Satellite remote sensing – a conservation revolution

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Who am I?

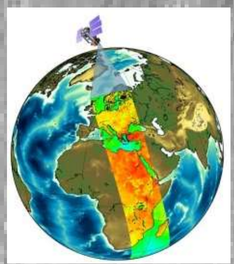
Biodiversity Research & Conservation Applications

Assess and predict the impact of global environmental change on biodiversity; use this to inform conservation

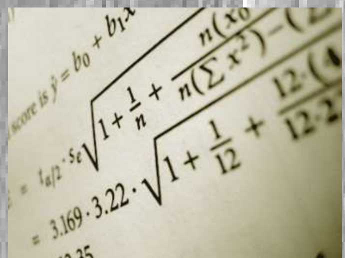
My methods

Statistics

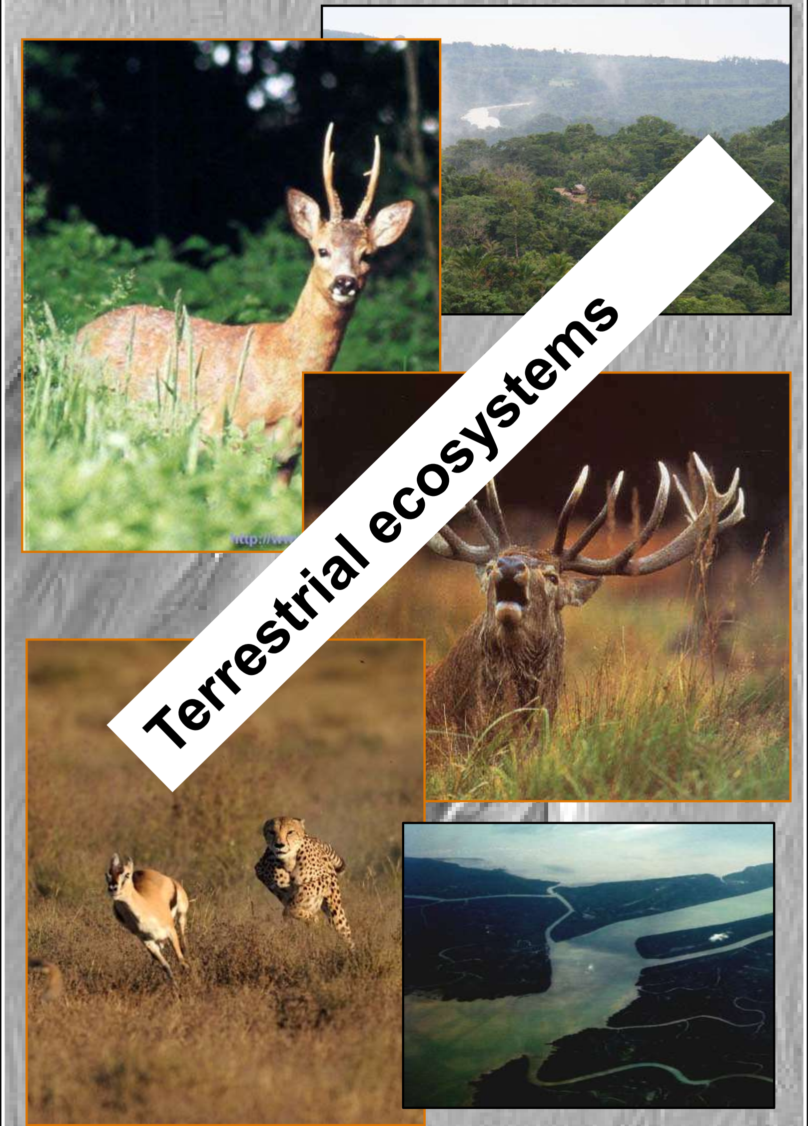
Remote Sensing



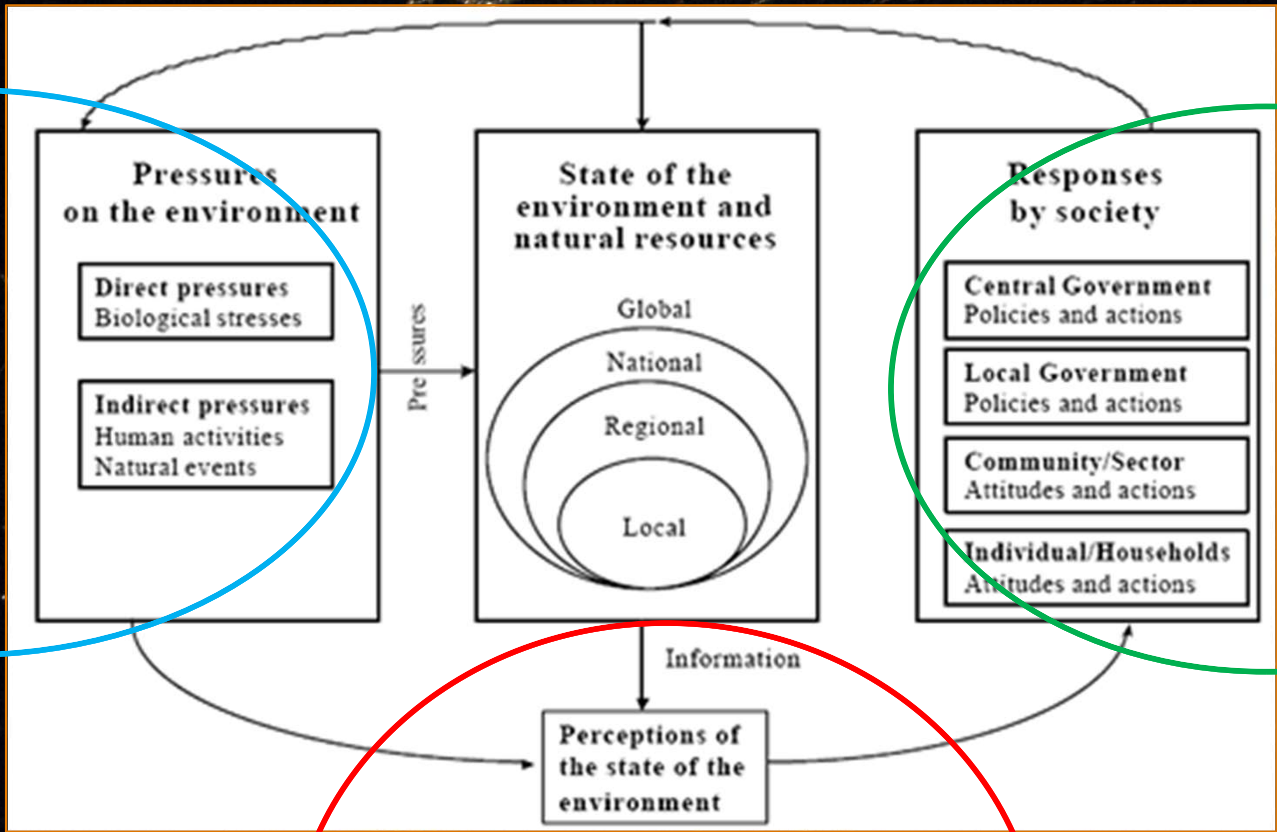
Simulations



Biological models



My research framework: a typical research framework for conservation science



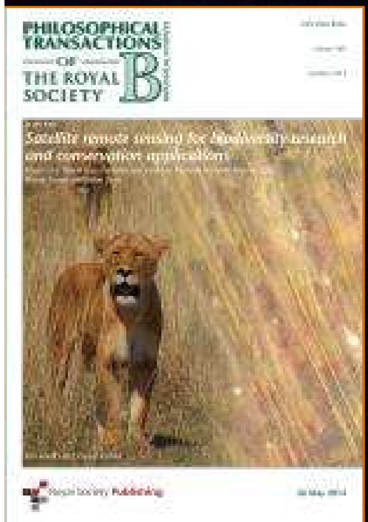
Climate change
Land conversion
Invasives
Overexploitation

