Making the Hidden Visible: Accelerated Land-Use Change Caused by Narco-Trafficking In and Around Central America's Protected Areas

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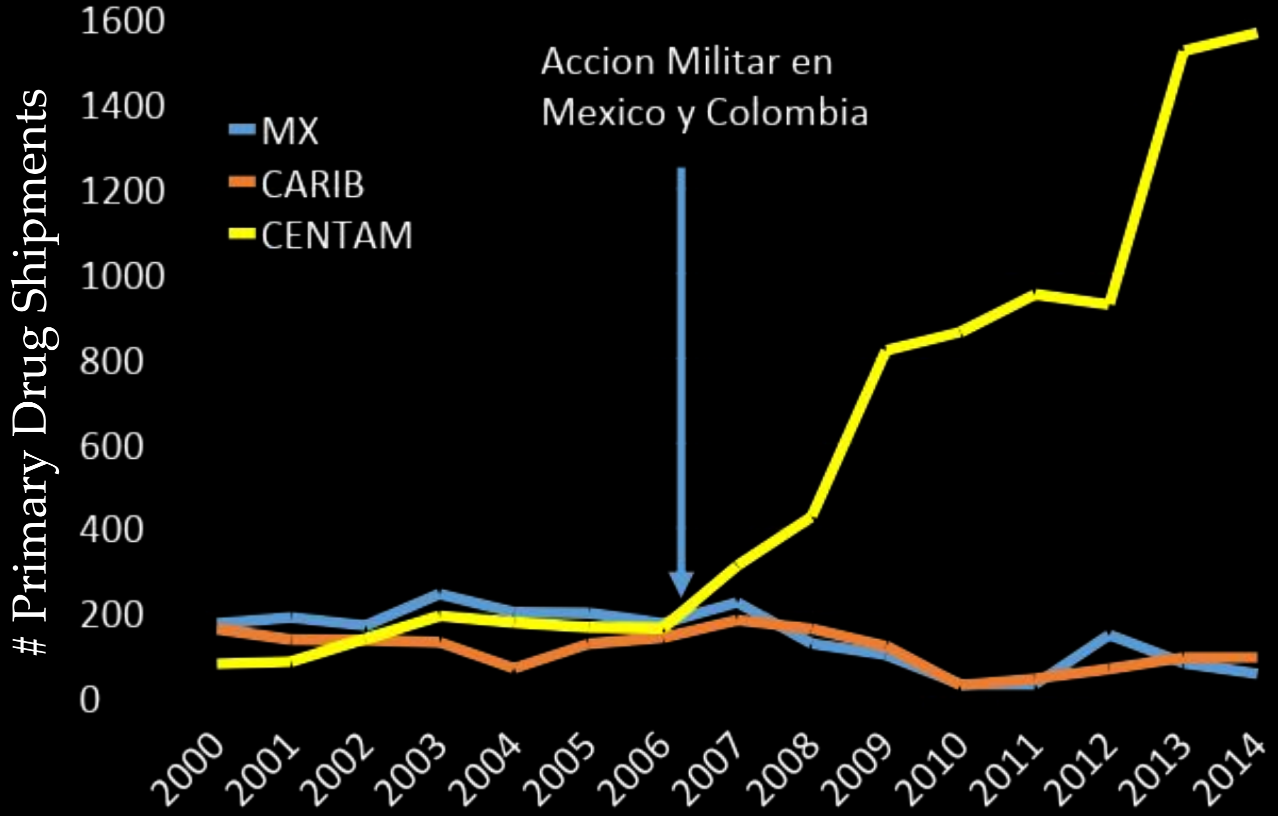
NASA LCLUC #80NSSC21K0297

Source: Daniele Volpe for The Washington Post

Narco-Trafficking

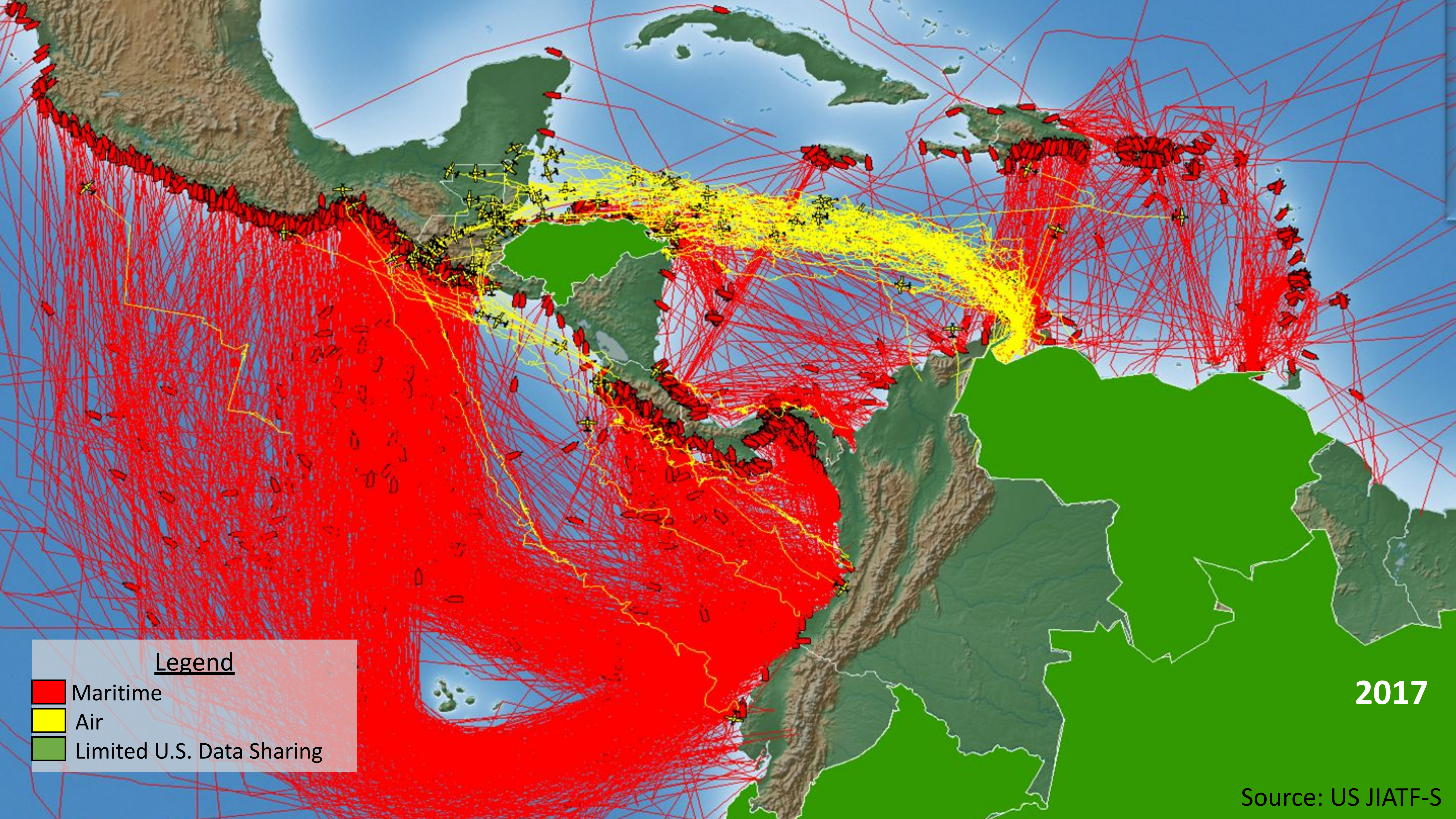
- Before 2015, Narco-trafficking through the Central American corridor supplied over 80% of the cocaine consumed in North America (UNODC, 2010, 2012)
- Central America became the preferred transshipment location in the early to mid-2000s
- Response to interdiction



Numero de movimientos primaries (mar y aire) destinado por países indicadas. Source: Consolidated Counterdrug Data Base (CCDB), Office of National Drug Control Policy (ONDCP); extracted 1/31/2016.

Maritime	220 Events (281 MT)
Air (northbound)	172 Events (144 MT)

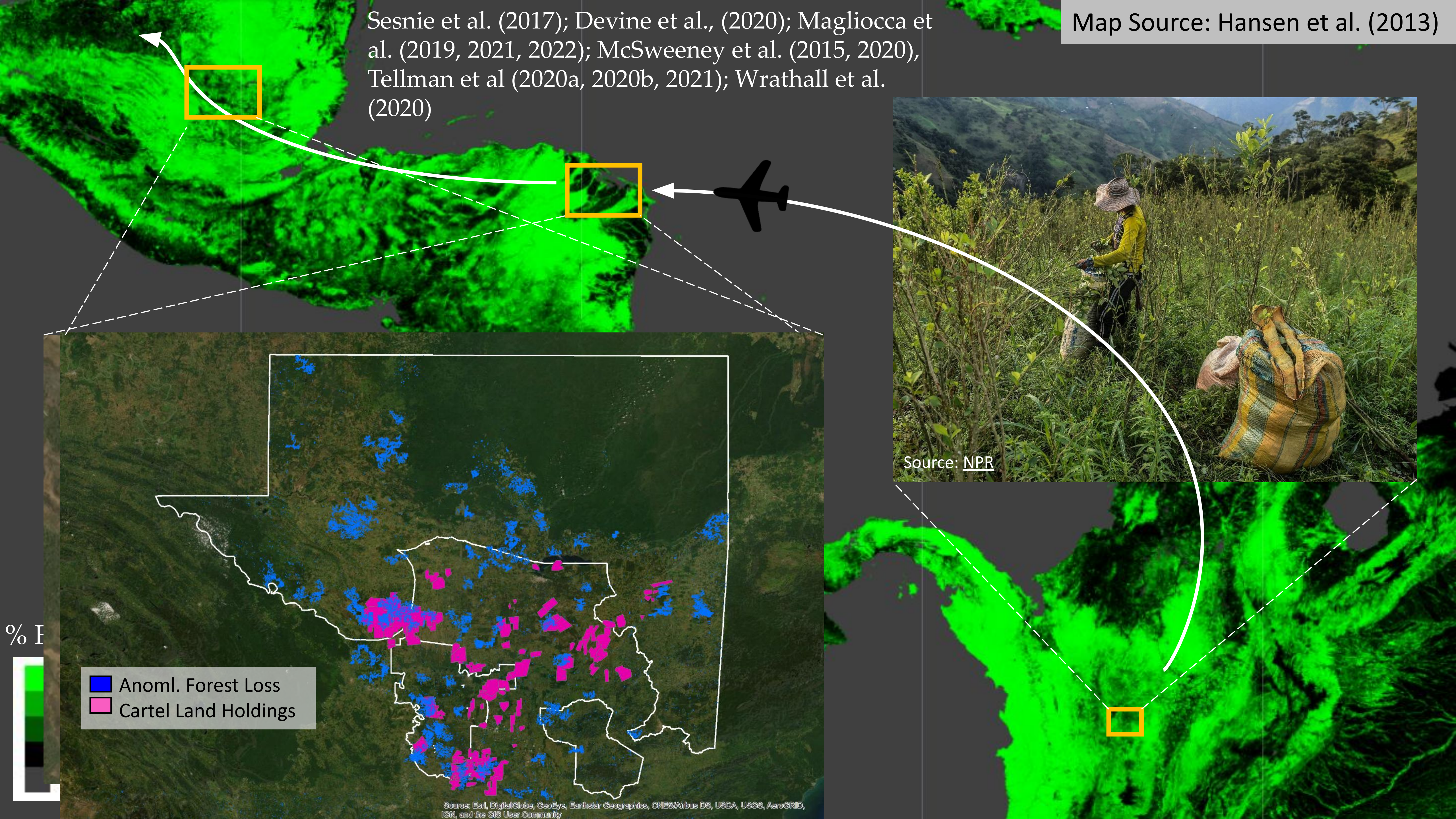
Rank	Country	Me (pas
1	MEX	
2	GTM	
3	HND	
4	DOM	
5	PAN	
6	ESP	
7	CRI	


Legend
Maritime
Air
Limited U.S. Data Sharing
2017
Source: US JIATF-S

Source: McSweeney et al. (2014)

Three main pathways for narco-trafficking driven land-use change:

- Direct use (e.g., narco-pistas, territorial control)
- Money laundering (e.g., cattle ranching, palm oil)
- Indirect effects (e.g., informal markets, reinvestment of illicit capital)


Sesnie et al. (2017); Devine et al., (2020); Magliocca et al. (2019, 2021, 2022); McSweeney et al. (2015, 2020), Tellman et al (2020a, 2020b, 2021); Wrathall et al. (2020)
Map Source: Hansen et al. (2013)
Source: NPR
Anoml. Forest Loss
Cartel Land Holdings
Sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Quantifying Narco-Land-Use Change

- How much, when, and where is land-use change caused by narco-trafficking?

