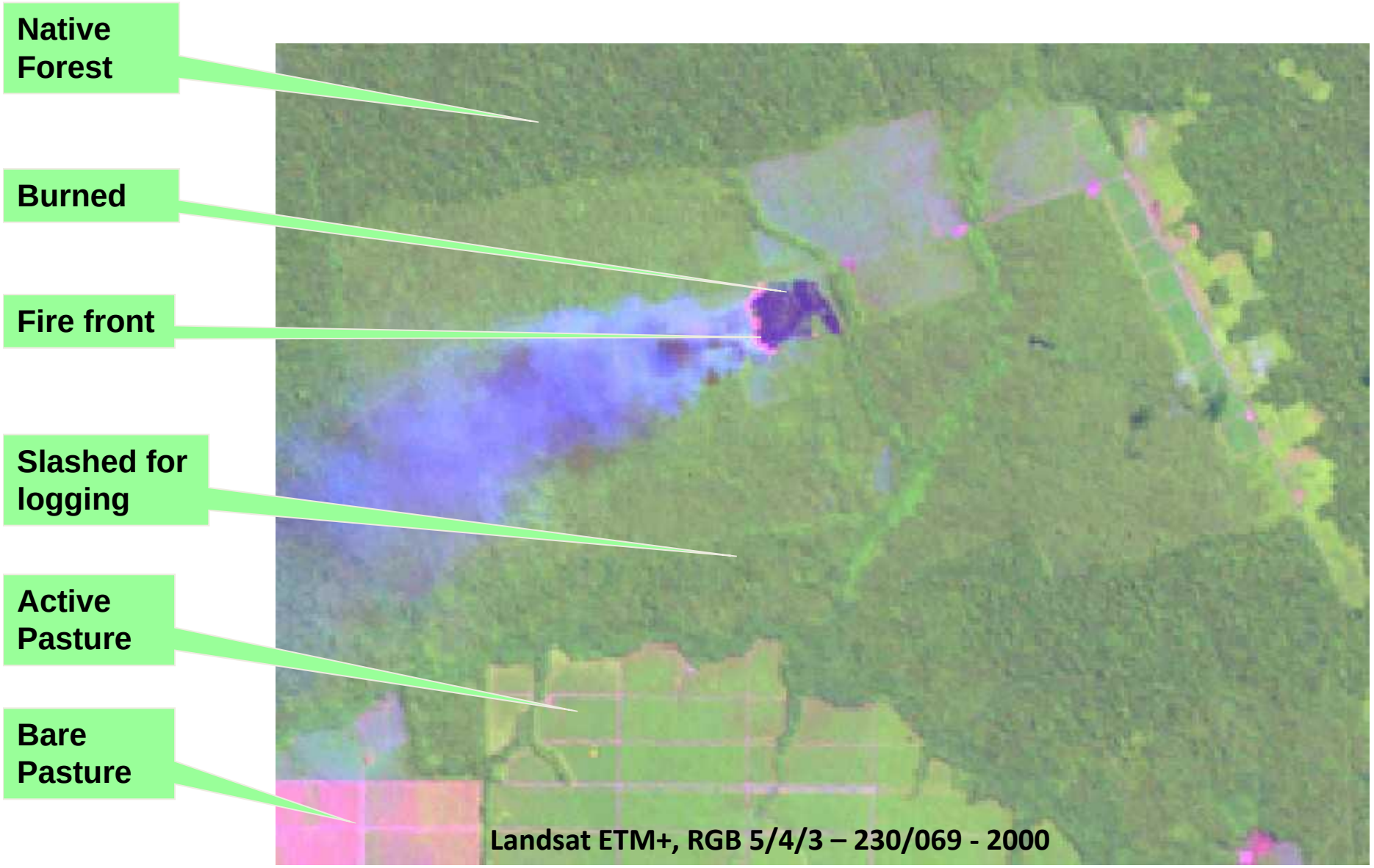
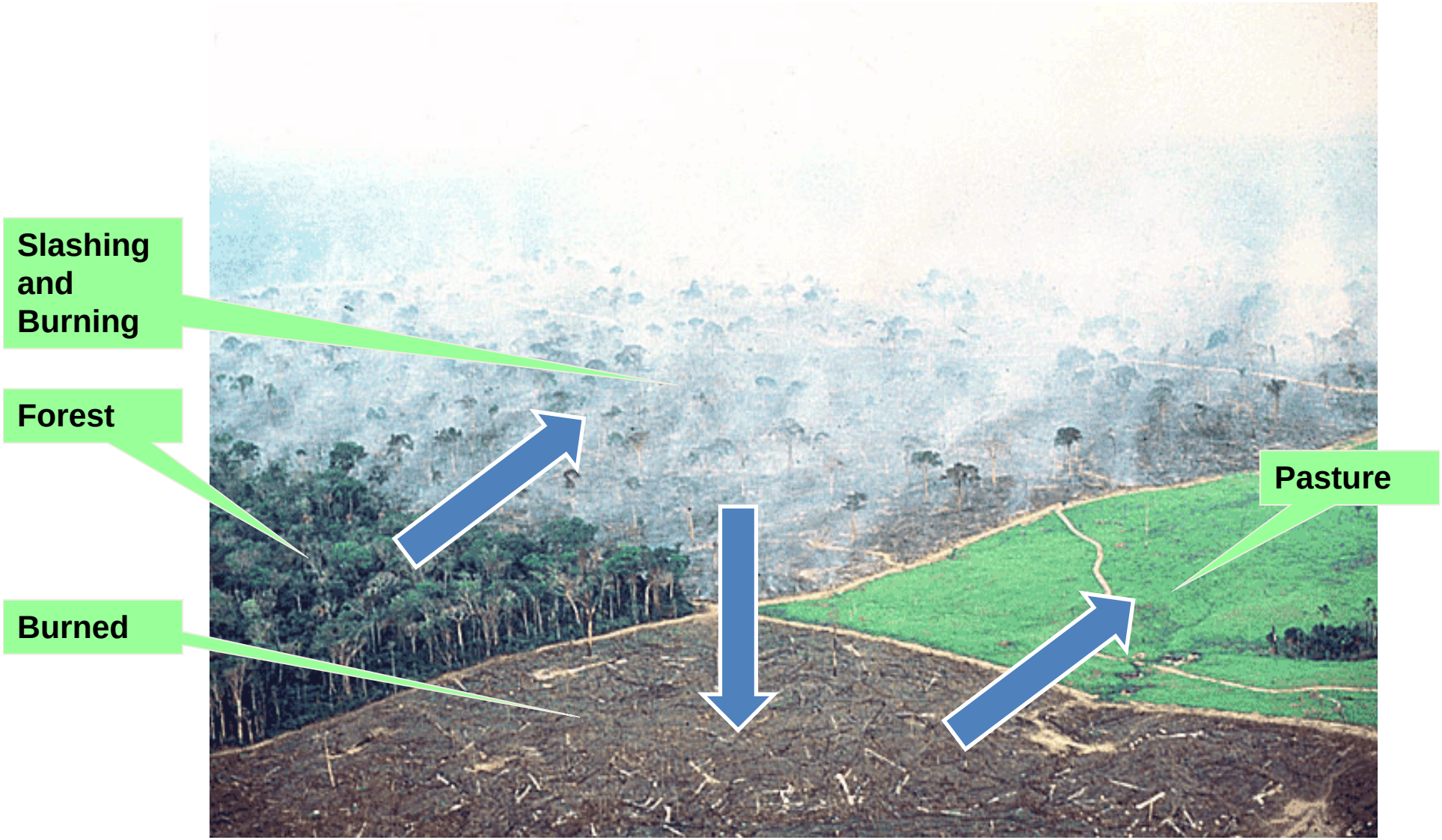
Global Observatory for Ecosystem Services

Carbon, Forests and Livelihoods

David Skole
Department of Forestry
Michigan State University


Native Forest
Burned
Fire front
Slashed for logging
Active Pasture
Bare Pasture
Landsat ETM+, RGB 5/4/3 – 230/069 - 2000


Slashing and Burning
Forest
Burned
Pasture

Linking carbon and development

- The challenge: The Millennium Development Goals (MDGs) establish two interrelated objectives: poverty alleviation and environmental sustainability.
  - Over 1.5 billion people of the world's population live in extreme poverty…
  - …of which 1.0 billion live in rural areas where their livelihoods depend on the consumption and sale of natural products.
  - About two-thirds of the rural poor live in ecologically vulnerable areas and marginally productive landscapes.
  - A significant share of the world's poor are small-hold farmers

Linking carbon and development

- An approach: increasing the amount of carbon in soil and biomass for small holder systems:
  - carbon sequestration in the adoption of reforestation, sustainable land use, agroforestry and related livelihood activities;
  - reforestation, sustainable land use and agroforestry as adaptation strategies for climate change;
  - additional co-benefits related to biodiversity conservation and other environmental concerns, livelihoods and poverty reduction (i.e., sustainable development)

Biomass outside of dense forests

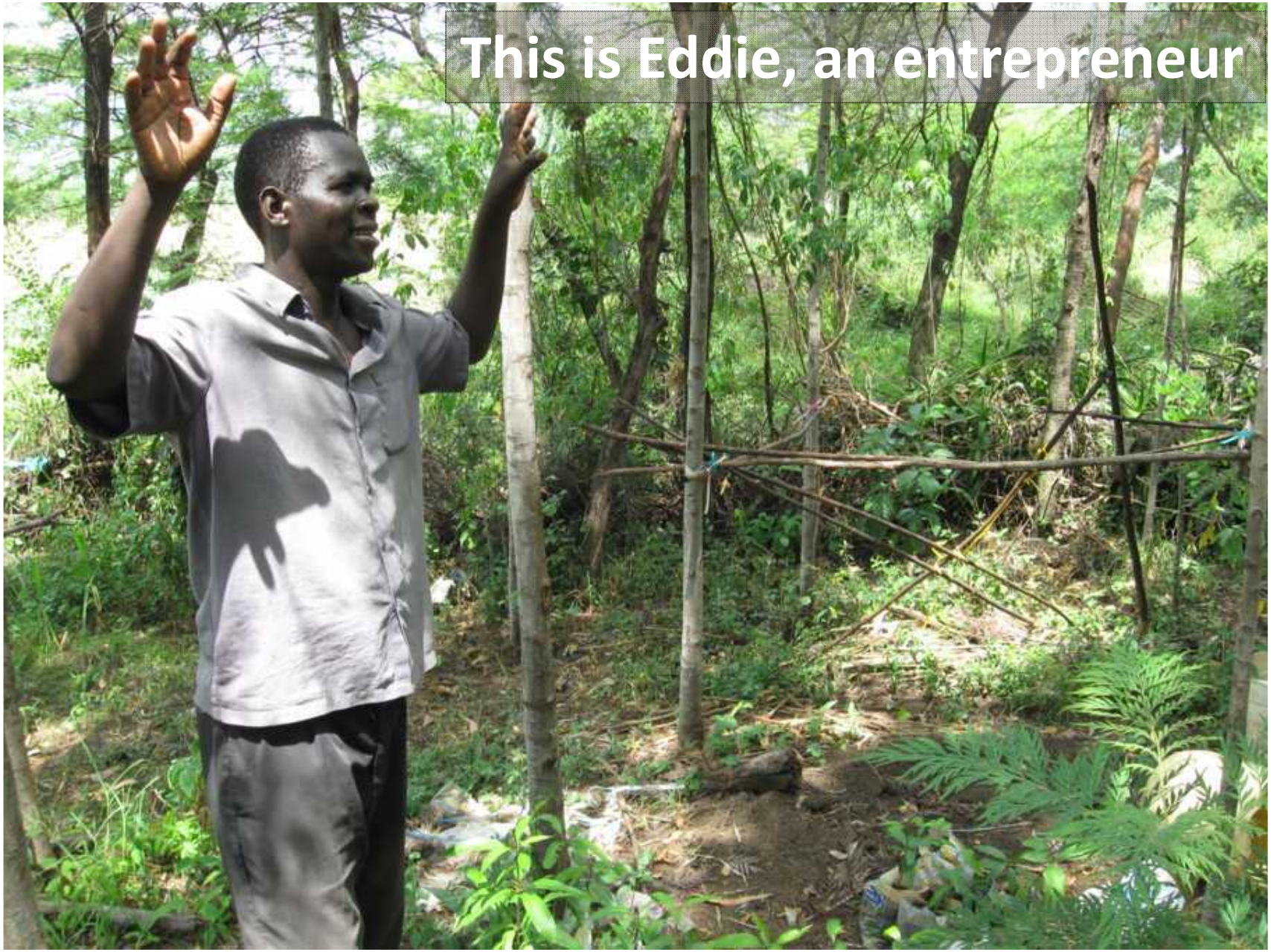
- 1) regeneration systems on managed landscapes where biomass recovery occurs as plantations, orchards, agroforestry, and widely-spaced tree complexes associated with agriculture.

- 2) open woodlands such as the cerrado and the chaco ecosystems in South America, woodlands of East and West Africa, and other open forest ecosystems in the tropics and sub tropics,

Agro-Forestry and Carbon

- Some estimates from international organizations suggest there is a large amount of carbon sequestration already occurring in these managed landscapes (Verchot and Singh 2009).
- For example, remote sensing in 64 rural locations in Africa:
  - forested area declined 50%, agricultural area increased 23%, and the proportion of agricultural land under tree cover increased 22% (Place 2001).
  - Agricultural land now accounts for over double the area of forested land in Africa (FAO 2006), giving justification to the slogan that, “the future of trees is on farms.”


One landscape in Western Kenya:
-Annual maize farming system
-High soil erosion, low productivity


This is Eddie, an entrepreneur

Poor adoption rates

- Although preferred for economic and environmental benefits, not widely adopted
- The problem of delayed benefits
- The Carbon2Markets model
  - Natural Products + carbon benefits and returns

Simplified Traditional West African Farming System (cont.)

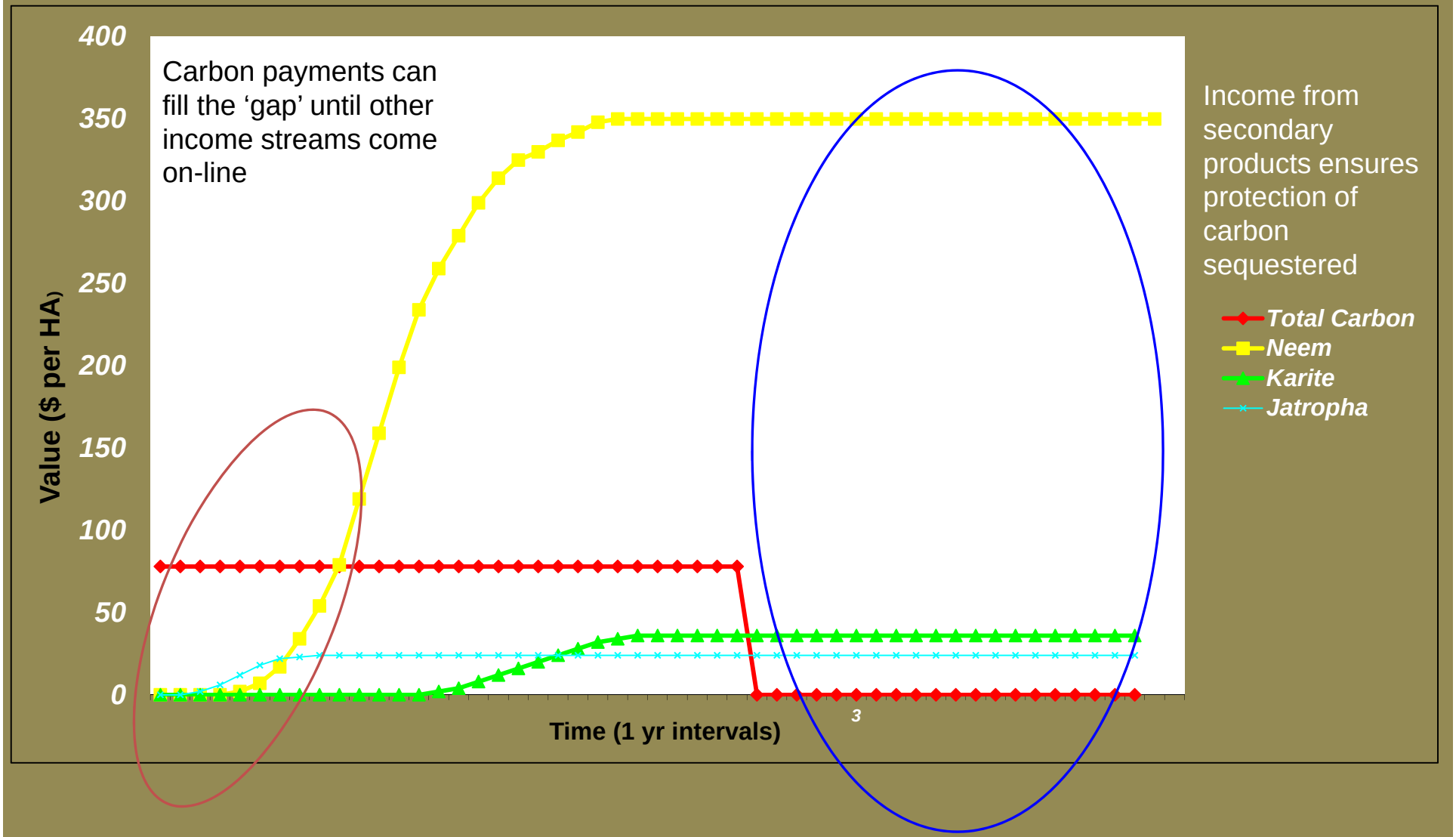
- Total system income:

240	USD/ha/yr	Cereal
36	USD/ha/yr	Shea Oil
24	USD/ha/yr	Jatropha Oil
350	USD/ha/yr	Neem Oil
78	USD/ha/yr	Carbon
728	USD/ha/yr	

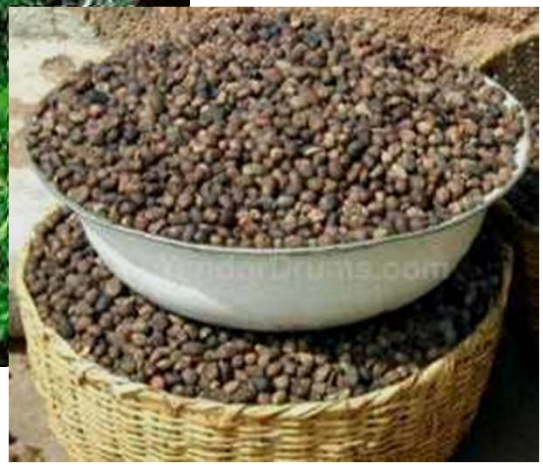
x 2.4 ha (per capita average) = 1747 USD

Nearly double the average annual income for those living at the "ethical poverty" level of $2.40/day

Carbon Can Boot-strap Agro-Forestry



Two Value Chains: Shea Nut Over Cassava




Viet Nam


Thailand

- # Inpang Network – Carbon Training

Jay Samek Michigan State Univ.