Protected areas
Land development planning
Vaccinations

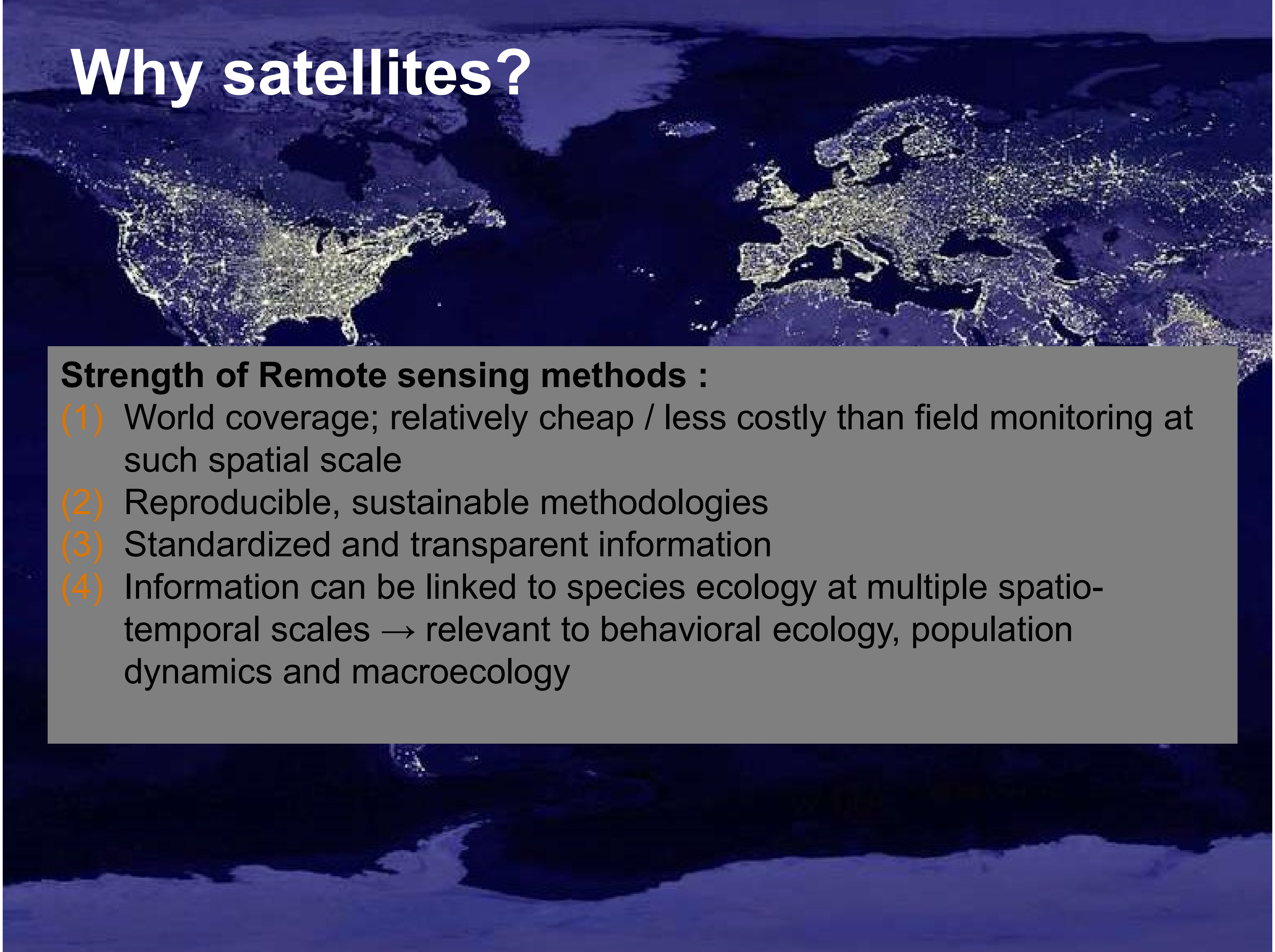
Structural attributes

Functional attributes

Compositional attributes



Pettorelli et al. 2014

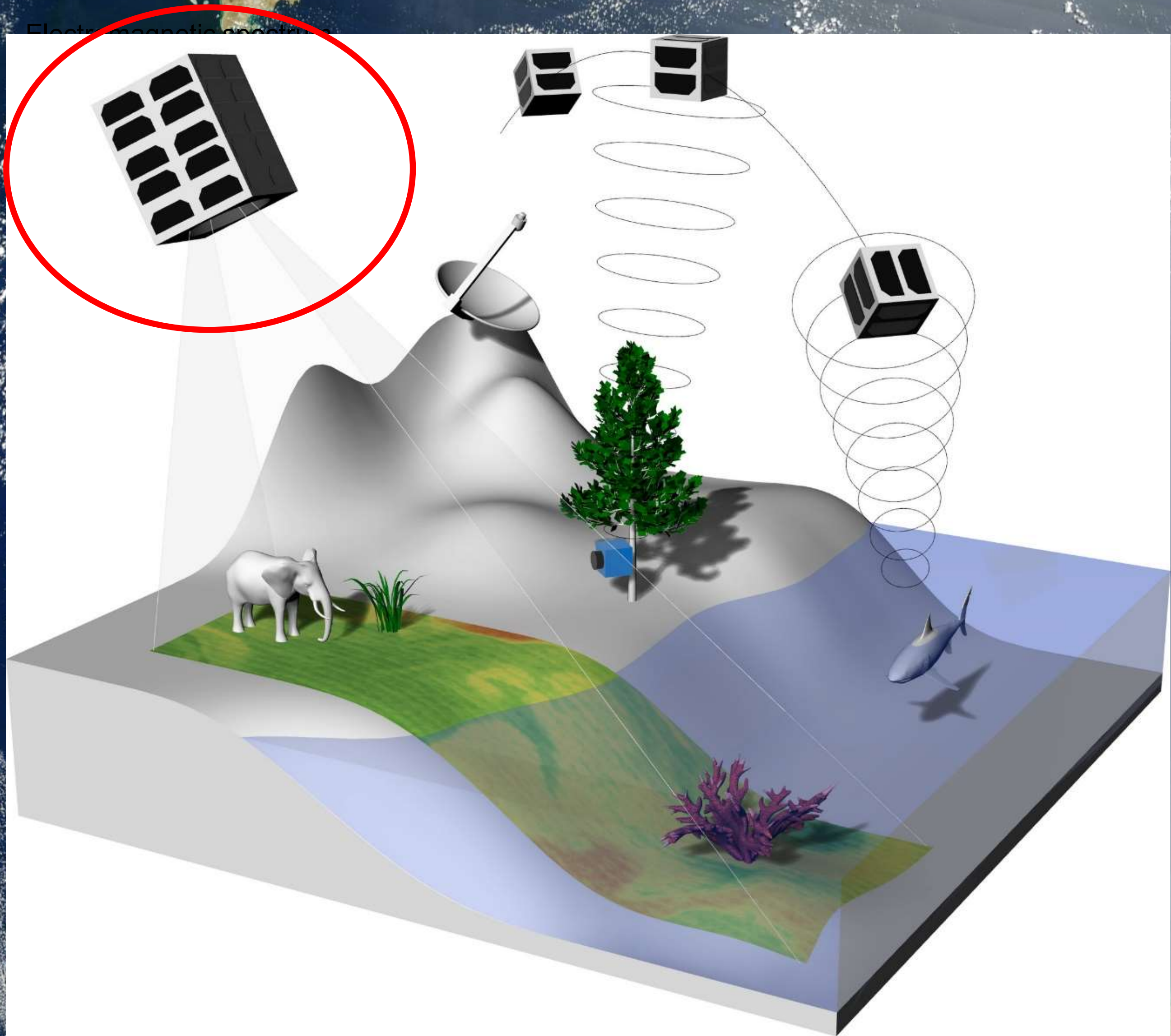


Why satellites?

Strength of Remote sensing methods :

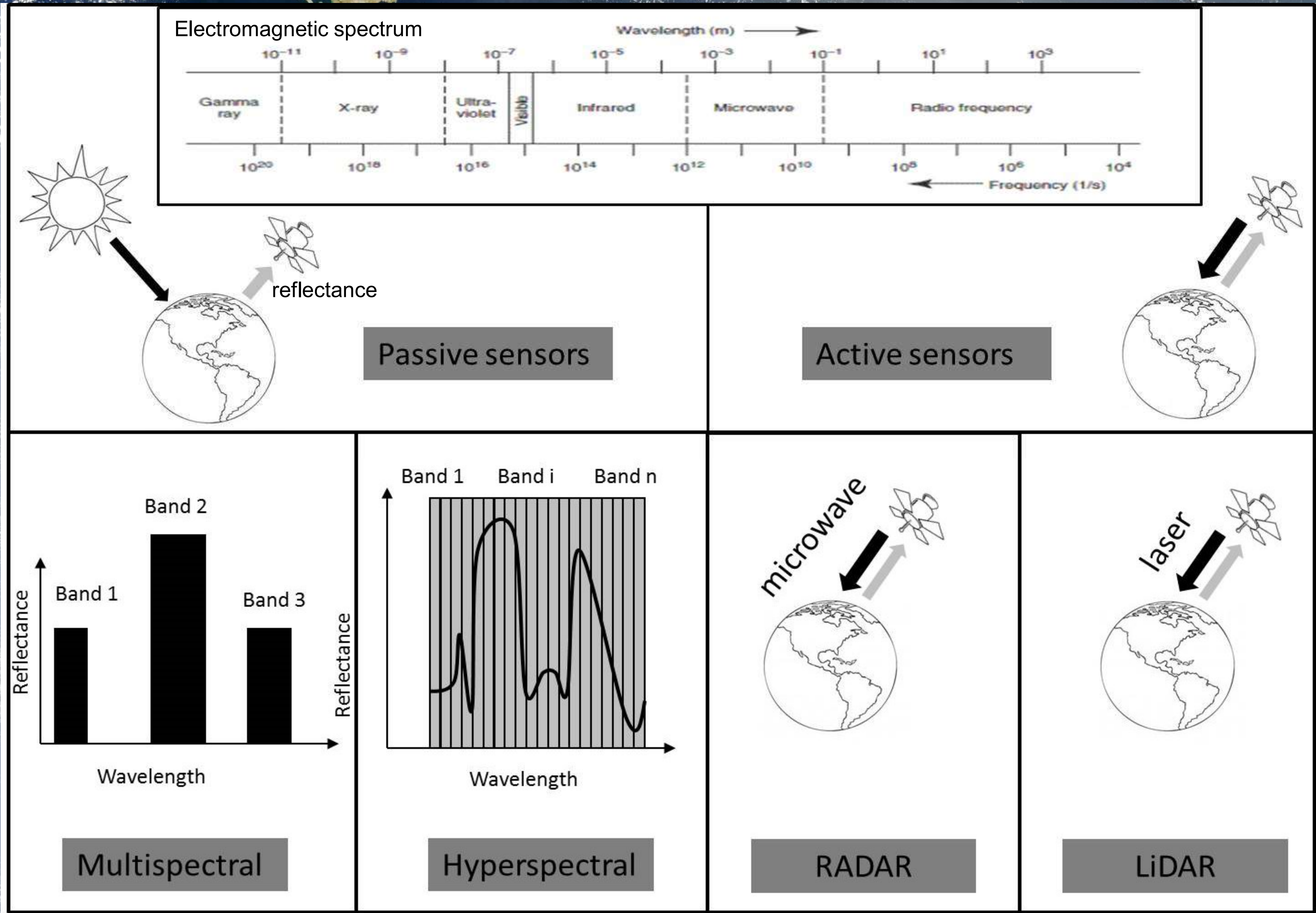
(1) World coverage; relatively cheap / less costly than field monitoring at such spatial scale
(2) Reproducible, sustainable methodologies
(3) Standardized and transparent information
(4) Information can be linked to species ecology at multiple spatio-temporal scales → relevant to behavioral ecology, population dynamics and macroecology

Not all satellites are the same



Curnick et al. 2021

Not all satellites are the same



Pettorelli et al. 2014

Not all satellites are the same

Electromagnetic spectrum

a. Landsat ETM+ b. ATLAS c. QuickBird

Pettorelli et al. 2018 WWF Conservation Technology Series

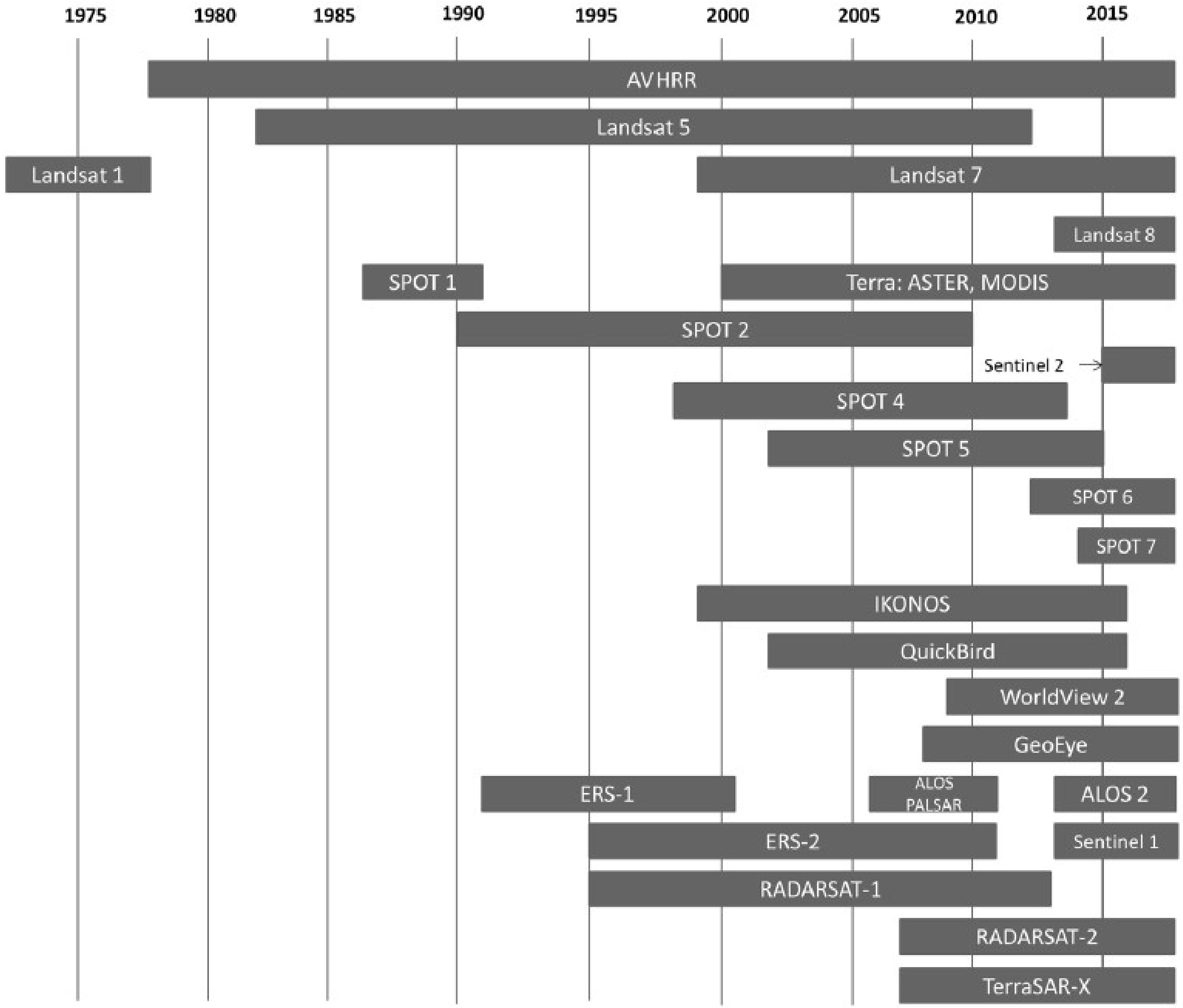


Figure 3.3. Timeline of satellite missions.

