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# Carbon and Co-benefits from Sustainable Land Use Management

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# Purpose of overall project

- Improve and strengthen monitoring and reporting of carbon impacts across selected USAID forestry projects.
- Improve and modify the tools for designing, measuring and monitoring carbon and co-benefits in Land-Use Change and Forestry (LULUCF) activities with special attention to forest protection and changes in forest management
- Disseminate experience with measurement and monitoring of USAID projects to local, national, and international organizations to improve the global reporting and integrity of LULUCF activities.

# Quantifying impacts of forest harvesting on carbon stocks

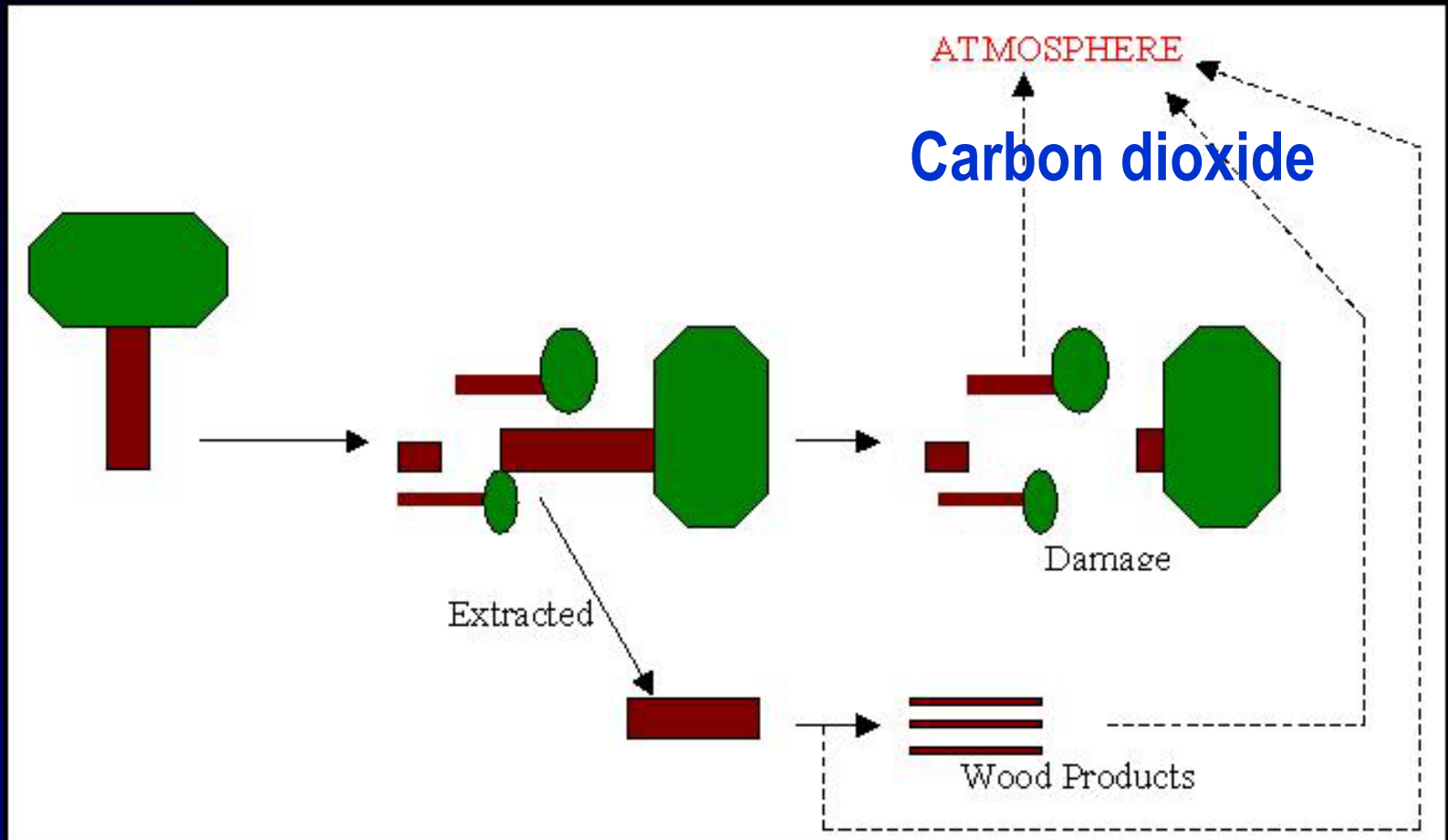
# Need to estimate the change in carbon stocks between -with and without harvesting or -no harvesting

