Forest transition in mountain area's: topographic correction, large scale mapping and modeling of ecosystem services

Anton Van Rompaey[1], Veerle Vanacker[2], Vincent Balthazar[2], Eric Lambin[2], Jaclyn Hall[2], Patrick Hostert[3], Patrick Griffiths[3], Steven Vanonckelen[1], Armando Molina[1], Derek Bruggeman[2], Marie Guns[2]

1: Geography Research Group, Dep. Earth and Environmental Sciences, KULeuven

2: Department of Geography, Earth and Life Institute , UCLouvain

3: Geographisches Institut, Humbolt-Universität zu Berlin

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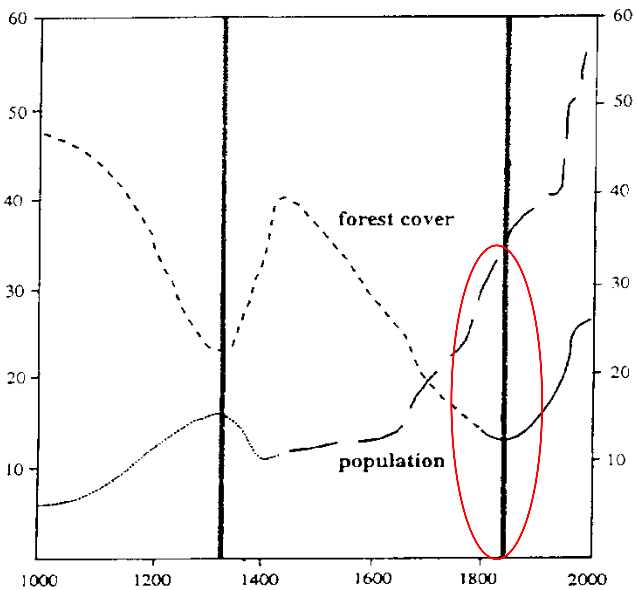
What is this research project about?

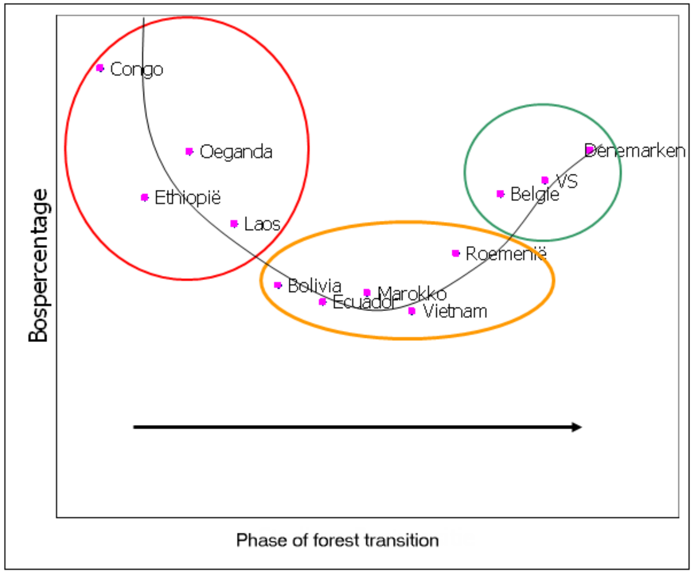
- Forest transition
- Mountain areas
- Topographic correction
- Large scale mapping
- Ecosystem service assessment

Forest transition

- Transition from a phase of net deforestation to a phase of net afforestation?
- For a region: pathway through time driven by
  - Economic development -> off-farm jobs -> land abandonment (+ forest plantations)
  - Land degradation → lowering of yields -> land abandonment (+ forest plantations)



Mather, 1995: FT in France



Regional patterns of FT

Mountain areas

- Forest transitions typically occur in mountain areas

DETECTION OF FOREST TRANSITIONS

- Remote sensing seems privileged tool but many difficulties
  - Transition are of **subtle**: gradual forest degradation in stead of clear cuts
  - Typically **patchy landscape** with various phases of degradation, natural regrowth, plantations, …
  - Understanding of mechanisms only possible with **large scale mapping**
  - Mountain environment: atmospheric conditions, illumination effects
  - Impact on **ecosystem services** is important (= both cause and consequence of FT)

RESEARCH QUESTIONS

- To what extent is it possible to detect forest transitions and their effect on ecosystem services?
  - Atmospheric and topographic correction procedures exist but was is their **added value** for FT-mapping
  - Most complex procedure not always appropriate because of **difficulty to automate**
  - Development of **automated preprocessing chains** and large scale mapping procedures
  - **Monitoring ecosystem services** in FT-landscapes
- 3 study sites
  - Romanian Carpathians
  - Buthan Himalayas
  - Ecuadorian Andes

ADDED VALUE OF TOPOGRAPHIC AND ATMOSPHERIC CORRECTIONS?

	TOPOGRAPHIC CORRECTIONS					
ATMOS-PHERIC CORRECTIONS		No Corr	Band ratioing	Cosine corr	C-corr	Minnaert corr
	No Corr					
	Dark object subtraction					
	Physical transfer function					

SOME FORMULAS

- DN values to **at-satellite radiances**
- Calculation of **corrected path radiance $L_{t,\lambda}$:**

AC	Equation	Reference
DOS	$L_{t,\lambda} = L_{s,\lambda} - L_p$	Chavez, 1996
TF	$L_{t,\lambda} = \dfrac{L_{s,\lambda} - L_p}{0.5(1+T_{r,\lambda})T_{r,\lambda}T_{w,\lambda}^2}$ $T_{r,\lambda} = \exp\left[-\dfrac{P}{P_0}M\dfrac{1}{115.6406\lambda^4 - 1.335\lambda^2}\right]$ $M = \dfrac{1}{\cos\theta_s + 0.15(93.885-\theta_s)^{-1.253}}$ $T_{w,\lambda} = \exp\left[-\dfrac{0.2385a_wWM}{(1+20.07a_wWM)^{0.45}}\right]$	Kobayashi and Sanga-Ngoie, 2008

$L_{s,\lambda}$ is the uncorrected radiance value of the image and L_p represents the minimum radiance value of the image, calculated as the 1th percentile. $T_{r,\lambda}$ is the Rayleigh scattering transmittance function, including the sea-level atmospheric pressure (P_0; in mbar), the ambient atmospheric pressure (P; in mbar) and the band wavelength (λ). M is the relative air mass and ϑ_s is the solar zenith angle (in degrees). $T_{w,\lambda}$ is the water-vapor transmittance function, calculated with the precipitable water vapor (W; in cm), relative air mass (M) and water-vapor absorption coefficients (a_w).

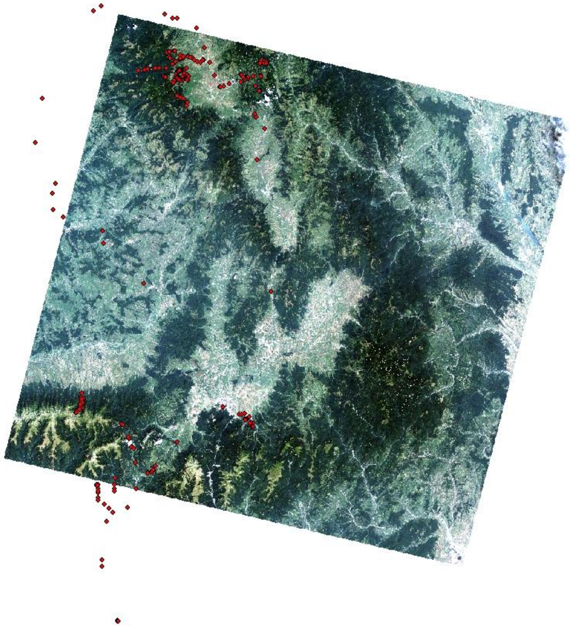
Some formulas

- Conversion to observed **reflectance on an inclined terrain $\rho_{t,\lambda}$**
- Conversion to **normalized reflectance of a horizontal surface $\rho_{H,\lambda}$**

TC	Equation	Reference
Band ratio	$\rho_{H,\lambda}^{(i)} = \frac{\rho_{T,\lambda}^{(i)}}{\frac{1}{N}\sum_{j=1}^{N}\rho_{T,\lambda}^{(j)}}$	Ono et al., 2007
Cosine	$\rho_{H,\lambda} = \rho_{T,\lambda}\frac{\cos\theta_s}{\cos\beta}$	Teillet et al., 1982
PBM	$\rho_{H,\lambda} = \rho_{T,\lambda}\frac{\cos\ \theta_n}{(\cos\ \theta_n\ \cos\beta)^{k,\lambda}}$	Lu et al., 2008
PBC	$\rho_{H,\lambda} = \rho_{T,\lambda}\frac{\cos\theta_s + C_\lambda h_0^{-1}}{\cos\beta + C_\lambda h_0^{-1}h}$	Kobayashi and Sanga-Ngoie, 2008

