1bitat-iii.
[71] Los Cogelones, *500 Años*, Vinyl, Hijos Del Sol (Song 9: Piccolo Records, 2020).
[72] María Dolores Espino, "International Tourism in Cuba: An Economic Development Strategy?" in *Annual Proceedings*, vol. 1 (The Association for the Study of the Cuban Economy, 1991).
[73] Víctor Pérez et al., "Composite Indicator for the Assessment of Sustainability: The Case of Cuban Nature-Based Tourism Destinations," *Ecological Indicators* 29 (June 2013): 316–24, https://doi.org/10.1016/j.ecolind.2012.12.027.
[74] Nicolás Crespo and Santos Negrón Díaz, "CUBAN TOURISM IN 2007: ECONOMIC IMPACT," 1997, 12.
[75] Philip Peters, "International Tourism: The New Engine of the Cuban Economy," *Arlington, VA: Lexington Institute*, 2002.
[76] Central Intelligence Agency, "The World Factbook 2014-2015."
[77] Eros Salinas, Lluis Mundet, and Eduardo Salinas, "Historical Evolution and Spatial Development of Tourism in Cuba, 1919–2017: What Is Next?" *Tourism Planning & Development* 15, no. 3 (May 4, 2018): 216–38, https://doi.org/10.1080/21568316.2018.1427142.

known segregated spaces is the Varadero tourist enclave in the Province of Matanzas where neoliberal urbanism and foreign consumption habits dominate the landscape.[78]

Cuba has also leveraged colonial developments for historical tourism: it currently has seven cultural and two natural UNESCO World Heritage sites. On the island, integration of sustainable tourism has been guided by UN conventions that define such tourism as one that is economically, socially, and ecologically sustainable.[79] The Chávez and Osorio study demonstrated that the biggest challenge to sustainable tourism are infrastructures to manage wastewater and solids and more regions receiving a designation of some kind of environmental protection. Overall social sustainability is closer to being met because of Cuba's majority national stake in tourism projects and use of private hosts. This comes with challenges, such as scarcity of goods to share with foreigners and uneven access to remittances from abroad. This challenges egalitarian ideals and practices by introducing capital-based distribution. Regions to develop for tourism are chosen by State institutions and even private citizens that host visitors must have a license from the State to do so.[80] This kind of sector management could have impacts on land cover by promoting development in already urbanized areas and urbanization close to the shoreline for sun and sand tourism.

Mining - "No olvidamos lo que pasó en Perú con la mina de Yanacocha"[81]

Thanks to political innovations of dispossession through development, Canada has operated mines throughout Latin America since the 1960's.[82] A notable example are the land concessions in Guatemala, aided by the U.S. backed military Guatemalan government, that required the assassination of local opposition leaders and eventually genocide of Mayan populations. Similarly in South American countries the Canadian government found allies in the U.S. backed dictatorships of Chile and the Dominican Republic.[83] In contrast, Canada's involvement in Cuba seems to be more closely associated with a political stance against the embargo and

[78] Jesús M. González et al., "The City of Varadero (Cuba) and the Urban Construction of a Tourist Enclave," *Urban Affairs Review* 50, no. 2 (March 2014): 206–43, https://doi.org/10.1177/1078087413485218.
[79] Eduardo Salinas Chávez and José Alberto La O Osorio, "Turismo Y Sustentabilidad: De La Teoría A La Práctica En Cuba," *Cuadernos de Turismo* 0, no. 17 (January 1, 2006): 201–21.
[80] R. Estévez Pazó, Y. Del Risco Yera, and F. Serrano Raffo, "Planeamiento del turismo y Geografía. Desarrollo en Cuba en los últimos 40 años," *Geographicalia*, no. 37bis (June 28, 2016): 151, https://doi.org/10.26754/ojs_geoph/geoph.200037bis1387.
[81] Systema Solar, *Somos La Tierra*, Mp3 (Song 7: National Records, 2017). Lyric translates to "We do not forget what happened in Peru with the Yanacocha mine"
[82] Eduardo Canel, Uwafiokun Idemudia, and Liisa L. North, "Rethinking Extractive Industry: Regulation, Dispossession, and Emerging Claims," *Canadian Journal of Development Studies / Revue Canadienne d'études Du Développement* 30, no. 1–2 (January 2010): 5–25, https://doi.org/10.1080/02255189.2010.9669279.
[83] Daviken Studnicki-Gizbert, "Canadian Mining in Latin America (1990 to Present): A Provisional History," *Canadian Journal of Latin American and Caribbean Studies/Revue Canadienne Des Études Latino-Américaines et Caraïbes* 41, no. 1 (2016): 95–113.

humanitarian aid through FDI.[84] Locations of Canadian mines in Cuba are found where known deposits of metals are found, which is now mostly in the Eastern states (see Figure 10 below). This capital-intensive industry brings technology, machinery, and labor to the island. In exchange Cuba passed a decree in 1994 to allow a 10-year grace period for meeting environmental regulations. This means, in the words of the study's authors:

> *"Quer dizer, foi concedida permissão legal para uma empresa com capital parcialmente estrangeiro não prestar atenção à contaminação do meio ambiente."*[85]

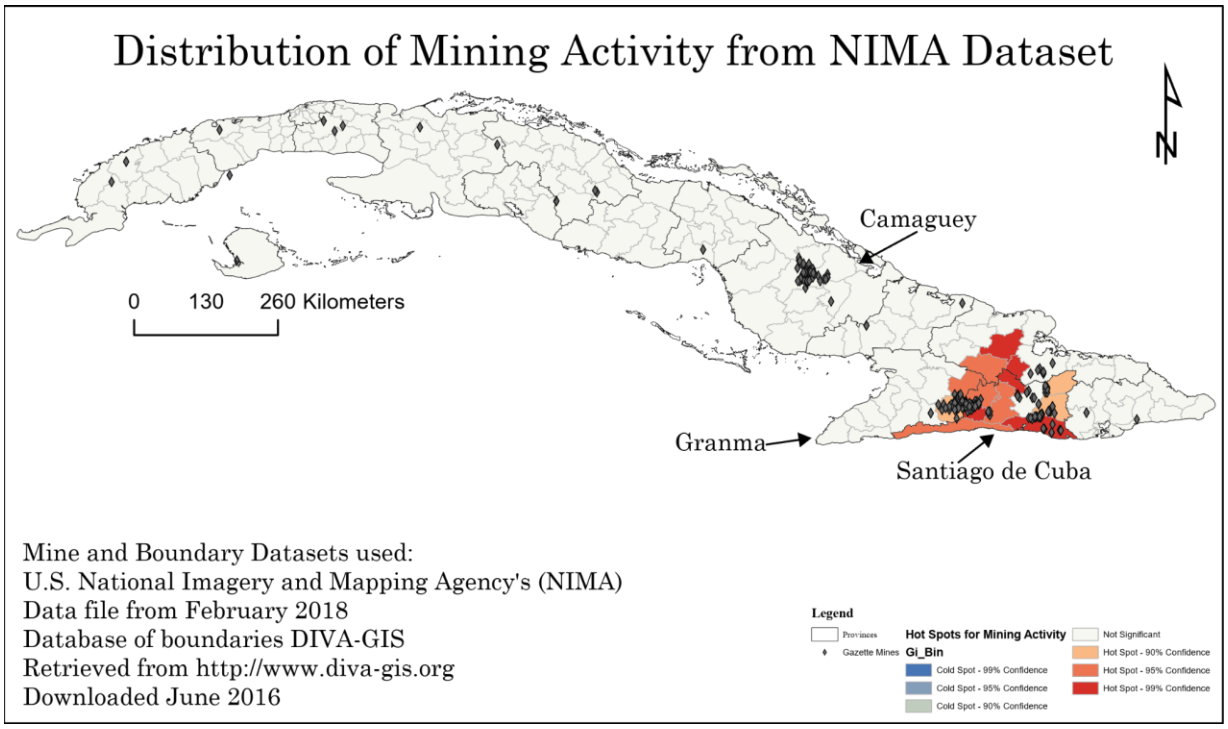

Figure 10 Mining hotspots in Cuba

Mining is Canada's largest destination of foreign investment in Latin America where exploration is less necessary because of their longer history of mining and geological mapping. Canadian firms typically prefer locations where governments privatize natural resources.[86] Studies have identified the politics of Canadian mining as a type of new imperialism based on secondary power.[87] At the spatial

[84] Julia Sagebien, "The Canadian Presence in Cuba in the Mid-1990s," *Cuban Studies*, 1996, 143–68.
[85] Eglis Martín Astorga, Manuel Fidel Sonhi Manassa, and Antonio Francisco Mateus Joao, "Inserção Da Atividade Mineira Nas Cadeias Globais De Valor: O Caso Das Mineiras Canadianas Em Cuba E No México," *Revista Eletrónica KULONGESA–TES. ISSN 2707-353X* 2, no. 2 (2020): 68–79. Quote from page 74 translates to: "Meaning, legal permission was conceded for a company with partial foreign capital to not pay attention to the contamination of the environment."
[86] Pablo Heidrich, "Determinants, Boundaries, and Patterns of Canadian Mining Investments in Latin America (1995–2015)," *Latin American Policy* 7, no. 2 (2016): 195–214.
[87] Jerome Klassen, "Canada and the New Imperialism: The Economics of a Secondary Power," *Studies in Political Economy* 83, no. 1 (March 2009): 163–90, https://doi.org/10.1080/19187033.2009.11675060.

resolution of the ESA CCI it would be hard to use this data to keep governments and mining companies accountable for environmental externalities. Depending on the footprint of mines in Cuba, land cover classified as Barren by the CIA Factbook may increase with mining activities. The metals historically mined in Cuba include gold, copper, silver, zinc, lead, manganese, iron, Nickel, and cobalt.[88] Mining activities have historically been small in comparison to other metal extraction operations in Latin America. One researcher noted that a large amount of the metal mining in Cuba happens through recycling and reuse of metal products and components.[89] Despite the comparative size of inverse mining, these efforts were substantial enough to support local populations, for example a now closed mine in Pinar del Río named Matahambre, *killer of hunger,* had been active for more than 75 years and was the primary source of jobs in the area.

Land Change Science

Land change science is a powerful tool for understanding spatial patterns and discerning the processes that led to them. Land cover changes are analyzed to assess environmental quality, the added dimension of time series data means that analyses can be performed to understand the impact of a policy and global network of actors and development pressures.[90] These analyses are often used to support narratives explaining the policies or cultural factors that contribute to change can be biased by researchers and their distance from local actors. Simplifications of land change drivers can displace responsibility and provide inadequate background to inform policy makers.[91] Lowering the burden of monitoring necessitates a methodologically consistent, long-term dataset at functional resolutions.[92] The ESA dataset promises some of these essential characteristics, since it is primarily a consistent classification schema and resolution, and its annual maps extend as far back as 1992.

Methods

> *"Often when the radical voice speaks about domination we are speaking to those who dominate. Their presence changes the*

[88] Virginia Costa-Llanos and Daniellis Rodríguez-Mejías, "La Minería En La Cultura Cubana," *Minería y Geología* 32, no. 4 (December 2, 2016): 170–78; Eduardo L. Moyano Bazzani and Serena Fernández Alonso, "La minería cubana en las últimas décadas del siglo XIX," *Anuario de Estudios Americanos* 55, no. 1 (June 30, 1998): 221–42, https://doi.org/10.3989/aeamer.1998.v55.i1.373.
[89] Alcides Francisco Antúnez Sánchez, "La minería inversa en el ordenamiento jurídico en cuba. una apuesta al desarrollo sostenible desde la economía circular," *Revista Innova ITFIP* 6, no. 1 (June 30, 2020): 71–92.
[90] Turner, Lambin, and Reenberg, "The Emergence of Land Change Science for Global Environmental Change and Sustainability."
[91] Lambin et al., "The Causes of Land-Use and Land-Cover Change."
[92] Watson et al., "Land-Use Change: Incorporating the Frequency, Sequence, Time Span, and Magnitude of Changes into Ecological Research."

> *direction and shape of our words. Language is also a place of struggle. I was just a girl coming slowly into womanhood when I read Adrienne Rich's words: 'this is the oppressor's language, yet I need to talk to you.'"*[93]

The limitations of satellite imagery are mitigated through methodological conventions chosen by the researcher to best the phenomenon they think they are observing. Such a distance from on the ground actors and managers plagues contemporary top-down academic research and institutional assessments. My dissertation research has also been affected by distance, policy changes and remotely sensed data sources. Rapid Cuban American policy changes by U.S. president D.J. Trump and the outbreak of the COVID-19 pandemic limited my field work and collaboration with Cuban agriculturalists and cultural specialists on interpretations of data analysis. I refer to my dissertation work as "magical realism" because I used established methodology and datasets to tell a story of development trajectories in Cuba from a distant and foreign perspective; it is an imaginary fueled by educated guesses. To avoid committing grave errors, I limit my analyses in this chapter to the following questions:

What was the magnitude of change captured?

What direction did the changes take?

What were the locations of changes?

I also limited my methods to: assessing the magnitude of change through a gain and loss intensity analysis and assessing the direction of change through a correspondence matrix and location of changes with a hotspot analysis. My analyses of island-wide and municipal landscape changes focused on key spatial processes, urbanization, cropland stability, deforestation, and revegetation. These analyses provide insight into ecosystem dynamics that are intrinsically connected to Cuba's economic production models.

I prepared the data for analysis using similar methods as Liu et al (2018) to narrow down the number of change pixels by removing potentially erroneous or temporary changes such as land laid fallow.[94] The dataset is then analyzed for direction, magnitude, and intensity of change using methods from Aldwaik (2012) and the

[93] Bell Hooks, *Talking Back: Thinking Feminist, Thinking Black* (South End Press, 1989). Quote from page 28.
[94] Xiaoxuan Liu et al., "Identifying Patterns and Hotspots of Global Land Cover Transitions Using the ESA CCI Land Cover Dataset," *Remote Sensing Letters* 9, no. 10 (2018): 972–81.

OpenLand software.[95] Finally, I provided validation of changes captured in the dataset. My overall workflow can be seen in Figure 11 below.

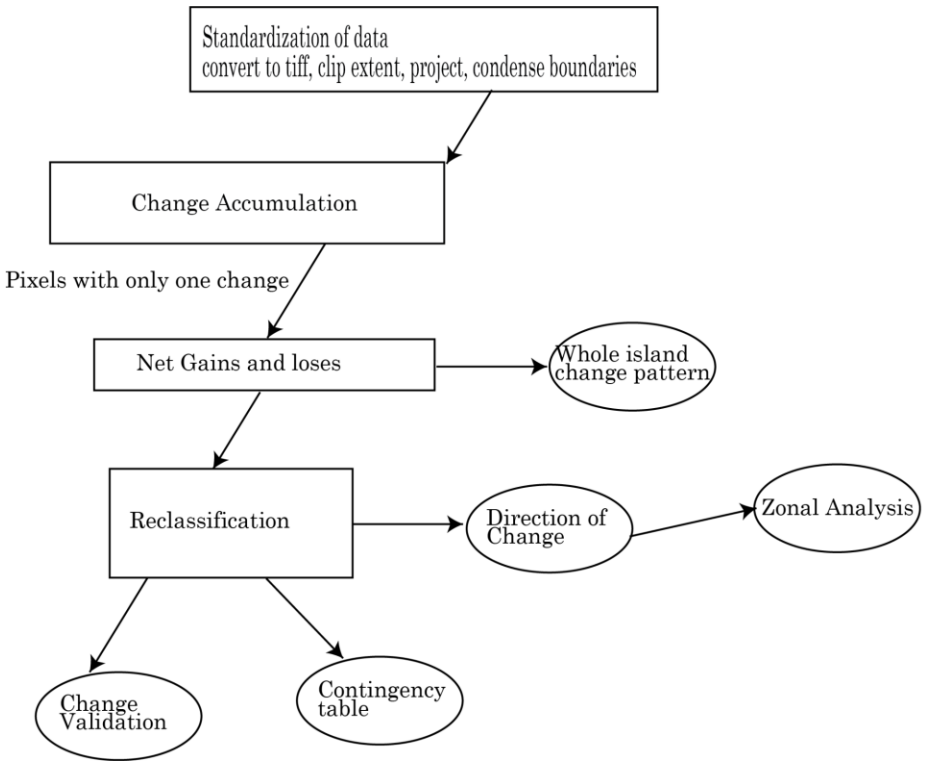

Figure 11 Diagram of data workflow for this chapter.

Software Used

This research utilized a variety of Geographic Information System (GIS) tools; the patchwork of software is a result of searching for the most replicable and well documented functions available. While these tools provided ready-to-deploy operations that made standard analyses easier, the combination of several coding languages and proprietary software added complexity.

ArcGIS 10.4 was used to initially manage v.2.0.7 (1991-2015) and standardize the extent and CRS.[96] RStudio was used to convert NetCDF files for years 2016-2019 into geotiffs using the raster library before taking the TIFFs into ArcGIS. For the 2020 data ArcGIS PRO 3.0 was used to convert to tiff and standardize. R was also used for the change analysis using the following packages: focal, LULCC,

[95] Safaa Zakaria Aldwaik and Robert Gilmore Pontius, "Intensity Analysis to Unify Measurements of Size and Stationarity of Land Changes by Interval, Category, and Transition," *Landscape and Urban Planning* 106, no. 1 (May 2012): 103–14, https://doi.org/10.1016/j.landurbplan.2012.02.010.
[96] ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

OpenLand, tmap, raster, rgdal, sf, raster, ggplot2.[97] These tools were new to me and were chosen in part for their convenience and ease of learning, both for myself and for others who might seek to replicate my work. I used standalone software when time available for me to learn and implement new techniques was limited.

Datasets

This study uses free time series data from the European Space Agency's (ESA) Climate Change Initiative Land Cover product (CCI LC) annual global land cover maps from 1992-2020. The CCI Climate Research Data Package: annual land cover maps come in two volumes. The first is v2.0.7 with 24 bands representing annual rasters from 1992-2015 at approximately 300m resolution (or 0.002778°). This comprehensive dataset is based on an array of sensors including AVHRR, SPOT-VGT, MERRIS FR and RR; a complete list is available in the Product user Guide summary of the CCI-LC products on Table 2-1.[98] This dataset is the only consistent global land cover map available for such an extensive time period.[99] The user guide estimates a general user accuracy of 71.1% with some higher values for more homogeneous and distinct classes such as urban, bare, and water.

The ESA's CCI Climate Research Data Package provides the most consistent and complete global record of land cover during the time-period in question. Perez-Hoyos (2017) uses nine land cover products to note discrepancies between the products, calculate accuracy when compared to Food and Agriculture Organization of the United Nations (FAO) crop statistics, and develop an agreement map.[100] The researchers reconcile the product legends before combining them and generating a confusion matrix using reference site data. The cropland probability map produced by Perez-Hoyos is favorable for the area being studied despite having high disagreement in other parts of Latin America. Perez-Hoyos also found the ESA CCI product had the most agreement with Cuba, followed by the Chinese GlobeLand30. In other studies, the CCI product was also found to have the highest global consistency, although still lower than desirable.[101] Global products need to improve in accuracy through more inclusive collaborations but in the meantime provide a necessary record of global change.

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[97] RStudio Team, "RStudio: Integrated Development for R" (Boston, MA: PBC, 2020), http://www.rstudio.com/.
[98] ESA Land Cover CCI, "Product User Guide Version 2.0," *UCL-Geomatics: London, UK*, 2017.
[99] Michael A. Wulder et al., "Land Cover 2.0," *International Journal of Remote Sensing* 39, no. 12 (June 18, 2018): 4254–84, https://doi.org/10.1080/01431161.2018.1452075.
[100] Ana Pérez-Hoyos et al., "Comparison of Global Land Cover Datasets for Cropland Monitoring," *Remote Sensing* 9, no. 11 (November 3, 2017): 1118, https://doi.org/10.3390/rs9111118.
[101] Ting Hua et al., "Spatial Consistency Assessments for Global Land-Cover Datasets: A Comparison among GLC2000, CCI LC, MCD12, GLOBCOVER and GLCNMO," *Remote Sensing* 10, no. 11 (November 21, 2018): 1846, https://doi.org/10.3390/rs10111846.

As of January 2021, a netCDF file containing v2.1.1 of global annual maps for 2016-2019 was made available. These maps are based on the PROBA-V satellite but with the same specifications, such as resolution, legend, and coordinate referencing system, as the previous dataset to maintain continuity. The netCDF files are considerably larger than the previous multiband raster that was published. The break in datasets and difference in format meant that to work with the extended timeline the netCDF files had to be converted to tiff files, cropped, and projected separately. This was first attempted in R, but it led to an error in the data showing up; thus, the conversion workflow was completed in ArcGIS Pro. The Copernicus Climate Change Service (C3S) website provides an API protocol to download datasets and a Toolbox to analyze data, but their toolbox and Learning Bundles are not tailored for specific land cover change analysis or for beginners using API to work with the data locally, as would be the case without access to cloud storage. Only global datasets are available to download, meaning that researchers have to download a very large global file then clip to their area/s of interest. This study uses the 2018 file as well as five years from the first volume. The composite band that was studied includes the following years: 1992, 1997, 2002, 2007, 2012, and 2018. This series was chosen because the frequency was convenient for both data management and a narration congruent with major policy changes in Cuba. In order to build a composite band with the grids from 6 rasters the 2018 world land cover file was clipped to Cuba using the Mask tool in ArcGIS Pro rather than the shapefile of Cuba. An initial iteration of the 2018 clipping revealed a lack of grid alignment between the v2.0.7 data and the 2018, leading to a change in procedure.

Shapefile representations of National, Provincial, and Municipal boundaries of the Republic of Cuba came from the free and easy to use site DIVA-GIS, created for studying global biodiversity, the site is a resource developed by researchers to alleviate the pressure to find commonly used data. Their administrative data comes from GADM (the Database of Global Administrative Areas) includes boundaries at all three levels of governance and come in a WGS84 datum. The ease of use and reliability across State boundaries of the DIVA-GIS repository cannot be understated.

As in other chapters of this dissertation, longitudinal information about Cuba from the World Factbook is used as a reference point to identify major changes in trends. This information was obtained from PDFs or HTML copies of the annual

Factbook.[102] For shapefiles of protected areas, the UNEP's World Database on Protected Areas was utilized.[103]

Dataset Legend

The definitions of various land cover classes are important to understand in any study where the researcher defines them and their spectral signatures so that they can be identified by computer algorithms. The typology used for the CCI-LC maps uses the level 1, or global scale, UN Land Cover Classification System (LCCS) FAO classification system.[104] The FAOSTAT (FAO Statistics) Land Cover domain treats land cover as an accounting of physical "assets" for national statistics.[105] Land cover is internationally recognized as important for climate change modeling and mitigation. These classifications are now built into change models guiding adaptation. Among the available land cover classifications, I focused on those referencing cropland, urbanized, grasslands, and barren or sparse land. The Cuban maps had no pixels classified as irrigated cropland, only rainfed cropland and vegetation/cropland mosaics. FAOSTAT combines common methodologies and language to harmonize datasets from NASA MODIS and CCI-LC. The definitions of cover types of interest are described in Table 1 below, adapted from FAOSTAT metadata guide.

[102] "Catalog Record: The World Factbook | HathiTrust Digital Library." The 1982-1988 editions are biannual.
[103] UNEP-WCMC and IUCN, "Protected Planet: The World Database on Protected Areas (WDPA) and World Database on Other Effective Area-Based Conservation Measures (WD-OECM)" (Cambridge, UK, 2022), https://www.protectedplanet.net/country/CUB.
[104] U. C. L. Geomatics, *Land Cover CCI: Product User Guide, Version 2.0* (European Space Agency: Louvain la Neuve, Belgium, 2017).
[105] "FAOSTAT," accessed May 1, 2023, https://www.fao.org/faostat/en/#data/LC/metadata. "Land is a central component of economic and environmental accounting. As defined by the System of Environmental-Economic Accounting Central Framework (SEEA CF) land is "a unique environmental asset that delineates the space in which economic activities and environmental processes take places and within which environmental assets and economic assets are located". Land cover refers to the observed physical and biological land cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces (SEEA CF, 5.257). The land cover classification of the SEEA CF currently is the international standard to prepare the physical accounts for land cover. The SEEA Agriculture, Forestry and accessed June 20, 2019, http://www.fao.org/faostat/en/#data/QC. Fisheries SEEA-AFF (FAO and UN, 2020) also applies the land cover classification of the SEEA CF. In the scope of the SEEA CF and SEEA AFF, land cover information is relevant for understanding the changing composition and condition of countries ecosystems, including its agricultural and forest landscape. A physical asset account for land cover with opening stocks, additions and reductions to stock, recording of net changes and closing stock is formulated in the SEEA AFF (Table 4.9 Physical land cover asset account)."

Table 1 Land cover classification definitions

Class	CCI-LC	MODIS
Cropland, rainfed	Class 10 includes Rainfed tree crops, Rainfed shrub crops, Rainfed herbaceous crops	
Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	Class 30 includes mosaic of Cultivated and managed terrestrial areas and Natural and semi-natural primarily terrestrial vegetation	
Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	Class 40 includes mosaic of Natural and semi-natural primarily terrestrial vegetation and cultivated and managed terrestrial areas	
Urban	Class 190 includes Artificial surfaces and associated areas	At least 30% of the area is made up of impervious surfaces including building materials, asphalt, and vehicles.
Sparse	Class 10 includes any geographical areas where the cover of natural vegetation is between 2 per cent and 10 per cent. This includes permanently or regularly flooded areas.	
Barren	Class 200 includes Bare areas of either Consolidated or Unconsolidated Materials	At least 60% of the area is non-vegetated barren (sand, rock, soil) or permanent snow/ice with less than 10% vegetation.
Grassland	Class 130 includes natural vegetation of Herbaceous, closed to very open	Class 5 includes any geographical area dominated by natural herbaceous plants (grasslands, prairies, steppes, and savannas) with a cover of 10 per cent or more, irrespective of different human and/or animal activities, such as grazing or selective fire management. Woody plants (trees and/or shrubs) can be present, assuming their cover is less than 10 per cent.

Standardization of Data

For the standardization of V2.0.7, ESA's first release covering 1992-2015, the model builder tool in ArcMap 10.4 was used to batch process the multiband raster into 24 individual files then clip them to a minimalistic boundary of Cuba in the desired projection, see Figure 12 below. Land cover data from 2016-2019 were released as individual netCDF files. The file for 2018 was converted to raster files in ArcGIS Pro. They were saved as geotiffs with a CRS of EPSG 4326 then individually run through the same process as the earlier volume. All raster and vector datasets were transformed from World Geodetic System 1984, EPSG 4326, to Lambert Azimuthal Equal Area with a central meridian at -76.00000000 and Latitude of origin at 16.00000000. This projection is used in the Caribbean datasets made available by the Nature Conservancy.[106] Borrowing their projection made it easier to project the data to something that is appropriate for national level analysis with the OpenLand library. Some of the analyses required the multiple rasters to be saved as a raster brick, or multiband raster stack depending on the software used, to facilitate ease of handling time series data. These data stacks were made in ArcGIS Pro using the Composite Bands tool.

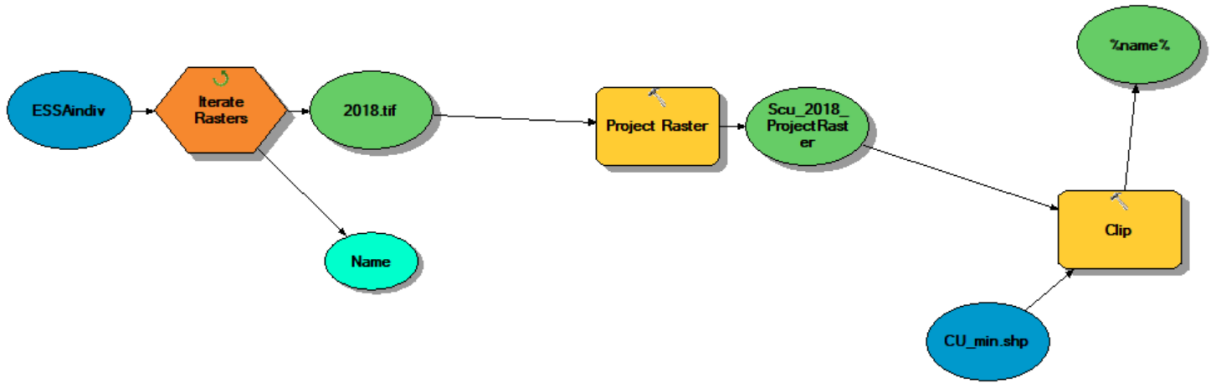

Figure 12 Model built in ArcMap 10.4 to Batch Process Data.

[106] The Nature Conservancy Caribbean, "Caribbean Science Atlas," accessed September 19, 2021, https://caribbeanscienceatlas.tnc.org/.

All data was clipped to a minimal version of the Cuban national shapefile before analysis. All three units of boundaries were cleaned of small islands and disconnected keys to minimize capturing changes in more dynamic shoreline areas that were not part of the major landscapes of interest or the researcher's area of knowledge. This was done to establish a standard boundary of the Republic of Cuba and its nested provinces and municipalities. The total area before reducing the data was 110,731 km2; after reduction the total area is 106,585 km2. Figure 13 below shows the removed areas in red, showing the core of the country stayed intact. The largest units removed are keys in the Ciego de Ávila and Camagüey provinces. In these vulnerable areas there are developed sites for tourism. Those east of the mouth of Nuevitas Bay, in Playa Santa Lucia, are included as they are not in the keys. Unfortunately resorts on Coco, Guillermo, and Santa Maria keys were not included; preliminary exploration showed some confusion between the classification of sand and development in these areas.

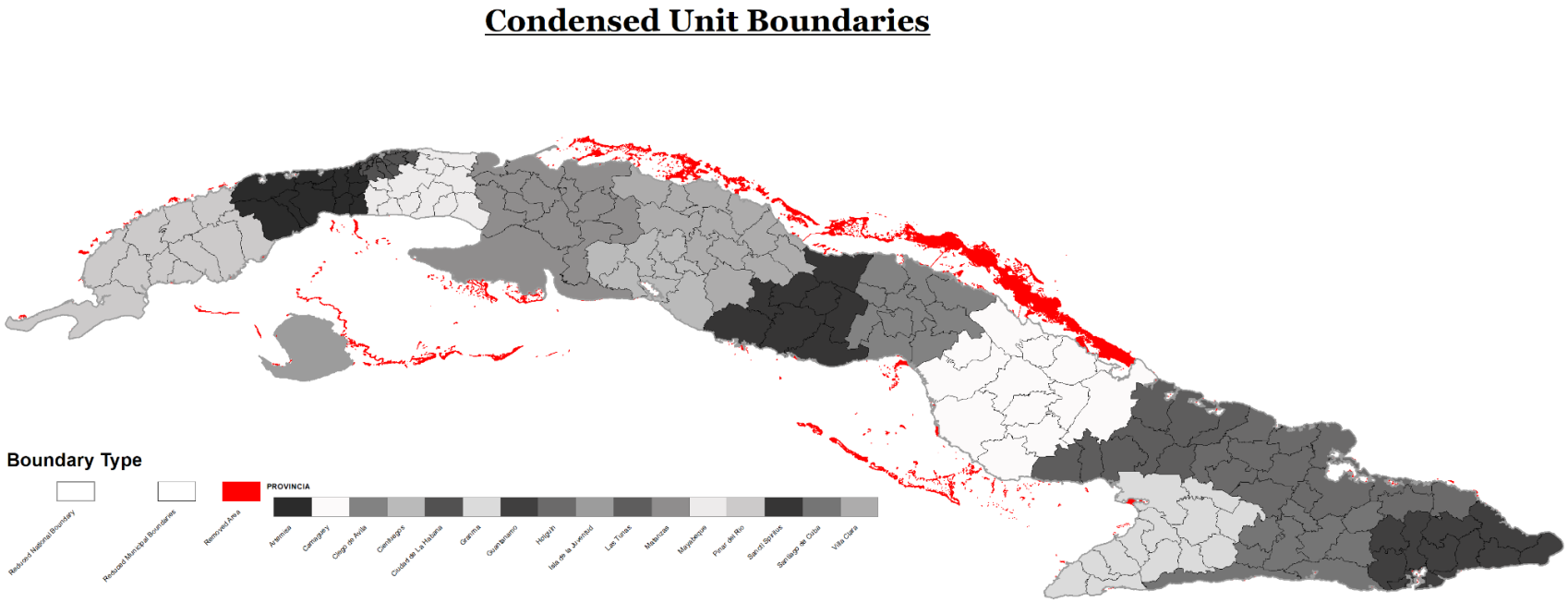

Figure 13 The island of Cuba. Areas in red were not included in the land cover change analysis.

Change Accumulation

The OpenLand library has a function (acc_changes) that allows the user to quickly analyze all of the years in the dataset as a raster brick to calculate the accumulation of changes in each pixel. This helps to eliminate change pixels that are not long term or erroneous peppering. In the area of study, the majority of changed pixels (4.28%) had a single change, 95.6% had no change, 0.14% had two changes, and 0.0005 (6 pixels) had 3 changes. See Figure 14 below for the distribution of change pixels. A mask of pixels with only one change was generated using R. The raster was taken into ArcGIS Pro to combine with reclassified and standardized 1992 and 2018 data. Extract by attribute tool then extracted pixels from the raster containing initial and final land cover classes with a single change. This raster became the base dataset for the directional, location, and economic analyses. For raster stacks of 5-year data each year has single change values extracted by mask of raster with single change pixels, and then made into a multiband raster using the Composite band tool.

In the case of Cuba, much information could be lost by reducing pixels to a single change. Cases where agricultural fields changed while resources were low and were slowly converted back to cropland would be lost. The scope of this study focuses on long term changes; shorter term changes would be better identified with partners on the ground who have been working on these sites and want a regional review of their development trajectories. Removing isolated change pixels can remove errors and make general trends clearer, but in Cuba one might expect that small, localized changes led the effort in feeding local populations. Filters that remove isolated change pixels could limit the scale of analysis too much, missing the dispersed cropland plots.

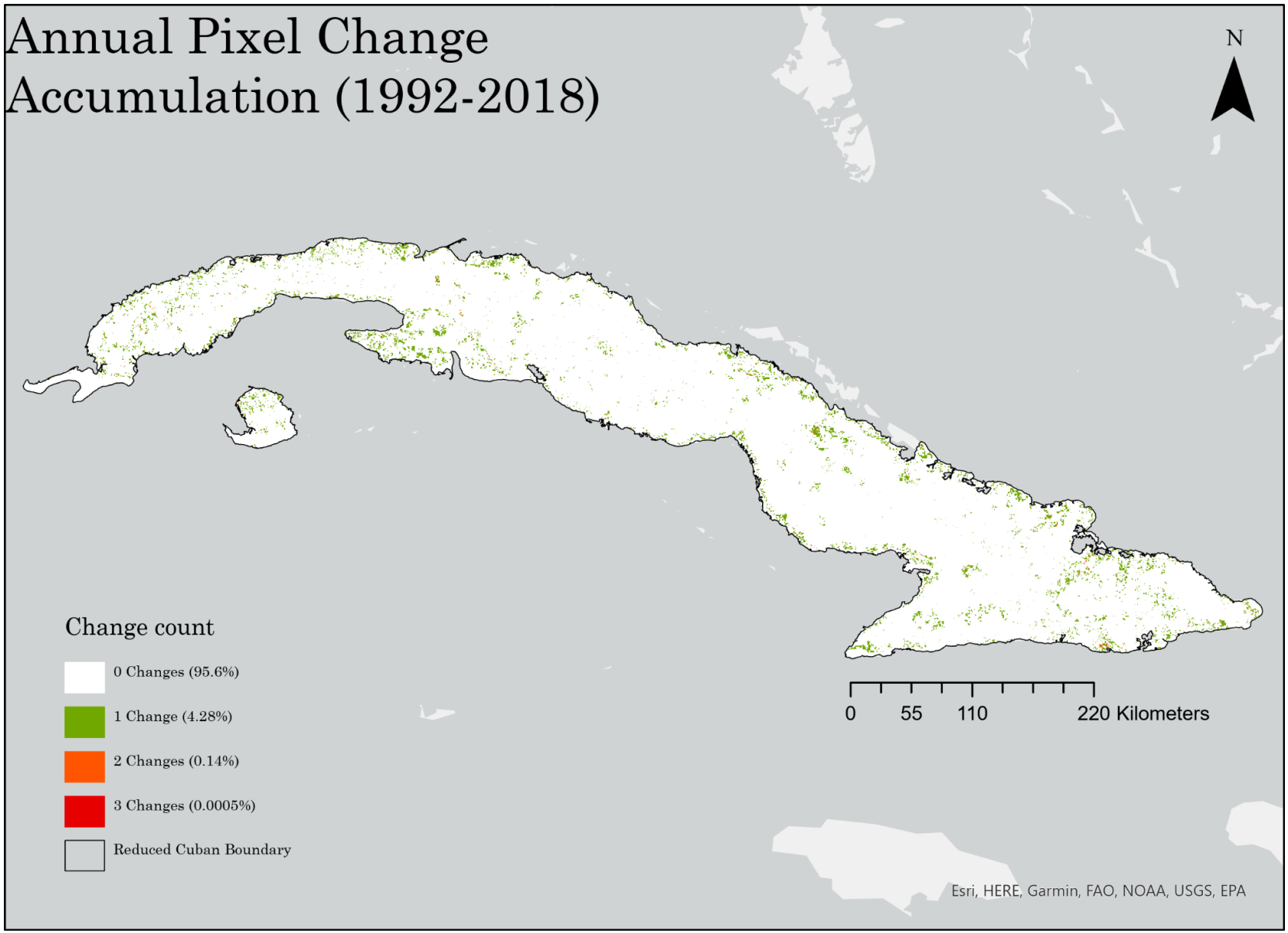

Figure 14 Accumulation of land cover changes in ESA data for Cuba

Preliminary Data Exploration

Before reclassifying the original land cover classes, OpenLand was used to conduct an Intensity Analysis on all classifications to get an idea of general trends and to highlight classes with a direct role in the economy and to narrow down the changes to be analyzed. The Net and gross gain and loss analysis was initially run on all original land cover classes, see Figure 15 below. This helped inform which classes could be prioritized for further analysis. Most classes that fall under vegetation were not discussed in depth because of their complicated relationship with the mainstream economy or complex underlying ecological processes. For example, Wetland vegetation and (surface) Water decreased in area; analyzing these would be a significant research task that is out of scope for this study. Evergreen trees had the most gross changes of any class, losing and gaining close to 1,500 km throughout the island. The environmental impact of deforestation is well documented, but understanding the forestry practices and the best practices employed or ignored is also out of scope for this study. Moreover, classes that were prioritized were more directly associated with economic activity that was slowed down by the economic crisis, like Cropland and Urban covers. Mosaic Cropland with less than 50% vegetation as well as Mosaic Vegetation with less than 50% cropland, will be referred to as Mosaic Cropland or Mosaic Vegetation, could have captured abandoned croplands going through succession or smaller farms which Cuban policy promoted during the time period in question.

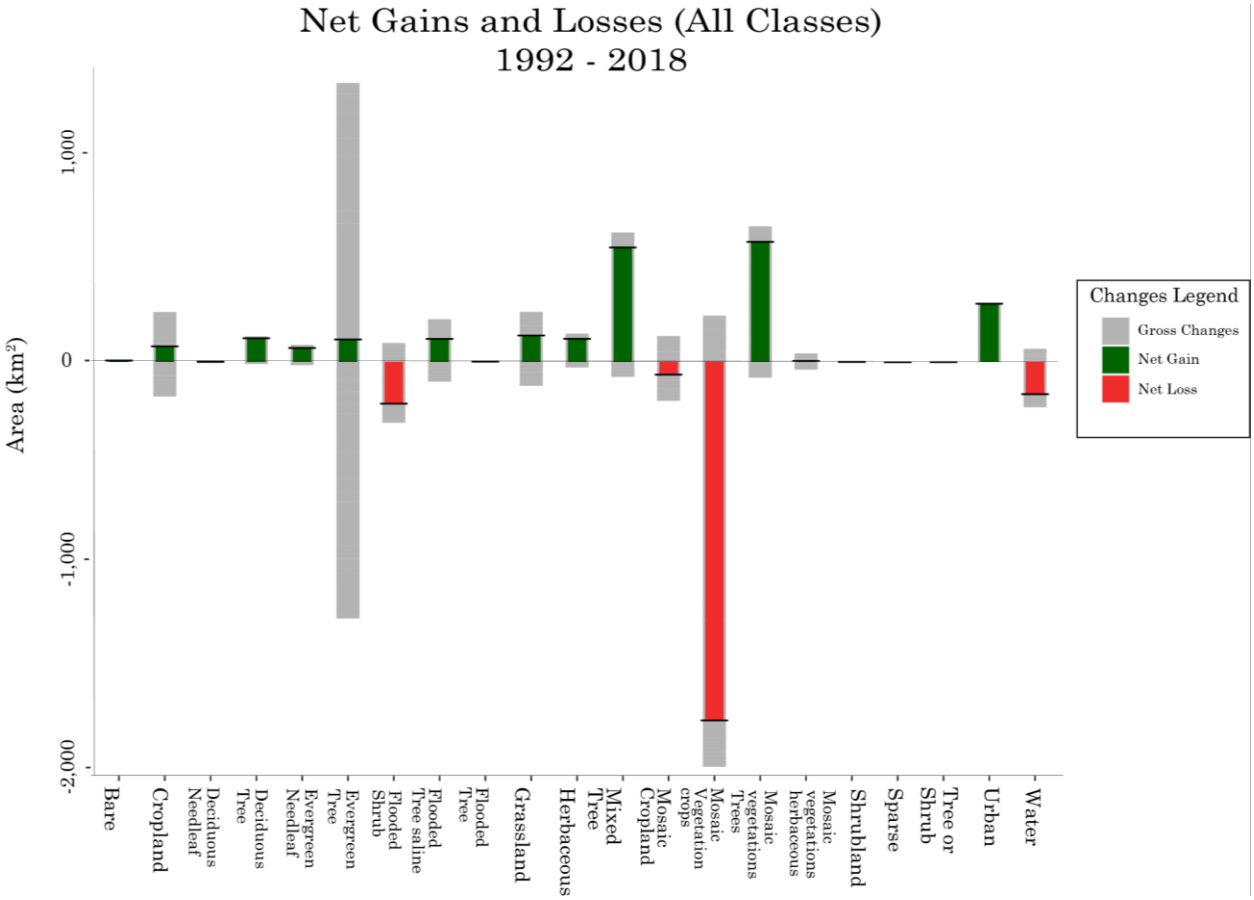

Figure 15 Net and Gross Gain and Loss stacked bar chart adapted from OpenLand output for the years 1992 to 2018.

Reclassification

My study is particularly focused on land cover categories and changes that provide insight into the impacts of economic development trajectories in Cuba. To that end land cover classes were generalized and aggregated to highlight classes of interest, such as cropland, mosaic croplands, and urban change. This reclassification mostly impacted tree and vegetation covers as seen in the table below. I experimented with various schema, testing several versions. Notable iteration insights came from a combination of literature review and attempting to interpret the direction of economic changes from land cover fluxes. In my early iterations, grasslands and all tree covers were also aggregated into vegetation. This completely obfuscated economic activities embedded in pasture grasslands and tree cover used in forestry, leading me to choose a less aggregated reclassification shown in Table 2, below.

Table 2 Net and Gross Gain and Loss stacked bar chart adapted from OpenLand output for the years 1992 to 2018.

ID	Class	Reclass	NewID
50	Tree cover, broadleaved, evergreen, closed to open (>15%)	Forest	1
60	Tree cover, broadleaved, deciduous, closed to open (>15%)	Forest	1
70	Tree cover, needleleaved, evergreen, closed to open (>15%)	Forest	1
80	Tree cover, needleleaved, deciduous, closed to open (>15%)	Forest	1
90	Tree cover, mixed leaf type (broadleaved and needle leaved)	Forest	1
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	Vegetation	2
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	Vegetation	2
120	Shrubland	Vegetation	2
160	Tree cover, flooded, fresh or brackish water	Wetland	3
170	Tree cover, flooded, saline water	Wetland	3
180	Shrub or herbaceous cover, flooded, fresh/saline/brackish water	Wetland	3
10, 11, 12	Rainfed cropland	Cropland	10
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	Mosaic cropland	30
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	Mosaic veg/crop	40
130	Grassland	Grassland	130
190	Urban areas	Urban	190
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	Sparse or barren	200
200	Bare areas	Sparse or barren	200
210	Water Bodies	Water	210

The resulting classification scheme is simpler and allows for the interpretation of generalized trends (see Table 3 below). I ran a second reclassification on the data to tease out economically meaningful classes, which is explained in greater detail in the Direction of Change section below.

Table 3 Land cover reclassification chosen for this study.

Class ID	Cover Type
1	Forest
2	Vegetation
3	Wetland
10	Cropland
30	Mosaic cropland
40	Mosaic veg/crop
130	Grassland
190	Urban
200	Sparse or barren
210	Water bodies

Magnitude of Change

Magnitude of changes in land cover can be interpreted from several analyses. Magnitude is an important feature of landscape change because it reflects the intensity of change an ecosystem had to adapt to. If the changes were driven by anthropogenic forces, it also reflects the intensity of change human activities had on landscapes. R OpenLand library produced two key analyses that show the magnitude of change. The Sankey diagram shows magnitude of change in area via the thickness of the to-from lines and the gain and loss bar charts.[107] The intensity of change analysis chosen was a percent change per class, where for each five-year period, except for 2012-2018 which is 6 years, the change in pixels for each classification is divided by the count of pixels from the previous time period in the same classification.

Percent change = ((Pixel count class x at time 2 - Pixel count class x at time 1) / Pixel count class x at time 1) * 100

A bar chart of percent changes in pixels per class for each decade was created using Google sheets and class pixel counts for each.

Hotspot Analysis

Global patterns and hotspots in this dataset were analyzed by Liu et al (2018) using

[107] Aldwaik and Pontius, "Intensity Analysis to Unify Measurements of Size and Stationarity of Land Changes by Interval, Category, and Transition."

methods that reduce error.[108] In that study, the dataset is filtered by analyzing only pixels that had 1 change during the time series, reducing the number of changes that do not reflect long-term directional change. For example, agricultural land that is left fallow for a short number of years but returned to agriculture cyclically over the 27 years are not labeled as a change of land cover using this method. They further focus their analysis by running a moving window hotspot analysis that removes potential "salt and peppering and reduces the pixels to those in concentrated areas or "hotspots" of change. This speckle effect is more common in high resolution images but can be seen in any pixel-based classifications, especially in landscapes with high heterogeneity.[109] Since all land cover classifications were used for this analysis, there were more single-change pixels than if the reclassified scheme had been used as the input. For the 3 by 3 pixel moving window hotspot filter, R focal was run on a raster with pixels that underwent only a single change during the time series. The results are saved as a raster with values between 1 and 0. The value represents the average value of a pixel when a change pixel had a value of one and those around it with no changes would have a value of zero. Pixels with a value of 1 are considered to be in a hotspot of change. These pixels were counted per municipality as one measure of intensity of change.

Direction of Change

At this point, two themes were considered for describing the direction of land cover change. The first is the from-to direction of land cover classification. This can be observed through a correspondence matrix and the multitemporal Sankey diagram produced by OpenLand. A post-classification comparison using a cross-matrix analysis on the 1992 and 2018 rasters was then done in ArcGIS using the Combine tool, as proposed by Lu et al 2004.[110] The resulting confusion table was brought into Google Sheets to be turned into a table and to calculate percent changes.

Net Economic Gain and Loss

Results from the Net Gains and Losses analysis were used to inform a reclassification of pixels which aggregates forest and other natural vegetation. A second reclassification on pixel shifts with implications about economic trajectories was also performed. For this analysis and the change error matrix validation, only certain changes were of interest: primarily in Cropland, Mosaic cropland, and Urban loss or gains, as they are directly related to an increase, decrease, or shift in

[108] Liu et al., "Identifying Patterns and Hotspots of Global Land Cover Transitions Using the ESA CCI Land Cover Dataset."
[109] Maggi Kelly et al., "Terrestrial Remotely Sensed Imagery in Support of Public Health: New Avenues of Research Using Object-Based Image Analysis," *Remote Sensing* 3 (December 1, 2011): 2321–45, https://doi.org/10.3390/rs3112321.
[110] D. Lu et al., "Change Detection Techniques," *International Journal of Remote Sensing* 25, no. 12 (June 1, 2004): 2365–2401, https://doi.org/10.1080/0143116031000139863.

economic activity. Grasslands and Sparse/Barren areas might have contributed to the economy if they were used as grazing fields or mining. New Barren areas where not considered for economic changes while new Grasslands were.

During the initial validation process, it became clear that the methods were insufficient to distinguish productive forms of grasslands and barren lands from non-productive ones, thus these were not considered in the validation. Some shifts are hard to classify as growth or contraction. Land cover conversion to the Grassland class could be a form of contraction if it is read as vegetation growth on previously economic producing cover or it could be a shift of economic activity if they are being used for grazing. Similarly, barren land cover could represent a loss of economic value and environmental degradation, or it could represent growth of mining activity. For the purpose of classifying changes into economic meaning, it is also probable there are dataset errors or drought conditions when Open Water is either the initial or end class. It could mean a reduction in surface area and revegetation of a lakebed, or it could be misclassified wetlands. Table 4 describes my hypotheses used to reclassify changes into economically meaningful classes.

Table 4 Economic reclassification scheme used for part of the study.