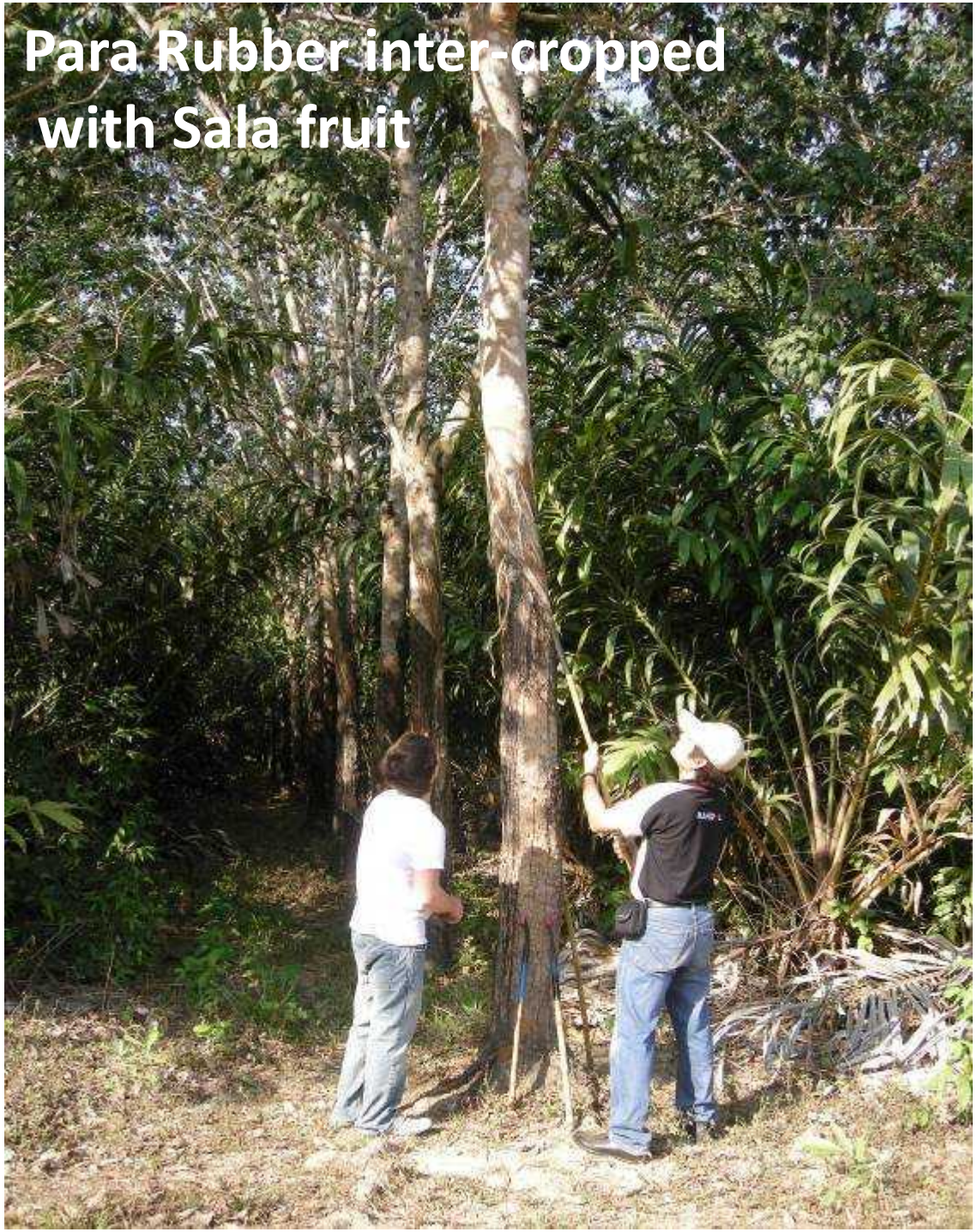
August 11, 2007

อันว่าฟ้าหลงทีปแม่นหย้อนโลกฮ้อน

Carbon Bank project


Natural Para Rubber Plantation on Degraded Land


FUSA


Para Rubber inter-cropped
with Sala fruit

Mixed natural and product species community forest


ศูนย์จัดการสุขภาพชุมชน
เครือข่ายอินแปง.
ต.โพนงาม อ.อากาศอำนวย จ.สกลนคร


เครือสะคาน


เครือตานกก


หม่วยเลือด






Indigo dying


DVD THEATRE


อินแปง

General Structure of the Carbon in Woody Biomass Measurement System

OBJECTIVES:

Measurement	Monitoring	Reporting	Verification

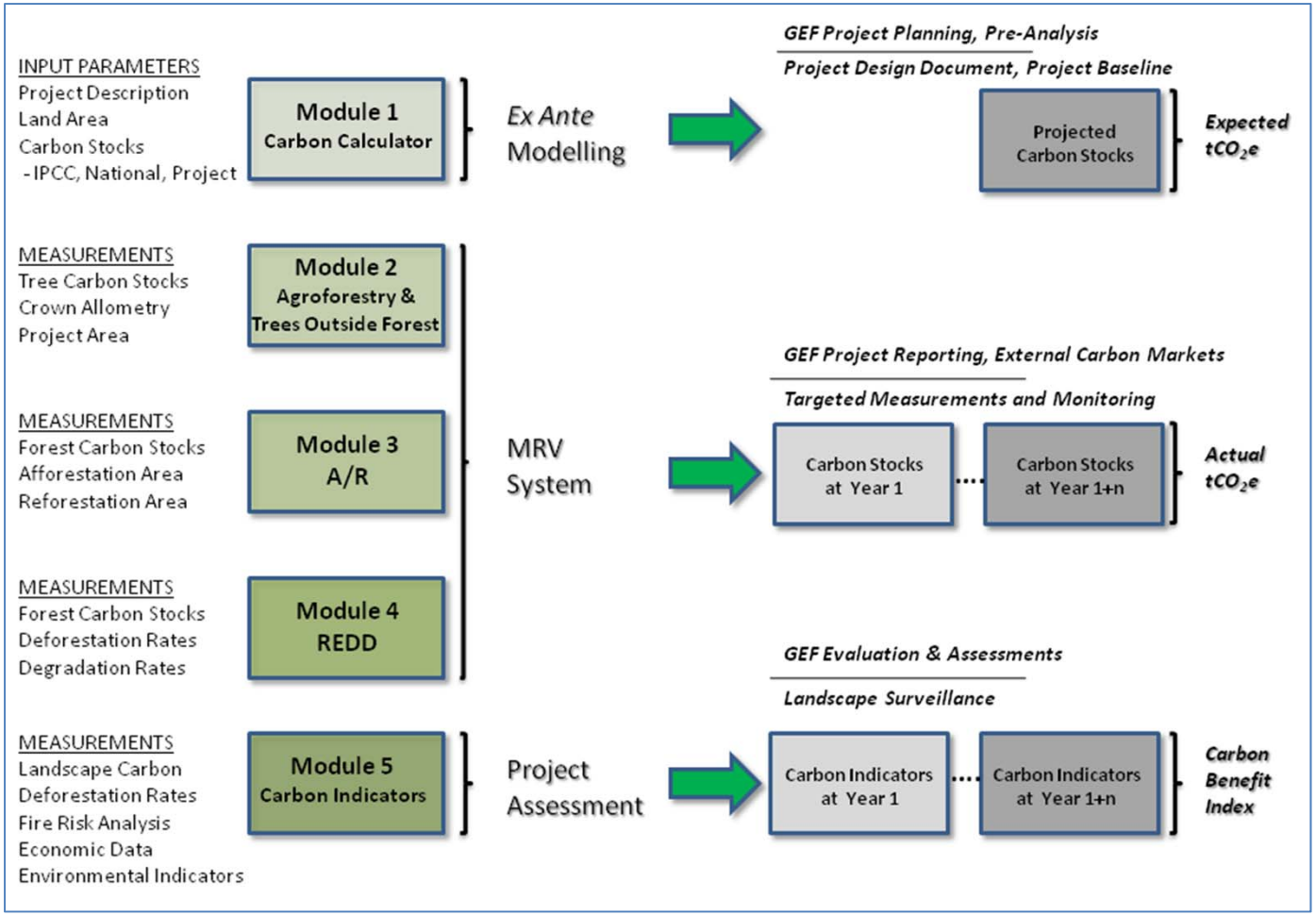
TOOLS:

Remote Sensing, Field Sampling Geographic Information Systems	Online Geospatial Information Management System for MRV

PROCESS:

STEP 1: Acquire coarse, moderate and fine resolution satellite data	STEP 4: Preliminary analysis of satellite data	STEP 7: Full landscape analysis of land cover change in project lifetime	STEP 10: Online data storage and display	STEP 12: Generate reports using UNFCCC guidelines for national communications	Website archives data and all content can be accessible to third parties for transparent verification
STEP 2: Define project boundaries	STEP 5: Measure carbon in individual trees to calibrate remote sensing analysis	STEP 8: Carbon mapping based on tree object detection	Step 11: Repeat measurements at five year intervals and at project end		
STEP 3: Stratify by land use and forest type	STEP 6: Refine allometric equations for crown attributes	STEP 9: Determine uncertainty of carbon stock estimate			

Activity 1 - Monitoring, Reporting and Verification System

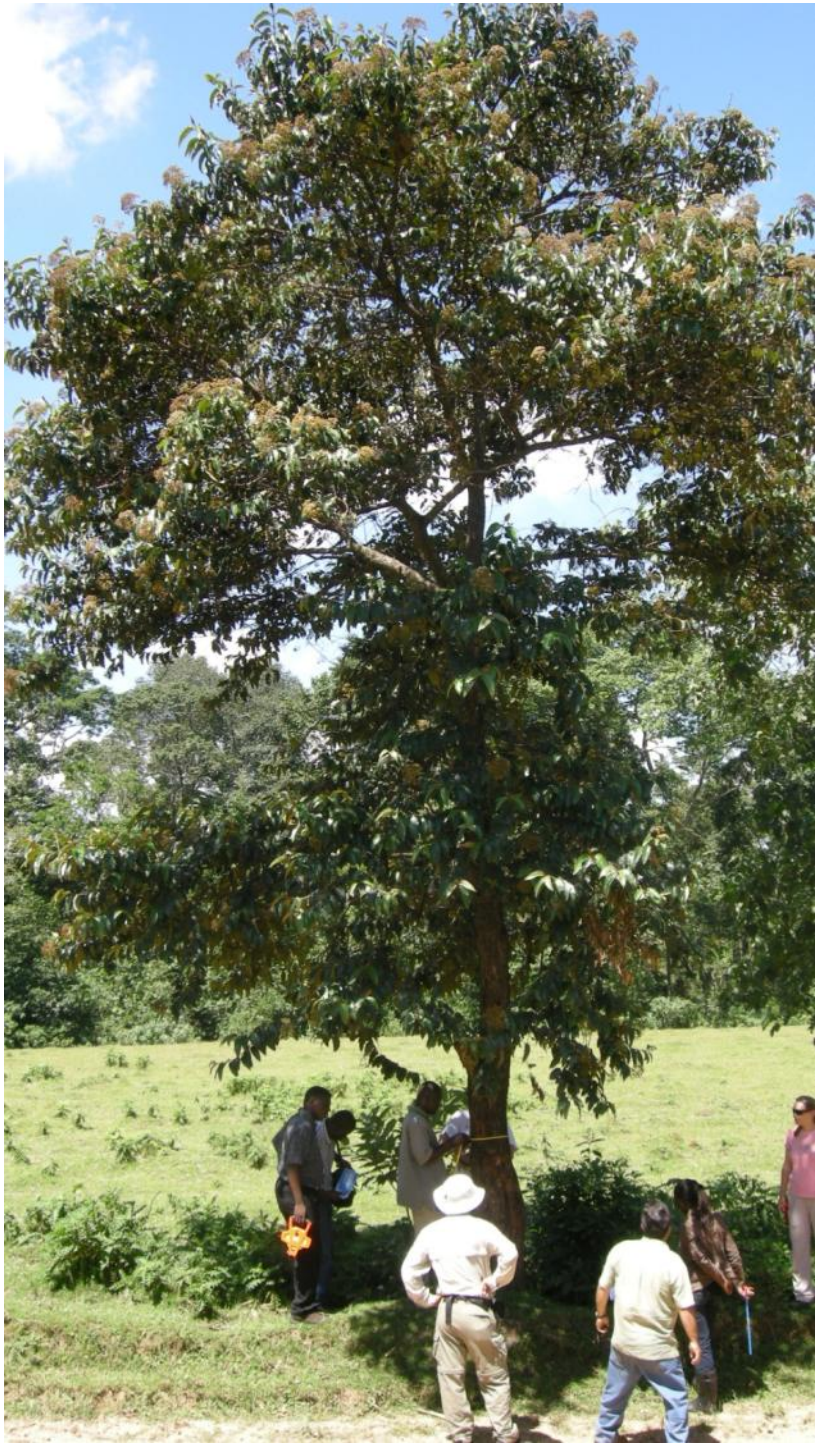


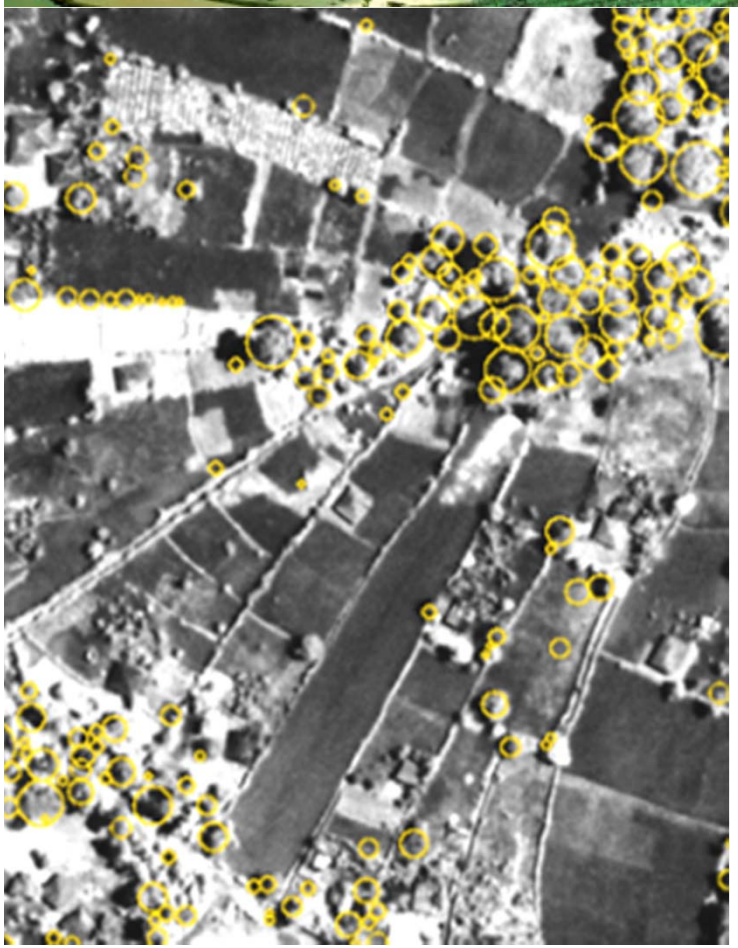
METHODS

Documents to provide guidance for field measurements, lab analysis, and remote sensing analysis

TOOLS

MRV Info System - web based geographic information system to upload, store, analyze, monitor, report, and verify data