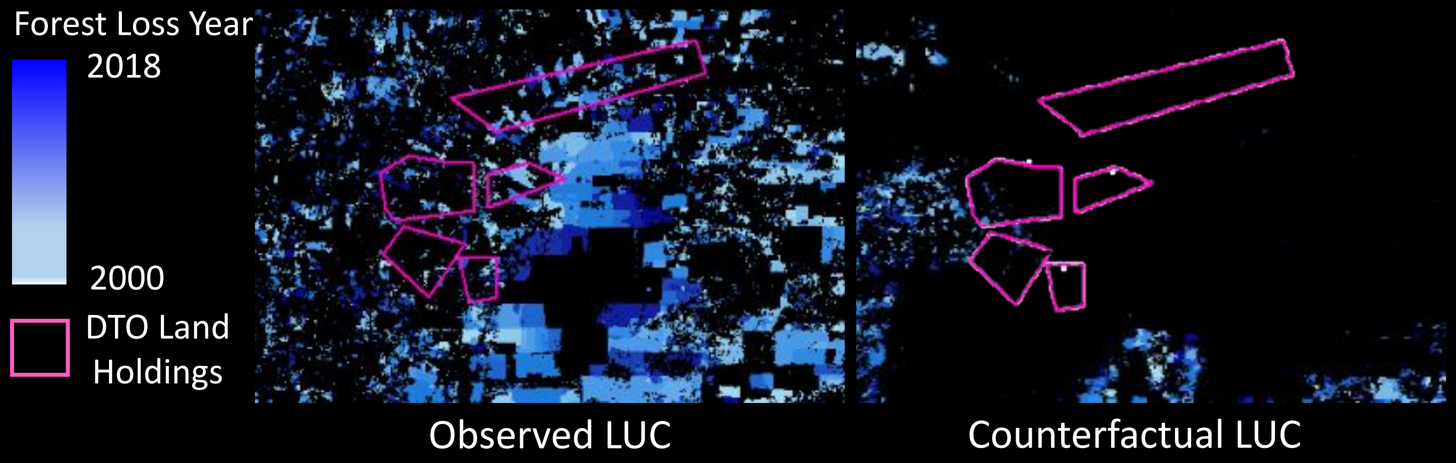
Challenges:

- Detailed time series needed for causal inference > LUC Mapping
- Data are fragmented, incomplete, and unreliable > Data Pedigree
- Quantifying causal effect of direct + indirect narco-trafficking activity > Counterfactual LUC Modeling

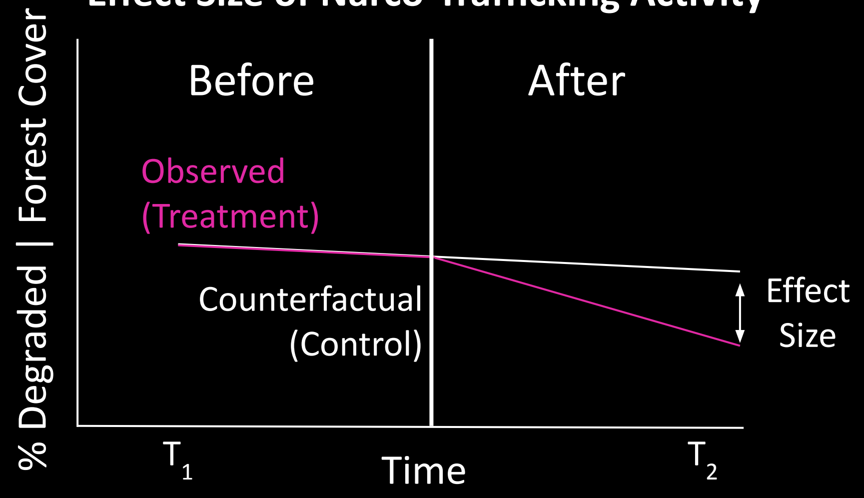
Quantifying Narco-Land-Use Change

Counterfactual land change modeling

Locations of Known Narco-Trafficking Activity



Effect Size of Narco-Trafficking Activity

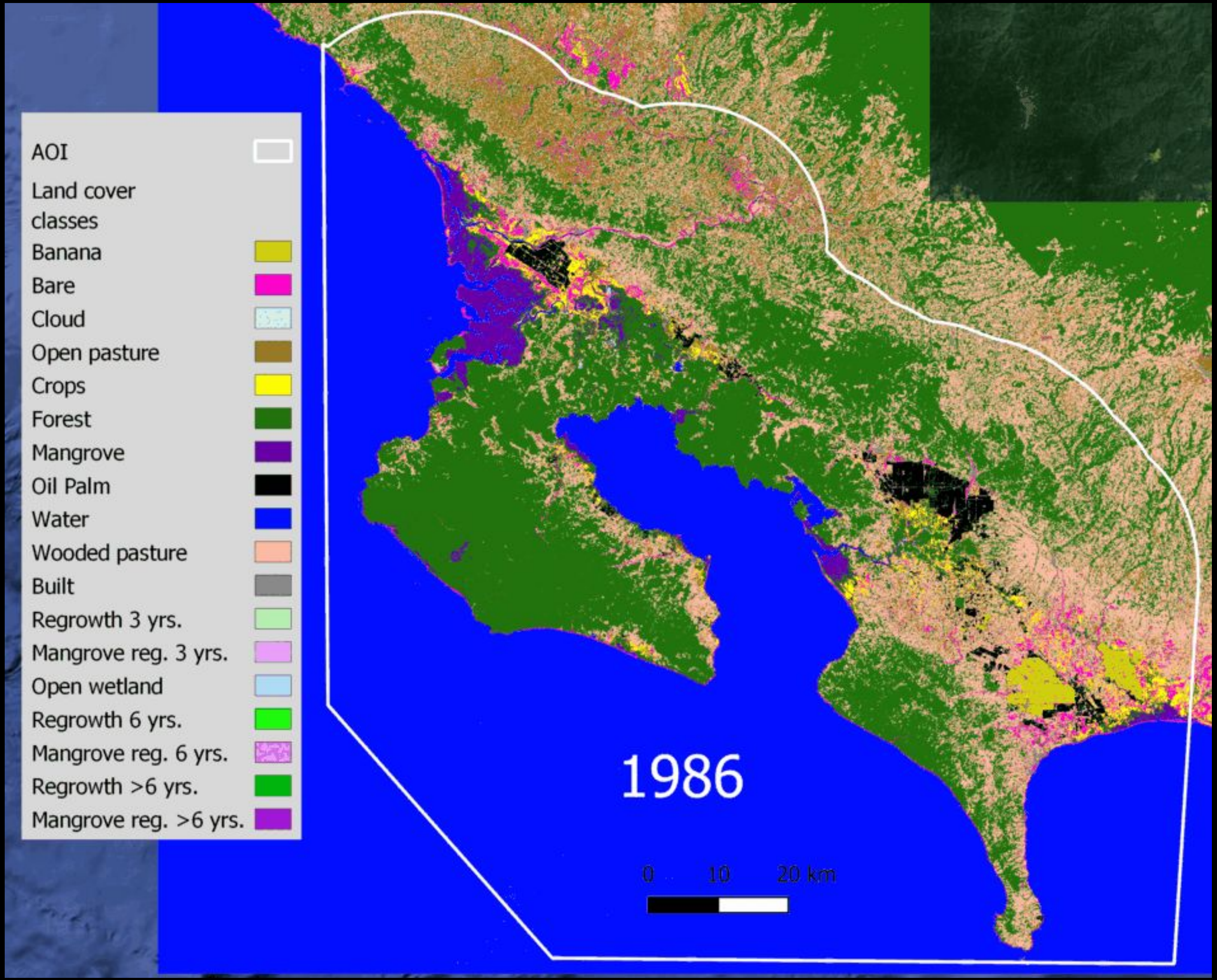


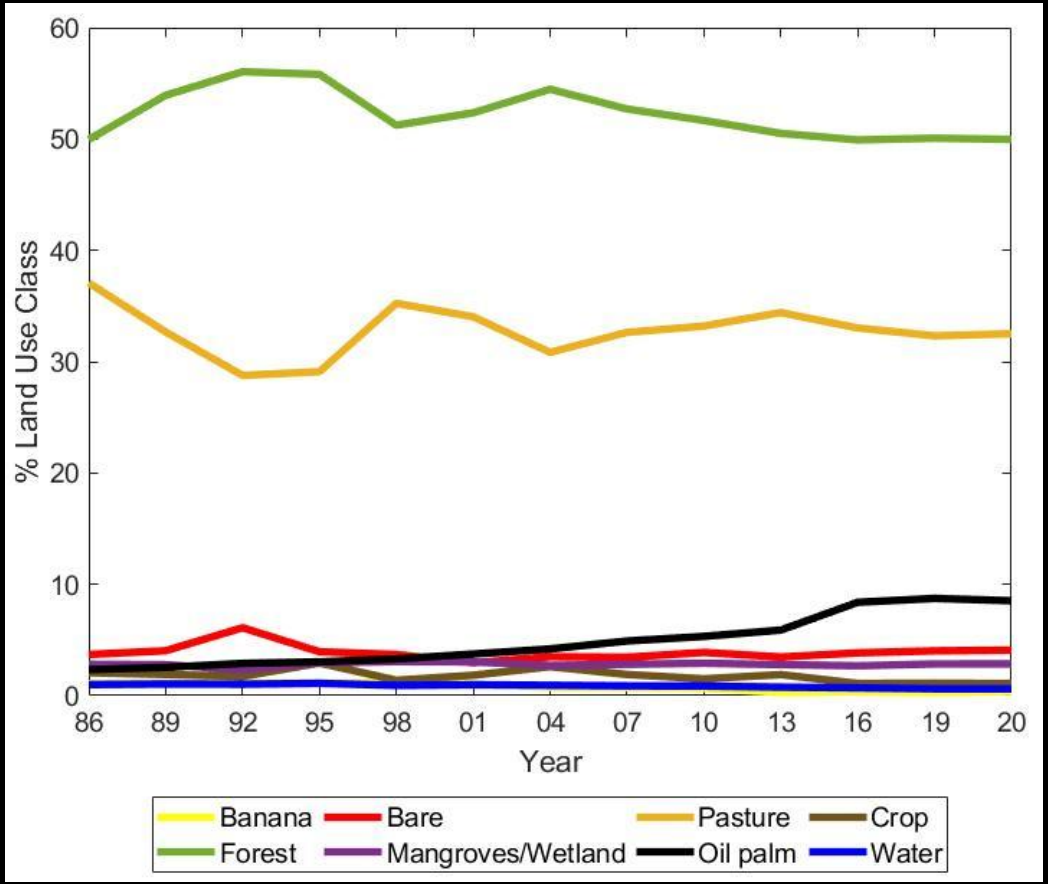
- How much, when, and where is land-use change caused by narco-trafficking?

Magliocca, Dhungana, Sink (2023). Review of spatially explicit land change modeling for counterfactual analysis in land system science, *J. Land Use Science*

LUC Mapping Results

Land Use Change Maps 1986-2020





Fagan et al. (*in prep*). Oil palm expansion threatens Costa Rica's protected areas.