1992 class	2018 class	Land cover change trajectory	Growth or contraction
Any vegetation	Water	Flooded	Not considered for growth or contraction counts
Forest	other vegetation	Forest loss	growth
Any other	Barren or sparsely vegetated	New barren	Not considered for growth or contraction counts
Water	Mosaic	New low intensity	Growth
Water	Cropland	New cropland	Growth
Forest	Urban	Urbanized tree loss	Growth
Vegetated	Urban	Urbanized	Growth
Any vegetation	to crop	New cropland	Growth
Mosaic cropland	Cropland	Higher intensity cropland	Growth
Mosaic vegetation cropland	Cropland or mosaic cropland	Higher intensity cropland	Growth
Mosaic cropland	Mosaic vegetation cropland	Lower intensity mosaic	Contraction
Croplands	any other	crop loss	Contraction
Urban	any other	Urban loss	Contraction
Mosaic to any vegetation	any other	Mosaic loss	Contraction
Any Vegetation	Grassland	Gained grassland	Growth
Vegetated	Any Mosaic	New low intensity crop	Growth
Any vegetation	Wetland	New wetland	Not considered
Any vegetation	Forest	reforestation	Not considered
Grassland	other vegetation	grassland loss	Contraction

Location of Change

After generating the change detection matrix from the ESA raster, the Tabulate Area and Summarize tools were used to calculate class distribution by province and municipality. Municipal and provincial counts of changes in Forest were calculated as the percent of total change area that is forest loss or gain per municipality. Similarly, the percent area change in each economic trajectory type represents the percent of the total change area.

Validation

It became clear when starting the validation process that the disseverment of my field work from Cuba was going to be poorly replaced by ancillary images from Google Earth or LandScan. Having never lived in a tropical country or routinely walked on Cuban soil, it is difficult for me to interpret images for all but the most obvious land covers. The Change Detection Error Matrix (CDEM) is similar to the traditional error matrix for classification errors in a single time period, but error is assessed for classification errors between two time periods.[111] This increases the dimensions of the matrix and adds a change/ no change section. Since this research covered the entirety of Cuba, an island with complex landscapes, and my interest is in known economic drivers, the number of classes assessed in this CDEM is limited. The changes of interest to my research questions are: urban growth, forest change, and cropland loss and gains. Because of the spatial resolution (300m) and the known use of smaller cooperatives or individual plots in Cuban agricultural development, it would be difficult to find validation points in pixels that are not part of a hotspot. Thus, instead of using pixels with single changes, only pixels identified as a hotspot from the moving window filter were considered for sampling. Notably, this method misses out on describing hyper local changes that might reflect a deeper level of sustainability. The resolution of this data limits this research to regional studies.

Results "Venid a ver lo que no queréis"[112]

Generally, land cover change in Cuba from 1992-2018 shows an island that is reducing previous human impacts on vegetation. Whether these changes were a type of managed retreat or signal a departure from economic growth that is linked to ecological destruction is not observable with this dataset alone. Vegetative and

[111] Russell G. Congalton and Kass Green, *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices, Third Edition* (CRC Press, 2019).
[112] Rata Negra, *Venid a Ver*, Una Vida Vulgar (Song 1: Humo Internacional, 2021). This sets the tone to read the results and discussion section.

Forest covers had the highest area growth, while new urbanization stagnated and was largely dispersed.

Magnitude of Change

A reaction lag can potentially be seen between shocks in the agricultural sector and landscape response. The literature discussed 1993 as the sector's worst year, and Figure 17 shows a large decrease in the number of mosaic class pixels the following year 1994-1995.[113] While I can observe some natural land covers increasing in extent, there are no obvious large-scale changes that would be indicative of a national-level shift to more sustainable land management practices. This dataset needs to be considered in conjunction with regional level data for a specific province to determine if sustainable shifts occurred after changes to local policy.

Net Gains and Losses

Figure 16 below is an open land graphic that shows the dominant patterns in landscape change. Land that was classified as mosaic vegetation, predominantly vegetation with less than 50% cropland intermixed, shows the largest reduction by almost 2,000 km^2. Cropland shows a modest increase of less than 500 km^2. Similarly Urban land cover area grew slightly more but still less than 1,000 km^2. Vegetation and forest cover have the largest net gains by almost 1,000 km^2 each. Sparse and Barren covers had a net gain but only by 54 pixels.

[113] J.m. Febles-González et al., "Cuban Agricultural Policy in the Last 25 Years. From Conventional to Organic Agriculture," *Land Use Policy* 28 (January 1, 2011): 723–35, https://doi.org/10.1016/j.landusepol.2010.12.008.

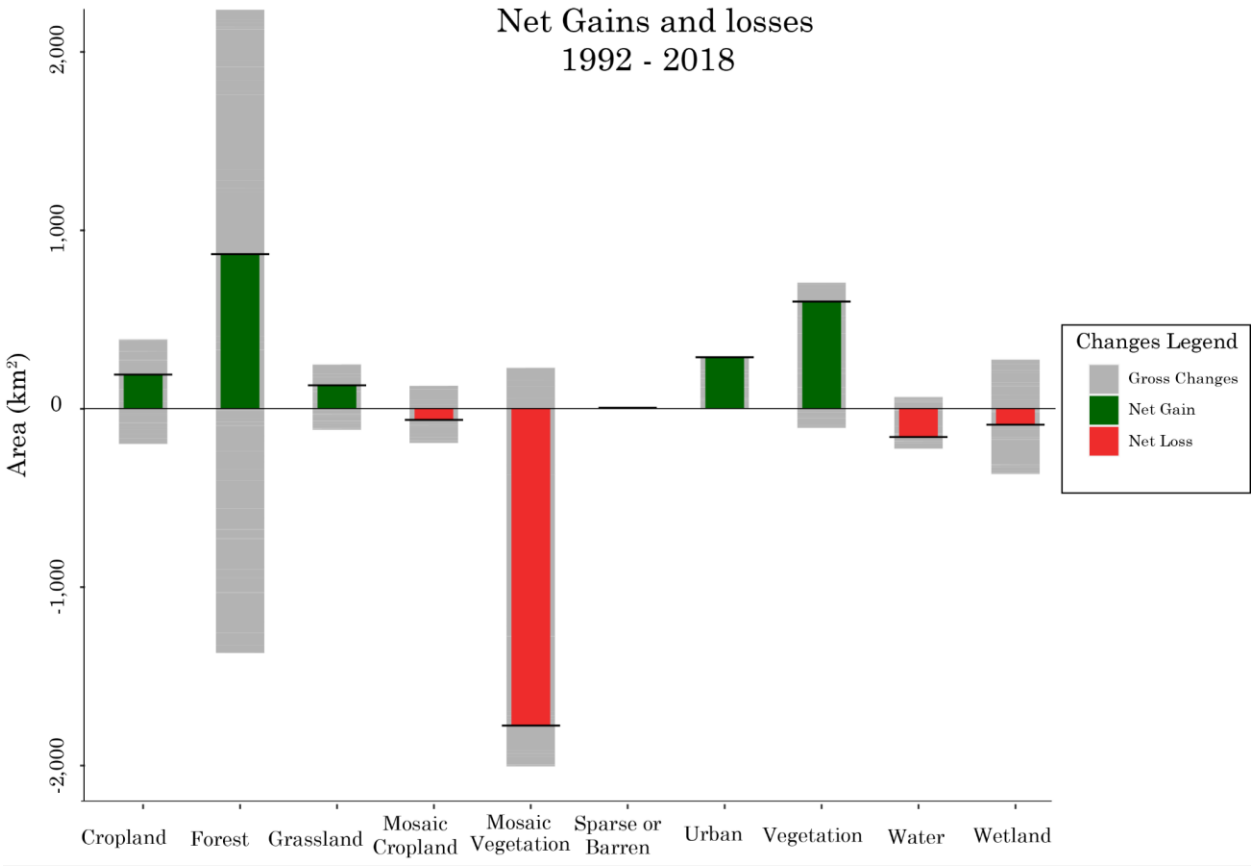

Figure 16 Net changes in area of each land cover class

Percent net change in pixel count for each of the classes in Cuba shows an intense change in the 6-year period between 2012-2018, see Figure 17 below.

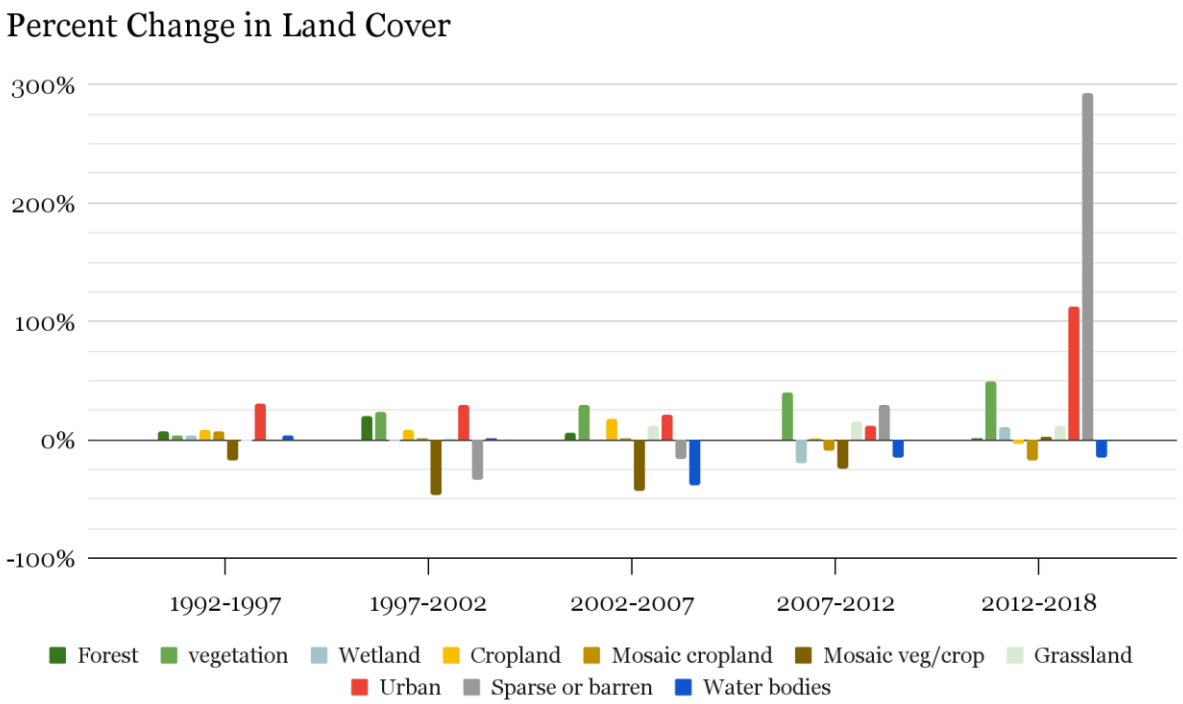

Figure 17 Intensity of land cover changes in five-year intervals

In this intensity analysis, I observed that gains in vegetation cover intensity after 1997. I can also see that the largest growth of cropland occurred in the period between 2002 and 2007. This is consistent with the economic relief Cuba received at the time and a more established system for bringing in foreign income through tourism. Urbanization stalled between 2007-2012, a time period marked by intense tropical storms. The largest gain in urban land cover occurred 2012-2018. This is also the most intense period of Sparse/Barren land cover which only had a net increase from 2007-2012. Loss of Water bodies from 2002-2007 are consistent with drought conditions.

A closer look at cropland changes shows most of the changes in Mosaic Vegetation and Cropland occurred in the first two decades of the time period in question (see Figure 18 below). The Mosaic Vegetation and Cropland classification is the most intense loss of land cover categories on the island from 1992-2018. If interpreted as low intensity cropland, this could represent a loss in small scale producers despite government efforts to decentralize production. This loss could also be interpreted as successive revegetation of former croplands that were abandoned before 1992 when

the time series data begins. Remarkably, one can see a loss of cropland in the 2012-2018 period, following a low growth period between 2007 and 2012. This could be attributed to major reductions in sugar production mandated by the State in conjunction with drought and intense tropical storms during those times.

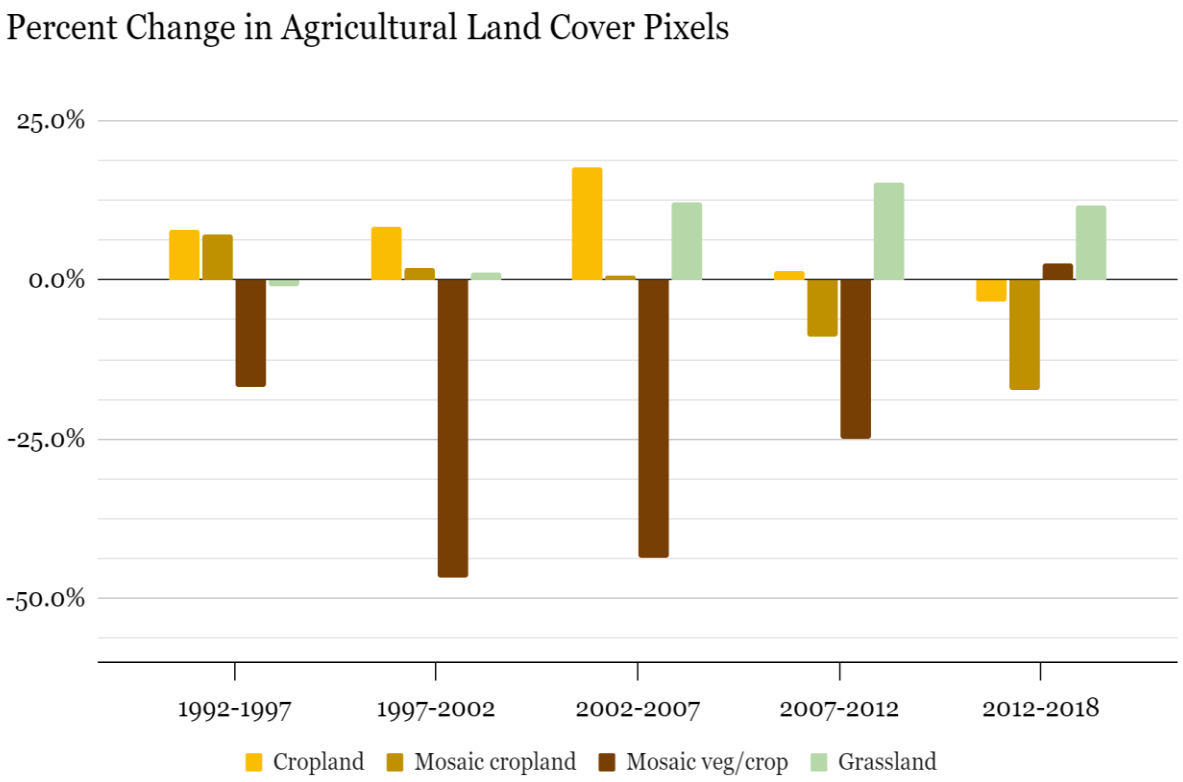

Figure 18 Normalized changes in Agricultural classes.

Direction of Change

The standard way to look at the direction of the change of land cover type is by comparing classes in the first year with the last. This can be visualized in a correspondence matrix which allows you to see the sources and sinks of land cover changes.

Correspondence Matrix

Table 5 below is a standard correspondence matrix with added color symbology for the economic direction they were assigned. Red is for decline, green for growth, gray not considered, yellow is for no change, and orange is for changes not considered but that do not fit either growth or decline because of their complexity. Cropland shift to urban areas is considered economic growth, a change to any other cover is considered a loss of economic activity. The largest source of new barren land was Water, perhaps indicating a period of drought during the observed time period.

Some surprising results are the sources of new Urban land cover which are primarily from cropland types (2,690 pixels) and 294 from wetlands. There are also 14 from barren which could be confusion. Knowing some water pixels changed to barren, we might consider the wetland source pixels to be drying areas showing bare earth rather than urbanized spaces.

Table 5 Color codes for economic significance of land cover changes

Production shift	
Economic activity loss	
Gain of Economic activity	
Not considered for economic shift analysis	
no change	

Table 6 Correspondence matrix highlighted with economic significance.

Pixel Frequency *2018*

1992	Cropland	Forest	Grassland	Mosaic cropland	Mosaic veg/crop	Sparse or barren	Urban	Vegetation	Water	Wetland	Grand Total
Cropland	312,988	3,439	2,302	13,499	3,964	2	1,725	317	200	277	338,713
Forest	6,575	385,637	3,894	3,611	5,064	4	139	5,704	708	2,264	413,600
Grassland	2,370	2,901	54,721	866	1,123	1	378	833	103	385	63,681
Mosaic cropland	13,553	3,653	960	116,992	3,391	3	624	205	55	151	139,587
Mosaic veg/crop	4,183	22,293	1,744	3,499	97,159	1	341	1,784	189	1,522	132,715
Sparse or barren	4	3			1	79	14		10	5	116
Urban	236	6	24	73	25	1	5,739	19	22	18	6,163
Vegetation	323	1,333	943	125	466	1	332	28,287	40	377	32,227
Water	309	1,258	110	87	92	70	54	547	16,833	1,761	21,121
Wetland	465	3,409	554	269	375	8	294	1,739	1,511	43,497	52,121
Grand Total	**341,006**	**423,932**	**65,252**	**139,021**	**111,660**	**170**	**9,640**	**39,435**	**19,671**	**50,257**	**1,200,044**

In Figure 19 below we can see the magnitude of the directions of change. The most prominent is the transfer of Mosaic vegetation cropland (MVC) to Forest. This may be supporting evidence for the succession theory behind the loss in the lowest intensity cropland type.

Despite internal migration control and a focus on investing outside of the main

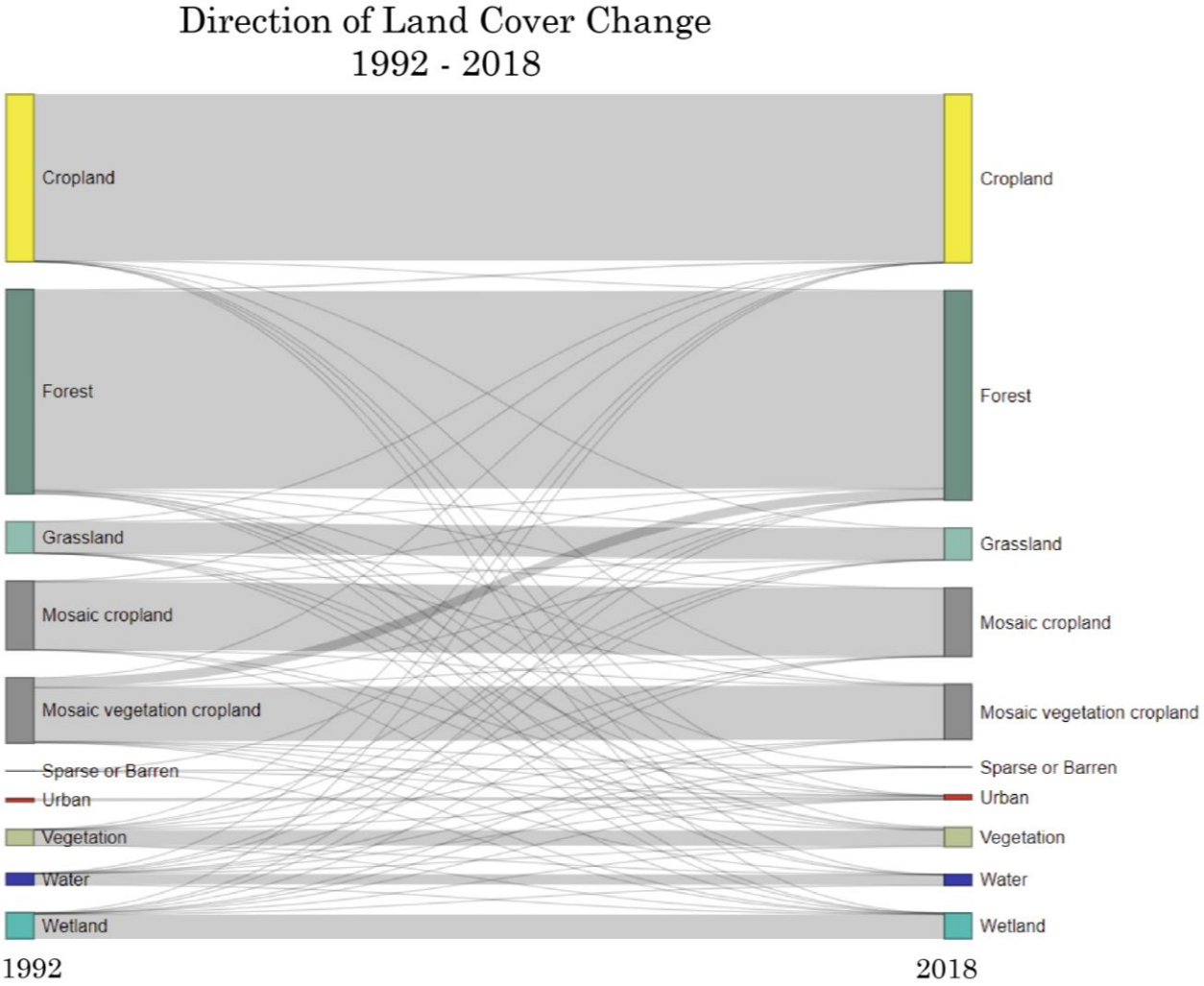

Figure 19 Modified OpenLand Sankey diagram of land cover shifts from 1992 to 2018.

capital, Havana has the most new urban pixel types. Other large cities like Santiago de Cuba in the east have clusters of urban growth, while in most other places urban growth is scattered (see Figure 20 below).

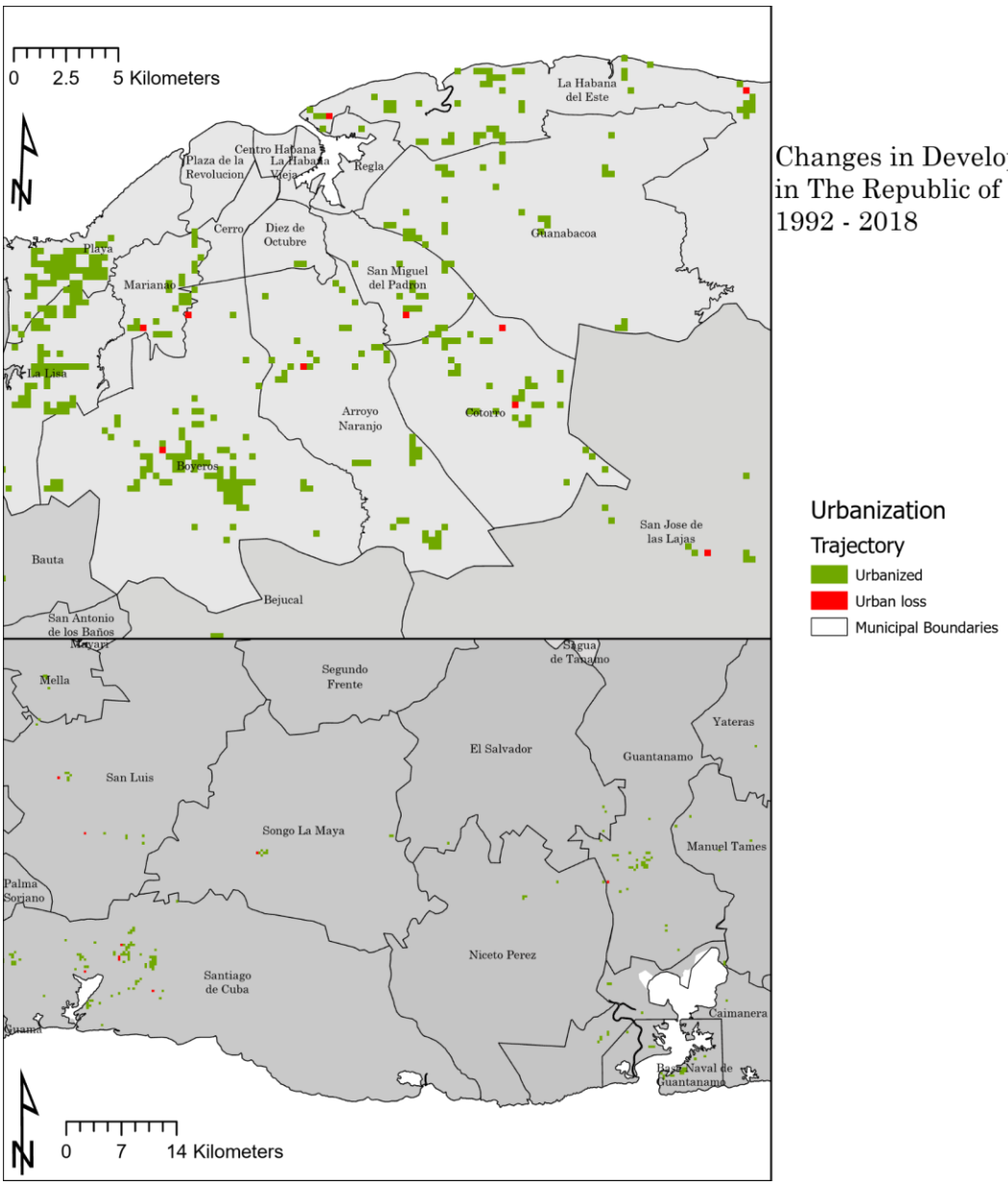

Figure 20 Focused view of urban growth in Havana and the Eastern coast.

The Forest change captured in Cuba shows a much more clustered change pattern. Meaning areas that are gaining or losing forest are doing so in larger areas rather than small plots. We can also observe in Figures 21 & 22 that most of the protected areas in Cuba are along the coast, leaving most upstream areas of watersheds vulnerable to human activities. Upstream impacts can have negative effects on water quality that eventually reaches the shore, making this schema inefficient

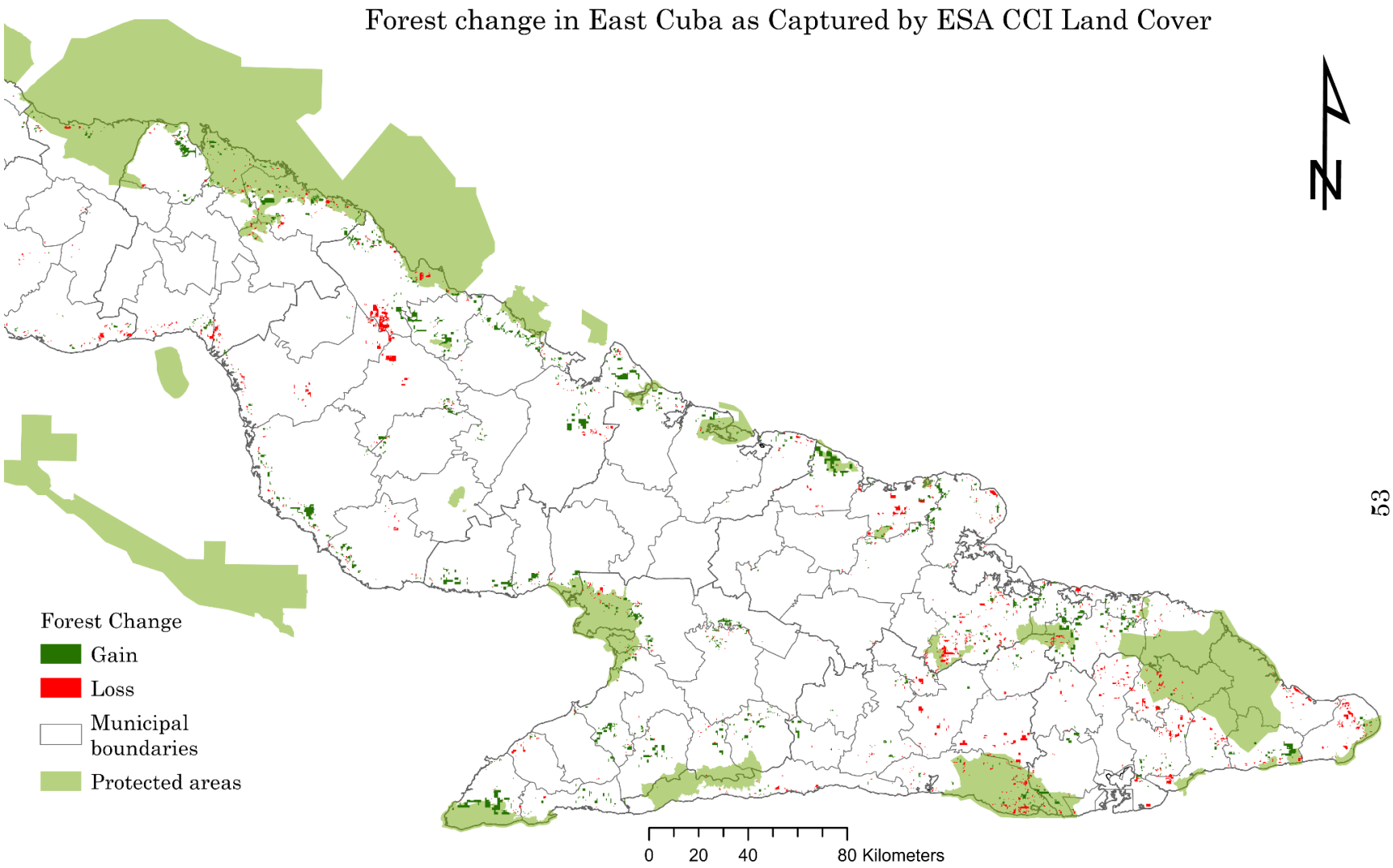

Figure 21Coastal growth of forests contrasted by interior deforestation in Eastern Cuba

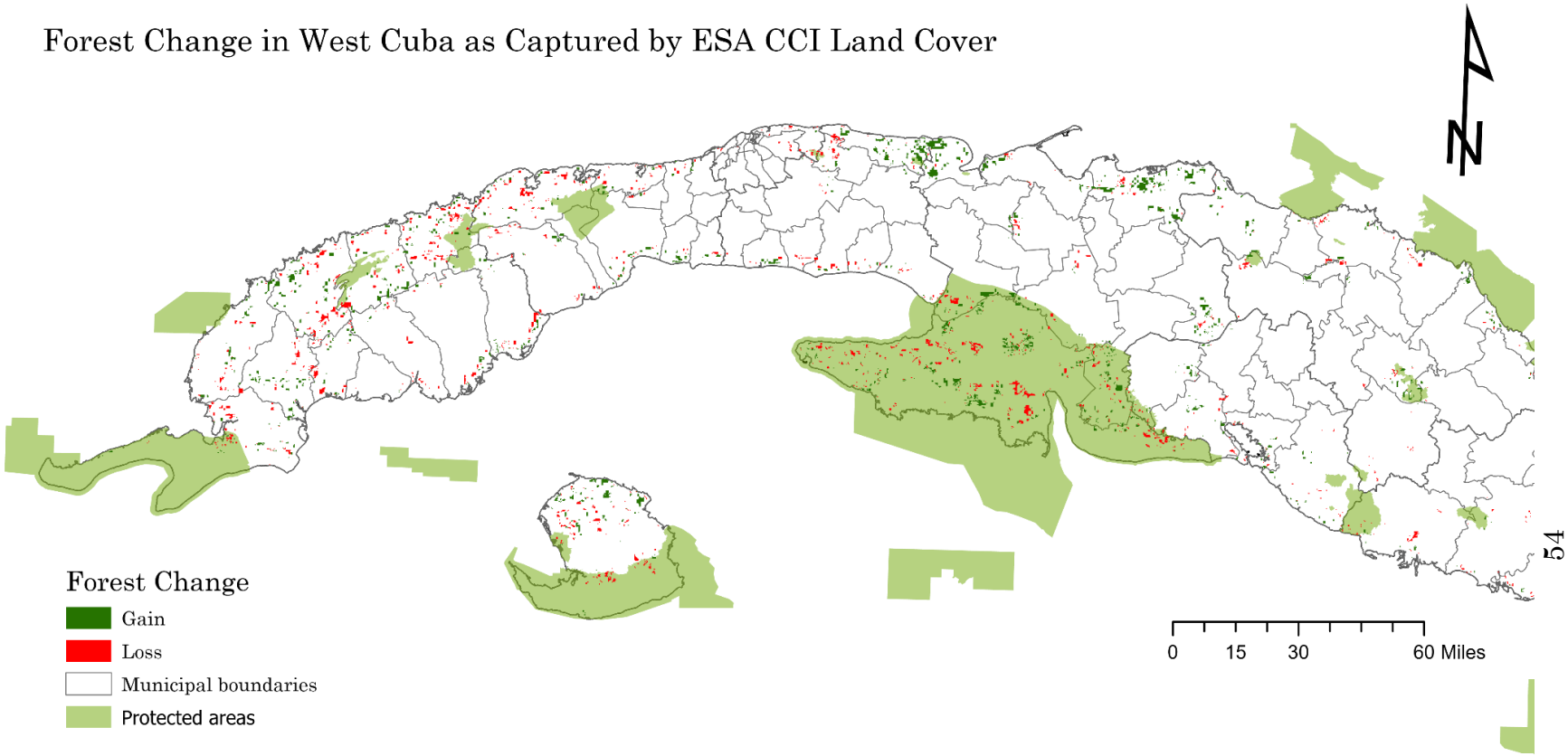

Figure 22 Dominant loss of Forest cover West of Havana around protected areas with large reforestation near Matanzas.

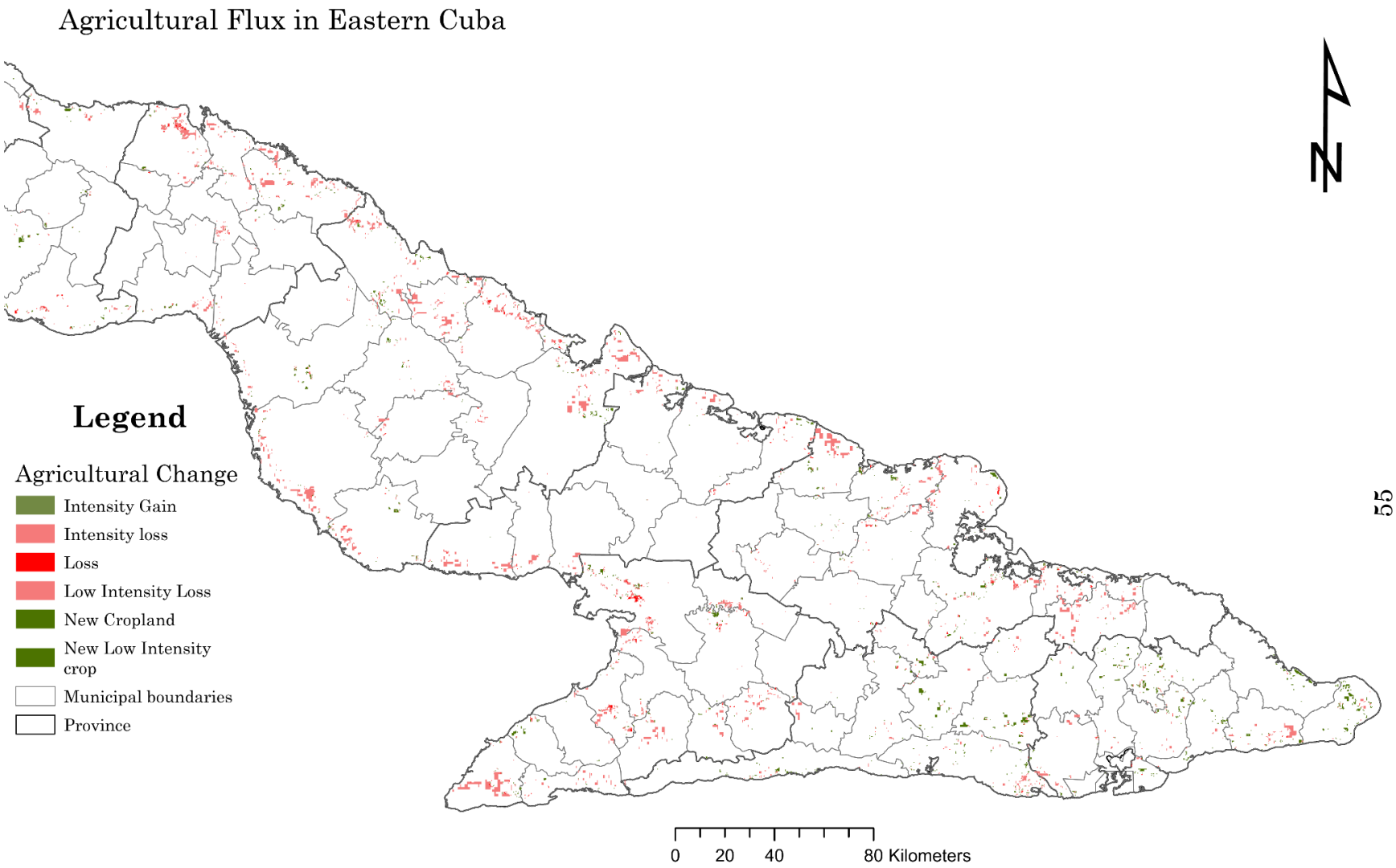

Figure 23 Changes in the Eastern Half of Cuba capture the decline in Central agriculture and abandonment of hard to exploit soils.

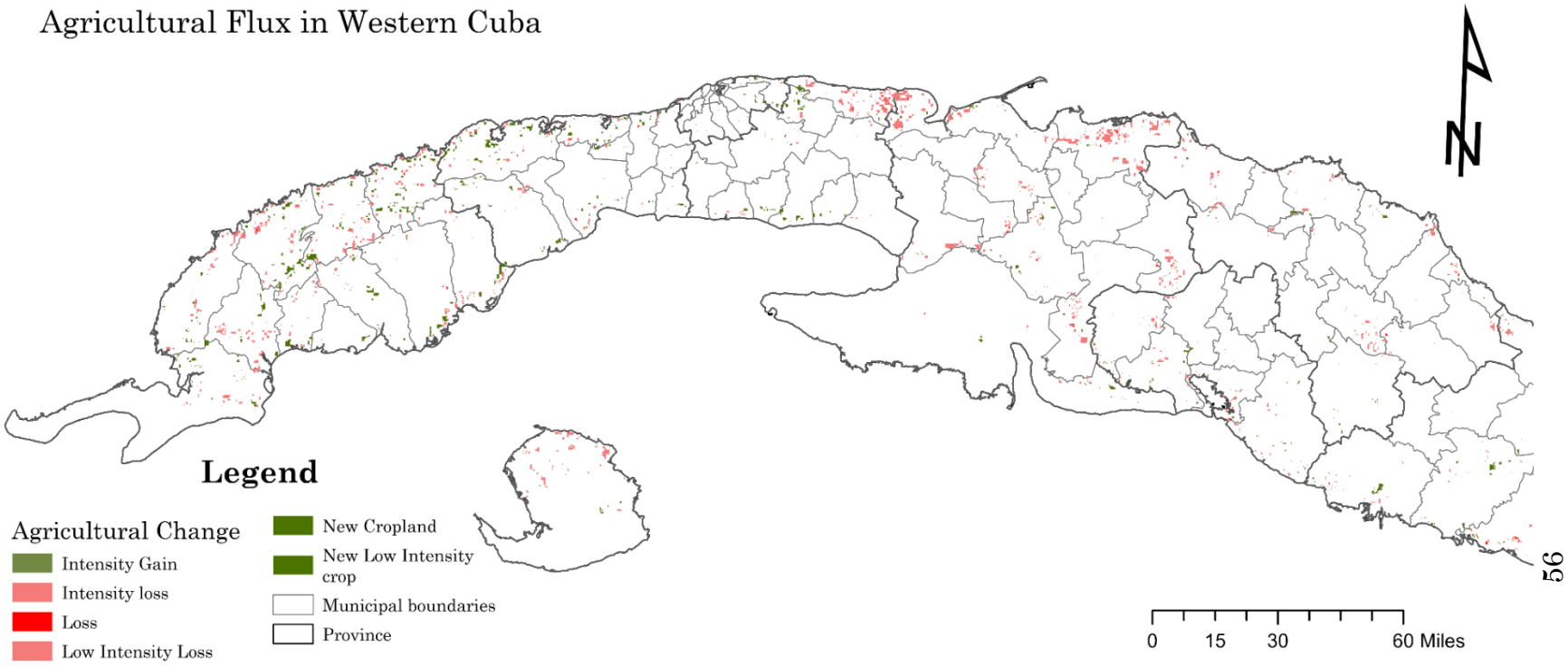

Figure 24 Directions of agricultural changes in Western half of Cuba are distinct from those in the East.

In Figures 23 & 24, a pattern of agricultural loss is evident along the Northern coastline of Cuba. This is consistent with the presence of environmental factors that are hard to work with, such as salt water, low nutrient soils, and frequent flooding. The proximity of these agricultural lands to gulf waters indicates a higher risk of salinization, high winds, variable day/night temperatures, relatively low rainfall, and soils that are high in clay content. Remarkably the Southern side of Pinar del Rio is very different in terms of agricultural fluctuations. This area is known for producing tobacco for Cuban cigars.[114] This value-added product with a production schema that stayed relatively traditional seems to have not only survived the Special Period but also allowed this region growth and stability during the crisis.

Economic Changes "Con todo y que la economía cada paso desafía"[115]

Using the reclassification scheme from Table 4 we can simplify land cover changes into economic terms. Figures 25 & 26 below show the growth and contractions of the Cuban economy in these terms. This map is essentially a summation of the direction of changes on the island in urban, forest, and agricultural land covers. We see that throughout the Eastern half of the country there is contraction along both the Northern and Southern coastlines. These areas are coastal plain zones in Agro-ecological terms and are dominated by vertisols and gleysols which are not ideal for agriculture.[116] In the Western half of the country, a continuation of contraction along the North coastal plain zone in Pinar del Rio can be observed.

While there are some changes on the Southern side of the province, they are much less pronounced indicating that Northern areas of the province made more adjustments to adapt than the South. One can see the concentration of growth in Havana and conversely, contraction to the East of the capital in Mayabeque and Matanzas provinces. Most clusters of contraction are along the edges of the country while growth is relatively scattered within the interior with the exception of the Municipality of Esmeralda. This central municipality had a large hotspot of deforestation that took place and was replaced by vegetation.

This outlier of concentrated change is an example of how this dataset can be used to identify hotspots of change that can be explored further with local policy analysis. While the large, protected wetland known as Ciénega de Zapata had many changes recorded. This largely natural ecosystem likely went through changes that are mostly not human driven. There is a band of Phaeozem soil that runs through the

[114] Scarpaci and Portela, *Cuban Landscapes*.
[115] Los Wálters, *Mayagüez*, vol. Isla Disco, Isla Disco (Song 4: Los Wálters, 2016). Lyric translates to "with the economy and all every step is defiance."
[116] FAO, "Fertilizer Use by Crop in Cuba" (Food and Agriculture Organization of the United Nations, 2003), https://www.fao.org/3/y4801e/y4801e.pdf.

middle of the wetland that has historically had settlements and some agriculture.[117] By comparing the forest change and agricultural flux maps I can observe that most of the positive economic changes here likely came from deforestation, although there is a small hotspot of agricultural additions. This wetland was where the failed Bay of Pigs invasion was attempted and where many enslaved Cubans ran from their captors to because of its complex terrain. The dense and humid ecosystem in this area is protected in part because of its natural resistance to human exploitation. Most of the changes there were not considered in terms of economic gains and losses because they were vegetation or water shifts. Figure 27 shows the net economic changes captured in land cover aggregated from the pixel level to the Municipal scale. One can notice a pattern of net losses in the North coast municipalities where poor soil and storms played a role. Perhaps also because North shore municipalities are closer to the waters that separate Cuba from the U.S. This proximity makes it easier for Cubans to migrate North. At the Provincial level it is evident that large proportions of the municipalities experienced net losses in Granma, Las Tunas, and Camagüey in the eastern part of the country. The limits of this method are also evident in three municipalities that showed either a net neutral change or no detected changes.

[117] FAO.

Economic Trajectories in Cuban Land Cover Changes (East)

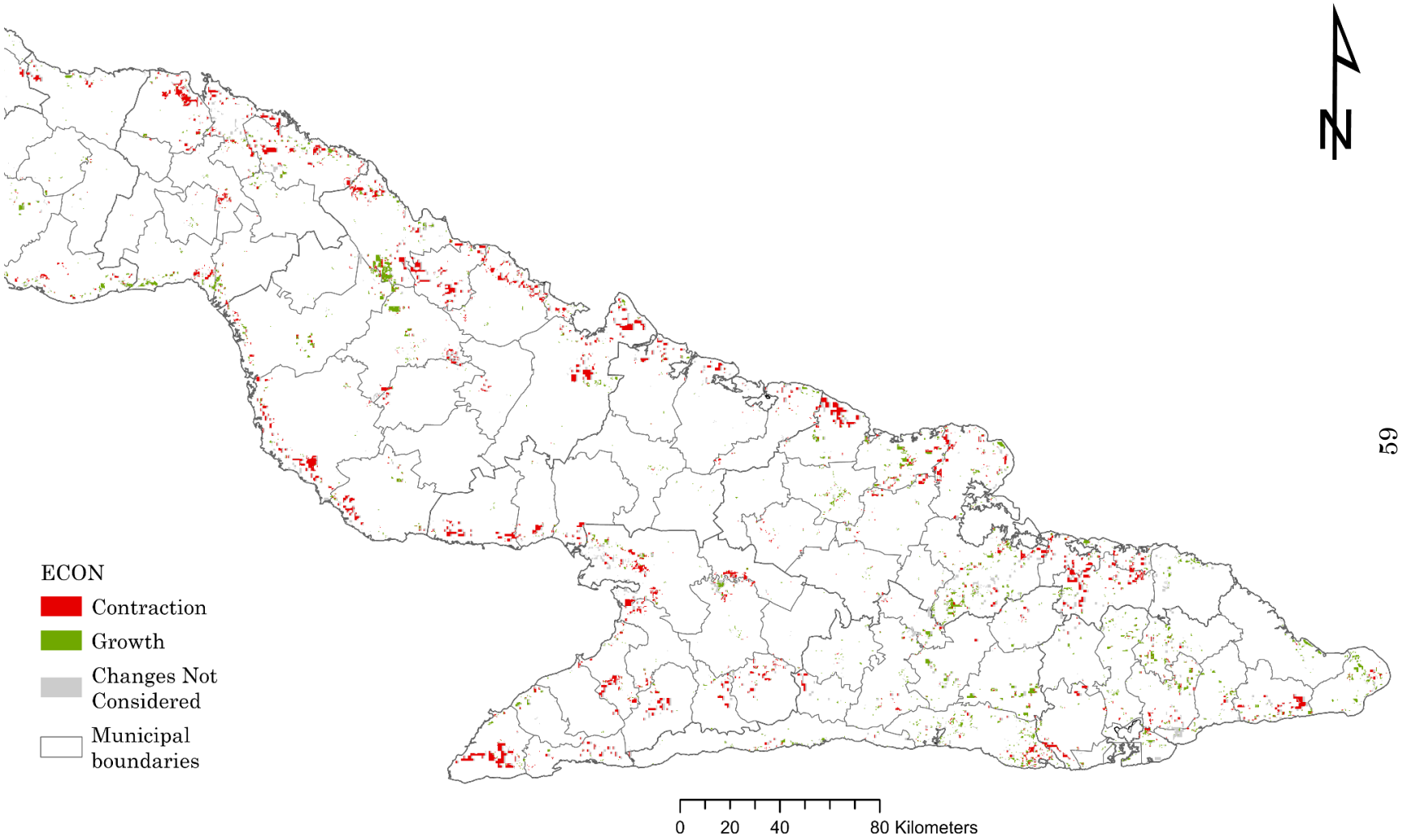

Figure 25 Economic trends reflected in land cover in Easter Cuba

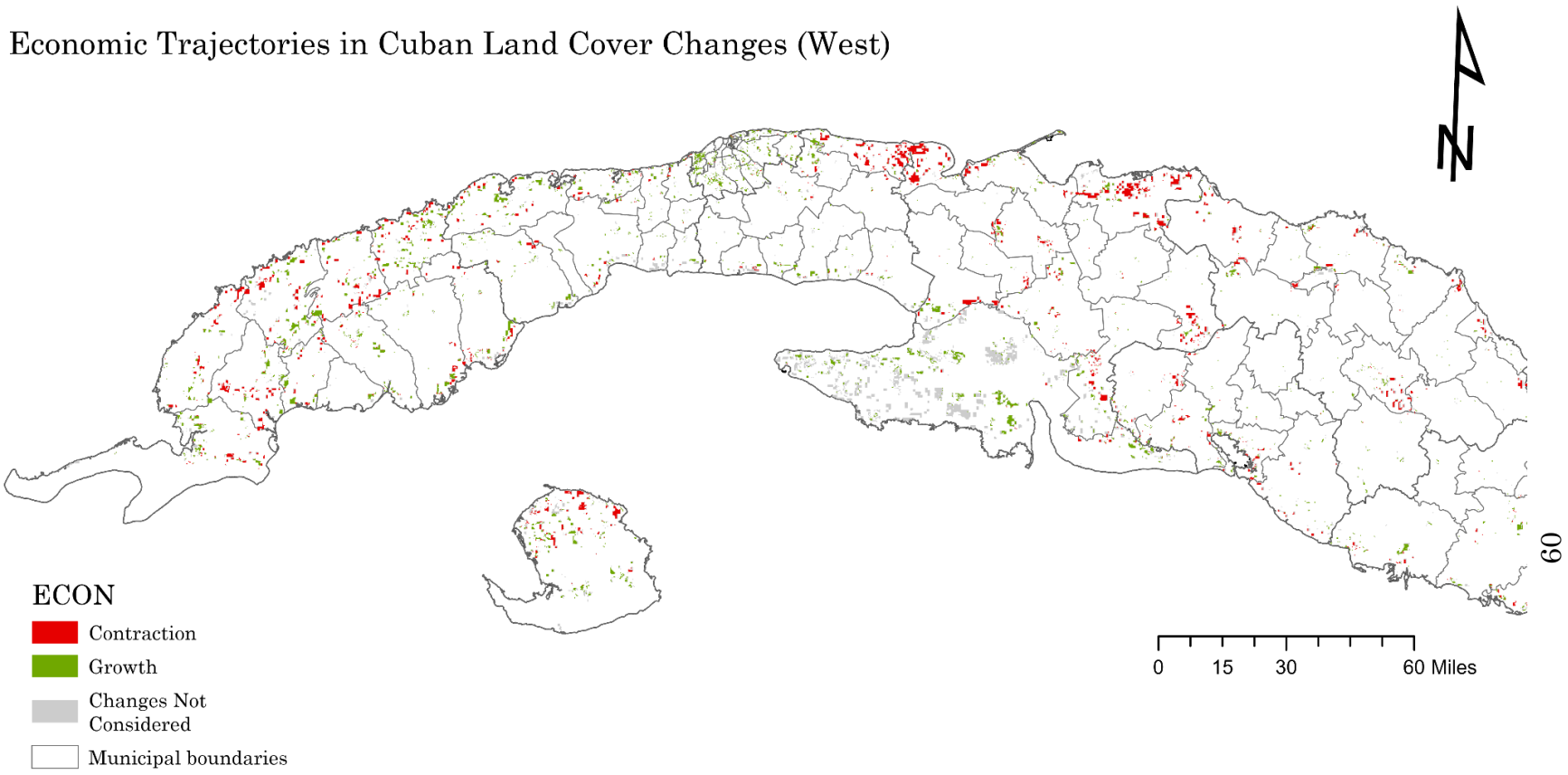

Figure 26 Economic trends in Land cover change in Western Cuba

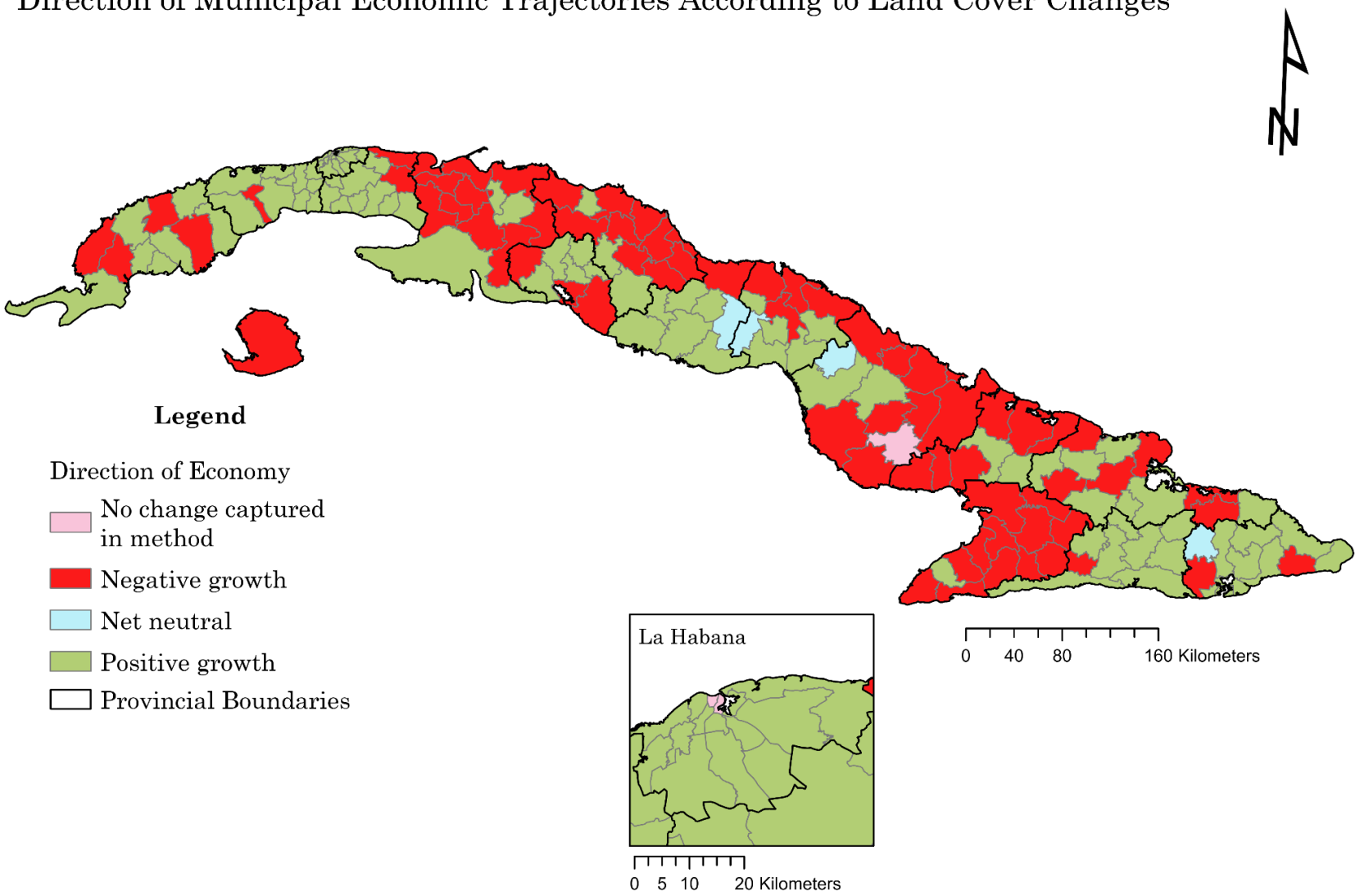

Figure 27 Net Changes to Economic Uses of Land Cover

Location of change

The locations of shifts in land cover can be seen in Table 6 & 7. Changes were aggregated to the provincial level to simplify their interpretations and because each of the 168 municipalities have their own particularities that are best explored in collaboration with Cuban Scholars. Moreover, Provincial trajectories are more readily described in publications about the country, while municipal stories are found in individualized publications. Immediately we can see the tumultuous time Havana has had; it is the primary source of both gains and losses in Urban land cover. Notably, the Eastern province of Santiago de Cuba and Central provinces of Camagüey and Holguin also suffered urban losses greater than 10% of the nation's total. Central provinces are also the primary sources of cropland loss with Granma, Camagüey, and Holguin beating Pinar del Rio to the top three positions. These provinces represent the top losers of any cropland cover and forest. This potentially signals they are some of the hardest hit areas by agricultural restructuring and had to resort to forestry as economic activities. Their names are also significant in the economic gains categories; this is potentially due to a shift in the location of activities to areas within the province that are better suited for low input activities. Matanzas was the source of most water loss and new forests. Most of the water loss happened in the Ciénega de Zapata and around reservoirs indicating a drought. There was also a fair amount of Forest increase in this area but also in the highlands adjacent to the town of Matanzas.