Change in carbon stocks =

$$\Delta \text{ live C} + \Delta \text{ dead C} + \Delta \text{ wood products C}$$

Logging has the effect of decreasing the stocks in live biomass and increasing the stocks in dead wood and wood products

# Modeling selective logging = net change per harvested tree x amount harvested



# Extracted volumes



# Tree fall damage



# Road and skid trail damage



# Change in live biomass

Change in live C stocks =  
carbon extracted + carbon damaged

Carbon damaged = crown + snapped or uprooted trees

These quantities are measured and estimated directly after logging

# Examples logging damage

Statistics	t C damaged per t C extracted
Belize-43 logging impact plots	
Range	0.7 – 7.0
Mean	3.1
S.E.	0.2
95% CI (% of mean)	± 13%
Bolivia-97 logging impact plots	
Range	0.7 – 6.4
Mean	2.9
S.E.	0.14
95% CI (% of mean)	± 10%

# Change in Dead

Change in Dead =

Damage biomass x Decomposition Rate

No measurement of change in dead. Damage is measured with change in live and decomposition is modeled

# Change in wood products

$$\text{Change in Wood Products} = \text{Extracted} \times \text{Conversion Efficiency} \times \text{Retirement Rate}$$

Change in wood products is not measured. The extracted wood is converted to wood products with a given efficiency - typically approximately 30 %.

Over time wood products are retired and replaced and enter landfills or often burned— this is modeled.

# Regrowth of residual stand

- Can have a positive or negative effect on change in carbon stocks
  - Positive because removing timber enhances the growth of the remaining trees
  - Negative if this is unbalanced by removing the growth of the large timber tree
- In a study in Bolivia the effect was negative
  - growth in the logged plots was 1.3 t C/ha.yr
  - but in adjacent plots that were not logged 2.52 t C/ha.yr