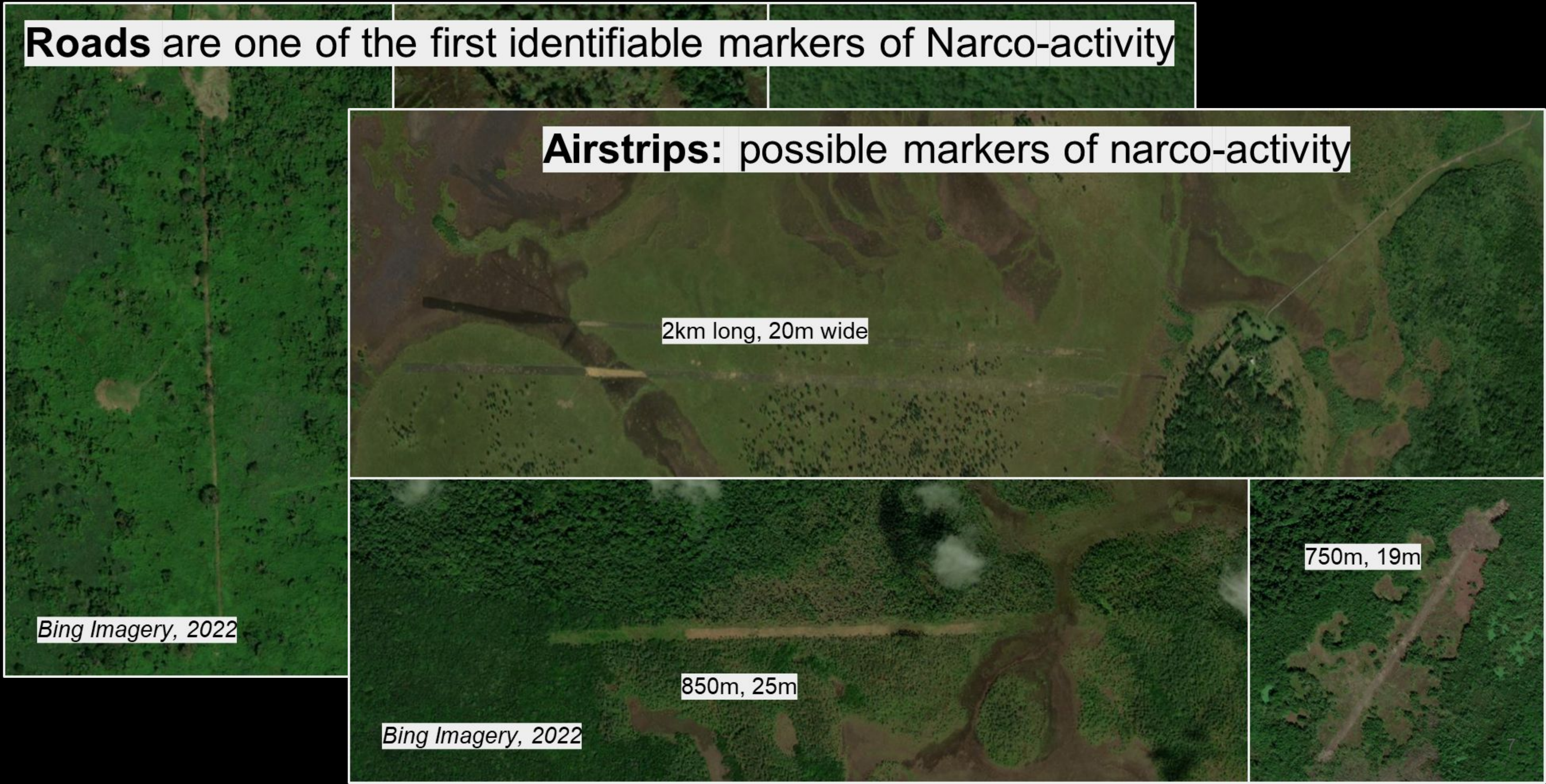
Data Pedigree

Need an approach to use as much data as possible

A *data pedigree* is a systematic grading system to assess the quality and appropriateness of a wide range a data – from precise and authoritative observations to informed guesses (Costanza et al. 1992).

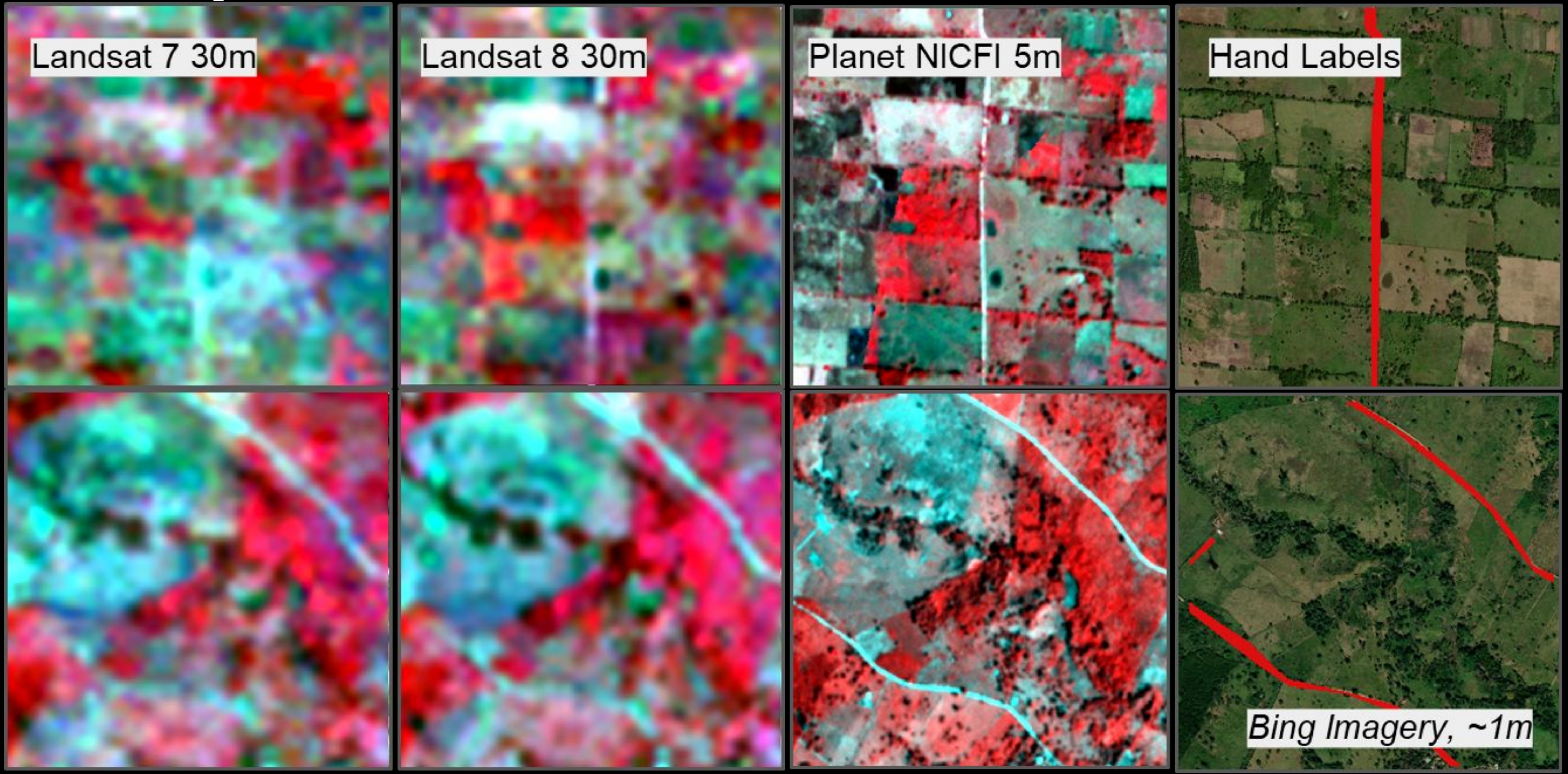
Costanza, Funtowicz, Ravetz (1992). Assessing and communicating data quality in policy-relevant research, *Environmental Management*