Pettorelli et al. 2018 WWF Conservation Technology Series

Pressures

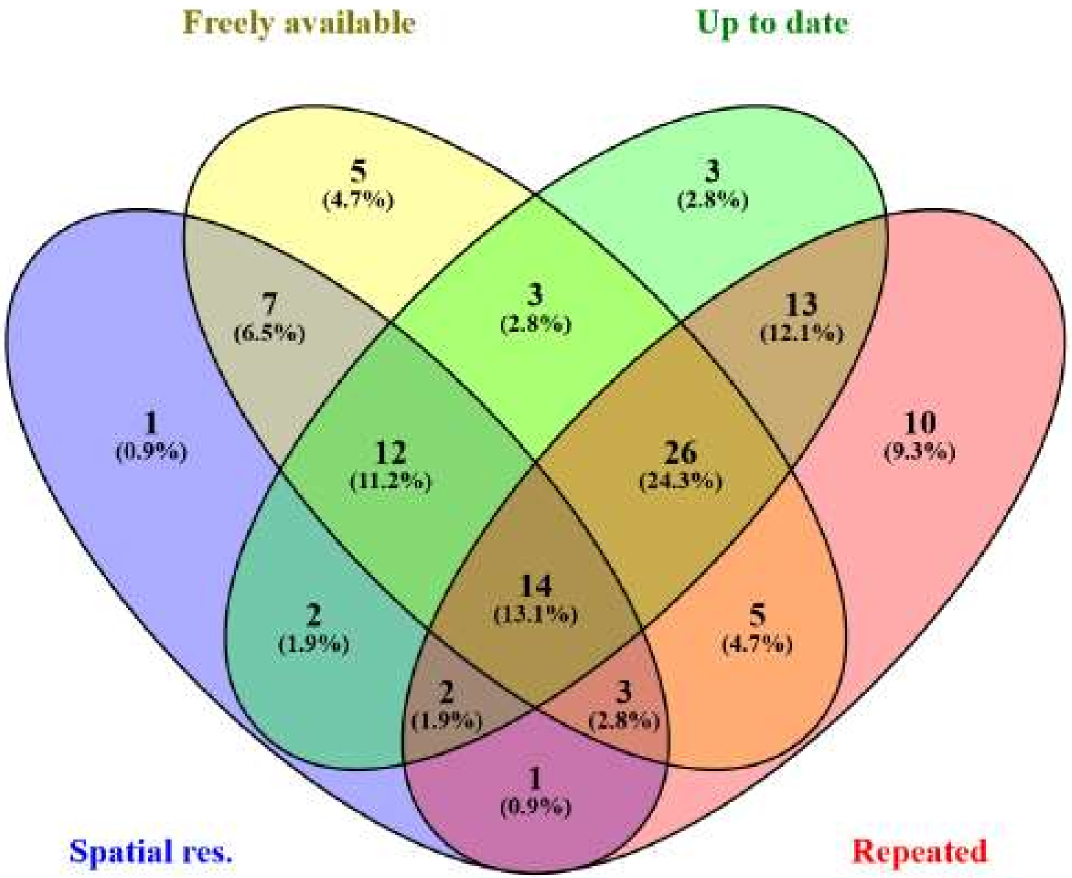
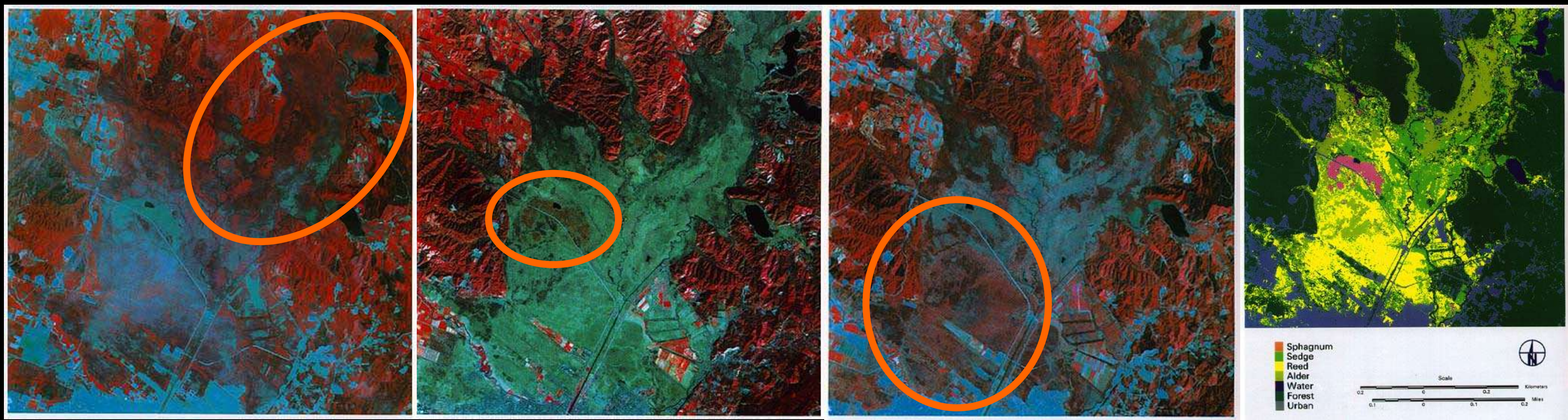


Figure 2: The number of datasets that meet each of four desirable dataset attributes outlined in Table 1 as well as being global in coverage and representing either models assessed for accuracy or empirical observations. Numbers in each intersection represent the number of datasets that meet those constraints. See Table S1 for a full list of datasets and their quality attributes.

Joppa et al. 2016

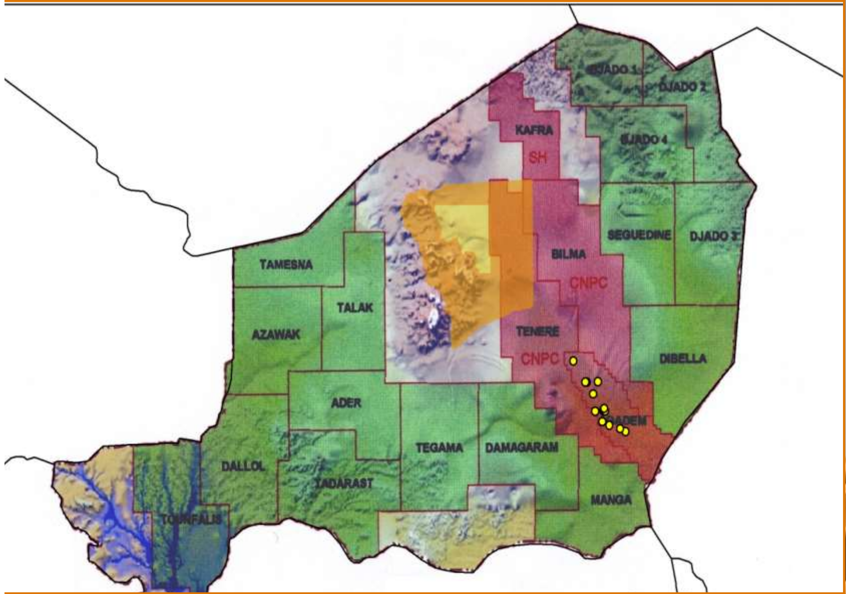
Passive sensors & pressure monitoring: Landsat as an example

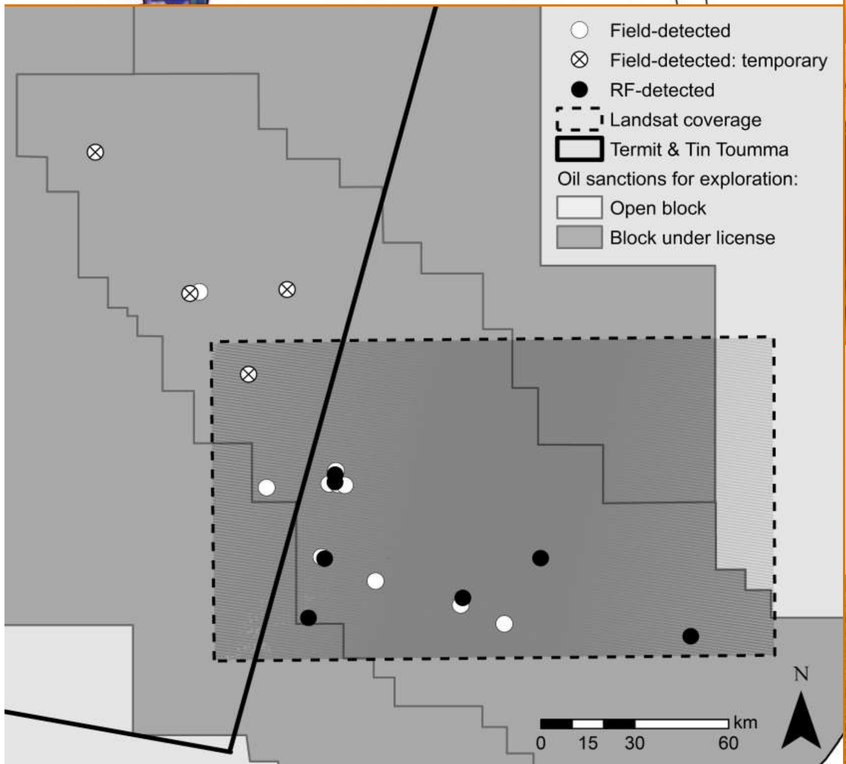
- Landsat started in the late seventies
- Landsat satellites use an instrument that collects several images at once. Each image shows a specific section of the electromagnetic spectrum, called a band
- The combination of the information encapsulated in the different bands allows differentiating habitats
- Ground truth generally needed, in order to relate image data to real features and materials on the ground (calibration)



Oil exploration activities

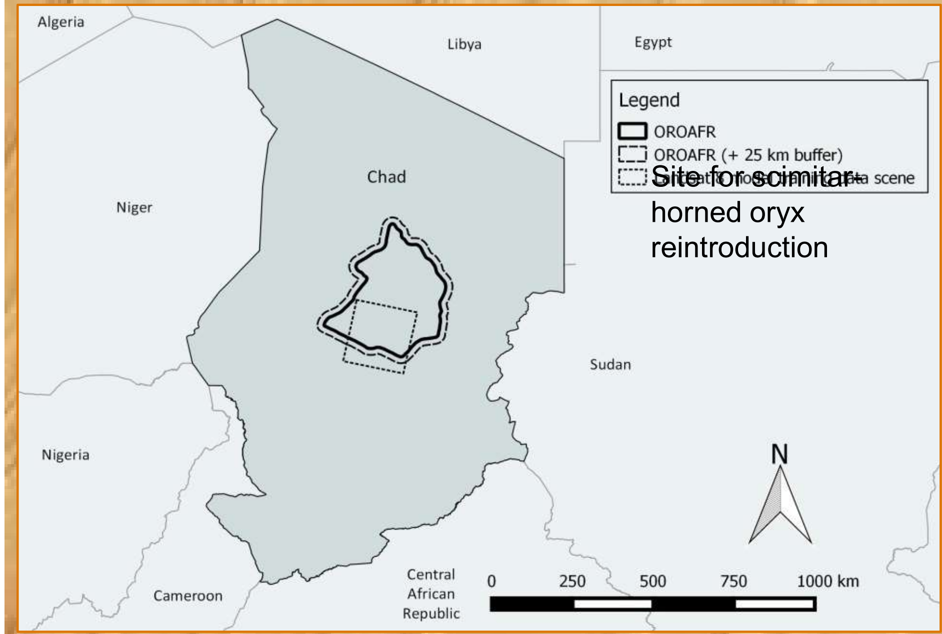
→ No spatial information available yet multiple reports of degradation/poaching associated with these developments