# Change in Carbon Stocks

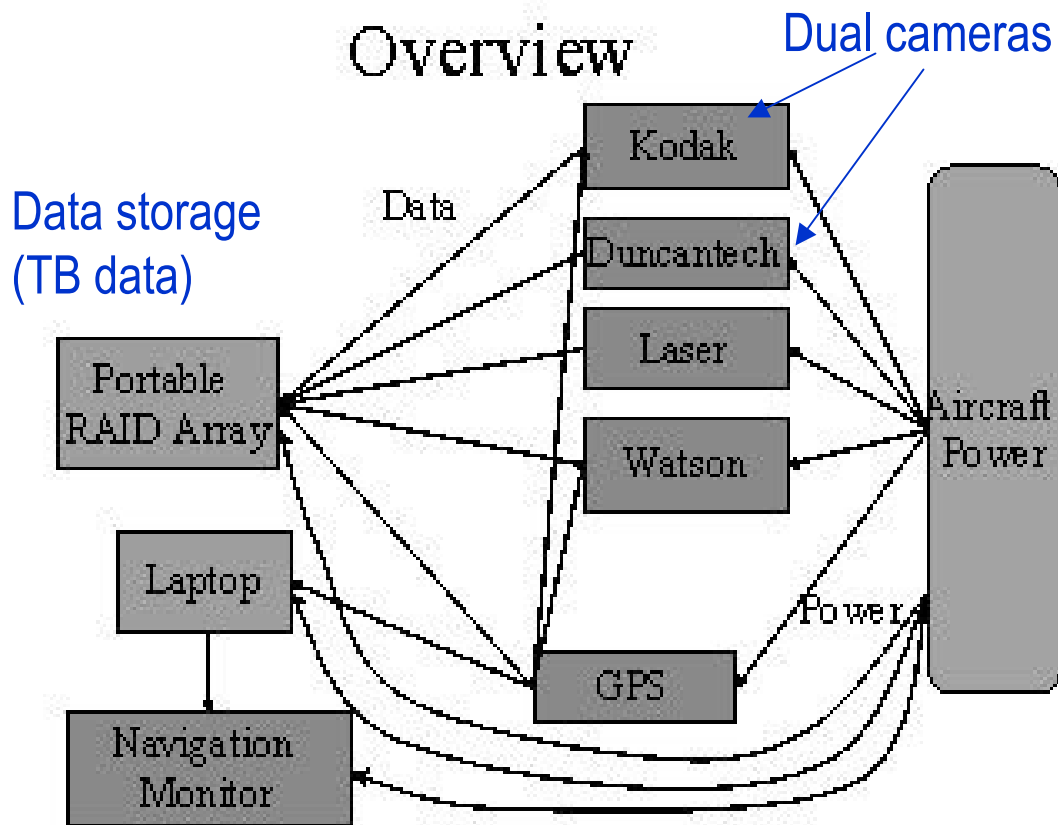
Change in Carbon Stocks =

- [Carbon extracted during logging + Carbon damaged during logging]
  - – [Carbon in dead wood – dead wood decomposition]
  - – [Carbon in wood products – wood products decomposition]
  - + Regrowth factor
- 
- Low intensity logging (about 3 m<sup>3</sup>/ha.yr), net emissions are about
    - 1 metric ton of C per m<sup>3</sup> logged
    - 3 metric ton of C per ha logged

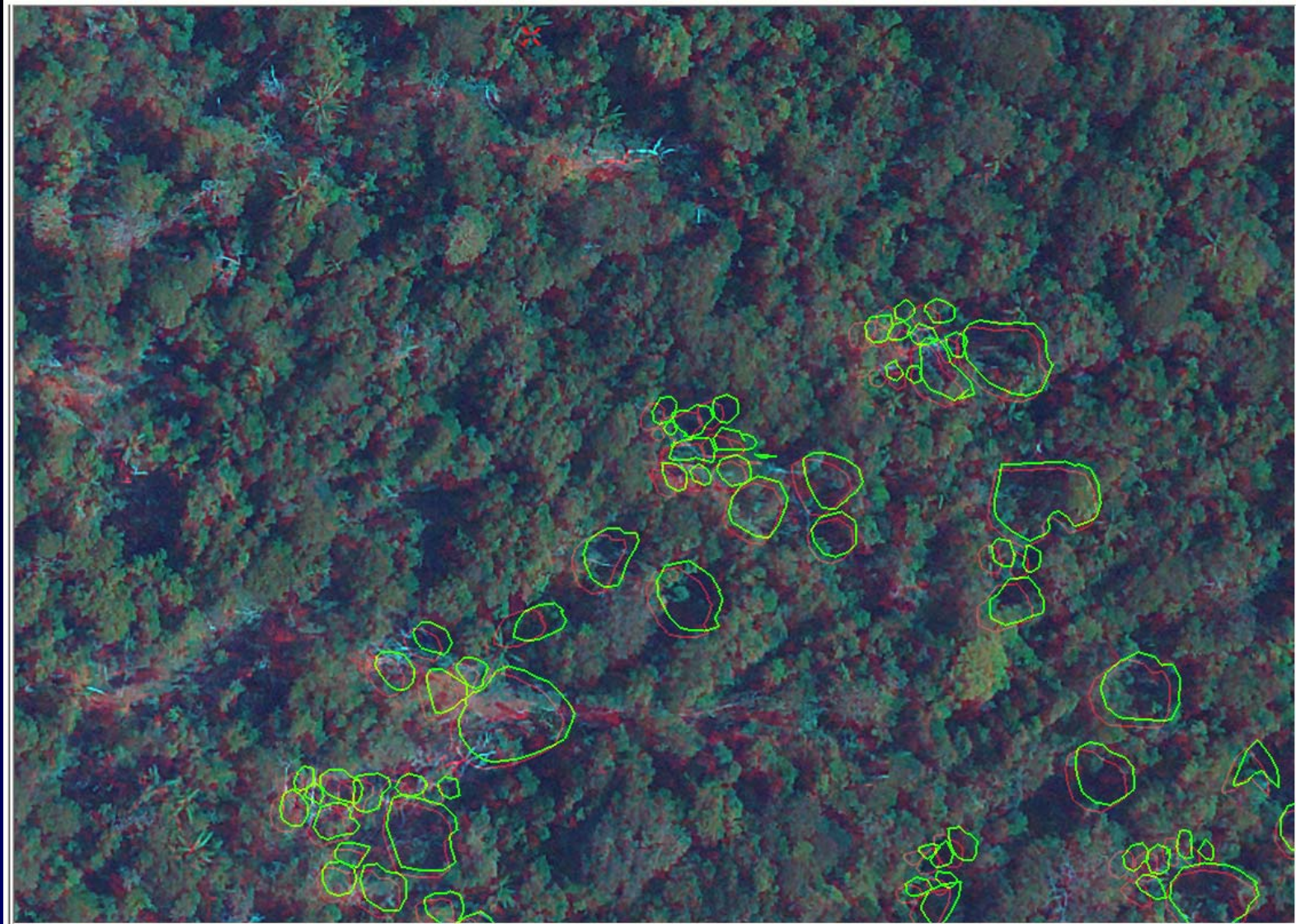
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**Measuring the amount harvested  
by aerial imagery**