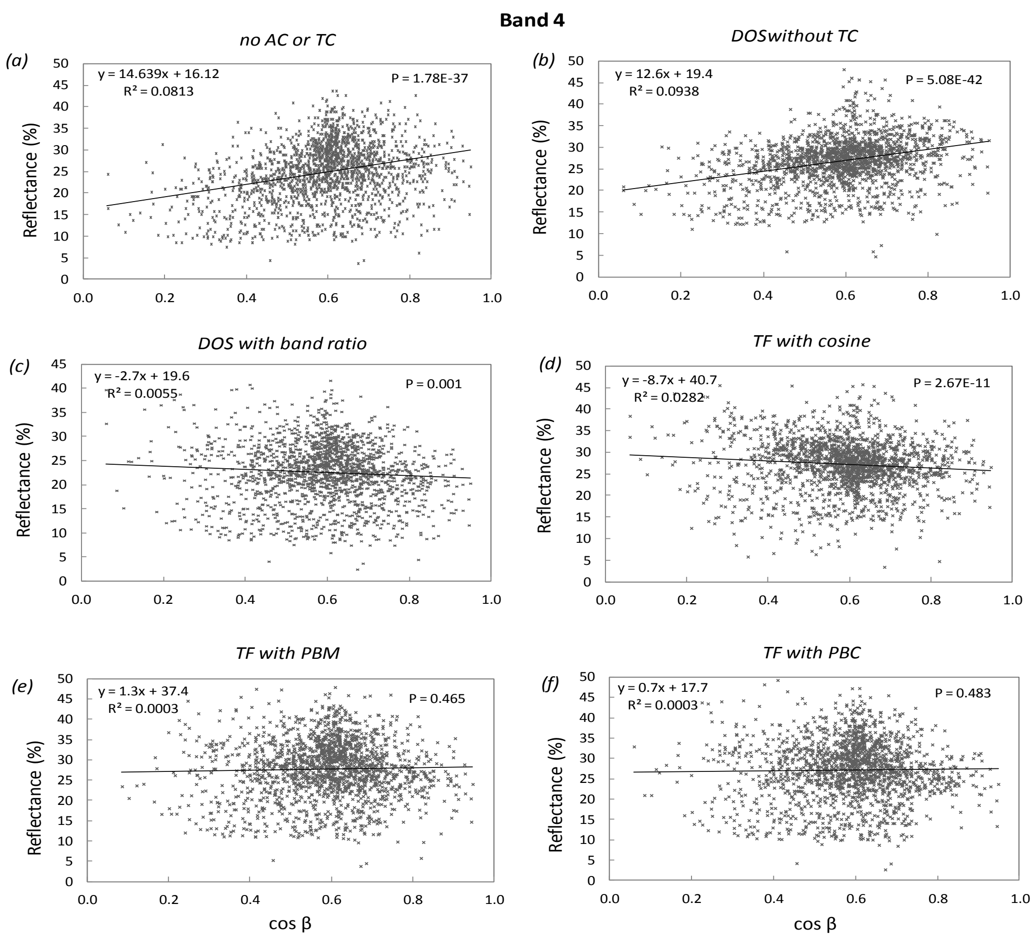
ϑ_s is the solar zenith angle and β is the incident solar angle, $\cos\beta = \cos\vartheta_s \cos\vartheta_n + \sin\vartheta_s \sin\vartheta_n \cos(\phi_t - \phi_a)$, ϑ_n is the slope angle of the terrain and $k_{,\lambda}$ is the slope of the regression between $x = \log(\cos\vartheta_n \cos\beta)$ and $y = \log(\rho_{T,\lambda} \cos\vartheta_n)$. Parameter C_λ is the quotient of intercept (b_λ) and slope (m_λ) of the regression line between x and y, the h-factor represents a topographic parameter derived from the SRTM ($h = 1-\vartheta_n/\pi$) and the h_0-factor an empirical parameter derived from the regression line between reflectance and $\cos\beta$ ($h_0 = (\pi + 2\vartheta_s)/2\pi$).

APPLICATION AND EVALUATION OF EFFICIENCY



Statistical analysis

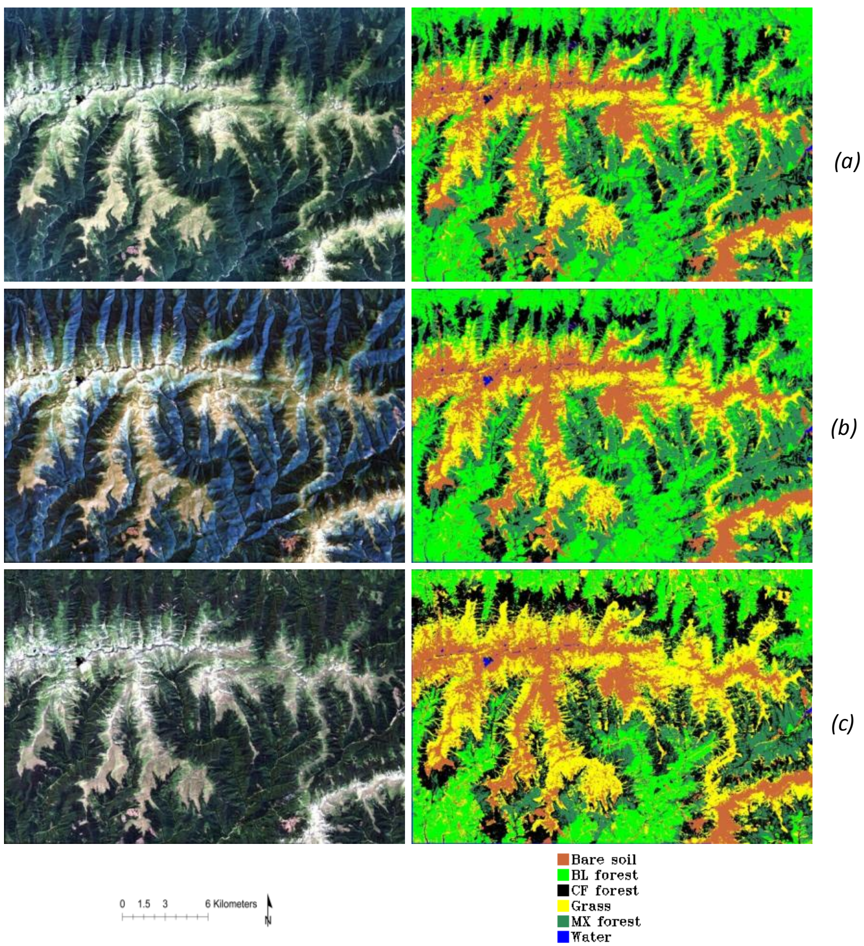
- Efficient methods reduce the reflectance values between shaded and illuminated slope segments?



(a) no AC or TC;
(b) DOS without TC;
(c) DOS with band ratio;
(d) TF with cosine;
(e) TF with PBM;
(f) TF with PBC.

STATISTICAL ANALYSIS

- Efficient preprocessing results in better land cover maps?