Table 7 Location of land cover changes that represent potential economic losses.

Province	Urban loss	Cropland loss	Forest loss	Grassland loss	Crop Intensity decrease	Intensity loss	Mosaic loss	Water loss
Guantanamo	2%	3%	3%	15%	6%	6%	3%	0%
Ciego de Avila	2%	5%	6%	12%	11%	2%	8%	0%
Mayabeque	3%	4%	1%	0%	1%	4%	4%	0%
Cienfuegos	3%	4%	0%	1%	3%	3%	2%	1%
Granma	3%	18%	0%	4%	14%	13%	12%	3%
Las Tunas	6%	4%	1%	2%	1%	2%	5%	0%
Pinar del Rio	6%	11%	12%	7%	9%	13%	12%	1%
Villa Clara	8%	4%	2%	5%	2%	2%	4%	0%
Matanzas	12%	8%	33%	8%	7%	8%	14%	88%
Camagüey	12%	13%	14%	18%	10%	14%	18%	2%
Santiago de Cuba	14%	5%	3%	5%	2%	6%	2%	2%
Holguin	14%	14%	16%	12%	14%	14%	11%	1%
Ciudad Habana	15%	1%	1%	0%	5%	3%	0%	
Artemisa	0%	3%	0%	0%	3%	3%	2%	0%
Isla de la Juventud	0%	0%	5%	7%	0%	0%	2%	3%
Sancti Spiritus	0%	4%	3%	4%	11%	6%	1%	0%

Table 8 Location of land cover changes that represent potential economic gains.

Province	Urban gain	Crop Intensity increase	Mosaic gain	New barren	New cropland	New grassland	New low intensity crop	New mosaic	New forest
Artemisa	0%	0%			0%		1%		
Isla de la Juventud	1%	0%			1%	14%	1%		4%
Artemisa	2%	2%	8%		8%	0%	6%	4%	1%
Ciudad Habana	28%	3%			2%	3%	4%		0%
Artemisa	5%	3%	2%		4%	0%	3%		5%
Guantanamo	4%	3%	13%	17%	4%	12%	19%	2%	6%
Mayabeque	4%	3%	2%		6%	1%	5%		3%
Las Tunas	2%	3%	5%		1%		1%		2%
Sancti Spiritus	2%	7%	16%		4%	2%	4%	11%	1%
Cienfuegos	4%	3%	2%		2%	1%	3%	2%	1%
Villa Clara	3%	3%	4%		1%	1%	2%	8%	1%
Ciego de Avila	3%	5%	2%		2%	14%	3%	8%	5%
Santiago de Cuba	8%	6%	2%	17%	10%	11%	5%	2%	4%
Matanzas	5%	6%		33%	3%	11%	5%	19%	35%
Pinar del Rio	6%	14%	29%		32%	3%	24%	8%	7%
Camagüey	5%	11%	5%		6%	15%	8%	4%	4%
Holguin	16%	12%	8%	17%	8%	12%	3%	34%	18%
Granma	3%	15%	3%	17%	8%	0%	3%		4%

Hotspot Moving Window Average

Figures 27 and 28 summarize the locations of concentrated changes to land cover on the island. A concentration of change is evident along the edges of the island and in the protected Ciénega de Zapata. The whisker plot shows that the largest magnitude of change in each region is usually found within a single province. In the West that province is Matanzas, and, in the East, it is Holguin. In the Central region Camagüey is the leader of change with Ciego de Ávila also experiencing a large amount of change.

Figure 28 Resulting hotspots of change in Cuba using a moving window average.

The history of development in Cuba is one of urban primacy that included the heads of provinces, and within each province is also a capital which historically held the area's sugar mills and was the end route of railroads bringing in the sugarcane harvest from the rural areas around it. We can see from the box-and-whisker plot in Figure 29 that provinces still show this concentration of development with a concentration of change in municipalities that have the provincial capital.

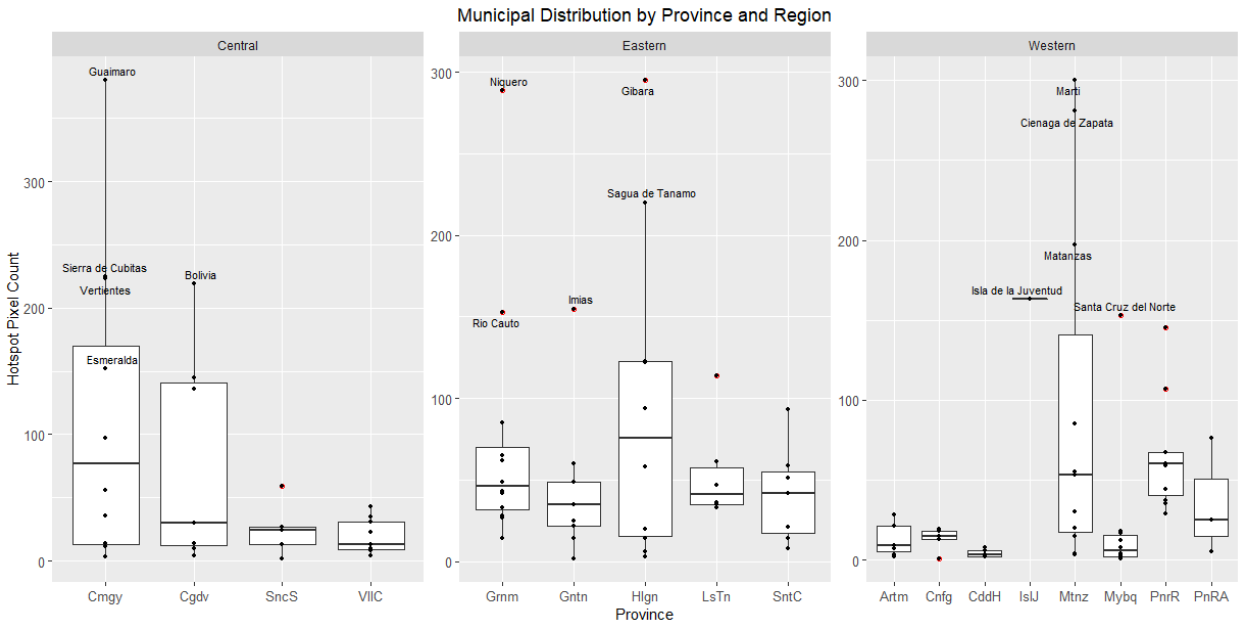

Figure 29 Boxplot analysis of Provincial primacy in hotspots of change across Cuban regions

Décroissance ou Décomposition (Discussion)

From 1992 to 2018 Cuba's land cover changed over 4.28% of its area (within the reduced boundary used for this study). Overall, the main drivers of land cover change on the island were of decreasing or location shifting of human activity. Loss of agriculture and regaining of vegetation can especially be seen along the North Coastal Plain zone where vertisols dominate. Despite the broadness of the ESA dataset, it is possible to see the evolution of Cuban landscapes as they adapted to the stressors of human exploitation. Areas that are hard to cultivate but had agricultural expansion during the Soviet period of industrialization, through the mechanization and chemically intensive methods of the Green Revolution, collapsed once intermediate products were no longer available.

In the case of tobacco, areas that produced higher value-added products did not suffer as much decline as those that focused on raw commodities. Vegetation shifts aside, the island experienced net economic growth (3,619 pixels of growth to 2,739 contraction) as reflected in land cover changes (see Figure 1 in Appendix). At a disaggregated municipal level, there are more municipalities with net losses than municipalities with net gains (see Figure 2 in Appendix).

The loss of agricultural land was concentrated in soil types that are poor for cultivation. The dominant direction of land cover change for these areas was revegetation. The greatest loss of cropland cover happened in the last 6 years of the

dataset after policies that more intensely restructured agriculture and sugarcane production. Most of these losses were concentrated in the Central region of the country, the primary production area of sugarcane.

As noted by Galford et al. 2018 Cuba's 8 largest watersheds have between 37% and 60% agricultural land cover.[118] While large sections of the Island are protected, protections are centralized along the coast, not distributed throughout the island. These protections are essential but limit conservation to areas most enjoyed by humans and are not necessarily the most impactful for water quality improvement. In some municipalities there is forest loss presented in large clusters. While there was a net gain in forest cover, the top three municipalities that suffered net losses were also in the Central region of the island. The island had a small amount of urbanization during this time span, less than 1,000 km^2. Despite efforts to distribute growth outside of Havana, the province that contains the Capital had the most growth in Urban pixels during the period 1992-2018.

Cuba experienced degrowth in the agricultural sector as it shifted away from sugarcane production and pulled back from areas that are not ideal for cultivation. There was a net gain in forest cover, but some municipalities likely turned to forestry when other industries were stagnating or shutting down. The nation's endeavor to become more self-sufficient while surviving an embargo by the U.S. prevented them from significant urban expansions. The classification system hints at medium and low intensity cropland features that would be especially relevant for measuring Cuban efforts to grow food locally and by small co-ops. No particular trend stood out from this analysis about the success or failure of these local food farms. These could be better evaluated with a dataset that delineated cooperative farms and State farms.

Conclusions

From this analysis, changes are evident in Cuban landscapes that reflect the economic restructuring that took place during the period of study (1992-2018). It is clear the country struggled to promote urban growth and abandoned large agricultural fields in less productive soils. In total, 4.28% of the area considered, see figure 14, experienced a change in landcover. This only includes single changes, as the methods describe. The primary change was in Mosaic Vegetation with less than 50% cropland, with almost a 2,000 km^2 decrease and Forests with a net increase of almost 1,000 km^2. The main driver of the change is likely succession of vegetation

[118] Galford et al., "Cuban Land Use and Conservation, from Rainforests to Coral Reefs."

and forests as previous crop fields were abandoned and a mix of deforestation in some areas and forest growth in others. There was almost twice as much growth in the Vegetation class as there was new urban growth. A modest net growth in cropland and grassland cover of around 500 km^2. This is reflective of the efforts to increase food production on the island. The highest intensity of Urban and Barren growth happened between 2012-2018. While most of the decrease in Mosaic Vegetation and Cropland happened between 1997-2007. The areas with the most loss in cropland were in the Central municipalities as well as in municipalities with a coastline. The losses appear to be prominent in areas with vertisols and gleysols that are difficult to cultivate without intermediary products.

Limitations – Terra Incognita

At this resolution it is difficult to spot low intensity agriculture and smaller plots with denser, more diverse covers used in the agroecology, which Cuba is known for. There is also no information captured in the dataset on fruit trees that supply the population with food. A lack of GIS data from the Cuban government makes it difficult to verify which regions have shifted away from growing sugarcane and which have lost production all together. For regional watershed health studies, knowing where non-State farms are operating would allow for an analysis of the difference in impact these two systems have on the surrounding landscapes. Additionally, having land cover maps of 1988-1991 might help us capture the initial loss in cropland immediately after access to intermediate goods started to decrease.

These limitations are evident by the lack of validation. A full validation was not performed as funding ran out for the researcher's time, to purchase high resolution images that would more clearly show ground conditions, or for extended collaborative visits to the island. A close reading of the island was not possible because of a lack of familiarity with its landscapes. Even though hours were spent observing satellite images and a few short pre-research visits took place. Doing a traditional to-from matrix to calculate error was made difficult by the lushness of Cuban landscapes and the lack of images from the limitations in functionality of the free to access Google Earth Pro. The software changes images as you zoom in, attempting to offer you the best resolution but this changes the year the image can be seen at. At resolutions available, it is also difficult to distinguish a productive grassland from a successional one with no human use. Validation sets would be much better constructed by locals who want to contribute to a narrative and have a use for the studies.

Despite the lack of validation in this study we must consider that this is the only land cover dataset of its kind. It is readily used by researchers around the world to

persuade policymakers to make decisions, regardless of errors. The ESA dataset has a known error of around 30% which is acceptable by researchers who use it and policy makers who make choices based on it. After many attempts to begin the change error matrix process of tagging hundreds of points it became clear that the validation was hopeful at best. Free images across time were not of sufficient quality to confidently determine land cover. Furthermore, the U.S. embargo made it impossible for a lone doctoral student to find funding to travel to Cuba and make more assertive determinations of land cover at random points. This is a clear sign that research that heavily depends on satellite images must be in collaboration with people on the ground. It is clear that ground-up researchers are at a severe disadvantage from mainstream or corporately funded satellite researchers that push hegemonic agendas. In a similar vein, self-funded doctoral candidates are at a disadvantage when held to the same standards as researchers with budgets from well-funded institutions.

Future Studies

Globally there is a need for consistent production of finer scale datasets to meet global climate change adaptation goals and assess equity. They would help us monitor watershed health by tracking changes that impact water quality or large land cover changes that could lead to erosion and loss of biodiversity. Better public datasets would also help us more adequately identify human specific problems like food insecurity, war, or tax evasion. This analysis showed a decrease in surface water, such an indicator could be important for preventing crises that arise from droughts by allowing international agencies and countries to collaborate in monitoring the situation and begin response planning early on. ESA imagery resolution is high enough that local areas of concentrated change can be detected, as well as the direction those changes took in terms of economic development. To really understand the processes behind changes that result from local management of land, ancillary information and a greater amount of contextual information is necessary. This dataset holds promise in its ability to be combined with local expertise for intranational monitoring and evaluation of economic transitions. To further evaluate a change in sustainability after economic restructuring, this dataset could be used in future studies to measure changes at the watershed unit and to calculate landscape metrics. The impact of such studies would be greater if they were done in collaboration with local stakeholders.

2. Crisis Response: Development trajectories in nighttime lights of Cuba

Since 1959, the revolutionary government of Cuba made rural development a priority in an effort to build a more egalitarian society. Starting with Spanish colonization, Cuba's development schema was one of rural exploitation and urban primacy. The Special Period at a Time of Peace, triggered by the collapse of the Soviet Union, has been the most challenging economic moment for the island in the 20th century. Leveraging the free global nighttime light dataset DMSP-OLS (hereafter NTL), this study investigates their ability to capture economic instability and recovery of urbanized spaces on the island. GDP and energy output and consumption are not stable in Cuba and the trajectories of NTL show moments of decline on the island. The deterioration of some areas of Havana is observed in this time series. We are also able to observe efforts by the government to distribute energy infrastructure to rural areas. While working with limited resources there were localized improvements to the distribution of light. Based on trajectories of NTL, there is clearly developmental differentiation between regions on the island.

Thesis Q: What are the main development trajectories captured in the DMSP-OLS NTL dataset in Cuba from 1992-2013?

- What clusters of NTL trajectories are in Cuba?
- What years saw the most changes in NTL?
- Was the distribution of light equitable to the resident population?

Introduction

Unsupervised classification in computation social sciences gives us a guide to use grounded theory in landscape semiotics. Nelson's usage of inductive data-driven unsupervised learning to understand the social world has been mostly applied to analyzing text created by people.[119] The advantages of unsupervised classification in computational social sciences are combining the human ability to interpret computationally derived patterns with human knowledge of processes that tend to create those patterns. Her research inspired the approach to this nighttime lights analysis aiming to investigate development patterns in Cuba. Nighttime lights are not a natural phenomenon; as such, they intrinsically represent a complex social phenomenon. As in Nelson's work with grounded theory and text analysis, this research applies computational methods to read semiotic themes (patterns) in

[119] Laura K. Nelson, "Computational Grounded Theory: A Methodological Framework," *Sociological Methods & Research* 49, no. 1 (February 1, 2020): 3–42, https://doi.org/10.1177/0049124117729703.

Cuban landscapes at night in relation to land use and socioeconomic changes during the study period.

Applications of Night-Time Lights

Use of satellite images in economic growth studies is common. Results from studies with access to ancillary data with more robust validation schema can provide a guide to using remotely sensed datasets. Trajectories for Cuban night lights are derived from the radiance calibrated Version 4 DMSP-OLS Nighttime Lights Time Series (NTL) 1992-2013 data using unsupervised clustering. The results are then interpreted through knowledge of Cuban political and economic history. The distribution of NTL within the population of Cuba is also calculated overtime to investigate Cuba's egalitarian development schema.

There are a number of studies that helped understand and interpret NTL in Cuba. Zhou et al looked at global urban dynamics using NTL data to delineate urban boundaries over time. The study found that developing countries experienced more growth than developed countries from 1992-2013.[120] One key issue in defining urban extent is thresholding the intensity of development that is considered "urban". Variability in definitions lead to a range in estimated global urbanization of 0.45% to 3% of Earth's land.[121] The dataset is susceptible to light "blooming" outside of developed areas, falsely suggesting presence of nighttime activity in undeveloped areas, and it is convention to filter out these pixels. This sets up a need for a method to select light only coming from known developed areas.

There is an added challenge in time series when it is expected the developed area will change (likely grow) over time. Measures of rural electrification in more remote places show a significant output of lights from the presence of streetlights more than household electricity use.[122] The study also remarks that the noise removal, cleaning, methods used on the datasets can eliminate ephemeral light output that is likely to occur in areas with erratic power supplies. This is a relevant consideration to studying Cuba, who has had unstable energy supplies and frequent blackouts.

When local human development (wealth, health, and education) data is available, NTL has been shown to be a 'good' proxy for human development at the local level. With a substantial portion of variability in human development between locations

[120] Yuyu Zhou et al., "A Global Record of Annual Urban Dynamics (1992–2013) from Nighttime Lights," *Remote Sensing of Environment* 219 (December 2018): 206–20, https://doi.org/10.1016/j.rse.2018.10.015.
[121] Zhifeng Liu et al., "How Much of the World's Land Has Been Urbanized, Really? A Hierarchical Framework for Avoiding Confusion," *Landscape Ecology* 29, no. 5 (May 1, 2014): 763–71, https://doi.org/10.1007/s10980-014-0034-y.
[122] Brian Min et al., "Detection of Rural Electrification in Africa Using DMSP-OLS Night Lights Imagery," *International Journal of Remote Sensing* 34, no. 22 (November 20, 2013): 8118–41, https://doi.org/10.1080/01431161.2013.833358.

explained by NTL.[123] While NTL studies can show a relationship between lights and human activity, they are limited in the amount of social complexity they can explain. A 2015 study on Sweden with detailed local data found NTL as a useful proxy for economic activity and density of population but not as closely related to wages.[124] Comparing percent change in NTL and the relationship between the (log) sum of stable lights and GDP by state in India, the Rehman study showed that changes in NTL can be used as a stand-in for economic growth and urbanization.[125] The paper showed variability between states that could be explained by differences in regional development.

A previous study calculated the national level Night Light Development Index (NLDI) for the globe in 2006, quantifying the distribution of human development.[126] Like the Lorenze curve, a value of 0 indicated a perfect equal distribution of light, while a score closer to 1 described more intense inequality. In Elvidge 2012, the national score for Cuba (0.801556) was higher than (among others) Jamaica (0.699792), Venezuela (0.758668), China (0.790197), Spain (0.711576) or the United States (0.542142). While this study gives a global overview, intra-national differences are not explored. A study used Elvidge's NLDI to assess the potential for measuring regional differences in NTL distribution between counties in Romania.[127] As noted in the paper, the United Nation's Sustainable Development Goal 10 asks for the reduction in inequality within and among States. The former is harder to track globally because of differences in data collection by individual governments. In these cases, satellite data becomes a potential source of information about what is happening within national boundaries. The study was able to utilize local tax income and GDP, data that is not readily available for Cuban municipalities. The study showed that in Romania, NLDI is regionally correlated to income and could be used to monitor progress on SDG 10. The Sustainable Development Goals attempt to bring light to the necessity of equity in the operationalization of climate change adaptation strategies.

Grounding Cuban Lights

Soviet style development dominated Cuban politics since the 1960 Bilateral Trade and Clearing Agreement and extension of Most Favored Nation tariff designation by

[123] Anna Bruederle and Roland Hodler, "Nighttime Lights as a Proxy for Human Development at the Local Level," *PLoS ONE* 13, no. 9 (September 5, 2018), https://doi.org/10.1371/journal.pone.0202231.
[124] Charlotta Mellander et al., "Night-Time Light Data: A Good Proxy Measure for Economic Activity?," ed. Guy J-P. Schumann, *PLOS ONE* 10, no. 10 (October 23, 2015): e0139779, https://doi.org/10.1371/journal.pone.0139779.
[125] Sami Rehman et al., "Spatio-Temporal Variations in Night Lights, Economy and Night Light Emissions in States of India," *Journal of the Indian Society of Remote Sensing*, 2021, 1–11.
[126] Christopher D. Elvidge et al., "The Night Light Development Index (NLDI): A Spatially Explicit Measure of Human Development from Satellite Data," *Social Geography* 7, no. 1 (2012): 23–35.
[127] Kinga Ivan et al., "Potential of Night-Time Lights to Measure Regional Inequality," *Remote Sensing* 12, no. 1 (2020): 33.

the USSR.[128] Favorable trade policies with the USSR further strained U.S.-Cuba relations as the island became increasingly dependent on Soviet terms of trade. These terms furthered Cuba's path dependence on sugar production and status as a developing nation primarily focused on producing raw goods. This dependence on sugar and Soviet trade would prove to be the most challenging factor when adapting to the collapse of the USSR. In the last three decades Cuba had to adapt to waves of economic instability without stable major trade partners. The nation managed a 68% reduction in the dependance on a primary trade partner between 1958 (the U.S. commanded 62%) and 2008 (USSR had 72% in 1987) with Venezuela now accounting for at least 20% of trade.[129] The economic crisis, named the Special Period at a Time of Peace, created a scarcity of resources and restructuring of rural production that pushed some people back into cities. Urbanization of land has been slow. Without much capital to purchase or produce construction materials, infrastructure has been left needing major repairs and expansions. This is especially evident in areas damaged by natural disasters.

There is a history of regional inequality on the island, disfavoring the East and rural areas, and of Urban Primacy in the capital city.[130] The State has the goal of creating an egalitarian society, thus any inequalities in NTL would be signs of challenges to their efforts. In 2006 an energy revolution was started by the government to specifically target infrastructure development in remote regions with small-scale, decentralized, energy systems. These programs were paired with replacing fluorescent tubes in State institutions, replacing inefficient pumps used in water systems, other electronic devices like refrigerators, changing household energy prices to increasing block rates, and educating citizens on the complexities of energy issues the country faces as well as how to use energy responsibly. From visits to the cities of Havana, Trinidad, Matanzas, and Pinar del Río I observed a low density of streetlights. Lighting was effective enough to help see but not overwhelmingly bright and much dimmer than Bay Area streets. This did not impact my feeling of safety as it is well known that Cuba is one of the safest countries in the Global South.

The primary sources of energy on the island, as reported in 2015, are liquid fossil fuels (81.5%) and natural gas (14.54%). Renewable energy sources are biomass (3.46%), which are closely linked to sugar production, hydropower (0.24%) and

[128] Lawrence H. Theriot and JeNelle Matheson, "Soviet Economic Relations with the Non-European CMEA: Cuba, Vietnam, and Mongolia," *Soviet and Eastern European Foreign Trade* 21, no. 1/2/3 (1985): 144.
[129] Carmelo Mesa-Lago, "Economic and Social Balance of 50 Years of Cuban Revolution," *Annual Proceedings* 19 (2009), https://econpapers.repec.org/article/qbaannpro/v_3a19_3ay_3a2009_3aid_3a830.htm.
[130] Jorge I. Domínguez, "National Institutions, Spatial Differentiation and Race: Variation in Cuba's Political Regime," *International Journal of Cuban Studies*, July 1, 2021, https://doi.org/10.13169/intejcubastud.13.1.0086.

wind/photovoltaic (0.25%). While wind production is low relative to total energy sources, Cuba ranked 58 in world wind power capacity rankings in 2015.

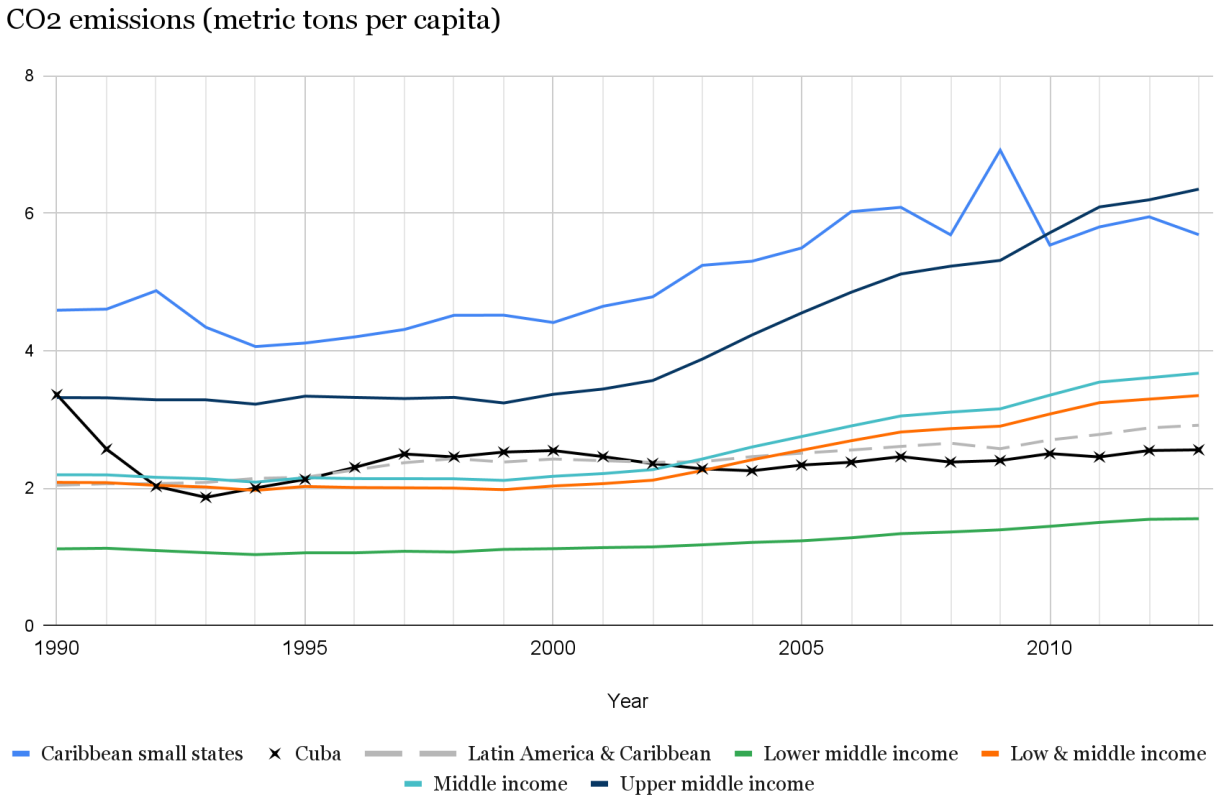

Figure 30 Comparison of CO2 emissions by Cuba and others.

Because of their efforts to decentralize the vulnerable national grid and attend to the needs of the rural population, almost 25.6% of power generated is from small-scale decentralized generation.[131] Cuba's CO2 emissions over this time are distinct from other middle-income countries and the Caribbean small states, matching the trend at a slightly lower intensity as LAC annual averages see Figure 30 above. Though Cuba has an aging energy infrastructure that burns fossil fuels, per capita emissions are significantly less than upper middle-income countries. This is likely due to both the national education programs on lowering energy consumption and scarcity of electric devices as well as automobiles. Emissions estimates for small Caribbean states are higher than upper middle-income countries; this is potentially related to the tourism industry these countries depend on, in conjunction with aging, fossil fuel based, energy infrastructure.

During the 2007-2009 Global Financial Crisis the world experienced a 4%-7.5% decline in GDP. With "advanced economies" experiencing the upper limit and

[131] Mario Alberto Arrastía-Avila and Lisa M. Glidden, "Cuba's Energy Revolution and 2030 Policy Goals: More Penetration of Renewable Energy in Electricity Generation," *International Journal of Cuban Studies* 9, no. 1 (2017): 73, https://doi.org/10.13169/intejcubastud.9.1.0073.

"emerging and developing countries" the lower; tourism in the Americas dropped an estimated 5%.[132] The majority of the Caribbean economy suffered negative growth during this time, with additional drops in the amount of remittances coming in, which are an important aspect of the Cuban economy.[133] Unemployment rates, especially those related to the tourism sector, also rose around the Caribbean, impacting younger generations the most.[134] The region is independent on tourism for between 7% and 90% of GDP.[135] The Caribbean dependence of Foreign Direct Investment and trade on hard-hit higher income countries tied up the LAC in the Global Financial Crisis of 2009. In Cuba the crisis prompted austerity measures that reduced government spending and cut food and electricity rations.[136] Like other LAC countries, the financial sector did not reflect the crisis as much as the general economy did through a decline in FDI, remittances, Tourism, commodity prices, and export destinations.[137] While not covered in this study, the COVID-19 crisis has been detrimental to LAC economies.[138] Cuba likely suffered an economic downturn during the pandemic despite having a burgeoning medical industry.

Tropical storms common in the Caribbean cause billions of dollars in damage to energy systems. Blackouts caused by damaged infrastructure from large storms were particularly bad on the island until decentralization efforts allowed for better consistency in power generation, fewer disruptions throughout the island, and faster recovery after storms. The literature highlighted 2005 and 2008 as particularly bad years for energy distribution due to storm damage.[139] The government highlighted efforts in upgrading their energy systems in 2006 with specific energy related goals after an early 2000's drop in sugar prices led to a decrease in biomass production. That year the State installed dispersed generation units in 110 of their municipalities. The distributed generators and micro-grids are cheaper to install than large power plants, making it a more feasible option for the cash strapped nation.

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[132] Andreas Papatheodorou, Jaume Rosselló, and Honggen Xiao, "Global Economic Crisis and Tourism: Consequences and Perspectives," *Journal of Travel Research* 49, no. 1 (February 1, 2010): 39–45, https://doi.org/10.1177/0047287509355327.
[133] Auguste Kouame and Maria Ivanova Reyes, "The Caribbean Region beyond the 2008-09 Global Financial Crisis," in *Documento Presentado En La Conferencia "Options for the Caribbean after the Global Financial Crisis", Bridgetown*, 2011, 27–28.
[134] Inci Ötker-Robe and Anca Maria Podpiera, *The Social Impact of Financial Crises: Evidence from the Global Financial Crisis*, Policy Research Working Papers (The World Bank, 2013), https://doi.org/10.1596/1813-9450-6703.
[135] Krishna Srinivasan et al., *Unleashing Growth and Strengthening Resilience in the Caribbean* (International Monetary Fund, 2017).
[136] Lorenzo Pérez, "The Impact of the Global Financial and Economic Crisis on Cuba," in *Annual Proceedings*, vol. 19 (The Association for the Study of the Cuban Economy, 2009).
[137] Carmelo Mesa-Lago and Pavel Vidal-Alejandro, "The Impact of the Global Crisis on Cuba's Economy and Social Welfare," *Journal of Latin American Studies* 42, no. 4 (November 2010): 689–717, https://doi.org/10.1017/S0022216X10001331.
[138] Henry Mooney and Maria Zegarra, *Extreme Outlier: The Pandemic's Unprecedented Shock to Tourism in Latin America and the Caribbean*, 2020, https://doi.org/10.18235/0002470.
[139] Nicholas Newman, "Cuba's Power Struggle [Power Cuba]," *Engineering & Technology* 4, no. 16 (2009): 51–53.

Cuban Population Dynamics

Existing literature shows that population densities are correlated with NTL. Population estimates for Cuba are not made readily available by the government through workable datasets. National estimates are available from the World Bank and United States Central Intelligence Agency (CIA).[140] For less aggregate estimates, the raster formatted LandScan is available from the Oak Ridge National Laboratory but with a limited temporal resolution. The datasets were compared to show that LandScan successfully demonstrates general population trends on the Island. Figure 31 below shows a decrease by 2010 in all three datasets.

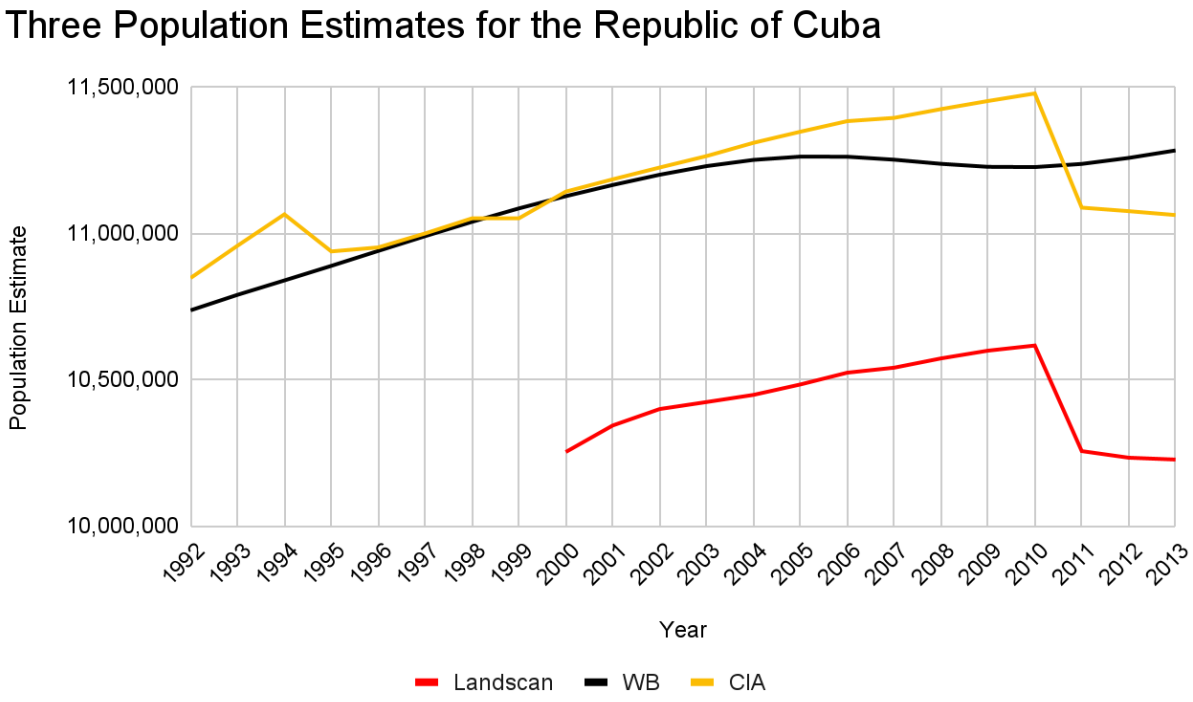

Figure 31 Variation in population estimates of Cuba with similar trends.

There is the potential for shifting populations in Cuba because of changes in productive activities, some moving out of rural areas into urban ones when sugar mills closed (refer to chapter 1). The Cuban government controls internal migration to a degree through location specific work permits, housing allocation, and resource rationing system.[141] In contrast to most LAC countries Cuba had the lowest population growth in its capital city. Perez attributes this in part to the lowering of pull and push factors citizens experience that incentivize urban living. Notably,

[140] Central Intelligence Agency, "The World Factbook 2014-2015"; World Bank Group Archives, "World Development Indicators (WDI)."
[141] Lisandro Perez, "Internal Migration in Latin America: The Contrasting Cases of Colombia and Cuba," *Sociology in Latin America*, 1994, 191.

there was also a 1997 policy requiring authorization from property owners and certification from building inspectors to move to Havana. As a result, Cuba had among the lowest numbers of migration between administrative units in the LAC.[142] There is a noted influx of Eastern Cubans migrating to Havana during the peak of the Special Period.[143] Although the revolutionary government of Cuba did not perform a national census until 1970, it has been collecting data on internal migration since 1964. Blet 2020 provides a detailed look at rural population dynamics on the island. While considering the differences in government definitions of rural overtime, Blet calculated that the percent urban population overtook the rural one in 1996. While the crisis population trends show the desire to shelter in cities, his analysis also shows the efforts of the Cuban government to strengthen the agricultural sector. He also found a recent, 2001-2006, growth in rural populations and a leveling off of changes since the 1991 crisis strategy to survive the economic collapse and food insecurity by producing their own food stuffs.[144] Overall he found crude birth rates to drop from ~2.1% to 1%. While the CIA methods for estimating population are unknown and are aggregated to the national level, the long-term trends match what is in the literature and the LandScan dataset, which depicts intranational data, matches the CIA trends, See Figure 32 below. The World Bank and LandScan datasets do not use NTL as a population modeling input.

[142] Aude Bernard et al., "Comparing Internal Migration across the Countries of Latin America: A Multidimensional Approach," *PLOS ONE* 12, no. 3 (March 22, 2017): e0173895, https://doi.org/10.1371/journal.pone.0173895.
[143] Benigno E. Aguirre, "Social Control in Cuba," *Latin American Politics and Society* 44, no. 2 (ed 2002): 67–98, https://doi.org/10.1111/j.1548-2456.2002.tb00206.x.
[144] Arnoldo Oliveros Blet, "La población rural en Cuba: cambios cuantitativos en el período 1990-2006.," 2010, 163.

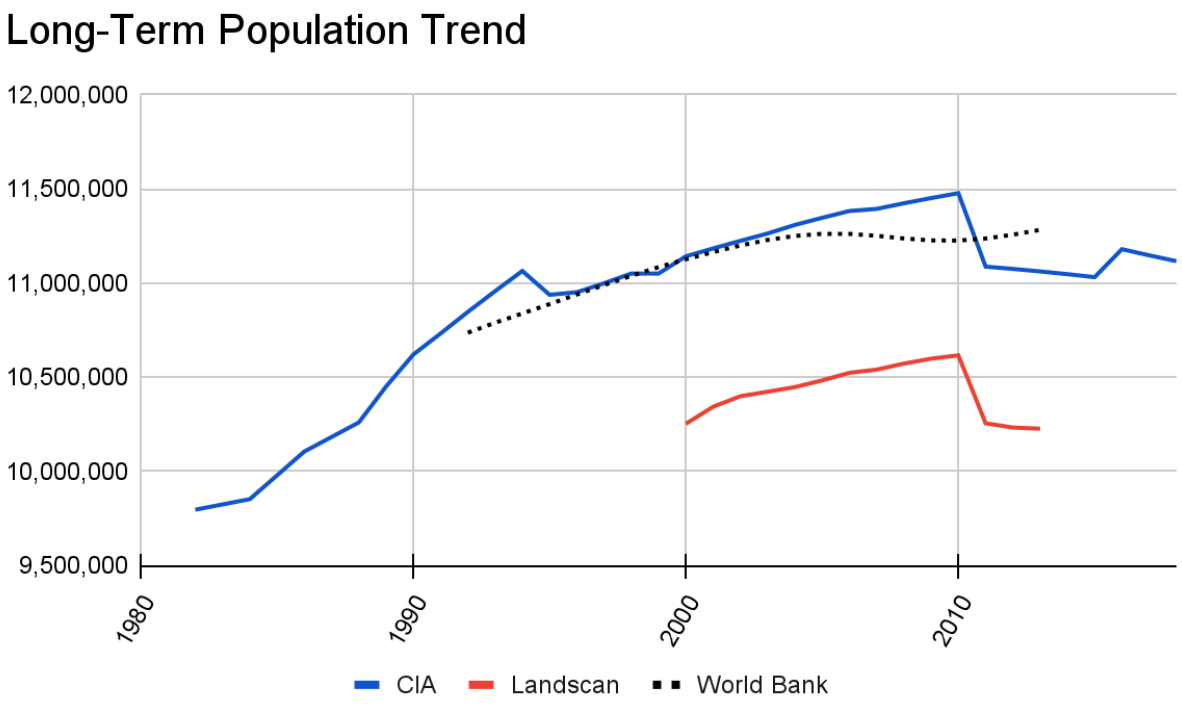

Figure 32 Extended temporal resolution on Cuban population estimates

The long-term CIA trend also shows the decrease in population in the middle of the crisis that was likely due to emigration. The World Bank estimates appear to be a smoothed trend, which is why it is more difficult to see the 2010 drop. Like the literature has noted, birth rates are low in Cuba and have impacted the national growth rate. As can be observed in Figure 33 below, CIA growth rate estimates reflect known crises on the island, especially after 2010 when values are negative.

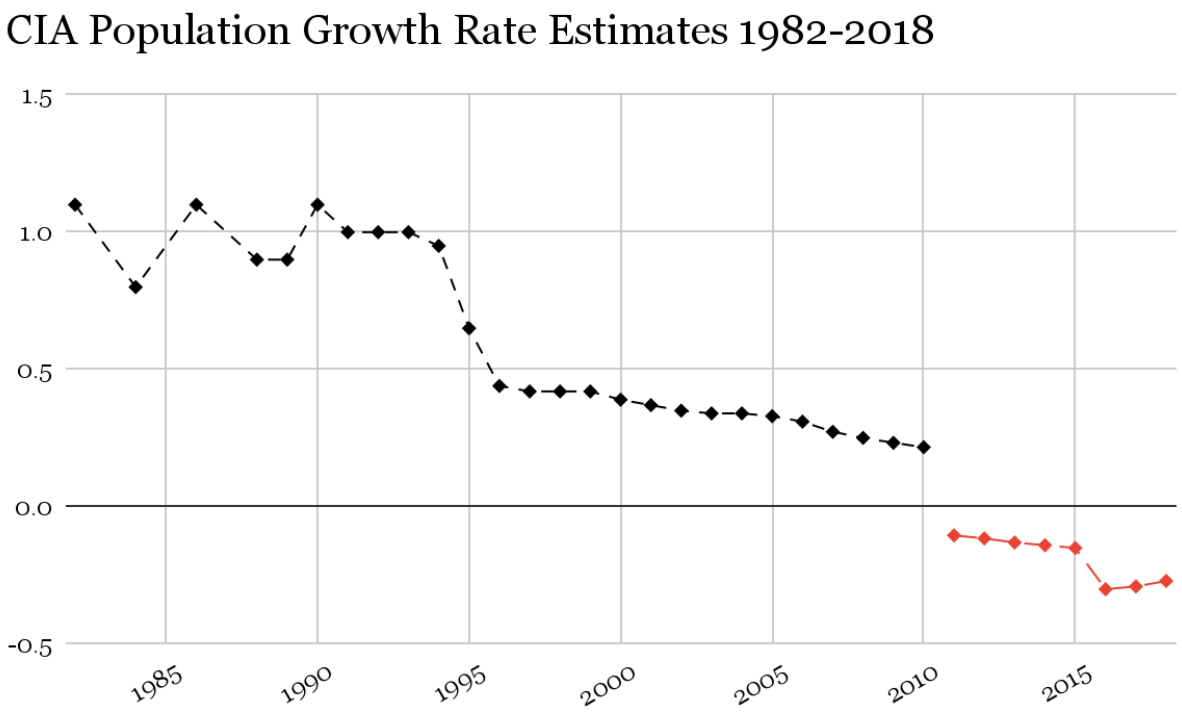

Figure 33 Growth rate estimates by the CIA of the Cuban Population. The red indicates a negative value.

The World Bank estimates an increase of 5% in the Cuban population between 1992 and 2013. The LandScan dataset consistently underestimated the population by comparison. Capturing a decrease of 0.25%. The WB dataset has 600,00+ to over a million more people between 2000 and 2013. Changes in population and NTL captured in these two datasets between 2000 and 2013. During the same time period the LandScan dataset captured these general trends in population change, see Figure 34 below. We can see that LandScan reported much higher changes in certain years.