Data Pedigree: Infrastructure

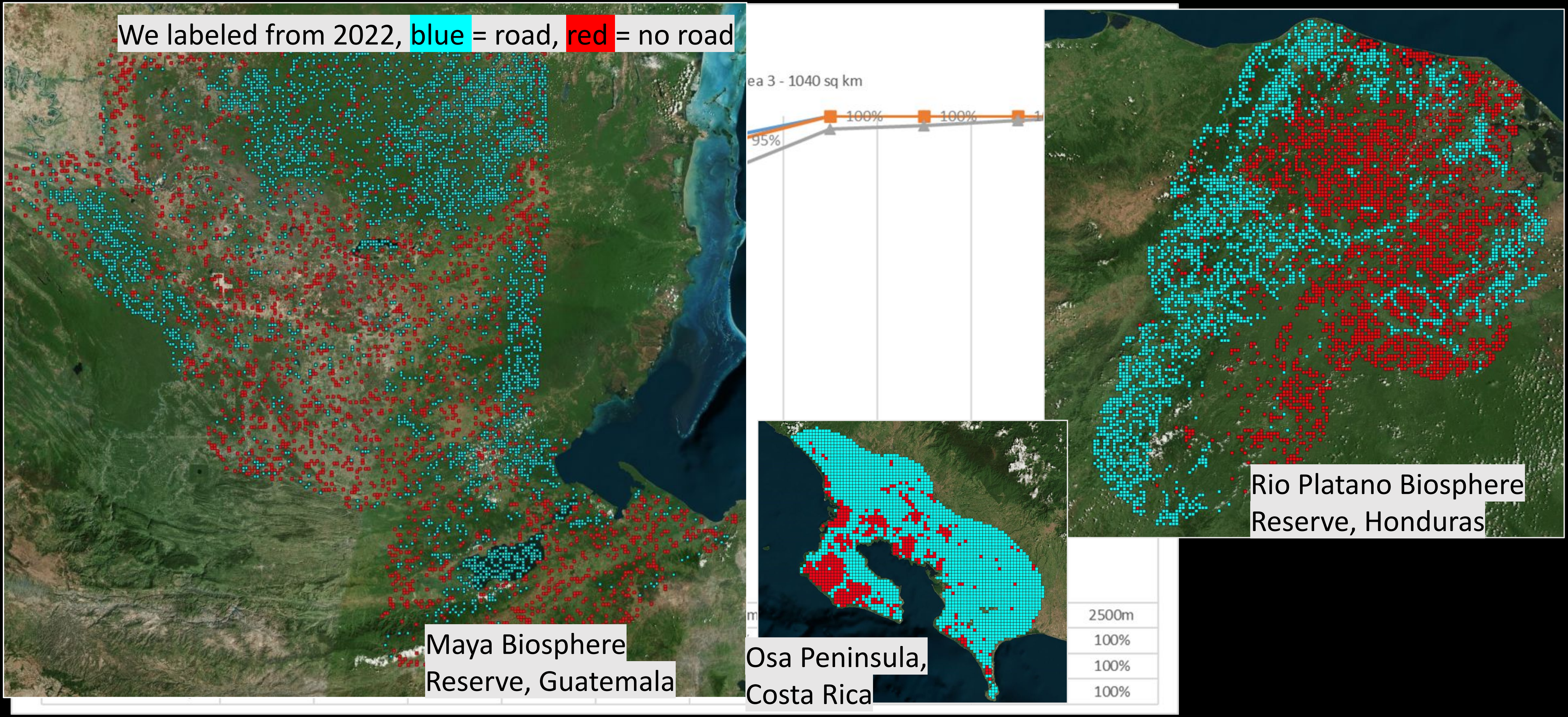


Data Pedigree: Infrastructure

Challenge: detection needs VHR data; time series to 2000



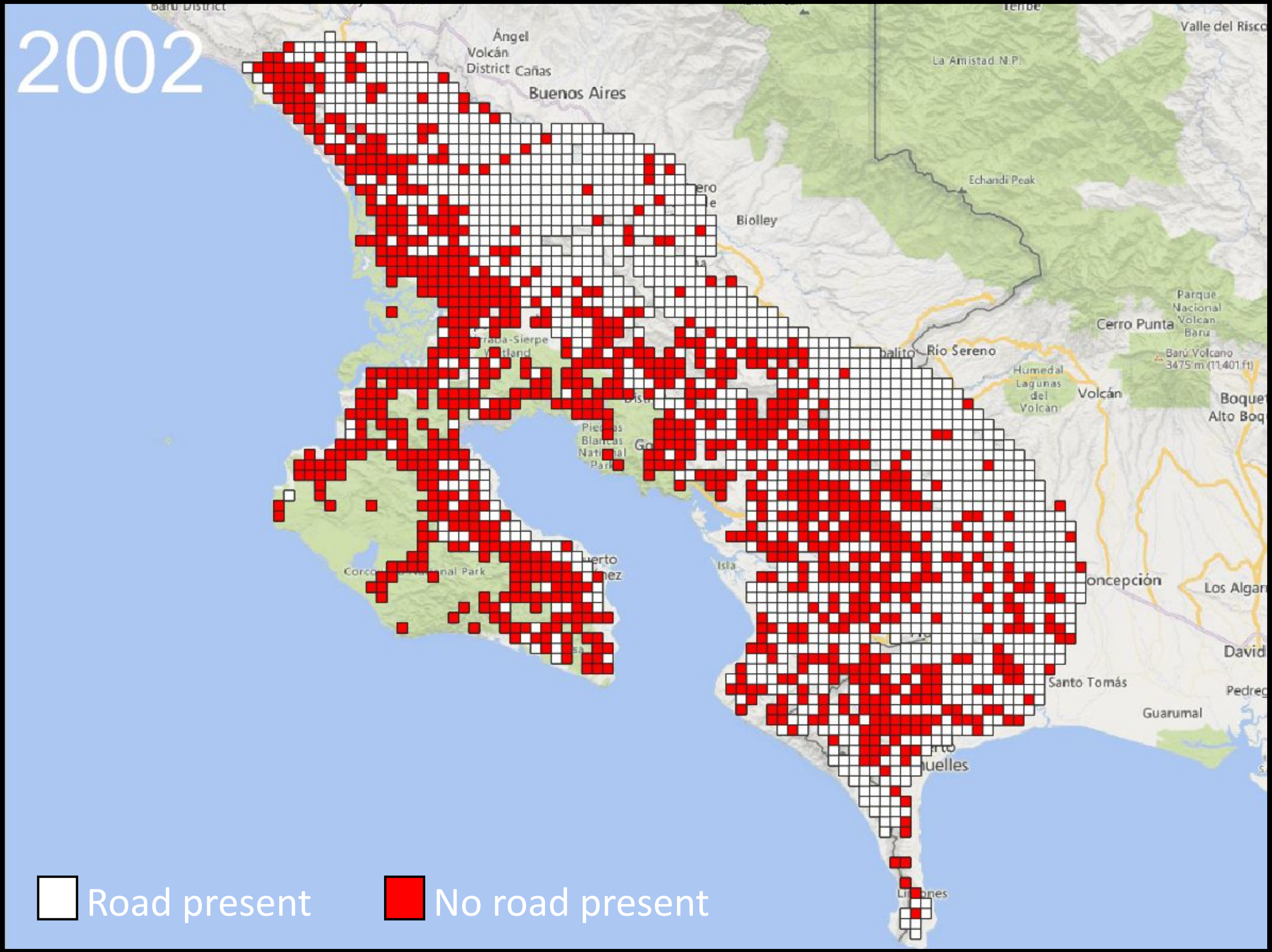
Data Pedigree: Infrastructure

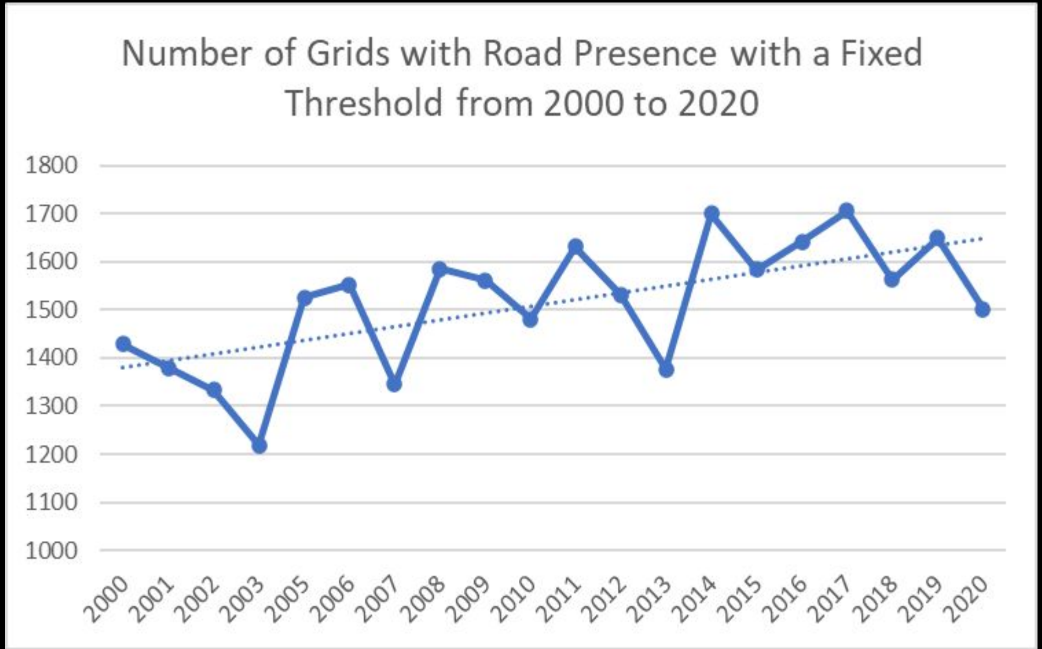


Mukherjee et al. (*in prep*). Gridded informal infrastructure probability from 2000-2022 using Landsat.
Mukherjee et al. (*in prep*). Pixel-based informal infrastructure detection using RapidEye and PlanetScope imagery.
Magliocca/Tellman-Sullivan et al. (*in prep*). Land-use change causal inference with informal infrastructure detection.

Data Pedigree: Infrastructure

Scene-based classification for infrastructure time series





Results will be more consistent after post processing:

- Removing cloudy, low quality grids
- Applying year-wise threshold instead of a blanket threshold
- Combining multiple years to improve grid data quality

Data Pedigree

Creates a standardized, comparable, and integrated database

Data Pedigree

Qualitative decision-trees to score all data sources

Geographic Clarity

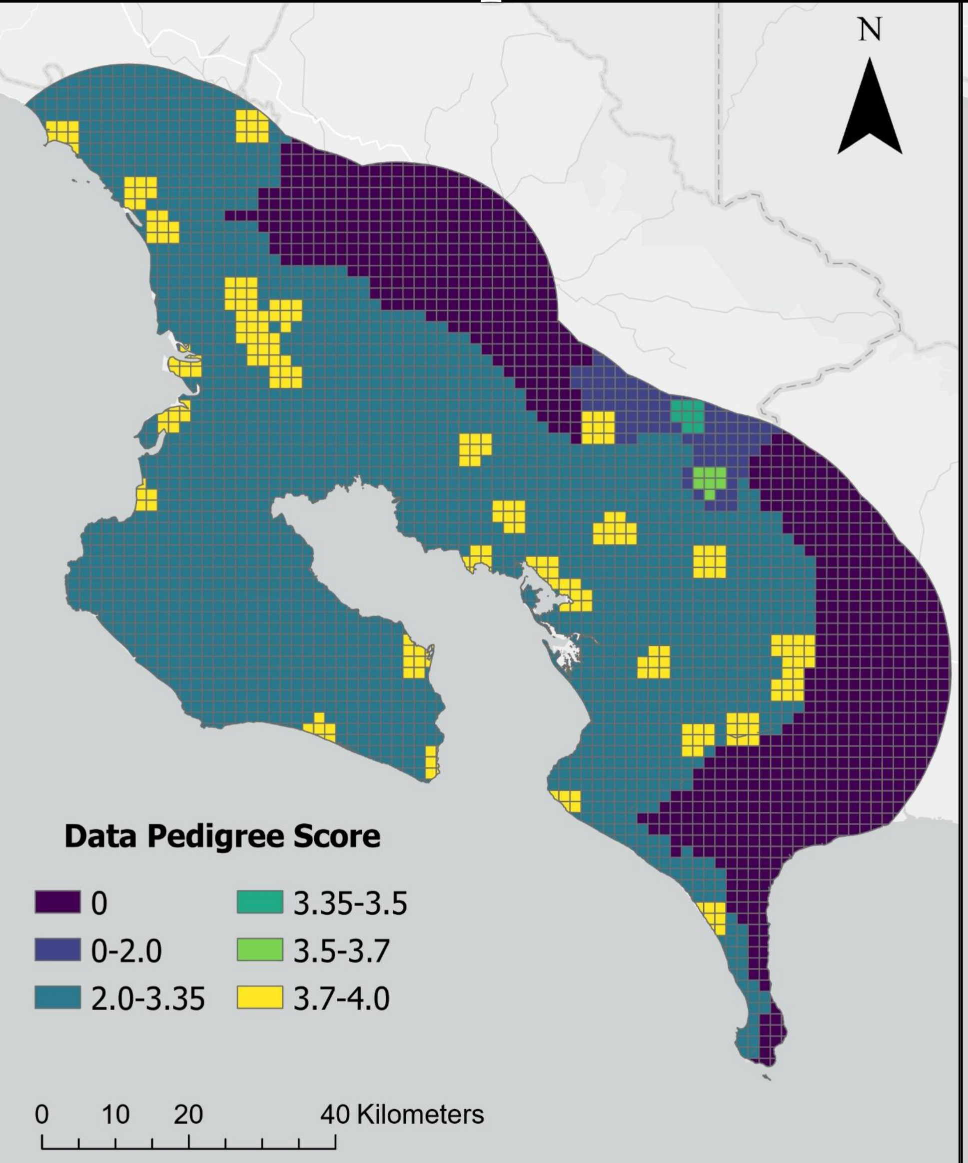
Is the department (or more precise geometry) of the event provided?

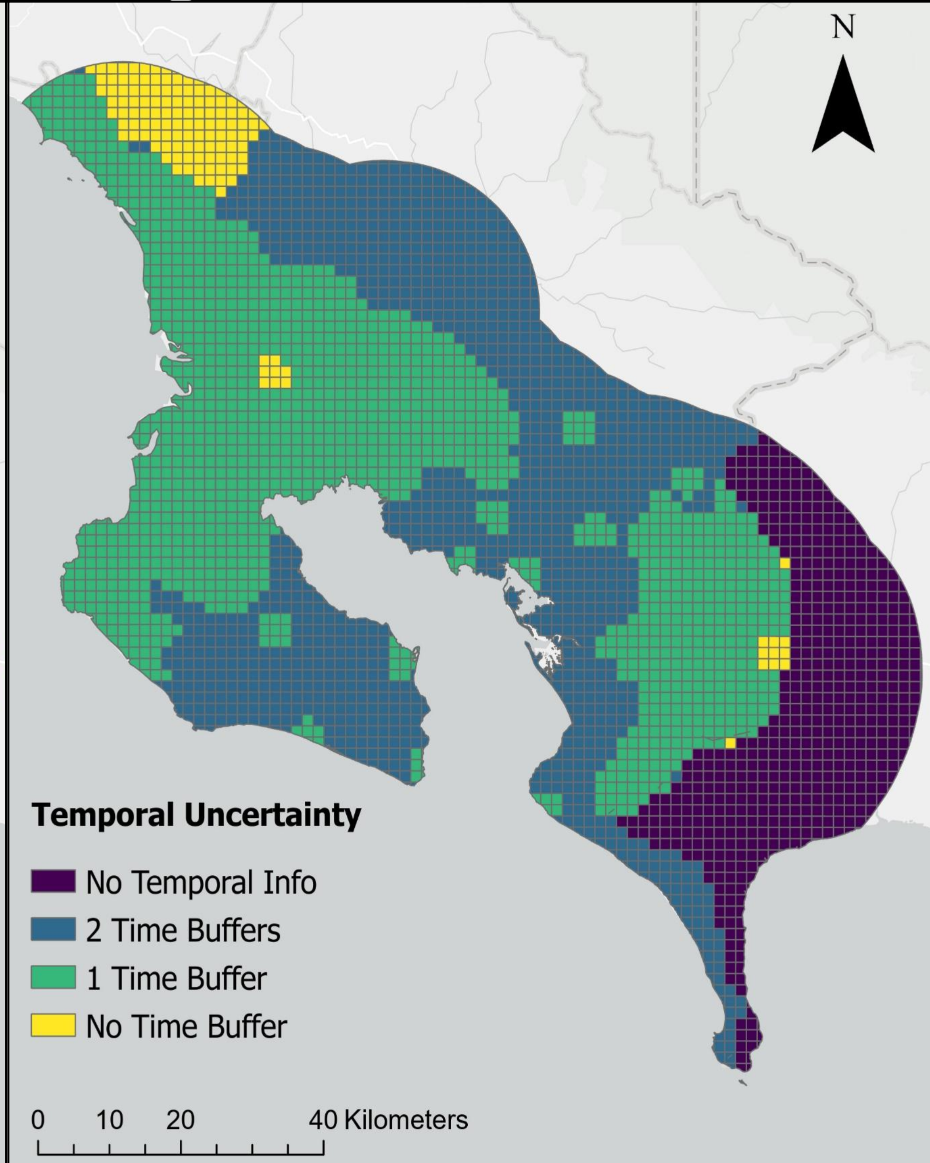
- No
  - National data
  - **Score = 1**
- Yes — Is the municipality (or more precise geometry) of the event provided?
  - No
    - Mapped to department boundary
    - **Score = 2**
  - Yes — Is the event appropriately represented by a point/polygon at the given lat/lon coordinates (e.g., property, address, town)?
    - No — Does the *largest* administrative area approximate the area influenced by the event (i.e., administrative area smaller than level 2)?
      - No
        - Mapped to large sub-national geometry (e.g., rural district)
        - **Score = 2**
      - Yes
        - Mapped to small sub-national geometry (e.g., populated municipality)
        - **Score = 3**
    - Yes
      - Mapped as a point/polygon
      - **Score = 4**

Magliocca et al. (*in prep*). Overcoming poor data availability with a data pedigree to study illicit economic activities.

