Assessment of ecosystem diversity and urban boundaries:

Combining surface reflectance and emissivity

Petya K. E. Campbell*, ** and Kurtis J. Thome**

* Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County
** NASA Goddard Space Flight Center

Project Collaborators

- *Dr. Nicholas Coops (UBC, Vancouver, CA)*
- *Dr. Nona R. Chiariello (Stanford University, CA)*
- *Professor Goodenough (CFS Victoria, BC)*
- *Dr. Tony Trofymow (CFB Esquimalt, BC)*
- *Dr. Elizabeth Middleton (NASA/GSFC)*

The project will also provide research experience for graduate and undergraduate students. They will participate through established programs with GSFC, UMBC and FIU, Miami, providing support to process and organize data, and assisting with preparation of reports.

Background

Problem: With the increase in the population density and the ever expanding conversion of land from rural to urban, the urban heat island (UHI) effect has become a problem of critical importance. *Land cover type and land surface temperature (LST) in urban and rural areas display significant differences, such as higher LST and lower moisture content, with increasing urbanization.*

Hypotheses: The distribution, and spectral and spatial characteristics of optical and thermal data co-vary, in significantly different way in natural and anthropogenic environments; The combination of high spectral resolution optical and thermal infrared imagery will provide a powerful capability for more precise land cover type discrimination and ecosystem monitoring than possible using current satellite systems.

Science Questions

- How do natural and anthropogenic ecosystem compositions compare with regard to land cover types, diversity, function, and spectral properties?

- How do environmental characteristics, associated with natural factors and effects of urban pressure and UHI, affect vegetation composition and function, and ecosystem health?

- How do species, functional type, and ecosystems biodiversity composition differ spectrally, in relation to gradients of anthropogenic and non-anthropogenic stressors?

- How do natural ecosystems respond to impinging environmental changes, particularly to urban growth and land cover change and the associated impacts of urbanization?

Goals

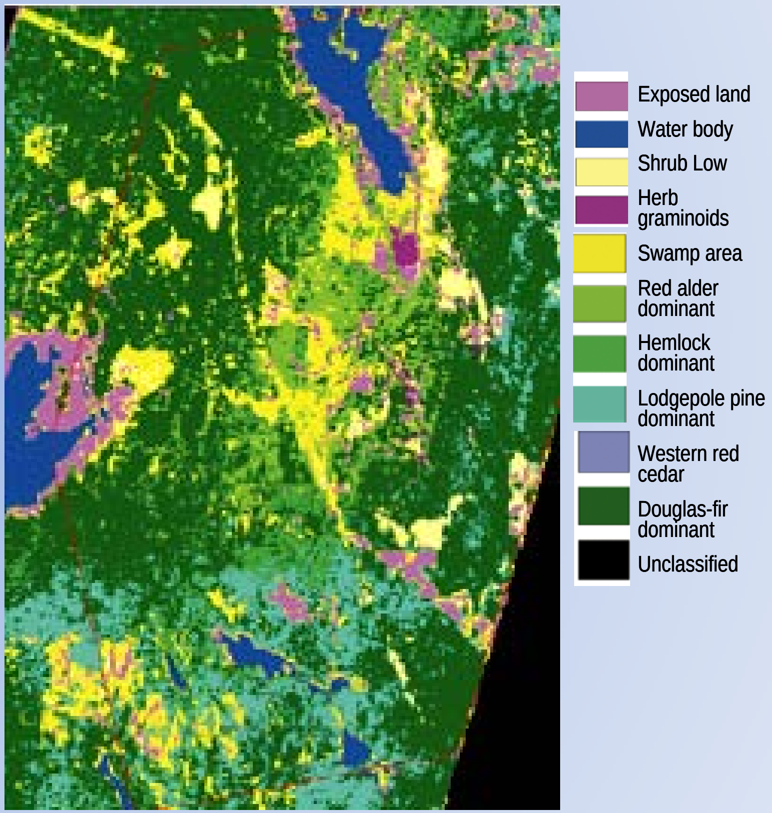
1. Using together VSWIR and TIR measurements, to assess the differences in natural and anthropogenic ecosystem composition and their vegetation bio-physical parameters.
2. Provide data that can elucidate how urbanization impacts the environment. Seeking common spectral trends associated with vegetation function, induced by natural and anthropogenic factors such as effects of urbanization and UHI, we would contribute toward improving the current capabilities for vegetation assessments.
3. Generate HyspIRI-like datasets and tools for work with the data.