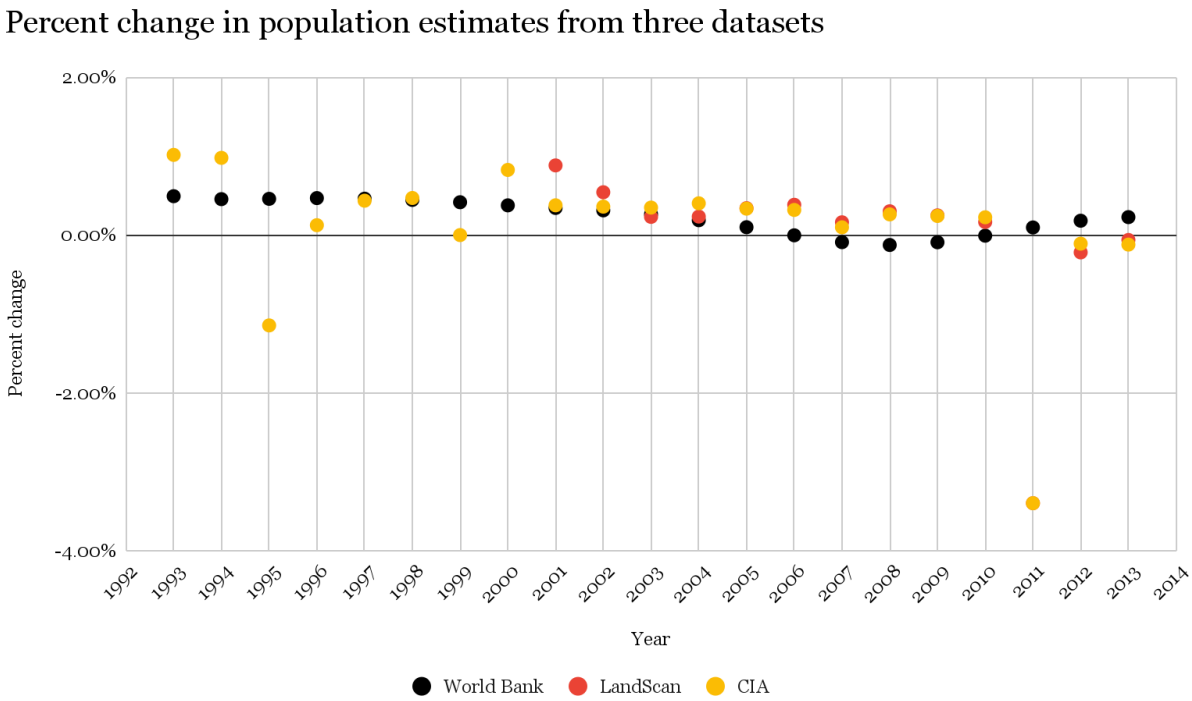

Figure 34 Normalized comparison of changes in the Cuban population between datasets. There was no significant difference found between the datasets when using a T-test.

By regressing total population and national sum of lights from 2000-2013 we can see the relationship between the two over time. Figure 35 & 36 below compares regression results using LandScan or World Bank population estimates. We expect a positive relationship, more people, more light emitted. The LandScan population estimates had greater interannual changes in some years than NTL, this is reflected in the low r-squared and slightly negative trend. The smoothed WB population fits nicely in this pattern, with some clustering of higher end values, meaning NTL emitted does not change much relative to population increases. This could signal they met a certain capacity to produce NTL.

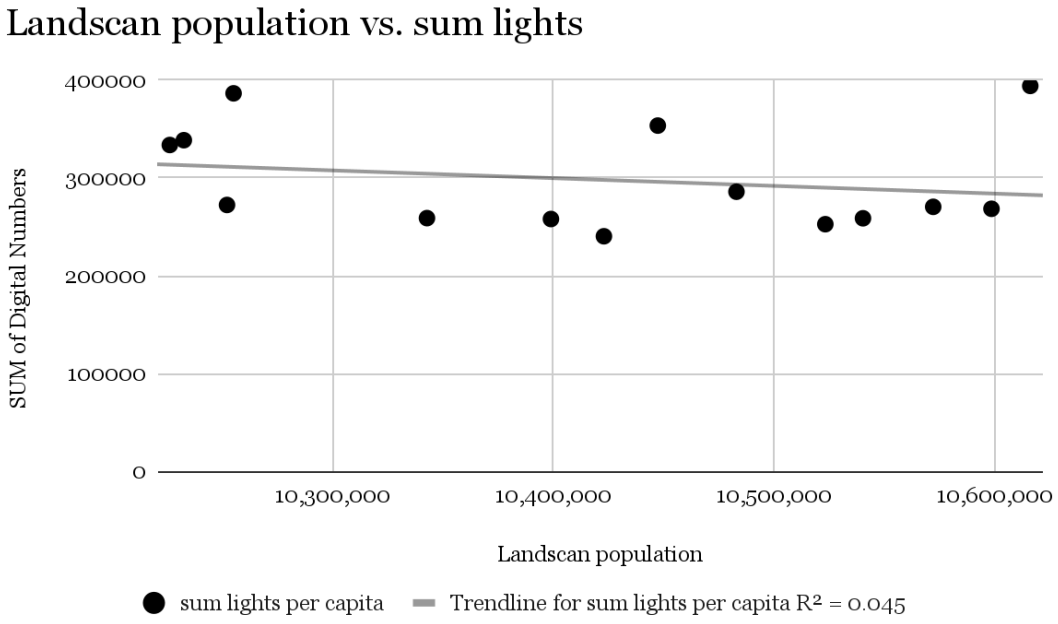

Figure 35 Relationship between sum of NTL and LandScan population estimates over time. P-value is not significant and indicates a lack of correlation between the LandScan population and sum of lights over time.

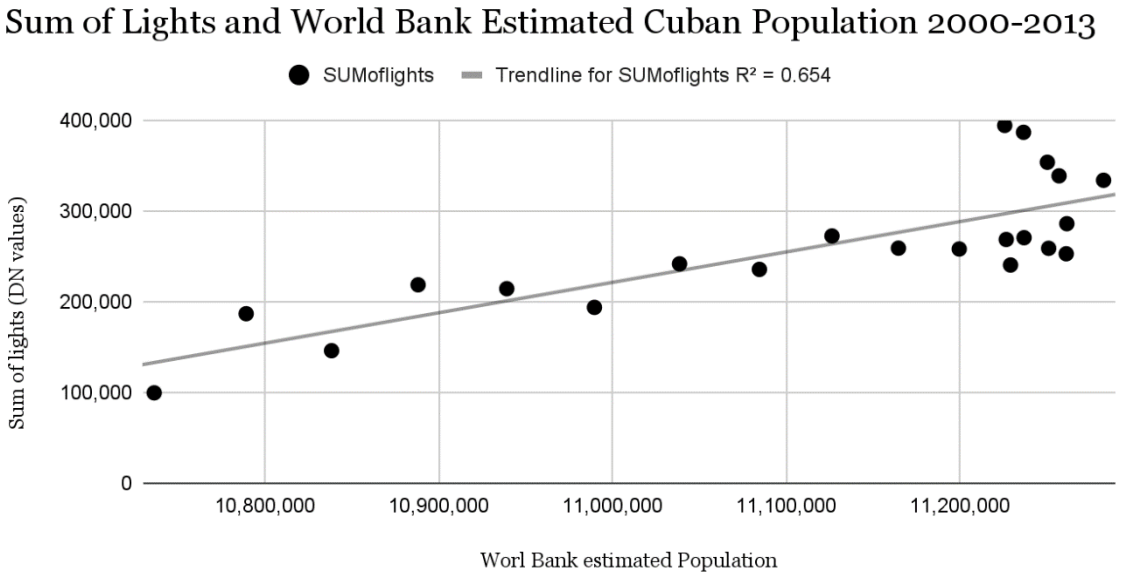

Figure 36 Relationship between sum of NTL and World Bank Population estimates over time. P-value is less than 0.01 indicating a correlation between both datasets.

Figure 36 shows a much closer fit between the national sum of lights and the WB population estimates. This is likely because WB estimates have gone through a smoothing process and are not raw numbers.
While the LandScan estimates show a smaller relationship to sum of lights, their availability in raster format allows for municipal population estimates to be calculated. From 1992 to 2013 Co2 emission increased by 26%. Night lights from DMSP-OLS do not explain the majority of CO2 emissions estimated by the World Bank over this time period, See Figure 37 below. Since most of Cuba's energy is fossil fuel based, we would expect a higher correlation. This could be due to a large fraction of energy consumption occurring for economic activities of the daytime.

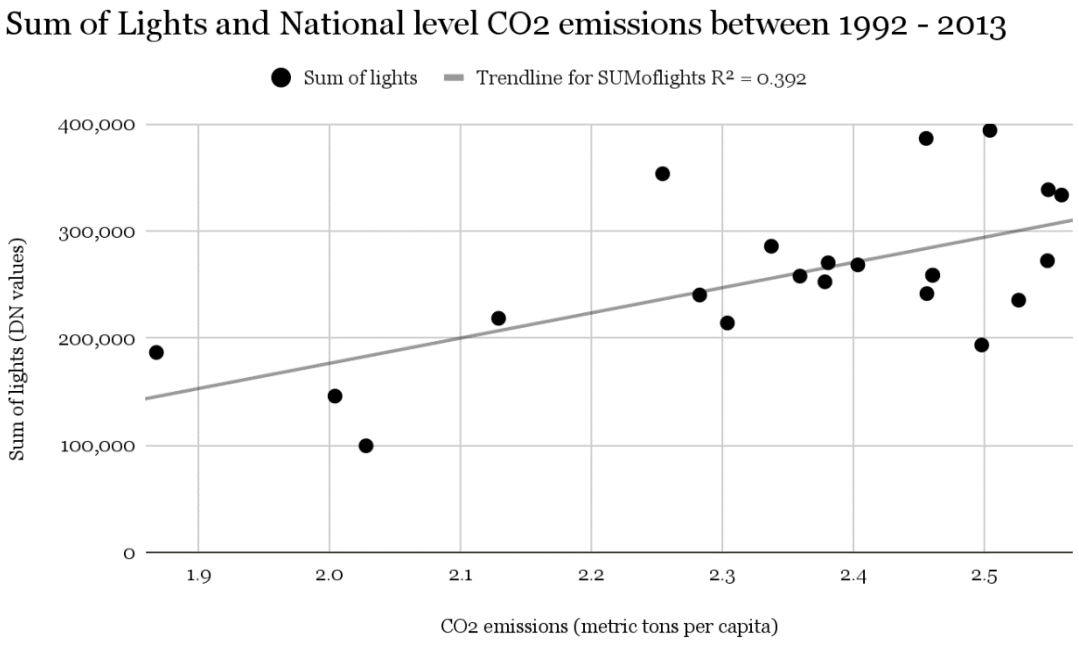

Figure 37 Relationship between national sum of lights and CO2 emissions in Cuba. P-value is 0.0018 indicating a correlation between the datasets over time.

Methods

This chapter explores univariate time series analysis methods of numerical variables using the DMSP-OLS night-time lights Digital Number. This quantitative measurement is used to describe the economic unfolding and rearranging that occurred in Cuba during the Special Period. Interpreting development trajectories from nighttime lights data in Cuba will be done in two parts. The first part uses a time series clustering analysis of the digital number trajectories in each pixel to capture patterns of trends in light growth or decline across the island. The second is

Lorenz curve to calculate the Night Light Development Index (NLDI), a distribution of light per capita on the island, to better understand electrification equity on the island, as captured in this particular dataset analysis.[145]

Construct 4 Construct[146] (Datasets used)

All datasets are run through an ArcMap 10.7.1 model builder which clips data to the same reduced boundary as in chapter one (Figure 12) and to the same projection, Lambert Azimuthal Equal Area with a central meridian at -76.00000000 and Latitude of origin at 16.00000000. This projection is used by the Nature Conservancy for Caribbean datasets. The spatial resolution from GHS and LandScan was downloaded at 1 km to match the DMSP-OLS dataset. Both datasets were resampled in ArcMap to match grids with the NTL dataset using the Mask too. This was the only method in ArcMap that successfully matched grids.

Global Human Settlement Report

Global Human Settlement report data was used as a mask to get an idea of the range of Digital Numbers (DN) that are represented on 'known' developed or urbanized land in Cuba.[147] This dataset was created through funding by the European Union through the European Commission, after a 2003 directive to re-use public sector data. The website is managed by the Joint Research Centre and is updated regularly with new models and data updates. The updates often help with accuracy but add to the confusing language about what data is available, how to download it, and which version is more accurate in rural areas. The creators of the data used Sentinel2 and Landsat data to estimate built up area from 1975 to present and predict it into 2030. The data was downloaded at a spatial resolution of 1km, to match the other datasets. Not all areas potentially inhabited by people are marked on this map. Isolated people living far from town in small houses surrounded by natural vegetation or agriculture could easily be missed by the satellites used to map land cover. This is observable when looking at the NTL, GHS, and LandScan rasters in unison. Additional erasures of settlement occurred during initial data processing. Using the Extract by Attributes tool pixels with a built-up area of less than 5,000 m2 were removed from the data that is used to extract NTL values for analysis. After exploring the data this was determined to be the most compatible threshold for extracting NTL data from location that could easily be

[145] Elvidge et al., "The Night Light Development Index (NLDI)."
[146] This is a self-identified Queer of Color critique of the idea that data is unbiased and reflects truth. In the queer lexicon it is common to communicate a preference for certain identities with the number 4, as in 'for'. Examples of this are T4T (trans for trans), Femme4Femme, or Vers4Vers. The constructs being referred to here are unbiased datasets and statistically significant, yet reductive, models of reality.
[147] Martino Pesaresi, "GHS Built-up Surface Grid, Derived from Sentinel2 Composite and Landsat, Multitemporal (1975-2030)" (European Commission, Joint Research Centre (JRC), 2022), https://doi.org/10.2905/D07D81B4-7680-4D28-B896-583745C27085.

confirmed from Base map imagery.[148] Figure 38 below shows this phenomenon. The main town of Ciro Rendon is represented in GHS data but nearby lower density built-up areas are not.

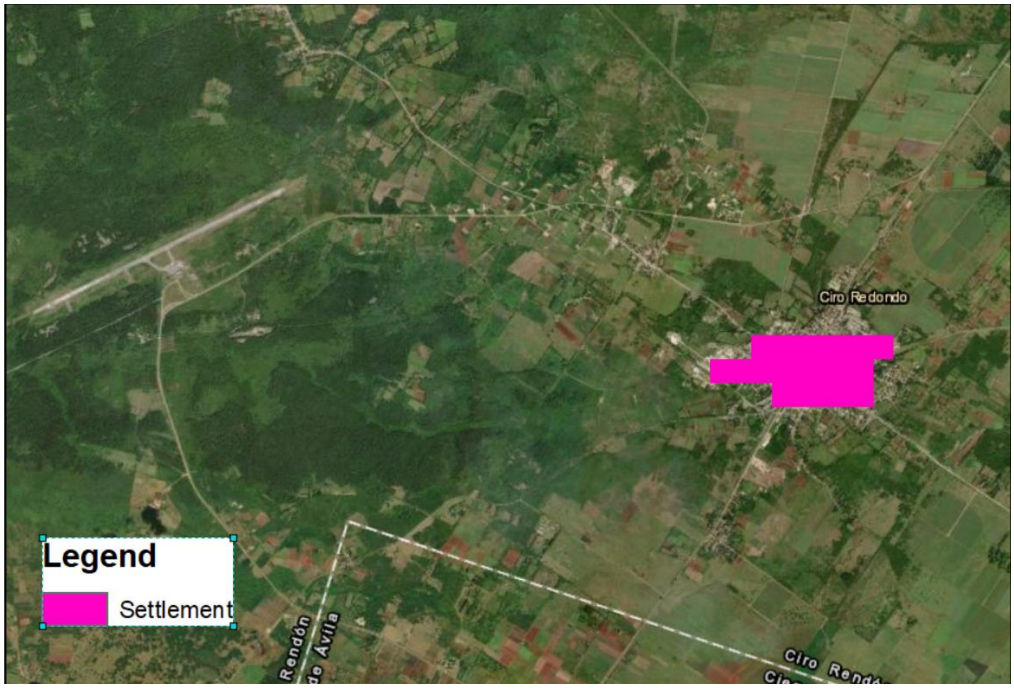

Figure 38 Town of Ciro Redondo captured in GHS but unable to capture smaller villages.

After removing pixels with less than 5,000 m2 of built-up area the distribution of pixel values is still skewed to the left, indicating that most inhabited places are of lower built density than the larger cities represented by higher proportions, see Figure 39 below.

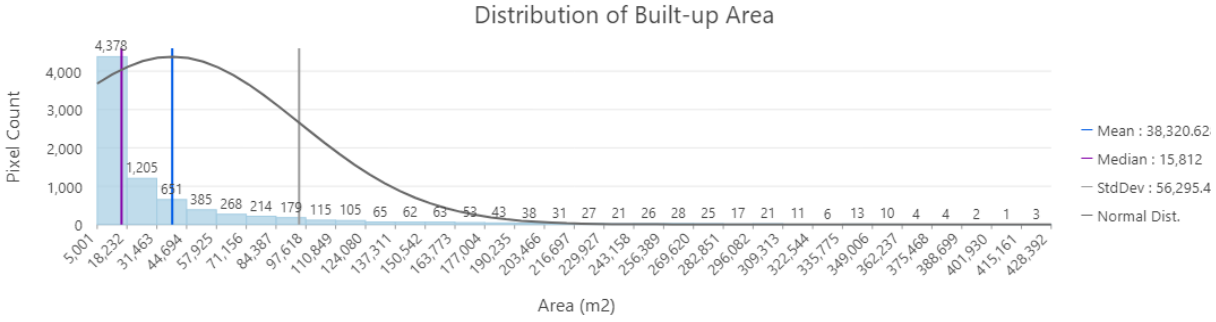

Figure 39 Histogram of built-up density in GHS data for Cuba.

[148] World Boundaries and Places - Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community. World Imagery - Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LandScan

After requesting access from the Oak Ridge National Laboratory, the LandScan product was downloaded for the years 2000 to 2013. This dataset is available up to the year 2018 but was only downloaded to 2013 to match the NTL dataset. The LandScan data has a resolution similar to DMSP-OLS of 1km (30 x 30 arc seconds). This dataset was used in Elvidge's original NLDI paper; it is especially useful because no NTL data was used in making the LandScan dataset.[149]

Cuban Boundary data

Shapefile representations of National, Provincial, and Municipal boundaries came from the free and easy to use site DIVA-GIS, created for studying global biodiversity, the site is a resource developed by researchers to alleviate the pressure to find commonly used data.[150] Their administrative data comes from GADM (the Database of Global Administrative Areas) includes boundaries at all three levels of governance and come in a WGS84 datum. These were later projected to the same Lambert Azimuthal Equal Area as the raster datasets.

World development indicators

The World Bank's World Development Indicators were used for the annual GDP for Cuba in the introductory exploration of NTL in Cuba.

DMSP-OLS

A stable light, radiance calibrated, Version 4 DMSP-OLS Nighttime Lights Time Series 1992-2013 was recently made available by the Colorado School of Mines.[151] This dataset has a temporal and spatial resolution of annual 30 arc seconds (Approximately 1 km) data for a 22-year period (1992-2013). Twelve of the years had two satellite observations, 1994 and 1997-2007. The original dataset has known issues of saturation if brightness is 'above' the 6-bit scale; the data is reported with the value 63 as the highest recorded intensity. This new version addresses some of the saturation in city centers and inter-satellite calibration. Previously, the stable lights dataset had to be calibrated by the analyst using one of many techniques, usually the Elvidge et al (2009) quadratic polynomial method, which the dataset used in this study was also calibrated with.[152] There are many ways to calibrate this

[149] Elvidge et al., "The Night Light Development Index (NLDI)."
[150] "Global Administrative Areas (GADM)," 2018, https://gadm.org/data.html.
[151] "Earth Observation Group - Defense Meteorological Satellite Program, Boulder | Ngdc.Noaa. Gov," accessed March 26, 2019, https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html; Feng-Chi Hsu et al., "DMSP-OLS Radiance Calibrated Nighttime Lights Time Series with Intercalibration," *Remote Sensing* 7, no. 2 (2015): 1855–76; Christopher D. Elvidge et al., "Radiance Calibration of DMSP-OLS Low-Light Imaging Data of Human Settlements," *Remote Sensing of Environment* 68, no. 1 (1999): 77–88.
[152] Christopher D. Elvidge et al., "A Fifteen Year Record of Global Natural Gas Flaring Derived from Satellite Data," *Energies* 2, no. 3 (2009): 595–622.

dataset. Li 2016 found Least Median of Squares to render the most accurate calibration, but none have their code published for reproducibility as the World Bank did with the Taylor polynomial.[153] The World Bank module partnered with Google Earth Engine to produce an instructional notebook. However, their code is difficult to use outside of the Google cloud configuration. The coefficient table is also made available by the Earth Observation Group (EOG) as a csv.[154] Avoiding this calibration task was recently made possible and for convenience the already calibrated dataset was used. The data was downloaded from Earth Observation Group Version 4 DMSP-OLS Nighttime Lights Time Series (NTL).[155] Cuba is known for having some instability in access to electricity, since the dataset is an annual average, some blackouts are averaged into the annual value.

As is standard in the literature, years with two different satellites reporting data were averaged to a final raster to be used for that year (see yellow highlights in Table 9 below). After this consolidation, NTL rasters were stacked in chronological order for more streamlined computation. This was done by creating a multiband raster in ArcGIS Pro using the Composite Band tool. One of the first tasks after projecting to the desired coordinate system was to clip the data to the main territory of Cuba without smaller keys to stay consistent with other analyses and to reduce complexity in the calculations caused by the rapidly changing environments of these areas. The reduced boundary is shown in Figure 40 below.

[153] "1.
DMSP-OLS Intercalibration (10 Min) — Open Nighttime Lights," accessed October 12, 2021, https://worldbank.github.io/OpenNightLights/tutorials/mod5_1_DMSP-OLS_intercalibration.html; Chang Li et al., "Study on Radiometric Intercalibration Methods for DMSP-OLS Night-Time Light Imagery," *International Journal of Remote Sensing* 37, no. 16 (2016): 3675–95.
[154] The CSV and other related data can be downloaded here https://eogdata.mines.edu/products/dmsp/
[155] "Earth Observation Group - Defense Meteorological Satellite Program, Boulder | Ngdc.Noaa.Gov."

Table 9 Corresponding satellites begin with the letter F and years of data captured with highlights of datasets with more than one satellite producing data that were averaged.

Average Visible, Stable Lights, & Cloud Free Coverages						
Year	**F10**	**F12**	**F14**	**F15**	**F16**	**F18**
1992	F101992					
1993	F101993					
1994	F101994	F121994				
1995		F121995				
1996		F121996				
1997		F121997	F141997			
1998		F121998	F141998			
1999		F121999	F141999			
2000			F142000	F152000		
2001			F142001	F152001		
2002			F142002	F152002		
2003			F142003	F152003		
2004				F152004	F162004	
2005				F152005	F162005	
2006				F152006	F162006	
2007				F152007	F162007	
2008					F162008	
2009					F162009	
2010						F182010
2011						F182011
2012						F182012
2013						F182013

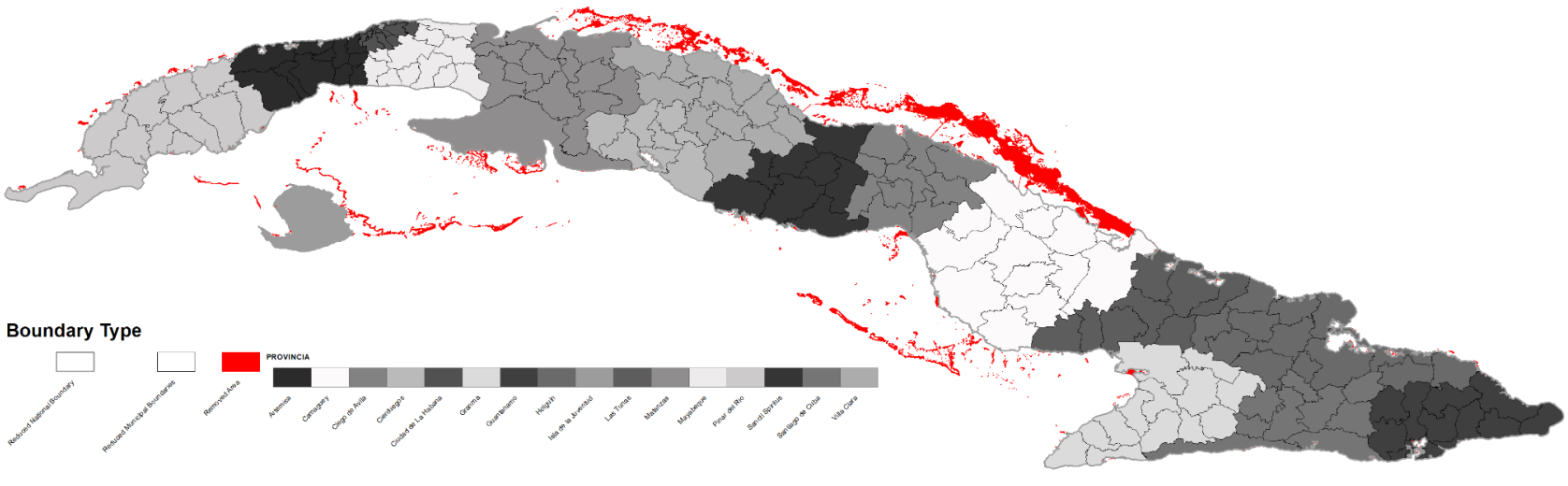

Figure 40 Areas in red were removed from the data to stay consistent with the condensed Cuban boundary used in other analyses. These areas are mostly keys with rapidly changing environments.

One known issue with the DMSP-OLS dataset is light spilling over from developed spaces into non-developed ones. The most common methods of reducing this error are to clip or mask to a known urban extent or to set a threshold value where values below it is not considered in the study. This study uses a combined approach where urbanization footprint is used to determine the threshold value. Since Cuba had very little urban development during the time in question, the reduced 2015 Global Human Settlement Layer was used as a mask to extract pixel values. This results in lower value pixels in the early years as the developments grow. This process may have picked up some light spilling, but the error was deemed acceptable because later in the analysis these pixels show a growth process. Figure 41 below shows the NTL DN values in the selected 2015 GHS layer pixels for the start and end year of the NTL data.

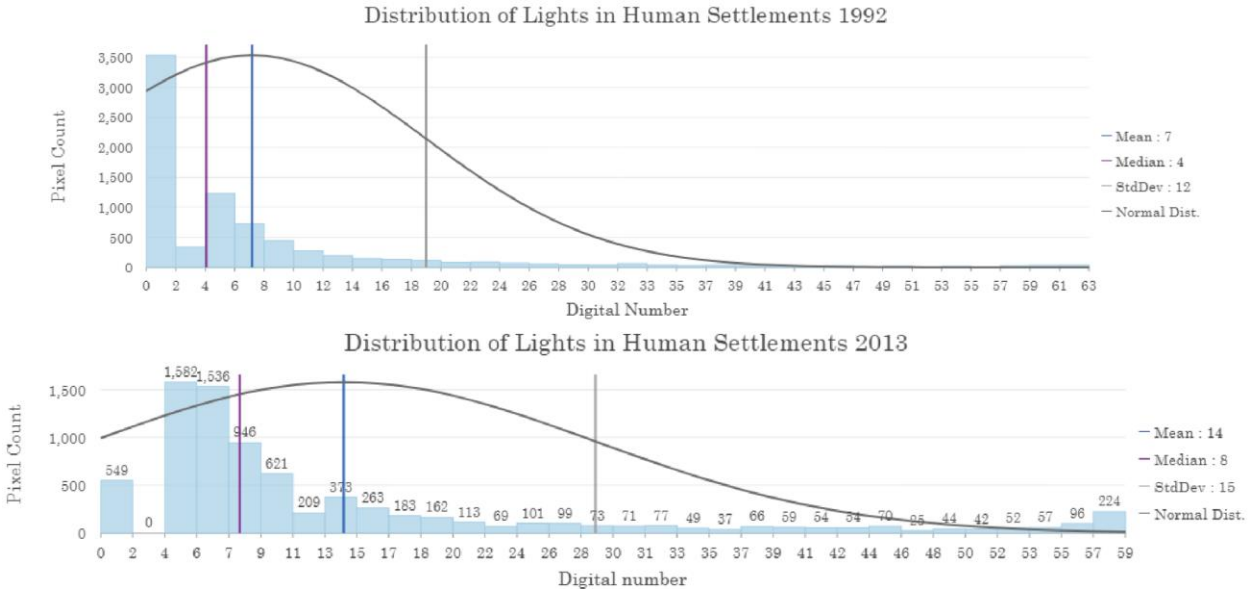

Figure 41 Distribution of lights in areas selected from GHS layer.

The GHS layer is used to extract NTL pixels across time using the Mask tool. Initially a DN threshold was investigated but it was found that there were many settlements with 0 or very low DN values that showed up on GHS. Extracting using the GHS layer helps this study include low density areas that are not electrified. A threshold was used to reduce GHS pixels with low developed areas that are sometimes roads. The threshold was determined by comparing the GHS to satellite imagery and deducing a value that captures some low intensity development but not roads. Once the NTL pixels were filtered using the GHS layer as a mask, centroids of the pixels were created using the Raster to Point tool. These points were used to extract NTL values across the years available in the dataset using the Extract Multi Values to Points tool. The time series saved at these points serves as the input for a Euclidean based K-Means clustering algorithm in the tslearn library

and the NLDI calculations. There were 7956 pixels selected with this method. Some of the pixels, 393, had all 0 values and were removed. Another 501 were also removed because they had 0 in 1992 and 2013 with low values intermittently, while these could be small villages struggling to keep an energy source, they gave the clustering algorithm trouble. This left 7,062 pixels, or sample points, to run the analyses on. For simple sum of lights calculations across Cuba and within municipalities, the total sum of lights was calculated without any filtering as this was more an analysis of relative differences than absolute night light values.

NTL Trajectories

NTL trajectory clustering was inspired by Ju et al for the potential their methods give to grouping development trajectories.[156] In order to reduce dimensionality for a k-mean unsupervised classification Digital Number timeseries are normalized by Mean Variance scalar. The values are normalized using the TimeSeriesScalerMeanVarience method supported by tslearn.

Once the time series are stationary, we run them through a series of test clustering trials to see what the optimal number of clusters are. The distortion elbow method calculates distortion scores for 2 to 10 clusters in a Kmeans loop. The distortion values are plotted for each of the clusters in Figure 42 below shows an elbow at 4 clusters. The lack of clarity in this method and easy use of code to optimize for cluster numbers prompted a calculation of the Calinski-Harabasz score also identified 4 as the optimal number of clusters.

[156] Yang Ju et al., "Analysis of Urbanization Dynamics in Mainland China Using Pixel-Based Night-Time Light Trajectories from 1992 to 2013," *International Journal of Remote Sensing* 38, no. 21 (January 1, 2017): 6047–72, https://doi.org/10.1080/01431161.2017.1302114.

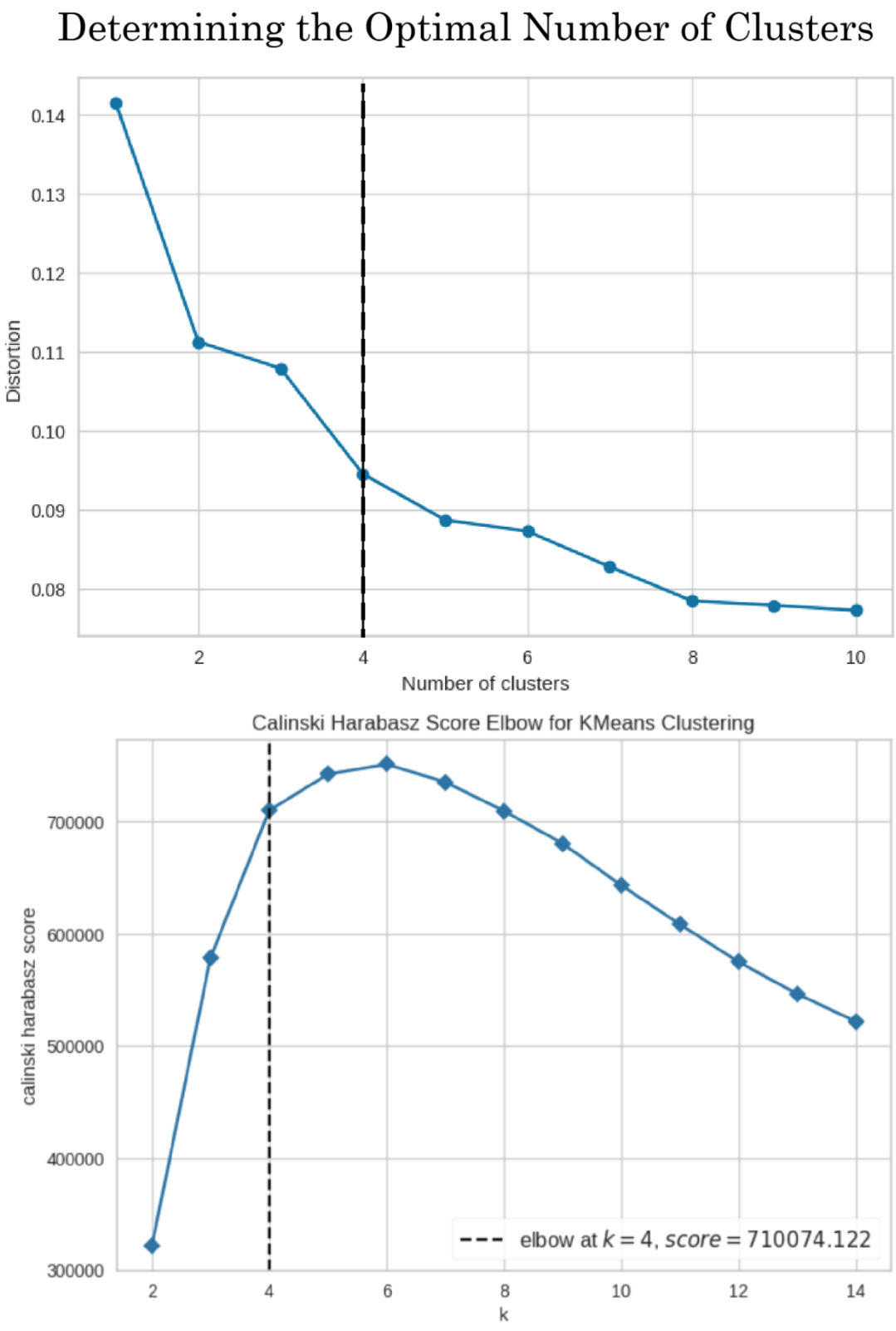

Figure 42 Comparison of methods to choose optimal number of clusters.

The output labels for 4 clusters are saved as a CSV to be joined back to the points, by a unique point ID, which extracted the values for mapping. The CSV was also brought into Google Sheets to calculate the percent of each cluster type in the municipality and a column was added with the name of the cluster type that had the highest percent in pixel counts for each municipality.

NLDI

For each year where a corresponding LandScan and GHS filtered DMSP-OLS data exist the NLDI calculation was made. Resampling of the LandScan Data to match the corresponding year of the DMSP-OLS dataset was performed using the Mask tool to match population data using the NTL grid. The centroid data was then used to extract multiple values (from the multiband time series raster). They were both at a 1km resolution. As was done in the 2020 study, pixels were aggregated to administrative regions, municipalities, in the NLDI calculation.[157] In order to compare administrative regions of Cuba, the centroids were also tagged with the name of the municipality they fall into using the Spatial Join feature in ArcGIS. These points were then exported into a CSV and brought into a python environment for NLDI calculations. Using municipal name as an index, a for loop for each year ran each row through the NLDI function.

Patterns in Cuban Lights (Results & Discussion)

The sum of lights allows us to explore the overall trend of nighttime lights from the time period covered in the DMSP-OLS dataset. Figure 43 shows the sum of lights for the portion of Cuba considered in this study. We can see a generally positive trend over time with a total increase of around 235% in total lights.

[157] Ivan et al., "Potential of Night-Time Lights to Measure Regional Inequality."

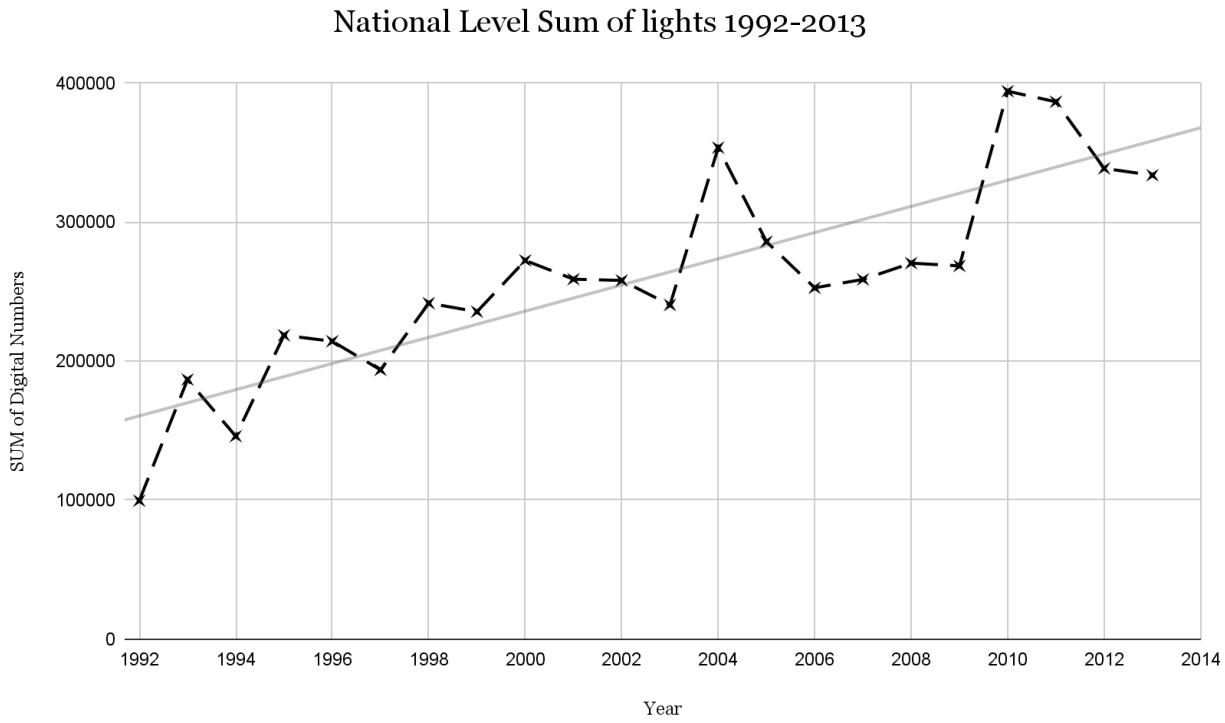

Figure 43 Annual national sum of lights from DMSP-OLS data with increasing trend. A decrease from 2006-2009, years of recovery from major storms, can be seen.

The sum of lights for the years 1993-1995 show the fluctuations of the economic crisis. This can be more easily seen in Figure 44 below. There was an increase in 1993 of 47% followed by a 28% decrease in 1994, the largest decrease between years, and a 33% increase in 1995. There was a 32% increase in 2004 and saw the largest increase in sum of lights with a 32% increase in both years and 24% decrease in 2005 and 14% decrease in 2012.

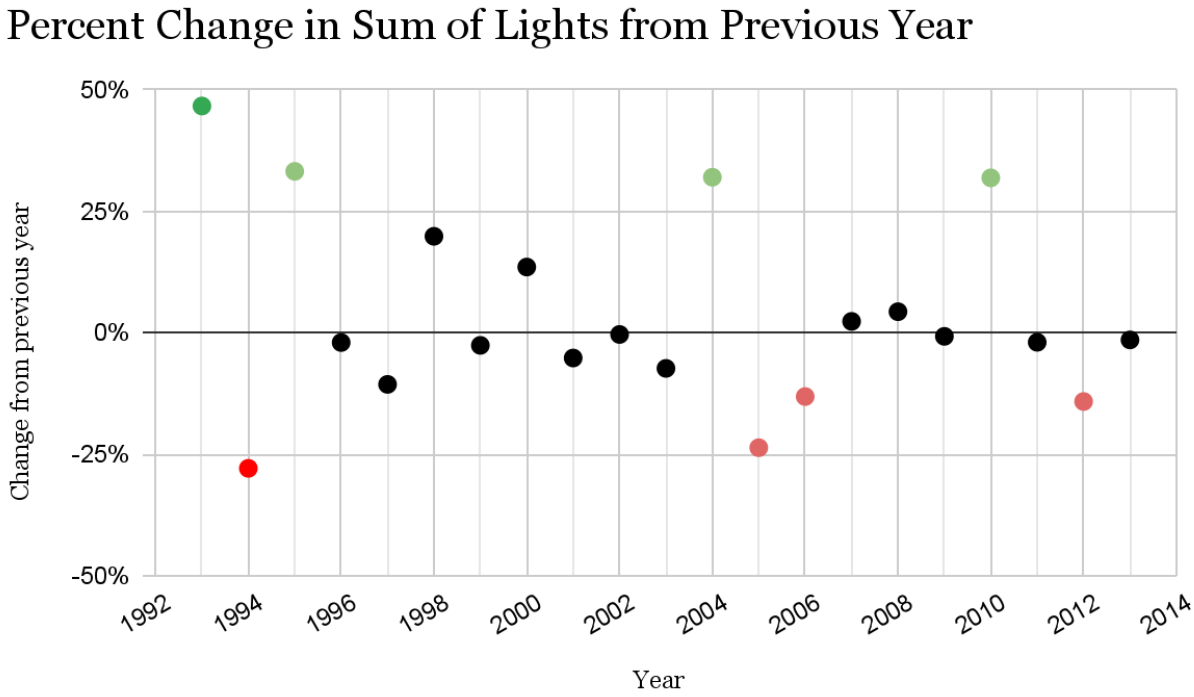

Figure 44 Normalized annual changes in sum of lights with four best (green) and four worst (red) years highlighted. The highest growth was 1993 and the highest decrease was 1994.

Direction

At the Municipal level, the change in sum of lights shows the reported decay of the historically developed coastal areas of the capital city Havana, refer to Figure 45 below. The only municipalities to report a decrease in lights were in the Province of the City of Havana; Playa, Diez de Octubre, Regla, Cerro, Plaza de la Revolución, Centro Habana and La Habana Vieja (Historic center). This is all but one, the Habana del Este, of the coastal municipalities in the province. Of the top ten largest increases in light, eight were in Eastern Provinces, four in Guantanamo, three in Santiago de Cuba, and one in Granma. The inland Segundo Frente Municipality in the Province of Santiago had the largest increase of light, by 1,171% followed by the 4th-7th largest municipal increases happened in Guantanamo Province of between 377% and 159% in San Antonio del Sur, Yanteras, Maisi, and Imias. The relatively slow growth of the Cuban economy is also reflected in the results of percent change in NTL. Most of the municipalities (93) had very low increases from 0.14 to 5%. Tercer Frente in the same Province had a 1,038% increase. The next largest increase, 897%, was in the La Sierpe Municipality in the central province of Sancti Spiritus.

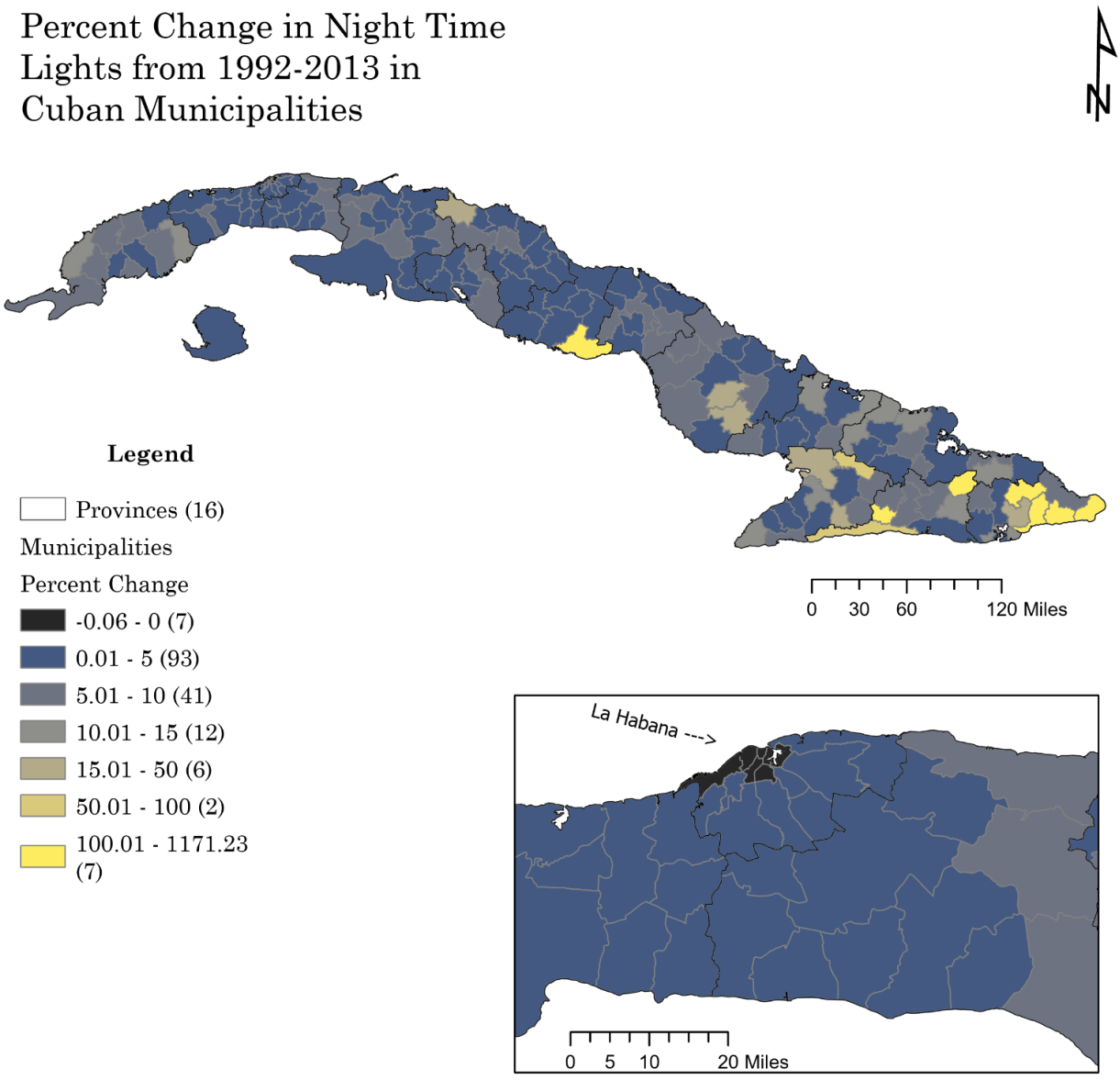

Figure 45 Change in the sum of nighttime light Digital Number (DN) values by municipality.

Clustering Trajectories

The variability in NTL trajectories on the island is further observable in the clustering results. The four time series clusters (Figure 46) depict the following trajectories: a more or less steady increase in NTL (Cluster 2), Slow growth with small change in values over time (Cluster 4), growth towards the end of the time series between 2007-2013 (Cluster 3), and early growth with a downturn around 2009 that later began to increase (Cluster 1). Figure 46 below plots each observed time series as the gray background with the cluster they were assigned to. As mentioned in the methods the DN values they depict are the mean variance normalized values, not the raw DN. This allows for a clearer comparison from year to year. The clusters can be interpreted as a reflection of the variety of sectors that different regions specialize in. Cluster 1 might be interpreted as areas that were hard hit by the 2009 Global Financial Crisis after experiencing higher than usual growth in the late 90's and early 2000's. By the end of the NTL time series these areas began to recover. Cluster 2 represents areas that successfully adapted to changes and managed to keep the lights on while experiencing moderate growth. Cluster 3 areas experienced low growth until changes after 2009 positively impacted their light output. Cluster 4 is the least adapted area that had slow to no growth during the time series.

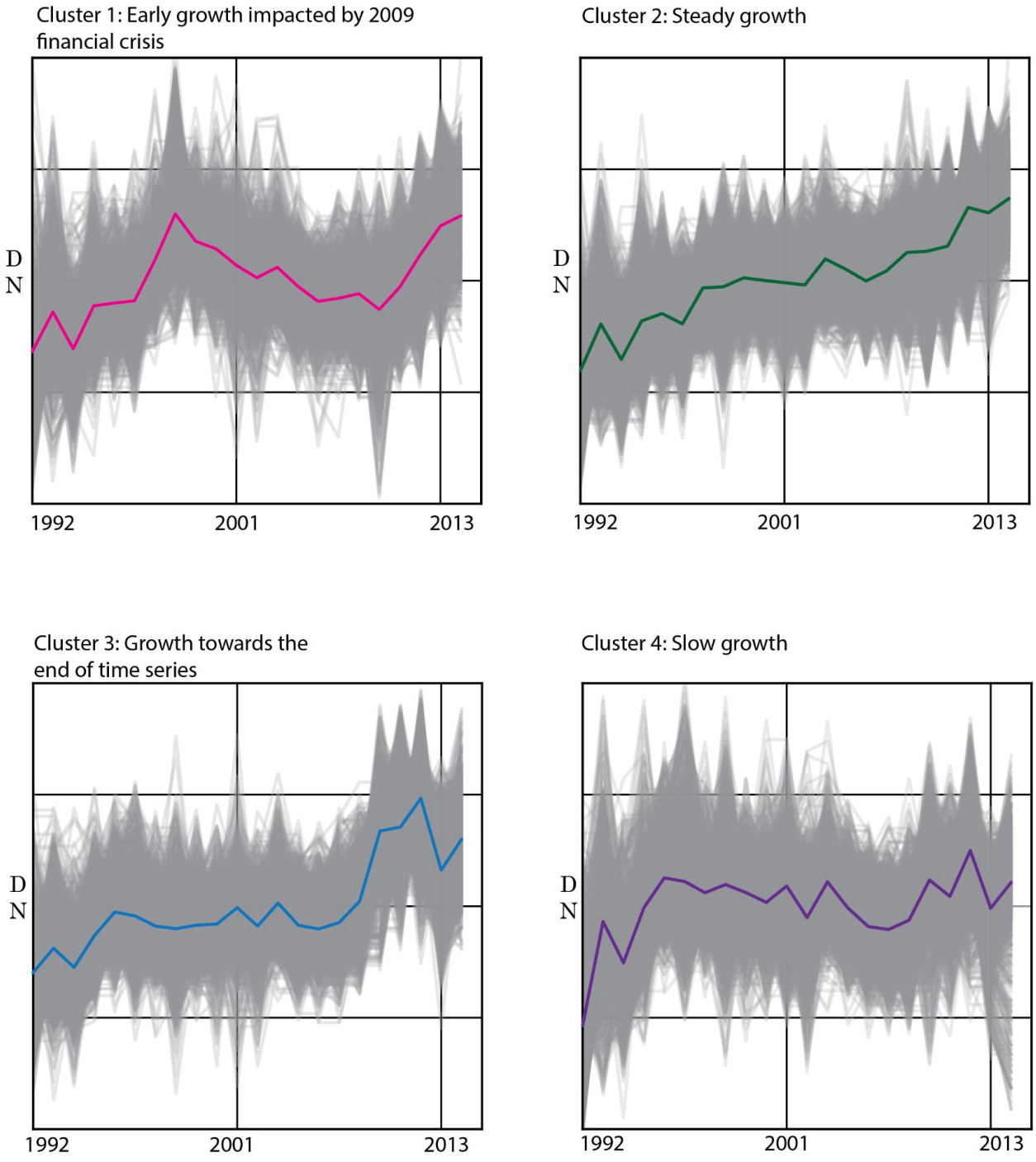

Figure 46 The resulting K Means unsupervised clusters from Cuban Nightlights.