Data Pedigree

Creates a standardized, comparable, and integrated database

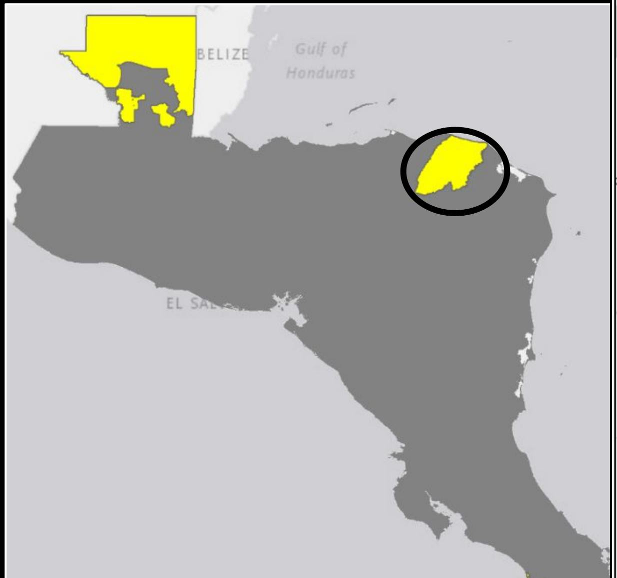




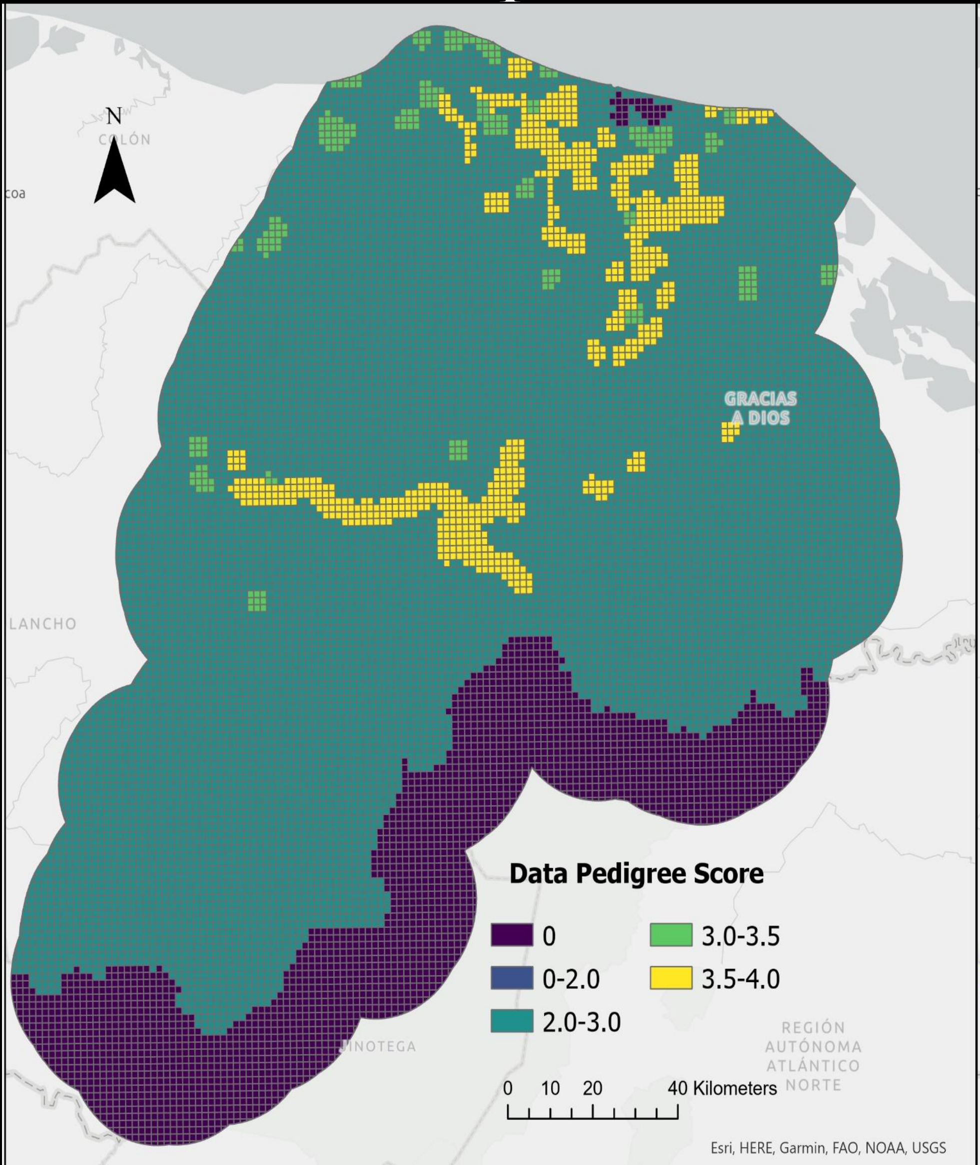
Narco-activity in locations > 3.35

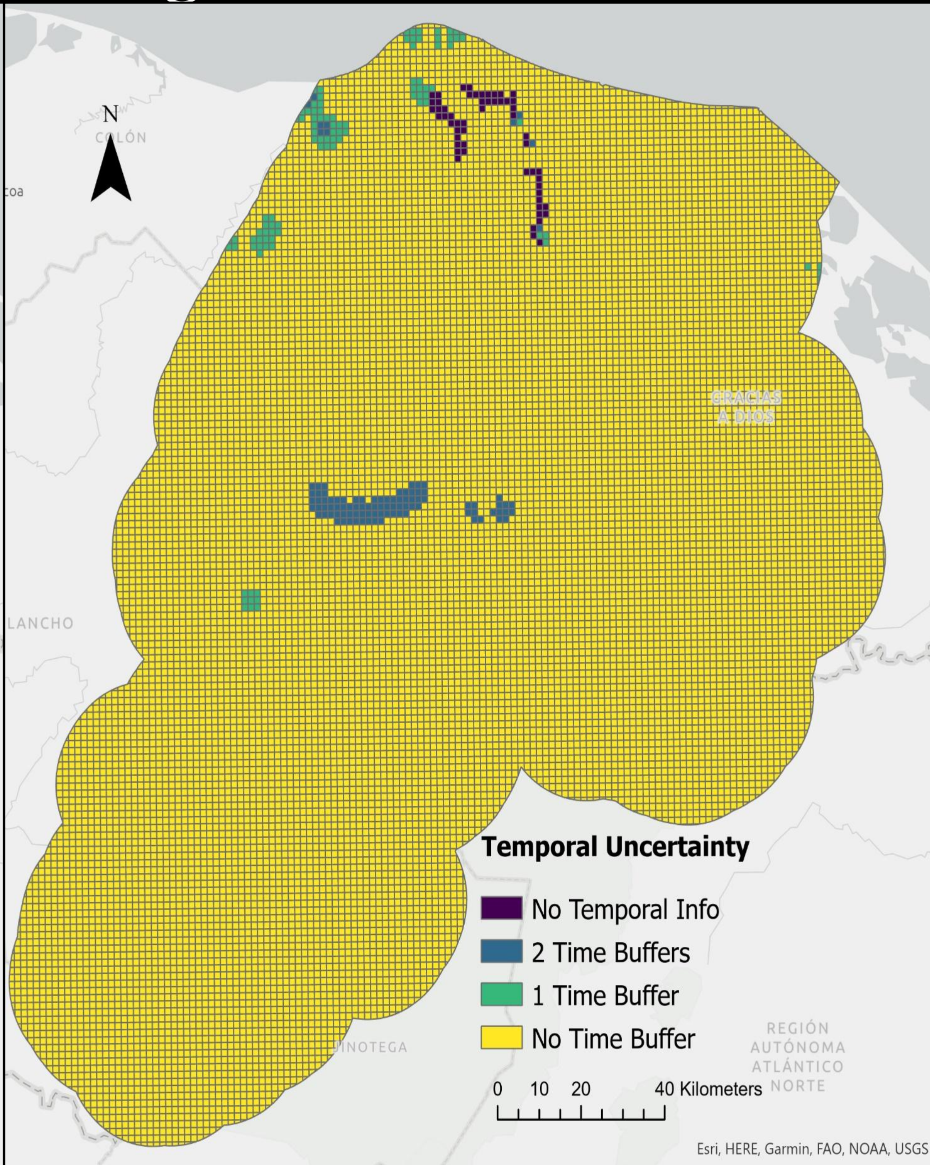
Data Pedigree

Creates a standardized, comparable, and integrated database



Rio Platano Biosphere Reserve

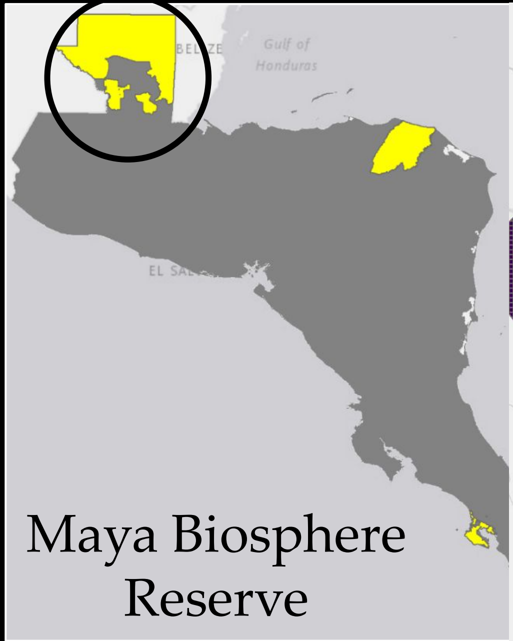




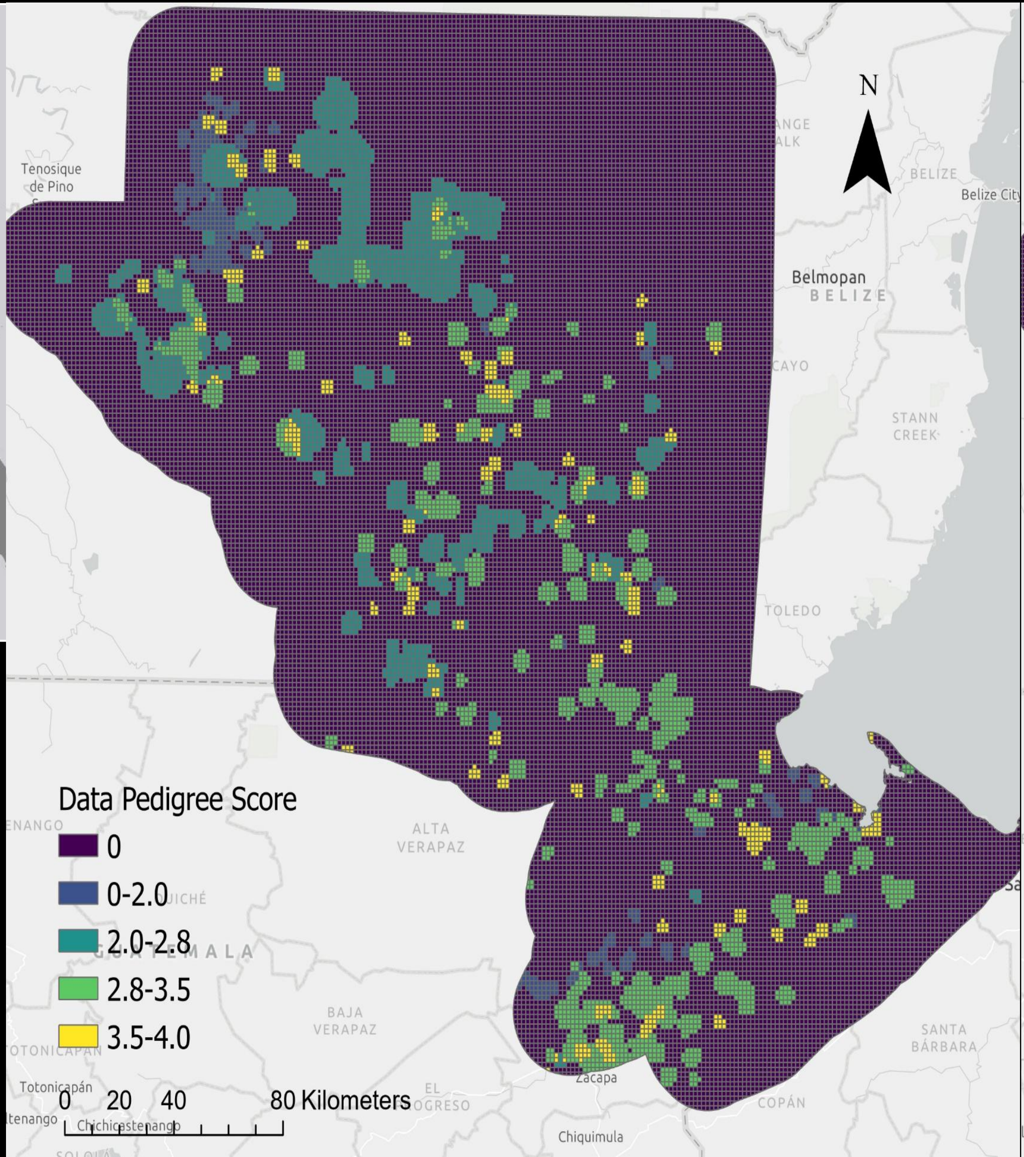
Narco-activity in locations > 3.0

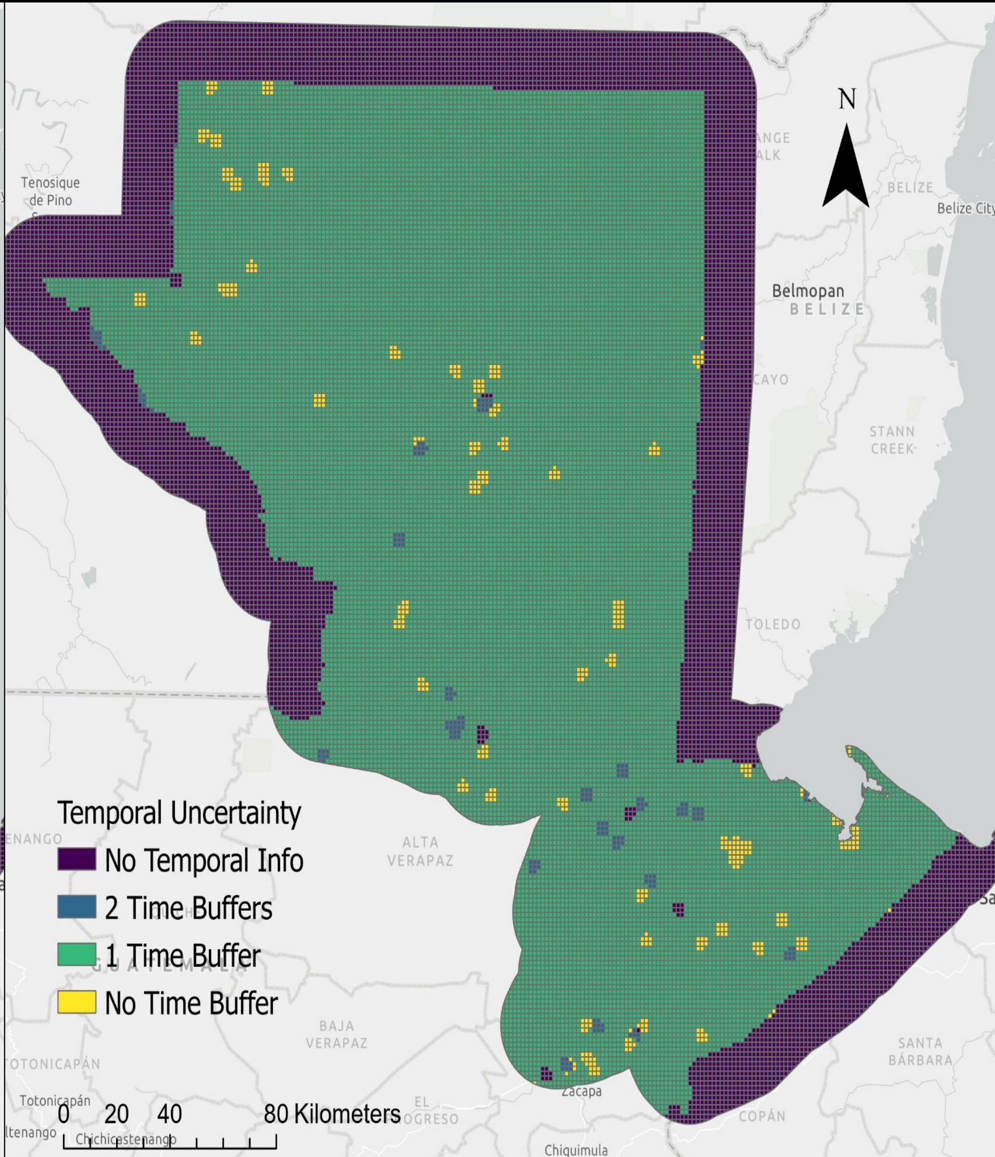
Data Pedigree

Creates a standardized, comparable, and integrated database

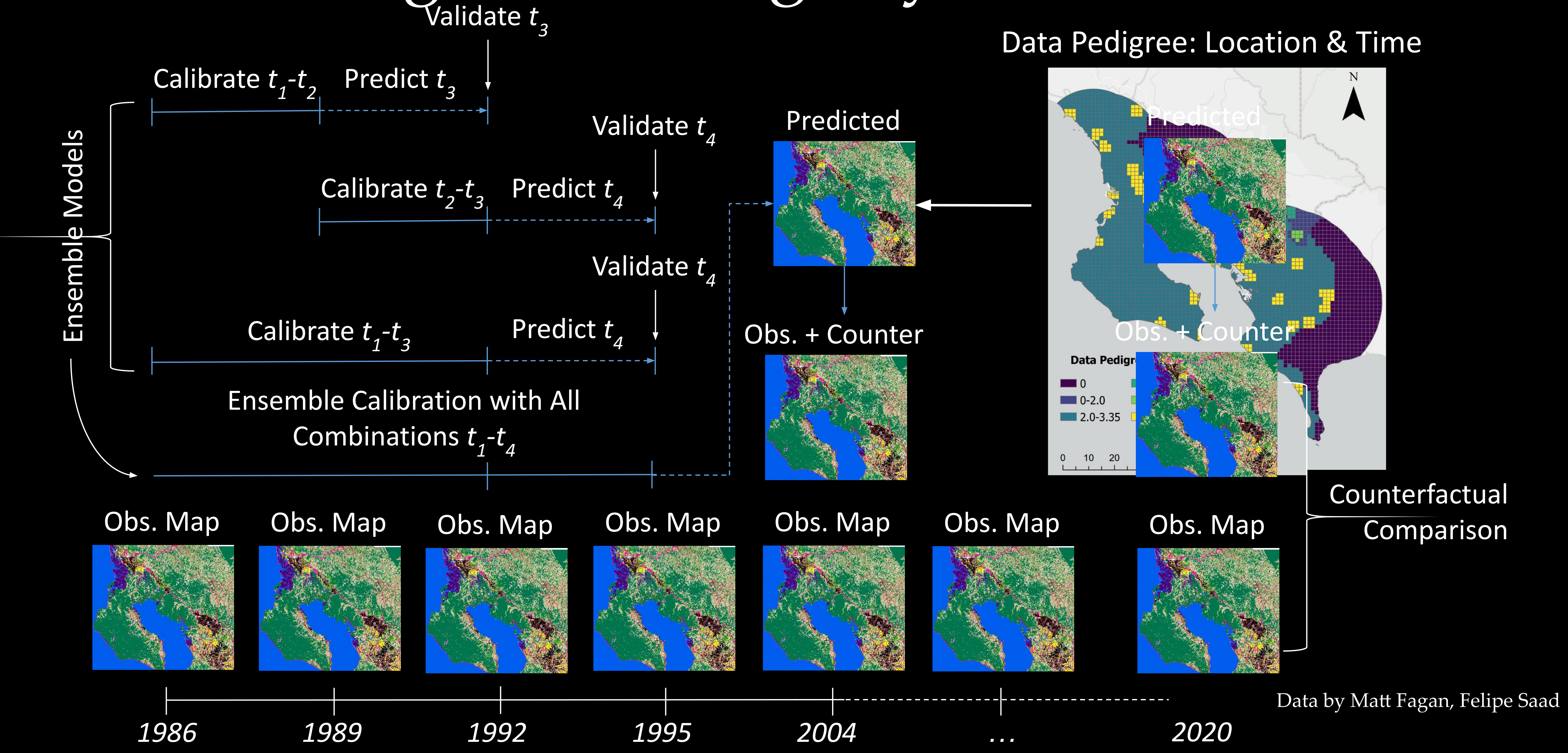


Narco-activity in locations > 2.8