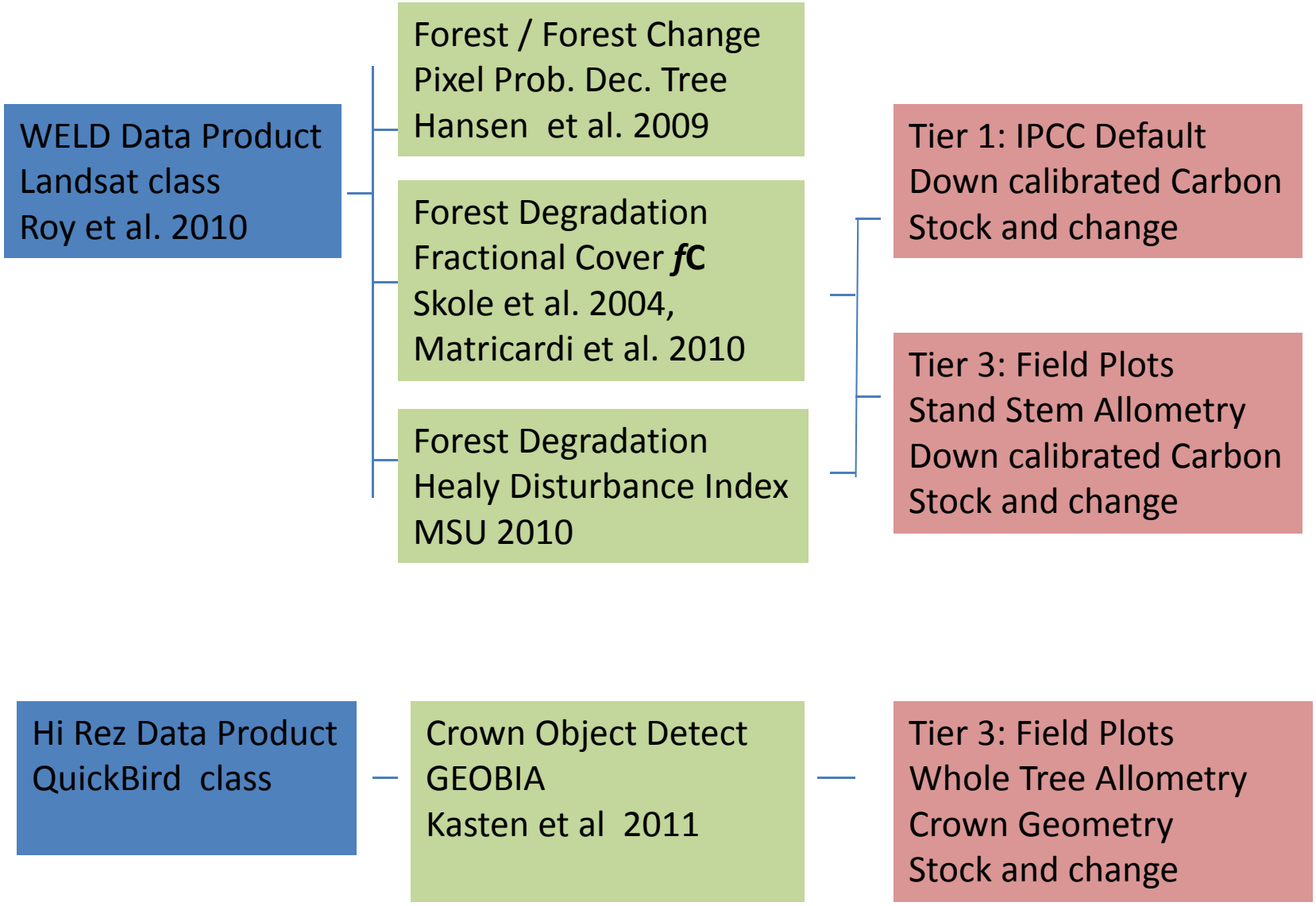


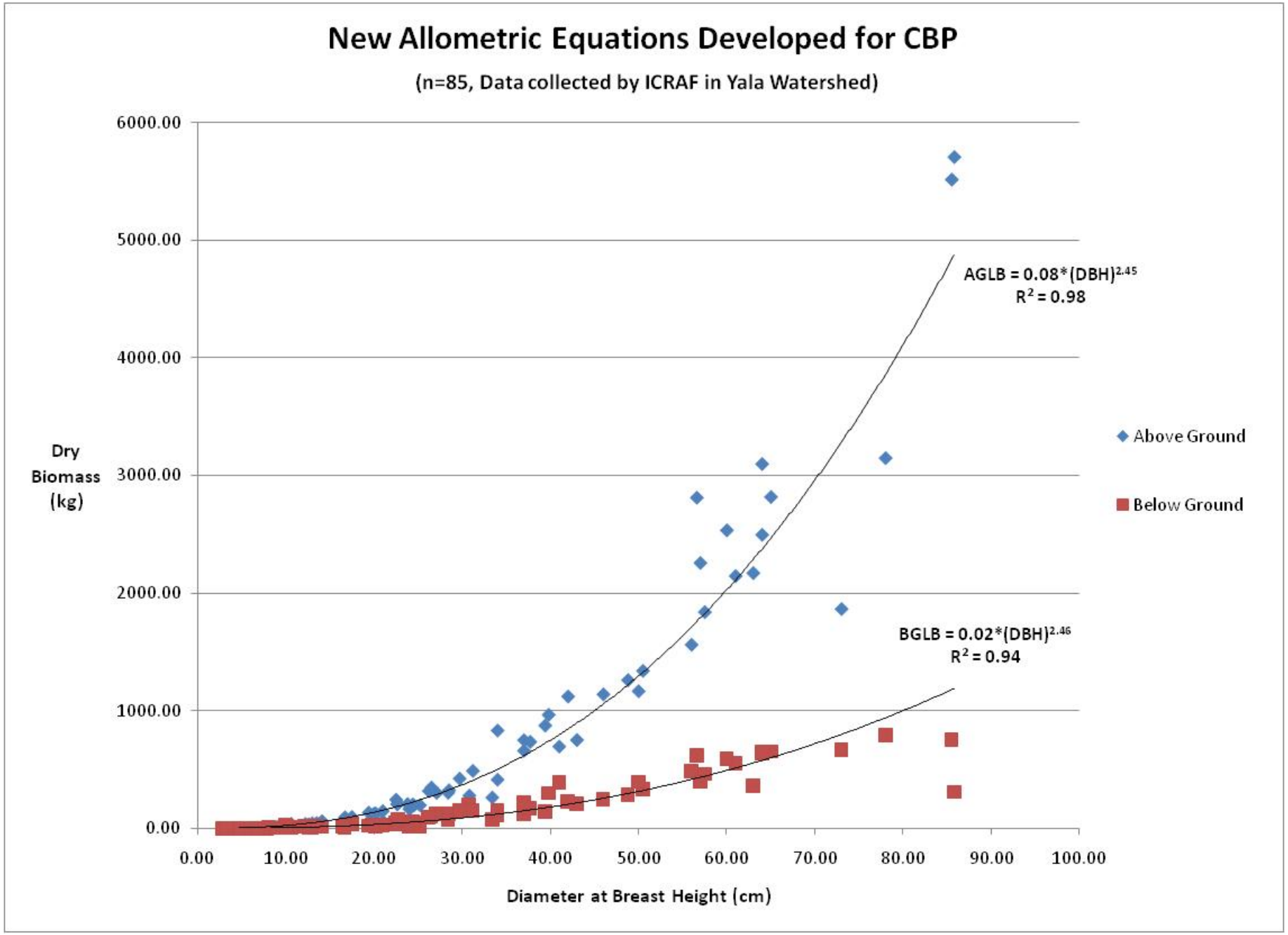


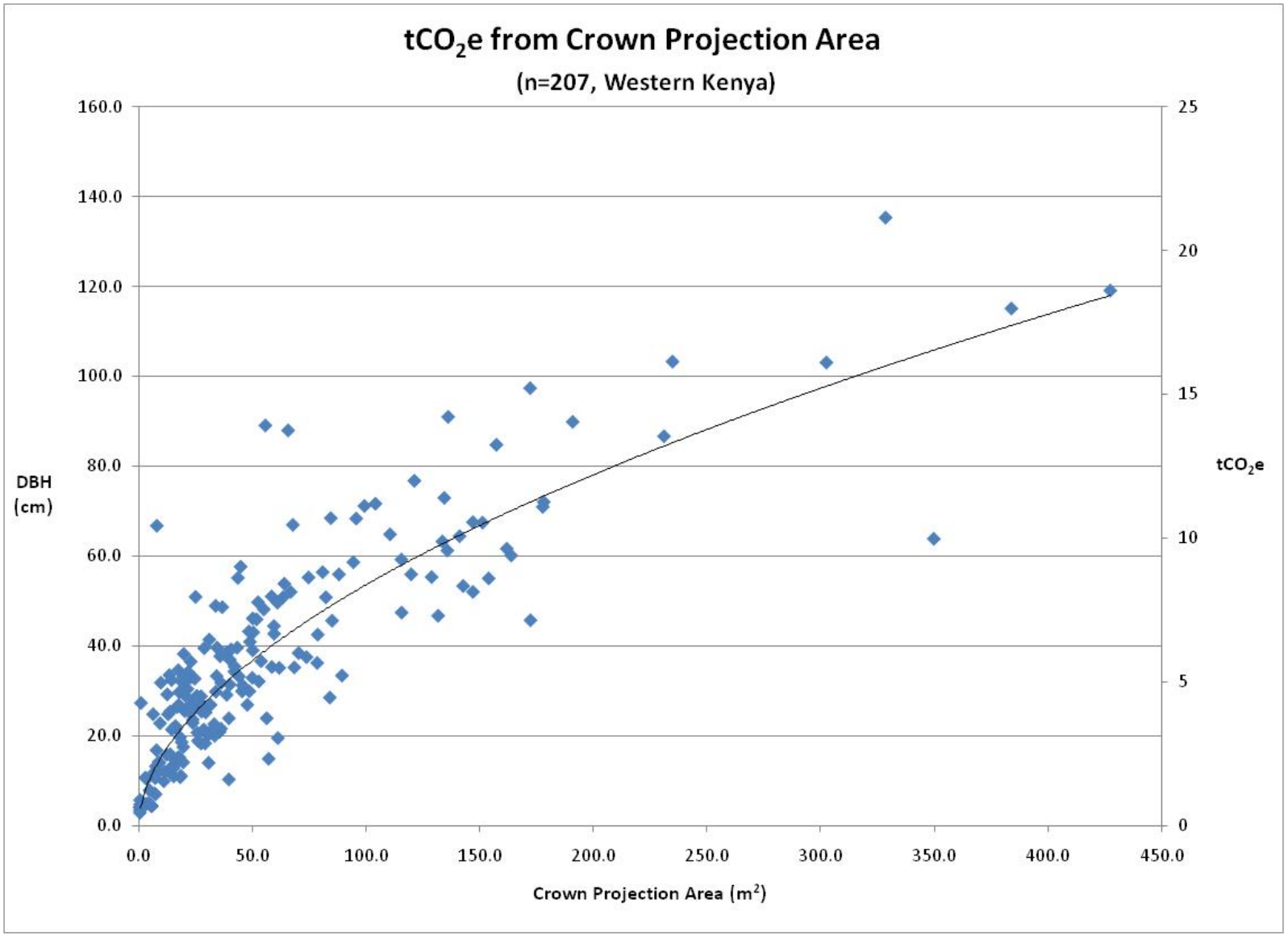
(0.6 m PAN Quickbird image of Western Kenya)

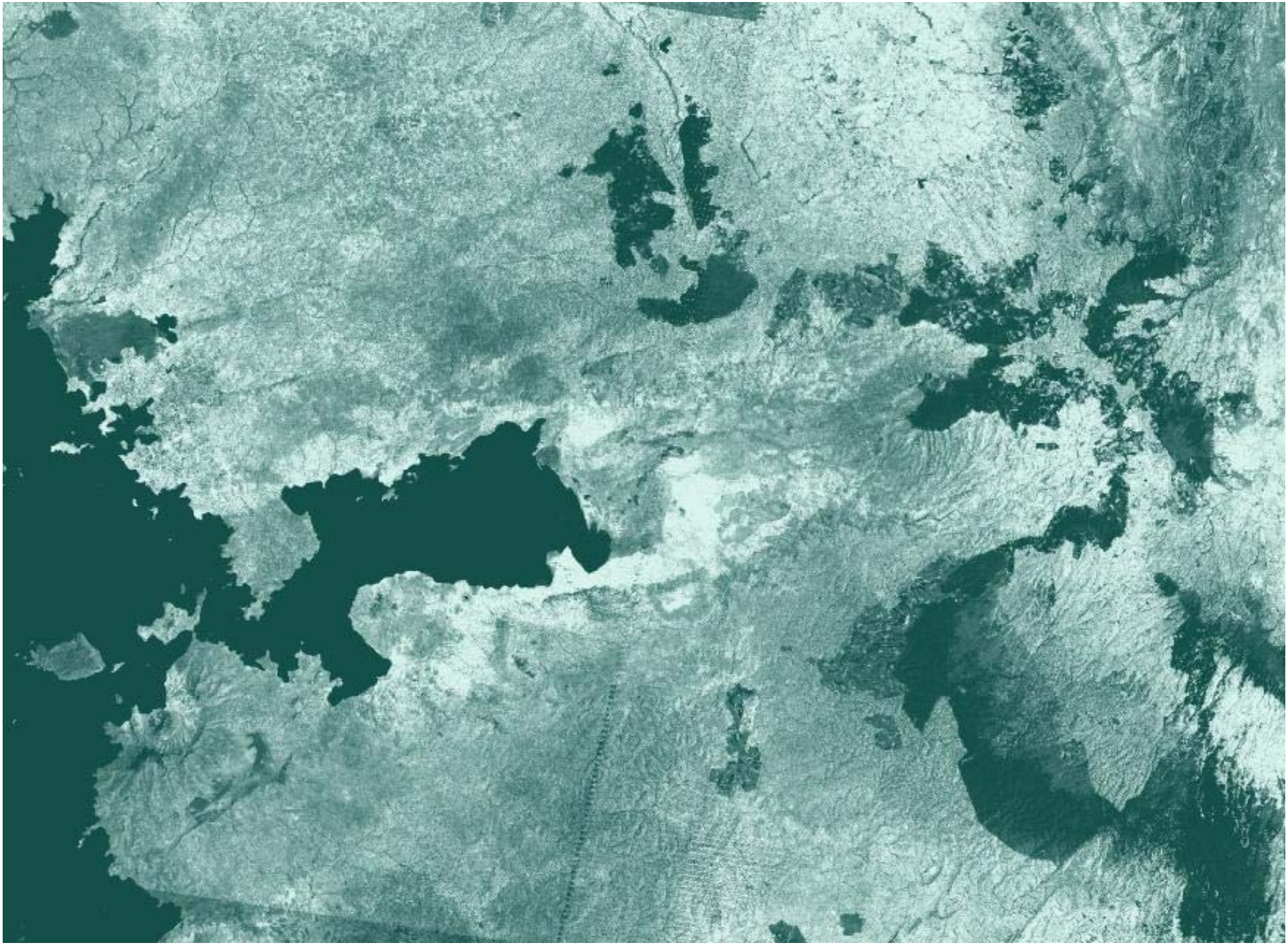
Measurement of Trees Outside of Forests and Open Woodlands

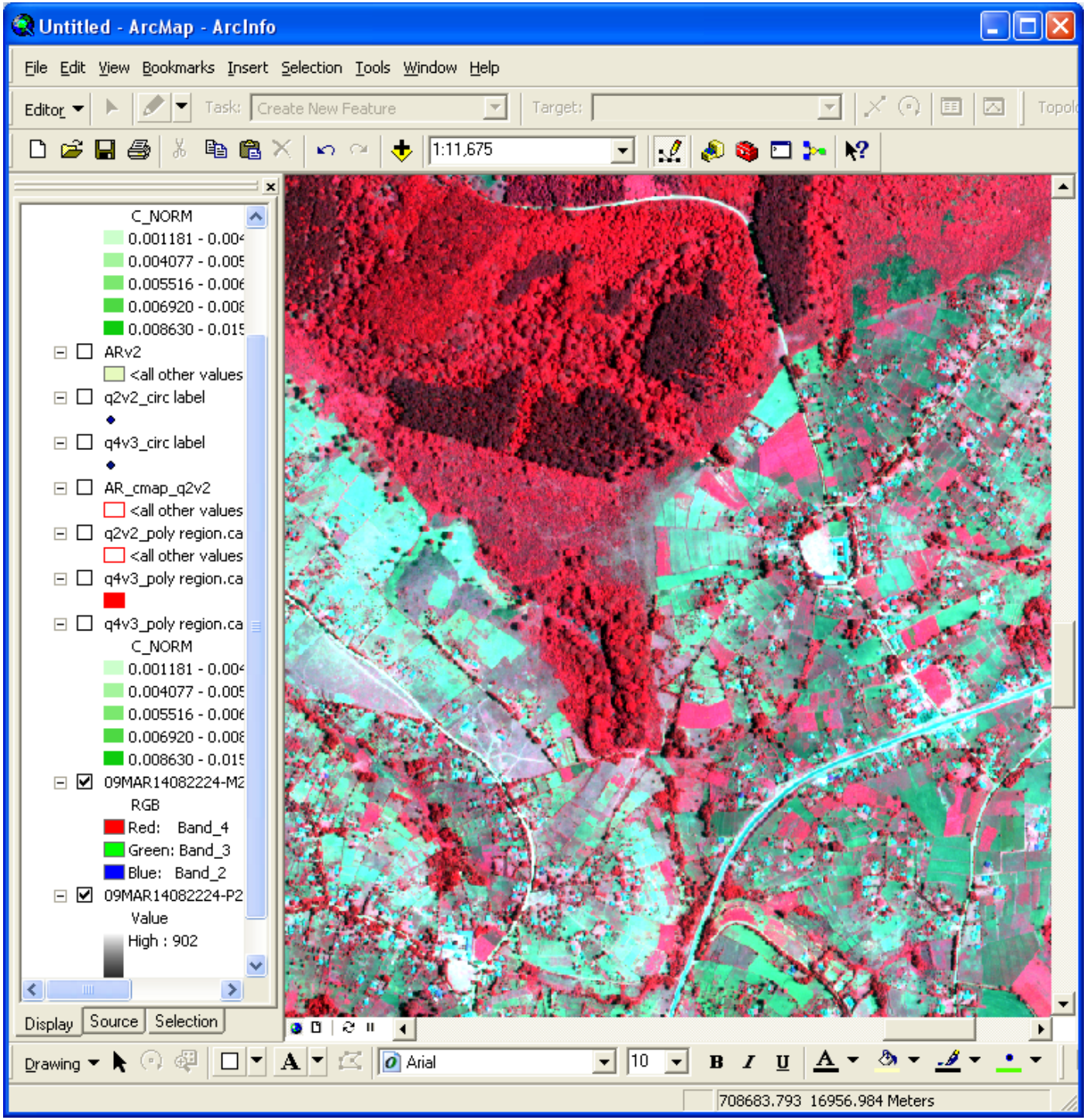
- Identify and measure individual trees in non-forest land cover including trees on farms, trees outside forest, grasslands, settlements, etc
- Requires fine resolution (<1m) satellite imagery (Quickbird, Worldview, etc)
- Requires modified allometry to relate crown attributes (crown projection area, crown diameter) to stem DBH or directly to AGB
- Map carbon in all trees within area of interest