Duncan et al. 2014

Artificial water points

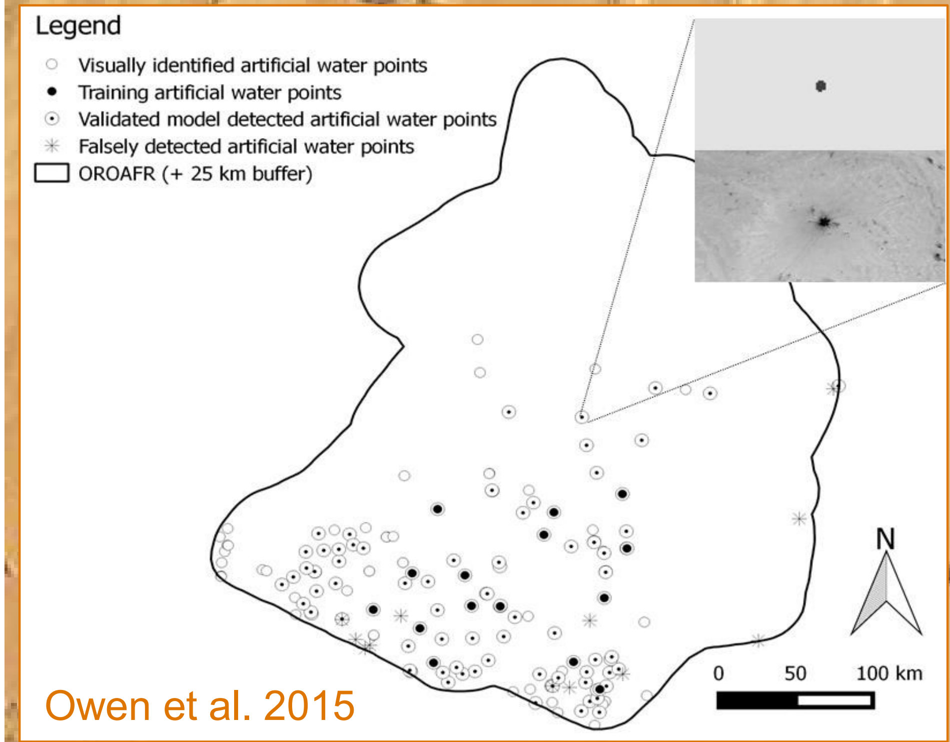


Site for scimitar-horned oryx reintroduction

→ Uncontrolled expansion, no information

→ Landsat combined with VHR data & Random Forest

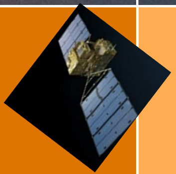
→ 126 different points in the reserve, 24% omission rate, accuracy of 92%



Owen et al. 2015

State

Biodiversity monitoring so far

	Compositional	Structural	Functional
Gene level	*Genes*	*Genetic structure*	*Genetic processes*
Species level	*Species, populations* 	*Population structure*	*Demographic processes*
Ecosystem level	*Communities* 	*Ecosystem structure* 	*Ecosystem processes, functions* 

Monitoring penguins from space

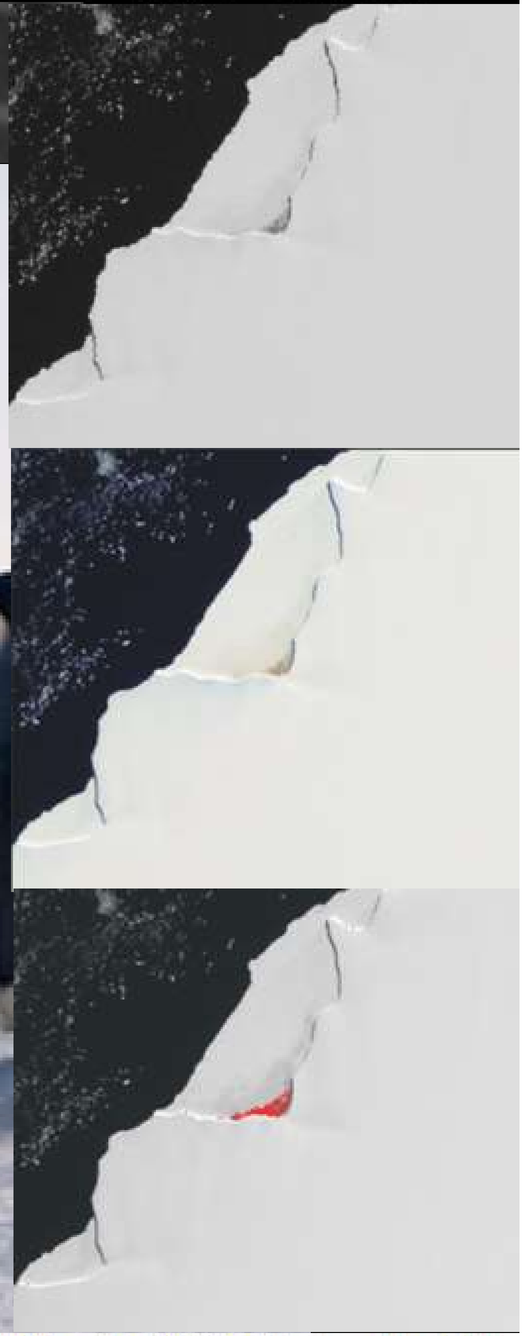
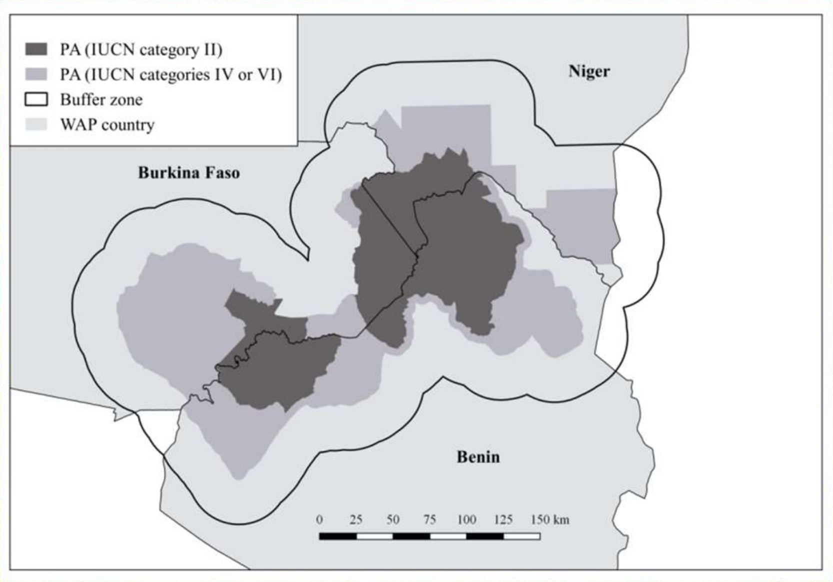


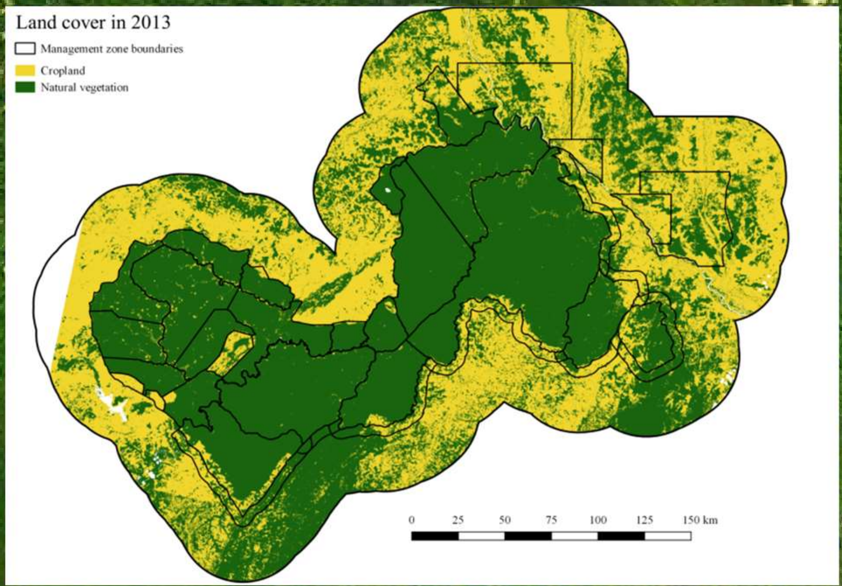
Figure 1 Comparison of data types: (a) screenshot of online Landsat Image Mosaic of Antarctica (LIMA); (b) Landsat ETM tile, downloaded from the LIMA website – note brown staining at the colony location; (c) spectral analysis red minus blue band, positive values shown in red, picking out the exact area of the colony.

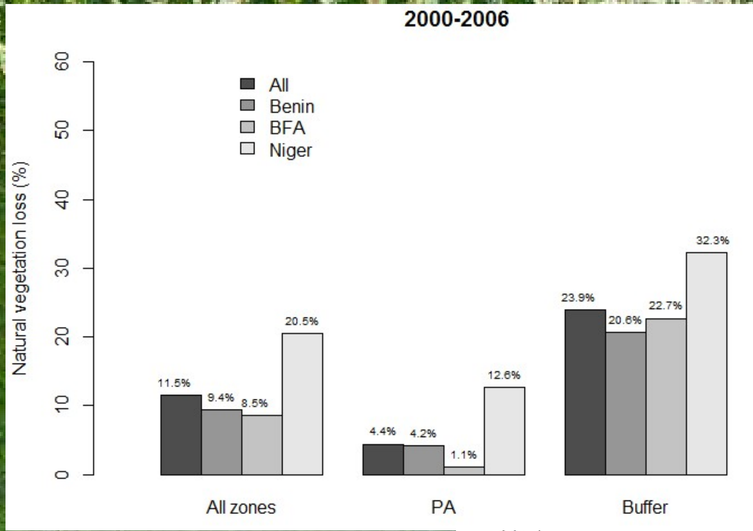
Fretwell & Trathan 2009

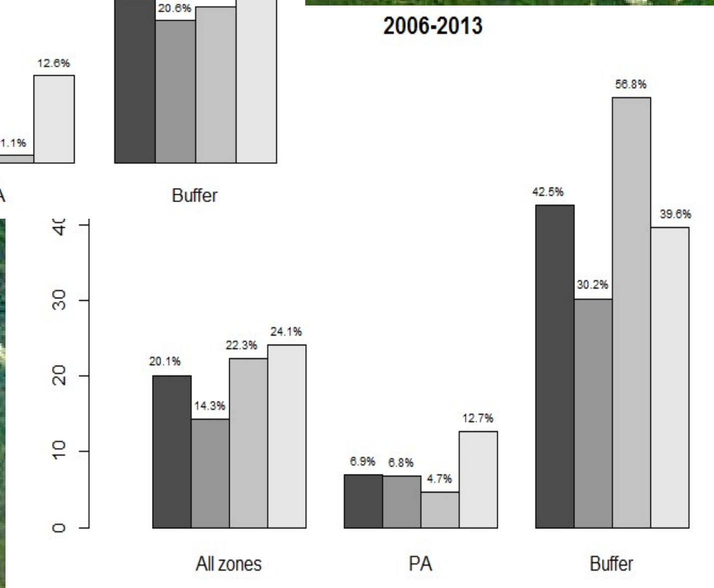
Natural vegetation loss

→ **Biodiversity hotspot**
→ **Uncontrolled cropland expansion, no information on transboundary PA effectiveness**