Land Change Modeling: Dyna-CLUE

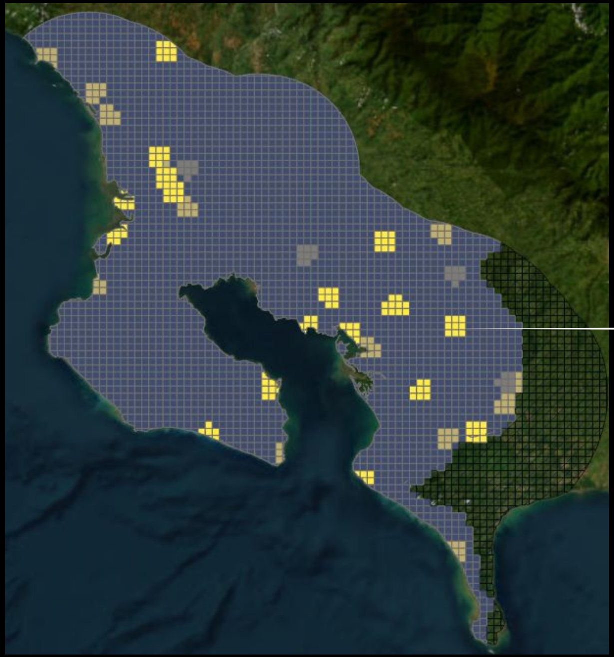


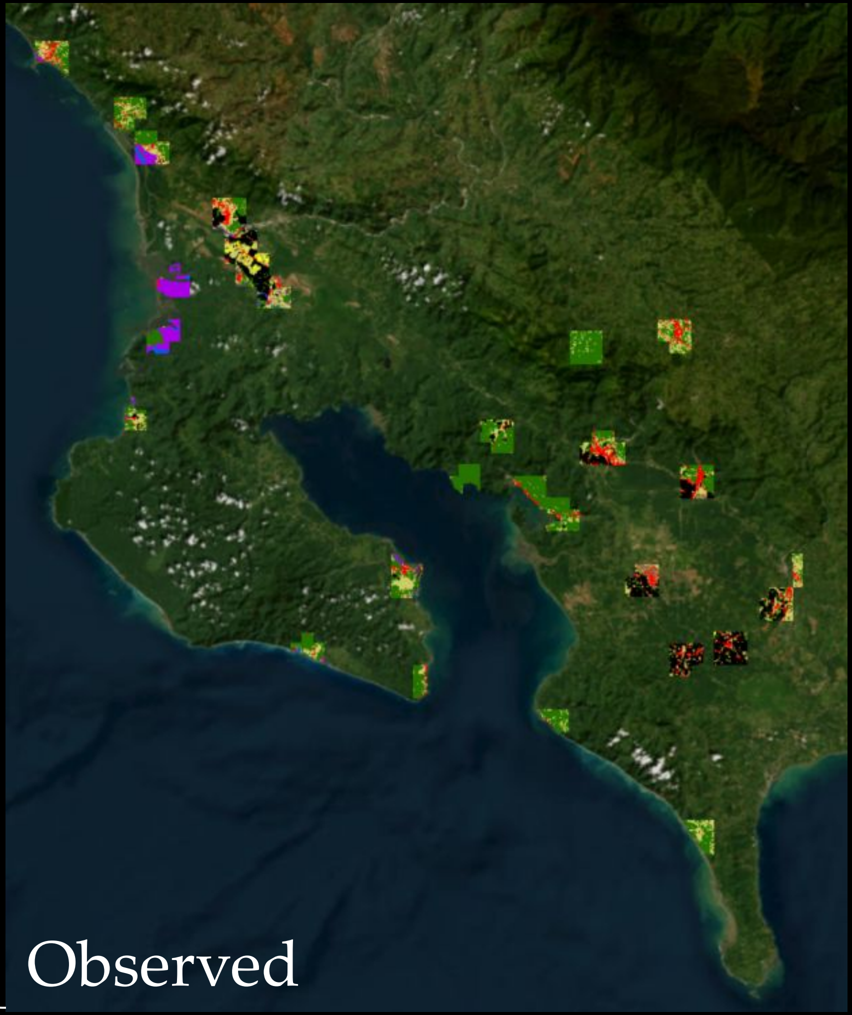
Magliocca, Dhungana, Sink (2023). Review of spatially explicit land change modeling for counterfactual analysis in land system science, *J. Land Use Science*

Counterfactual Land Change Modeling

Effect size (%) of narco-trafficking presence

Data Pedigree:
Location & Time





Magliocca et al. (*in prep*). Narco-trafficking caused land-use change in and around Central America's protected areas.
Magliocca et al. (*in prep*). Comparative performance of quasi-experimental matching and counterfactual modeling for causal inference in land-use change research.