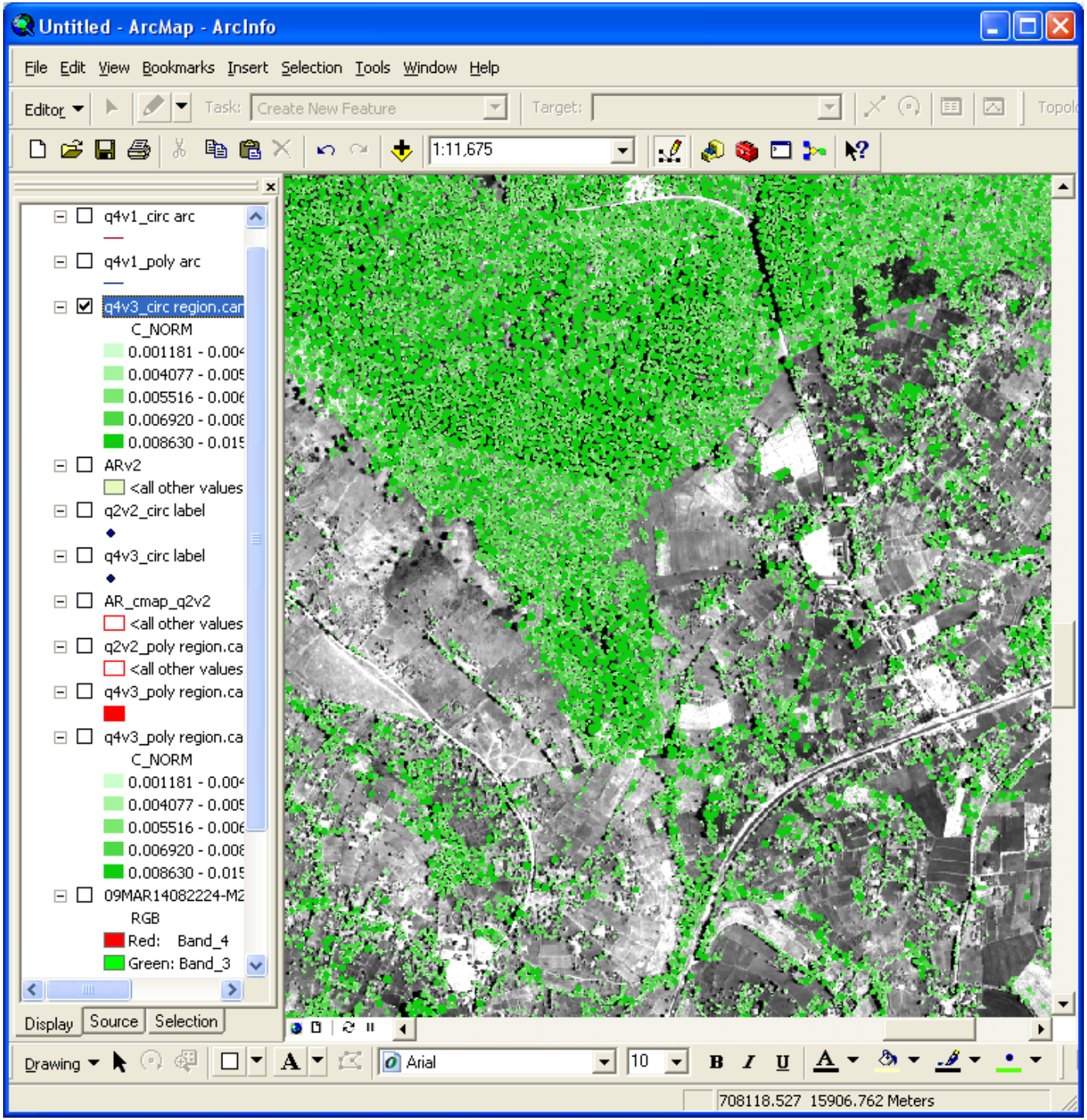

WELD Data Product
Landsat class
Roy et al. 2010
Forest / Forest Change
Pixel Prob. Dec. Tree
Hansen et al. 2009
Forest Degradation
Fractional Cover fC
Skole et al. 2004,
Matricardi et al. 2010
Forest Degradation
Healy Disturbance Index
MSU 2010
Tier 1: IPCC Default
Down calibrated Carbon
Stock and change
Tier 3: Field Plots
Stand Stem Allometry
Down calibrated Carbon
Stock and change
Hi Rez Data Product
QuickBird class
Crown Object Detect
GEOBIA
Kasten et al 2011
Tier 3: Field Plots
Whole Tree Allometry
Crown Geometry
Stock and change


New Allometric Equations Developed for CBP
(n=85, Data collected by ICRAF in Yala Watershed)
Dry Biomass (kg)
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Diameter at Breast Height (cm)
AGLB = 0.08*(DBH)2.45
R2 = 0.98
BGLB = 0.02*(DBH)2.46
R2 = 0.94
Above Ground
Below Ground

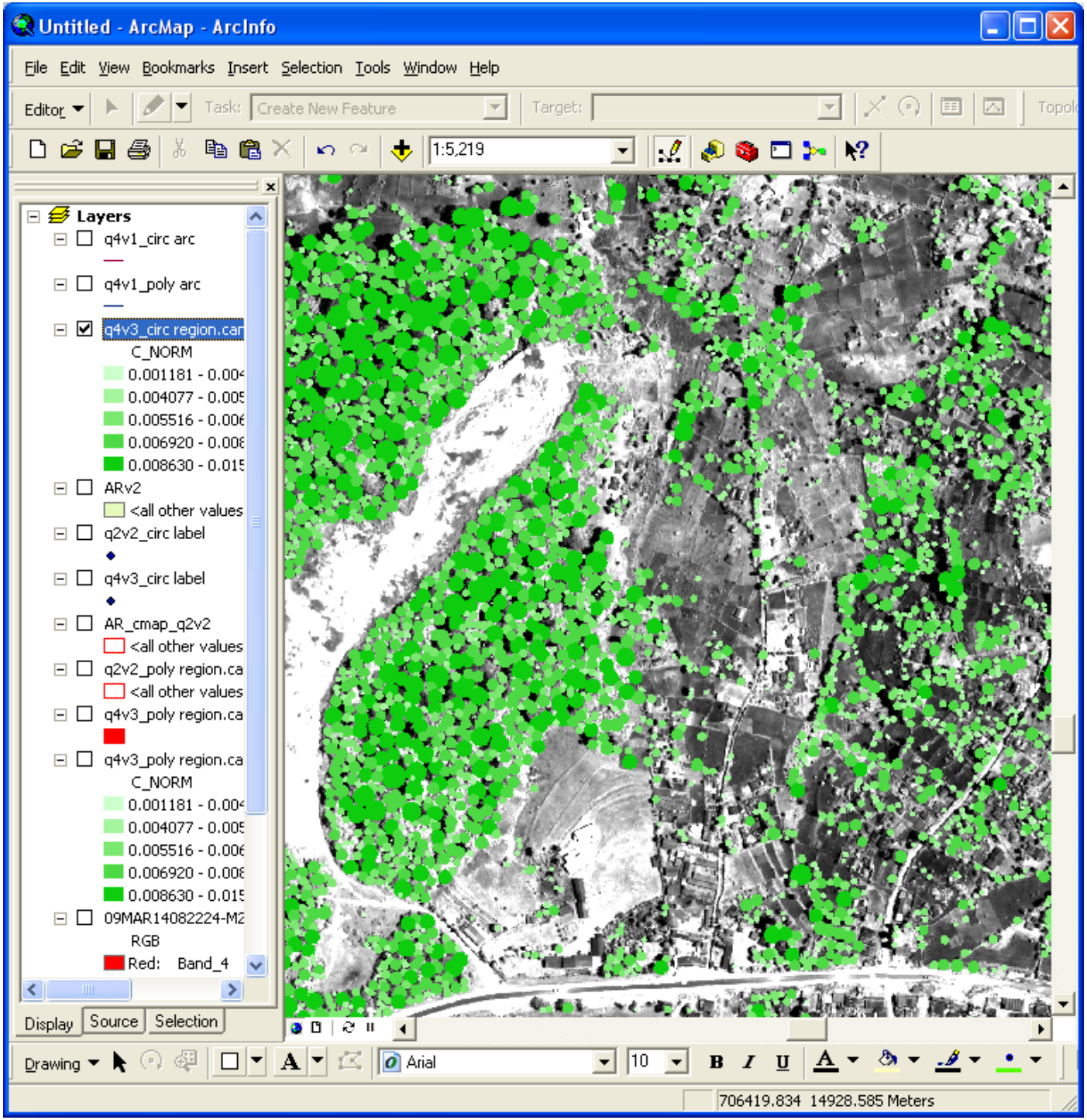

tCO2e from Crown Projection Area
(n=207, Western Kenya)
DBH (cm)
tCO2e
Crown Projection Area (m2)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
25
20
15
10
5
0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0




Untitled - ArcMap - ArcInfo
File Edit View Bookmarks Insert Selection Tools Window Help
Editor
Task: Create New Feature
Target:
1:11,675
C_NORM
0.001181 - 0.004
0.004077 - 0.005
0.005516 - 0.006
0.006920 - 0.008
0.008630 - 0.015
ARv2
<all other values
q2v2_circ label
q4v3_circ label
AR_cmap_q2v2
<all other values
q2v2_poly region.ca
<all other values
q4v3_poly region.ca
q4v3_poly region.ca
C_NORM
0.001181 - 0.004
0.004077 - 0.005
0.005516 - 0.006
0.006920 - 0.008
0.008630 - 0.015
09MAR14082224-M2
RGB
Red: Band_4
Green: Band_3
Blue: Band_2
09MAR14082224-P2
Value
High : 902
Display
Source
Selection
Drawing
Arial
10
708683.793 16956.984 Meters

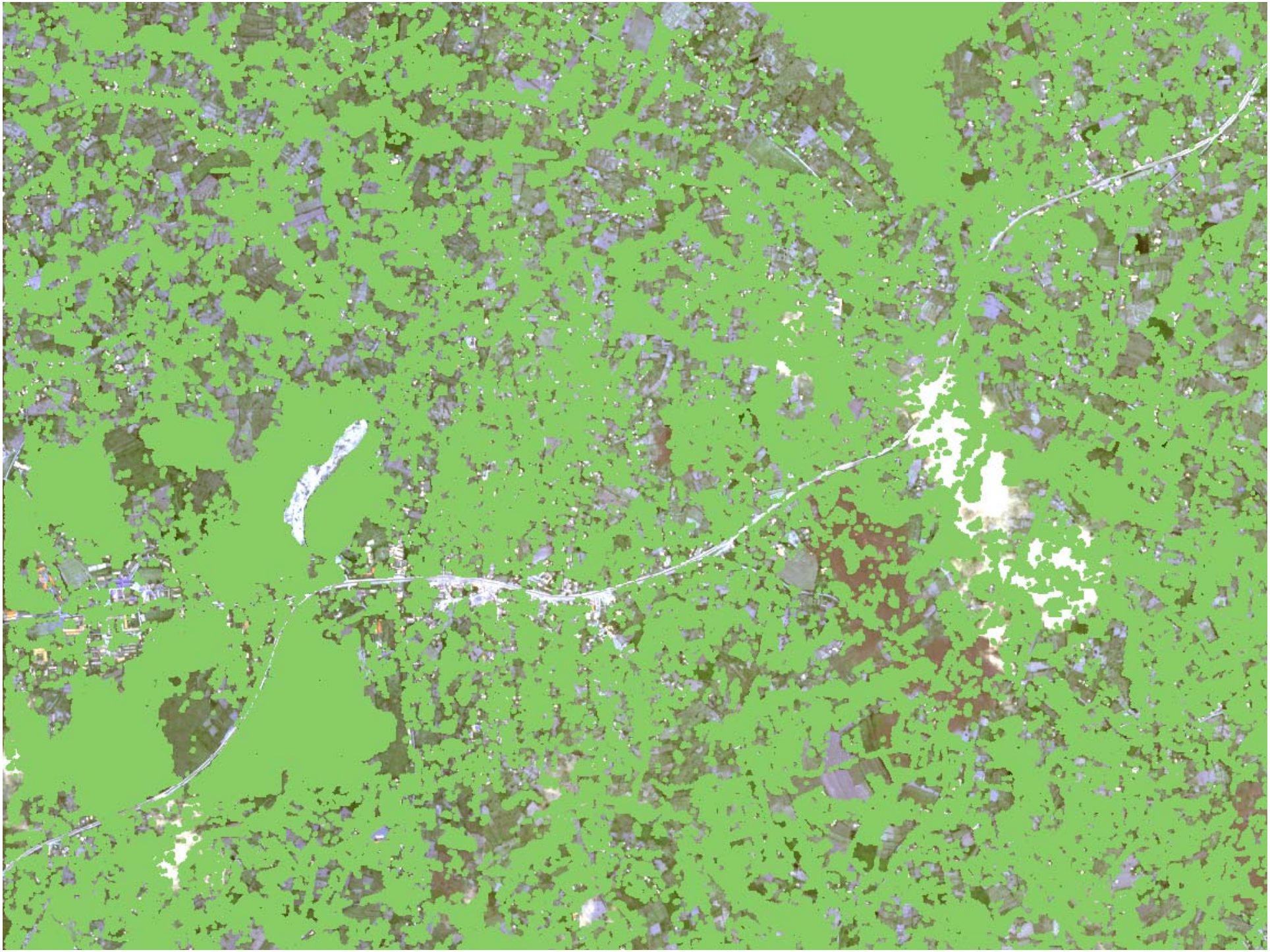


Carbon Map –circle regions (with Pan Image)