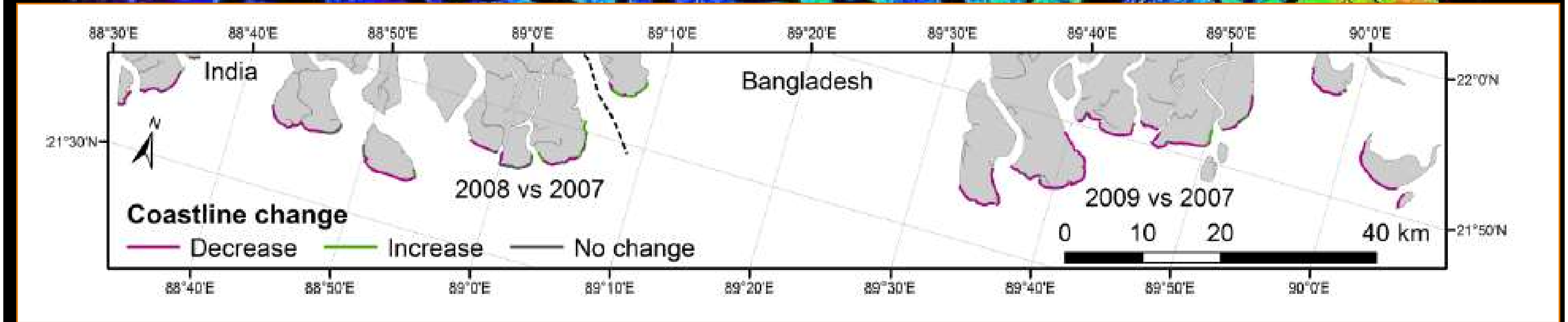




Schulte to Buhne et al. 2017

Sea rise and coastal retreat

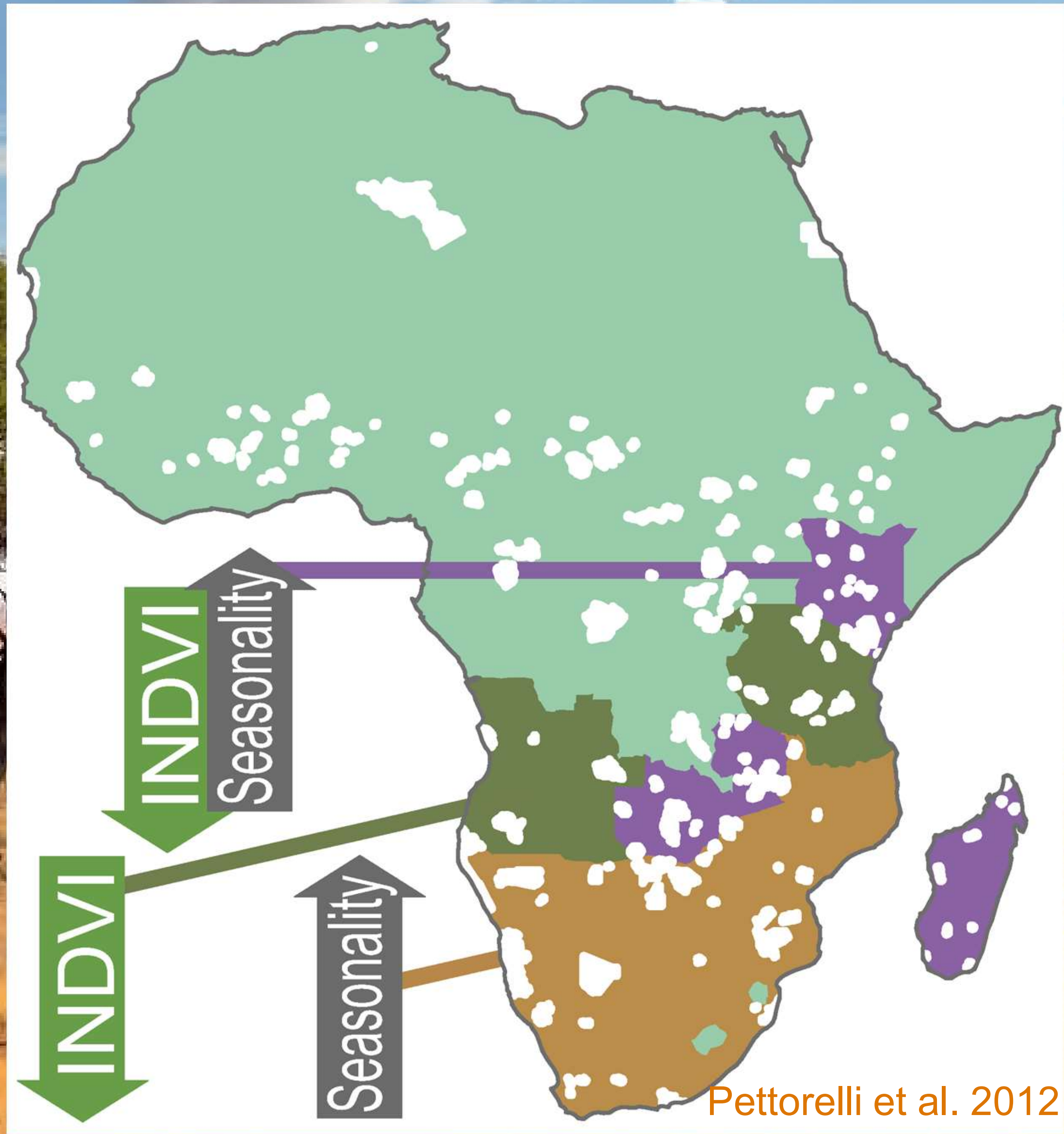
100m recession on average over 2 years (2007 to 2009); up to 170m max



Bangladesh
India

Cornforth et al. 2013

Changes in primary productivity as an example of what can be done

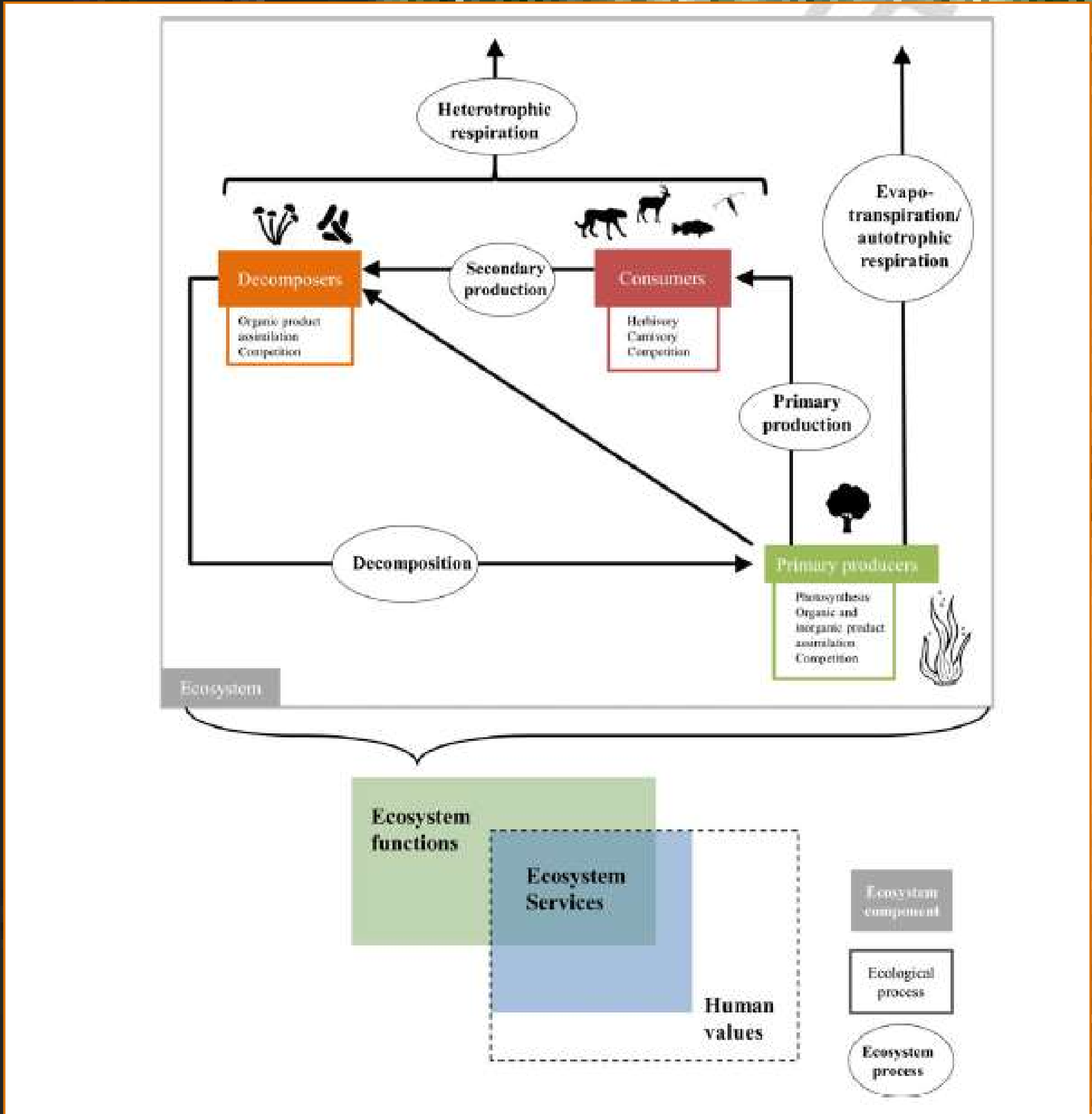


Pettorelli et al. 2012

- 168 protected areas (I and II), 1982-2008 NDVI dynamics analysed

→ *results mostly supported current expectations of CC impacts*

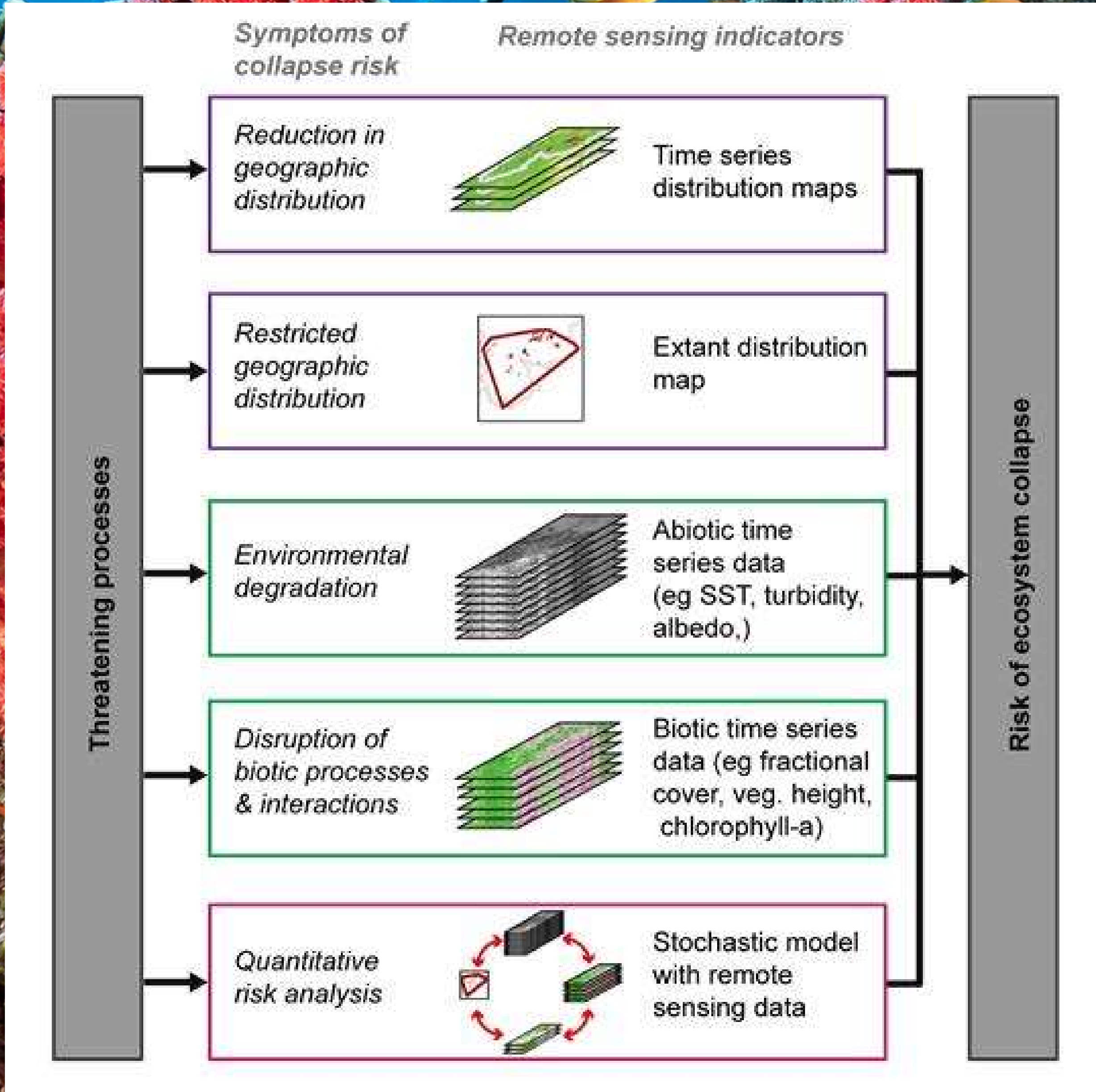
Satellites to track changes in processes and functions