Next Steps

Infrastructure detection and classification

- Validation of Landsat gridded model (May fieldwork)
- Gridded Landsat model of MBR, RPBR AOIs
- Pixel-based road segmentation, adding RapidEye to 2009

Land change mapping

- MBR and RPBR AOIs, validation

Counterfactual land change modeling

- Implementation and scalability at 30m resolution
- Compare with quasi-experimental matching

Thank you!

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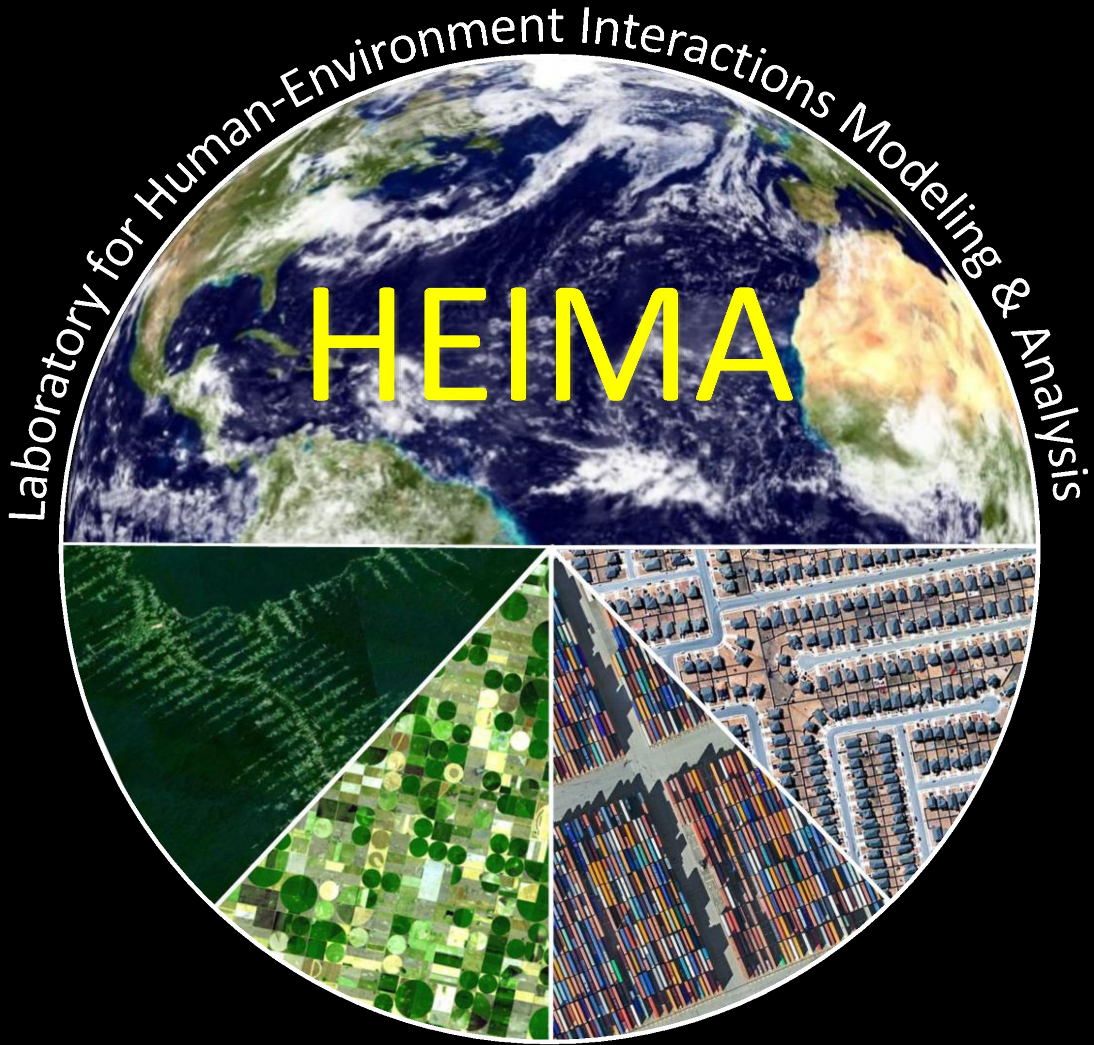

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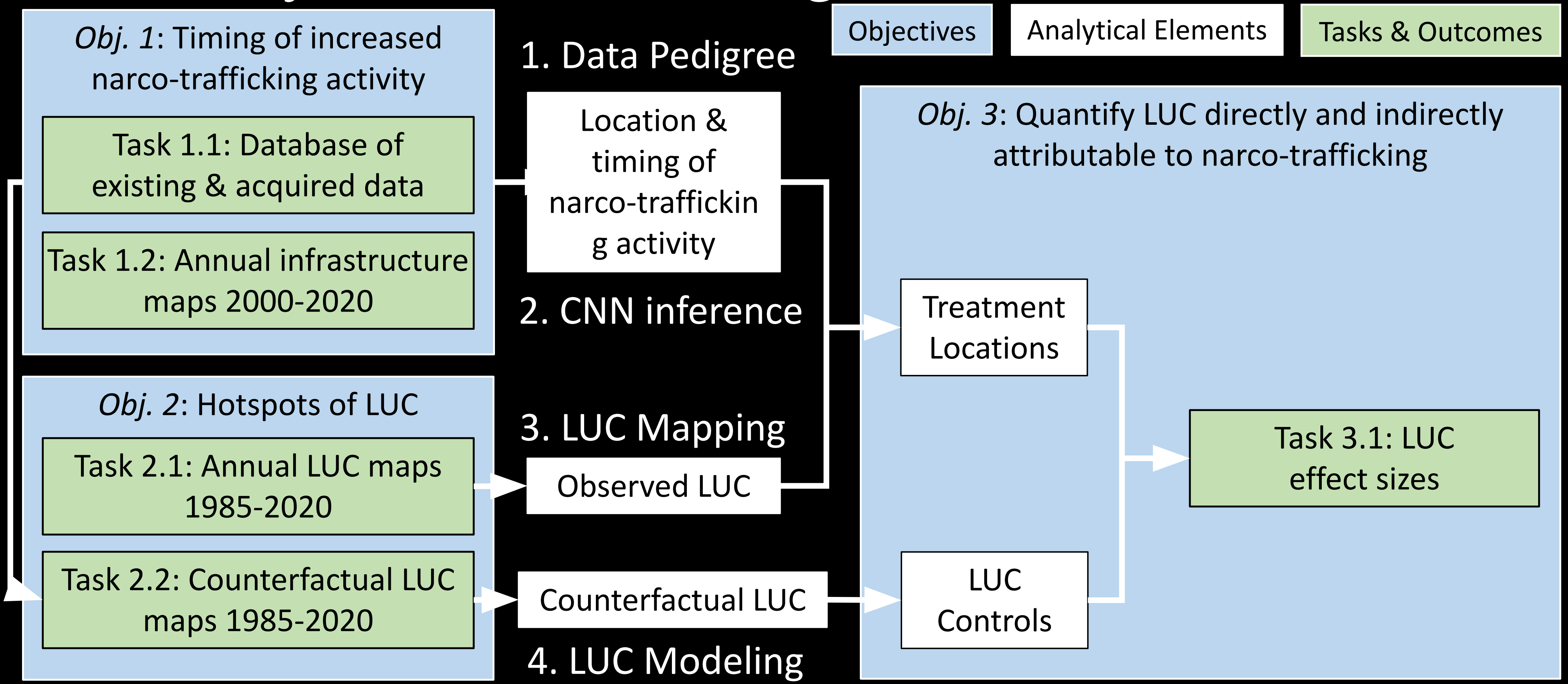
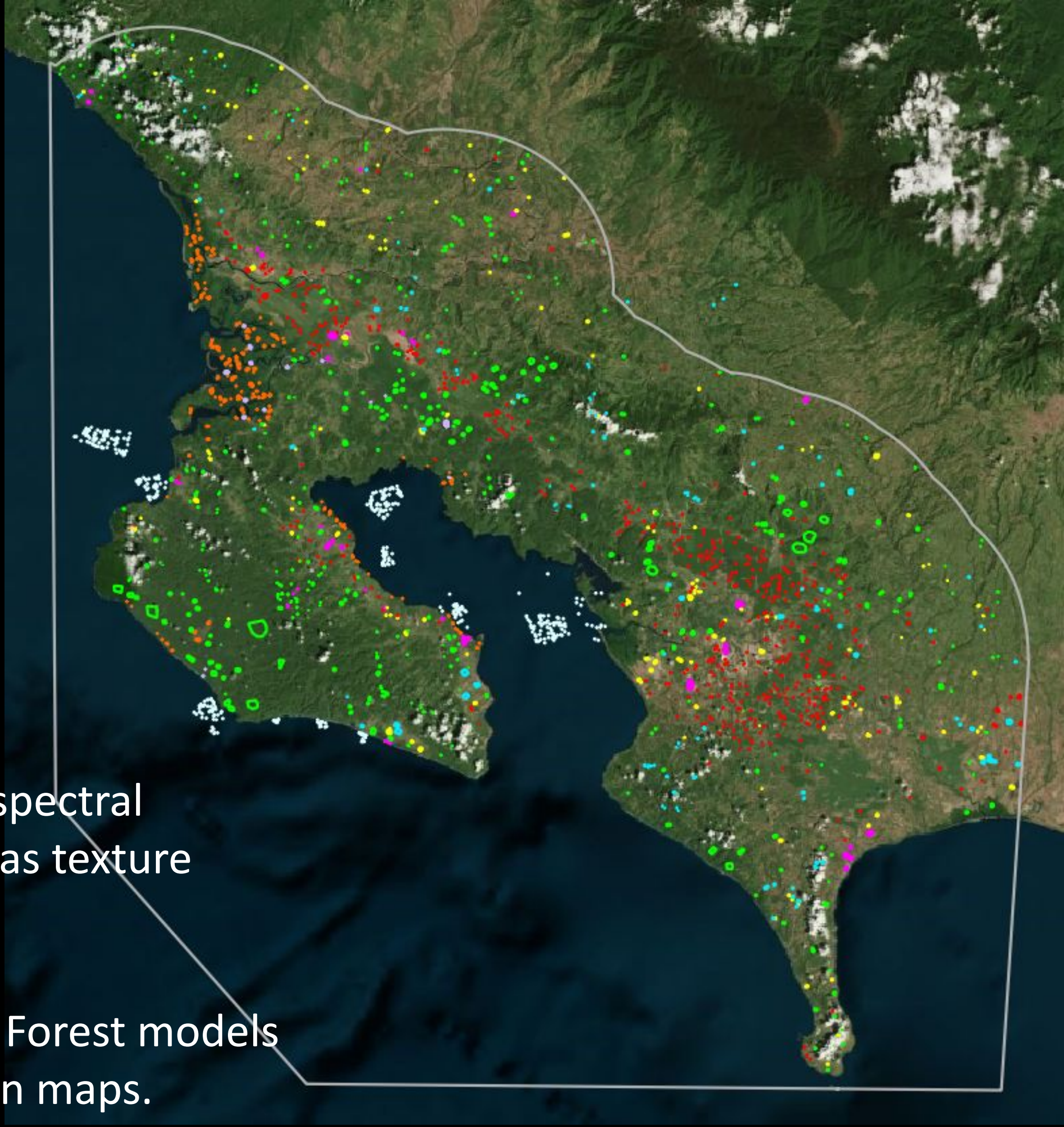
Research Plan

- How much, when, and where is land-use change caused by narco-trafficking?