# Multispectral 3D digital aerial imagery system (M3DADI)



# Gaps left were measured where trees existed



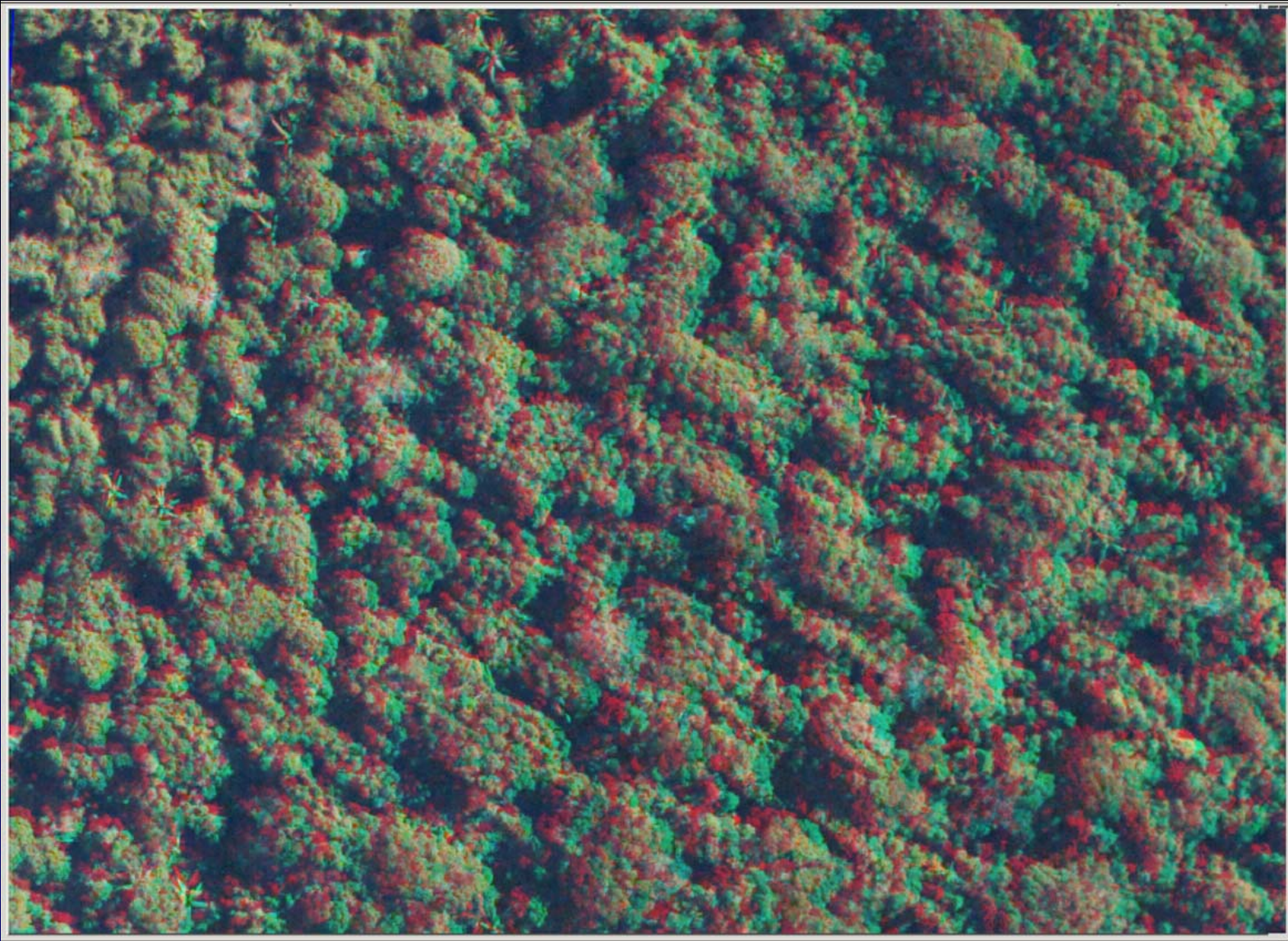
# Total change in carbon stocks

- Measure characteristics of logged trees—crown area and height and estimate volume or biomass
- Use logging damage plots to obtain estimated mean change in C stock per unit area of gap
- Use imagery to obtain total area of logging gaps
- Combine area and damage in simple model to estimate impact on carbon stocks