(a) no AC or TC;
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STATISTICAL ANALYSIS

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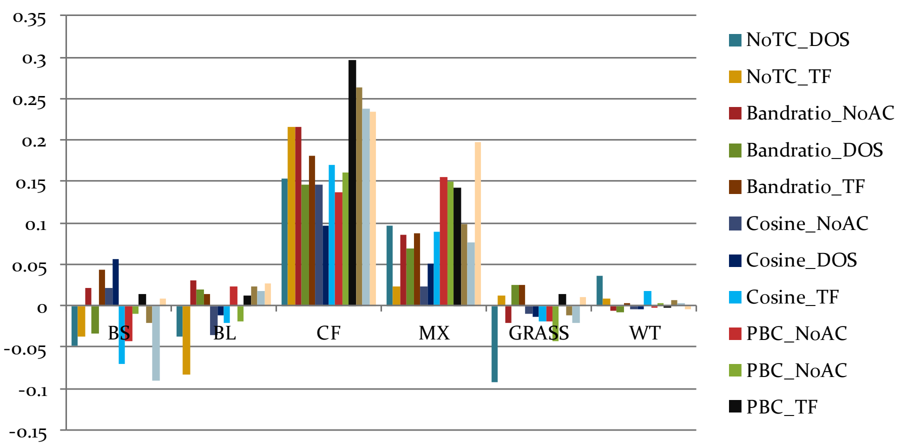
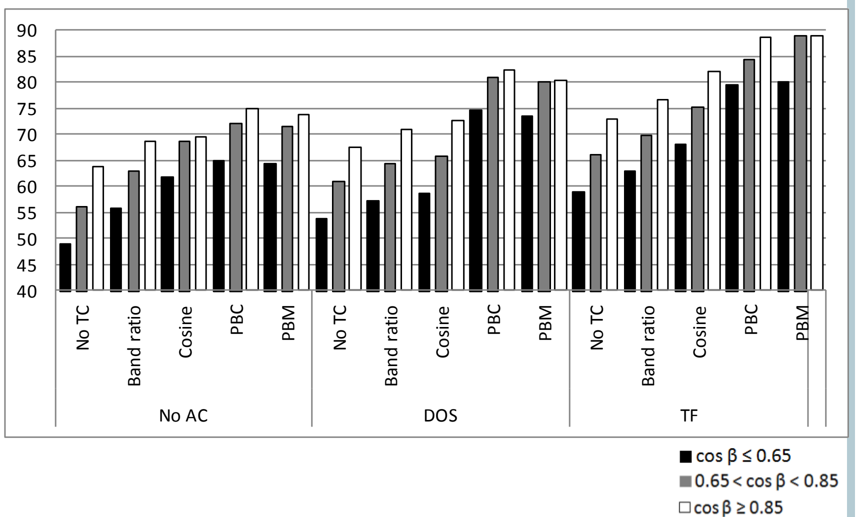




AUTOMATION POTENTIAL OF PREPROCESSING TECHNIQUES

	No TC	Band ratio	Cosine	PBM	PBC
No AC	3	3	12	15	18
DOS	5	5	14	17	20
TF	11	11	20	23	26

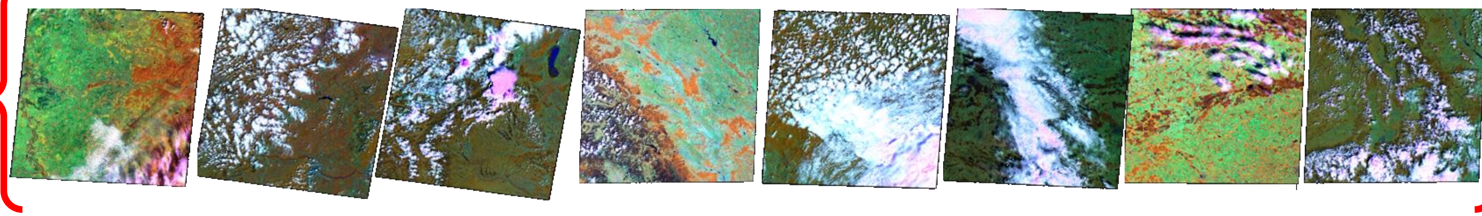
LARGE SCALE MAPPING

- Improved data policy, image products and IT makes image compositing an appealing option for moderate resolution data analysis
- Key features:
  - pixel based perspective!
  - “increase” observation frequency
- Objectives:
  1. Develop algorithm to produce regional, cloud free, radiometrically consistent image datasets
  2. Use image composites for pan Carpathian forest change mapping

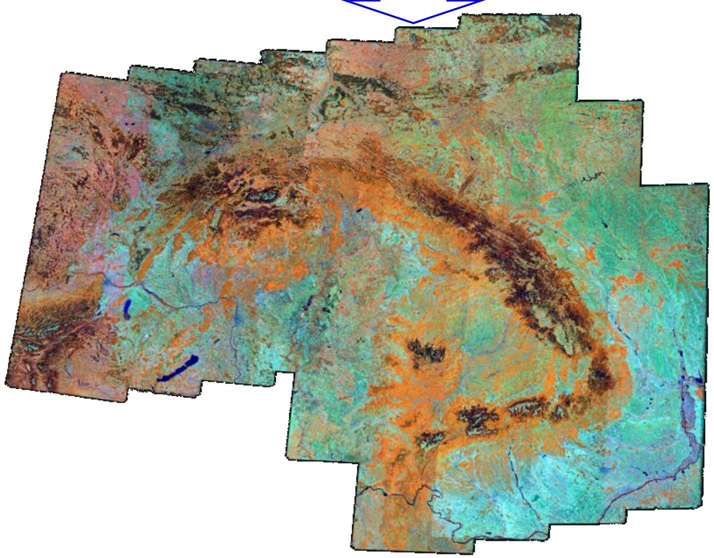
Image compositing principle

Use:

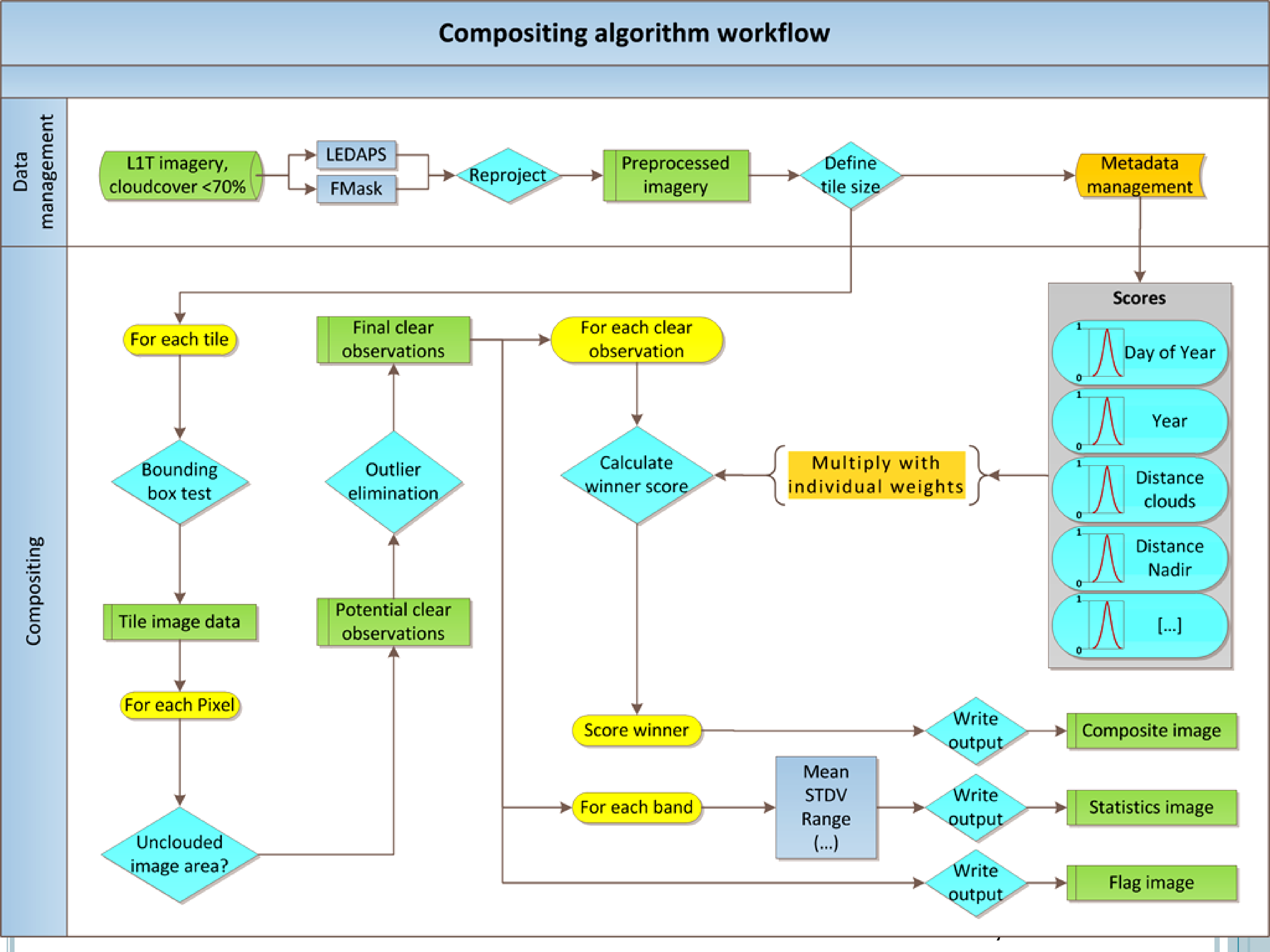
- All images..
- Multiple years
- Multiple seasons