In Figure 47 below we can see the location of clusters after georeferencing the sample points (centroids of original NTL raster) and converting them to a raster. The grid over Havana is an artifice from converting points to a raster. Similar to the percent change in NTL, we see that the Western part of the country had more steady growth than the rest. The resolution of the dataset allows us to see differences within cities as well as regionally. The wider Havana area is experiencing all the trajectory types in different locations. The areas frequently visited by tourists along the coastal part of the city are also the oldest, and they seem to have experienced both the decrease in lights from building collapses and the 2009 fluctuations in foreign visitors. Although common around the world, unexpected results can be seen in Santiago de Cuba, where the city is split into two opposing types. The Eastern with steady growth and the Western with stagnation. This pattern is also observable in other major cities like Santa Clara, Pinar del Rio, Sancti Spiritus, Ciego de Avila, Florida, Camagüey, Las Tunas, and Holguin. The lack of homogenous classification in each city could be related to developmental differences in different areas of the city that likely reflect the complicated histories and urban metabolisms that cities in non-communist countries experience. To know what divides these cities, a more localized study is needed but the results point to the possibility of Global NTLs to be used in determining spatial distinctions in local development. In the Western Province of Pinar del Rio, the central spine is the Sierra del Rosario which boasts a large, protected park. Cities and towns in this area have a divide that is lower and slower growth on the side abutting the park and steady growth in the areas further from the park. This could be a sign of protecting against development close to the park while reaping benefits from environmental tourism.

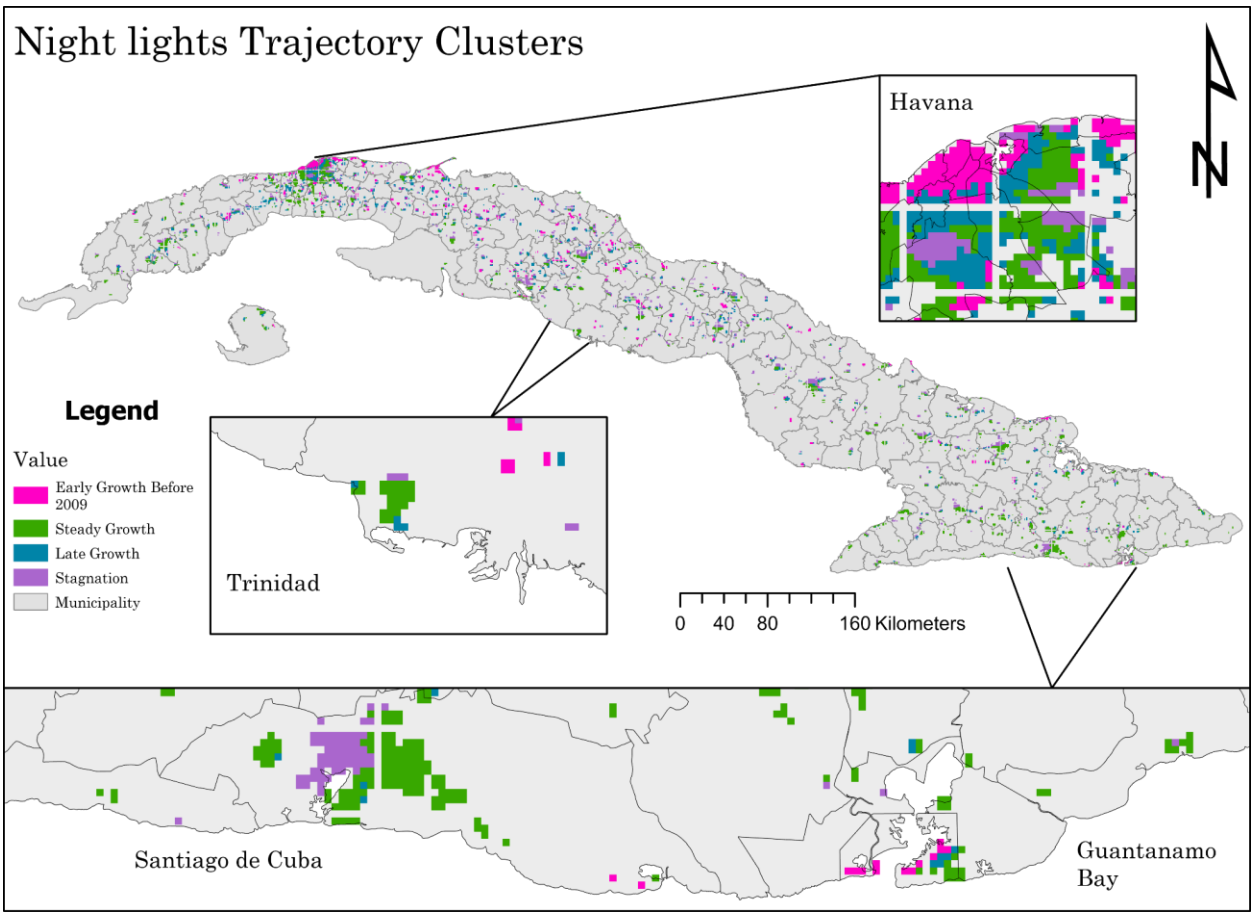

Figure 47 Centroids labeled with cluster type rasterized to show area they covered as pixels. With this localized resolution we can see variance within a single city.

In order to better understand results at a resolution that is adequate for the researcher's local knowledge, the clustering results were aggregated to the municipal level by classifying them into their most common cluster type. Some municipalities were split evenly in the type of cluster they had pixels for. These are noted in Figure 48 below with 'and' cluster types and amount to only 6 municipalities. At this aggregated level we can see the prevailing pattern of growth in Eastern municipalities, low growth in Central areas, a distinct Havana regional response, and growth in previously underdeveloped far West municipalities.

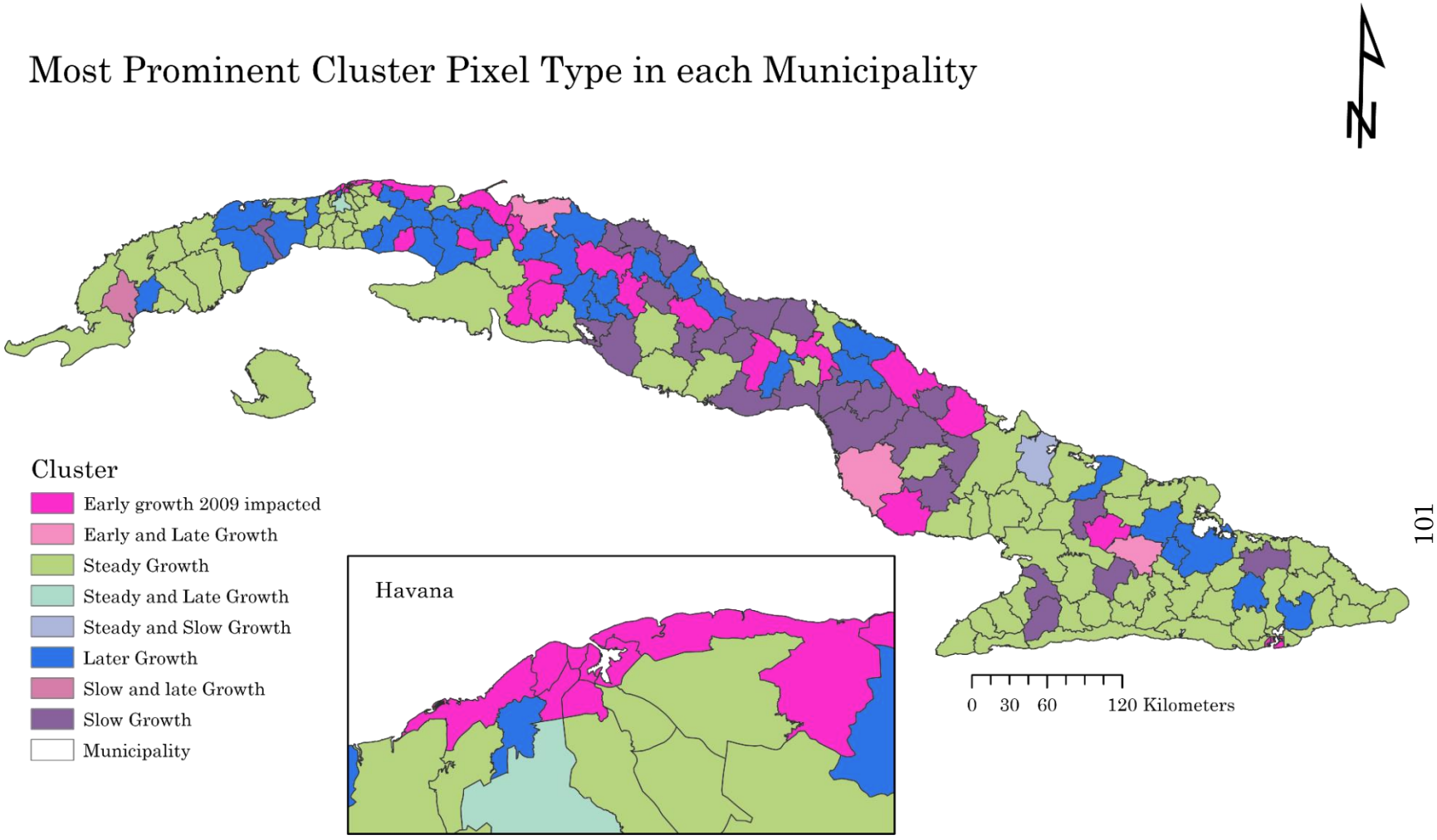

Figure 48 Cuban municipalities by most common NTL cluster type.

While there is some connection between tourism and municipalities that were classified as 2009 impacted. Municipalities in Havana that are frequented by tourists (those along the coast) were all labeled cluster 1, or 2009 impacted. As was the municipality of Matanzas which has the resort town of Varadero. The presence of cluster 1 in some Central municipalities further expands the idea that Latin American countries were impacted by the GFC indirectly through changes in commodity prices and remittances. A further explanation are the changes in agricultural production policies that Cuba underwent in 2008 to encourage usufruct farming and further reduce sugarcane hegemony in the central region of the country. An interesting occurrence of the 2009 impacted cluster is in the U.S. controlled military base. Most municipalities in the province were classified as steady growth, except for Manuel Tames and El Salvador that were classified as showing later (post 2009) growth.

Population Trajectories

Along with changes in Night-time lights there are some small but notable changes in municipal population. Remarkably, some negative trends in the capital city of Havana demonstrate both the deterioration of the city and the government's efforts to prevent mass migration into the already primate city, see Figure 49 below. Throughout the Western and Eastern provinces there are instances of negative population trends. This could impact NLDI calculations as over time there are less people to divide up the sum of light among. Another interesting pattern in LandScan population changes are coupled municipalities that show growth adjacent to decreasing areas. This is observable in the municipalities adjacent to cities that are provincial heads such as Las Tunas, Camagüey, Santa Clara, Ciego de Avila, Cienfuegos, and Pinar del Rio. These provinces are where sugar production was concentrated, and the pattern could signal a move out of municipalities with closed sugar mills into nearby ones with more opportunities to participate in new agricultural schemes.

The Western province of Pinar del Rio has a history of cigar tobacco production and beautiful landscapes that attract tourists. The municipality of Viñales on the North coast (same as Havana) has the highest growth percentage of the province and has an ecologically protected area with limited, non-mechanized, agricultural activities allowed. One limitation of the dataset time series chosen can be seen in Minas Matahambre in the same province. It has a decreasing trend despite efforts to reintroduce mining in 2015 after the 1997 closing of a copper mine that had been in operation since the early 20th century.

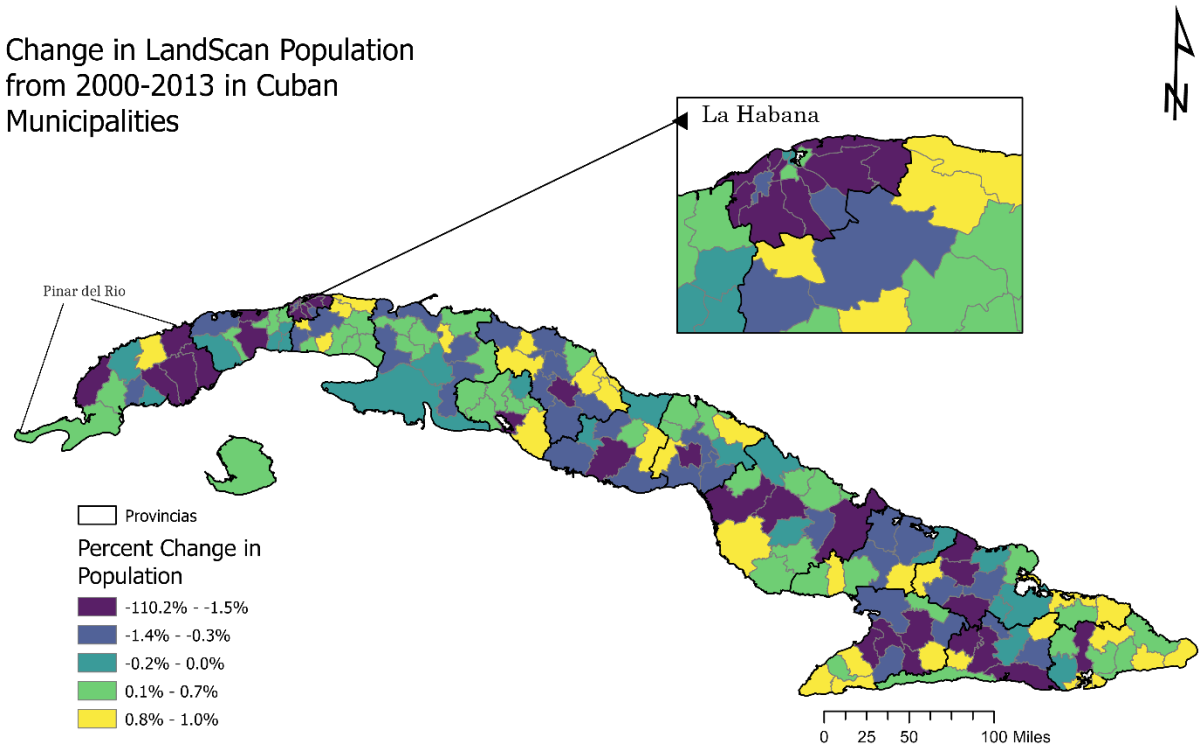

Figure 49 Percent change in municipal population

Distribution of Lights

The woes of Havana can be further seen in Figure 50; the names of Havana's municipalities are in the smaller text. Most of the municipalities in the province are below the national trendline, meaning the city of Havana saw more population decreases than other provinces. In slightly larger text are outliers with higher values than the national trendline. Most of these are in the Provincial heads that also experienced a population decline. This might signal a delay or lag effect in reallocating light related resources away from areas with planned decline in sugarcane activities. Like in Elvidge 2012, Figure 50 also tells us something about the general population distribution in the country, which more closely resemble the scatterplot for the U.S. in Elvidge's research. Unlike low-income countries there is no horizontal clustering indicating low light emissions throughout the country. Unlike China's vertical clustering indicating high population densities with the most nightlights, Cuba's scatterplot shows a general trend of less dense and more evenly distributed light. Municipalities far above the trendline are mostly in the Central region and represent areas with more NTL per capita than the trend displayed by other municipalities.

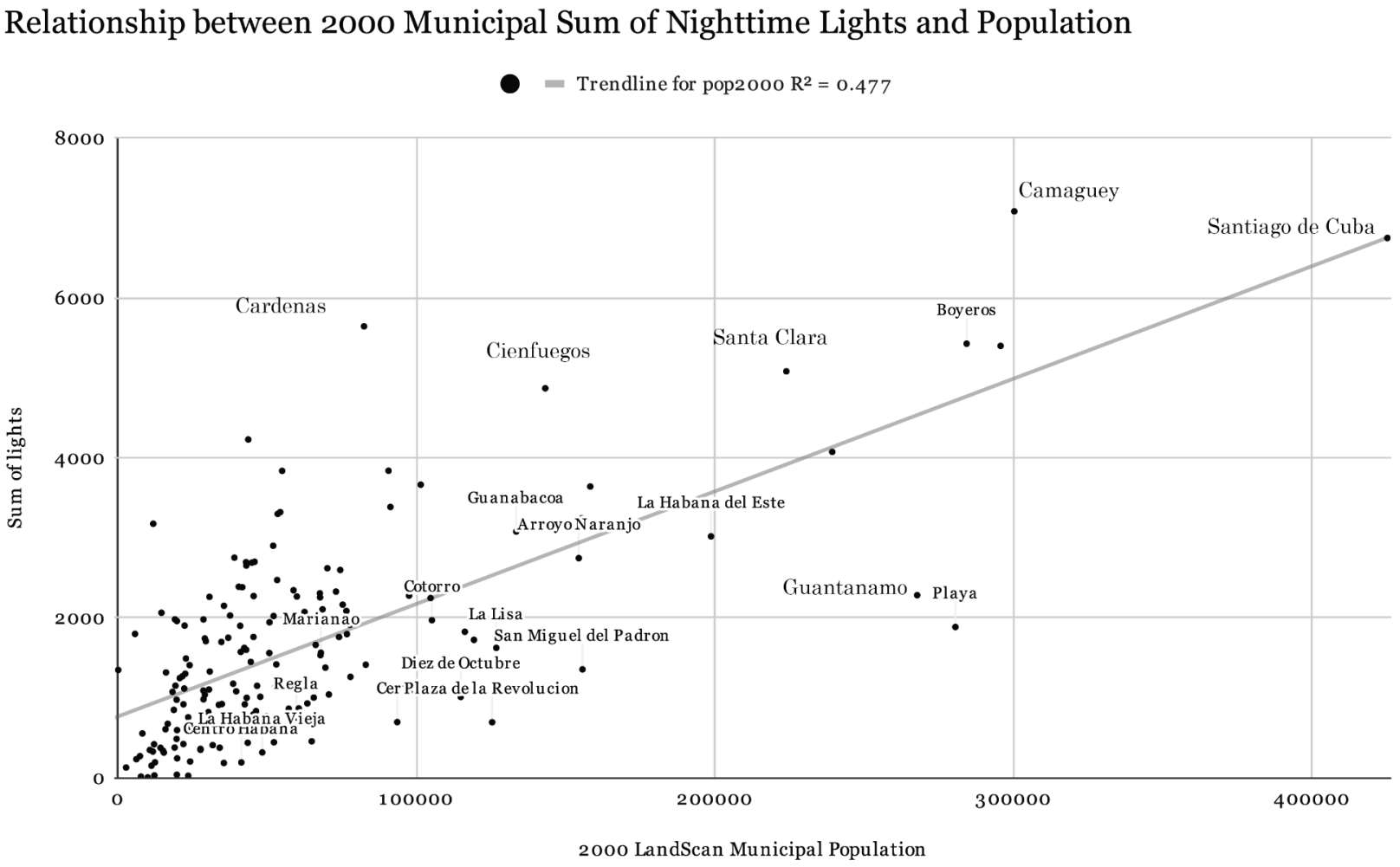

Figure 50 Municipal relationship between sum of night lights and population in 2000. Municipalities of Havana as labeled in smaller text that other outlier municipalities.

NLDI

The NLDI calculations show a less favorable result for Eastern municipalities than general NTL trends. Figure 51 below shows the average municipal NLDI over the time period studied. Municipalities on the Northern and Southern coasts of the island have less equitable light distribution than those running in the spine of it. This could be due to the concentration of energy infrastructure in central municipalities that historically produced sugarcane. They experienced more development before the crisis including building up energy access essential for manufacturing cane sugar. High NLDI values can be seen throughout the East, West, and around Havana. The isolated and underdeveloped island of Isla de la

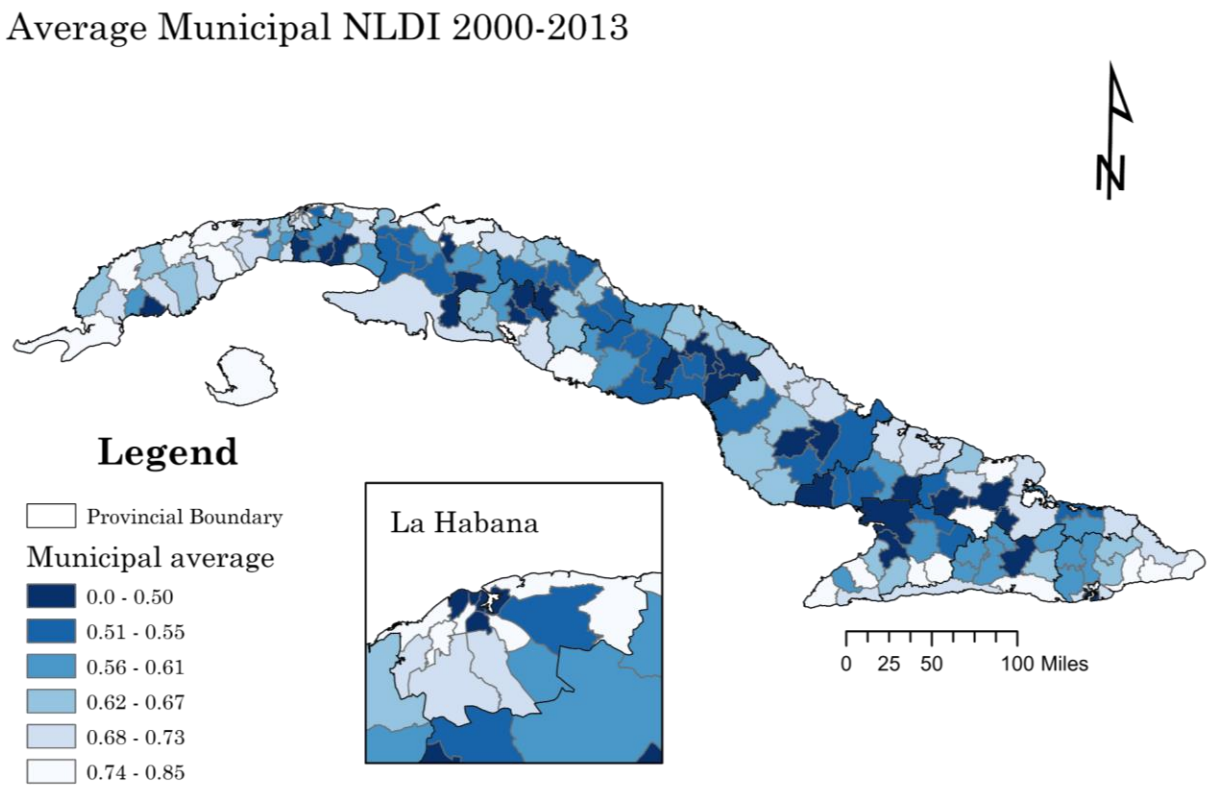

Figure 51 Average municipal NLDI over a thirteen-year period

Juventud also has a high NLDI despite the government installing a decentralized energy system there.

Over the course of 13 years changes to NLDI values can help demonstrate where government efforts improved distribution of electricity. Figure 52 below shows an improvement of NLDI values (lowering of value and inequality) in many of the Eastern municipalities and a worsening in some coastal municipalities. The province of Havana experienced an NLDI increase, worsening of distribution, in all

but one municipality, La Lisa. Overall coastal Havana had a low NLDI meaning there was a more equitable distribution of light than in non-coastal municipalities of the province of Havana. This is likely because of the high density of the city and well-established power infrastructure relative to the island. They could have a worsening NLDI as some of the infrastructure suffered from the recession and natural disasters. The top three provinces with increasing inequality were: Ciudad Habana, Artemisa, Matanzas, and Cienfuegos. Guantanamo and Santiago de Cuba were the only provinces to post an aggregated lower NLDI trend, increasing equality. The Western part of the country had the highest percent increase in NLDI followed by the Central region with the Eastern region having the lowest average increase in NLDI.

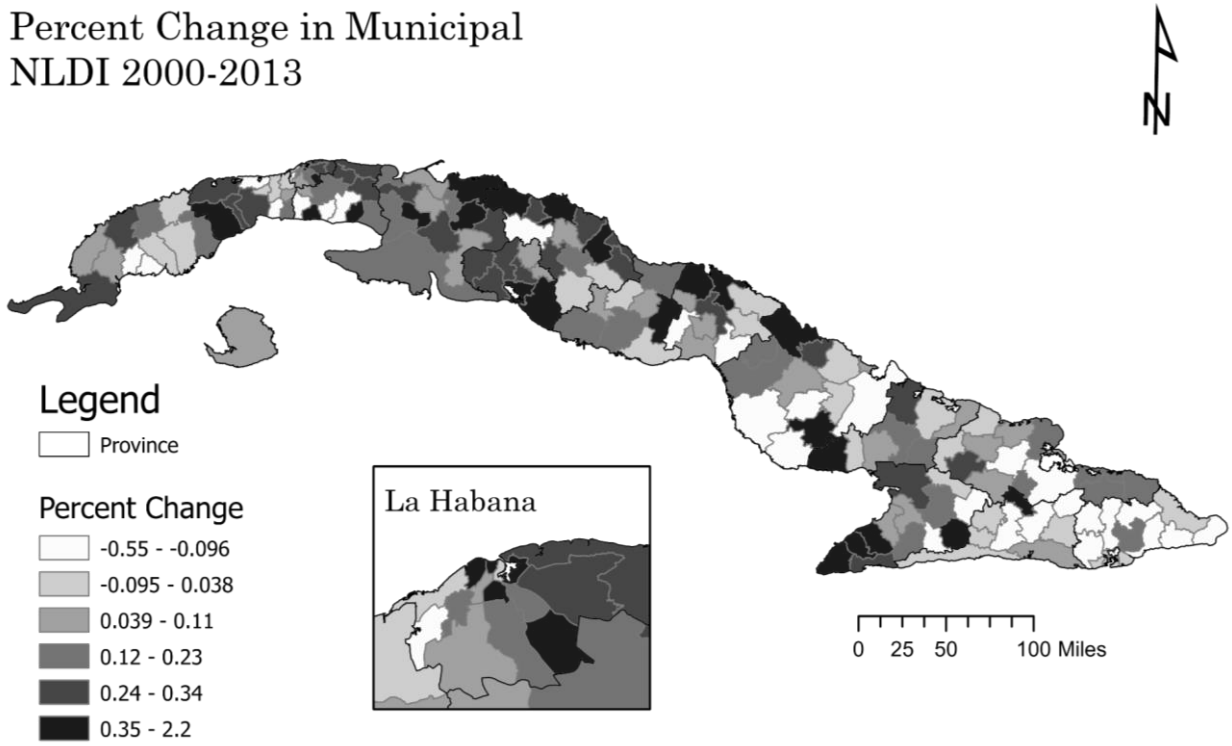

Figure 52 Normalized comparison of change in municipal light distribution equity.

Pájaro Cenzontle[158] (Conclusions)

The unsupervised clustering of night-time light trajectories revealed 4 cluster types. These clusters could be interpreted through an economic lens as: steady growth, stagnation, slow growth followed by rapid growth, and rapid growth with a

[158] Son Rompe Pera, *Pájaro Cenzontle*, Batuco (Song 6: AYA Records, 2020).

downturn in 2009. Although 2009 had some impact in all clusters, the highest decrease seen across the island was in 1994 during the peak of the Special Period crisis. While NTL increases are higher in Eastern municipalities, we can see from the NLDI that distribution of light has not sufficiently improved inequality in distribution of development. In general, we see a growing inequality in the spatial distribution of NTL on the island with some municipalities in historically underdeveloped areas improving as the government invested in decentralized energy production. Cuba's energy revolution in the 20th century was predicated on user efficiency and energy use awareness. Since their energy was predominantly fossil fuel based, polluting, and a continuation of practices that are counter to sovereignty and sustainability, their energy sector could hardly be considered sustainable. The government has made policies that in theory would improve energy distribution and sustainability. However, the impact of the illegal U.S. embargo, natural disasters, and internal economic restructuring have limited the amount and scale of projects.

Limitations

Clustering analyses are better done on raster data, not sample points, especially when creating a spatial visualization of the results. While the sample point method uses the same number of samples as pixels in a raster, using raster pixels would have made for better graphics that more authoritatively communicate the results as an uninterrupted field. This would have also made it easier to communicate results to localities who could have seen differences by neighborhoods. The clustering method chosen in chapter two was a relatively simple K-means calculation rather than a Dynamic Time Warping one which is much better for time series clustering and is often used in the lucrative finance sector. The reason for using the K-means was a lack of computing power available to the researcher. Global night-time light satellite products have the ability to show patterns in development at the local and regional level. Results from unsupervised clustering analyses can be used to trigger further studies into the development dynamic of localities. Change patterns in lights cannot be taken out of context, areas that show a lot of growth could be previously marginalized areas catching up to historically privileged locations. While they show improved growth, they do not tell the whole story about the changing state of the human condition in those locations. Having additional data on income or other development indicators would allow us to monitor improvements and equity with more significance. These data are not made easy to access by the Cuban government, as they are either not published or are published in formats, such as PDF, that are not intended for immediate transfer into analysis software. Such

public data warehouses are costly to build and maintain, especially by governments who are already working with strained budgets and do not prioritize transparency.

Future Studies

In order to truly use this satellite data to discern intranational patterns at the local level, municipal or city, additional data and collaboration with locals would be needed. For example, to monitor the Cuban government's energy program, adding data on the locations of decentralized energy production would allow for policy impact evaluations. Similarly, combining this dataset with information on localized impacts of hurricanes and tropical storms, and local experiences of energy access would allow us to evaluate equity in disaster recovery. While satellite data facilitates regional or local level research, stronger arguments and consequences could be created with Participatory Action Research based methods.

3. Political Economy in Environmental Data

With an interpretivist research design, this dissertation uses process tracing in the case study of a singular system, the Republic of Cuba.[159] Multiple datasets are used to compile national features that are available (with varying accuracy) for the entire globe. This ubiquity is tapped into to comment on the data burden adaptation requires but is not yet met by the main contributors of the atmospheric carbon causing climate change. Using a political economy method, this chapter contextualizes the two datasets used in the previous chapters along with Cuba's position in the international adaptation ecosystem as an assay of heterodox economics. Sustainable Development Goals make certain data collectible which the UN then hosts and uses in their reports. This data is also used by UN researchers in predictive models, policy forming and impact evaluations through which donor countries exert influence and power over sovereign nations.
The benefits of using the political economy approach for this study are primarily that it does not assume a price can be reasoned for everything, unlike mainstream economic approaches. This framing is important for climate change adaptation, which aims to reduce and mitigate ecological collapse and major loss of human life, which are things that cannot be priced.

Thesis Questions:

- How do our definitions of 'development' assume neo-colonial frameworks?
- Is Cuba more sustainable than other countries in Latin America and the Caribbean?
- What regional differences in sustainable development within the Republic of Cuba can be identified from the two previous analyses?

Frames

The 2017 Special Issues of the Third World Quarterly heavily influenced this chapter. Nulman (2017) qualitatively analyzes the collective action frames of the public discourses of solidarity organizations.[160] Referencing Benford & Snow, Nulman describes diagnostic framing, prognostic framing, and motivational framing as a template for describing purpose and reasoning behind institutions.[161] This template was followed for describing the framing and perspective of this paper. By

[159] Pascal Vennesson, "12 Case Studies and Process Tracing: Theories and Practices," *Approaches and Methodologies in the Social Sciences* 223 (2008).
[160] Eugene Nulman, "Neo-Imperialism in Solidarity Organisations' Public Discourses: Collective Action Frames, Resources and Audiences," *Third World Quarterly* 38, no. 11 (November 2, 2017): 2464–81, https://doi.org/10.1080/01436597.2017.1368011.
[161] Robert D. Benford and David A. Snow, "Framing Processes and Social Movements: An Overview and Assessment," *Annual Review of Sociology* 26, no. 1 (2000): 611–39.

applying these frames, we also see the ways in which International Development can assume neocolonial frameworks.

Diagnostic Framing

Current political and economic structures enforce an international climate apartheid. Similar to other leaps in development (such as industrialization, globalization, or the information age) the response to a changing climate is continuing a legacy of uneven distribution of burdens and privileges. As described by Rice et al, these differences create populations that are treated as expendable by privileged groups.[162] This is made clear by the lack of prioritizing Caribbean and other island nations in setting temperature increase targets, operationalizing carbon emissions reduction goals, and funding adaptation.[163]

This paper assumes a non-normative ethical framework is needed to surpass the inclination of powerful states to utilize liberal social contract theories that obfuscate racial capitalism under a veil of ignorance. As demonstrated by Grasso's normative work in 2007, liberal frameworks tend to reason the vulnerability of poorer countries on their failure to be less dependent on agriculture, low access to financial capital, backwardness of institutions and technocracy, and low knowledge and research capacity.[164] Grasso shows how ignorance of the racial contract can perpetuate deficit and imperialist frameworks in well-meaning development approaches.

Ignorance of positionality also plagues prominent work on climate change ethics. In Grasso's more recent work exploring interdisciplinary "diversity", the overwhelming majority of authors referenced are from rich Western countries.[165] This ignorance limits calls for changes to global power imbalances and adaptation options. Overall, climate change is viewed as a metabolic rift created by those seeking growth for the purpose of accumulation of capital and leveraging racial capitalism to distribute the burden of pollution away from privileged groups. Modern imperialism challenges American hegemony, mainly by other power-seeking nations but also by international movements for third world liberation, some of which are nestled in

[162] Jennifer L Rice, Joshua Long, and Anthony Levenda, "Against Climate Apartheid: Confronting the Persistent Legacies of Expendability for Climate Justice," *Environment and Planning E: Nature and Space*, March 12, 2021, 2514848621999286, https://doi.org/10.1177/2514848621999286.
[163] Leon Sealey-Huggins, "'1.5°C to Stay Alive': Climate Change, Imperialism and Justice for the Caribbean," *Third World Quarterly* 38, no. 11 (November 2, 2017): 2444–63, https://doi.org/10.1080/01436597.2017.1368013.
[164] Marco GRASSO, "A Normative Ethical Framework in Climate Change," *Climatic Change* 81, no. 3–4 (2007): 223–46, https://doi.org/10.1007/s10584-006-9158-7.
[165] Marco Grasso and Ezra M. Markowitz, "The Moral Complexity of Climate Change and the Need for a Multidisciplinary Perspective on Climate Ethics," *Climatic Change* 130, no. 3 (2015): 327–34, https://doi.org/10.1007/s10584-014-1323-9.

Cuban and Caribbean scholarship.[166] Though not as recognized as European scholars, Caribbeans have long been leaders in anti-imperialist innovations.[167] Just as Haiti was the first island to free itself from colonial control, scholars such as C.L.R. James, Charles Mills, Frantz Fanon, and Audre Lorde all have Caribbean roots. Since data is the way governments, institutions, and other imagined communities see the world and manage it, the production of data reflects the worldview in which these governments operate. One way the Caribbean can contribute to demands for climate change reparations is by demanding data creation and access equity. The Caribbean is well positioned to do this not only because of its history but also because of its environmental appeal to foreign visitors and proximity to the global elite.

Prognostic Framing

Lefebvre argues that conflict arises when protocol is established to maintain a beneficial steady state that seems in itself 'unnatural' and requires the State to form a logic and enforce it through policies to maintain 'stability'. Since space is both object and subject for human analysis, it is susceptible to human ideology that can be mystical in character.[168] This indicates a need for deep structural changes to adequately adapt. For example, research into the climate change ethics of U.S. farmers found structural barriers in their application of mitigation and adaptation strategies. Over 99% of cropland in the U.S. is privately owned and operated, leaving little room for the kind of sweeping centralized changes we see in Cuba.[169] Additionally, farmers are typically restricted by seed contracts with a few large corporations. These contracts reward farmers who maximize yields, effectively constraining their choices to move away from artificial fertilizers and other mitigation efforts.[170] This Stuart and Schewe study highlights how political and economic drivers outside the hyperlocal retrain farmers in conventional, environmentally degrading practices. Though in the U.S. these drivers are a result of neoliberal capitalism, they have parallel results to Cuba's Soviet period of State

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[166] John Narayan and Leon Sealey-Huggins, "Whatever Happened to the Idea of Imperialism?" *Third World Quarterly* 38, no. 11 (November 2, 2017): 2387–95, https://doi.org/10.1080/01436597.2017.1374172.

[167] Michel Gobat, "The Invention of Latin America: A Transnational History of Anti-Imperialism, Democracy, and Race," *The American Historical Review* 118, no. 5 (December 1, 2013): 1345–75, https://doi.org/10.1093/ahr/118.5.1345.

[168] Henri Lefebvre and Donald Nicholson-Smith, *The Production of Space*, vol. 142 (Oxford Blackwell, 1991). In chapter 1 Lefebvre discusses the epistemology of Space. They present the dichotomy set up by early philosophers and mathematicians that describe either physical space or social space, leading to deterministic models when combined, for example, with Cartesian philosophy.

[169] Nelson Amaro, "Decentralization, Local Government, and Participation in Cuba," *Cuban Communism*, 1998, 30–43; Jorge Mario Sánchez Egozcue, "Challenges of Economic Restructuring in Cuba," *Socialism and Democracy* 26, no. 3 (November 1, 2012): 139–61, https://doi.org/10.1080/08854300.2012.716928.

[170] Diana Stuart and Rebecca L. Schewe, "Constrained Choice and Climate Change Mitigation in U.S. Agriculture: Structural Barriers to a Climate Change Ethic," *Journal of Agricultural & Environmental Ethics* 29, no. 3 (2016): 369–85, https://doi.org/10.1007/s10806-016-9605-z.

Capitalism. The solution in either place is decentralization of land management and development programs.

Another salient example of the failure of steady state centralized planning is the use of conservation in protecting the environment. While the ethics of using conservation as a catalyst for international development has been questioned, it is a practice commonly used throughout the world. Global designations of identity to space through UNESCO's World Heritage Site program promote international tourism and the mixed use of ecological and archeological sites. Additionally, federal, state, and local governments designate spaces as serving cultural or environmental purposes. These spaces create hotspots for social-ecological systems that form agglomeration economies with environmental and cultural services embedded in them.[171] Further centralizing land holdings and management practices.

In the LAC there is an ongoing and historical process of encroachments on land managed by indigenous communities through the use of racial hierarchies and 'novel' ways to maximize profit from landscapes.[172] There has already been research pointing at the potential for climate change mitigation projects to effectively function as land grabs from local actors to internationally backed policies that assign value to forests or overvalue projects for biofuel rather than current uses of 'natural' land.[173] Predicted changes in climate patterns and sea level rise will be testing the resilience of these places, not only physically but also economically. While mitigation and adaptation practices may help relieve some of the burden of change, decision support systems have to be built in the context of an evolving locality. One such support system in Cuba was the restructuring of university research and agricultural extension services.[174]

It is no secret that in the climate change discussions economics and moral philosophies are at the forefront of arguments.[175] Normative analyses of climate change implications dictate the value of adaptations. These analyses attempt to find

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[171] Raymond, C. M., Bryan, B. A., MacDonald, D. H., Cast, A., Strathearn, S., Grandgirard, A., & Kalivas, T. (2009). Mapping community values for natural capital and ecosystem services. Ecological economics, 68(5), 1301-1315.
Alessa, L. N., Kliskey, A. A., & Brown, G. (2008). Social–ecological hotspots mapping: a spatial approach for identifying coupled social–ecological space. Landscape and urban planning, 85(1), 27-39.
[172] Sharlene Mollett, "The Power to Plunder: Rethinking Land Grabbing in Latin America," *Antipode* 48, no. 2 (2016): 412–32, https://doi.org/10.1111/anti.12190.
[173] Carol Hunsberger et al., "Climate Change Mitigation, Land Grabbing and Conflict: Towards a Landscape-Based and Collaborative Action Research Agenda," *Canadian Journal of Development Studies / Revue Canadienne d'études Du Développement* 38, no. 3 (2017): 305–24.
[174] Jorge Núñez Jover et al., "Higher Education, Innovation and Local Development: Experiences in Cuba," *National Innovation Systems, Social Inclusion and Development*, August 29, 2014, https://www.elgaronline.com/view/edcoll/9781782548676/9781782548676.00014.xml.
[175] Benjamin S. Lowe, "Ethics in the Anthropocene: Moral Responses to the Climate Crisis," *Journal of Agricultural & Environmental Ethics* 32, no. 3 (2019): 479–85, https://doi.org/10.1007/s10806-019-09786-z.

the pareto optimal balance of suffering and duties of noncomplier nations.[176] Purdon (2017) argues from a neoclassical realist perspective that concerns over relative gains, i.e. material gains and losses, prevent certain states from committing to reduce emissions and contribute to climate funds for impacted nations.[177] Additionally, they are primarily using funds already made available for development projects rather than funding new adaptation and reparations projects.

In 'Prosperity without Growth: Economics for a Finite Planet' Jackson argues 'decoupling' increasing resource use and economic growth is impossible.[178] He argues that grassroots efforts are needed to change our convention that affluence is prosperity. This assumption by many, that access to consumption is equity, translates into a desire to 'develop' that creates conflicting values between the economy, environment, and an equitable society. In practice, researchers have found that degrowth efforts are prone to foisting Western style development on countries trying to recover from Western colonialism and neocolonialism.[179] Synonymous with growth in past international development efforts were the construction of Western infrastructure projects that promised to correct failing economies. Lesser are the efforts to value the knowledge and experiences of local people when deciding how to adapt and compensating them for their ideas as well as we compensate major engineering and design firms.

In Hornborg's 2009 paper, notably published in a sociology journal, he calls out resilience and sustainability discourses as disarming the reality of a developing societal collapse.[180] He names five 'cultural illusions' that aid in postponing response to the crisis. Among them are machine fetishism, interpreting inequality as developmental stages; reaching a 'sustainable development through consensus; and acknowledging that fossil-fuel consumption is driving climate change. Through these cultural illusions and the structuring of the UN and development banks, polluting nations stall change. Such control of global policy by the wealthiest countries is also well noted and described by Bond.[181] The evaluation and promotion

[176] Ravi Kanbur and Henry Shue, *Climate Justice: Integrating Economics and Philosophy* (Oxford: OUP Oxford, 2018), https://doi.org/10.1093/oso/9780198813248.001.0001.
[177] Mark Purdon, "Neoclassical Realism and International Climate Change Politics: Moral Imperative and Political Constraint in International Climate Finance," *Journal of International Relations and Development* 20, no. 2 (April 1, 2017): 263–300, https://doi.org/10.1057/jird.2013.5.
[178] Jackson, Tim. Prosperity without Growth: Economics for a Finite Planet. London: Earthscan, 2009
[179] Schneider, François, Giorgos Kallis, and Joan Martinez-Alier. "Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue." *Journal of cleaner production* 18, no. 6 (2010): 511-518. Demaria, Federico, Francois Schneider, Filka Sekulova, and Joan Martinez-Alier. "What is degrowth? From an activist slogan to a social movement." *Environmental Values* 22, no. 2 (2013): 191-215.
[180] Hornborg, Alf. "Zero-sum world: challenges in conceptualizing environmental load displacement and ecologically unequal exchange in the world-system." International Journal of Comparative Sociology 50, no. 3-4 (2009): 237-262.
[181] Patrick Bond, "Politics of Climate Justice," *Paralysis above, Movement below. University of Kwa Zulu Natal Press, Cape Town*, 2012; Patrick Bond, "From Copenhagen to Cancún to Durban: Moving Deckchairs on the Climate Titanic," *Capitalism Nature Socialism* 22, no. 2 (2011): 3–26.

of adaptation is further complicated by attempts to assess social sustainability. Colantonio describes critiques of social impact assessments, narrow definitions of environment, and a lack of measuring 'soft' concepts of social well-being.[182] She finds some promising examples in local authorities defining social sustainability, something that would clearly be a complex endeavor and make it difficult to compare progress of different localities. In short, if social sustainability was represented using meaningful local concepts, there would not be a major global consensus as is sought by the UN.

Motivational Framing – Positionality Statement

The primary motivation for this study is to meet the requirements of completing a dissertation. Additionally, I sought to inform myself on the international adaptation ecosystem to better position themselves in laboring for a more just future. The overarching goal in seeking this knowledge is to be better informed on how to reduce poverty while operationalizing environmental sustainability. Two datasets used in this study were created by the two largest contributors to climate change, the United States, and the European Union. The area of study, Cuba, and the datasets used were chosen for the mordancy of using data created by mainstream economies to 'see' and interpret a nation that practices heterodox economies. This tension was leveraged in this chapter to highlight the limitations of capital driven development.

The overarching purpose of this dissertation is to investigate the development trajectories of Cuba after its economic collapse in the 1990s. This is partially motivated by Cuba's singularity in the region but also because it had to significantly reduce fossil fuel consumption and reorganize its economy to survive. In order to discern patterns in development, datasets that are part of the International Development and climate change adaptation canon are used. The sociotechnical system that generated the data must be acknowledged to understand the limitations of the data and any analysis produced. This chapter contextualizes the datasets and the concept of development in which they were created. This chapter also lays out what aspects of Cuba stand out from other countries in its region. The adaptive capacity of a nation has physical and social components. Social limitations to climate change adaptation described by Adger, including ability to set and meet goals at all levels of government, may be different in Cuba.[183] At the very least, the institutions managing land in Cuba use alternate methods from mainstream

[182] Andrea Colantonio, "Social Sustainability: A Review and Critique of Traditional versus Emerging Themes and Assessment Methods," ed. M. Horner et al. (Loughborough: Loughborough University, 2009), 865–85, http://www.sue-mot.org/conference/.
[183] W. Neil Adger et al., "Are There Social Limits to Adaptation to Climate Change?" *Climatic Change* 93, no. 3–4 (2009): 335–54.

governments. On the island there is far less influence from multinational corporations, better educational equity, and close to thirty years of experimenting with more ecologically sound agricultural methods. The island also has social constraints unique to its situation, related to a government that is still very centralized despite efforts to release some control over the nation, and limitations to participating in the global economy that are related to the illegal U.S. embargo. Studying Cuba provides a unique look at alternative mechanisms nations can deploy to adapt to climate change.

In recent interviews, Colombian President Gustavo Petro and Congressmember Jesús "Chuy" García of Illinois made a clear connection between U.S. interventions in Latin America and the ongoing economic and sociopolitical crises that are leading to an increase in refugees leaving their homes to find opportunities in the global North.[184] In addition to the changing environment caused by global warming, making it harder for people in LAC to survive, U.S. economic blockades and political interventions throughout the present and past centuries have promoted instability and violence in the region. During a scoping visit to Havana, I witnessed a large billboard that stated the U.S. embargo was "the longest genocide in history". At first, I thought this was an impassionate Cuban exaggeration, but as this research progressed, I began to see the connections between such political decisions and loss of life. As a Mexican-American, I am further motivated by the desire to understand alternative perspectives on geo-politics in my home region, the LAC. Having been raised in the U.S. public school system, my understanding of international development came primarily from the perspective of American politics. I was fortunate to both travel back to Mexico throughout my life and witness their perspectives, as well as build community in the U.S. that enacted values of cross-cultural understanding, solidarity, popular education, and anti-oppression. These experiences have contributed to my positionality and motivation for this study.

Big D Development in the LAC[185]

Immediately after World War Two the UN promoted economic development were focused on building infrastructure for irrigation, transportation, and energy to serve as the backbone of "emerging economies" in attempts to have them emulate industrialized nations. This focus on large projects benefited those who could take

[184] Amy Goodman, Colombian President Gustavo Petro: Full Interview on Democracy Now! accessed September 25, 2023, https://www.democracynow.org/2023/9/22/full_interview_colombian_president_gustavo_petro; Democracy Now! "'Breaking Point': Cities Struggle with Rise in Asylum Seekers; U.S. Foreign Policy Linked to Increase," accessed September 27, 2023, https://www.democracynow.org/2023/9/27/immigration_border.

[185] Reference to a capital letter development comes from a lecture by Isha Ray in Water & Development course at UC Berkeley. It signals a formalized type of development.

advantage of economies of scale, mainly large landowners, those with investment capital, and cities; furthering the marginalization of rural areas and those historically marginalized by colonialism. Irrigation and road networks allowed these developing nations, such as Mexico, to grow agricultural and mineral exports.[186] As previously colonized nations began to industrialize the export of natural resources, the colonizing nations reaped benefits on a scale never seen before.