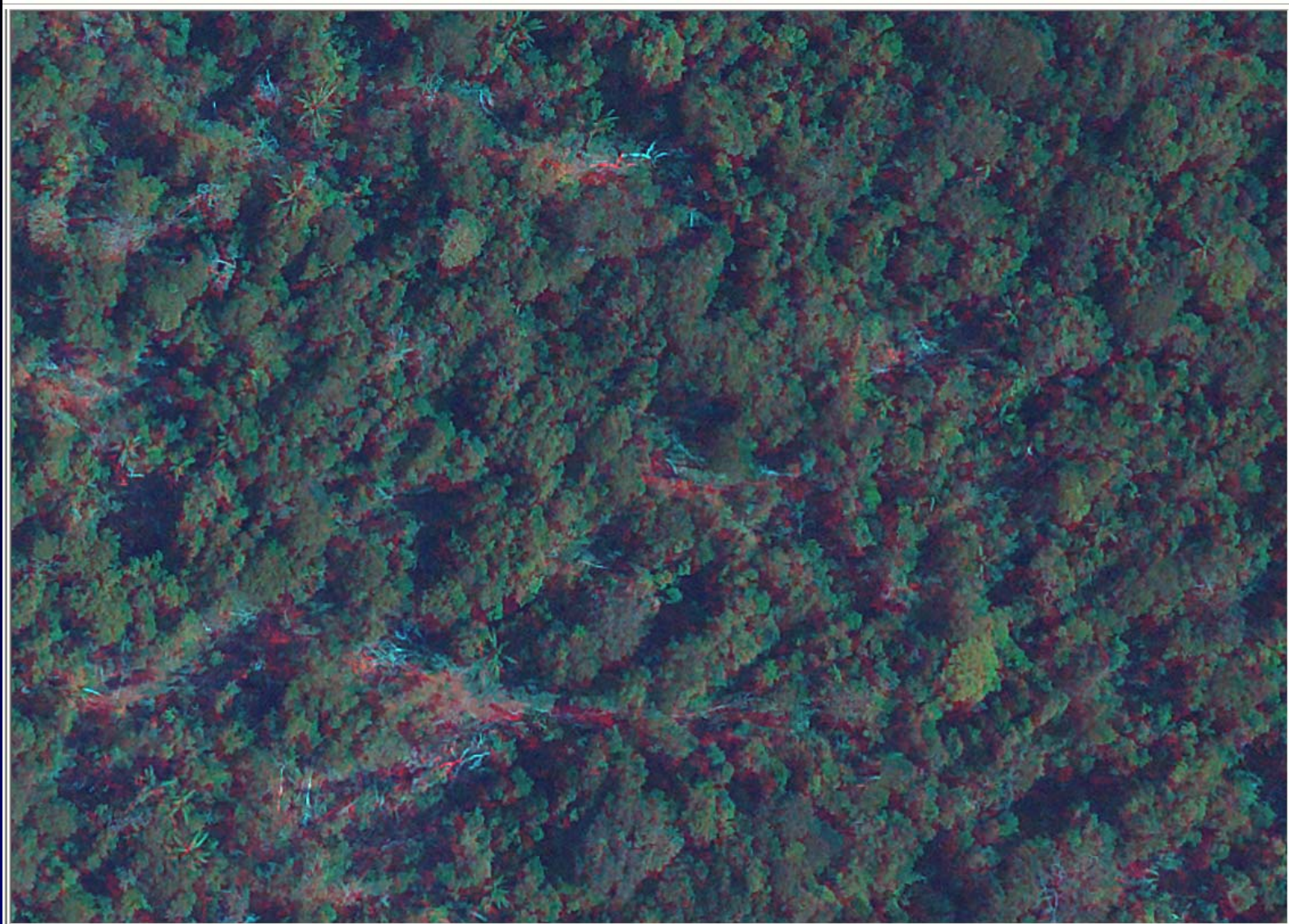
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Alternative approach