Land cover maps: methodology



- Osa receives 5+ meters of rain a year; very cloudy, especially in the 1990s.
- Google Earth Engine was used to create 3-year composites of Landsat data from 1986 to 2020.
- Landsat clouds were masked using the CFMask algorithm and custom cloud masks.
- Using GEE, additional SAR (Sentinel-1, ALOS Palsar) and spectral (Sentinel-2) data were added for available years, as well as texture variables.
- Extensive training data set (n=~120,000 pixels); Random Forest models were developed for each year to produce 30 m resolution maps.
- Rules-based land cover map compositing was used to further minimize the effects of clouds and cloud shadows.

Model Training Accuracies

ALOS PALSAR, 30m, only 2 bands (HH, HV) = Overall 81.5%, no road correctly detected = 79.8%, road correctly detected = 82.8%

PlanetScope NICFI, 5m, 4 bands = Overall 90.1%, no road correctly detected = 87%, road correctly detected = 92.5%

Landsat 8, 30m, 6 bands = Overall 88.75%, no road correctly detected = 86.7%, road correctly detected = 90%

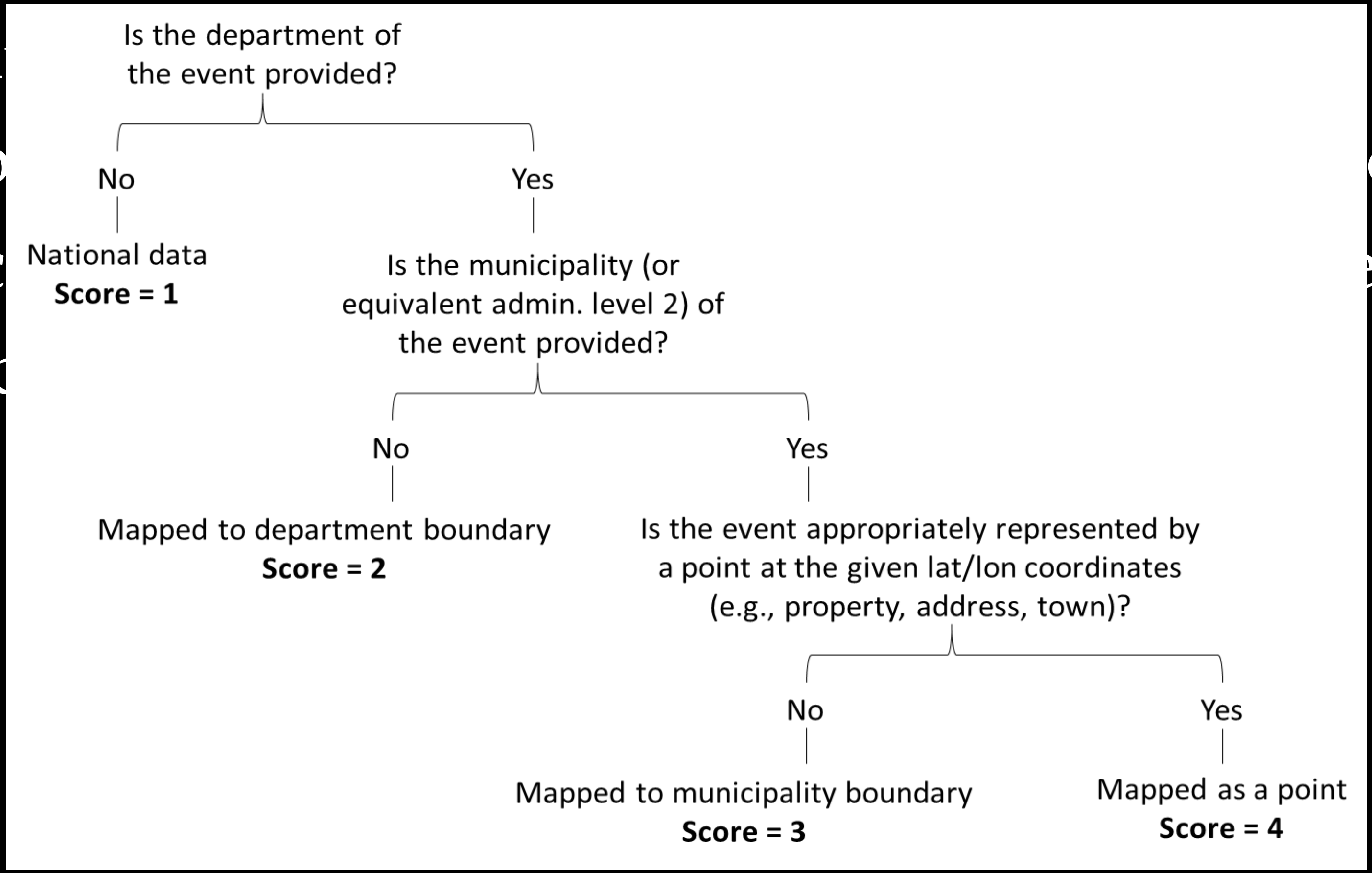
Landsat 7, 30m, 6 bands = Overall 87.54%, no road correctly detected = 81.1%, road correctly detected = 91%

Data Pedigree

Creates a standardized, comparable, and integrated database

Criteria:

- Geospatial Clarity – does the data represent the event?
- Geospatial In
- Authorial Pro ovider?
- Narco-Traffic enomenon?
- Temporal Acc



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No

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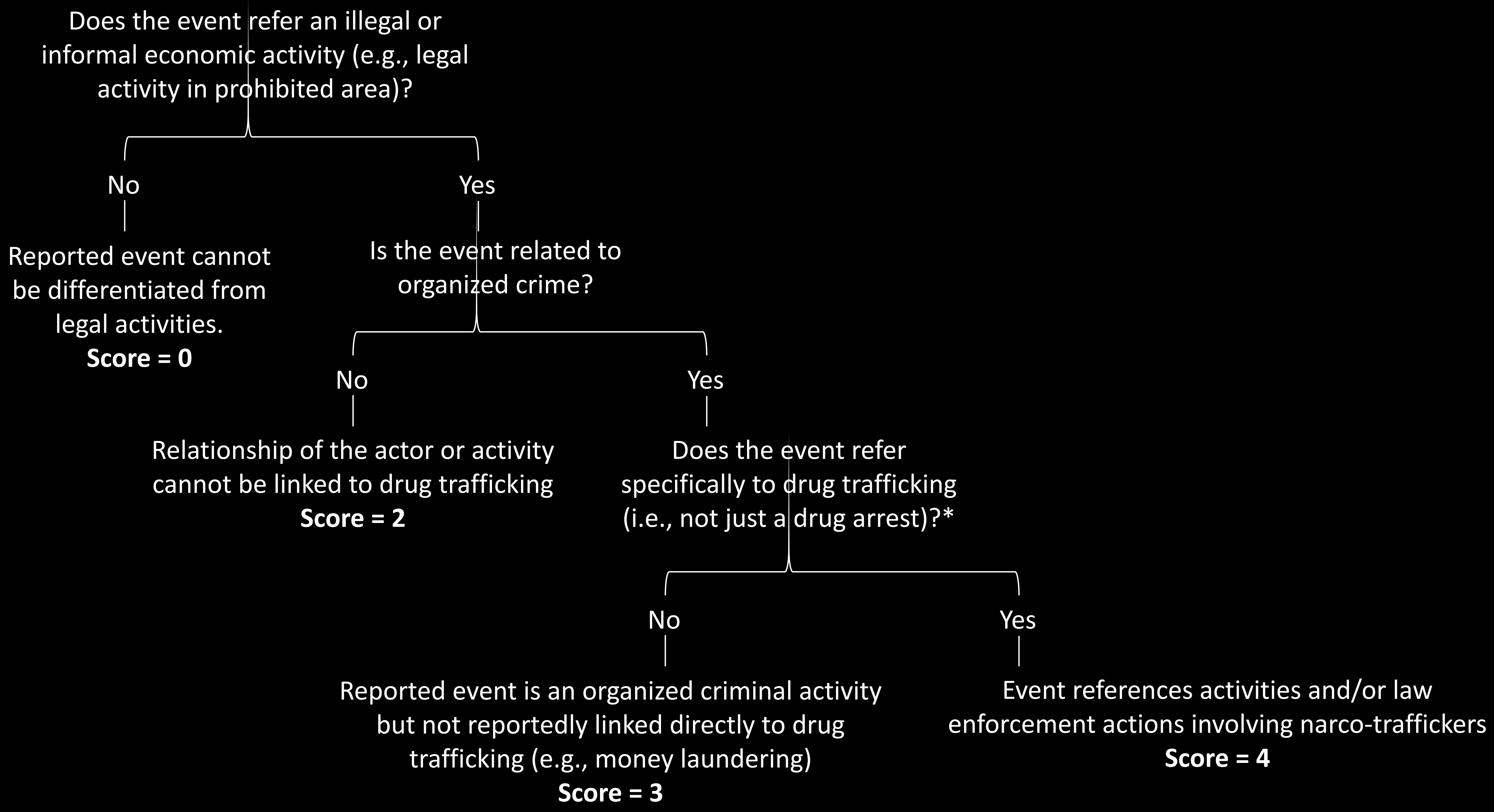
Score = 3

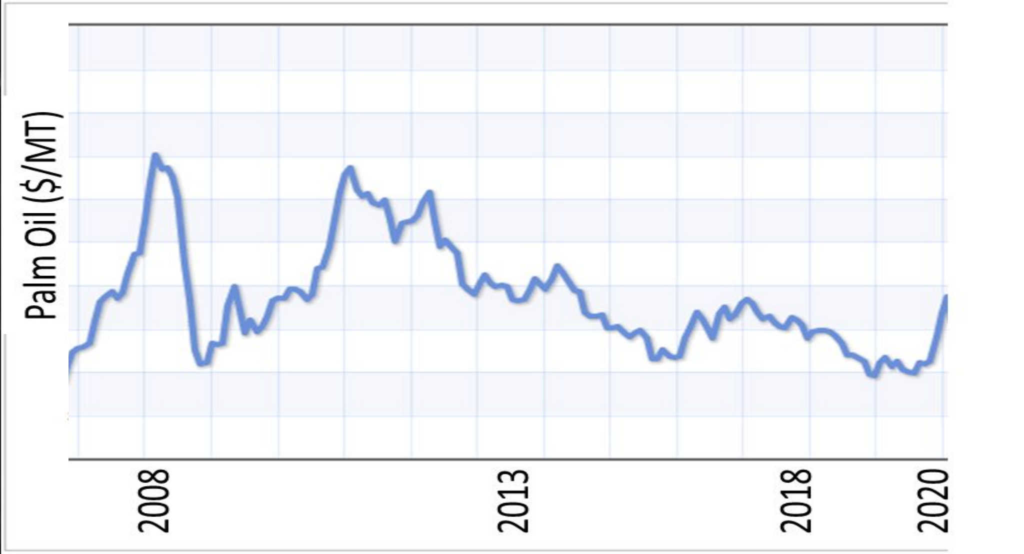
Narco-Trafficking Certainty



Discussion

Rate of oil palm expansion:

- Sumatra and West Malaysia: 2.26% from 2000-2015 (Wagner et al., 2022)
- Osa study region: 15.1% from 2007-2019
- Narco-trafficking areas: 40.37% from 2007-2019
  - Counterfactual rates highest 2013, 2016



Insights from field interviews:

- Oil palm sector vulnerable to infiltration in all supply chain phases
- Rapid infrastructure development in ag and tourism sectors
- Costa Ricans serving as 'logistics contractors'
- Illicit capital from trade visible in poor communities

Wagner, Wentz, Stuhlmacher (2022). Quantifying oil palm expansion in Southeast Asia from 2000 to 2015: A data fusion approach. *JLUS*