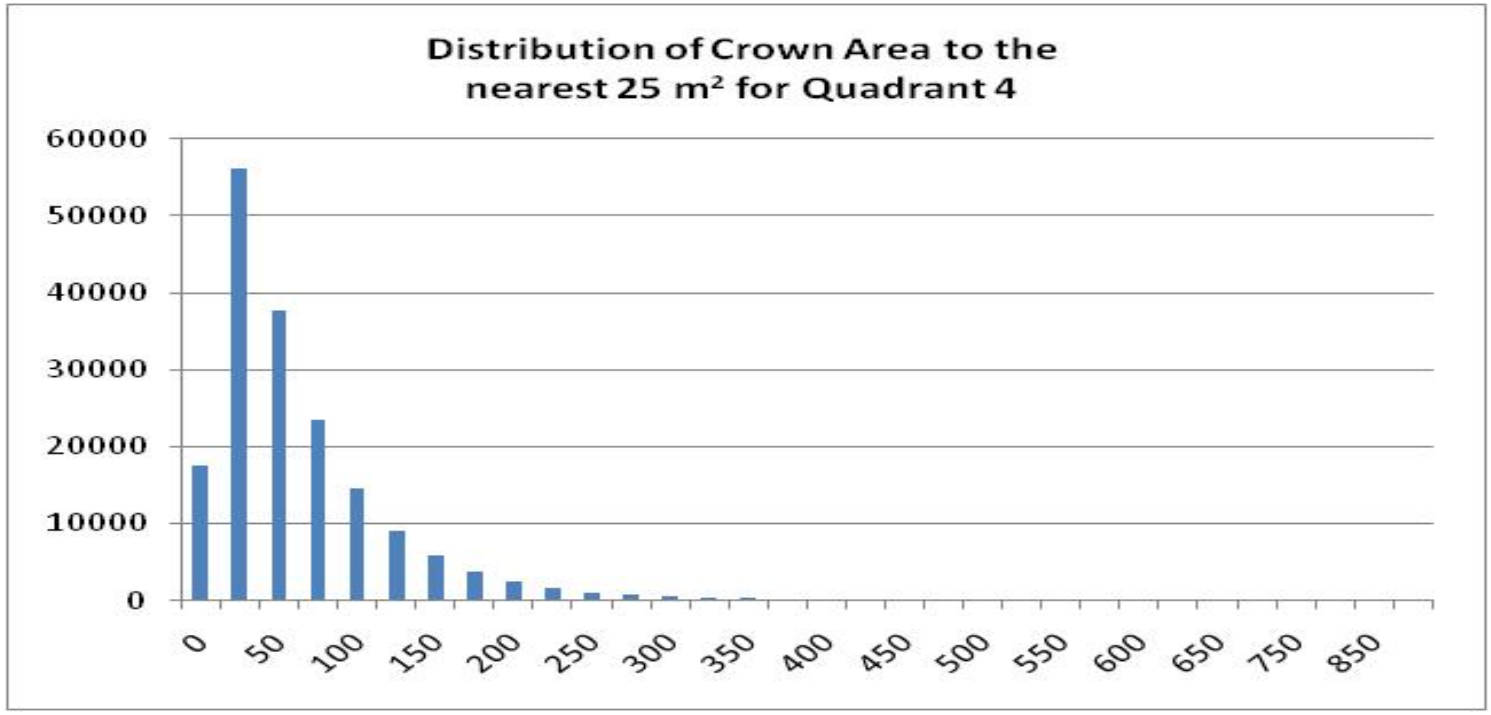


Forest-Ag landscape

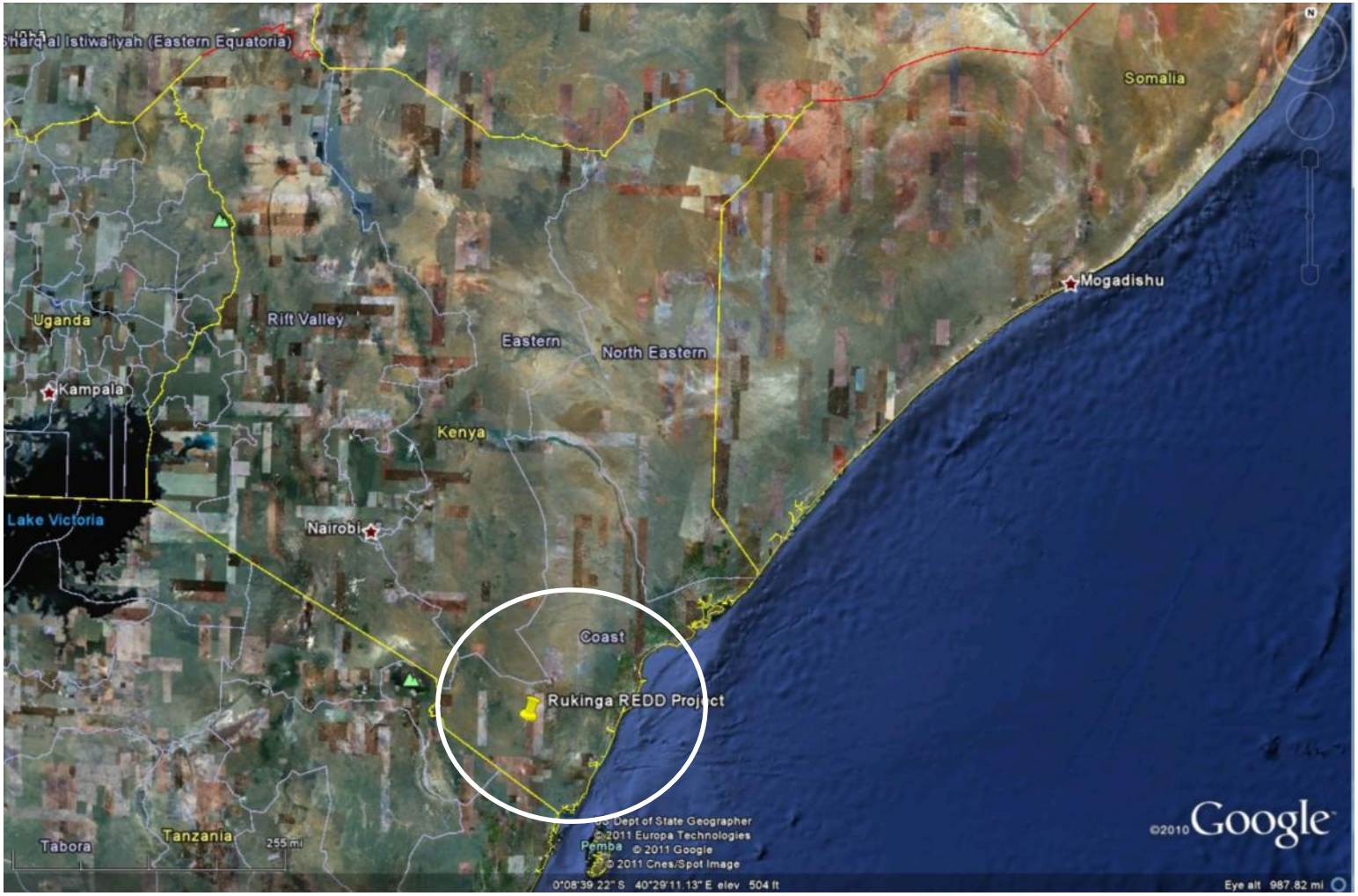
Carbon Map –circle regions (with Pan Image)



	Quadrant 2	Quadrant 4	Quadrant 3 partial
Land Cover	Forest and some Agriculture	Agriculture and some Forest	Agriculture
Area (ha)	3,795	3,795	1,131
Crowns Detected	326,853	175,210	41,804
Average Crown Area (m2)	66	63	50
Area of Crowns (ha)	2,157	1,099	210
Crown Area Index	57%	29%	19%
Total Carbon (t)	167,338	82,744	14,648
t Carbon / ha	44	22	13
Ave t C / tree	0.51	0.47	0.35

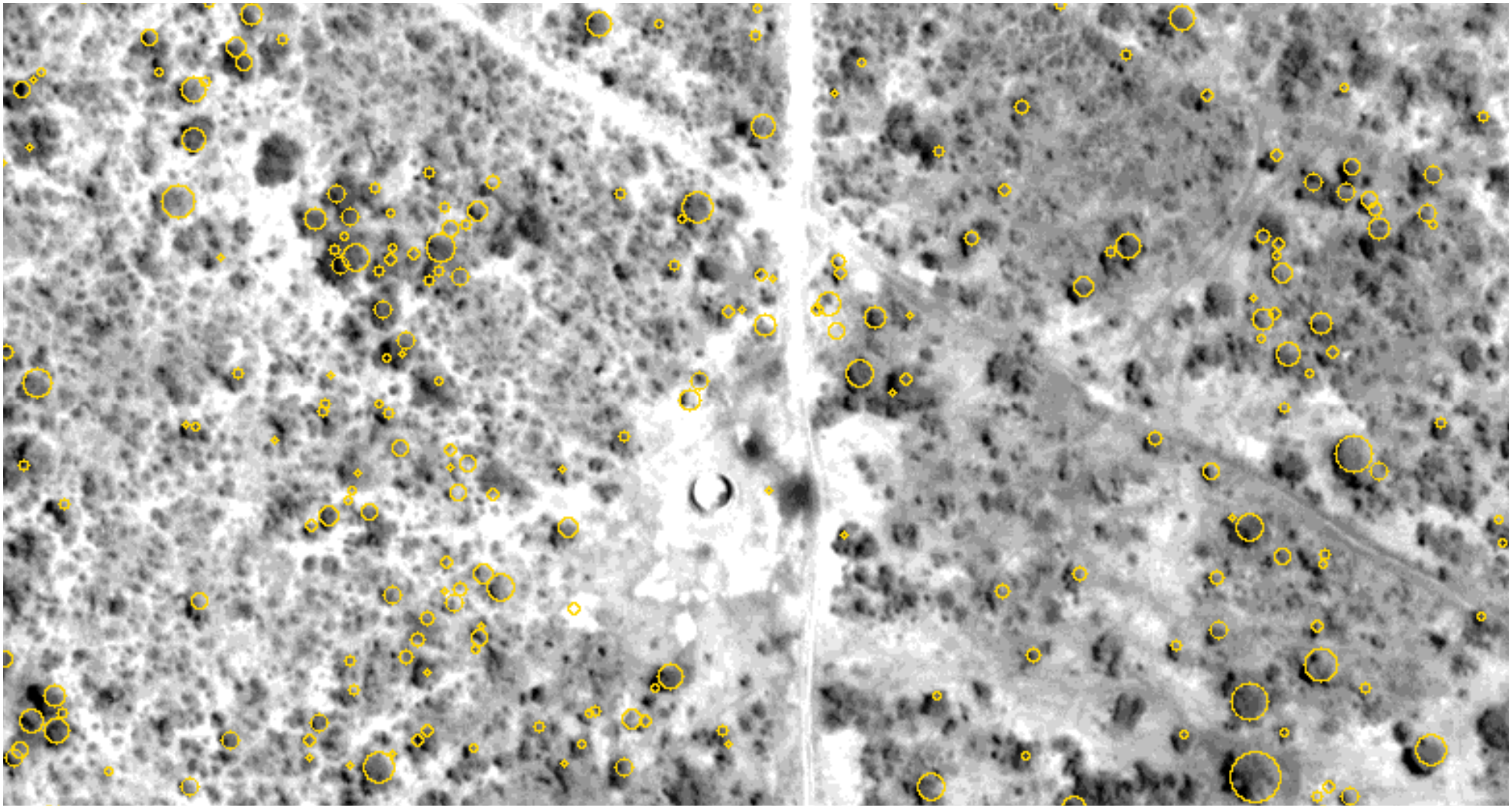


Measuring trees in dry forests and semi-arid shrub land in southeastern Kenya



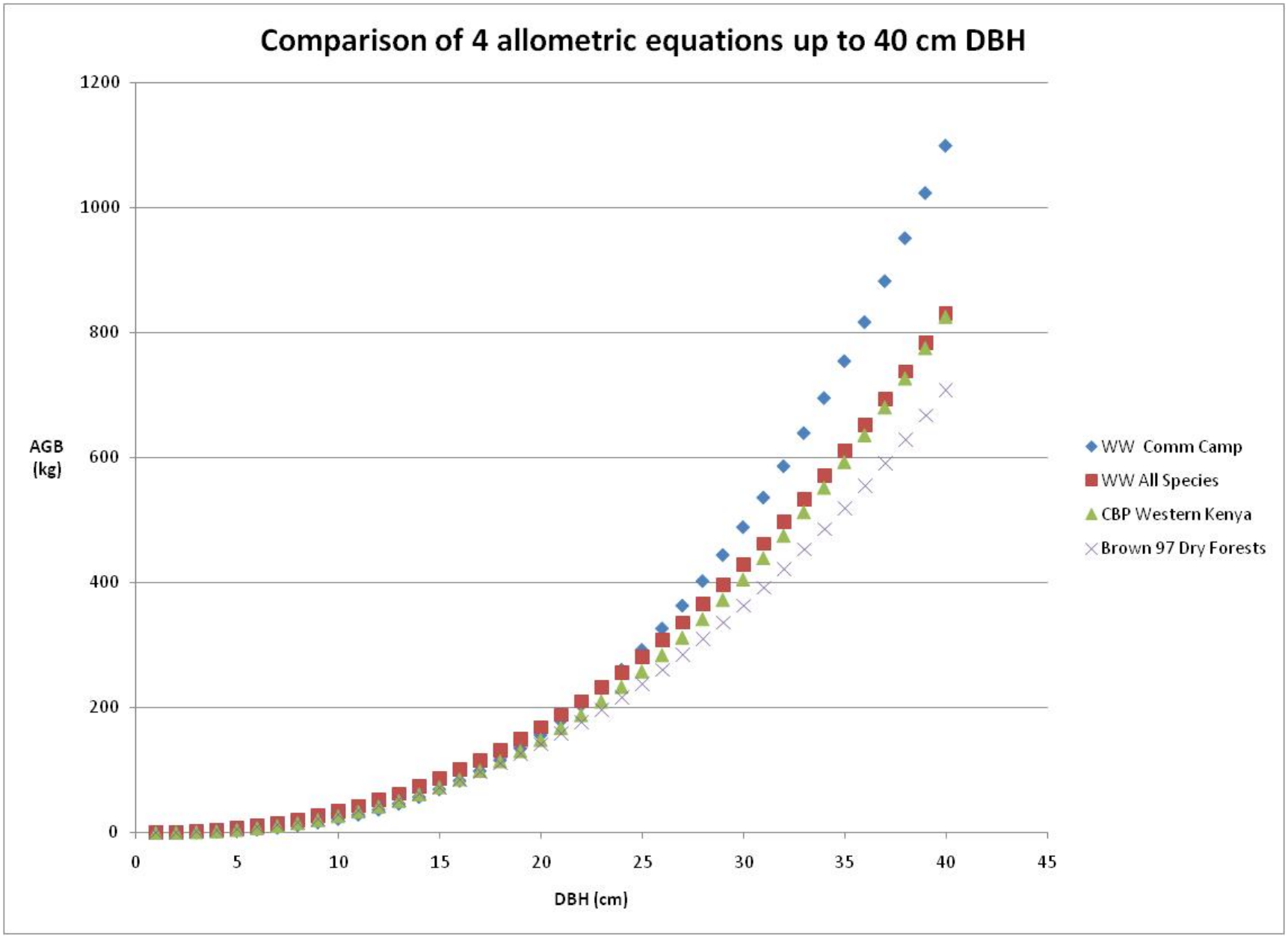
Rukinga Ranch Area of Interest: Latitude is 3°38'10.91"S; Longitude is 38°45'39.80"E