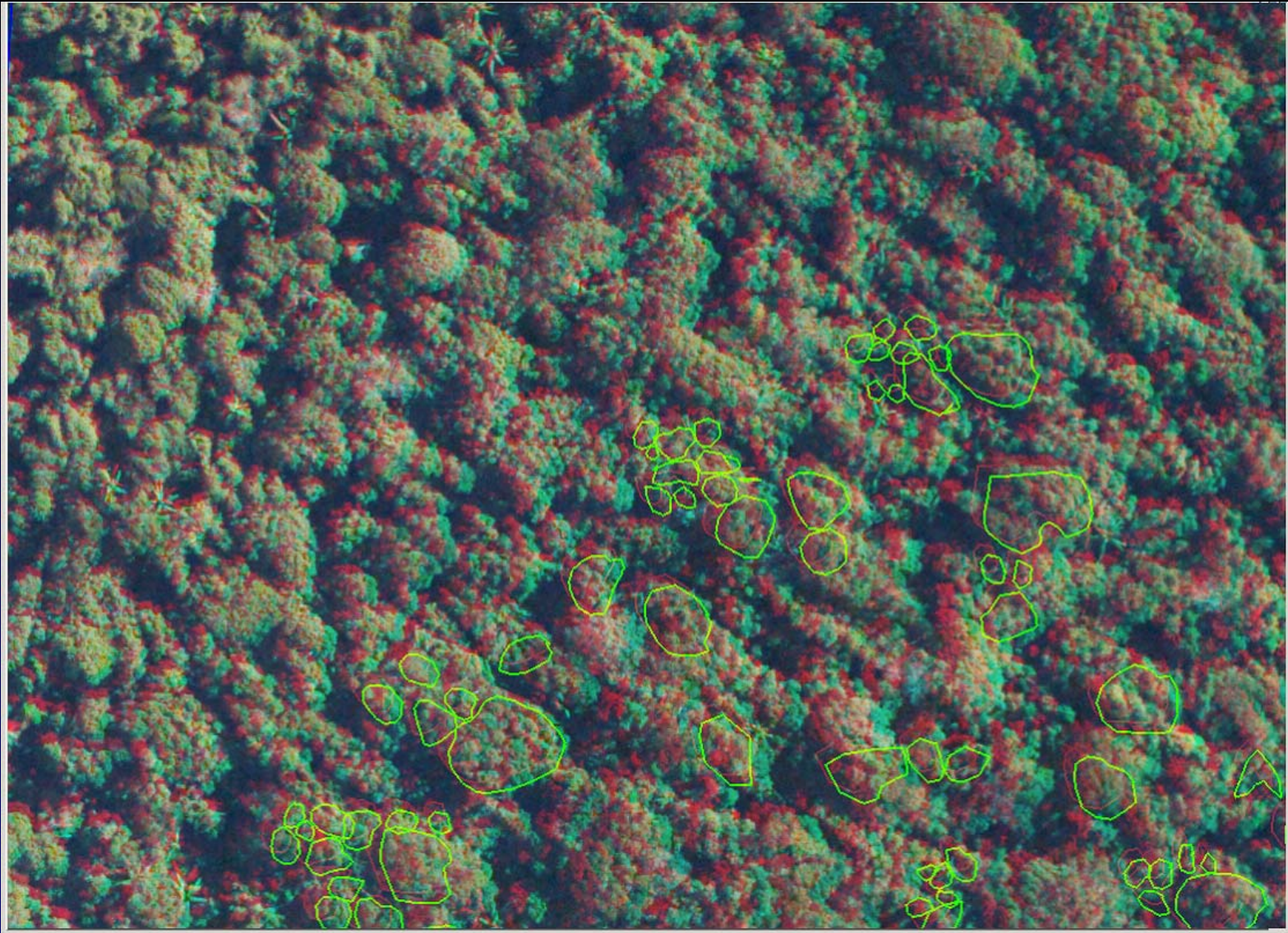
# Bolivia closed forest—before exploitation