The Prebisch-Singer thesis, published at the end of the 40's, argued that the terms of trade between industrialized nations and those exporting primary products would always favor the former. LAC countries continued to borrow money to fund infrastructure projects from productive sectors. Part of the Prebisch-Singer thesis sees their resources (GDP) funneled abroad as they traded raw goods or primary products with little added value for manufactured products that they lacked the industries to produce. Mainstream theorists pushed for an export based industrial economy as the means to generate economic growth; while dependency theorists also argued for protecting the local manufacturing sector so that it may develop without global competition.[187] Import substitution industrialization (ISI) incentivized LAC countries to invest in major urban areas and social development programs that promoted industrial labor. In order to protect the emerging industrial sector, promote key materials for export, and increase social capital, central governments grew in size and scope.[188] To finance these activities LAC governments took on large amounts of international debt rather than promoting foreign direct investment or self-sustenance.

During this phase of industrialization, urban areas grew dramatically in an unplanned fashion and there was significant degradation of the environment as it was left unprotected to facilitate the economic activities.[189] Pollution and habitat loss throughout the LAC region thus resulted in capital gains for the international elite. The massive loans, corruption, and extraction of GDP from LAC created an economic crisis when these countries could not pay back the loans.

The loan crisis of the 1980's exposed the degradation of the environment, disparities in the quality of education, and informal sections of major metropolitan areas

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[186] Janet Torres, "Integrated Water Management Practices in Mexico and Their Impact on Local Drinking Water Quality: Efficient Assessment Methods" (Thesis, 2016), https://oaktrust.library.tamu.edu/handle/1969.1/156791.
[187] Oscar Altimir, "Desigualdad, empleo y pobreza en América Latina: Efectos del ajuste y del cambio en el estilo de desarrollo," *Desarrollo Económico* 37, no. 145 (April 1997): 3, https://doi.org/10.2307/3467151.
[188] Carlos De Mattos, "Modernización Capitalista y Transformación Metropolitana En América Latina: Cinco Tendencias Constitutivas," *América Latina: Cidade, Campo e Turismo* 1 (2006): 41–73.
[189] Osvaldo Sunkel, "La interacción entre los estilos de desarrollo y el medio ambiente en América Latina," *Revista CEPAL Economic Commission for Latin America and the Caribbean*, Seminario Regional sobre Estilos de Desarrollo y Medio Ambiente en América Latina, December 1980, https://repositorio.cepal.org/handle/11362/12022.

populated with rural migrants seeking refuge and dignity. The migration pressure was so high that between 1950 and 1980 the region saw the rural labor pool decrease from 55% to 32%. The economic contraction, known in the region as the "Lost Decade", led to a 15% decrease in per capita GDP after the crisis and an increase in poverty from 35% to 39% mostly in urban areas.[190] Cuba's leader at the time, Fidel Castro, responded to the debt crisis by suggesting a united front among the LAC to have debts cancelled, arguing it would benefit international trade because it would increase purchasing power.[191] While not calling for a full-on boycott of payments, Castro suggested loaner countries pay the loans with part of their defense budgets in order to prevent the banks from going under. Cuba's own foreign debt at the time was considerable and coming from both Western and Soviet sources.

Debt significantly increased in the 1970's as favorable sugar markets and increased yields from industrialized sugarcane production allowed Cuba to keep up repayments. Cuba was able to negotiate debt and interest forgiveness from Soviet lenders in the 1980's after sugar prices crashed and, while less favorable, also reached agreements with Western (mainly European) lenders to reschedule payments.

Structural adjustment and austerity programs were imposed by IMF and WB throughout the LAC as a means to continue imposing a hierarchy of nations who have power in determining the global terms of trade.[192] The impact of development programs on national sovereignty and sociopolitical conditions in LAC have been described as an essential testing ground for policies that are now scaled to the globe and can be described as neocolonial.[193] While some attribute Cuba's position on loan repayment as a means to increase regional influence and acceptance, their alternative stance on negotiating loan repayments did result in more sovereign terms and lower costs.[194] Cuba is also credited as a main promoter of the idea of "odious debt" that continues to influence international debt markets.[195] Considering the size and relative purchasing power of Cuba, the island nation has a successful

[190] Altimir, Oscar. "Desigualdad, empleo y pobreza en América Latina: Efectos del ajuste y del cambio en el estilo de desarrollo." *Desarrollo Económico* 37, no. 145 (April 1997): 3. https://doi.org/10.2307/3467151.
[191] Rene lynette Bartusch, "Cuba: An Historical Appraisal of Its Foreign Debt and Soviet Economic Assistance and Cuba: An Evaluation of Its Military Relations with the Soviet Union.," *The University of Texas, Thesis*, 1986, 128.
[192] Larry Cata Backer, "Ideologies of Globalization and Sovereign Debt: Cuba and the IMF," *Penn State International Law Review* 24 (2006 2005): 497–562.
[193] Greg Grandin, *Empire's Workshop: Latin America, the United States, and the Rise of the New Imperialism* (Metropolitan Books, 2006).
[194] H. Michael Erisman, "Cuban Foreign Policy and the Latin American Debt Crisis," *Cuban Studies* 18 (1988): 3–18.
[195] L. C. Backer, "Cuba and the Development of Odious Debt Doctrine in an Age of Financial Crisis," *Transnational Dispute Management (TDM)* 6, no. 1 (2009).

history of global influence on development strategy. Cuba will be critical to observe as they manage climate change adaptation and mitigation negotiations.

The habitus of many of the permanent nations in the Security Council is one predicated on seeking economic growth. Their position of power has created a homogeneous approach to climate change adaptation that threatens to recreate historical power imbalances that created the climate crisis. A "critical transition" is being anticipated in general systems theory which hypothesizes that the adaptation of human systems will depend on the systems' connectivity and component heterogeneity, rather than the centralized practices of the past.[196] A particularly vulnerable component of global human systems are the landscapes we depend on for food and ecosystem services. Industrialized systems of agricultural production with high input requirements have been established in many nations to satisfy global demand. Place specific changes to landscapes and the local habitus have marked participants of neoliberal globalization with environmental degradation, unsustainable urbanization, and the disentanglement of local social networks.[197] In participating LAC countries, the impacts have been well researched and many social limitations have been found in the implementation of sustainable practices.[198] Among them, highly variable educational quality and weak local governments have made decentralization difficult. Additionally, interference with national sovereignty, exploitative international relationships, and an assimilatory approach to international development are recognized social limits to a just and sustainable climate change adaptation.[199] Small Island nations are the most vulnerable to natural disasters, not only because of their increased exposure to extreme weather events but also from a lack of economic diversity and resources for recovering.[200]

Climate justice politics point to the necessity of the global elite paying climate reparations to the Caribbean, among other places. Reparations are owed for damages rooted in a history of violently enforced colonial logics that led to contemporary environmental degradation, international debts, and social exploitation through neo-liberalization. Considering the climate debts owed to

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[196] Scheffer, M., Carpenter, S. R., Lenton, T. M., Bascompte, J., Brock, W., Dakos, V., ... & Vandermeer, J. (2012). Anticipating critical transitions. science, 338(6105), 344-348.

[197] Eric F. Lambin and Patrick Meyfroidt, "Global Land Use Change, Economic Globalization, and the Looming Land Scarcity," *Proceedings of the National Academy of Sciences* 108, no. 9 (March 1, 2011): 3465–72, https://doi.org/10.1073/pnas.1100480108; Ruth S. DeFries et al., "Deforestation Driven by Urban Population Growth and Agricultural Trade in the Twenty-First Century," *Nature Geoscience* 3, no. 3 (2010): 178; Thomas Reardon and Christopher B. Barrett, "Agroindustrialization, Globalization, and International Development: An Overview of Issues, Patterns, and Determinants," *Agricultural Economics* 23, no. 3 (2000): 195–205.

[198] Stallings, Barbara, and Wilson Peres. *Growth, employment, and equity: The impact of the economic reforms in Latin America and the Caribbean*. Brookings Institution Press, 2010.

[199] John Narayan and Leon Sealey-Huggins, "Whatever Happened to the Idea of Imperialism?," *Third World Quarterly* 38, no. 11 (November 2, 2017): 2387–95, https://doi.org/10.1080/01436597.2017.1374172

[200] Adelle Thomas et al., "Climate Change and Small Island Developing States," *Annual Review of Environment and Resources* 45, no. 1 (2020): 1–27, https://doi.org/10.1146/annurev-environ-012320-083355.

Caribbean nations, and the importance of data in restructuring our systems to allow our societies to reach a sustainable state, it is paramount that we test the data's legitimacy in capturing change in the region. At the most basic level of human needs, food security and food sovereignty are major issues in SIDS that is tightly linked to their engagement with international trade.[201] Within laissez faire framing, economists look for 'natural experiments' to observe and learn from. As much as policy is natural, Cuba is an assay for states trying to show adaptability and resilience in the face of environmental challenges and major shifts in what they consume, produce, and trade. Cuba also has limited trade relations because of the U.S. embargo, which tests not only the ability of the island to self-sustain but also challenges mainstream economic thought that small nations must trade with the global elite.

Formal but UNenforceable Definition

Development is defined internationally by the United Nations through development goals and funding choices.[202] In general, Development refers to a change towards a more desired state. The ideologies of the participating nation, with corresponding balances of power, define the desired state with a set of goals, targets, and indicators. Previously associated with the Millenium Development goals, the UN acknowledged the complexity in defining development, including defining a vision for a desirable society acknowledging historical process and that action were needed to advance the agenda.[203] Since the Brundtland report in 1987 the UN acknowledged, to some extent, our need to consider future generations in our actions.[204] The UN's Sustainable Development Goals (SDG) are the closest to an international comprehensive plan to integrate complexity into planning through integrative systems management.[205] Even so studies have found them to insufficiently hold States accountable to the extraterritorial responsibilities they set (through development goals and international agreements); regardless of their

[201] Connell et al., "Food Security and Sovereignty in Small Island Developing States."
[202] Richard Jolly, "Global Development Goals: The United Nations Experience," *Journal of Human Development* 5, no. 1 (March 2004): 69–95, https://doi.org/10.1080/1464988031000166021O.
[203] https://www.mdgmonitor.org/what-is-development-guide/ accessed 9/6/2018 Development is complicated as noted "Development as a historical process: This refers to social change that occurs over extended periods of time due to inevitable processes. For instance, it is widely believed that both communism and capitalism are an inevitable outcome of progress."
[204] SPECIAL WORKING SESSION WCED, "World Commission on Environment and Development," *Our Common Future*, 1987. "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
[205] Griggs, David, Mark Stafford Smith, Johan Rockström, Marcus Öhman, Owen Gaffney, Gisbert Glaser, Norichika Kanie, Ian Noble, Will Steffen, and Priya Shyamsundar. "An integrated framework for sustainable development goals." Ecology and Society 19, no. 4 (2014).

knowledge that the majority of the harm climate change brings will be imposed on smaller economies.[206]

The SDG's integrative framework is based on complex systems theories that communicate interactions between systems (ecological, social, economic, political, etc.) and scales of systems.[207] For example, the political system may be divided into hierarchical boundaries (federal, state, county, and city governments) which overlap despite jurisdictional limits and are further complicated by separate social processes at each level. Each of these system scales has a corresponding relationship with macro and micro forces in the economy and all of the possible environmental regions they intersect with.[208] Together these systems give rise to complexity, which planning must manage, not resist. The interactions between planning and ecology have also transferred concepts like resilience, adaptation, and regime shifts into development theory.[209]

The concept of resilience is used widely across other fields, providing a common lexicon across the soft and hard sciences.[210] Interest has naturally arisen in optimizing resilience for human benefits.[211] Folke examines resilience with temporal dimensions, looking at the trajectories of systems through select indicators to discern patterns of alternate system states. As a system moves from a desired state to a less desired state, thresholds appear that if crossed can lead to cascading system failure or new but different desirable states.[212] Success of models in predicting system state direction are based on the robustness of the indicator used to measure change.[213] Finding robust indicators of system change is important for the creation of early warning systems and the evaluation of policy effectiveness.[214] Folke hypothesizes that once appropriate indicators are found, they can be applied to solve complex problems threatening human settlements that require integrative solutions.

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[206] Daniel Chong, "The Sustainable Development Goals and Climate Change," *Social Alternatives* 37, no. 1 (2018): 43–48, https://doi.org/10.3316/ielapa.573720576046699.
[207] Cs Holling, "Understanding the Complexity of Economic, Ecological, and Social Systems," *ECOSYSTEMS* 4, no. 5 (August 2001): 390–405.
[208] C.s. Holling, "From Complex Regions to Complex Worlds," *Minnesota Journal of Law, Science & Technology*, 2005, 1.
[209] Lance H Gunderson, "Ecological Resilience: In Theory and Application," *Annual Review of Ecology and Systematics*, 2000, 425.
[210] Hosseini, Seyedmohsen, Kash Barker, and Jose E Ramirez-Marquez. "A review of definitions and measures of system resilience." Reliability Engineering & System Safety 145 (2016): 47-61.
[211] Biggs, Reinette et al. "Toward principles for enhancing the resilience of ecosystem services." Annual review of environment and resources 37 (2012): 421-448.
[212] Folke, Carl et al. "Regime shifts, resilience, and biodiversity in ecosystem management." Annual Review of Ecology, Evolution, and Systematics (2004): 557-581.
[213] Dakos, Vasilis et al. "Robustness of variance and autocorrelation as indicators of critical slowing down." Ecology 93.2 (2012): 264-271.
[214] Dakos, Vasilis et al. "Resilience indicators: prospects and limitations for early warnings of regime shifts." Philosophical Transactions of the Royal Society B: Biological Sciences 370.1659 (2015): 20130263.

Indicators alone are reductive and their use alone in determining if ideas are successful can politicize desired outcomes. While mathematical, indicators are subjective and can normalize the ideals of those powerful enough to influence their creation.[215] The GDP (Gross Domestic Product) is an indicator known to have stimulated controversy over its ability to measure the wellbeing of a country. Angrist et al explains some common critiques, including governments lying or changing the way GDP is measured to gain a more favorable position globally. This is thought to be true especially of developing economies. However, their research showed that while it is hard to capture all of the growth and decline because of a lack of broad statistics, and hard to measure growth in the agricultural sector and the informal economy, they did not find a first order issue in the statistical integrity of IMF GDP data.[216] Even so they admit that year to year changes are difficult to capture because of possible noise in GDP data, and that using supplementary data like Nighttime Lights helps in determining longer term trends.

Datafied World for Sustainable Development

The Fourth scientific paradigm, as declared by Microsoft research, centers scientific discovery on data intensive processes.[217] This paradigm requires expensive, large-scale computing infrastructure to operate. Some of the software and data are open source and publicly available but for the most part the best available data and software is proprietary and expensive to access. The creators of the data usually have priority access to analyzing it and generating a story about what is happening on the ground. Datasets related to the environment are frequently used in development studies to determine if a country is staying in line with the goals set for them. As used in this dissertation, datasets like nighttime lights and land cover are alternatives that can be used to model future state predictions, carbon cycles, and estimates of economic development, as well as studies that privilege mainstream economics, such as how much of a given resource is available for extraction.

The Millennium development goals were criticized for lacking intra-national data. In other words, the level of aggregation in the data collected was too low in resolution to meet the needs of people wanting to hold governments accountable for equitably distributing development. Alternatively, data collected by satellites has the potential to generate comparable information about what is happening within

[215] Simon Mair et al., "A Critical Review of the Role of Indicators in Implementing the Sustainable Development Goals," in *World Sustainability Series*, 2017, https://doi.org/10.1007/978-3-319-63007-6_3.
[216] Noam Angrist, Pinelopi Koujianou Goldberg, and Dean Jolliffe, "Why Is Growth in Developing Countries So Hard to Measure?" *Journal of Economic Perspectives* 35, no. 3 (August 2021): 215–42, https://doi.org/10.1257/jep.35.3.215.
[217] Anthony JG Hey, Stewart Tansley, and Kristin Michele Tolle, "The Fourth Paradigm: Data-Intensive Scientific Discovery" 1 (2009).

different countries' borders. This would be useful when trying to enforce an agreed upon set of goals in which equity and environmental responsibilities are being met. In practice, however, satellite data checks are mostly done to judge developing countries. If access to the data and analytical tools was equitable, citizens could counter with surveillance and sousveillance.[218] This level of bottom-up evaluation is only possible with engaged communities with mechanisms to hold governments liable.

In reality, limitations in early satellite technology and prioritization of the free market that allows high-resolution data to be privately held, have resulted in public global land cover datasets with low spatial resolutions. Low resolution data is most suitable for use in global models and "regional studies", not to monitor or analyze conditions at a subnational level. The need for subnational data has been highlighted as early as the Millenium Development Goals.[219] Higher spatial and spectral resolution data is available from the private sector at a cost that maximizes profit from minimally processed data that is not typically classified into land cover categories. Least developed to middle-income countries will face greater climate change adaptation challenges and within them, already marginalized populations will be more vulnerable.[220] These could be partially mitigated with access to quality, co-constructed data, empowering these countries to utilize this data in advancing their implementation of socio-economic goals catalyzed by climate change.

Global Land Cover

Currently, the United Nations (UN) recognizes the importance of accurate open data for monitoring and evaluating human interactions with the environment as we respond to the climate crisis. In response the European Space Agency produced annual global land cover maps from 1992-2019. The maps were produced through the Climate Change Initiative (**ESA CCI**) using the UN's Food and Agriculture Organization's (FAO) Land Cover Classification System with 22 global classes.[221] This dataset is the most extensive, standardized, open data source available for the entire Earth at a 300m spatial resolution.

This data is readily used by contemporary imperialists for global models that dominate the framing of climate change and are used to produce aggregated

[218] Simone Browne, *Dark Matters: On the Surveillance of Blackness* (Duke University Press, 2015).
[219] Maya Fehling, Brett D. Nelson, and Sridhar Venkatapuram, "Limitations of the Millennium Development Goals: A Literature Review," *Global Public Health* 8, no. 10 (December 2013): 1109–22, https://doi.org/10.1080/17441692.2013.845676.
[220] Bramka Arga Jafino, Jan H. Kwakkel, and Behnam Taebi, "Enabling Assessment of Distributive Justice through Models for Climate Change Planning: A Review of Recent Advances and a Research Agenda," *WIREs Climate Change* 12, no. 4 (2021): e721, https://doi.org/10.1002/wcc.721; Rose-Ann J. Smith and Kevon Rhiney, "Climate (in)Justice, Vulnerability and Livelihoods in the Caribbean: The Case of the Indigenous Caribs in Northeastern St. Vincent," *Geoforum* 73 (July 1, 2016): 22–31, https://doi.org/10.1016/j.geoforum.2015.11.008.
[221] Geomatics, *Land Cover CCI.*

regional land cover trends for nations to consider when creating environmental policies. An example of how worldviews are embedded in these datasets is apparent in the ESA's CCI land cover dataset. The focus on forest cover types can be interpreted as much as a reflection of the rich diversity of trees as it is a product of the Western obsession with deforestation, carbon sequestration, and the EU decision to categorize wood pellets as a renewable source of energy. For example, the CCI dataset has been used to calculate the "sustainable" planetary boundary of roundwood to supply Germany's bioeconomy, which is dependent on imports.[222] Directives on renewable energy from the European Union established their demand for wood products and sustainability criteria. Camia et al's research found inconsistencies of 20% in the amount of wood used and the reported sourced amount.[223] The report also found an increasing trend in the amount of wood used for energy production with unknown origin. These could be associated with illegal logging and the Egenolf et al acknowledge the need to improve quality of data to safeguard a sustainable and resilient resource use and warns that using the term "sustainable" for all renewable resources can be used as an excuse to continue unsustainable consumption patterns.[224] The report states that satellite data is becoming increasingly important as supplementary data to traditional inventory surveys. Adding to the urgency of distributing the power of generating data to monitor the Earth away from those primarily responsible for climate change.

Nighttime Lights

A fascinating dataset and ingenious creation by the U.S. Air Force is the nighttime lights dataset. This dissertation used the stable lights, radiance calibrated, Version 4 DMSP-OLS Nighttime Lights annual time series 1992-2013, which was recently made available by the Colorado School of Mines.[225] This dataset has been available to the public for many years but was not calibrated. This added to the burden of using it because it required the researcher to choose a calibration method and implement it. The calibrated annual dataset was finally released in 2021. Monthly versions are also available now for a cost. Since the DMSP-OLS and the VIIRS

[222] Vincent Egenolf et al., "The Timber Footprint of German Bioeconomy Scenarios Compared to the Planetary Boundaries for Sustainable Roundwood Supply," *Sustainable Production and Consumption* 33 (September 1, 2022): 686–99, https://doi.org/10.1016/j.spc.2022.07.029. The measure of sustainability used was one defined by the Finnish forest sector of less than or equal to 80% of annual increment. They note that Greenpeace recommends a limit to 50% removal. A 100% removal in forest plantation areas was used as the sustainable harvest rate.

[223] A. Camia et al., "The Use of Woody Biomass for Energy Production in the EU" (Publications Office of the European Union, 2020), https://publications.jrc.ec.europa.eu/repository/handle/JRC122719.

[224] Egenolf et al., "The Timber Footprint of German Bioeconomy Scenarios Compared to the Planetary Boundaries for Sustainable Roundwood Supply."

[225] "Earth Observation Group - Defense Meteorological Satellite Program, Boulder | Ngdc.Noaa.Gov," accessed March 26, 2019, https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html; Feng-Chi Hsu et al., "DMSP-OLS Radiance Calibrated Nighttime Lights Time Series with Intercalibration," *Remote Sensing* 7, no. 2 (2015): 1855–76; Christopher D. Elvidge et al., "Radiance Calibration of DMSP-OLS Low-Light Imaging Data of Human Settlements," *Remote Sensing of Environment* 68, no. 1 (1999): 77–88.

nightlight datasets are from very different satellites and require additional work that was out of the budgetary scope of this study, only the years 1992-2013 were analyzed. This requirement contributes to the limitations for smaller entities to use the datasets to monitor their government's work, including disaster recovery and socioeconomic programs.

Ancillary Data

Throughout this dissertation information from the Central Intelligence Agency (CIA) World Factbook and the World Bank's DataBank are used. The data collected and published by institutions like the CIA or the World Bank are often the only consistently collected and published indicators associated with development. The founding of the CIA in 1947 and its tampering with local political movements in order to build governments amenable to U.S. interests in the LAC is not something to be forgotten when using these datasets.[226] This data is collected to monitor stability and order as it is defined by the U.S. government and the UN, in the case of the DataBank. While the Factbook holds a significant amount of information over many decades, none of the data is available as a dataset. Any analysis of it by other parties required the data to be manually scraped from documents found across the two platforms. As mentioned here in Chapter One with regard to land cover types and limitations to time series analyses, the indicators chosen to appear in the Factbook are not consistent. All of these datasets are difficult to use and have poor distribution mechanisms that make them burdensome for non-experts with limited budgets. Through the exploration of power relations and reparations we can see that these datasets, produced by the largest lending banks, U.S. CIA, Air Force, and the European Space Agency, limit the way we can see development throughout the world.

Cuban Exceptionalism

Scholarly work on Cuban development typically reflects the lack of political neutrality felt since the 1959 revolution. Policy enacted by the government either has robust results because of the strength of the central government (i.e., the literacy campaign) or fails because of it (i.e., housing stock). Similarly, external factors like the illegal U.S. embargo on Cuba are either made central points of development failures, uncertainty in long term planning, and even their low economic footprint on the environment, or their impact is completely ignored.[227] Others have focused on the national level efforts to survive through self-reliance

[226] Grandin, *Empire's Workshop*.
[227] Crawford, "Necessity Makes the Frog Jump."

after the Special Period began, regarding it responsible for Cuba's low ecological impact.[228] I approach this research from the perspective that regardless of governmental complexities, Cubans are actively confronting difficult adaptation challenges and have made concrete paradigm changes towards sustainability.

The island is an outlier in the region for many reasons. Among them is its closed approach to private property and isolation from capital driven development. Import Substitution Industrialization policies were mostly replaced by neo-liberal free market models throughout Latin America and the Caribbean, except in Cuba.[229] Although still operating under the familiar centralized government archetypes of Latin America, with strong federal governments heading taxation and natural resource management, the political ideologies of the country created barriers to all-encompassing forms of neo-colonialism that result from opening national economies to foreign investors. Like most countries in Latin America, Cuba has historically had regional imbalances in development and access to investment, partially due to high levels of governmental centralization bringing more power to areas physically closer to Havana.[230] Since the revolution, a core objective of the government has been to equalize development across the island, focusing on rural areas that were developed for exploitation rather than social growth throughout the island's history. This has included construction of facilities for healthcare and education, as well as literacy and work programs.

In its initial phase after the revolution in 1959, Cuba had to incorporate new realities of isolation that resulted from the U.S. response to a forced redistribution of assets, from foreigners to the Cuban government. This was strengthened by the 1962 U.S. embargo after Cuba's decision to join the council for Mutual Economic Assistance and collaborative militarization. The Soviet phase that followed implemented a state capitalist system that depended on industrial technologies from the ecologically catastrophic Green Revolution. Their response to the economic isolation felt after the U.S. embargo was multilateralism elsewhere, in 1964 partnerships with the USSR took over almost all of the previous trade the island had with the U.S.[231] The Soviet's economic assistance for Cuba included purchasing sugar at a subsidized price so the island could continue to use agricultural production to fund social reforms. Cuban resources were increasingly tied with

[228] Cabello et al., "An Approach to Sustainable Development."
[229] Jorge G. Castaneda, "Latin America's Left Turn Essay," *Foreign Affairs* 85 (2006): 28–44; John H. Coatsworth, "Structures, Endowments, and Institutions in the Economic History of Latin America," *Latin American Research Review* 40, no. 3 (2005): 126–44, https://doi.org/10.1353/lar.2005.0040; Erisman, "Cuban Foreign Policy and the Latin American Debt Crisis."
[230] SERGIO DÍAZ-BRIQUETS, "Regional Differences in Development and Living Standards in Revolutionary Cuba," *Cuban Studies* 18 (1988): 45–63.
[231] Lawrence H. Theriot and JeNelle Matheson, "Soviet Economic Relations with the Non-European CMEA: Cuba, Vietnam, and Mongolia," *Soviet and Eastern European Foreign Trade* 21, no. 1/2/3 (1985): 144.

Soviet interests. At one point the USSR supplied 95% of petroleum goods. In 1970, Fidel Castro pushed for an output of 10 million tons of sugar to be exported. The mission failed and ignored other industries, funneling labor and capital into the sugar industry, and seriously undermining the environmental damage generated by agricultural intensification.

Overall, Cuba's Soviet era is characterized by a lack of national autonomy caused by new dependence on foreign Soviet trade partners. Since the Cuban government had centralized control of production, and most other aspects of daily life, participation at the local level was mostly symbolic. Soviet industrialization led to limited options for commodifying water and products derived from land use. While the legislative process was characterized as "highly participatory" most of the planning and management operated in a top-down fashion.[232] Garcia (1988) describes the environmental law of this time as one whose role is to balance between "conservative" strategies to prevent pollution and "rational" goals to maximize benefit to society through cost-benefit analysis. When combined with socialist economic theory at the time, Cuba's environmental law, in practice, did not recognize that environmental harm could be done if social good was being produced.[233] For example, a law prohibiting dams that significantly change the environment existed, as did constitutional duties to the state, society, and the individual to protect the environment, but had loose requirements for what constituted irreversible harm.

Post-revolution, Cuba experienced the first decrease in GDP in 1985 although it had started seeing a decrease in economic productivity in the 80's. This was due not only to soil degradation but also to inefficient management of the national economy and willful lack of participation in the centralized economy by workers.[234] Availability of laborers for economic activity was also impacted by the older age distribution of Cubans and slow rate of population growth.[235] These factors combined to lower the number of people able to work and thus lower economic productivity on the island. Using the OEC data visualizer and the SITC dataset we can see the spike in exports in the 1980's of Cuban exports from 1962 to 2018 in Figure 53.

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[232] Ricardo Garcia and Todd Howland, "Cuban Environmental Law: An Analysis from the International Right to Developmental Perspective," n.d., 26.
[233] Sergio Diaz-Briquets and Jorge F. Pérez-López, *Conquering Nature: The Environmental Legacy of Socialism in Cuba*, Pitt Latin American Series (Pittsburgh, Pa.: University of Pittsburgh Press, 2000., 1999).
[234] Juan Carlos Albizu-Campos Espiñeira, "¿Es El Descenso de La Actividad Económica de La Población Un Fenomeno Temporal En Cuba? Translated Title: Is the Decline in the Economic Activity of the Population a Temporary Phenomenon in Cuba? ," *International Journal of Cuban Studies*, July 1, 2020, https://doi.org/10.13169/intejcubastud.12.1.0053.
[235] Judith Hernández and Guillermo Foladori, "The Population Dynamic Challenge to Cuban Socialism," *International Journal of Cuban Studies* 6, no. 1 (2014): 25–40, https://doi.org/10.13169/intejcubastud.6.1.0025.

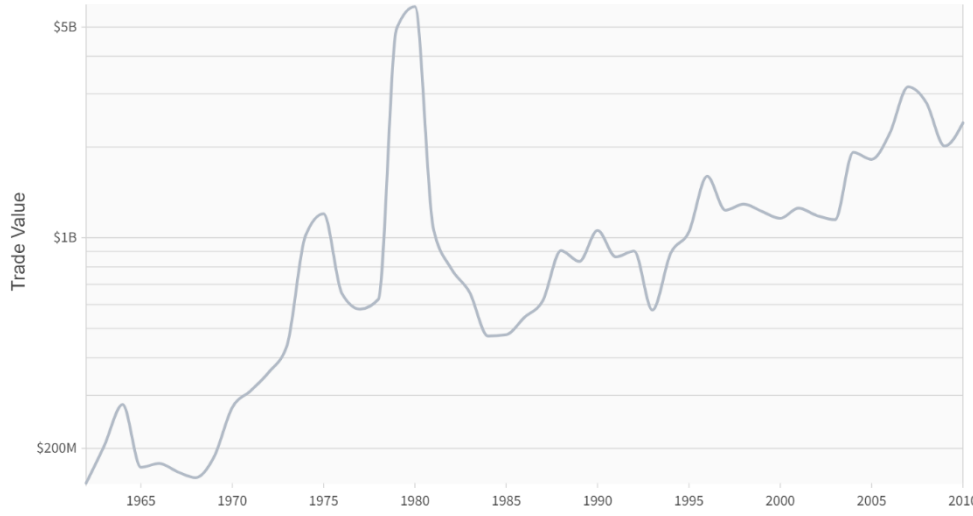

Figure 53 Trade value of Cuban Exports using SITC data 1962-2018

The Special Period saw an increase in the informal economy and rapid changes in industrial employment, making employment difficult to control and measure [236]. Early efforts to develop a socialist economy had mixed impacts on the environment. For example, the government employed people through reforestation projects while simultaneously engaging with the Green Revolution and expanding industrial agriculture. Only since the Special Period began has Cuba created a government agency for environment protection and restructured agricultural programs to recenter local producers and give support to farms of all sizes. The 1990's also brought a change in the role of inclusive development at Cuban universities who were tasked with innovation to aid in the economic recovery and eventually turned to local actors in a "territorial turn".[237] This academic practice of social inclusion and autonomy of local actors rather than a top-down approach proved to increase their ability to solve problems and innovate within a local context.

There is conflicting evidence on the amount of racial equity within the country. While the revolution did set out to make all Cubans equal, there is evidence that racial justice has not been served on the island to its full potential. During the Soviet period, programs to bring about a more egalitarian nation ignored race and did not specifically target a culture of racism that had been in production since the Spanish arrival and made worse by enslavement of African people. The lack of anti-racist programs only contributed to the reproduction of racist beliefs among communities despite progress being made in education and access to social

[236] V. O. Pérez et al., "Miradas a La Economía Cubana," *Editorial Caminos, La Habana*, 2009.
[237] Jorge Núñez Jover et al., "Higher Education, Innovation and Local Development: Experiences in Cuba," *National Innovation Systems, Social Inclusion and Development*, August 29, 2014, https://www.elgaronline.com/view/edcoll/9781782548676/9781782548676.00014.xml.

resources.[238] More recently, there is evidence that the Special Period is exacerbating inequality in Cuba.

During scoping trips there it was clear that some people had access to the convertible Cuban currency that foreign visitors use, and others did not. Hosts I stayed with also spoke of remittances from foreign relatives making it possible to refurbish buildings to host tourists. This can potentially lead to racial disparities, as families who left Cuba after the revolution and during the peak of the crisis tended to be of higher social status. There have also been studies indicating governmental representation was not equitable. This has been observed in the lack of diversity of councilmembers from districts with primarily afrodecendency and in the funding and legitimization of popular culture.[239] As much as the U.S. embargo impacted the access of goods and services available to the Cuban people, we must also highlight the undercutting to development that social repression by the Cuban government had, including censorship.[240] Control over society extended to individual mobility. For example, for the most part Cubans are not allowed to move freely throughout the island. Internal migration is controlled passively through work permits and driver's licenses.[241] There are even coastal resorts where Cubans are not allowed to visit unless they are employees. There is much evidence, and no need to deny, that many of the paradigm shifts towards sustainability and increased civil liberties were a manifestation of the need to survive rather than a comprehensive plan.[242] This makes Cuba a potential model for countries that are protracted in their efforts to adapt to climate change and will eventually find themselves in a crisis.

The "reanimation" of the Cuban economy started in 1996 but took a more serious turn after Fidel Castro stepped down.[243] In addition to the continuation of programs promoted during the Special Period, the reanimation sought new ties to the global economy and an even stronger emphasis on the private sector as a means to decentralize and stabilize the economy. In order to better capitalize on its citizen's high level of education, an increase in international financing has been sought.[244]

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[238] Katrin Hansing, "Race and Inequality in the New Cuba: Reasons, Dynamics, and Manifestations," *Social Research: An International Quarterly* 84, no. 2 (2017): 331–49.
[239] Domínguez, "National Institutions, Spatial Differentiation and Race"; Rebecca M. Bodenheimer, *Geographies of Cubanidad: Place, Race, and Musical Performance in Contemporary Cuba* (Jackson: University Press of Mississippi, 2015).
[240] Elzbieta Sklodowska, *Invento, luego resisto: El Período Especial en Cuba como experiencia y metáfora (1990-2015)*, 1st ed. (Chile: Editorial Cuarto Propio, 2016).
[241] Andrés García Molina, "Nostalgia, Internal Migration and the Return of Cuban Street-Vendor Songs," *Culture, Theory and Critique* 61, no. 2–3 (July 2, 2020): 229–45, https://doi.org/10.1080/14735784.2020.1828119.
[242] Mario A. Gonzalez-Corzo, "Transition or Survival? An Analysis of Cuba's Post -Soviet Economic Reforms" (Ph.D., United States -- New Jersey, Rutgers The State University of New Jersey - Newark), accessed July 25, 2022, https://www.proquest.com/docview/305284571/abstract/8C0B93DF83164CC7PQ/1.
[243] Julia E. Sweign and Michael J. Bustamante, "Cuba after Communism: The Economic Reforms That Are Transforming the Island," *Foreign Affairs*, no. Issue 4 (2013): 101.
[244] Font, Mauricio A., and Carlos Riobó 2015 Handbook of Contemporary Cuba: Economy, Politics, Civil Society, and Globalization. Routledge.

Foreign investment also allows the government to get infrastructure developments and repairs underway despite having liquidity constraints.[245] Cuba has engaged in several Public-Private-Partnerships, in which the socialist government is always the majority stakeholder. These are primarily in capital intensive sectors like mining, energy, and transportation.[246] The increasingly role of the U.S as a trade partner is regarded as a needed injection of capital from trade and investments.[247]. The unstable nature of Cuban trade partners since the end of the Soviet trade bloc can be seen in Figure 54 below. With the sharp change from one trade partner to another usually comes a period of instability.

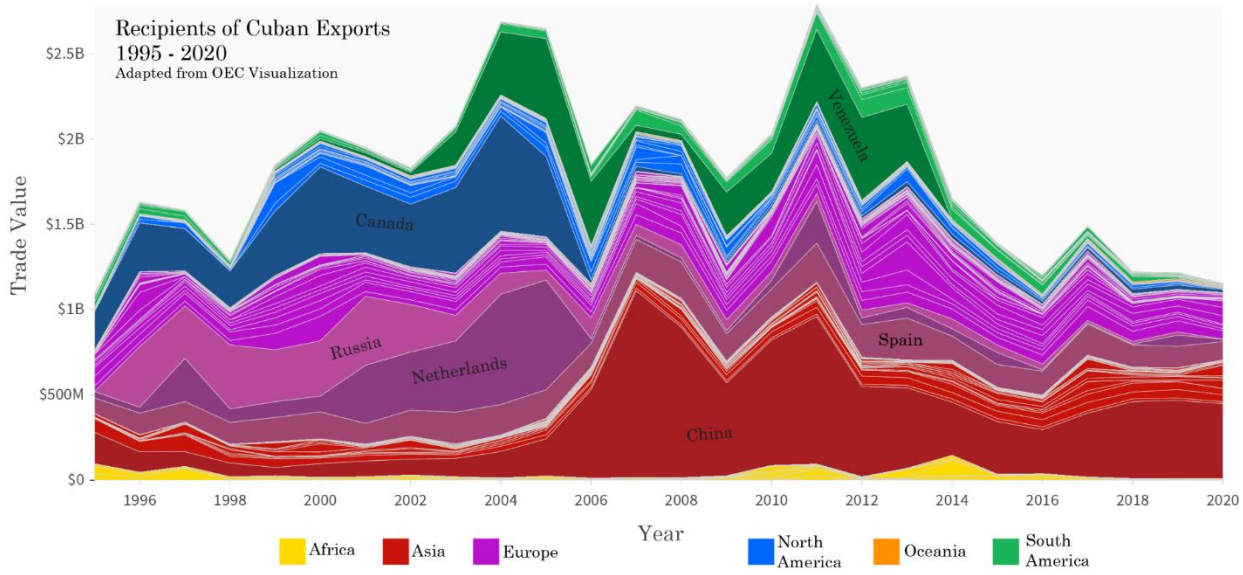

Figure 54 The changing Landscape of Cuban Trade Partners

We can see that Europe has been the primary recipient, with some intermittent increases from China, Venezuela, and the Cubans' primary North American trade partner, Canada. Canadian relations were maintained after the 1960's, one of only two from the continent, the other being Mexico. Canadian policy towards Cuba has been one of both aid and regional competitive advantage after the U.S. cut ties.[248] The illegal U.S. embargo, in direct contradiction to UN General Assembly policy

[245] Daito, Nobuhiko 2015 Infrastructure Public Private Partnerships in Cuba: An Overview. Center for Transportation P3 Policy. https://pdfs.semanticscholar.org/9f32/5749ef23bdce602c07a55884c920a362e71a.pdf
[246] Maal-Bared, Rasha 2006 Comparing Environmental Issues in Cuba before and after the Special Period: Balancing Sustainable Development and Survival. Environment International 32(3): 349–358.
Ritter, Archibald R. M., and Ted A. Henken 2014 Entrepreneurial Cuba: The Changing Policy Landscape. Lynne Rienner Publishers.
[247] "Overview of Cuban Imports of Goods and Services and Effects of U.S. Restrictions" (United States International Trade Commission, March 2016), https://www.usitc.gov/publications/332/pub4597.pdf.
[248] Eric N. Baklanoff and LaShondra Jones, "Deconstructing 'Constructive Engagement': Canada's Economic Relations with Cuba, 1993–2003," *ASCE* (blog), November 30, 2005, https://www.ascecuba.org/asce_proceedings/deconstructing-constructive-engagement-canadas-economic-relations-with-cuba-1993-2003/.

that has been approved annually since 1992 had and continues to have a profound impact on the resources available to Cuba.[249] Exports were chosen as an indicator of trade partnerships because it demonstrates who is willing to accept their exports and go against U.S. direction. Imports are equally important but were not chosen for display since the need to export is tied to a need for foreign capital to purchase imports. Exports also better capture the economic productivity on the island that is tied to land cover and NTL activity within its borders. To better understand fluxes in goods and capital available in Cuba we can simplify the matter by using the Balance of Trade (BOT) as an indicator.

The Balance of Trade between 2002-2018 was in greater deficit than the late 1990's as shown in Figure 55 below, adapted from the OEC.[250]

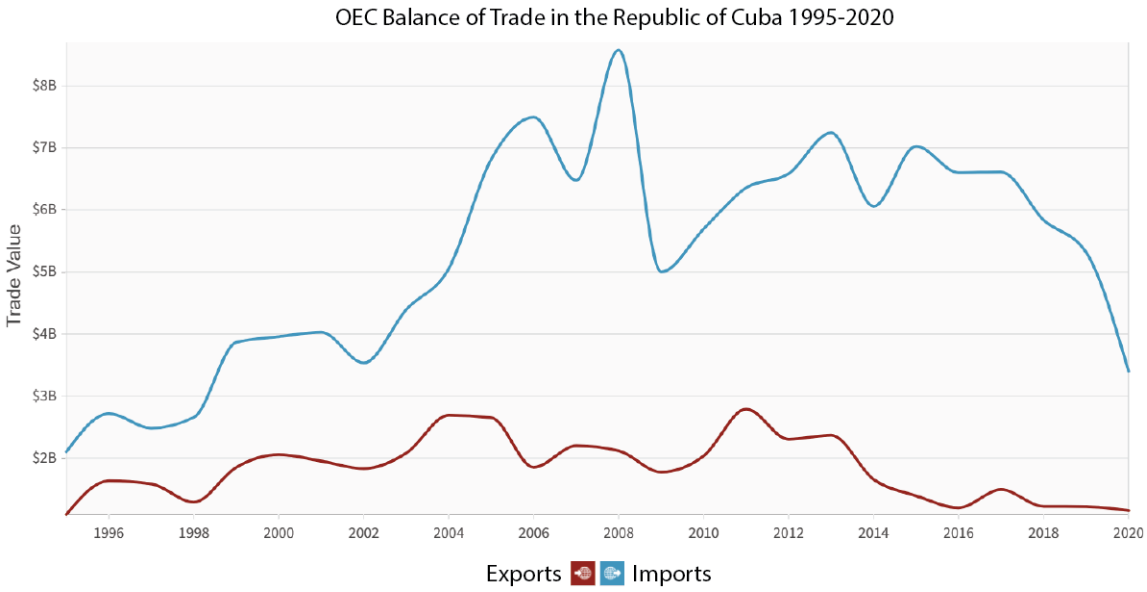

Figure 55 Data from the Observatory of Economic Complexity beginning after the Special Period was underway

The lack of digitized information obscured whether this was an improvement from the Soviet period and immediately after the collapse. Data travels and as it does the original sources can be obscured. The importance of easy-to-use data portals is highlighted by the number of spin-off data compilers. Historical trade balance Figures of Cuba were found on Macrotrends.net site. This website claims the information is from the World Bank's World Development Indicators.[251] When I

[249] General Assembly resolution 75/L.97, "Necessity of Ending the Economic, Commercial and Financial Embargo Imposed by the United States of America against Cuba" (A/75/L.97, June 9, 2021), https://undocs.org/en/A/75/L.97.
[250] Alexander James Gaspar Simoes and César A. Hidalgo, "The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development," in *Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence*, 2011.
[251] "Cuba Trade Balance 1970-2023," accessed March 31, 2023, https://www.macrotrends.net/countries/CUB/cuba/trade-balance-deficit.macro.

searched the WB for Cuban Current account balances none were available. The long-term BOT can be seen in Figure 56 below, which I compiled using the Macrotrends data. It shows a significant improvement after the Soviet era, even during the Special Period. It is possible that Macrotrends calculated the indicator subtracting data of goods and services exported from those imported from a different source than what is cited. Retrieving raw data from the WB database to check Macrotrends is difficult given that a more specific citation was not included by Macrotrends. Regardless, Macrotrends' data shows a clear improvement in the Cuban balance of trade and a crash in 2009. Nighttime lights analysis in Chapter two of this dissertation confirms a decrease in economic activity in 2009. Anecdotally from stories head while traveling there and from literature on socio-economic life in Cuba, it is possible that while the balance of trade has improved at the national level, scarcity is still experienced locally by people who cannot afford imported goods.

Figure 56 Alternative longer-term Balance of Trade Data from Macrotrends.net

One of the ways Cuba has sought to bring in foreign capital is by increasing foreign tourism activities on the island. At the start of tourism expansion in the Caribbean in the 1980's, development of tourism areas was already largely at the hands of international stakeholders.[252] As a result, the Caribbean has a special challenge in adapting to climate change because it must differentiate between adapting its

[252] Alfred Wong, "Caribbean Island Tourism: Pathway to Continued Colonial Servitude," *Études Caribéennes*, no. 31–32 (September 26, 2015), https://doi.org/10.4000/etudescaribeennes.7524; "Caribbean Tourism — Economic Development," *Tourism Management* 9, no. 2 (June 1, 1988): 155–61, https://doi.org/10.1016/0261-5177(88)90026-X.

economy and protecting foreign capital investments.[253] In contrast, Cuba was only concerned with satisfying internal tourism demand until 1993 when it was necessary to use tourism as a source of foreign capital. The areas developed for tourism after the Special Period absorbed tourists at an incredible rate; the estimated number of visitors in 1990 was 340,000 and grew to 1.8 million in 2000.[254] This previous period of growth serves as a test for Cuban planning and the ability for their socialist system to incorporate capitalist activities. The resulting changes in the tourism landscapes of Cuba give us insights into how the island might adapt to new capital flows that promote tourism development.

Foreign capital was allowed to act on Cuban land through a few economic sectors, including tourism. The capital acts as a catalyst for development; in tourism, these developments are site specific. The resulting development changes likely generate impacts throughout the site's region. One survey found an overall positive association between economic welling and tourism in the Municipio Morón, Ciego de ávila, Cuba. Interestingly, locals who participated in the survey did not find tourists or the federal government to be responsible for the health of the local environment, rather the locals themselves. They also found the behavior of locals to be negatively impacted by foreign tourism but the behavior of tourists to be positive or neutral.[255]This seems to blame the adoption of informal behaviors on locals rather than foreigners who bring new demands.

Tourism is clearly a priority for Cuban economic growth in the coming years. At the end of 2014 the Cuban Ministry of Foreign Commerce and Investment released a portfolio of 246 opportunities for foreign investment. Excluding projects in the Mariel Free Trade Zone West of Havana, the Tourism sector included 56 projects. This focus on tourism brings about questions of sustainability associated with the cumulative changes that would be experienced under both climate change and economic globalization.[256] Tourism can be particularly vulnerable to changes in coastal morphology and lead to economic vulnerability through dependence and imbalance of production. Tourism destination landscapes are the result of intersections between globalization, commodification of geography, and the dichotomy between locals and visitors. Destinations are available to visit only after

[253] Murray Simpson, Daniel Scott, and Ulric Trotz, "Climate Change's Impact on the Caribbean's Ability to Sustain Tourism, Natural Assests and Livelihoods," March 1, 2011, https://publications.iadb.org/en/climate-changes-impact-caribbeans-ability-sustain-tourism-natural-assests-and-livelihoods.

[254] Martínez, G. C., & Díaz, J. S. (2011). Trinidad, producto turístico integral y sostenible en Cuba. Cuadernos de turismo, (27), 95-114.

[255] Edianny Carballo Cruz, Oscar Fernández García, and Rubiselis Santana Alfonso, "Los Impactos Del Turismo Percibidos Por La Comunidad Municipio Morón, Ciego de Ávila, Cuba," *Estudios y Perspectivas En Turismo* 21, no. 5 (October 2012): 1299–1317.

[256] O'Brien, K. L., & Leichenko, R. M. (2000). Double exposure: assessing the impacts of climate change within the context of economic globalization. Global environmental change, 10(3), 221-232.

the physical and institutional infrastructure to move people through a space have been constructed. Destination landscapes are thus products of demand reinforced by frequent local users and visitors. It is the government's role to put in place policies to manage such spaces and avoid diseconomies of scale. Trade of Cuban culture and heritage will also be physically exported out of the country; products associated with the newly accessible Cuban culture such as rum and cigars will experience an increase in demand. Cuba's agricultural production is limited by cultivated area and its production capacity for these products will be tested. As new pressure is put on the Cuban economy by foreign demand of goods, Cuba's decisions to change or not change the designation of land uses in response to these demands will have impacts on the production opportunities of Cubans. Sánchez Egozcue outlines some of Cuba's challenges in restructuring their economy, finding a common thread to all nations facing climate change, the need to reconstruct goals for the future and the way the government plans for individual actors implement these changes. [257]

In comparison to the initial socialist revolution, recent reforms in Cuba are more aligned with market socialism and bureaucratic Leninism.[258] The ramped up effort to replace state-run companies with the private sector has created a new demographic of stakeholders, who are small business owners in the style of reform socialism.[259] The reallocation of capital through these privatization schemes has not only begun decentralization but also increased the agency of individuals over their landscapes and thus the level of participatory planning. Now that private companies, including foreign ones, can operate in Cuba, they too have secured a position as stakeholders.

Not mentioned so far in this paper is the significant difference in safety and security that Cuba has compared to other nations in the LAC.[260] Despite this, Cubans are still leaving the island in search of greater opportunities, a phenomenon being experienced throughout the Global South as failed international policies and climate change push people out of their homes.[261] This global trend is an indicator of failed international development policies by the economic elite.