Study Sites

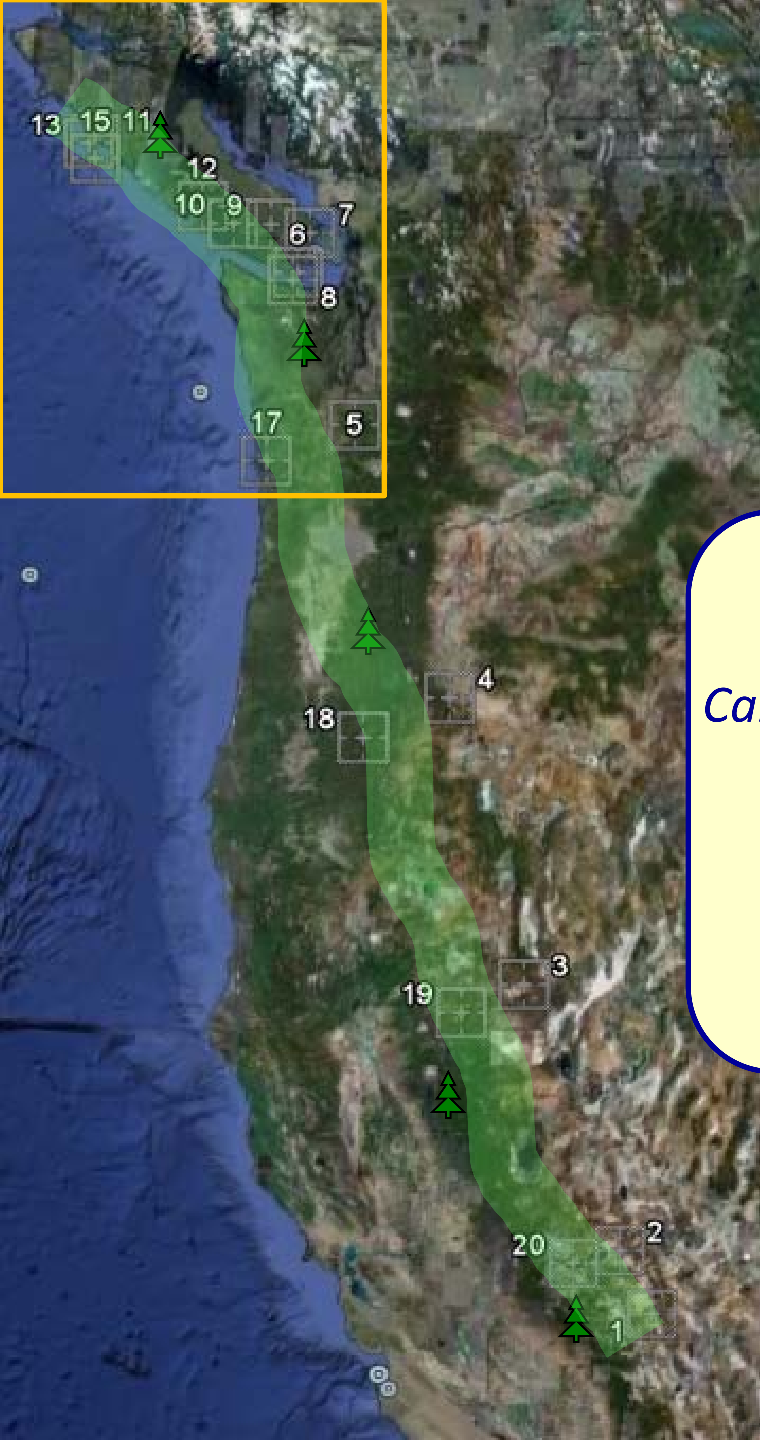
The study includes two independent locations with different regional climate and ecosystem types. Data aggregated to higher and lower spatial scales will be compared for the same locations.