Function	Indicator	Proxy	Satellite (sensor)
Barrier effect of vegetation	Vegetation barriers	Forest cover	Landsat (TM, ETM+, OLI)
			Terra/Aqua (MODIS)
		Tree cover	Terra/Aqua (MODIS)
			Landsat (TM, ETM+, OLI)
	Air quality	Aerosol particles	Terra (MODIS)
			CALIPSO (CALIOP/IIR/WFC)
			CALIPSO (CALIOP/IIR/WFC)
		Nitrogen dioxide	Metop (GOME)
			ENVISAT (Sciamacy)
		Sulfur dioxide	Aura (OMI)
	Wind speed	SRS-based wind speed estimates	QuikSCAT (SeaWinds)
Supporting habitats	Habitat extent	Land cover	ENVISAT (MERIS)
			SPOT (HRV, HRVIR, HRG)
			Terra/Aqua (MODIS)
		Forest cover	Landsat (TM, ETM+, OLI)
			Terra/Aqua (MODIS)
		Tree cover	Terra/Aqua (MODIS)
			Landsat (TM, ETM+, OLI)
		Water body distribution	Terra/Aqua (MODIS)
		Inland water dynamic	Landsat (TM, ETM+)
		Sea ice	Nimbus-7 (SMMR)
			DMSP (SSM/I, SSMIS)
			GRACE (KBR)
			Cryosat (SIRAL)
		Glaciers	Terra (ASTER)
	Habitat quality	Salinity	SMOS (MIRAS)
			SAC-D (Aquarius)

Pettorelli et al. 2017

Satellites facilitate ecosystem risk assessments



Murray et al. 2017


Response

Understanding and predicting distribution

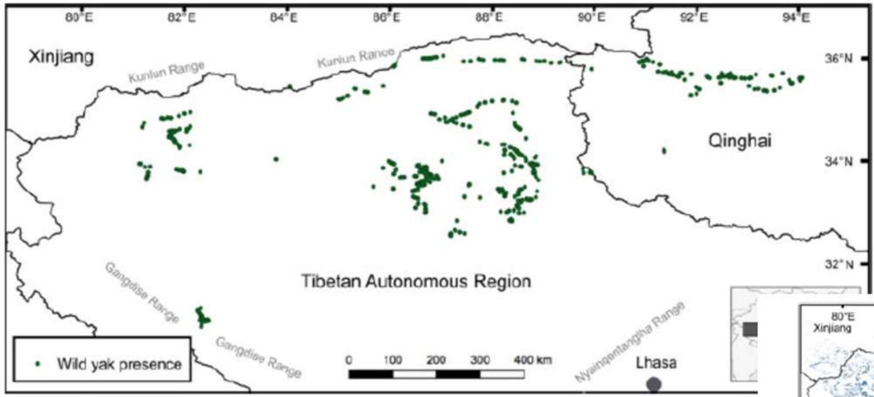


Fig. 1 Distribution of the wild yak *Bos mutus* on the Tibetan Plateau, China. The study area covers c. t
the entire Tibet Interior region defined by the Kunlun mountains in the north and the Gangdise and N
south, with slight eastward extension to incorporate part of the Sanjiangyuan region in Qinghai Provin

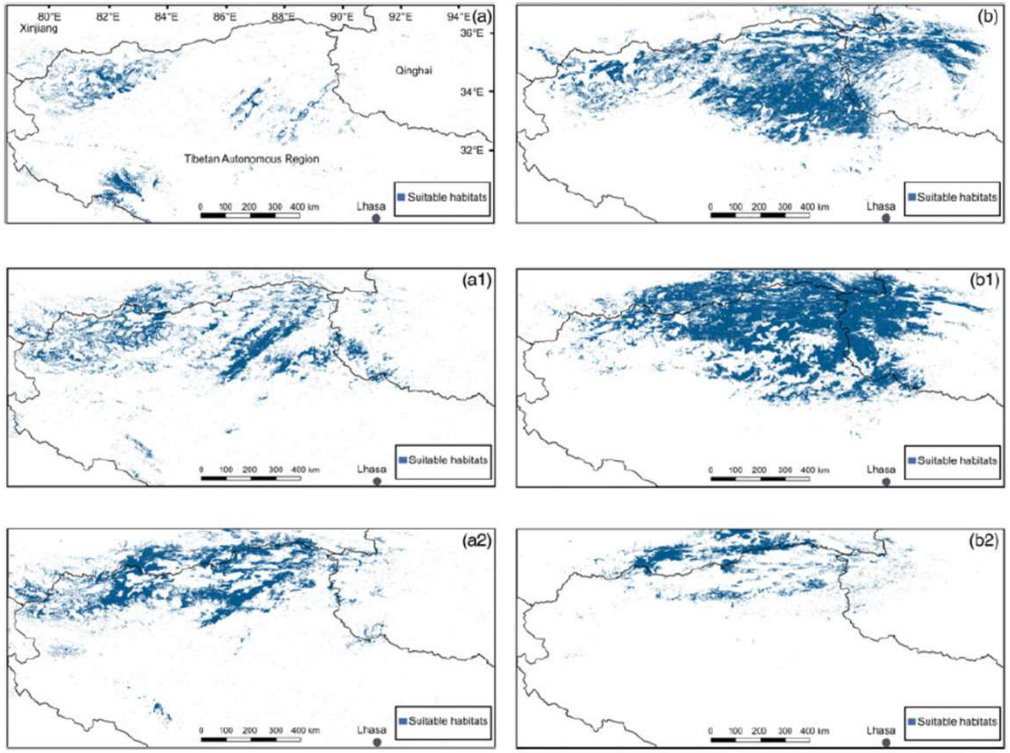
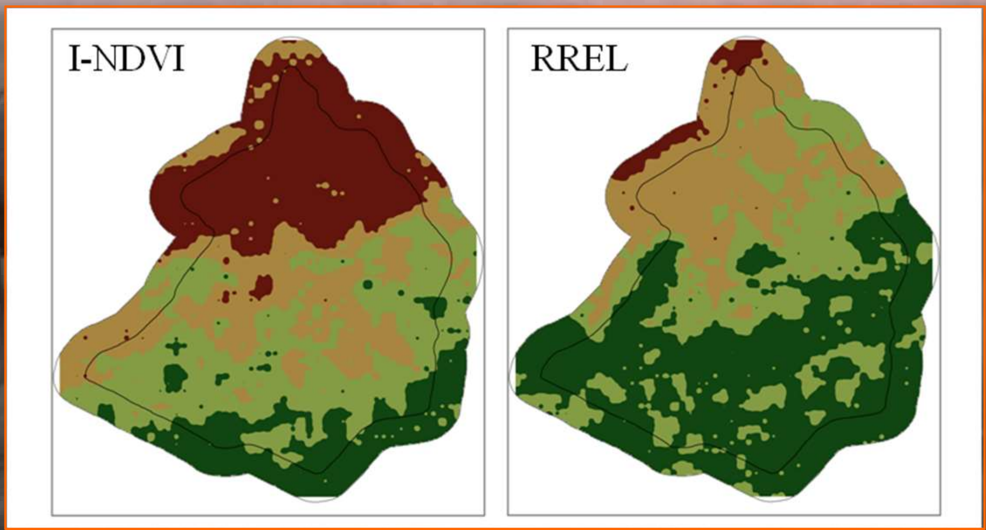


Fig. 3 Distribution of suitable habitat for wild yaks in (a) the vegetation growing season and (b) the non-growing season, and the predicted distributions under the RCP26 scenario (a1 & b1) and under the RCP85 scenario for both seasons (a2 & b2).

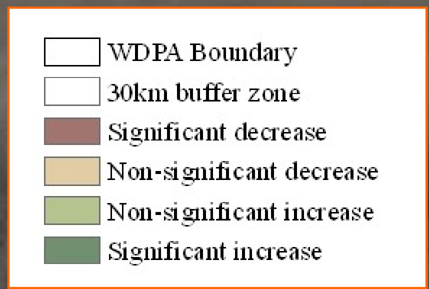
Variables: Climate, topography, distance to nearest village, distance to nearest glacier, NDVI (forage availability)

Informing reintroductions

Scimitar oryx reintroduction in Chad



RREL: level of seasonality
I-NDVI: annual primary productivity



Freemantle et al. 2013

1982-2008 trends in vegetation dynamics in Ouadi Rime Ouadi Achim

Informing translocations

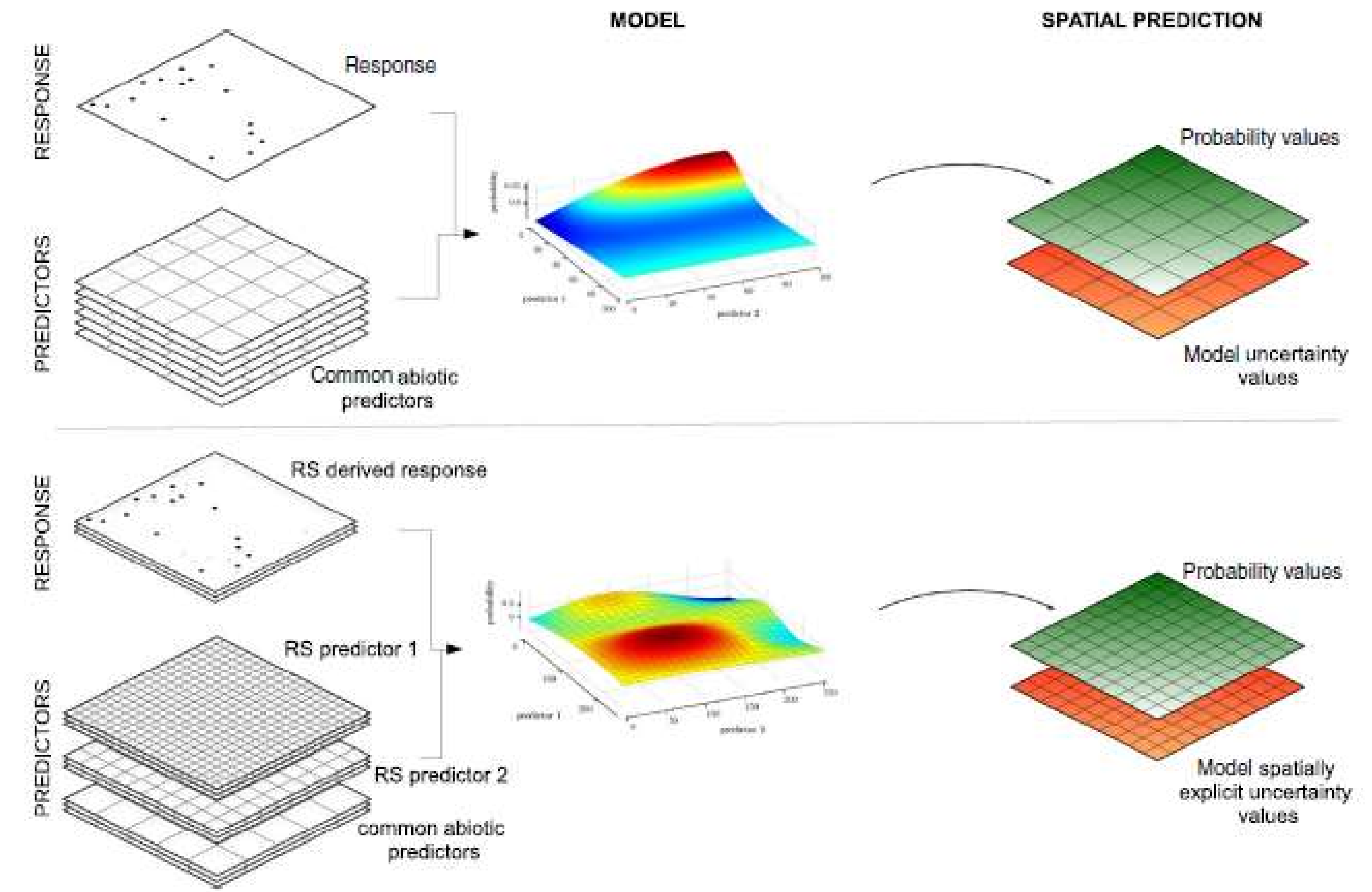


Figure 1. A comparative modeling framework of the current SDMs (above) and the NG-SDMs (below), showing remotely derived response variable and multi-scale predictor variables, including spatially explicit uncertainty of predictor variables. In classical SDMs, uncertainty is often not reported in a spatially explicit manner and one layer per predictor is used. In contrast, NG-SDMs can have a stack of images organized systematically by scales in time to capture each predictor, thus resulting predictions with high accuracy. NG-SDMs, next generation species distribution models.