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[257] Jorge Mario Sánchez Egozcue, "Challenges of Economic Restructuring in Cuba," *Socialism and Democracy* 26, no. 3 (November 1, 2012): 139–61, https://doi.org/10.1080/08854300.2012.716928.
[258] George W. Breslauer, *The Rise and Demise of World Communism* (Oxford University Press, 2021); Mauricio A. Font and Carlos Riobó, *Handbook of Contemporary Cuba: Economy, Politics, Civil Society, and Globalization*, A Paradigm Handbook (Boulder: Paradigm Publishers, [2013], 2013).
[259] Gonzalez-Corzo and Justo, "Private Self-Employment under Reform Socialism in Cuba."
[260] "Global Peace Index Latin America & Caribbean 2023," Statista, accessed October 6, 2023, https://www.statista.com/statistics/1124877/latin-america-caribbean-peace-index-country/.
[261] Andrew Selee Tanco Valerie Lacarte, Ariel G. Ruiz Soto, Diego Chaves-González, María Jesús Mora, Andrea Tanco Andrew Selee, Valerie Lacarte, Ariel G. Ruiz Soto, Diego Chaves-González, María Jesús Mora, and Andrea, "In a Dramatic Shift, the Americas Have Become a Leading Migration Destination," migrationpolicy.org, April 10, 2023, https://www.migrationpolicy.org/article/latin-america-caribbean-immigration-shift; Bernard et al., "Comparing Internal Migration across the Countries of Latin America"; "Latin America and Caribbean No Longer World's Fastest Growing Source

Regional Differences Within Cuba

In the latest contraction, national policies tackled deconstructing the commodity-based economy, particularly sugar. Sugar mills were central to the sugar economy of Cuba as processing centers known as Centrales. The 2002 initiative Tarea Álvaro Reynoso, which has had updates in 2012 and 2021, is part of a larger effort to 'update' the Cuban economy.[262] This effort includes a scale of diversification of the economy that had been absent since colonial exploitation of the land began. The Tarea Álvaro Reynoso policy initially closed almost half of existing sugar mills on the island. Arguably, the impetus for changes in the sugar sector is more related to lack of capital to maintain sugar mills or intermediary products to artificially feed plots for cultivation, not environmental sustainability.[263]

To better understand the ubiquity of sugar across the island, the following maps were made to visualize their distribution. A simple calculation of the Getis-Ord Gi was done in ArcMap using the HotSpot tool in the Mapping Clusters toolset.[264] The

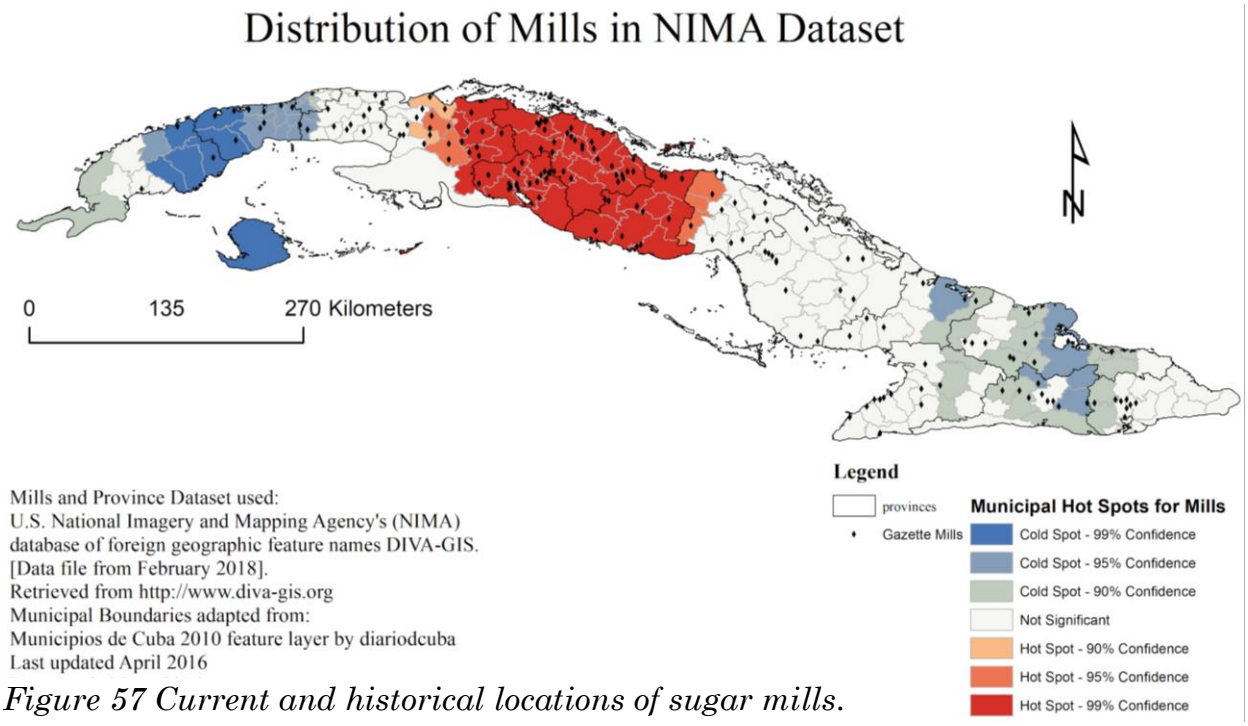

Figure 57 Current and historical locations of sugar mills.

of International Migrants," *Pew Research Center* (blog), accessed October 6, 2023, https://www.pewresearch.org/short-reads/2019/01/25/latin-america-caribbean-no-longer-worlds-fastest-growing-source-of-international-migrants/.

[262] "Tarea Ordenamiento: 2021 Comienza Con El Proceso Más Determinante Para Avanzar En La Actualización Del Modelo Económico › Cuba › Granma - Órgano Oficial Del PCC," accessed November 3, 2021, https://www.granma.cu/cuba/2020-12-10/esta-noche-informacion-especial-de-interes-para-la-poblacion-en-cadena-de-radio-y-television-10-12-2020-10-12-28.

[263] Crawford, "Necessity Makes the Frog Jump."

[264] ESRI, "Hot Spot Analysis (Getis-Ord Gi*) (Spatial Statistics)—ArcGIS Pro | Documentation," accessed November 20, 2023, https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/hot-spot-analysis.htm.

Getis-Ord Gi is a method of point pattern analysis that measures second-order effects which measure spatial dependency rather than mean variation.[265] The Z-scores are displayed as a background in the following figures. Figure 57 above uses data from the U.S. National Imagery Mapping Agency (NIMA) now known as the National Geospatial-Intelligence Agency. We can see that the primary location of mills are the provinces of Santi Spiritus, Villa Clara, Cienfuegos, and Easters Matanzas.

Using sugar mill status data from Alvarez, 2009, I georeferenced the location points of 105 mills that were listed.[266] See Figure 58 below for a map which includes a hot spot analysis of mills labeled "closed." Centrales (sugar mills) were geocoded using place point data from National Imagery and Mapping Agency (NIMA) gazetteer and OpenStreetMap (OSM) and by attributing a mill to a locality with the same name in the same province and municipality as stated on the Alvarez list. When an exact match was not found, the mill was attributed to the municipal head locality. This method is sufficient when aggregating the number of mills to the municipal level, but errors would increase if one attempted to measure changes in land cover directly around the mill. I searched for mills that were on the "closed" list with names not immediately identified on OSM data on Mapcarta and Google Earth, where I confirmed them either by name on Mapcarta, which is more detailed, or by visual confirmation of a mill or mill ruins in satellite images on Google Earth.

[265] U. R. Manepalli, Ghulam H. Bham, and Srinadh Kandada, "Evaluation of Hotspots Identification Using Kernel Density Estimation (K) and Getis-Ord (Gi*) on I-630," in *3rd International Conference on Road Safety and Simulation*, vol. 21 (National Academy of Sciences Indianapolis Indiana, United States, 2011), 14–16, https://onlinepubs.trb.org/onlinepubs/conferences/2011/RSS/2/Manepalli,UR.pdf; Amisha Bharti and Sonajharia Minz, "Getis-Ord (Gi*) Based Farmer Suicide Hotspot Detection," *Journal of Information Technology and Digital World* 4, no. 2 (July 6, 2022): 74–83.

[266] Alvarez, "The Current Restructuring of Cuba's Sugar Agroindustry."

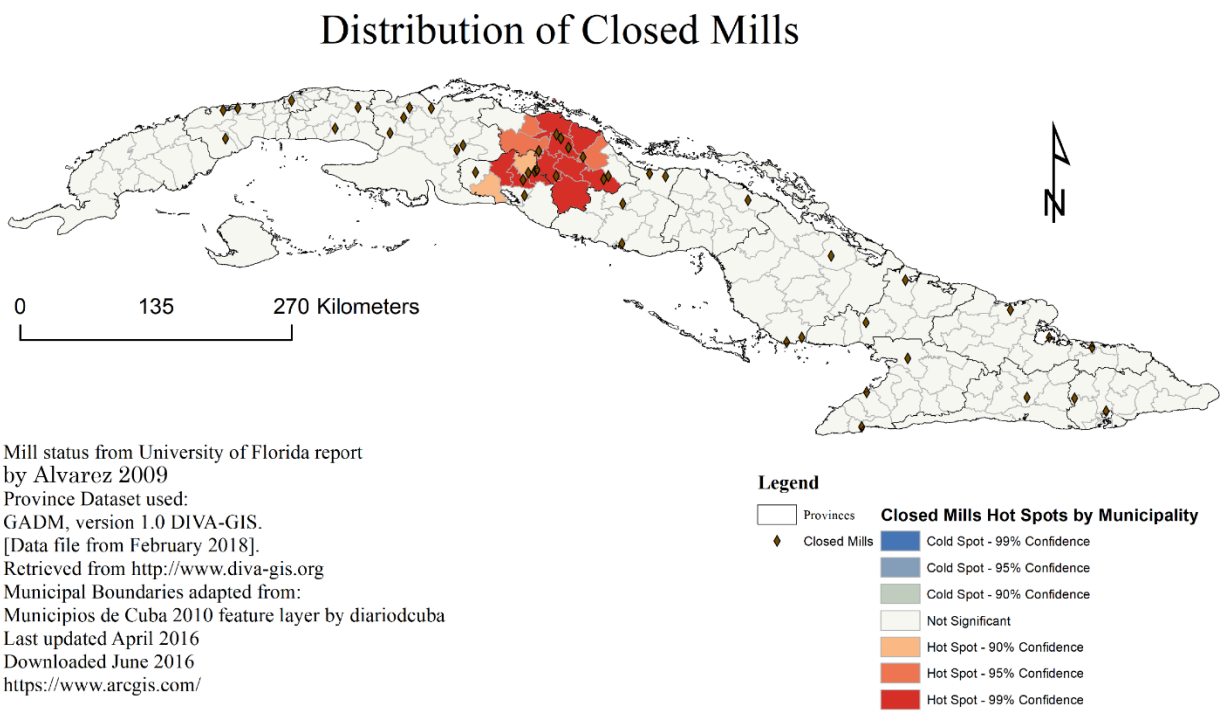

Figure 58 Sugar mills closed Island as of 2009.

Notably there is a hot spot of closures in the Central Region and a lack of closures in the Western region. The central region is the flattest in Cuba, an essential topography for cane cultivation while the Western region has historically produced more tobacco than sugarcane.[267]

[267] Scarpaci and Portela, *Cuban Landscapes*.

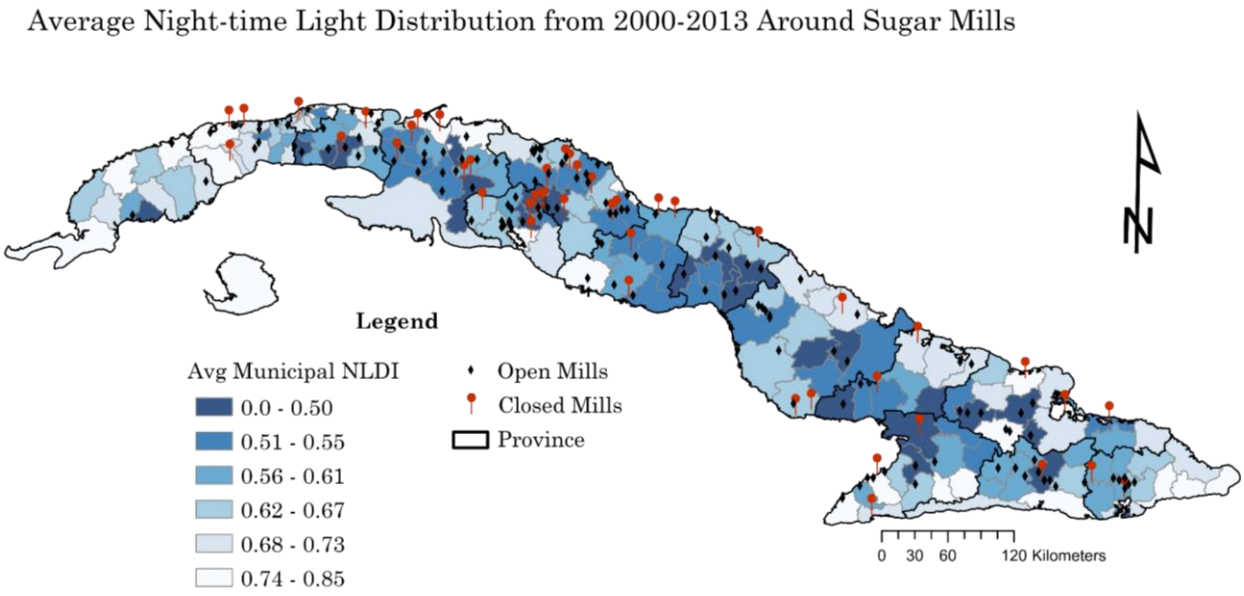

Figure 59 NTL distribution based on NLDI around sugar mills.

We can see from the overlay analysis in Figure 59 above that, despite closures being concentrated in the central provinces, NTL distribution is more equal in the central provinces than in coastal municipalities. There is also a low NLDI (greater equity) in municipalities with mills that are still open. This could be because of the historical development of energy infrastructure to support sugar production and the difficulty in maintaining a centralized electric grid along coastal areas that suffer from storms. As mentioned in Chapter two, the government has made a concerted effort to build decentralized systems in historically underdeveloped areas in the East which also has some non-coastal municipalities with lower NLDIs. In the East there seems to be less correlation between the presence of mills and NLDI. The mountainous region also contains Guantanamo Bay and Santiago de Cuba, the second largest city in the country. The influx of capital for the Guantanamo American military base and urbanization may contribute to this. There are also some agricultural hubs in the flatter parts of the southeastern coasts which might have demanded infrastructure. Despite low dependence on sugarcane cultivation in the Western provinces they have a higher number of municipalities with high NLDIs. While there are tourism opportunities there because of iconic land preserves (see Figure 22 for a map of their locations) and tobacco production, there must be other factors preventing the electrification of some areas. It is also possible that because of the machinery restrictions in land preserves and the primary use of manual labor in the production of cigar tobacco, the incentive to develop energy systems there for other purposes was lacking. This is also an area that is not flat, adding to the cost of building infrastructure.

Existing and Closed Sugar Mills in Cuba with Night-time Light Trends from 1992-2013

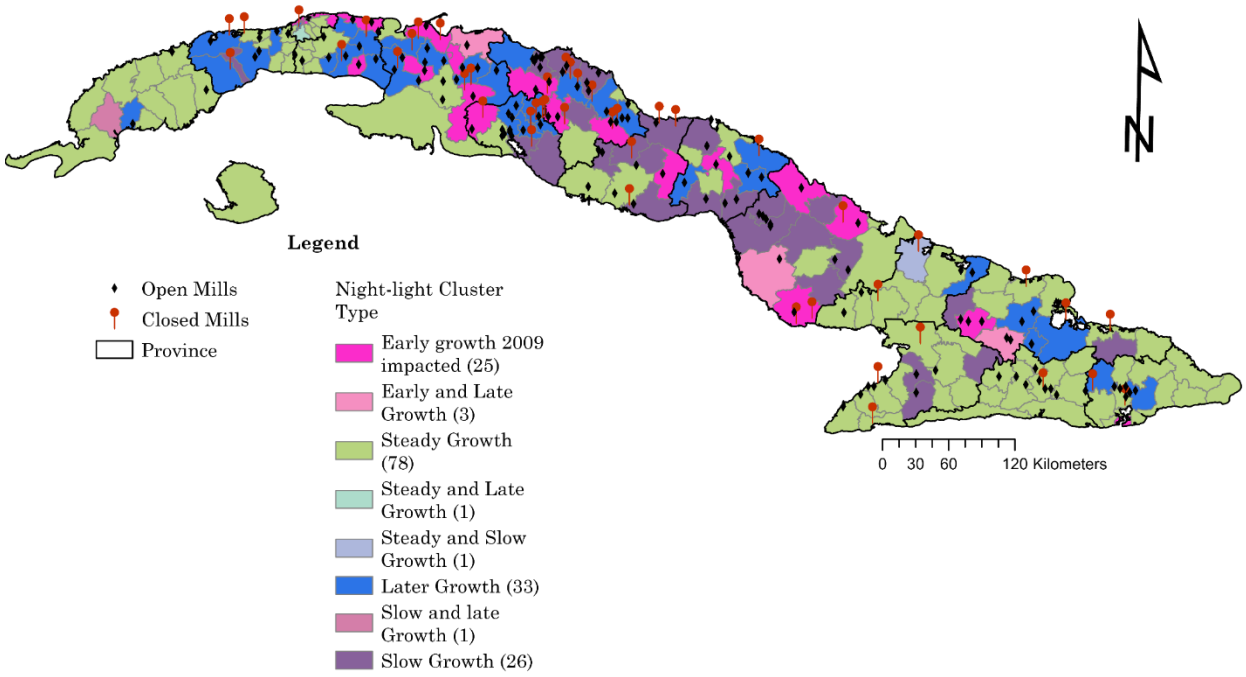

Figure 60 NTL trajectories around open and closed sugar mills

The overlay analysis with clustered trajectories seen in Figure 60 above shows a clearer picture of the economic woes of the central region of the country, which was impacted by the restructuring of the sugar industry and the national move towards economic diversification. We can also see that while the West and East of the country had higher NLDIs, they were overall improving their access to electricity, or NTL output. In coastal areas of Havana and in the province of Matanzas, home to the tourist enclave of Varadero, we see greater impact of the 2009 global financial crisis as these municipalities are in the 2009 impacted cluster. This could be a result of increasing tourism to these areas as the government shifted sources of economic output.

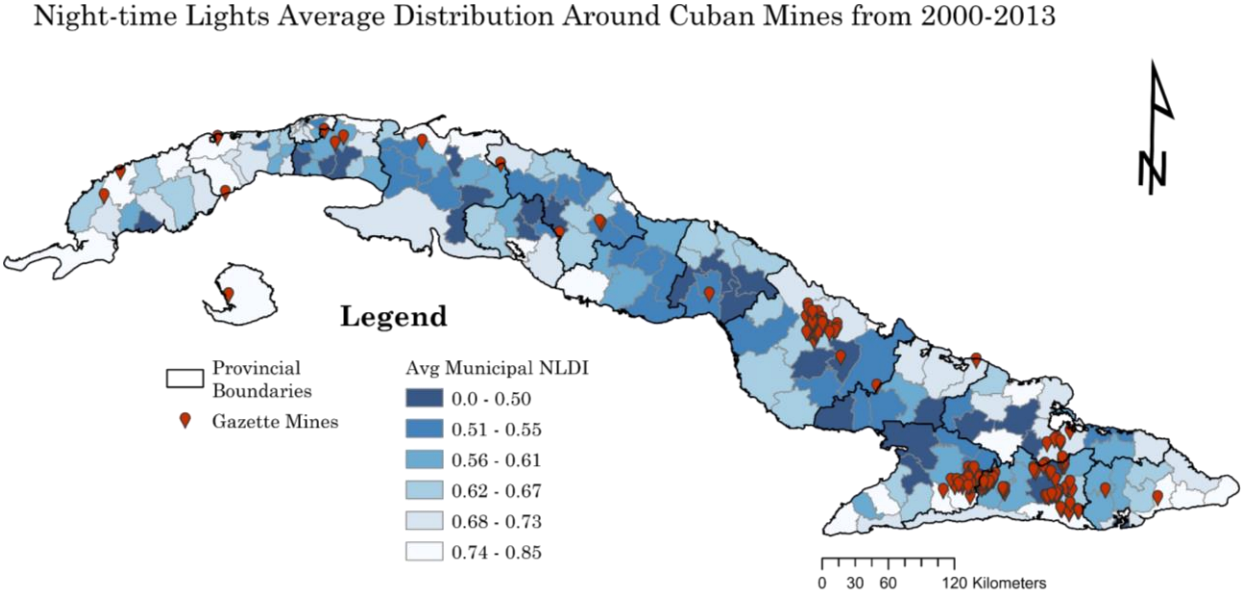

Figure 61 NTL distribution as measured by the NLDI around Cuban mines.

Cuban Mines were also chosen for an overlay analysis because they were one of the sources of foreign direct investment. Mines appear to have a positive impact on the distribution of NTL with some exceptions in municipalities on coasts. Interestingly, the mines near the town of Moa in Holguín province are not captured in the Gazette dataset even though they are large and clearly visible from satellite images. In the NLDI calculation Holguín has a mixture of high and low scores. The municipality of Moa scores are slightly high, though not as high as some interior municipalities where there are flat cultivated areas and where the provincial head is located. In the West of the country mines do not seem to have an impact on high NLDI scores. This preliminary review reveals that the presence of mines does not positively impact the distribution of NTL, interpreted as access to energy systems, as I expected. It is possible that energy used in mining primarily supplies mining sites and the distribution networks are not significantly expanded into residential areas.

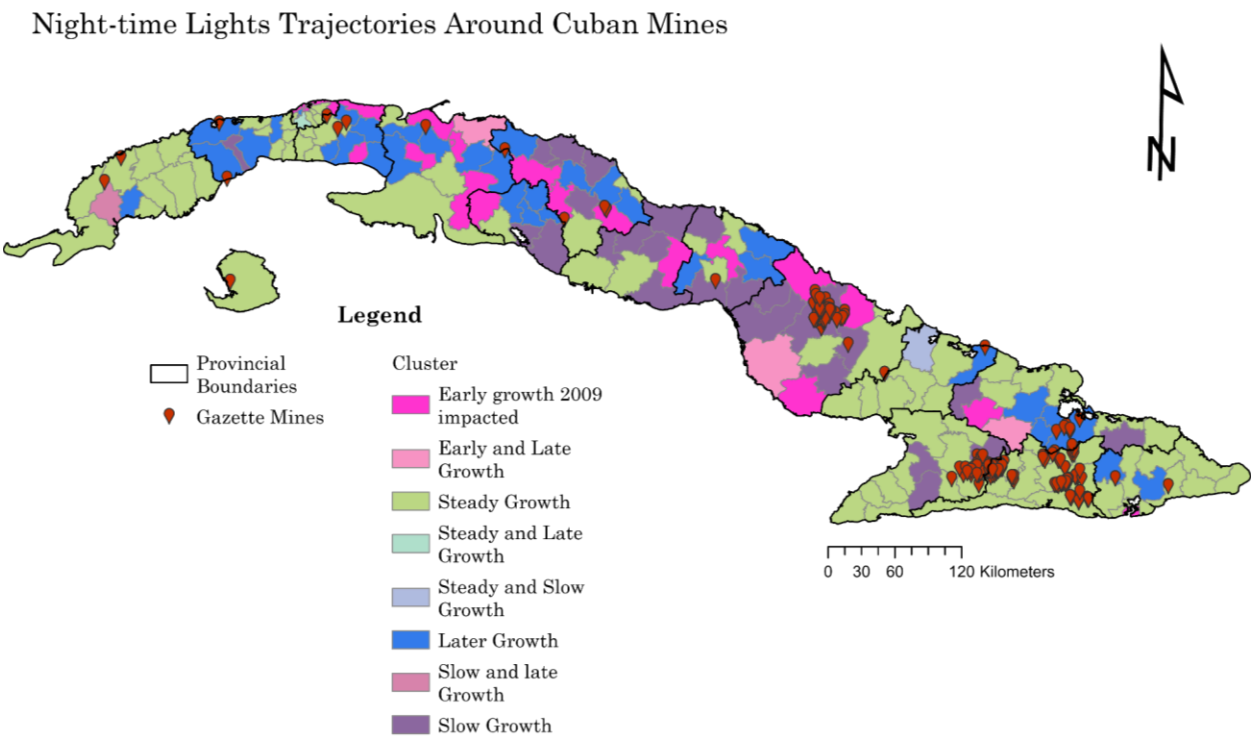

Figure 62 Development Trajectories Around Cuban Mines

The development trajectories captured by the changes to NTL emissions show contrasting patterns between the central region and the Eastern region, see Figure 62. Municipalities with mines in the East saw steady growth, except in Holguín Province. Camagüey province, with the second highest cluster of mines, saw mostly slow growth. This province is flatter, has more agriculture, and kept most of their mills open. It is possible that there were difficulties as the primary industries switched or that the mines there are smaller and could not quickly make up for any losses in sugar production.

In terms of economic trajectories derived from land cover changes in chapter one, the island had slightly over 500 pixels more of growth than contraction as can be seen in Figure 63 below. Most of the changes were not considered growth or contraction. These could have been changes that occurred to areas not managed by people or a limitation of the dataset classifications and the methods for determining growth or contraction. One critical aspect is the role of fruit trees which the dataset would have labeled as a type of tree cover but might have actually played a key role in the sustenance of the populations near them. Similarly, water is classified as such, but no indication is given of the quantity of fish harvested from them.

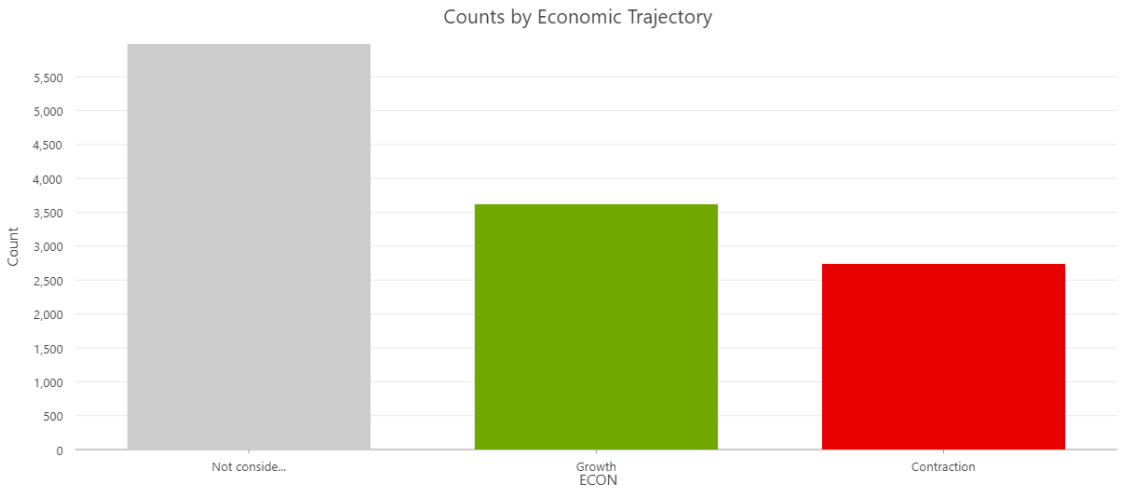

Figure 63 Classification of changes captured in Land Cover Change as they relate to economic growth.

In Figure 64 below the net changes per municipality were captured and arranged in increasing order. Interestingly, it is mostly Western and Central municipalities that had a contraction, while those in the East generally experienced more growth. Fewer municipalities, 72, had a net contraction or were net neutral,4, with 89 recording growth. Municipalities that had a net contraction had larger areas of decrease than the areas of increase. When considering the results from Figure 63, we can conclude that while there were more growth pixels they happened in concentrated areas, and only a handful of municipalities experienced a net economic growth in the utility of their land use.

Figures 65 and 66 use the economic trajectory analysis from chapter 1 as the base map to overlay mines and closed mills. They show a clearer picture of the impact of these economic activities than the more complex indicators from the Nighttime Light analysis. This could indicate a tighter link in Cuba between Agriculture and development. When looked at in conjunction with closed mills, municipalities with coasts, and the poor soils for cane cultivation that come with them, typically had contraction. Except for a few cases, municipalities with closed sugar mills and no coastal access still saw economic growth (see Figure 65). With the exception of Granma Providence, municipalities with clusters of mines saw more economic growth according to the methods used here (see Figure 66).

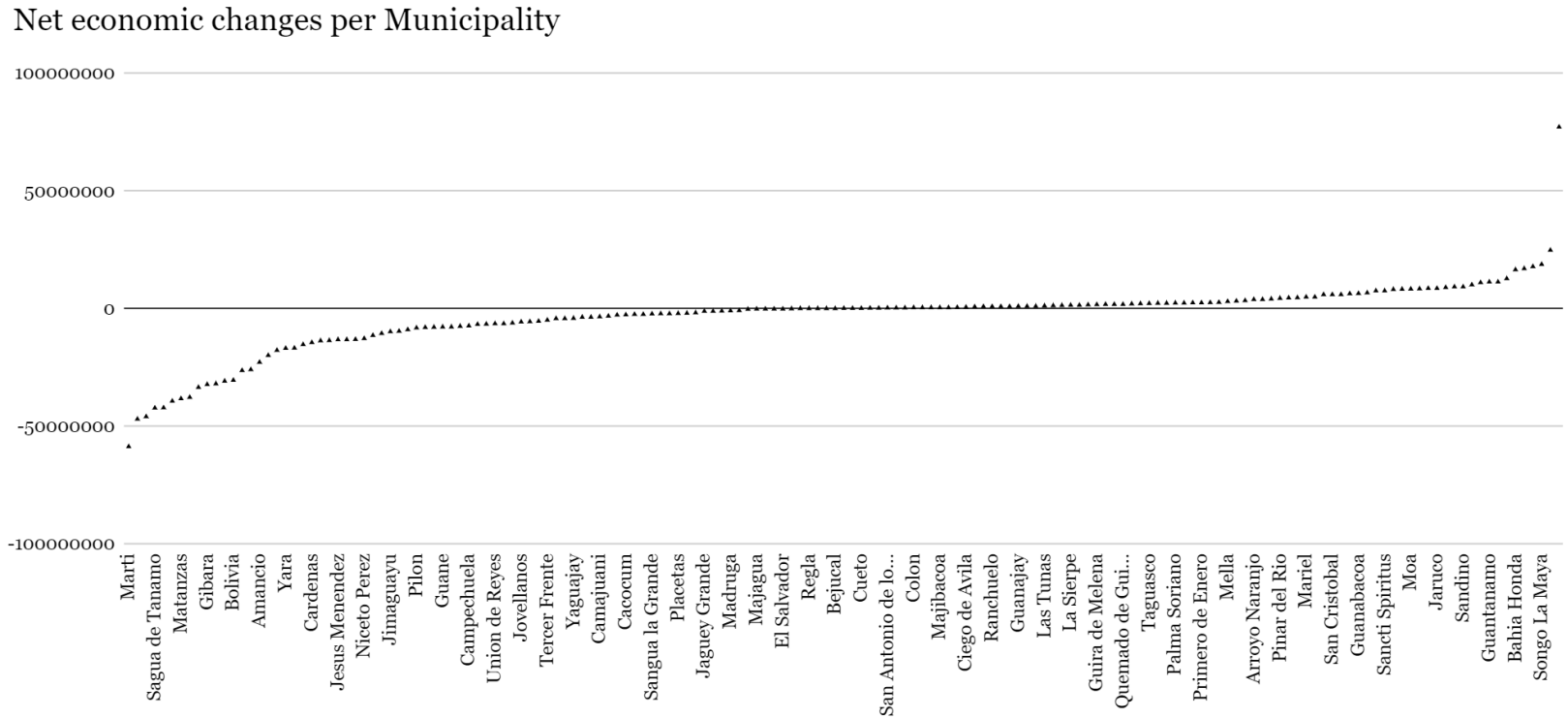

Figure 64 Municipal economic changes as reflected by land cover changes.

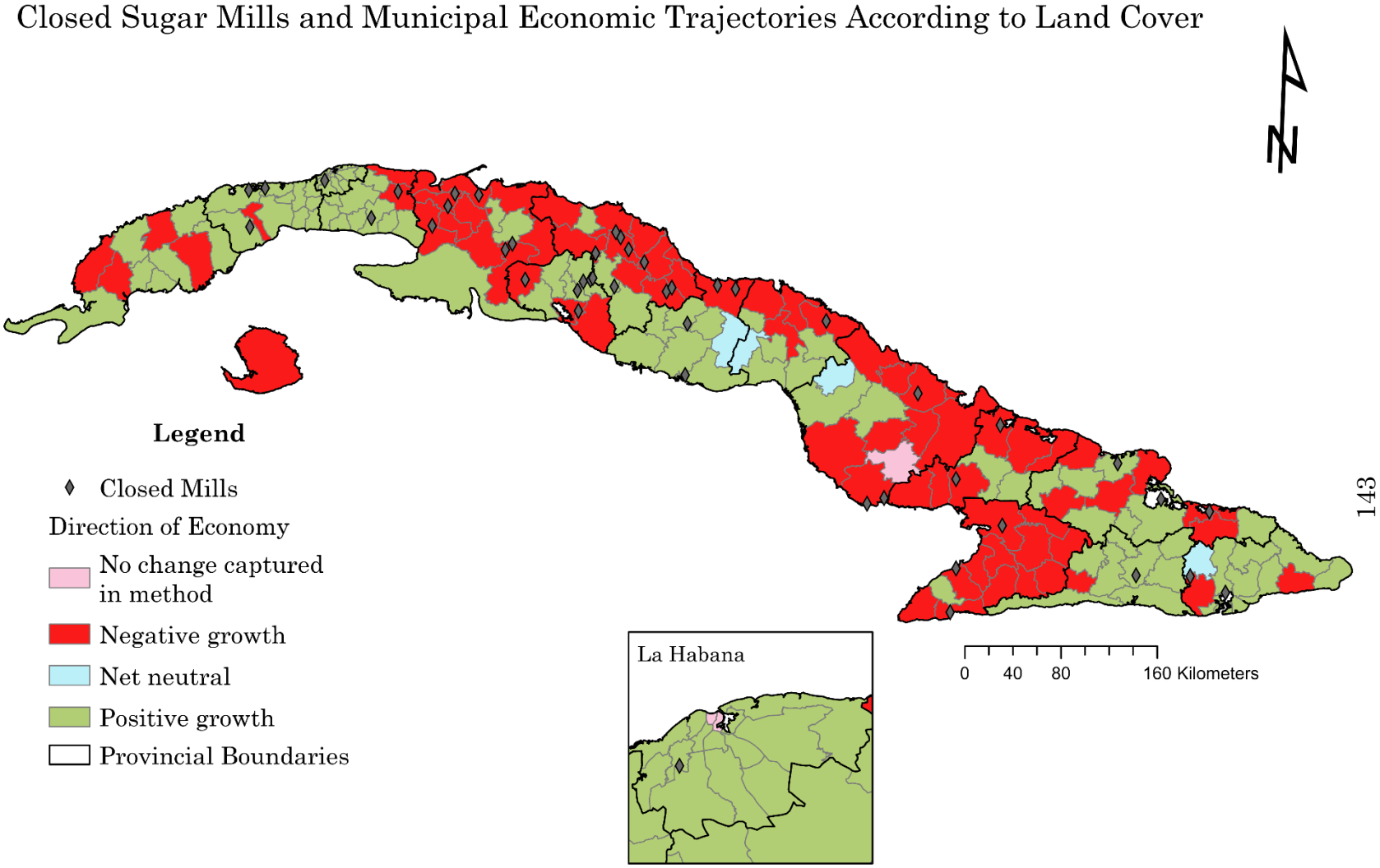

Figure 65 Closed Mills and Economic Trajectory from Land Cover Change.

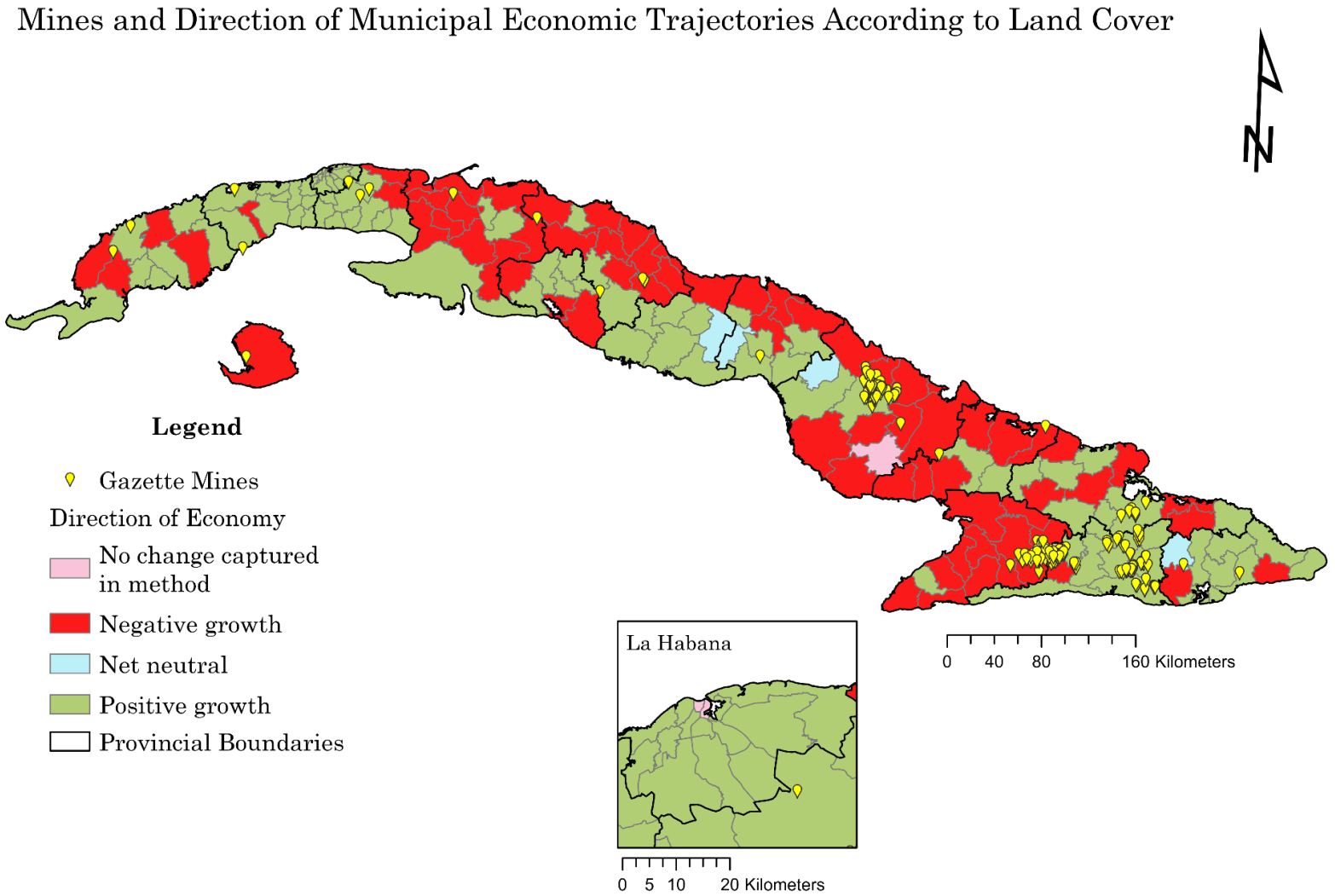

Figure 66 Mining Operations and Economic Trajectory from Land Cover Change.

Conclusions

Former colonial powers continue to exert power through data creation and the use of limited global indicators. Depoliticized concepts of vulnerability or development and a climate change framework that fails to fully acknowledge social injustices continues to thwart efforts to enact a system of reparations from the main contributors of atmospheric carbon to the most vulnerable.[268] As found by Aragón-Duran et al. governments like that of Cuba, while heterodox, are not free of this negligence. With a country as closed as Cuba, it is possible to make preliminary observations about regional landscape changes in responses to new policy from mostly remotely sensed data. Research on Cuba is a critical example of such data, as it presents difficulties in access to local datasets. The Cuban government has a low transparency rating, and it has been cited that the government may not be delivering accurate data on what goes on within its borders.[269] Despite these limitations Cuba stands out from other countries in the LAC region. It is already proclaimed by the UN as having made impressive changes towards sustainability, it has citizens with higher educational attainment, and, as mentioned earlier, is one of the safest in a region plagued by violence stemming from foreign interventions.

Within the island we can still see a reflection of regionalization in the patterns of land cover and NTL changes. We can see that the central region had more stagnant growth in NTL than the East or West. The economic trajectories through land cover showed decline along the Northshore of the island. The most obvious lack of agreement in the result of the development trajectories between the two datasets was in Granma province, where the landcover trajectory analysis resulted in predominantly pixel changes of economic contraction and the NTL showed steady growth. The location of municipalities in relation to shorelines and historical hotspots of sugarcane cultivation seemed to be more associated with economic trajectories than presence or absence of mines and closed mills. Facilities like these may show a tighter link with development if trajectories are analyzed at the city level. This study aggregated local results to the municipal level because it lacked collaboration with Cuban who would have been able to identify specific localities of interest based on, for example, locations of non-state operated food farms or interesting local politics of change. One observed change in land cover that points to a more sustainable production schema and simultaneously an economic contraction

[268] Ernesto Aragón-Duran et al., "The Language of Risk and the Risk of Language: Mismatches in Risk Response in Cuban Coastal Villages," *International Journal of Disaster Risk Reduction* 50 (2020): 101712; Paula Castro and Marlene Kammerer, "The Institutionalization of a Cleavage: How Differential Treatment Affects State Behavior in the Climate Negotiations," *International Studies Quarterly* 65, no. 3 (September 7, 2021): 683–98, https://doi.org/10.1093/isq/sqab045.
[269] Transparency International, "Corruption Perceptions Index," 1995 - 2021, 2022, https://www.transparency.org/en/cpi/2021.

is the loss of cropland cover along the coastal plain zones that are dominated by vertisols and gleysols. These soil types are poor for industrial cultivation. They appear as a major pattern in Cuba and were easy to spot. Areas with less obvious patterns were hard to pinpoint.

Distant, satellite driven, observations are not enough to determine local policy successes or failures from afar. What is needed, rather than additional supplementary information, is the collaboration with locals in each region to interpret initial findings and to decide what additional indicators of sustainability and resilience should be calculated. If the UN is to manage climate reparations that will be needed in the future, as it managed post-colonial development loans, they must also make data creation and analysis available to civilians so they can use it to hold their governments accountable for the adaptations they promise to deliver.

Limitations

Work carried out by Cuban researchers is also hard to access because their publications are not typically in mainstream journals. Additionally, the financial difficulties experienced by Cuba during the early years of the Special Period impacted the collection and dissemination of agricultural data that could be used to evaluate the implementation of agricultural sector reforms. This adds to the need for fieldwork to see what is happening. The Cuban government that requires foreign researchers be hosted by a national research institute in order to be granted a research visa. This requires the researcher to make visits to Cuba before official fieldwork begins to gain trust and make connections, adding to the cost and length of research.[270] For American researchers, the embargo adds to the difficulty of getting sufficient research funding and transport to the island.

During Julia Wright's dissertation work, she noted that researchers might experience different levels of distrust and openness from Cubans who work closely with the central government, especially when foreigners are investigating the effectiveness of their policies. She also noted the inappropriate nature of many of the traditional theoretical frameworks and survey instruments used for rural research because of the unique socio-political context of the island. This points to the inappropriate nature of a specific set of indicators, SDGs, to adequately capture intranational processes for the entire globe. For these reasons satellite data is a unique opportunity to assess development trajectories.

[270] Julia Wright, "Methodological Considerations on the Experience of Undertaking Doctoral Research in the Agricultural Sector in Cuba During the Special Period (1998–2000)," *International Journal of Cuban Studies* 8, no. 2 (2016): 296–308, https://doi.org/10.13169/intejcubastud.8.2.0296.

Future Studies

Since corruption in government is a worry throughout the globe, I propose a partnership between the UN (as manager of reparations funding), regional universities, local schools, and organizations to monitor progress, collect data, choose analyses, and make the process open source for others to learn from and replicate is so desired. We need a radical shift in the way essential datasets are made and distributed. They currently represent a narrow view of the world that enforces hegemonic adaptation efforts. Cuba is an appropriate assay because it works with the UN to some capacity but experiences different management styles than other countries in the LAC. The role of infrastructure and technology sharing in climate change adaptation and power structures must be taken into consideration when funding large, costly, projects that are for the most part designed and built by multinational corporations. There is an undeniable history of neocolonialism through promotion of certain development by those in power to those deemed in need of economic (sustainable) development.[271] One way satellite data can be used in the future is to monitor the impacts of adaptation projects in collaboration with locals. There are an almost endless number of metrics and indicators that could be used to measure economic trajectories with the datasets used in this study. The best way to choose them would be to work with Cubans and decide based on their particular needs.

Dissertation Conclusion

The largest impediment to utilizing remote sensing products to monitor global change in the face of crisis is the lack of free adequate high-resolution data products in developing countries. A regularly produced product generated by sufficiently funded local universities and validated with field data by local land managers would have less uncertainty. Satellite technology has improved significantly over the decades, we have the ability to produce higher spatial and temporal resolution datasets but not the free access to the data or the institutions to create land cover products that challenge hegemonic views of resources.

Datasets could be more appropriate for answering local questions of development and begin a process of sousveillance to hold national governments accountable for the adaptations they promise. This kind of data could also be used to evaluate the effectiveness of infrastructure that is built to adapt to global warming. Incorporating local production of data and analysis would more accurately reflect

[271] Jürgen Rüland, "The Long Shadow of the Developmental State: Energy Infrastructure and Environmental Sustainability in Southeast Asia," *Third World Quarterly* 0, no. 0 (February 24, 2023): 1–19, https://doi.org/10.1080/01436597.2023.2178890.

the realities of people who exist locally. Data creation and dissemination can be part of a reparations package that also includes funding for adaptation projects and energy transition. Data such as land cover and nighttime lights, if tuned to local needs has the potential to monitor changes, measure progress, and evaluate the effectiveness of adaptation schemes.

In the example of land cover data given in this dissertation, the need for generic categories for global change models was clearly prioritized in the making of the ESA's CCI land cover dataset. While such general understanding of land is necessary, so too are datasets that reflect the information local land managers need to mitigate and adapt to the climate crisis. In addition to data that reflects local experiences, communities should be able to calculate indicators that are most meaningful to them. Such can be noted from the second primary dataset of this dissertation, nighttime lights.

There are some inherent socio-technical assumptions when using nighttime light (NTL) trajectories and distribution as development indicators. It gives primacy to a technology that while important for engaging with a modern economy, is not essential for survival. Access to electricity in the context of global poverty reduction supports the theory of development leap rather than self-determined stages. Leap approaches can ignore the demands of local populations whose lives might have greater improvement if other utilities, for example water treatment or reliable roads, had been prioritized. Measuring 'sustainable' development using NTL brings an added level of difficulty. Distribution and allocation of lights can be quantified to measure a type of equity but says nothing about how the energy is being generated or transmitted. A power plant, using fossil fuels, and connected over long distances to bring electricity to rural areas is not a move towards sustainable, equitable, development. Especially, when we consider that the island faces routine tropical storms that damage power lines, lacks lifesaving wastewater treatment, and has an agricultural sector scrambling to adjust to climate change. The complexity of using lights to measure growth and wellbeing is complicated when we acknowledge the island is known for having the healthiest coral reefs in the Caribbean.[272] Night lights spilling into the environment can be detrimental to a variety of species. Some localities are attempting to reduce light pollution, setting a negative relationship between increased lights and sustainable development.

The difficulty in measuring development is not new and is made more complex by variable government institutions. Corrupt institutions can give false reports, publish data inconsistently, or use alternative computations for conventional

[272] Galford et al., "Cuban Land Use and Conservation, from Rainforests to Coral Reefs."

indicators.[273] A global community built on intellectual generosity (rather than intellectual property), open-source data collection, and analysis would allow us to break the cultural illusion of reaching a sustainable development through consensus that Hornborg discusses as postponing a meaningful response to the crisis.[274] I argue that this diversity in data and indicators would also harness human creativity and increase the variety of solutions generated to counter the crisis and the oppressive systems that created it.

Cuba's experience also gives us an idea of how to finance climate reparations and prevent another debt crisis. Castro's response to the debt crisis of the 1980's, experienced throughout Latin America, stands out to me for two main reasons.[275] One is the link he made between canceling debt, thus increase purchasing power of indebted nations, as better overall for the global economy. Secondly, the use of the generous defense budgets of the global elite to finance cancelations. Throughout his campaigning of alternative responses to the debt crisis he highlighted the importance of a nonaligned movement and the failures of military interventions by the elite in 'developing' countries. In our contemporary situation, climate change reparations to fund adaptations in nations not responsible for global warming, rather than indebting them, could not only be socially just but also financially sustainable, as the military interventions of the past have failed to create positive socioeconomic impacts in the long run.

[273] Angrist, Goldberg, and Jolliffe, "Why Is Growth in Developing Countries So Hard to Measure?"
[274] Alf Hornborg, "Zero-Sum World: Challenges in Conceptualizing Environmental Load Displacement and Ecologically Unequal Exchange in the World-System," *International Journal of Comparative Sociology* 50, no. 3–4 (2009): 237–62.
[275] Rene lynette Bartusch, "Cuba: An Historical Appraisal of Its Foreign Debt and Soviet Economic Assistance and Cuba: An Evaluation of Its Military Relations with the Soviet Union.," *The University of Texas, Thesis*, 1986, 128.

References

Adger, W. Neil, Suraje Dessai, Marisa Goulden, Mike Hulme, Irene Lorenzoni, Donald R. Nelson, Lars Otto Naess, Johanna Wolf, and Anita Wreford. "Are There Social Limits to Adaptation to Climate Change?" *Climatic Change* 93, no. 3–4 (2009): 335–54.

Aguirre, Benigno E. "Social Control in Cuba." *Latin American Politics and Society* 44, no. 2 (ed 2002): 67–98. https://doi.org/10.1111/j.1548-2456.2002.tb00206.x.

Aldwaik, Safaa Zakaria, and Robert Gilmore Pontius. "Intensity Analysis to Unify Measurements of Size and Stationarity of Land Changes by Interval, Category, and Transition." *Landscape and Urban Planning* 106, no. 1 (May 2012): 103–14. https://doi.org/10.1016/j.landurbplan.2012.02.010.