25 January 2011 Worldview 2 Satellite Image (water tank is 10 m diameter)

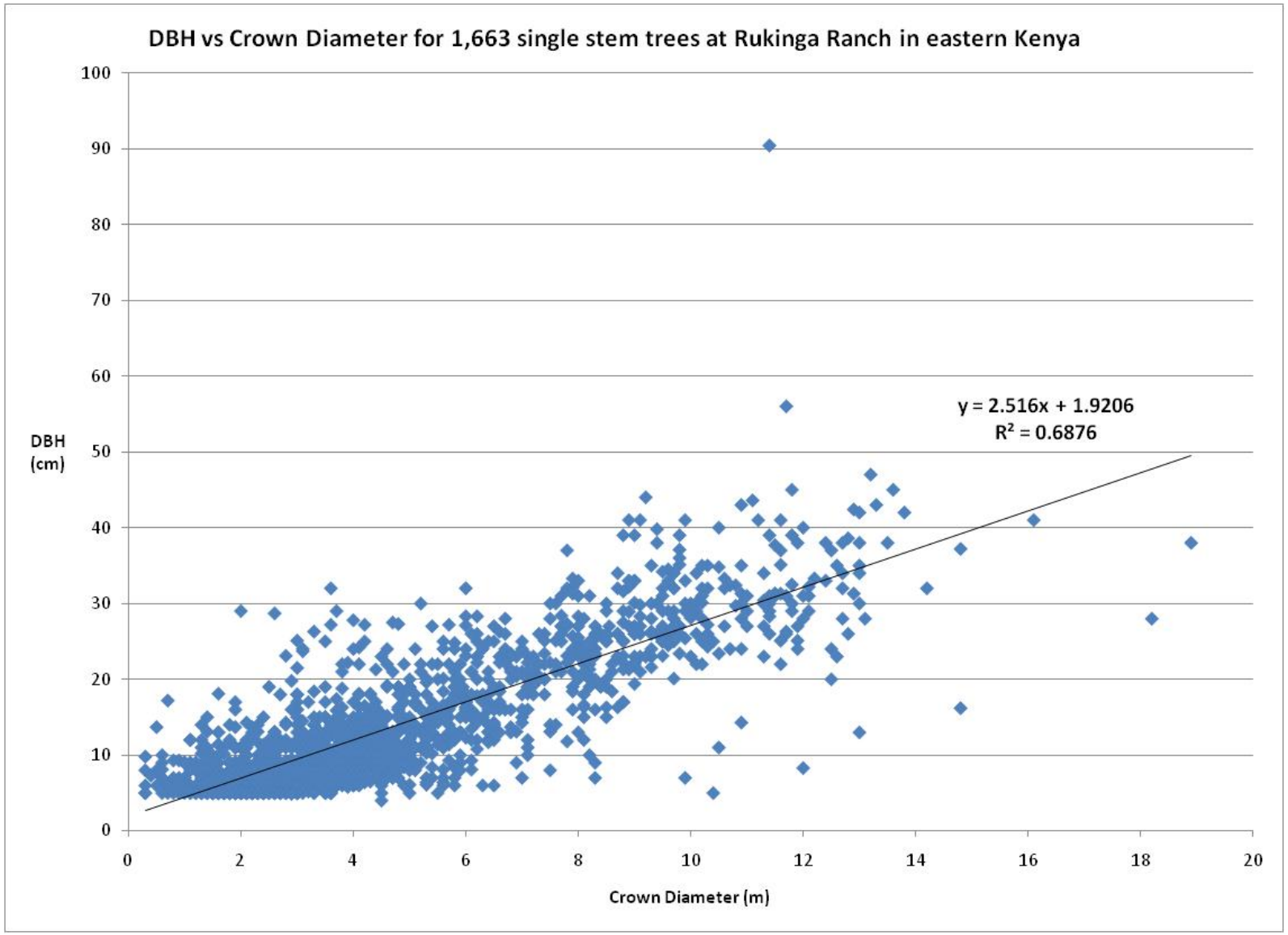


25 January 2011 Worldview 2 Satellite Image (water tank is 10 m diameter)

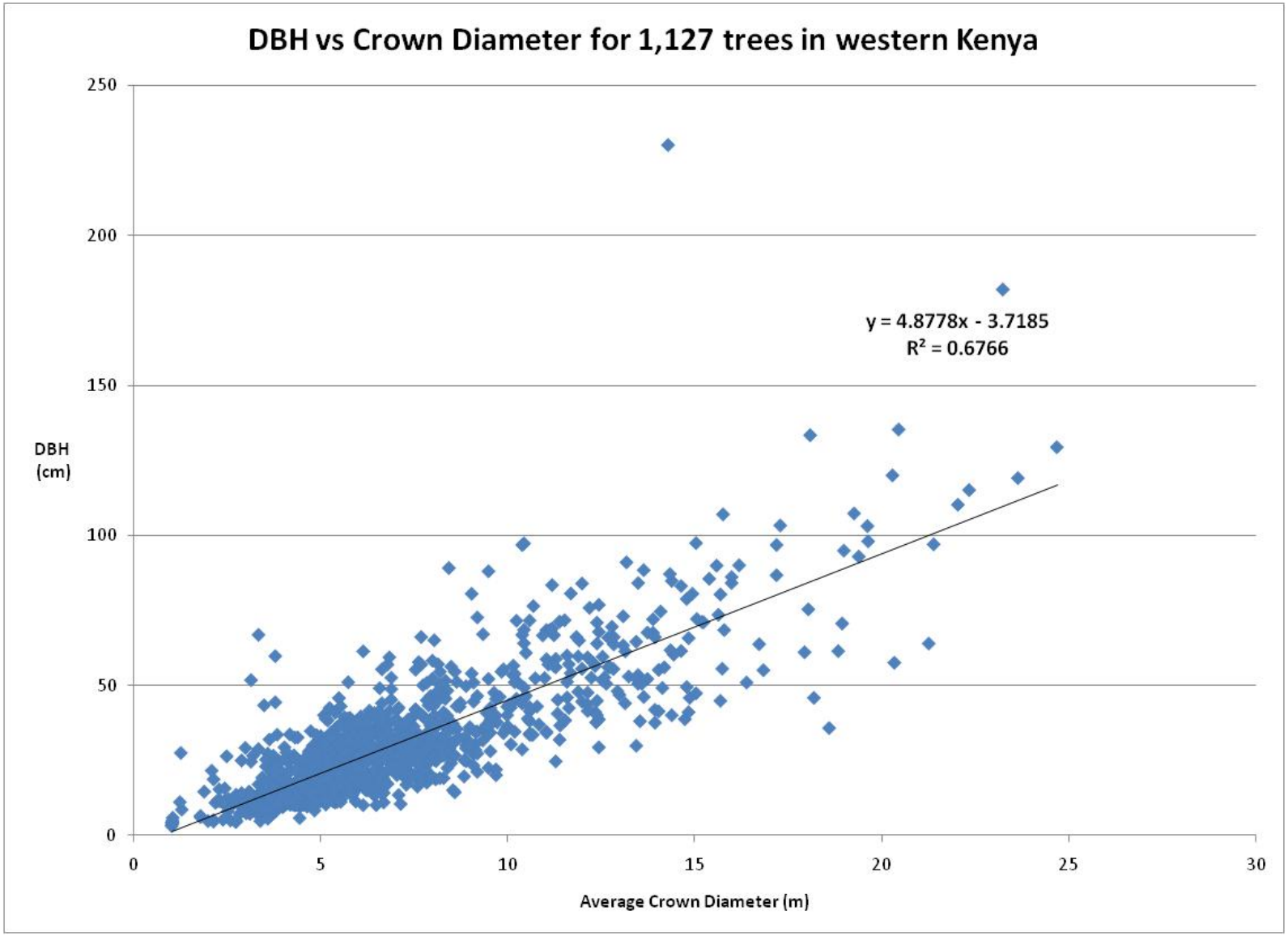
Wildlife Works General Equation comparable to Brown 97 Dry Forests and CBP



Relationship between DBH and crown diameter in Rukinga



Similar R^2 for trees in western Kenya



Wildlife Works Rukinga Ranch REDD Project

WW Plot ID	MSU Plot ID	AGB t C/ha	Total tCO2e/ha	Average DBH (cm)	Trees >10cm / plot	Canopy Cover (leaf OFF)
T17	222	18.5	95.0	21.6	31	28%
T16	223	4.4	22.5	13.8	22	22%
T14	224	1.5	7.9	12.2	11	5%
		8.2	**41.8**	17.3	64	18%

Stratum	n	Area (ha)	Trees Carbon Mean (tCO^2e / ha)	Shrubs Carbon Mean (tCO^2e / ha)	Herbaceous Carbon Mean (tCO^2e / ha)	Total Strata Mean (tCO^2e / ha)	Total Strata Carbon Stock (t C02-e)
ag active	12	713.7	67.98	23.08	2.88	172.24	122,925.5
dryland forest strata 1+2	26	6883.6	39.98	8.48	1.41	91.42	629,289.1
dryland forest strata 3	16	5651.1	40.75	2.45	0.99	81.01	457,776.5
dryland forest strata 4	11	2773.4	47.51	3.04	0.77	94.09	260,949.1
dryland forest strata 5	18	8133.4	46.23	2.30	2.14	92.89	755,520.4
dryland forest strata 6	23	4345.5	35.87	7.26	2.36	83.39	362,368.4
grassland	4	1610.9	3.05	1.40	4.85	17.06	27,474.3
montane forest	3	57.1	45.56	33.45	0.00	144.86	8,265.6
Total:		**30,168.66**					**2,624,568.9**

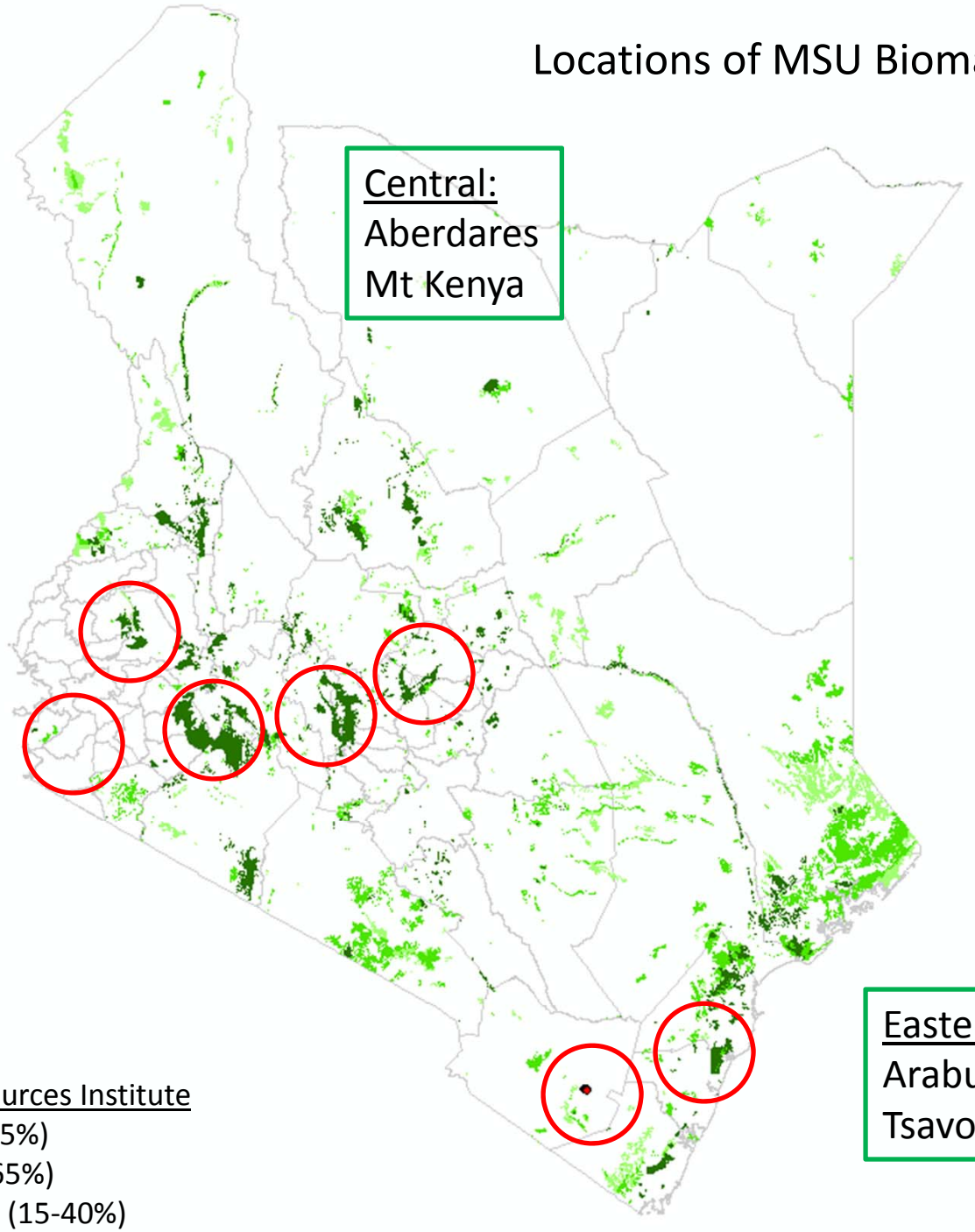
Table 11. Total carbon stocks for trees, shrubs and herbaceous material for Rukinga Ranch

Growth Rates of Trees at Rukinga Ranch

- WW inventory in March of 2009
- MSU inventory of 3 WW plots (14,16,17) in June of 2011

5 cm DBH Class	Tree Count	2 year DBH Growth (cm)	Annual DBH Growth (cm)	2 Year Percent Growth	Annual Percent Growth
5	2	4.1	2.0	75.0%	37.5%
10	9	0.5	0.3	4.8%	2.4%
15	16	1.3	0.7	9.3%	4.6%
20	7	1.8	0.9	8.9%	4.5%
25	7	2.6	1.3	10.8%	5.4%
30	4	2.8	1.4	9.7%	4.8%
35	1	1.9	0.9	5.6%	2.8%
	46	**1.7**	**1.1**	**11.4%**	**8.9%**

Locations of MSU Biomass Sampling



Central:
Aberdares
Mt Kenya

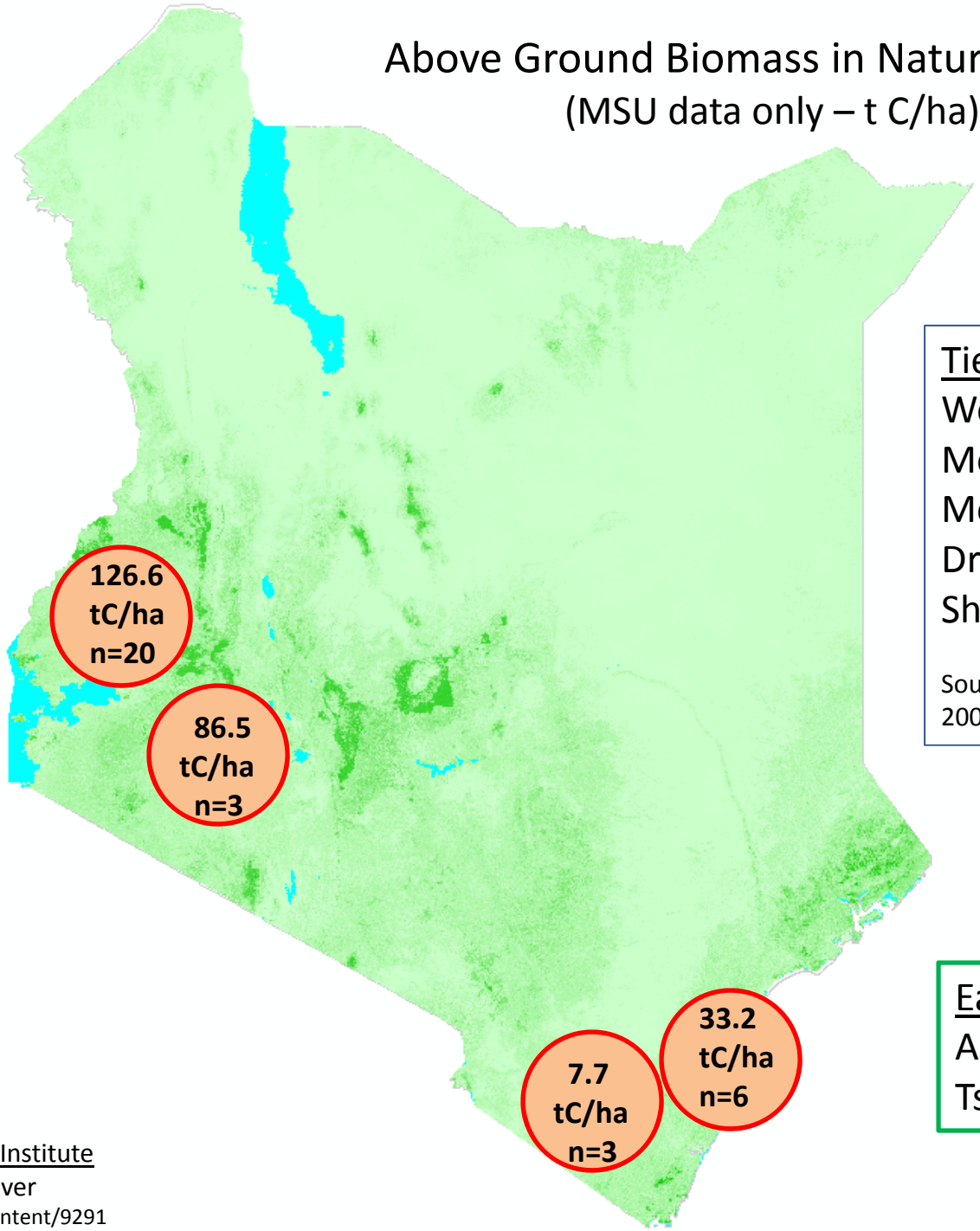
Western:
Kakamega
Mau
Lambwe

Eastern:
Arabuko-Sokoke
Tsavo

GIS Data – World Resources Institute

- Closed Forest (>65%)
- Open forest (40-65%)
- Very Open Forest (15-40%)

Above Ground Biomass in Natural Forests
(MSU data only – t C/ha)



Western:
Kakamega
Mau

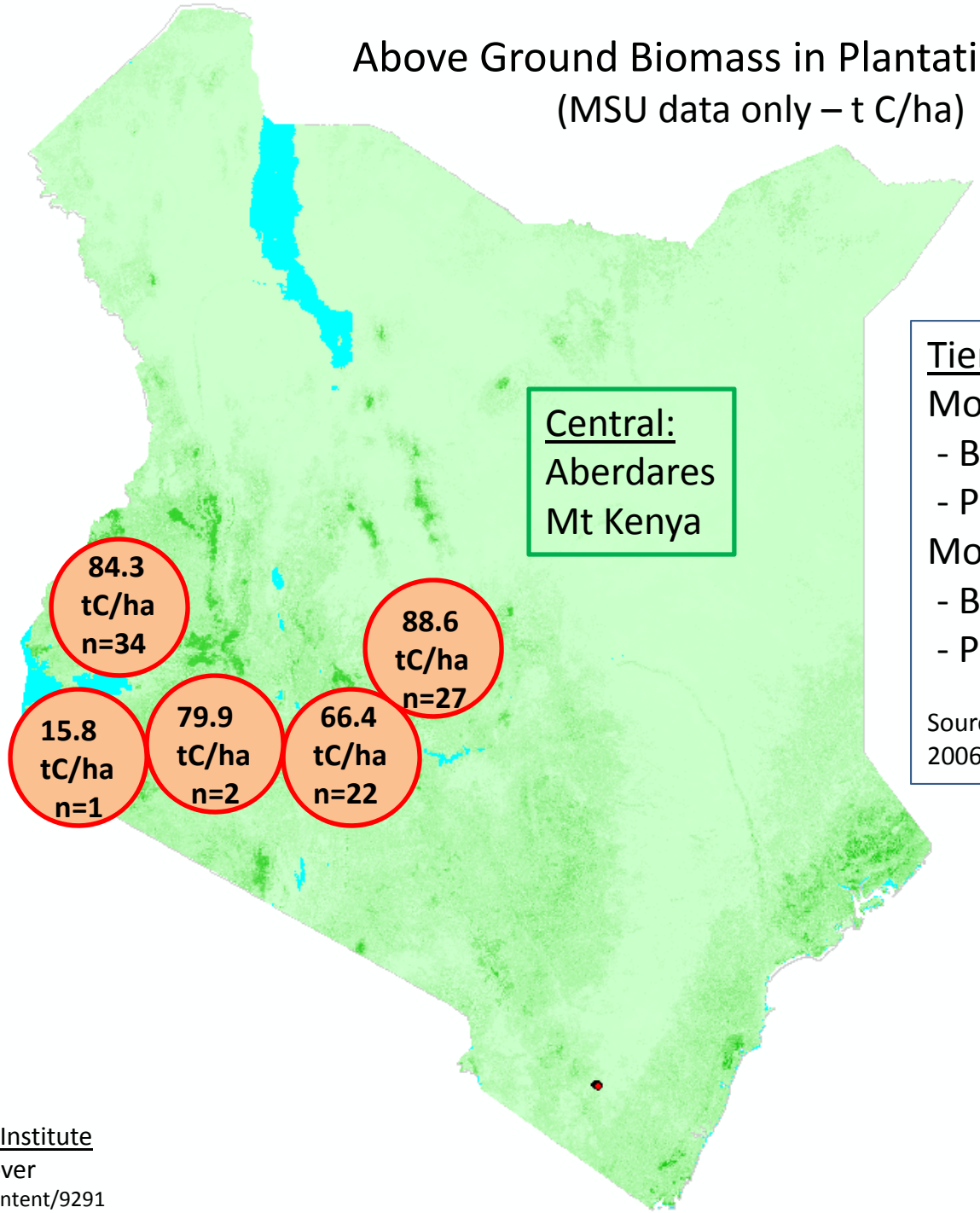
Tier 1 AGB	tC/ha
Wet	146
Moist	122
Montane	89
Dry	56
Shrub	33