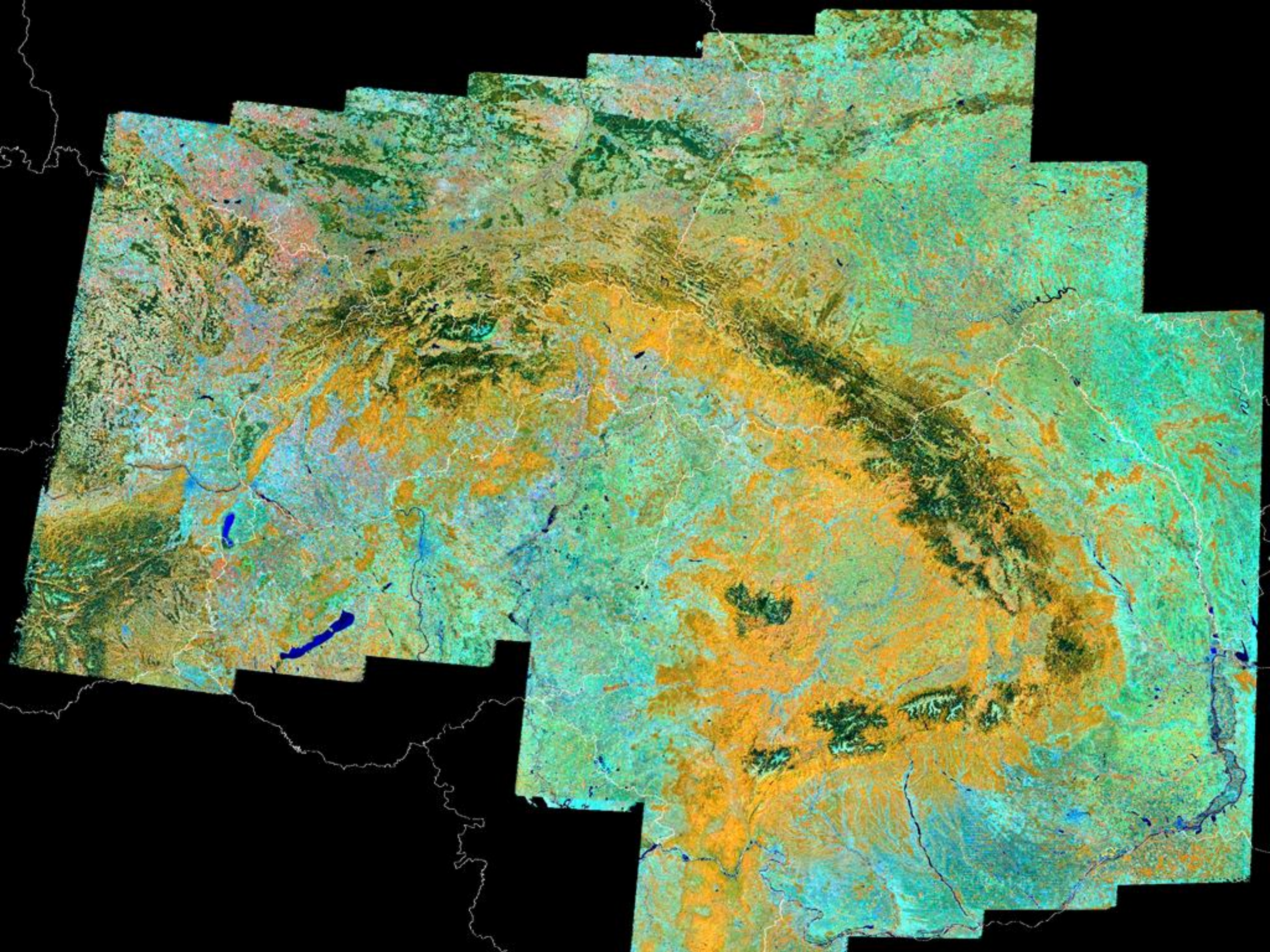


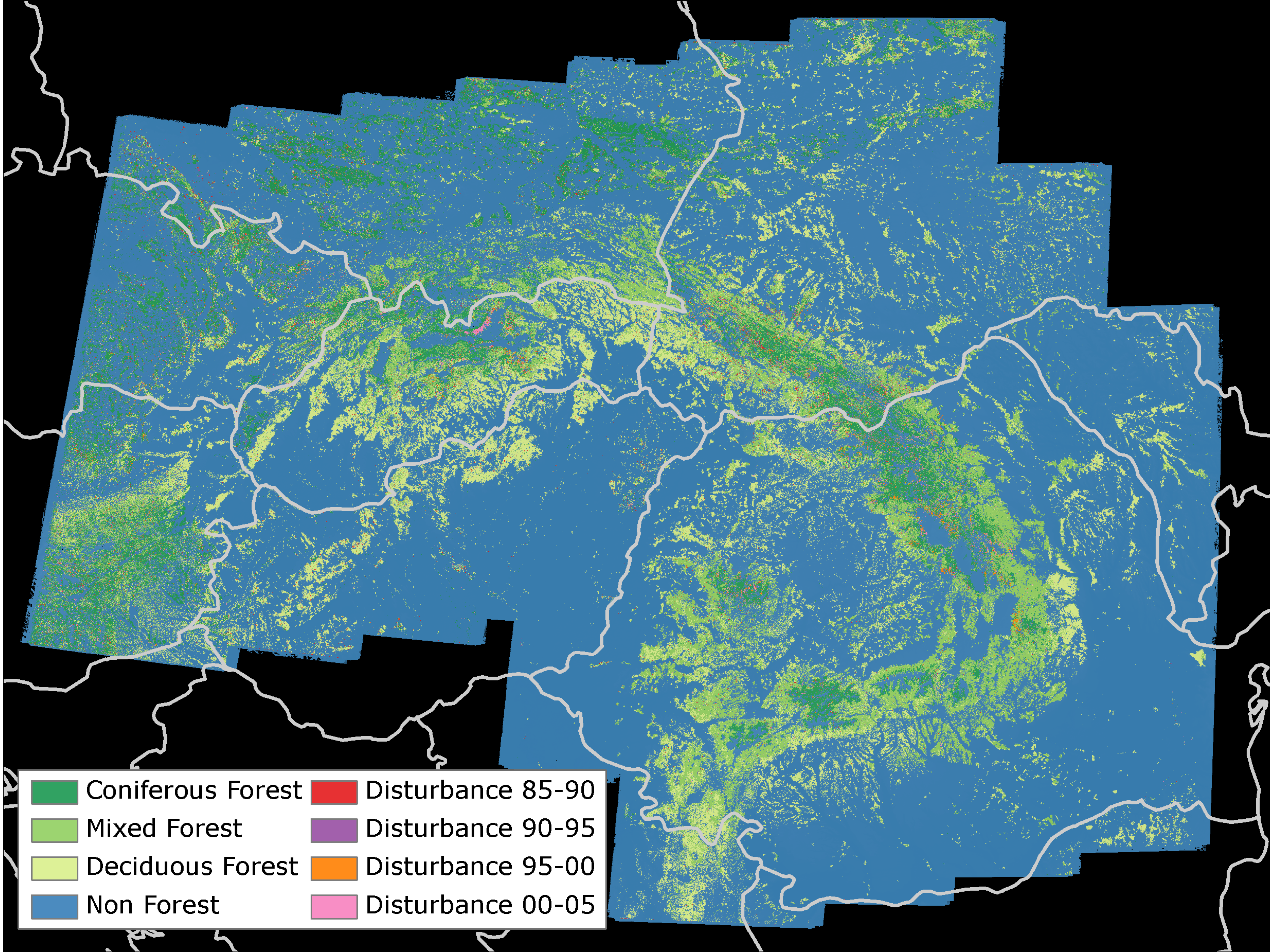
Decision rule set: select best observation per pixel



- Create best observation composite image
- Make use of all unclouded observations of a pixel