Altimir, Oscar. "Desigualdad, empleo y pobreza en América Latina: Efectos del ajuste y del cambio en el estilo de desarrollo." *Desarrollo Económico* 37, no. 145 (April 1997): 3. https://doi.org/10.2307/3467151.

Álvarez, Anicia García, and Betsy Anaya Cruz. "El Modelo Agropecuario y Su Vínculo Con El Acceso a Los Alimentos: La Experiencia Cubana (1959–2019) The Agricultural Model and Food Access: The Cuban Experience (1959–2019)." *International Journal of Cuban Studies*, July 1, 2020. https://doi.org/10.13169/intejcubastud.12.1.0076.

Alvarez, José. "The Current Restructuring of Cuba's Sugar Agroindustry." *University of Florida, Food and Resource Economics Department IFAS Extension*, no. FE472 (January 2004): 9.

Alvarez, Oscar L Parrado, Luisa Carrión Cabrera, Biofredis, and Castro Torres. "Epistemological Fundamentals of Education in Agriculture in Cuba," 2018. https://doi.org/10.13140/rg.2.2.26258.96963.

Amaro, Nelson. "Decentralization, Local Government, and Participation in Cuba." *Cuban Communism*, 1998, 30–43.

Amy Goodman. Colombian President Gustavo Petro: Full Interview on Democracy Now! Accessed September 25, 2023. https://www.democracynow.org/2023/9/22/full_interview_colombian_president_gustavo_petro.

Angrist, Noam, Pinelopi Koujianou Goldberg, and Dean Jolliffe. "Why Is Growth in Developing Countries So Hard to Measure?" *Journal of Economic Perspectives* 35, no. 3 (August 2021): 215–42. https://doi.org/10.1257/jep.35.3.215.

Aragón-Duran, Ernesto, Gonzalo Lizarralde, Gonzalo González-Camacho, Andrés Olivera-Ranero, Lisa Bornstein, Benjamin Herazo, and Danielle Labbé. "The Language of Risk and the Risk of Language: Mismatches in Risk Response in Cuban Coastal Villages." *International Journal of Disaster Risk Reduction* 50 (2020): 101712.

Astorga, Eglis Martín, Manuel Fidel Sonhi Manassa, and Antonio Francisco Mateus Joao. "INSERÇÃO DA ATIVIDADE MINEIRA NAS CADEIAS GLOBAIS DE VALOR: O CASO DAS MINEIRAS CANADIANAS EM CUBA E NO

MÉXICO.” *Revista Eletrónica KULONGESA–TES. ISSN 2707-353X* 2, no. 2 (2020): 68–79.
Backer, L. C. “Cuba and the Development of Odious Debt Doctrine in an Age of Financial Crisis.” *Transnational Dispute Management (TDM)* 6, no. 1 (2009).
Backer, Larry Cata. “Ideologies of Globalization and Sovereign Debt: Cuba and the IMF.” *Penn State International Law Review* 24 (2006 2005): 497–562.
Baklanoff, Eric N., and LaShondra Jones. “Deconstructing ‘Constructive Engagement’: Canada’s Economic Relations with Cuba, 1993–2003.” *ASCE* (blog), November 30, 2005. https://www.ascecuba.org/asce_proceedings/deconstructing-constructive-engagement-canadas-economic-relations-with-cuba-1993-2003/.
Bazzani, Eduardo L. Moyano, and Serena Fernández Alonso. “La minería cubana en las últimas décadas del siglo XIX.” *Anuario de Estudios Americanos* 55, no. 1 (June 30, 1998): 221–42. https://doi.org/10.3989/aeamer.1998.v55.i1.373.
Benford, Robert D., and David A. Snow. “Framing Processes and Social Movements: An Overview and Assessment.” *Annual Review of Sociology* 26, no. 1 (2000): 611–39.
Bernard, Aude, Francisco Rowe, Martin Bell, Philipp Ueffing, and Elin Charles-Edwards. “Comparing Internal Migration across the Countries of Latin America: A Multidimensional Approach.” *PLOS ONE* 12, no. 3 (March 22, 2017): e0173895. https://doi.org/10.1371/journal.pone.0173895.
Bharti, Amisha, and Sonajharia Minz. “Getis-Ord (Gi*) Based Farmer Suicide Hotspot Detection.” *Journal of Information Technology and Digital World* 4, no. 2 (July 6, 2022): 74–83.
Blet, Arnoldo Oliveros. “La población rural en Cuba:cambios cuantitativos en el período 1990-2006.,” 2010, 163.
Blue, Sarah A., Amy Trauger, Hilda Kurtz, and Jason Dittmer. “Food Sovereignty and Property in Cuba and the United States.” *The Journal of Peasant Studies* 0, no. 0 (July 8, 2021): 1–18. https://doi.org/10.1080/03066150.2021.1912026.
Bodenheimer, Rebecca M. *Geographies of Cubanidad : Place, Race, and Musical Performance in Contemporary Cuba*. Jackson: University Press of Mississippi, 2015.
Bond, Patrick. “From Copenhagen to Cancún to Durban: Moving Deckchairs on the Climate Titanic.” *Capitalism Nature Socialism* 22, no. 2 (2011): 3–26.
———. “Politics of Climate Justice.” *Paralysis above, Movement below. University of Kwa Zulu Natal Press, Cape Town*, 2012.
Boswell, Thomas D. “Characteristics and Processes of Urbanization in the Caribbean,” 1991, 36.
Breslauer, George W. *The Rise and Demise of World Communism*. Oxford University Press, 2021.
Browne, Simone. *Dark Matters: On the Surveillance of Blackness*. Duke University Press, 2015.

Bruederle, Anna, and Roland Hodler. "Nighttime Lights as a Proxy for Human Development at the Local Level." *PLoS ONE* 13, no. 9 (September 5, 2018). https://doi.org/10.1371/journal.pone.0202231.

Cabello, Juan José, Dunia Garcia, Alexis Sagastume, Rosario Priego, Luc Hens, and Carlo Vandecasteele. "An Approach to Sustainable Development: The Case of Cuba." *Environment, Development and Sustainability* 14, no. 4 (August 1, 2012): 573–91. https://doi.org/10.1007/s10668-012-9338-8.

Café Tacvba. *Ojalá Que Llueva Café*. Album. Tiempo Transcurrido. Song 6: Warner Music México, S.A. de C.V., 2001.

Camia, A., J. Giuntoli, K. Jonsson, N. Robert, N. Cazzaniga, G. Jasinevicius, V. Avitabile, G. Grassi, J. I. Barredo Cano, and S. Mubareka. "The Use of Woody Biomass for Energy Production in the EU." Publications Office of the European Union, 2020. https://publications.jrc.ec.europa.eu/repository/handle/JRC122719.

Canel, Eduardo, Uwafiokun Idemudia, and Liisa L. North. "Rethinking Extractive Industry: Regulation, Dispossession, and Emerging Claims." *Canadian Journal of Development Studies / Revue Canadienne d'études Du Développement* 30, no. 1–2 (January 2010): 5–25. https://doi.org/10.1080/02255189.2010.9669279.

Carballo Cruz, Edianny, Oscar Fernández García, and Rubiselis Santana Alfonso. "Los Impactos Del Turismo Percibidos Por La Comunidad Municipio Morón, Ciego de Ávila, Cuba." *Estudios y Perspectivas En Turismo* 21, no. 5 (October 2012): 1299–1317.

"Caribbean Tourism — Economic Development." *Tourism Management* 9, no. 2 (June 1, 1988): 155–61. https://doi.org/10.1016/0261-5177(88)90026-X.

Castaneda, Jorge G. "Latin America's Left Turn Essay." *Foreign Affairs* 85 (2006): 28–44.

Castro, Paula, and Marlene Kammerer. "The Institutionalization of a Cleavage: How Differential Treatment Affects State Behavior in the Climate Negotiations." *International Studies Quarterly* 65, no. 3 (September 7, 2021): 683–98. https://doi.org/10.1093/isq/sqab045.

"Catalog Record: The World Factbook | HathiTrust Digital Library." Accessed March 3, 2023. https://catalog.hathitrust.org/Record/000532922.

CCI, ESA Land Cover. "Product User Guide Version 2.0." *UCL-Geomatics: London, UK*, 2017.

Central Intelligence Agency. "The World Factbook 2014-2015." Government Printing Office, 2015. https://www.cia.gov/library/publications/the-world-factbook/.

Chen, Chao, Xinyue He, Zhisong Liu, Weiwei Sun, Heng Dong, and Yanli Chu. "Analysis of Regional Economic Development Based on Land Use and Land Cover Change Information Derived from Landsat Imagery." *Scientific Reports* 10, no. 1 (July 29, 2020): 12721. https://doi.org/10.1038/s41598-020-69716-2.

Chong, Daniel. "The Sustainable Development Goals and Climate Change." *Social Alternatives* 37, no. 1 (2018): 43–48. https://doi.org/10.3316/ielapa.573720576046699.

Coatsworth, John H. "Structures, Endowments, and Institutions in the Economic History of Latin America." *Latin American Research Review* 40, no. 3 (2005): 126–44. https://doi.org/10.1353/lar.2005.0040.

Colantonio, Andrea. "Social Sustainability: A Review and Critique of Traditional versus Emerging Themes and Assessment Methods." edited by M. Horner, A. Price, J. Bebbington, and R. Emmanuel, 865–85. Loughborough: Loughborough University, 2009. http://www.sue-mot.org/conference/.

Congalton, Russell G., and Kass Green. *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices, Third Edition*. CRC Press, 2019.

Connell, John, Kristen Lowitt, Arlette Saint Ville, and Gordon M. Hickey. "Food Security and Sovereignty in Small Island Developing States: Contemporary Crises and Challenges." In *Food Security in Small Island States*, edited by John Connell and Kristen Lowitt, 1–23. Singapore: Springer, 2020. https://doi.org/10.1007/978-981-13-8256-7_1.

Costa-Llanos, Virginia, and Daniellis Rodríguez-Mejías. "La Minería En La Cultura Cubana." *Minería y Geología* 32, no. 4 (December 2, 2016): 170–78.

Crawford, Colin. "Necessity Makes the Frog Jump: Land-Use Planning and Urban Agriculture in Cuba." *Tulane Environmental Law Journal*, no. Special Issue (2002): 733.

Crespo, Nicolás, and Santos Negrón Díaz. "CUBAN TOURISM IN 2007: ECONOMIC IMPACT," 1997, 12.

Daniel Whittle and Orlando Rey Santos. "Protecting Cuba's Environment: Efforts to Design and Implement Effective Environmental Laws and Policies in Cuba." *Cuban Studies* 37 (2006): 73.

De Mattos, Carlos. "Modernización Capitalista y Transformación Metropolitana En América Latina: Cinco Tendencias Constitutivas." *América Latina: Cidade, Campo e Turismo* 1 (2006): 41–73.

DeFries, Ruth S., Thomas Rudel, Maria Uriarte, and Matthew Hansen. "Deforestation Driven by Urban Population Growth and Agricultural Trade in the Twenty-First Century." *Nature Geoscience* 3, no. 3 (2010): 178.

Democracy Now! "'Breaking Point': Cities Struggle with Rise in Asylum Seekers; U.S. Foreign Policy Linked to Increase." Accessed September 27, 2023. https://www.democracynow.org/2023/9/27/immigration_border.

Díaz-Briquets, Sergio. "RECOGNIZING THE OBVIOUS WHILE MUDDLING THE WATERS: CUBA'S HOUSING SECTOR REFORMS," 2017, 12.

DÍAZ-BRIQUETS, SERGIO. "Regional Differences in Development and Living Standards in Revolutionary Cuba." *Cuban Studies* 18 (1988): 45–63.

Díaz-Briquets, Sergio. "THE ENDURING CUBAN HOUSING CRISIS: THE IMPACT OF HURRICANES," 2009, 13.

Diaz-Briquets, Sergio, and Jorge F. Pérez-López. *Conquering Nature : The Environmental Legacy of Socialism in Cuba*. Pitt Latin American Series. Pittsburgh, Pa. : University of Pittsburgh Press, 2000.

Domínguez, Jorge I. "National Institutions, Spatial Differentiation and Race: Variation in Cuba's Political Regime." *International Journal of Cuban Studies*, July 1, 2021. https://doi.org/10.13169/intejcubastud.13.1.0086.

"Earth Observation Group - Defense Meteorological Satellite Progam, Boulder | Ngdc.Noaa.Gov." Accessed March 26, 2019. https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html.

Ebanks, G Edward. "Urbanization in Cuba." *PSC Discussion Papers Series* 12, no. 10 (1998): 18.

Egenolf, Vincent, Martin Distelkamp, Christian Morland, Meghan Beck-O'Brien, and Stefan Bringezu. "The Timber Footprint of German Bioeconomy Scenarios Compared to the Planetary Boundaries for Sustainable Roundwood Supply." *Sustainable Production and Consumption* 33 (September 1, 2022): 686–99. https://doi.org/10.1016/j.spc.2022.07.029.

Egozcue, Jorge Mario Sánchez. "Challenges of Economic Restructuring in Cuba." *Socialism and Democracy* 26, no. 3 (November 1, 2012): 139–61. https://doi.org/10.1080/08854300.2012.716928.

Elvidge, Christopher D., Kimberly E. Baugh, Sharolyn J. Anderson, Paul C. Sutton, and Tilottama Ghosh. "The Night Light Development Index (NLDI): A Spatially Explicit Measure of Human Development from Satellite Data." *Social Geography* 7, no. 1 (2012): 23–35.

Elvidge, Christopher D., Kimberly E. Baugh, John B. Dietz, Theodore Bland, Paul C. Sutton, and Herbert W. Kroehl. "Radiance Calibration of DMSP-OLS Low-Light Imaging Data of Human Settlements." *Remote Sensing of Environment* 68, no. 1 (1999): 77–88.

Elvidge, Christopher D., Daniel Ziskin, Kimberly E. Baugh, Benjamin T. Tuttle, Tilottama Ghosh, Dee W. Pack, Edward H. Erwin, and Mikhail Zhizhin. "A Fifteen Year Record of Global Natural Gas Flaring Derived from Satellite Data." *Energies* 2, no. 3 (2009): 595–622.

Erisman, H. Michael. "Cuban Foreign Policy and the Latin American Debt Crisis." *Cuban Studies* 18 (1988): 3–18.

Espiñeira, Juan Carlos Albizu-Campos. "¿Es El Descenso de La Actividad Económica de La Población Un Fenomeno Temporal En Cuba? Is the Decline in the Economic Activity of the Population a Temporary Phenomenon in Cuba?" *International Journal of Cuban Studies*, July 1, 2020. https://doi.org/10.13169/intejcubastud.12.1.0053.

Espino, María Dolores. "International Tourism in Cuba: An Economic Development Strategy?" In *Annual Proceedings*, Vol. 1. The Association for the Study of the Cuban Economy, 1991.

ESRI. "Hot Spot Analysis (Getis-Ord Gi*) (Spatial Statistics)—ArcGIS Pro | Documentation." Accessed November 20, 2023. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/hot-spot-analysis.htm.

Estévez Pazó, R., Y. Del Risco Yera, and F. Serrano Raffo. “Planeamiento del turismo y Geografía. Desarrollo en Cuba en los últimos 40 años.” *Geographicalia*, no. 37bis (June 28, 2016): 151. https://doi.org/10.26754/ojs_geoph/geoph.200037bis1387.

Estrada, R., and A. Perera. “Determining Significance of Protected Areas in Cuba.” *Intern. J. Wilderness* 4, no. 2 (1998): 13–16.

Estrada, Reinaldo Estrada. *The National System of Marine Protected Areas in Cuba*. National Center for Protected Areas, 2004.

FAO. “Fertilizer Use by Crop in Cuba.” Food and Agriculture Organization of the United Nations, 2003. https://www.fao.org/3/y4801e/y4801e.pdf.

“FAOSTAT.” Accessed June 20, 2019. http://www.fao.org/faostat/en/#data/QC.

Faraji, Seyed J, Zhang Qingping, Saman Valinoori, and Mohamad Komijani. “URBAN PRIMACY IN URBAN SYSTEM OF DEVELOPING COUNTRIES; ITS CAUSES AND CONSEQUENCES” 6, no. 1 (2016): 13.

Febles-González, J.m., A. Tolón-Becerra, X. Lastra-Bravo, and X. Acosta-Valdés. “Cuban Agricultural Policy in the Last 25 Years. From Conventional to Organic Agriculture.” *Land Use Policy* 28 (January 1, 2011): 723–35. https://doi.org/10.1016/j.landusepol.2010.12.008.

Fehling, Maya, Brett D. Nelson, and Sridhar Venkatapuram. “Limitations of the Millennium Development Goals: A Literature Review.” *Global Public Health* 8, no. 10 (December 2013): 1109–22. https://doi.org/10.1080/17441692.2013.845676.

Font, Mauricio A., and Carlos Riobó. *Handbook of Contemporary Cuba : Economy, Politics, Civil Society, and Globalization*. A Paradigm Handbook. Boulder : Paradigm Publishers, [2013], 2013.

Funes-Monzote, Reinaldo. “The Rise and Fall of Dairy Cows in Socialist Cuba.” *Global Environment* 9, no. 2 (2016): 342–75.

Galford, Gillian L, Margarita Fernandez, Joe Roman, Irene Monasterolo, Sonya Ahamed, Greg Fiske, Patricia González, and Les Kaufman. “Cuban Land Use and Conservation, from Rainforests to Coral Reefs.” *Bulletin of Marine Science*, 2018. https://doi.org/10.5343/bms.2017.1026.

García Molina, Andrés. “Nostalgia, Internal Migration and the Return of Cuban Street-Vendor Songs.” *Culture, Theory and Critique* 61, no. 2–3 (July 2, 2020): 229–45. https://doi.org/10.1080/14735784.2020.1828119.

Gebelein, Jennifer. *A Geographic Perspective of Cuban Landscapes*. Landscape Series: V. 15. Dordrecht ; New York : Springer, 2012.

General Assembly resolution 75/L.97. “Necessity of Ending the Economic, Commercial and Financial Embargo Imposed by the United States of America against Cuba.” A/75/L.97, June 9, 2021. https://undocs.org/en/A/75/L.97.

Geomatics, U. C. L. *Land Cover CCI: Product User Guide, Version 2.0*. European Space Agency: Louvain la Neuve, Belgium, 2017.

“Global Administrative Areas (GADM),” 2018. https://gadm.org/data.html.

Gobat, Michel. "The Invention of Latin America: A Transnational History of Anti-Imperialism, Democracy, and Race." *The American Historical Review* 118, no. 5 (December 1, 2013): 1345–75. https://doi.org/10.1093/ahr/118.5.1345.

Gonzalez, Carmen G. "Seasons of Resistance: Sustainable Agriculture and Food Security in Cuba," Tulane Environmental Law Journal, 2007, 48.

González, Jesús M., Eduardo Salinas, Enrique Navarro, Antoni A. Artigues, Ricardo Remond, Ismael Yrigoy, Maité Echarri, and Yanira Arias. "The City of Varadero (Cuba) and the Urban Construction of a Tourist Enclave." *Urban Affairs Review* 50, no. 2 (March 2014): 206–43. https://doi.org/10.1177/1078087413485218.

González-Corzo, Mario. "USUFRUCT FARMING IN CUBA: RECENT DEVELOPMENTS AND FUTURE PROSPECTS," 2017, 6.

Gonzalez-Corzo, Mario A. "Agricultural Reforms, Land Distribution, and Non-Sugar Agricultural Production in Cuba," 2019, 8.

Gonzalez-Corzo, Mario A. "Transition or Survival? An Analysis of Cuba's Post - Soviet Economic Reforms." Ph.D., Rutgers The State University of New Jersey - Newark. Accessed July 25, 2022. https://www.proquest.com/docview/305284571/abstract/8C0B93DF83164CC7PQ/1.

Gonzalez-Corzo, Mario A, and Orlando Justo. "Private Self-Employment under Reform Socialism in Cuba." *Journal of Private Enterprise*, no. 32 : 2 (2017): 45.

Goulart, Fernando, Ángel Leyva Galán, Erin Nelson, and Britaldo Soares-Filho. "Conservation Lessons from Cuba: Connecting Science and Policy." *Biological Conservation* 217 (January 1, 2018): 280–88. https://doi.org/10.1016/j.biocon.2017.10.033.

Grandin, Greg. *Empire's Workshop: Latin America, the United States, and the Rise of the New Imperialism*. Metropolitan Books, 2006.

GRASSO, Marco. "A Normative Ethical Framework in Climate Change." *Climatic Change* 81, no. 3–4 (2007): 223–46. https://doi.org/10.1007/s10584-006-9158-7.

Grasso, Marco, and Ezra M. Markowitz. "The Moral Complexity of Climate Change and the Need for a Multidisciplinary Perspective on Climate Ethics." *Climatic Change* 130, no. 3 (2015): 327–34. https://doi.org/10.1007/s10584-014-1323-9.

Gunderson, Lance H. "Ecological Resilience: In Theory and Application." *Annual Review of Ecology and Systematics*, 2000, 425.

Hanon, Ingrid. "Cuba, Agriculture and Socialist Renewal." *International Journal of Cuban Studies* 12, no. 2 (2020): 196–227.

———. "Moishe Postone, the Mode of Production of Capital and Cuban Agriculture." *Capitalism Nature Socialism*, 2021, 1–19.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, et al. "High-Resolution Global Maps of 21st-Century Forest Cover Change (V2016." *Science* 342, no. 6160 (November 15, 2013): 850–53. https://doi.org/10.1126/science.1244693.

Hansing, Katrin. "Race and Inequality in the New Cuba: Reasons, Dynamics, and Manifestations." *Social Research: An International Quarterly* 84, no. 2 (2017): 331–49.

Heidrich, Pablo. "Determinants, Boundaries, and Patterns of Canadian Mining Investments in Latin America (1995–2015)." *Latin American Policy* 7, no. 2 (2016): 195–214.

Hey, Anthony JG, Stewart Tansley, and Kristin Michele Tolle. "The Fourth Paradigm: Data-Intensive Scientific Discovery" 1 (2009).

Holling, C.s. "From Complex Regions to Complex Worlds." *Minnesota Journal of Law, Science & Technology*, 2005, 1.

Holling, Cs. "Understanding the Complexity of Economic, Ecological, and Social Systems." *ECOSYSTEMS* 4, no. 5 (August 2001): 390–405.

Hooks, Bell. *Talking Back: Thinking Feminist, Thinking Black*. South End Press, 1989.

Hornborg, Alf. "Zero-Sum World: Challenges in Conceptualizing Environmental Load Displacement and Ecologically Unequal Exchange in the World-System." *International Journal of Comparative Sociology* 50, no. 3–4 (2009): 237–62.

Hsu, Feng-Chi, Kimberly E. Baugh, Tilottama Ghosh, Mikhail Zhizhin, and Christopher D. Elvidge. "DMSP-OLS Radiance Calibrated Nighttime Lights Time Series with Intercalibration." *Remote Sensing* 7, no. 2 (2015): 1855–76.

Hua, Ting, Wenwu Zhao, Yanxu Liu, Shuai Wang, and Siqi Yang. "Spatial Consistency Assessments for Global Land-Cover Datasets: A Comparison among GLC2000, CCI LC, MCD12, GLOBCOVER and GLCNMO." *Remote Sensing* 10, no. 11 (November 21, 2018): 1846. https://doi.org/10.3390/rs10111846.

Hunsberger, Carol, Esteve Corbera, Saturnino M. Borras Jr, Jennifer C. Franco, Kevin Woods, Courtney Work, Romulo de la Rosa, Vuthy Eang, Roman Herre, and Sai Sam Kham. "Climate Change Mitigation, Land Grabbing and Conflict: Towards a Landscape-Based and Collaborative Action Research Agenda." *Canadian Journal of Development Studies/Revue Canadienne d'études Du Développement* 38, no. 3 (2017): 305–24.

Ivan, Kinga, Iulian-Horia Holobâcă, József Benedek, and Ibolya Török. "Potential of Night-Time Lights to Measure Regional Inequality." *Remote Sensing* 12, no. 1 (2020): 33.

Jafino, Bramka Arga, Jan H. Kwakkel, and Behnam Taebi. "Enabling Assessment of Distributive Justice through Models for Climate Change Planning: A Review of Recent Advances and a Research Agenda." *WIREs Climate Change* 12, no. 4 (2021): e721. https://doi.org/10.1002/wcc.721.

Jennifer Gebelein. "Governmental Organization and Control Over Environmental Policies." *A Geographic Perspective of Cuban Landscapes*, Landscape Series. 15, 2011, 31. https://doi.org/10.1007/978-94-007-2406-8_3.

Jolivet, Violaine, and Mateo Alba-Carmichael. "Reinvesting in Havana: Housing Commodification and Gentrification in the Central Neighbourhoods of a

Socialist City in the Global South." *International Journal of Cuban Studies*, December 1, 2021. https://doi.org/10.13169/intejcubastud.13.2.0248.
Jolly, Richard. "Global Development Goals: The United Nations Experience." *Journal of Human Development* 5, no. 1 (March 2004): 69–95. https://doi.org/10.1080/1464988031000166021O.
Jover, Jorge Núñez, Isvieysys Armas Marrero, Ariamnis Alcázar Quiñones, and Galia Figueroa Alfonso. "Higher Education, Innovation and Local Development: Experiences in Cuba." *National Innovation Systems, Social Inclusion and Development*, August 29, 2014. https://www.elgaronline.com/view/edcoll/9781782548676/9781782548676.00014.xml.
Kanbur, Ravi, and Henry Shue. *Climate Justice: Integrating Economics and Philosophy*. Oxford: OUP Oxford, 2018. https://doi.org/10.1093/oso/9780198813248.001.0001.
Kelly, Maggi, Samuel Blanchard, Ellen Kersten, and Kevin Koy. "Terrestrial Remotely Sensed Imagery in Support of Public Health: New Avenues of Research Using Object-Based Image Analysis." *Remote Sensing* 3 (December 1, 2011): 2321–45. https://doi.org/10.3390/rs3112321.
Klassen, Jerome. "Canada and the New Imperialism: The Economics of a Secondary Power." *Studies in Political Economy* 83, no. 1 (March 2009): 163–90. https://doi.org/10.1080/19187033.2009.11675060.
Kouame, Auguste, and Maria Ivanova Reyes. "The Caribbean Region beyond the 2008-09 Global Financial Crisis." In *Documento Presentado En La Conferencia "Options for the Caribbean after the Global Financial Crisis", Bridgetown*, 27–28, 2011.
L Rice, Jennifer, Joshua Long, and Anthony Levenda. "Against Climate Apartheid: Confronting the Persistent Legacies of Expendability for Climate Justice." *Environment and Planning E: Nature and Space*, March 12, 2021, 2514848621999286. https://doi.org/10.1177/2514848621999286.
La Polla Records. *Criticos*. Album. Salve. Song 8: Cultural Rock Records SL/La Polla Records, 1984.
Lambin, Eric F., and Patrick Meyfroidt. "Global Land Use Change, Economic Globalization, and the Looming Land Scarcity." *Proceedings of the National Academy of Sciences* 108, no. 9 (March 1, 2011): 3465–72. https://doi.org/10.1073/pnas.1100480108.
Lambin, Eric F., Billie L. Turner, Helmut J. Geist, Samuel B. Agbola, Arild Angelsen, John W. Bruce, Oliver T. Coomes, Rodolfo Dirzo, Günther Fischer, and Carl Folke. "The Causes of Land-Use and Land-Cover Change: Moving beyond the Myths." *Global Environmental Change* 11, no. 4 (2001): 261–69.
Lawrence H. Theriot and JeNelle Matheson. "Soviet Economic Relations with the Non-European CMEA: Cuba, Vietnam, and Mongolia." *Soviet and Eastern European Foreign Trade* 21, no. 1/2/3 (1985): 144.
Lefebvre, Henri, and Donald Nicholson-Smith. *The Production of Space*. Vol. 142. Oxford Blackwell, 1991.

Li, Chang, Jia Ye, Shice Li, Guangping Chen, and Hao Xiong. "Study on Radiometric Intercalibration Methods for DMSP-OLS Night-Time Light Imagery." *International Journal of Remote Sensing* 37, no. 16 (2016): 3675–95.

Liu, Xiaoxuan, Le Yu, Yali Si, Chi Zhang, Hui Lu, Chaoqing Yu, and Peng Gong. "Identifying Patterns and Hotspots of Global Land Cover Transitions Using the ESA CCI Land Cover Dataset." *Remote Sensing Letters* 9, no. 10 (2018): 972–81.

Liu, Zhifeng, Chunyang He, Yuyu Zhou, and Jianguo Wu. "How Much of the World's Land Has Been Urbanized, Really? A Hierarchical Framework for Avoiding Confusion." *Landscape Ecology* 29, no. 5 (May 1, 2014): 763–71. https://doi.org/10.1007/s10980-014-0034-y.

Los Cogelones. *500 Años*. Vinyl. Hijos Del Sol. Song 9: Piccolo Records, 2020.

Los Wálters. *Mayagüez*. Vol. Isla Disco. Isla Disco. Song 4: Los Wálters, 2016.

Lowe, Benjamin S. "Ethics in the Anthropocene: Moral Responses to the Climate Crisis." *Journal of Agricultural & Environmental Ethics* 32, no. 3 (2019): 479–85. https://doi.org/10.1007/s10806-019-09786-z.

Lu, D., P. Mausel, E. Brondízio, and E. Moran. "Change Detection Techniques." *International Journal of Remote Sensing* 25, no. 12 (June 1, 2004): 2365–2401. https://doi.org/10.1080/0143116031000139863.

Mair, Simon, Aled Jones, Jonathan Ward, Ian Christie, Angela Druckman, and Fergus Lyon. "A Critical Review of the Role of Indicators in Implementing the Sustainable Development Goals." In *World Sustainability Series*, 2017. https://doi.org/10.1007/978-3-319-63007-6_3.

Manepalli, U. R., Ghulam H. Bham, and Srinadh Kandada. "Evaluation of Hotspots Identification Using Kernel Density Estimation (K) and Getis-Ord (Gi*) on I-630." In *3rd International Conference on Road Safety and Simulation*, 21:14–16. National Academy of Sciences Indianapolis Indiana, United States, 2011. https://onlinepubs.trb.org/onlinepubs/conferences/2011/RSS/2/Manepalli,UR.pdf.

Mario Alberto Arrastía-Avila and Lisa M. Glidden. "Cuba's Energy Revolution and 2030 Policy Goals: More Penetration of Renewable Energy in Electricity Generation." *International Journal of Cuban Studies* 9, no. 1 (2017): 73. https://doi.org/10.13169/intejcubastud.9.1.0073.

Mary Beth Sheridan. "In Cuba, a Frantic Search for Milk." *Washington Post*, May 21, 2022. https://www.washingtonpost.com/world/interactive/2022/cuba-economy-milk-shortage/.

Mellander, Charlotta, José Lobo, Kevin Stolarick, and Zara Matheson. "Night-Time Light Data: A Good Proxy Measure for Economic Activity?" Edited by Guy J-P. Schumann. *PLOS ONE* 10, no. 10 (October 23, 2015): e0139779. https://doi.org/10.1371/journal.pone.0139779.

Mesa-Lago, Carmelo. "Economic and Social Balance of 50 Years of Cuban Revolution." *Annual Proceedings* 19 (2009).

https://econpapers.repec.org/article/qbaannpro/v_3a19_3ay_3a2009_3aid_3a830.htm.
Mesa-Lago, Carmelo, and Mario A. González-Corzo. "Agrarian Reform and Usufruct Farming in Socialist Cuba." *Journal of Economic Policy Reform* 24, no. 2 (April 3, 2021): 119–33. https://doi.org/10.1080/17487870.2019.1683010.
Mesa-Lago, Carmelo, and Pavel Vidal-Alejandro. "The Impact of the Global Crisis on Cuba's Economy and Social Welfare." *Journal of Latin American Studies* 42, no. 4 (November 2010): 689–717. https://doi.org/10.1017/S0022216X10001331.
Min, Brian, Kwawu Mensan Gaba, Ousmane Fall Sarr, and Alassane Agalassou. "Detection of Rural Electrification in Africa Using DMSP-OLS Night Lights Imagery." *International Journal of Remote Sensing* 34, no. 22 (November 20, 2013): 8118–41. https://doi.org/10.1080/01431161.2013.833358.
Mollett, Sharlene. "The Power to Plunder: Rethinking Land Grabbing in Latin America." *Antipode* 48, no. 2 (2016): 412–32. https://doi.org/10.1111/anti.12190.
Monzon, Renee. "Introducing Private-Property Rights to Cuba: How Cuba's New Constitution Paves the Way for Economic Growth." *Case Western Reserve Journal of International Law* 52, no. 1/2 (Spring 2020): 629–68.
Mooney, Henry, and Maria Zegarra. *Extreme Outlier: The Pandemic's Unprecedented Shock to Tourism in Latin America and the Caribbean*, 2020. https://doi.org/10.18235/0002470.
Moretti, Franco. "Conjectures on World Literature." *New Left Review* 2, no. 1 (2000): 54–68.
Narayan, John, and Leon Sealey-Huggins. "Whatever Happened to the Idea of Imperialism?" *Third World Quarterly* 38, no. 11 (November 2, 2017): 2387–95. https://doi.org/10.1080/01436597.2017.1374172.
National Report. "Cuba Informe Nacional hacia Hábitat III." Text. Instituto Nacional de Ordenamiento Territorial y Urbanismo. ETECSA S.A., November 3, 2017. https://www.ipf.gob.cu/es/content/cuba-informe-nacional-hacia-h%C3%A1bitat-iii.
Nelson, Laura K. "Computational Grounded Theory: A Methodological Framework." *Sociological Methods & Research* 49, no. 1 (February 1, 2020): 3–42. https://doi.org/10.1177/0049124117729703.
Newman, Nicholas. "Cuba's Power Struggle [Power Cuba]." *Engineering & Technology* 4, no. 16 (2009): 51–53.
Nova González, Armando, and Galia Figueroa Alfonso. "Recent Transformations in Cuban Agricultural Policy and Impacts on Markets and Production." *Elem Sci Anth* 6, no. 1 (December 10, 2018): 78. https://doi.org/10.1525/elementa.323.
Nulman, Eugene. "Neo-Imperialism in Solidarity Organisations' Public Discourses: Collective Action Frames, Resources and Audiences." *Third World Quarterly* 38, no. 11 (November 2, 2017): 2464–81. https://doi.org/10.1080/01436597.2017.1368011.

OEC - The Observatory of Economic Complexity. “About the Site | OEC.” Accessed March 6, 2023. https://oec.world/en/resources/about.

Ötker-Robe, Inci, and Anca Maria Podpiera. *The Social Impact of Financial Crises: Evidence from the Global Financial Crisis*. Policy Research Working Papers. The World Bank, 2013. https://doi.org/10.1596/1813-9450-6703.

“Overview of Cuban Imports of Goods and Services and Effects of U.S. Restrictions.” United States International Trade Commission, March 2016. https://www.usitc.gov/publications/332/pub4597.pdf.

Palma, Isela Ponce, José Nahed Toral, Manuel Roberto Parra Vázquez, Norge Fonseca Fuentes, and Francisco Guevara Hernández. “Historical Changes in the Process of Agricultural Development in Cuba.” *Journal of Cleaner Production* 96 (June 2015): 77–84. https://doi.org/10.1016/j.jclepro.2013.11.078.

Papatheodorou, Andreas, Jaume Rosselló, and Honggen Xiao. “Global Economic Crisis and Tourism: Consequences and Perspectives.” *Journal of Travel Research* 49, no. 1 (February 1, 2010): 39–45. https://doi.org/10.1177/0047287509355327.

Perez, Lisandro. “Internal Migration in Latin America: The Contrasting Cases of Colombia and Cuba.” *Sociology in Latin America*, 1994, 191.

Pérez, Lorenzo. “The Impact of the Global Financial and Economic Crisis on Cuba.” In *Annual Proceedings*, Vol. 19. The Association for the Study of the Cuban Economy, 2009.

Pérez, Víctor, Flor Guerrero, Mercedes González, Fátima Pérez, and Rafael Caballero. “Composite Indicator for the Assessment of Sustainability: The Case of Cuban Nature-Based Tourism Destinations.” *Ecological Indicators* 29 (June 2013): 316–24. https://doi.org/10.1016/j.ecolind.2012.12.027.

Pérez-Hoyos, Ana, Felix Rembold, Hervé Kerdiles, and Javier Gallego. “Comparison of Global Land Cover Datasets for Cropland Monitoring.” *Remote Sensing* 9, no. 11 (November 3, 2017): 1118. https://doi.org/10.3390/rs9111118.

Pérez-López, Jorge F. “The Restructuring of the Cuban Sugar Agroindustry: A Progress Report.” *Cuba in Transition* 26 (2018): 49–57.

Pesaresi, Martino. “GHS Built-up Surface Grid, Derived from Sentinel2 Composite and Landsat, Multitemporal (1975-2030).” European Commission, Joint Research Centre (JRC), 2022. https://doi.org/10.2905/D07D81B4-7680-4D28-B896-583745C27085.

Peters, Philip. “International Tourism: The New Engine of the Cuban Economy.” *Arlington, VA: Lexington Institute*, 2002.

Pew Research Center. “Latin America and Caribbean No Longer World’s Fastest Growing Source of International Migrants.” Accessed October 6, 2023. https://www.pewresearch.org/short-reads/2019/01/25/latin-america-caribbean-no-longer-worlds-fastest-growing-source-of-international-migrants/.

Podiotis, Panagiotis. “Towards International Relations Data Science: Mining the CIA World Factbook.” arXiv, October 12, 2020. https://doi.org/10.48550/arXiv.2010.05640.

Purdon, Mark. “Neoclassical Realism and International Climate Change Politics: Moral Imperative and Political Constraint in International Climate Finance.” *Journal of International Relations and Development* 20, no. 2 (April 1, 2017): 263–300. https://doi.org/10.1057/jird.2013.5.

Rata Negra. *Venid a Ver*. Una Vida Vulgar. Song 1: Humo Internacional, 2021.

Reardon, Thomas, and Christopher B. Barrett. “Agroindustrialization, Globalization, and International Development: An Overview of Issues, Patterns, and Determinants.” *Agricultural Economics* 23, no. 3 (2000): 195–205.

Rehman, Sami, Vaishnavi Honap, Asfa Siddiqui, Ambadas Maske, and Sandeep Maithani. “Spatio-Temporal Variations in Night Lights, Economy and Night Light Emissions in States of India.” *Journal of the Indian Society of Remote Sensing*, 2021, 1–11.

Ritter, Archibald R. M. “Entrepreneurship, Microenterprise, and Public Policy in Cuba: Promotion, Containment, or Asphyxiation?” *Journal of Interamerican Studies and World Affairs* 40, no. 2 (ed 1998): 63–94. https://doi.org/10.2307/166374.

Ritter, Archibald R. M., and Ted A. Henken. *Entrepreneurial Cuba : The Changing Policy Landscape*. Boulder, Colorado ; London, [England] : First Forum Press, 2015., 2015.

Romero, José Luis Martín. “LA CULTURA DEL TRABAJO Y LA REESTRUCTURACIÓN DE LA AGROINDUSTRIA AZUCARERA.,” 2003, 18.

Rosset, Peter Michael, Braulio Machín Sosa, Adilén María Roque Jaime, and Dana Rocío Ávila Lozano. “The Campesino to Campesino Agroecology Movement of ANAP in Cuba: Social Process Methodology in the Construction of Sustainable Peasant Agriculture and Food Sovereignty.” *Journal of Peasant Studies* 38, no. 1 (January 2011): 161–91. https://doi.org/10.1080/03066150.2010.538584.

RStudio Team. “RStudio: Integrated Development for R.” Boston, MA: PBC, 2020. http://www.rstudio.com/.

Rüland, Jürgen. “The Long Shadow of the Developmental State: Energy Infrastructure and Environmental Sustainability in Southeast Asia.” *Third World Quarterly* 0, no. 0 (February 24, 2023): 1–19. https://doi.org/10.1080/01436597.2023.2178890.

Sagebien, Julia. “The Canadian Presence in Cuba in the Mid-1990s.” *Cuban Studies*, 1996, 143–68.

Salinas Chávez, Eduardo, and José Alberto La O Osorio. “TURISMO Y SUSTENTABILIDAD: DE LA TEORÍA A LA PRÁCTICA EN CUBA.” *Cuadernos de Turismo* 0, no. 17 (January 1, 2006): 201–21.

Salinas, Eros, Lluis Mundet, and Eduardo Salinas. “Historical Evolution and Spatial Development of Tourism in Cuba, 1919–2017: What Is Next?” *Tourism Planning & Development* 15, no. 3 (May 4, 2018): 216–38. https://doi.org/10.1080/21568316.2018.1427142.

Sánchez, Alcides Francisco Antúnez. "La minería inversa en el ordenamiento jurídico en cuba. una apuesta al desarrollo sostenible desde la economía circular." *Revista Innova ITFIP* 6, no. 1 (June 30, 2020): 71–92.
Scarpaci, Joseph L., and Armando H. Portela. *Cuban Landscapes: Heritage, Memory, and Place*. Guilford Press, 2009.
Sealey-Huggins, Leon. "'1.5°C to Stay Alive': Climate Change, Imperialism and Justice for the Caribbean." *Third World Quarterly* 38, no. 11 (November 2, 2017): 2444–63. https://doi.org/10.1080/01436597.2017.1368013.
Simoes, Alexander James Gaspar, and César A. Hidalgo. "The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development." In *Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence*, 2011.
Simón Reardon, Juan Alberto, and Reinaldo Alemán Pérez. "Agroecology and the Development of Indicators of Food Sovereignty in Cuban Food Systems." *Journal of Sustainable Agriculture* 34, no. 8 (October 27, 2010): 907–22. https://doi.org/10.1080/10440046.2010.519205.
Simpson, Murray, Daniel Scott, and Ulric Trotz. "Climate Change's Impact on the Caribbean's Ability to Sustain Tourism, Natural Assests and Livelihoods," March 1, 2011. https://publications.iadb.org/en/climate-changes-impact-caribbeans-ability-sustain-tourism-natural-assests-and-livelihoods.
Sklodowska, Elzbieta. *Invento, luego resisto: El Período Especial en Cuba como experiencia y metáfora (1990-2015)*. 1st ed. Chile: Editorial Cuarto Propio, 2016.
Smith, Rose-Ann J., and Kevon Rhiney. "Climate (in)Justice, Vulnerability and Livelihoods in the Caribbean: The Case of the Indigenous Caribs in Northeastern St. Vincent." *Geoforum* 73 (July 1, 2016): 22–31. https://doi.org/10.1016/j.geoforum.2015.11.008.
Son Rompe Pera. *Pájaro Cenzontle*. Batuco. Song 6: AYA Records, 2020.
Srinivasan, Krishna, Inci Otker, Uma Ramakrishnan, and Trevor Serge Coleridge Alleyne. *Unleashing Growth and Strengthening Resilience in the Caribbean*. International Monetary Fund, 2017.
Statista. "Global Peace Index Latin America & Caribbean 2023." Accessed October 6, 2023. https://www.statista.com/statistics/1124877/latin-america-caribbean-peace-index-country/.
Stuart, Diana, and Rebecca L. Schewe. "Constrained Choice and Climate Change Mitigation in US Agriculture: Structural Barriers to a Climate Change Ethic." *Journal of Agricultural & Environmental Ethics* 29, no. 3 (2016): 369–85. https://doi.org/10.1007/s10806-016-9605-z.
Studnicki-Gizbert, Daviken. "Canadian Mining in Latin America (1990 to Present): A Provisional History." *Canadian Journal of Latin American and Caribbean Studies / Revue Canadienne Des Études Latino-Américaines et Caraïbes* 41, no. 1 (2016): 95–113.
Sunkel, Osvaldo. "La interacción entre los estilos de desarrollo y el medio ambiente en América Latina." *Revista CEPAL Economic Commission for Latin America*

and the Caribbean, Seminario Regional sobre Estilos de Desarrollo y Medio Ambiente en América Latina, December 1980. https://repositorio.cepal.org/handle/11362/12022.

Sweign, Julia E., and Michael J. Bustamante. "Cuba after Communism: The Economic Reforms That Are Transforming the Island." *Foreign Affairs*, no. Issue 4 (2013): 101.

Systema Solar. *Somos La Tierra*. Mp3. Song 7: National Records, 2017.

Tanco, Andrew Selee, Valerie Lacarte, Ariel G. Ruiz Soto, Diego Chaves-González, María Jesús Mora, Andrea Tanco Andrew Selee, Valerie Lacarte, Ariel G. Ruiz Soto, Diego Chaves-González, María Jesús Mora, and Andrea. "In a Dramatic Shift, the Americas Have Become a Leading Migration Destination." migrationpolicy.org, April 10, 2023. https://www.migrationpolicy.org/article/latin-america-caribbean-immigration-shift.

"Tarea Ordenamiento: 2021 Comienza Con El Proceso Más Determinante Para Avanzar En La Actualización Del Modelo Económico › Cuba › Granma - Órgano Oficial Del PCC." Accessed November 3, 2021. https://www.granma.cu/cuba/2020-12-10/esta-noche-informacion-especial-de-interes-para-la-poblacion-en-cadena-de-radio-y-television-10-12-2020-10-12-28.

The Nature Conservancy Caribbean. "Caribbean Science Atlas." Accessed September 19, 2021. https://caribbeanscienceatlas.tnc.org/.

"The World Factbook Archives - The World Factbook." Accessed September 13, 2022. https://www.cia.gov/the-world-factbook/about/archives/.

Thomas, Adelle, April Baptiste, Rosanne Martyr-Koller, Patrick Pringle, and Kevon Rhiney. "Climate Change and Small Island Developing States." *Annual Review of Environment and Resources* 45, no. 1 (2020): 1–27. https://doi.org/10.1146/annurev-environ-012320-083355.

Torres Cala, Yerenis, Maricela María González Pérez, Zulma Ramírez Cruz, Roberto Muñoz González, Yerenis Torres Cala, Maricela María González Pérez, Zulma Ramírez Cruz, and Roberto Muñoz González. "El Proceso de Innovación En El Sector Forestal Cubano y Su Contribución a La Economía Nacional." *Revista Cubana de Ciencias Forestales* 6, no. 2 (August 2018): 146–61.

Torres, Janet. "Integrated Water Management Practices in Mexico and Their Impact on Local Drinking Water Quality: Efficient Assessment Methods," 2016. https://oaktrust.library.tamu.edu/handle/1969.1/156791.

Transparency International. "Corruption Perceptions Index." 1995 - 2021, 2022. https://www.transparency.org/en/cpi/2021.

Turner, Billie L., Eric F. Lambin, and Anette Reenberg. "The Emergence of Land Change Science for Global Environmental Change and Sustainability." *Proceedings of the National Academy of Sciences* 104, no. 52 (2007): 20666–71.

Underwood, Ted. “A Genealogy of Distant Reading.” *Digital Humanities Quarterly* 011, no. 2 (June 27, 2017).
UNEP-WCMC and IUCN. “Protected Planet: The World Database on Protected Areas (WDPA) and World Database on Other Effective Area-Based Conservation Measures (WD-OECM).” Cambridge, UK, 2022. https://www.protectedplanet.net/country/CUB.
United States Central Intelligence Agency. “The 1992 CIA World Factbook.” Project Gutenberg, January 1, 1993. https://www.gutenberg.org/ebooks/48/.
Valladares, Arturo. “The Community Architect Program: Implementing Participation-in-Design to Improve Housing Conditions in Cuba.” *Habitat International* 38 (April 1, 2013): 18–24. https://doi.org/10.1016/j.habitatint.2012.09.004.
Vennesson, Pascal. “12 Case Studies and Process Tracing: Theories and Practices.” *Approaches and Methodologies in the Social Sciences* 223 (2008).
Watson, Simon J., Gary W. Luck, Peter G. Spooner, and David M. Watson. “Land-Use Change: Incorporating the Frequency, Sequence, Time Span, and Magnitude of Changes into Ecological Research.” *Frontiers in Ecology and the Environment* 12, no. 4 (2014): 241–49.
WCED, SPECIAL WORKING SESSION. “World Commission on Environment and Development.” *Our Common Future*, 1987.
Wong, Alfred. “Caribbean Island Tourism: Pathway to Continued Colonial Servitude.” *Études Caribéennes*, no. 31–32 (September 26, 2015). https://doi.org/10.4000/etudescaribeennes.7524.
World Bank. “DMSP-OLS Intercalibration, Open Nighttime Lights.” Accessed October 12, 2021. https://worldbank.github.io/OpenNightLights/tutorials/mod5_1_DMSP-OLS_intercalibration.html.
World Bank Group Archives. “World Development Indicators (WDI),” 2018. https://datacatalog.worldbank.org/dataset/world-development-indicators.
Wright, Julia. “Methodological Considerations on the Experience of Undertaking Doctoral Research in the Agricultural Sector in Cuba During the Special Period (1998–2000).” *International Journal of Cuban Studies* 8, no. 2 (2016): 296–308. https://doi.org/10.13169/intejcubastud.8.2.0296.
———. *Sustainable Agriculture and Food Security in an Era of Oil Scarcity : Lessons from Cuba*. London ; Sterling, VA : Earthscan, 2009., 2009.
Wulder, Michael A., Nicholas C. Coops, David P. Roy, Joanne C. White, and Txomin Hermosilla. “Land Cover 2.0.” *International Journal of Remote Sensing* 39, no. 12 (June 18, 2018): 4254–84. https://doi.org/10.1080/01431161.2018.1452075.
Zhou, Yuyu, Xuecao Li, Ghassem R. Asrar, Steven J. Smith, and Marc Imhoff. “A Global Record of Annual Urban Dynamics (1992–2013) from Nighttime Lights.” *Remote Sensing of Environment* 219 (December 2018): 206–20. https://doi.org/10.1016/j.rse.2018.10.015.