Source: Table 4.7 in Vol 4, 2006 IPCC Guidelines

Eastern:
Arabuko-Sokoke
Tsavo

GIS Data – World Resources Institute
MODIS Percent Tree Cover
http://www.wri.org/publication/content/9291

Above Ground Biomass in Plantation Forests
(MSU data only – t C/ha)



Western:
Kakamega
Mau
Lambwe

Central:
Aberdares
Mt Kenya

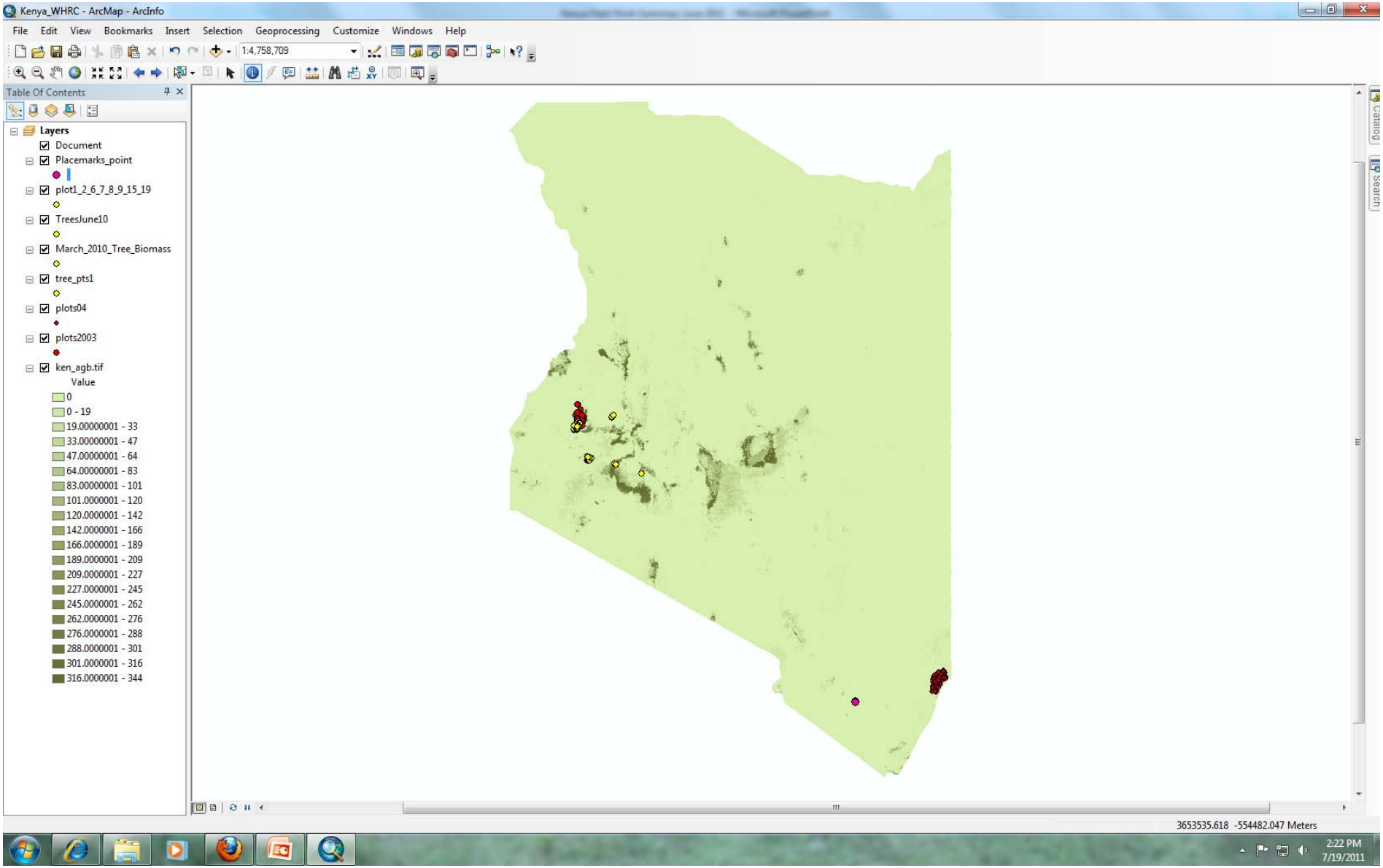
Tier 1 AGB	tC/ha
Moist >20yrs	
- Broadleaf	71
- Pinus	56
Montane >20yrs	
- Broadleaf	71
- Pinus	47

Source: Table 4.8 in Vol 4, 2006 IPCC Guidelines

GIS Data – World Resources Institute
MODIS Percent Tree Cover
http://www.wri.org/publication/content/9291

WHRC Carbon Map:
Vast areas of Kenya are greater than Zero t/ha AGB

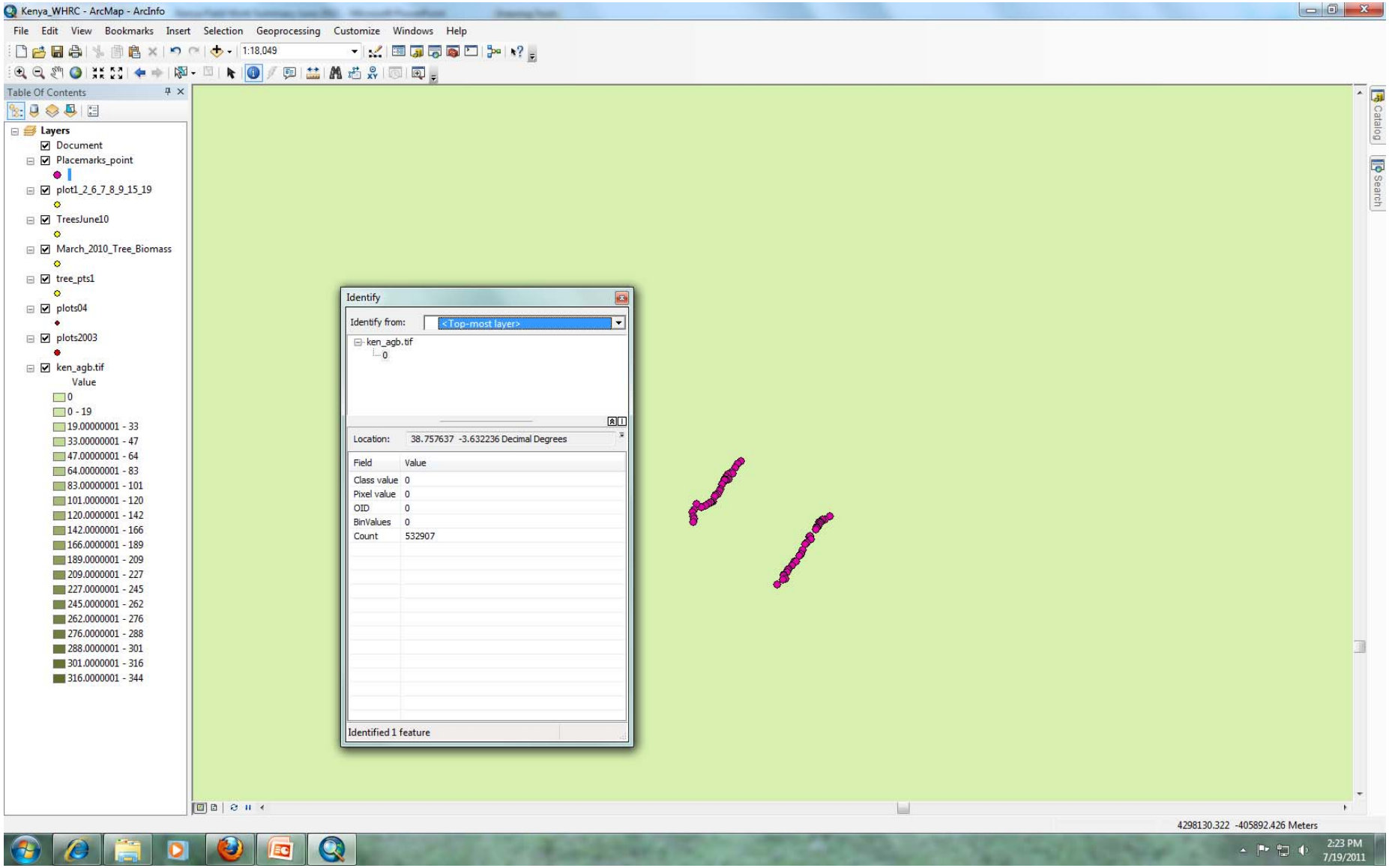
(Baccini et al. 2008. A first map of tropical Africa's above-ground biomass derived from satellite imagery.)



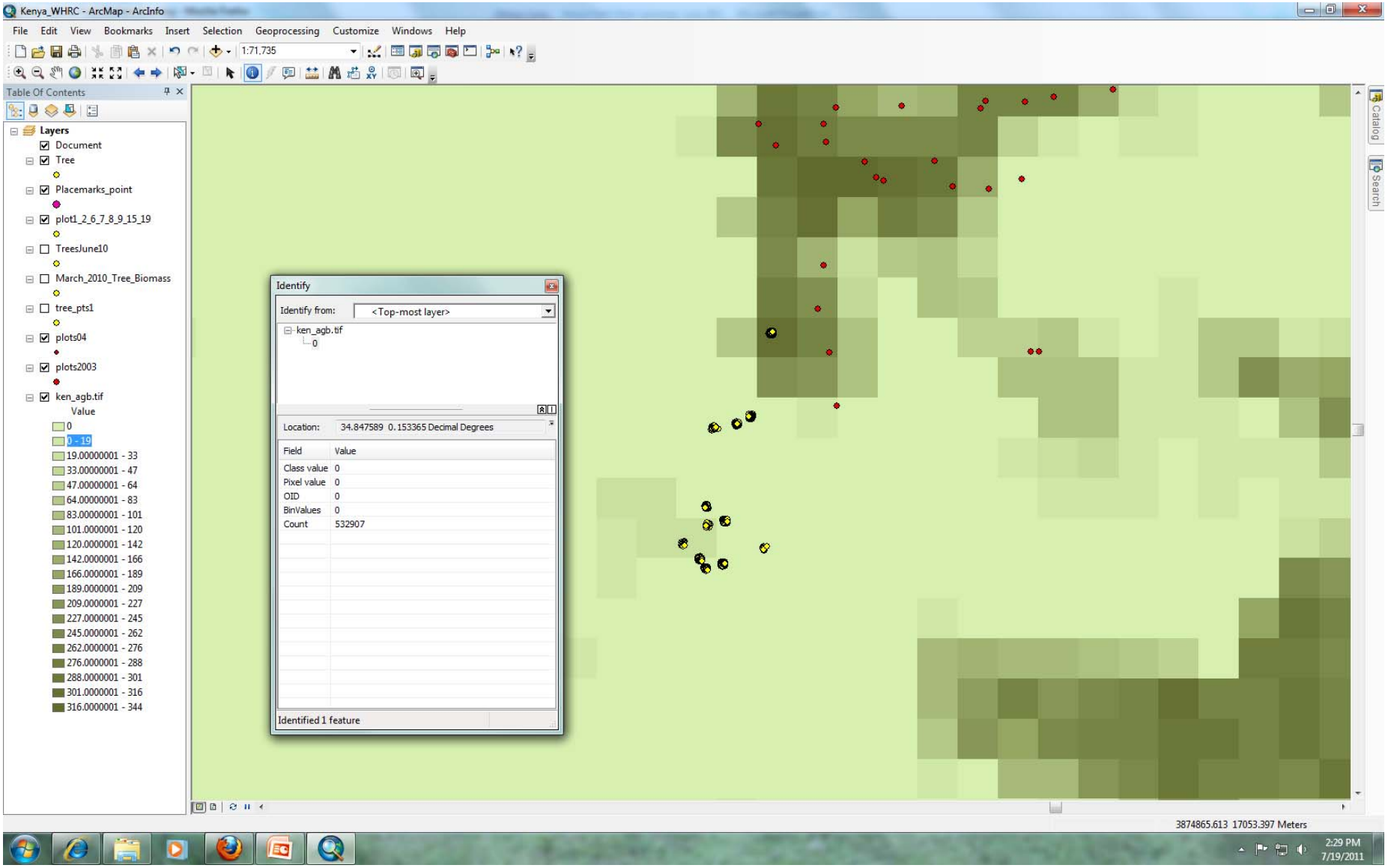
Rukinga Ranch Dry Forests ≠ 0 t/ha AGB

Rukinga Ranch = 15.8 t/ha AGB

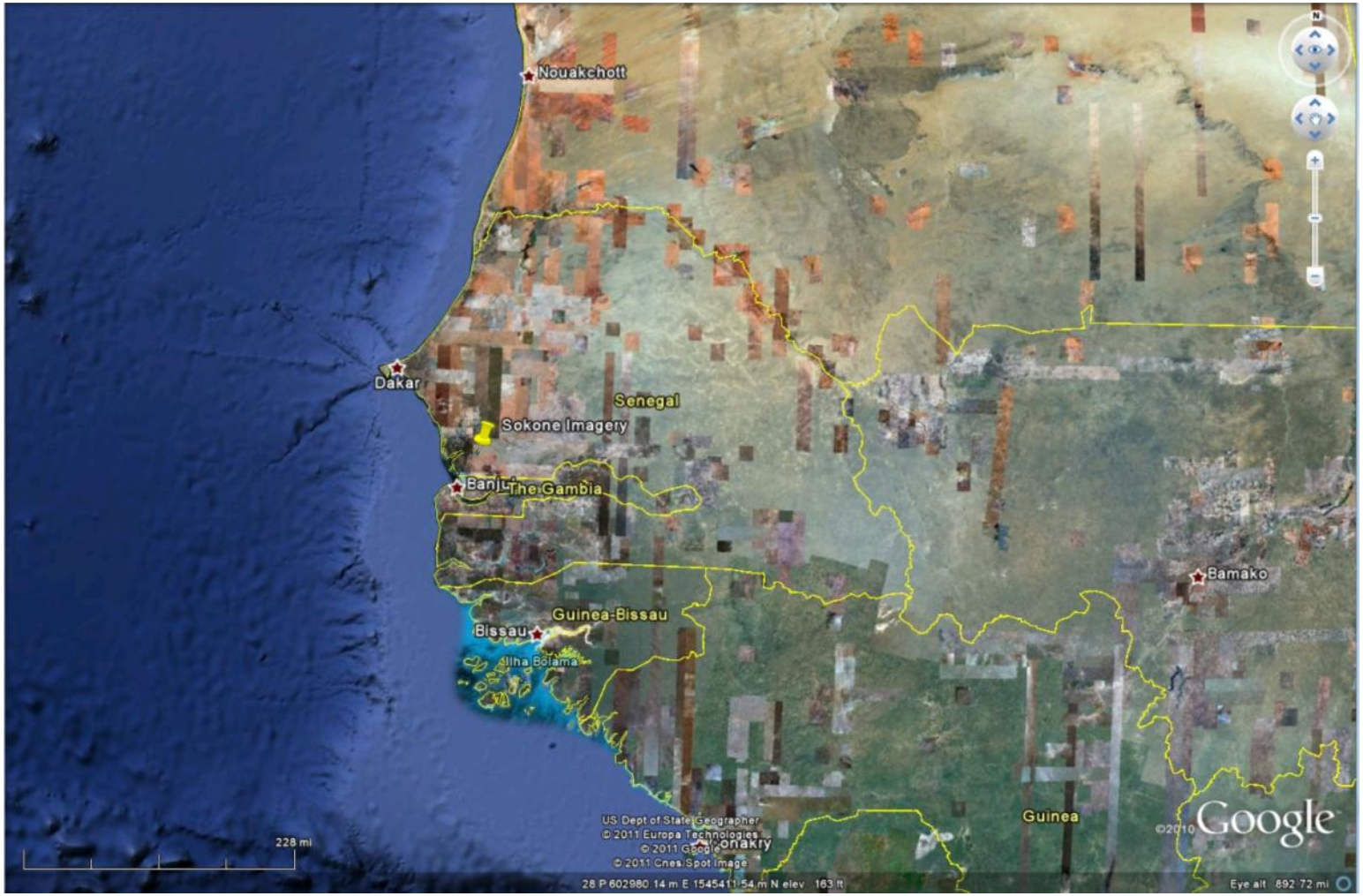
(238,668 tonnes C in AGB in 30,168 hectares – 7.9 tC/ha)



Agriculture in Western Kenya ≠ 0 t/ha
Mean of 9 one ha non-forest plots = 33.4 t/ha AGB