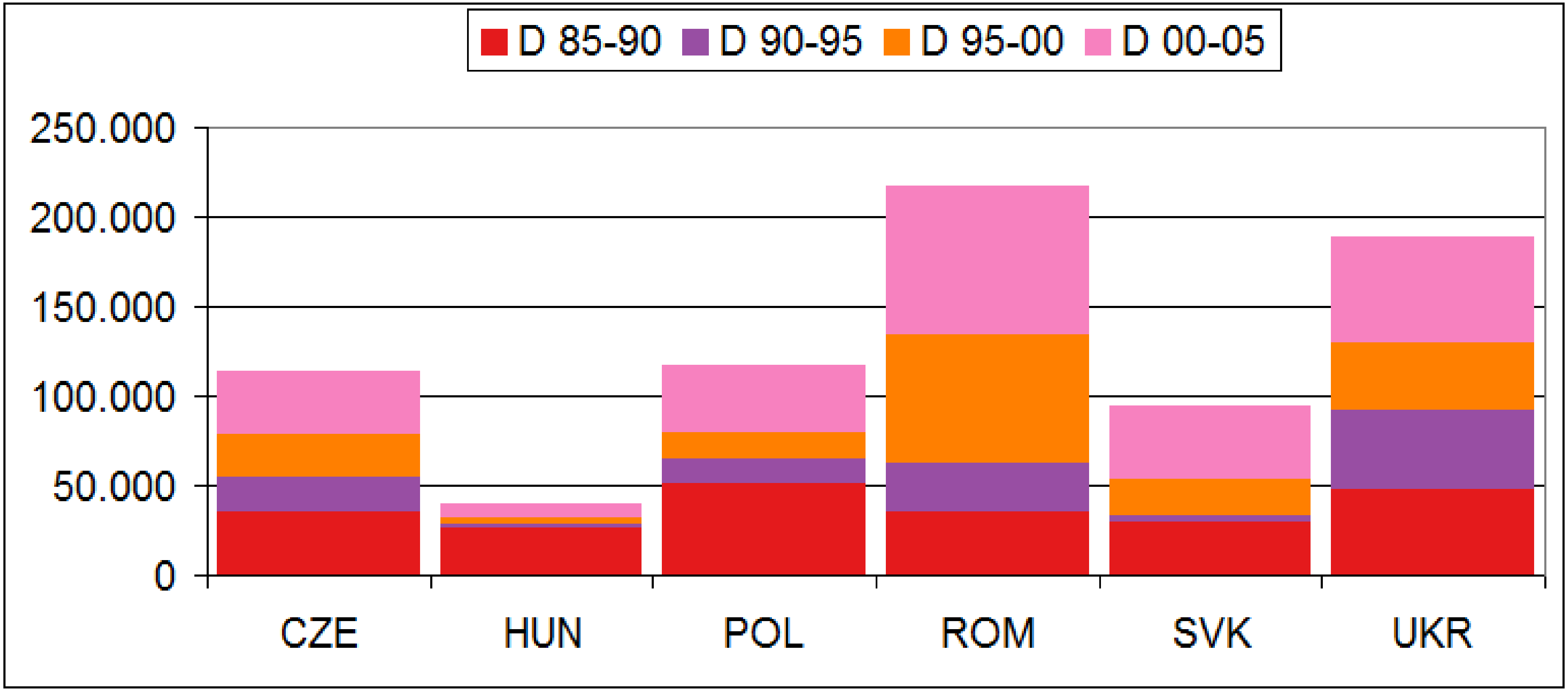

Compositing algorithm workflow
Data management
Compositing
L1T imagery, cloudcover <70%
LEDAPS
FMask
Reproject
Preprocessed imagery
Define tile size
Metadata management
Scores
Day of Year
Year
Distance clouds
Distance Nadir
[...]
Multiply with individual weights
For each tile
Bounding box test
Tile image data
For each Pixel
Unclouded image area?
Potential clear observations
Outlier elimination
Final clear observations
For each clear observation
Calculate winner score
Score winner
For each band
Mean
STDV
Range
(...)
Write output
Composite image
Write output
Statistics image
Write output
Flag image




Coniferous Forest
Mixed Forest
Deciduous Forest
Non Forest
Disturbance 85-90
Disturbance 90-95
Disturbance 95-00
Disturbance 00-05