He et al. 2015

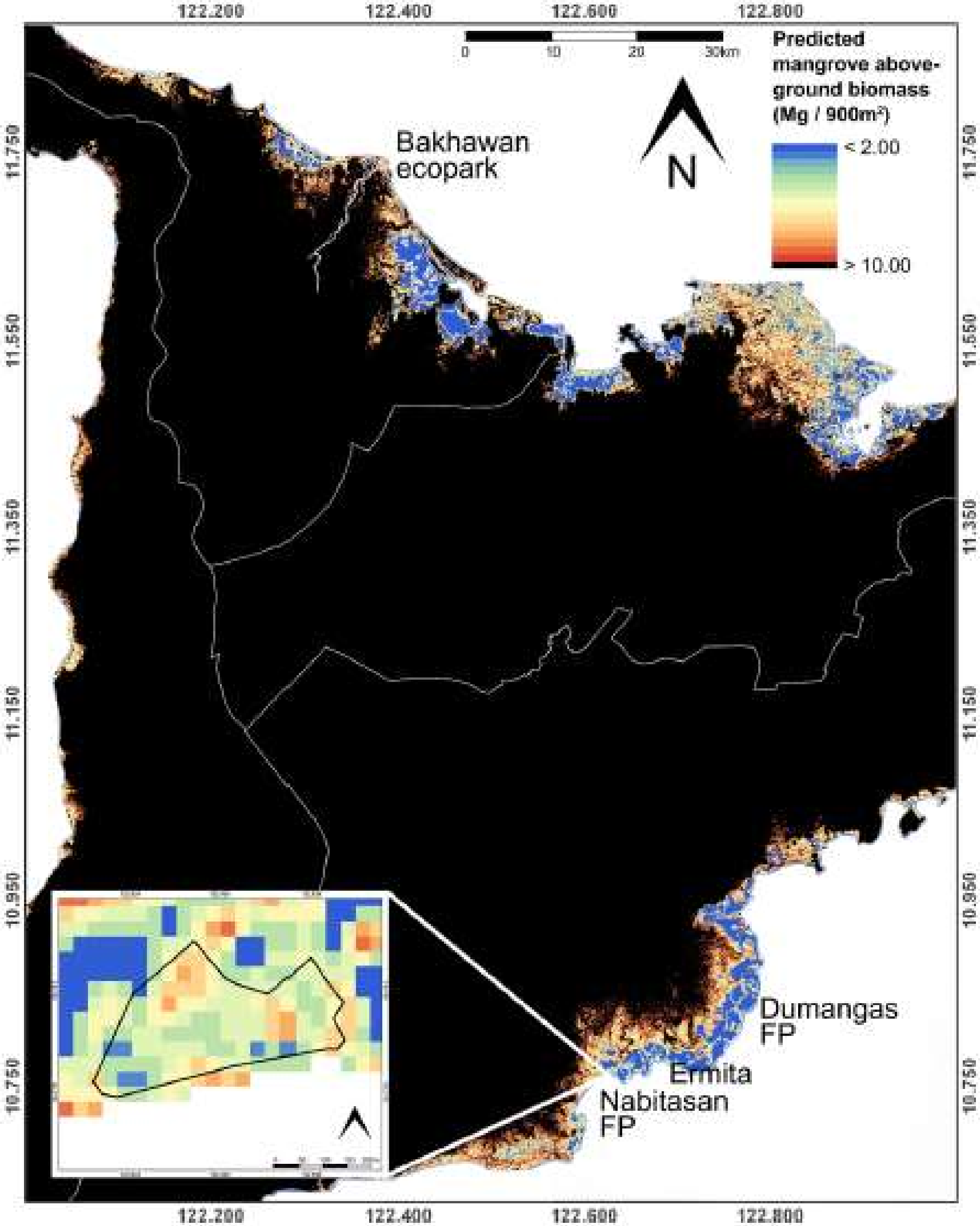


Fig. 4. Predicted aboveground mangrove biomass (Mg 900m^{-2}) across the two SRTM DEM tiles on Panay Island. Blue pixels denote areas of low biomass, while red areas denote higher biomass areas. Dark blue pixels indicate active aquaculture pond areas, and black pixels denote areas with biomass > 10 Mg 900 m^{-2}. N.B. This figure illustrates predictions of areas outside of the distribution of mangroves on Panay Island (e.g. beach forest and terrestrial forest and plantation areas), which were not included in the analyses of this study.

Duncan et al. 2016

Detailed information on ecosystem structure, at large scales

Here helped unveil the potential of abandoned pond reversion to mangroves for climate change adaptation and mitigation

So satellites are pushing traditional monitoring boundaries, but…

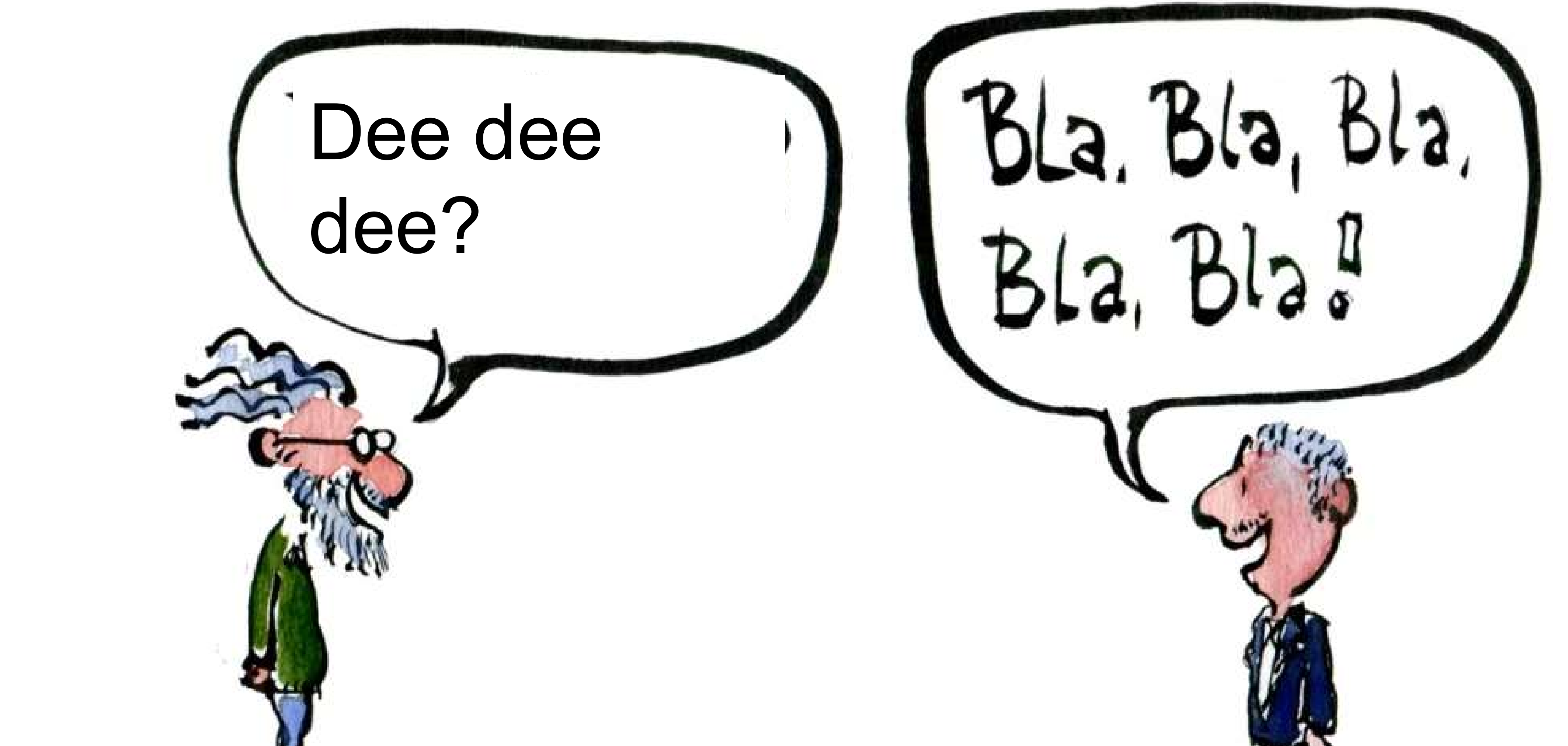
Understanding the limitations

- Choosing which sensor and which resolution: scale issue, quality issue, budget issue
- Trade-off between spatial and temporal resolution
- Usefulness might be a function of the scale, the question and the biological model considered
- RS is no replacement to ground-based data; complementary – best results when both types of data are integrated

Developing a SRS-based monitoring framework means that products need to be developed, understood and used

Pb: not all institutions/countries have the relevant capacities; SRS data are not systematically free; products need to be produced at the right scale, resolution and for a clearly identified purpose; someone need to take the responsibility to produce these products & maintain them

Pettorelli et al. 2016



Developing a SRS-based monitoring framework means that remote sensing experts, space agencies, ecologists/conservationists and policy makers need to talk

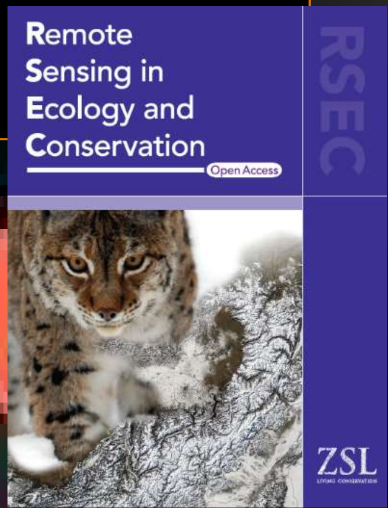
Pb: not many platforms for interdisciplinary talks; not much common understanding; conceptual differences exist; agenda not systematically synchronised; interdisciplinary work not systematically valued in all communities

Pettorelli et al. 2014


MOVING
FORWARD!