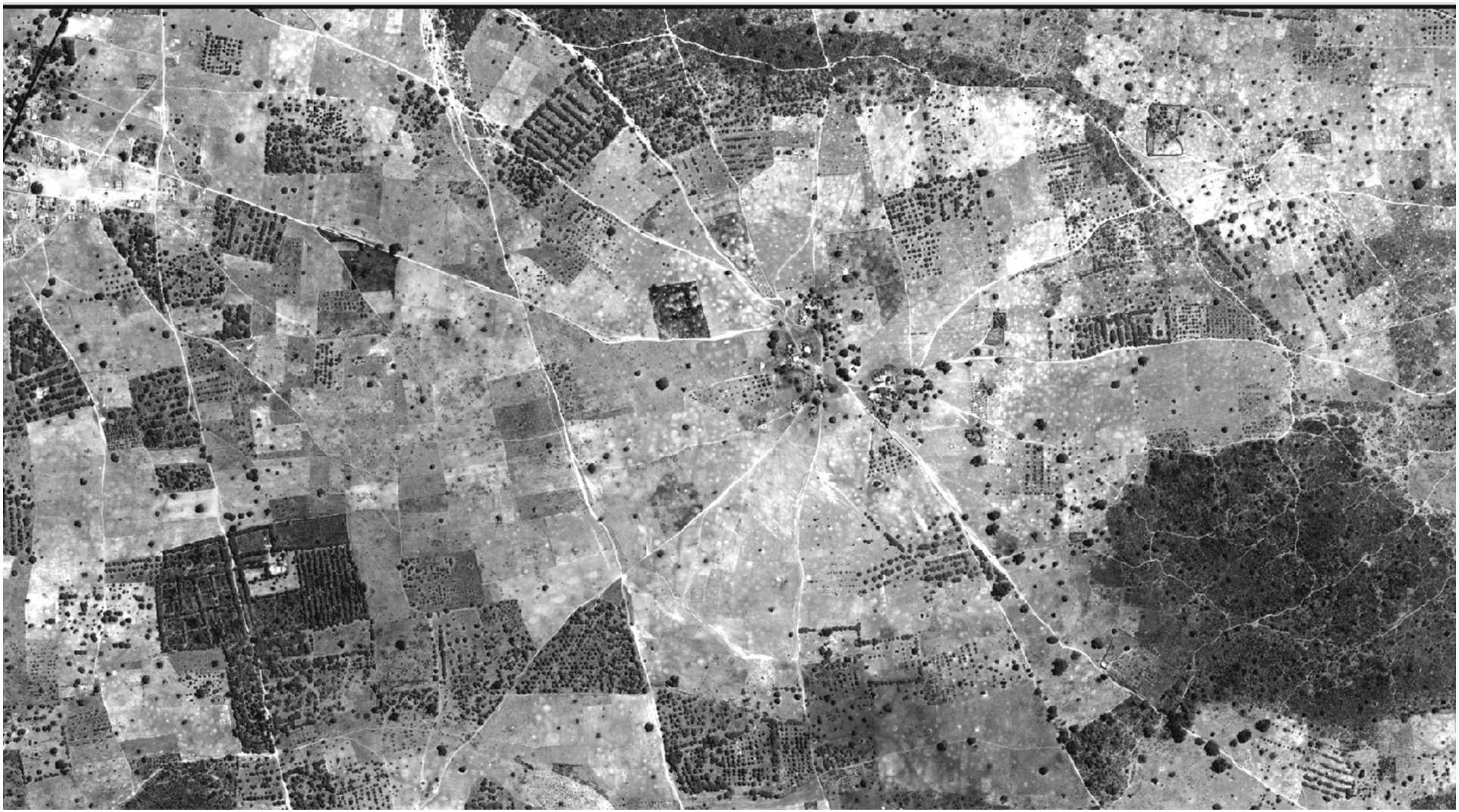


Detecting and Measuring Trees Outside Forests in Senegal



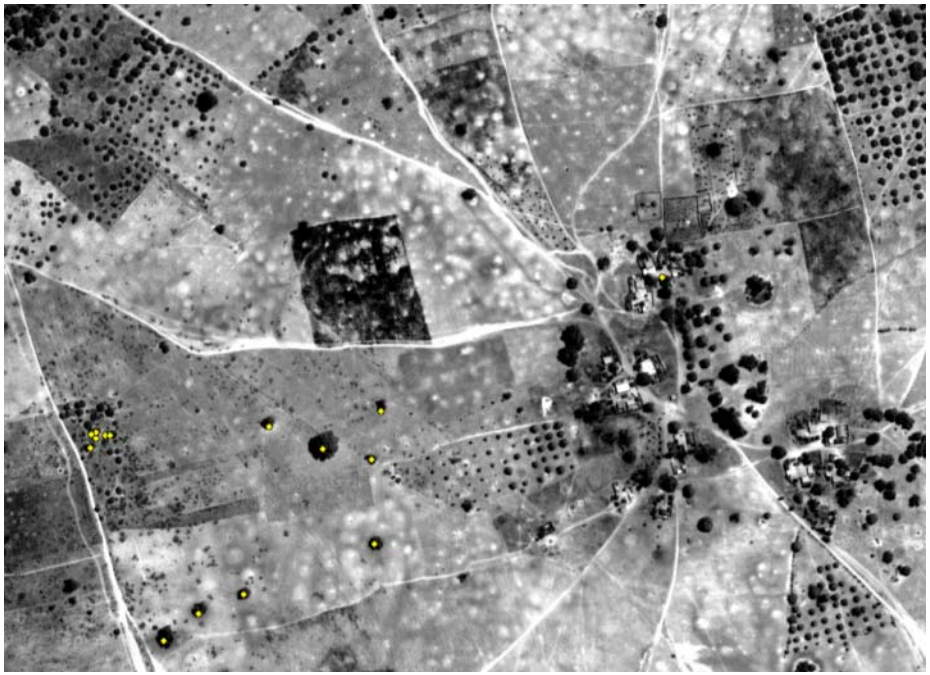
Sokone, Senegal Area of Interest: Latitude is 13° 50.7’ N; Longitude is 16° 21.1’ W

28 October 2010 - Worldview 2 Satellite Imagery – 0.5m PAN resolution - 3.4 x 1.8 km subset

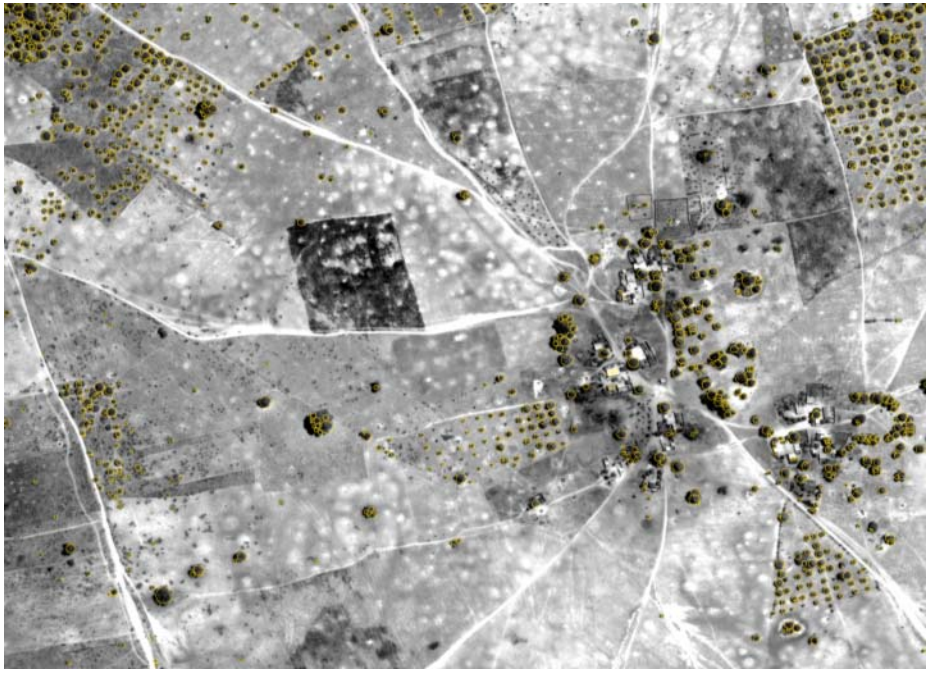


Semi-Automated Crown Detection of Individual Trees

(Image available at http://www.landsat.org/~kasten/senegal/senegal-circles.png)



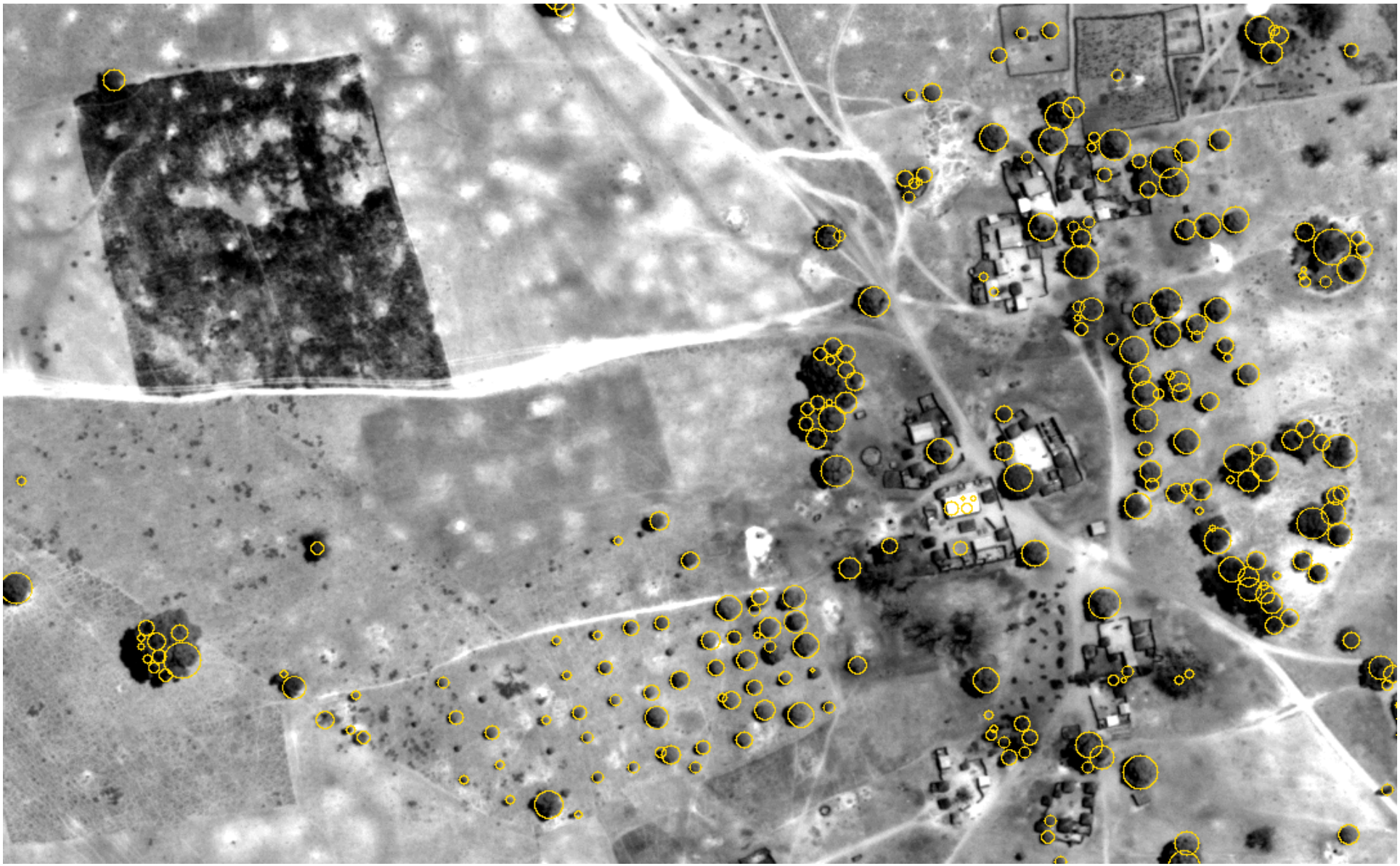
Yellow dots identify trees measured in June 2011 fieldwork.



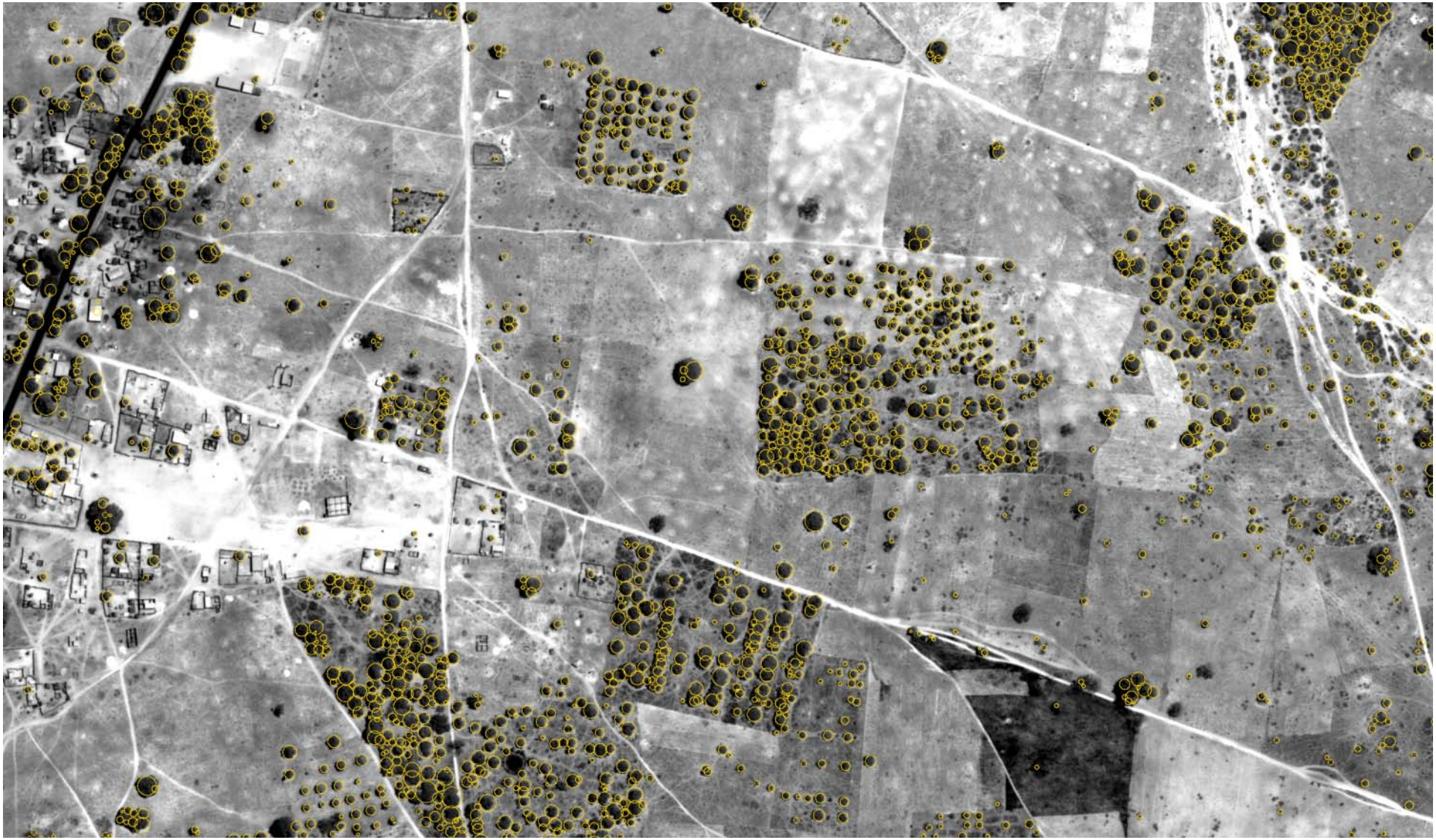
Semi-automated crown detection and measurement.

Global Observatory for Ecosystem Services


Carbon Benefits Project:
Modelling,Measurement and Monitoring



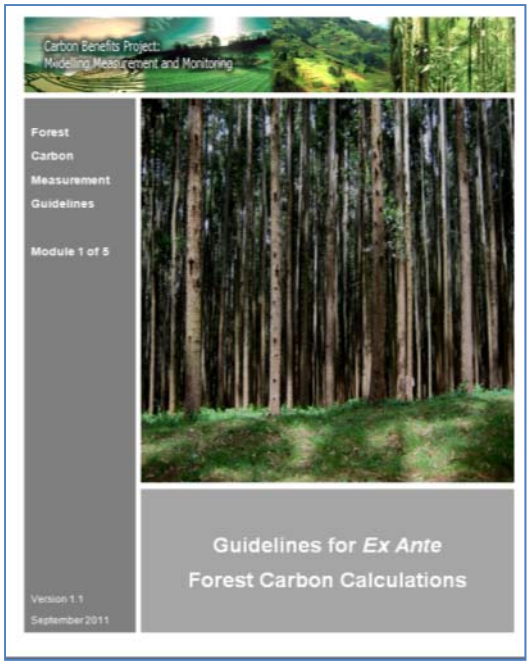

Carbon Benefits Project:
Modelling,Measurement and Monitoring

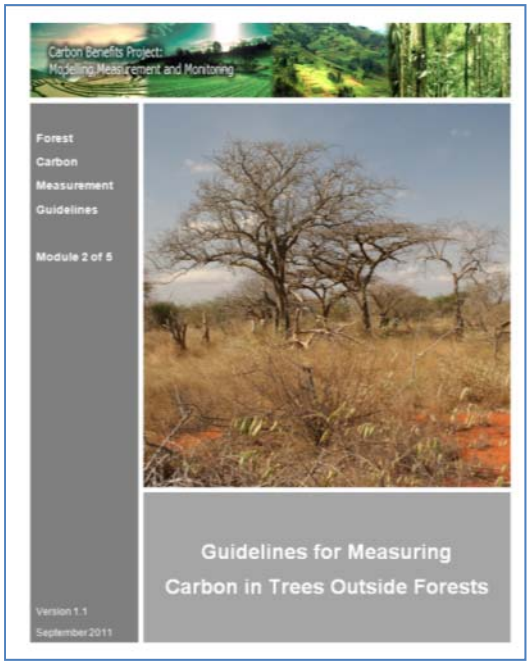


Measuring trees in litchi orchards in Vietnam

Area of Interest: Latitude is 21°23‘03“N; Longitude is 106°36‘10"E


Carbon Benefits Project:
Modelling,Measurement and Monitoring





Version 1.1 available online at http://www.goes.msu.edu/cbp/above-ground.html