Disturbance rate [%] per country

- Disturbed forest area [ha]
-

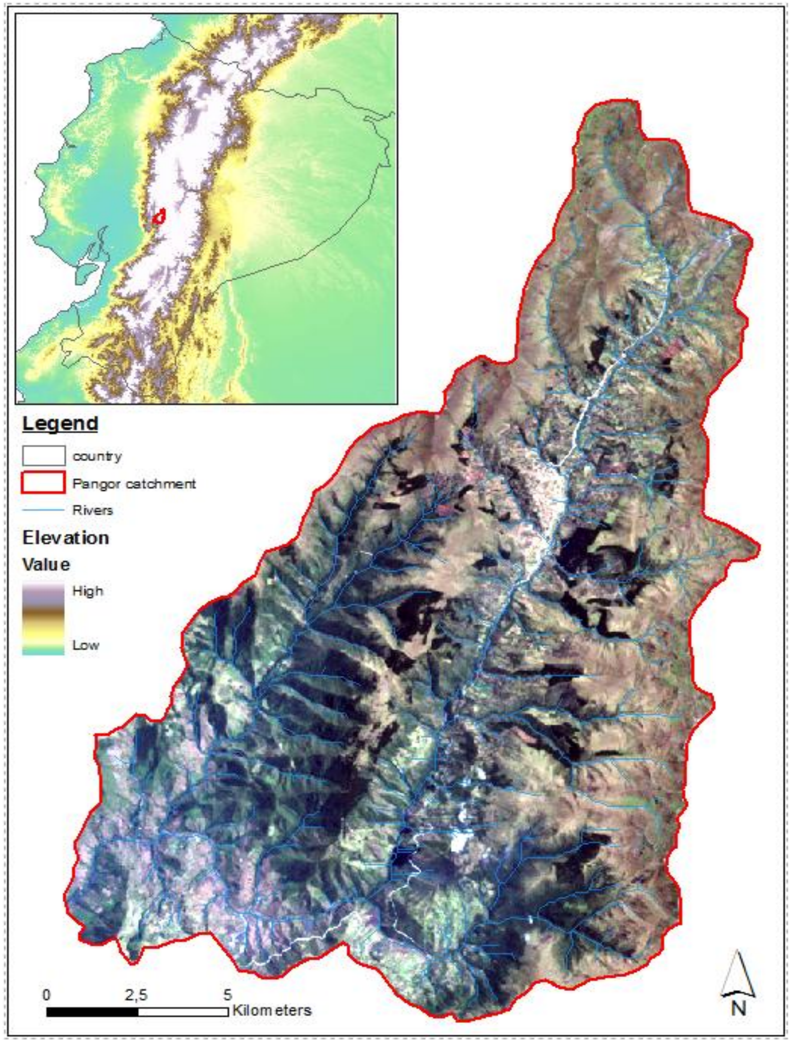


Ecosystem services assessment at regional scale

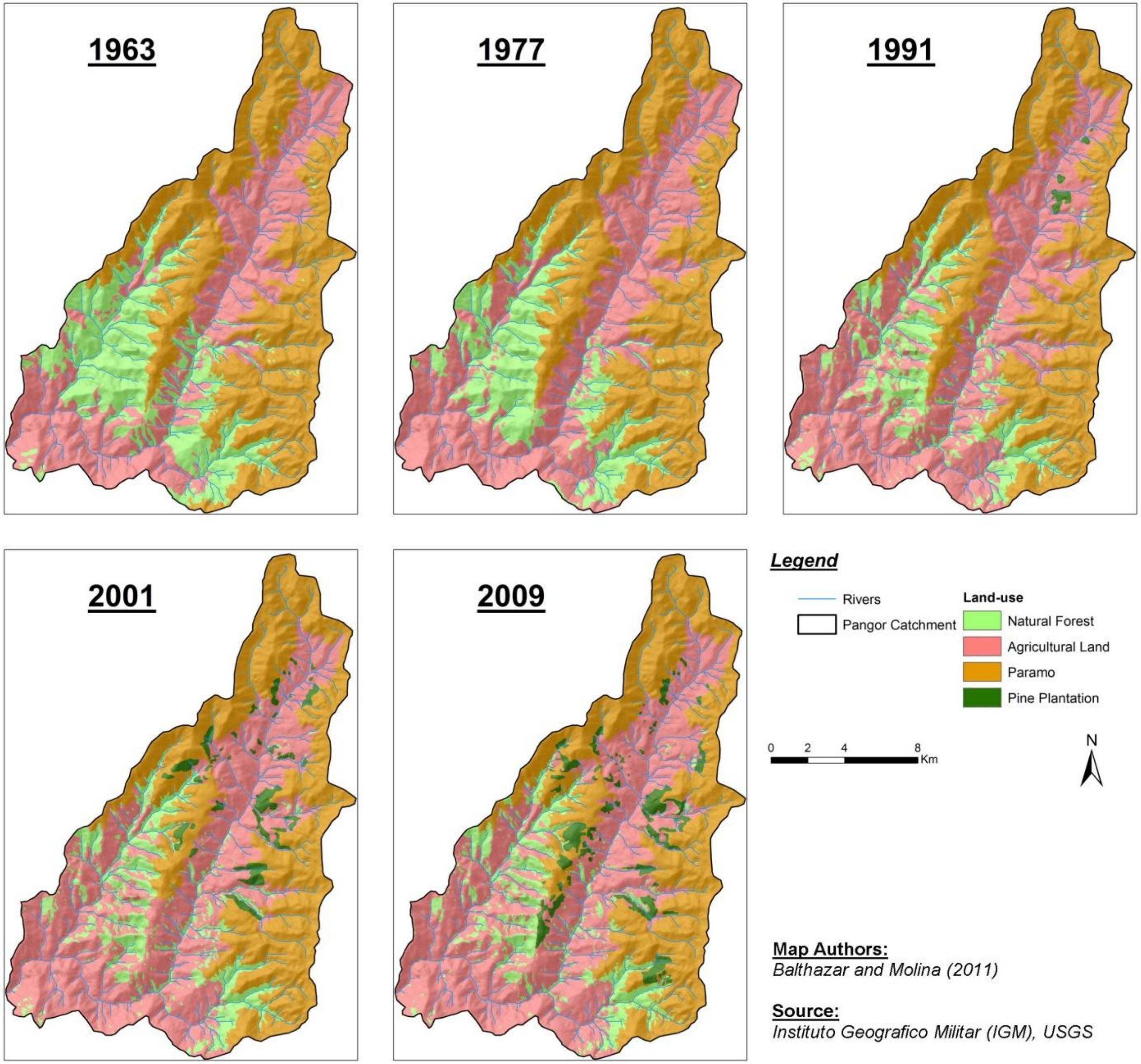
The significance of forest transitions in creating more sustainable societies depends on the effects of these transitions on the environmental services that forests provide" (Rudel et al., 2005)

- **Natural hazard regulation** (mass movements)
- **Water and erosion regulation** (agricultural production, water quality&quantity)
- **Carbon storage and biodiversity** (REDD/REDD+)

STUDY SITE: RIO PANGOR (ECUADOR)



IMPACT OF LAND COVER CHANGE?

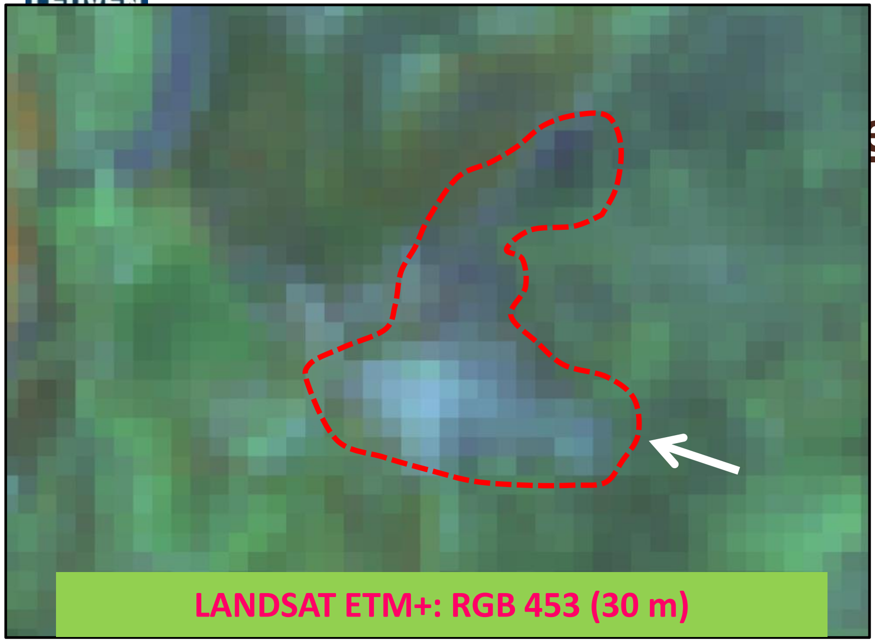


IMPACT ANALYSIS

- LINK WITH CHANGES IN LANDSLIDE FREQUENCY?
- LINK WITH CHANGES IN DISCHARGE REGIMES
- LINK WITH CHANGES IN CARBON SEQUESTRATION AND BIODIVERSITY?

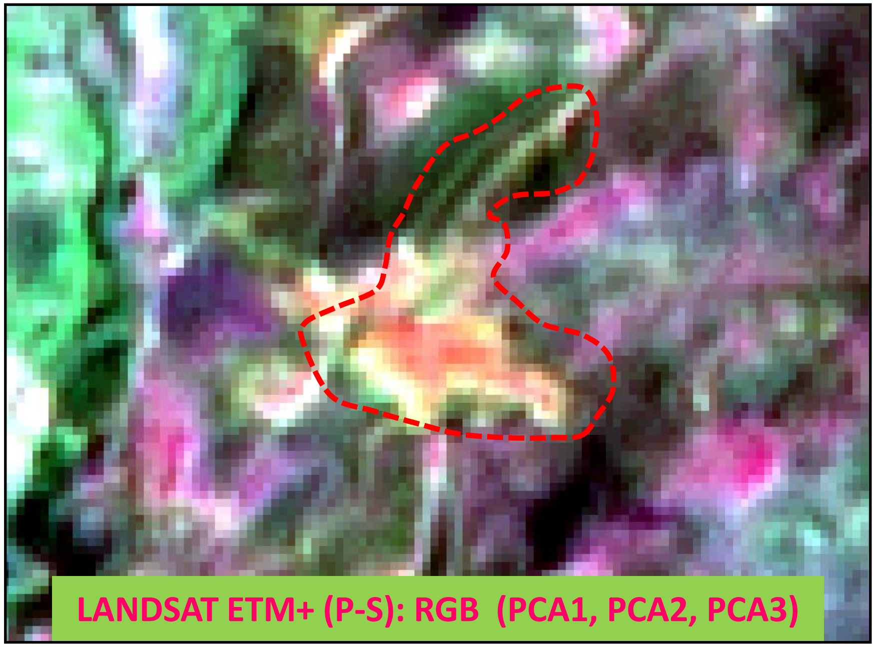
- Objective of creating **landslide inventories** for different years based on HR imagery
- **Selection and validation** of the method for a recent time-period (covered by VHR data)
- Application of **shape and spectral** characteristics back in time with HR imagery
- Combination with morphometric characteristics and use of semi-extraction techniques
- **Statistical relation** between landslide occurrences and land-use changes

WP 4: Ecosystem Services ASSESSMENT

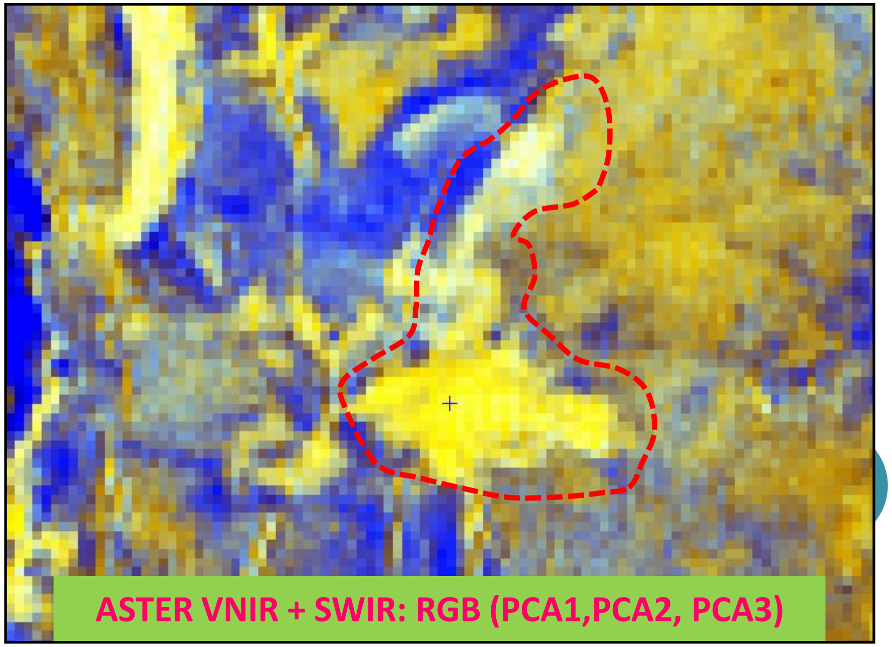


LANDSAT ETM+: RGB 453 (30 m)