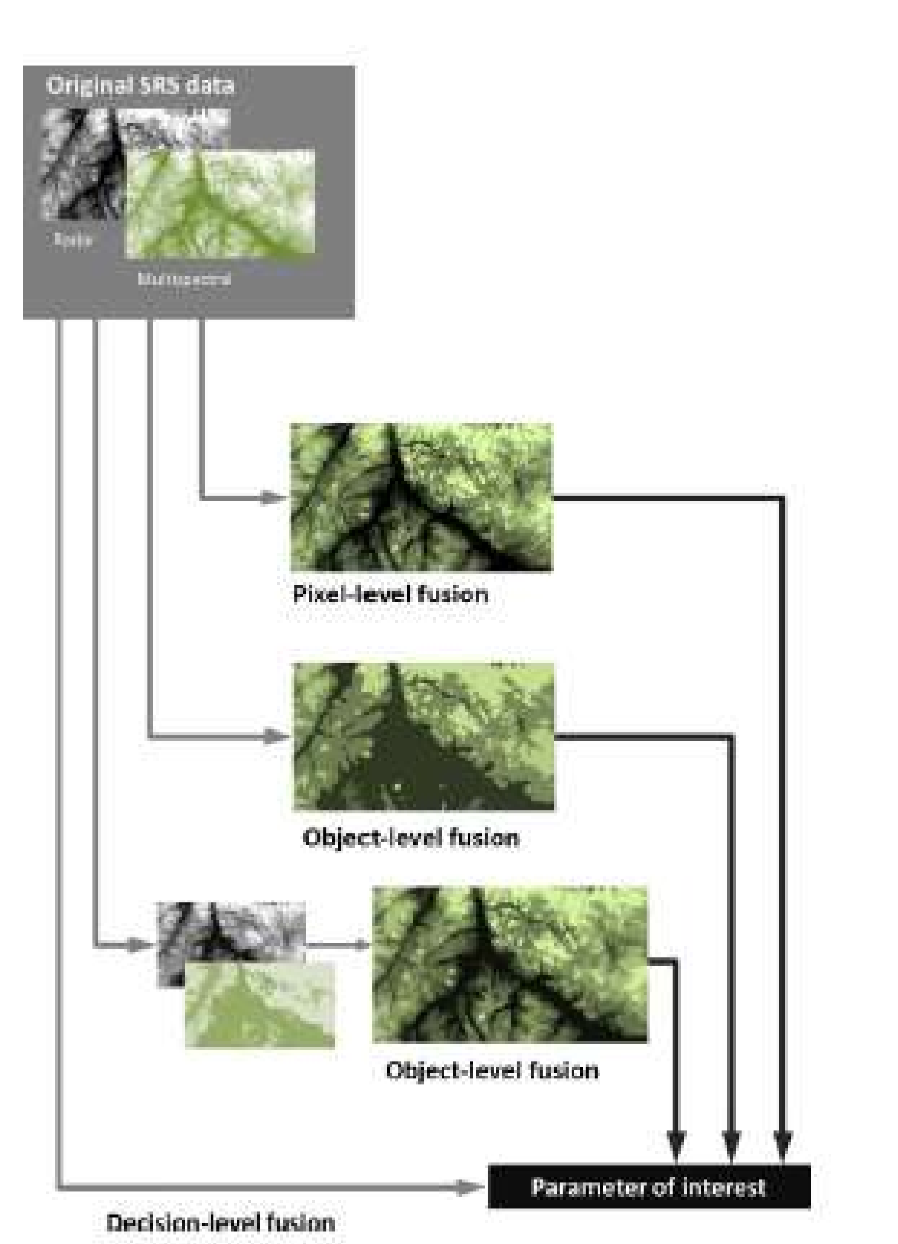
Facilitating interdisciplinary work

- Platforms to facilitate dialogue between RS and biodiversity experts, space agencies and policy makers (eg GEO)
- Capacity building is key for RS data to become more used, and therefore more useful: Animove, EcoSens, CRSnet, webinars & MOOC
- SRS data access: constant improvements by space agencies
- Tools: increase availability of open source software
- Synchronisation of scientific agendas: *Remote Sensing in Ecology and Conservation (Wiley)*



Schulte To Buhne & Pettorelli 2018

Capitalizing on new opportunities



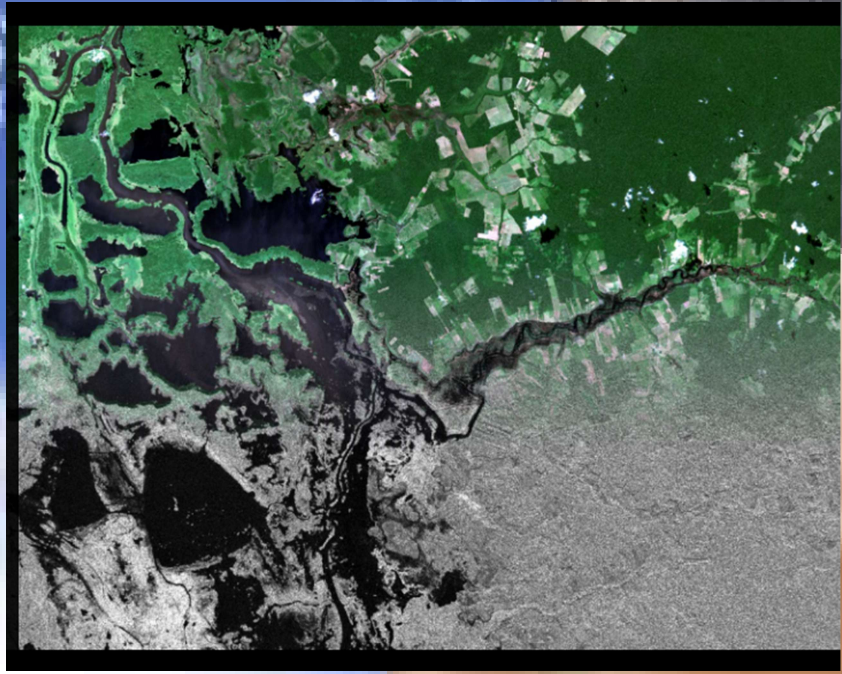
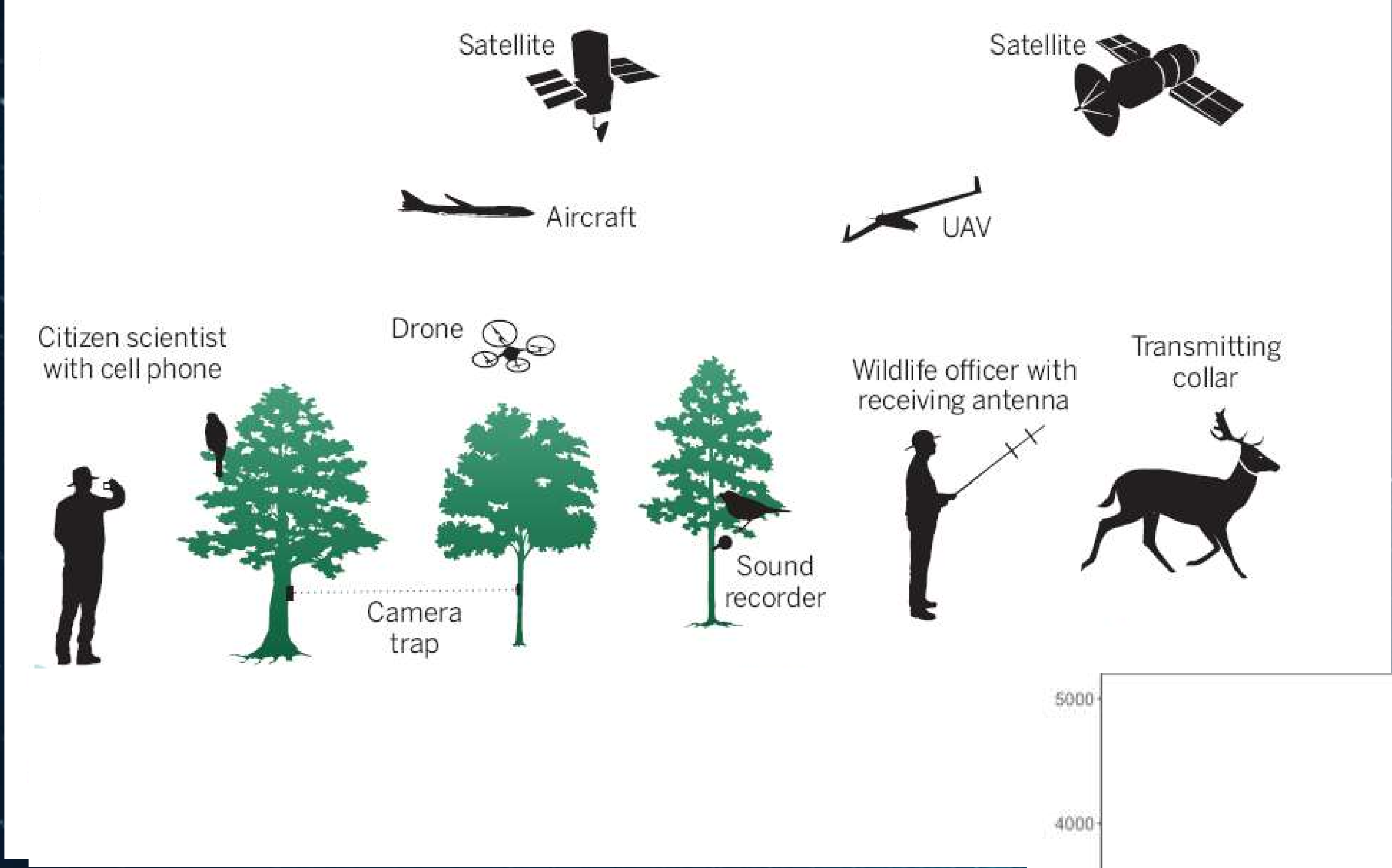
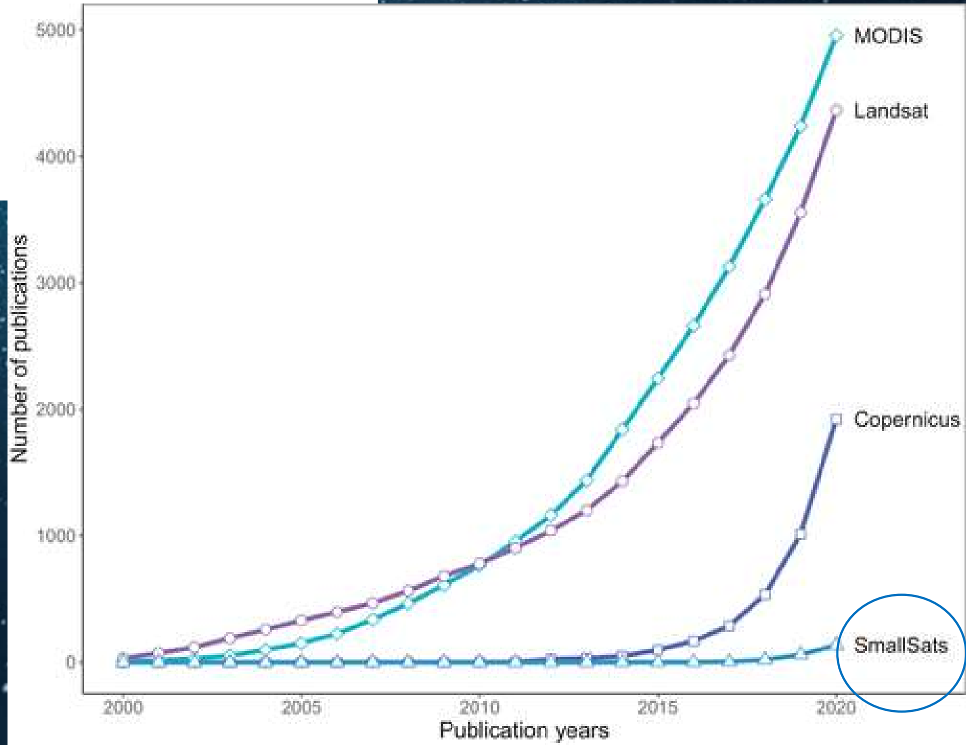


FIGURE 1 Schematic overview of multispectral-radar SRS data fusion techniques. The parameter of interest can be a categorical variable, like land cover, or a continuous variable, like species richness. In pixel-level fusion, the original pixel values of radar and multispectral imagery are combined to yield new, derived pixel values. Object-based fusion refers to (1) using radar and multispectral imagery is input into an object-based image segmentation algorithm, or (2) segmenting each type of imagery separately before combining them. Finally, decision-level fusion corresponds to the process of quantitatively combining multispectral and radar imagery to derive the parameter of interest (by e.g. combining them in a regression model, or classification algorithm)



Integration of information from different sensors, Cubesats/nanosatellites



Still a lot to be done...

- Better integration of training at university – don’t get the students specialised too quickly!
- Likewise, need to get RS experts to attend the ecological meetings; get ecologists to attend the ISRSE/ISPRS
- Clear funding opportunities for interdisciplinary work; better valuation of applied, interdisciplinary work
- What do we need in priority? consultation pathways to answer this question not in place
- No portal for easily accessible validation data (potential for citizen science projects)

Thank you!

More information

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WWF guidelines on SRS for conservation to be distributed for free very soon!