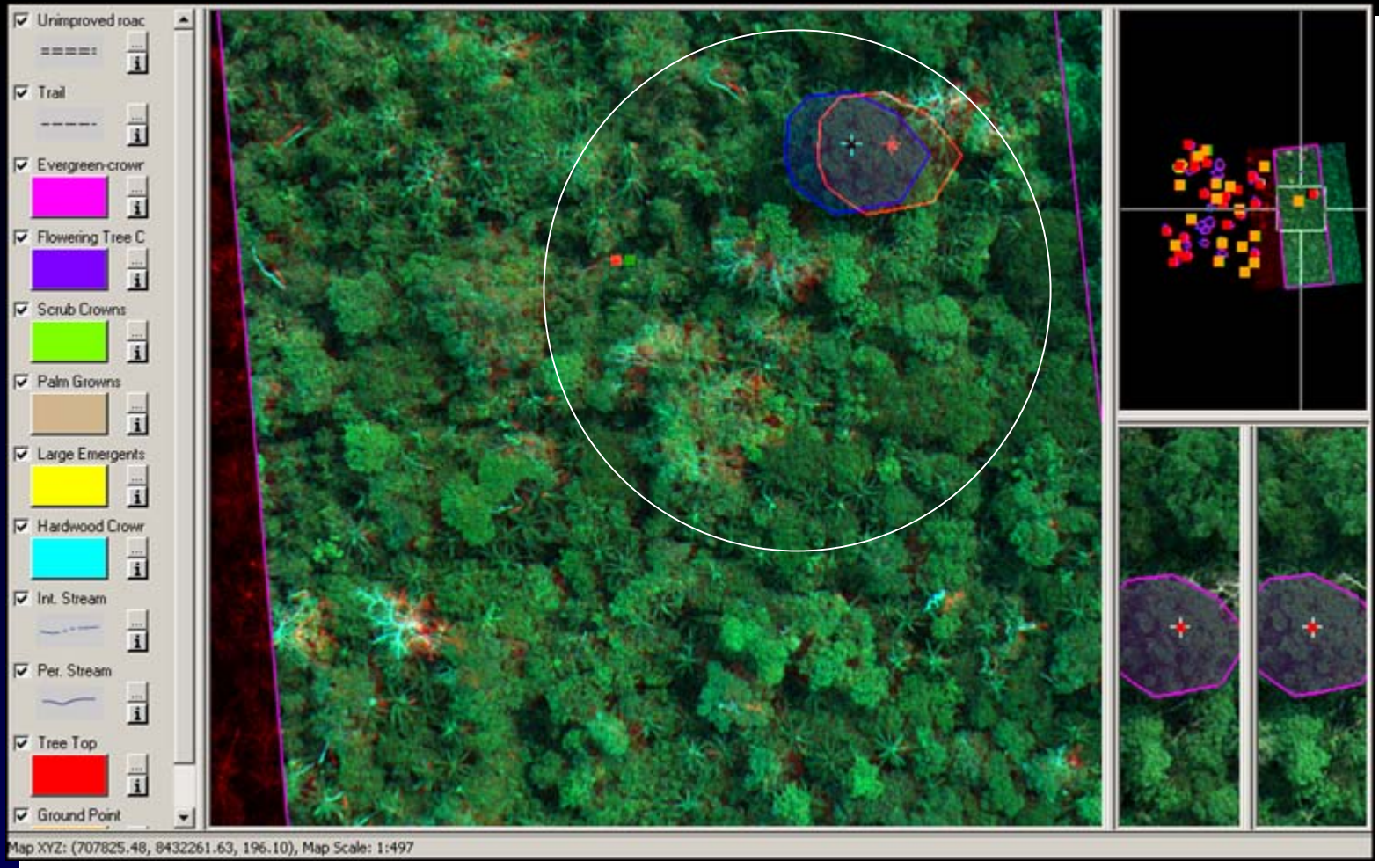
# Bolivia closed forest --after exploitation



# Individual tree crowns measured before exploitation



# Monitoring for carbon on a virtual forest



Individual trees can be measured for height, crown area, and in some cases species—combine with equation of biomass of tree or volume of tree vs crown area x ht

# Monitor change in carbon stocks

- From imagery, estimate carbon in missing trees
- Develop model of volume versus tree height and crown area
- Use imagery to estimate loss in biomass carbon over exploited area

# Use M3DADI for monitoring:

- Changes in logging intensity over time
- Change in logging damage
- Change in canopy closure
- Estimate change in canopy closure from exploitation