LANDSAT ETM+: RGB 453 (15 m PAN-fusion)



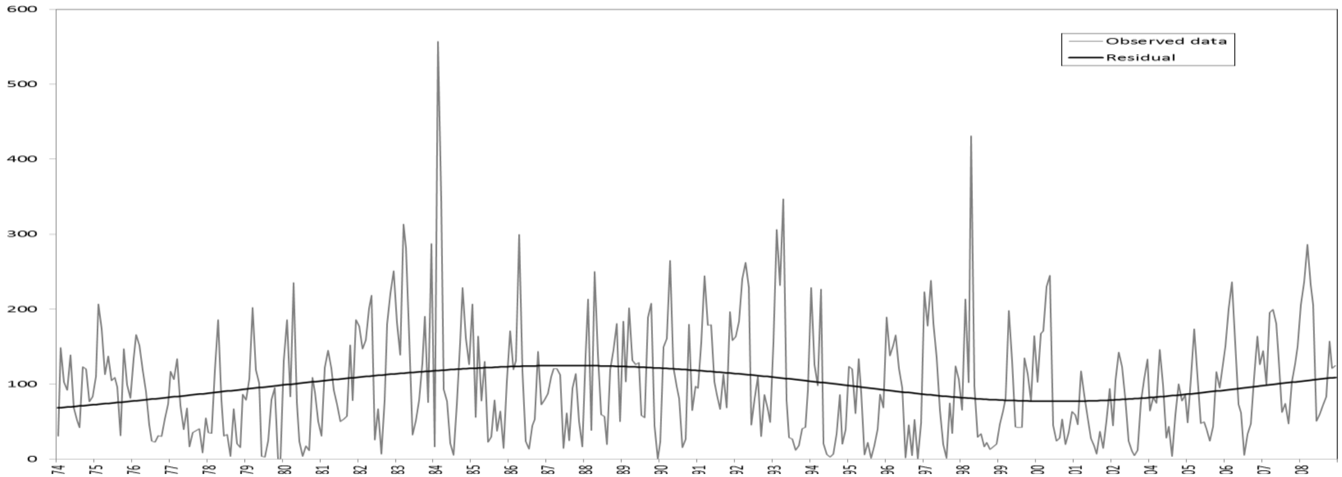
LANDSAT ETM+ (P-S): RGB (PCA1, PCA2, PCA3)



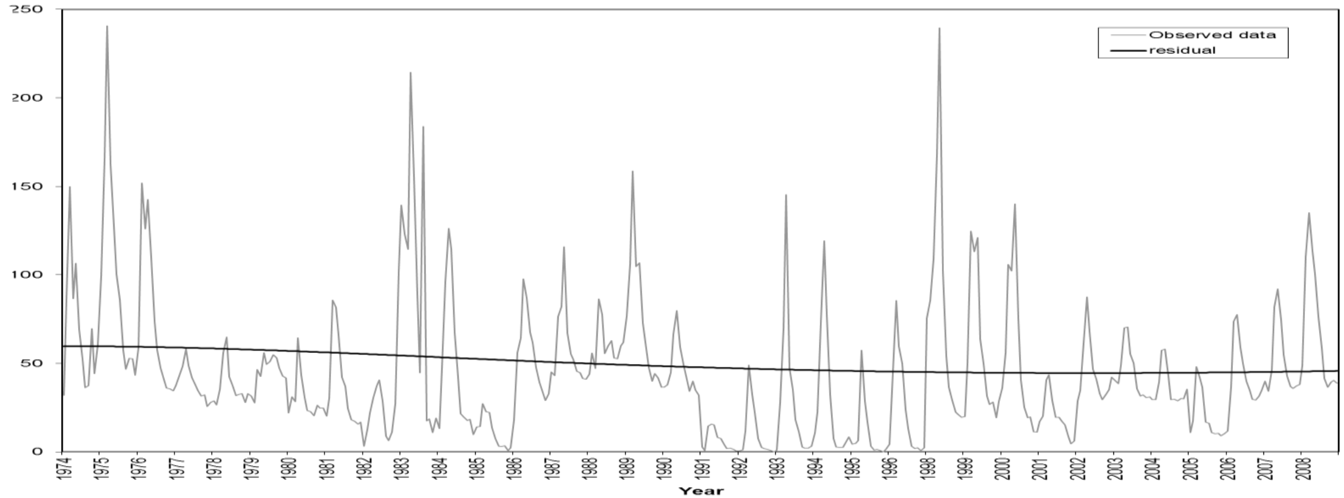
ASTER VNIR + SWIR: RGB (PCA1,PCA2, PCA3)

Long-term trends corrected for intra and interannual variation

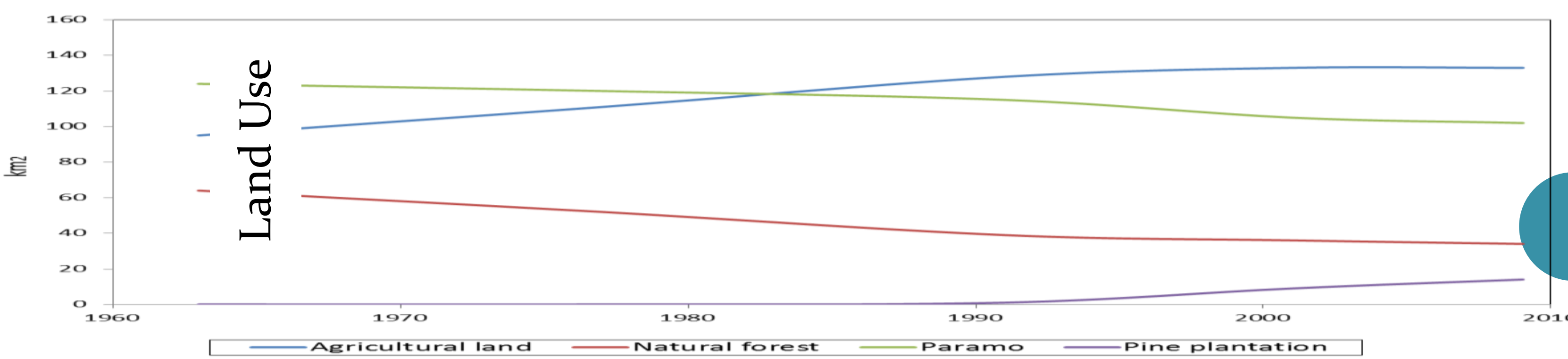
Monthly rainfall data



Monthly streamflow data

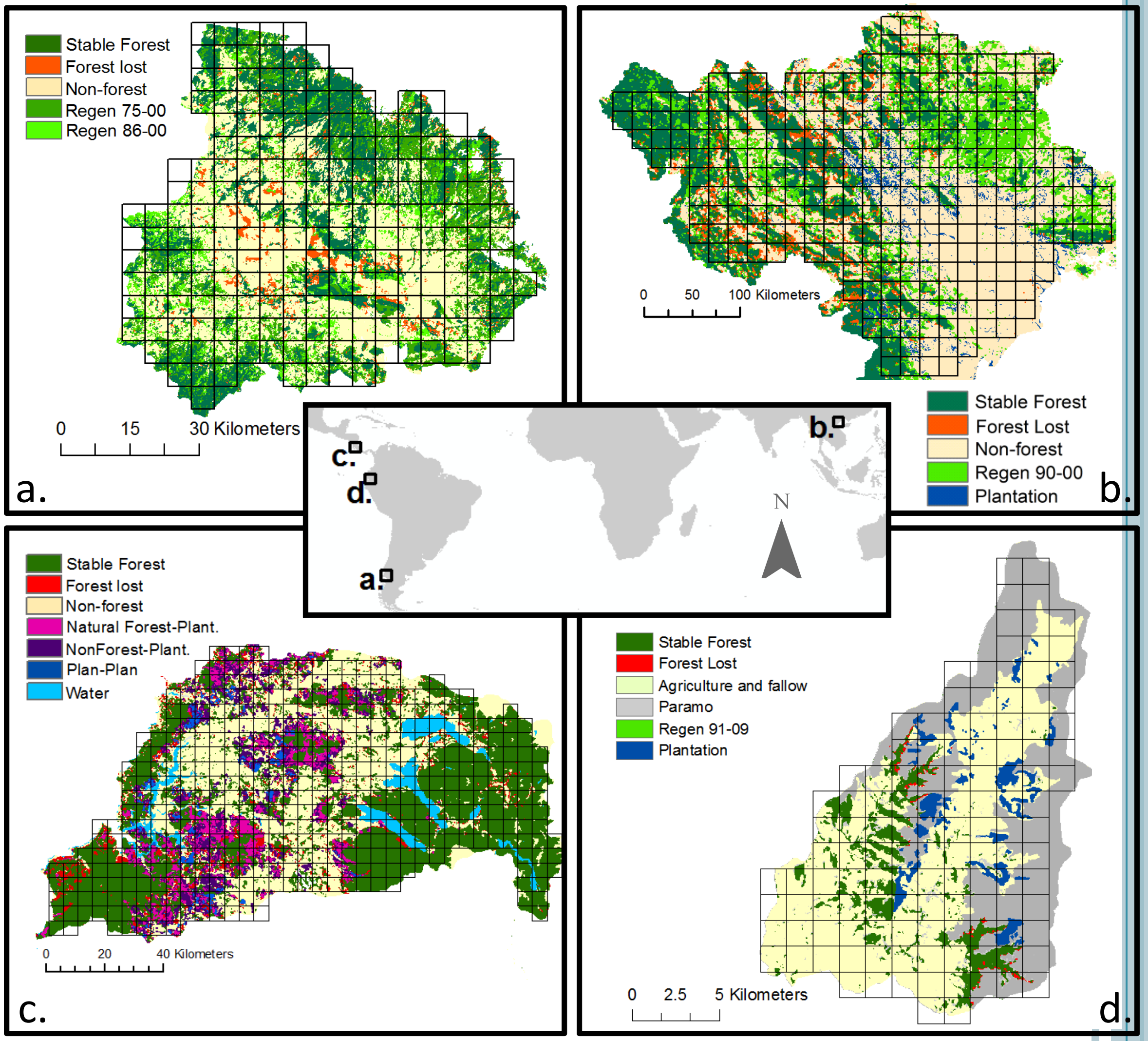


Land Use



Carbon and biodiversity

- **a. Northern Costa Rica**
  - Tempisque watershed
  - 5414 km^2
  - sea level - 1964 m
  - Sub-landscape 25 km^2
- **b. Northern Vietnam**
  - 91,600 km^2
  - ~100 - 3100 m
  - Sub-landscape 400 km^2
- **c. Valdivia Chile**
  - 11,775 km^2
  - Sea level - 1222 m
  - Sub-landscape 25 km^2
- **d. Highland Ecuador**
  - Pangor watershed
  - 282 km^2
  - ranging from 1431 to 4333 m
  - Sub-landscape 2.25 km^2



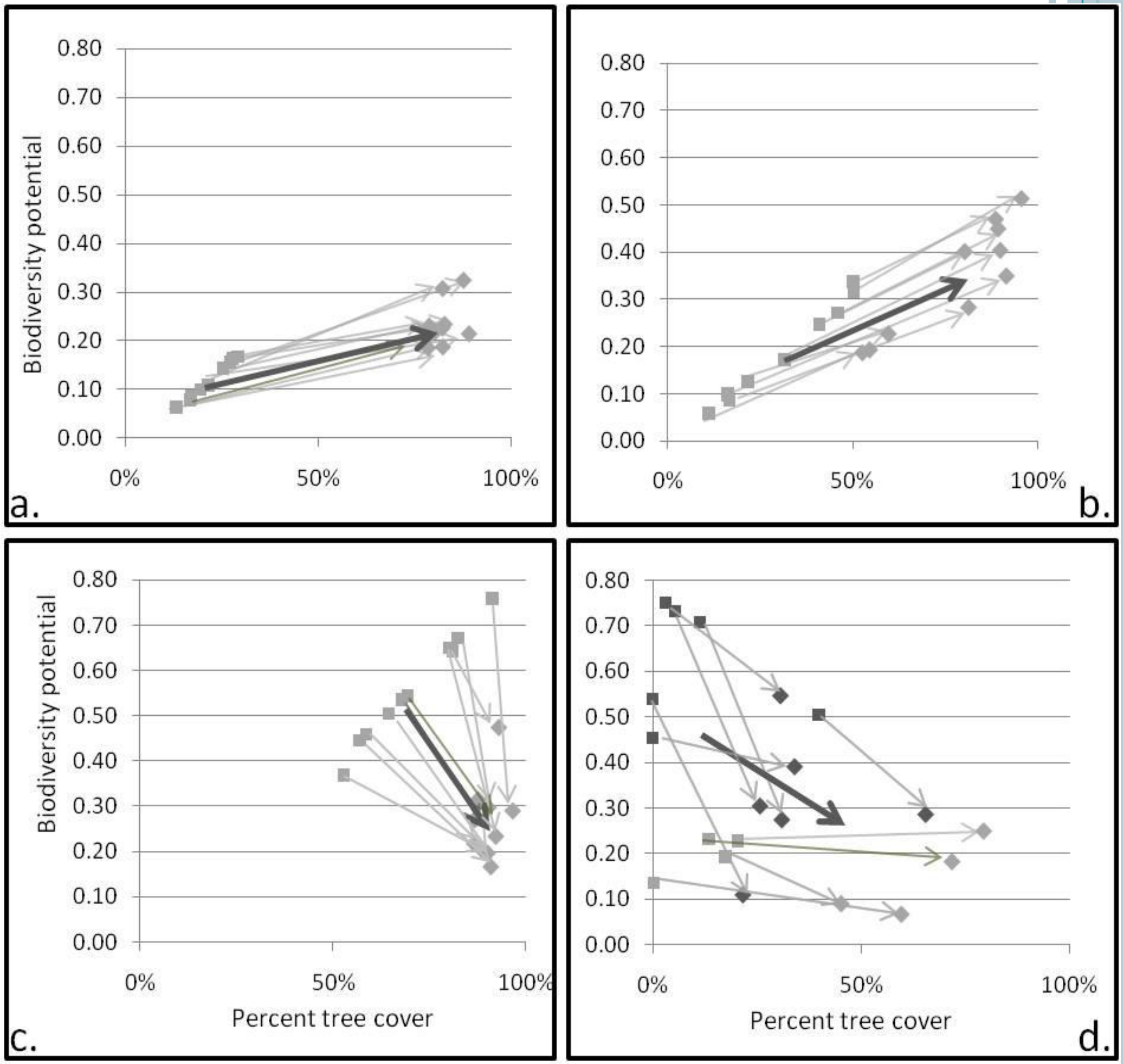
Potential to support native floral biodiversity

Vegetation type	Category*	Distribution	Rationale
Mature	Very High (1.00)	Mature natural forest in the largest patch	Larger intact mature forest will retain more species
	High (0.75)	Other mature natural forest core[1], natural páramo	Natural forest remnants will help maintain native species
	Medium (0.50)	Other natural forest edges	Edge effect will reduce native forest species richness
Secondary	Medium (0.50)	If > 150 ha core forest within 1km	More forest means more seed source and dispersers
	Low (0.25)	If between 150 -50 ha core forest within 1km	Less native forest in proximity, less seed source
	Very Low (0.15)	If between 50 -0 ha core forest within 1km	Limited seed source and appropriate habitat[2]
	Plus[3]	If < 5 km from largest mature forest patch	Large number within species pool in proximity
Non-native Plantation	Negligible (0.05)	Monoculture of non-native species	Short-rotation managed plantations have low diversity
Non-forest areas	(0.00)	Pasture, cropland, young fallow	Very little AGB in trees, very few native forest species

- Category values scaled between 0.00 and 1.00
- Plus - closest to the *largest* parch of mature forest – increase one step in value

IMPACT OF FOREST TRANSITION ON BIODIVERSITY

- **a. Northern Costa Rica**
  - Natural forest regeneration
- **b. Northern Vietnam**
  - Natural forest regeneration
- **c. Valdivia Chile**
  - Natural forest to plantation
- **d. Highland Ecuador**
  - Ag. to plantation
  - Páramo to plantation



ONGOING RESEARCH

- Integration and automation of total process chain
- Preprocessing → large scale mapping of LU and LUC → regional ecosystem service assessment
- Validation at different levels
- Evaluation of added value of procedures and mapping techniques


Thank you for your attention!