<u>*Vancouver Island, Canada/Hoquiam, WA*</u>: includes portions of unique natural ecosystems such as the Olympic National Park, WA and the Great Victoria Watershed (GVWD) test site on Vancouver Island, BC and rural, sub-urban and urban environment associated with the city of Victoria, BC.

<u>*Jasper Ridge Biological Preserve (JRBP), CA*</u>: provides Mediterranean-type climate, with five major vegetation types: evergreen forest, deciduous forest, chaparral shrublands, herbaceous perennial wetlands, and annual grasslands



Hyperion land cover classification of the Greater Victoria Watershed (GVWD) test site on Vancouver Island (September 10 2001, Goodenough et al. 2003).



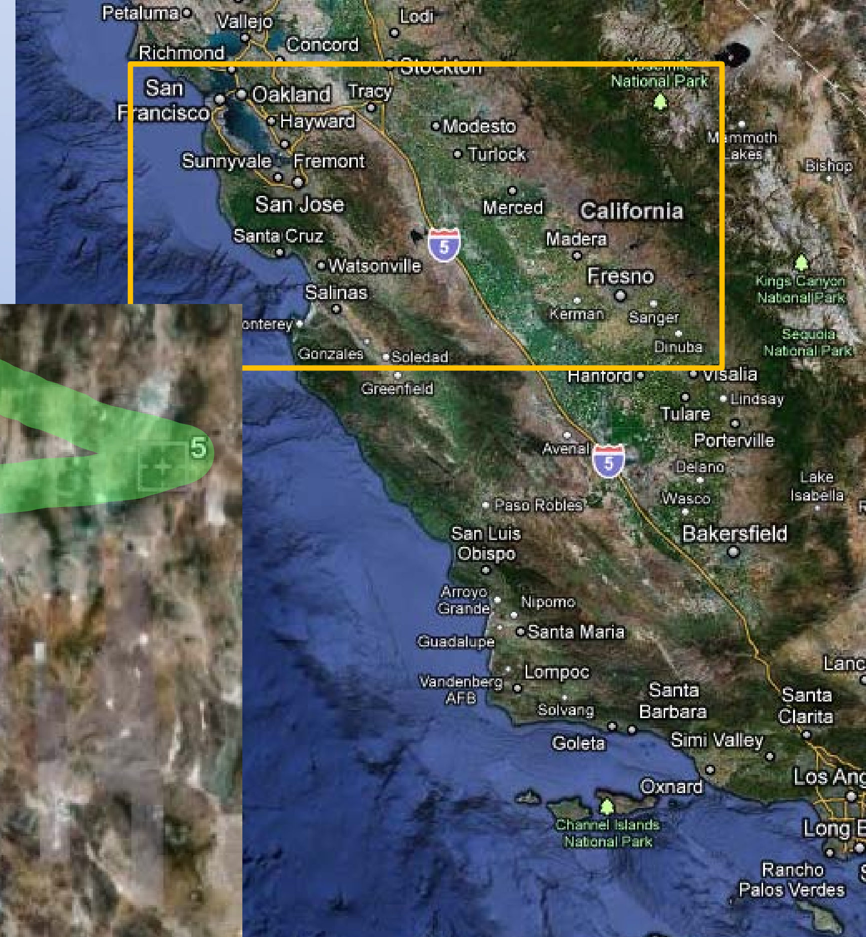
Area 1:

Vancouver Island
Canada/Hoquiam, WA

Data:

MASTER & AVIRIS
ASTER
EO-1 Hyperion

Area 2:
Jasper Ridge Biological Preserve (JRBP), CA



Data:

MASTER & AVIRIS

Calibration of TIR and VISWIR data

Lake Tahoe is a high-altitude, large-sized lake on the California-Nevada border near Reno, Nevada.

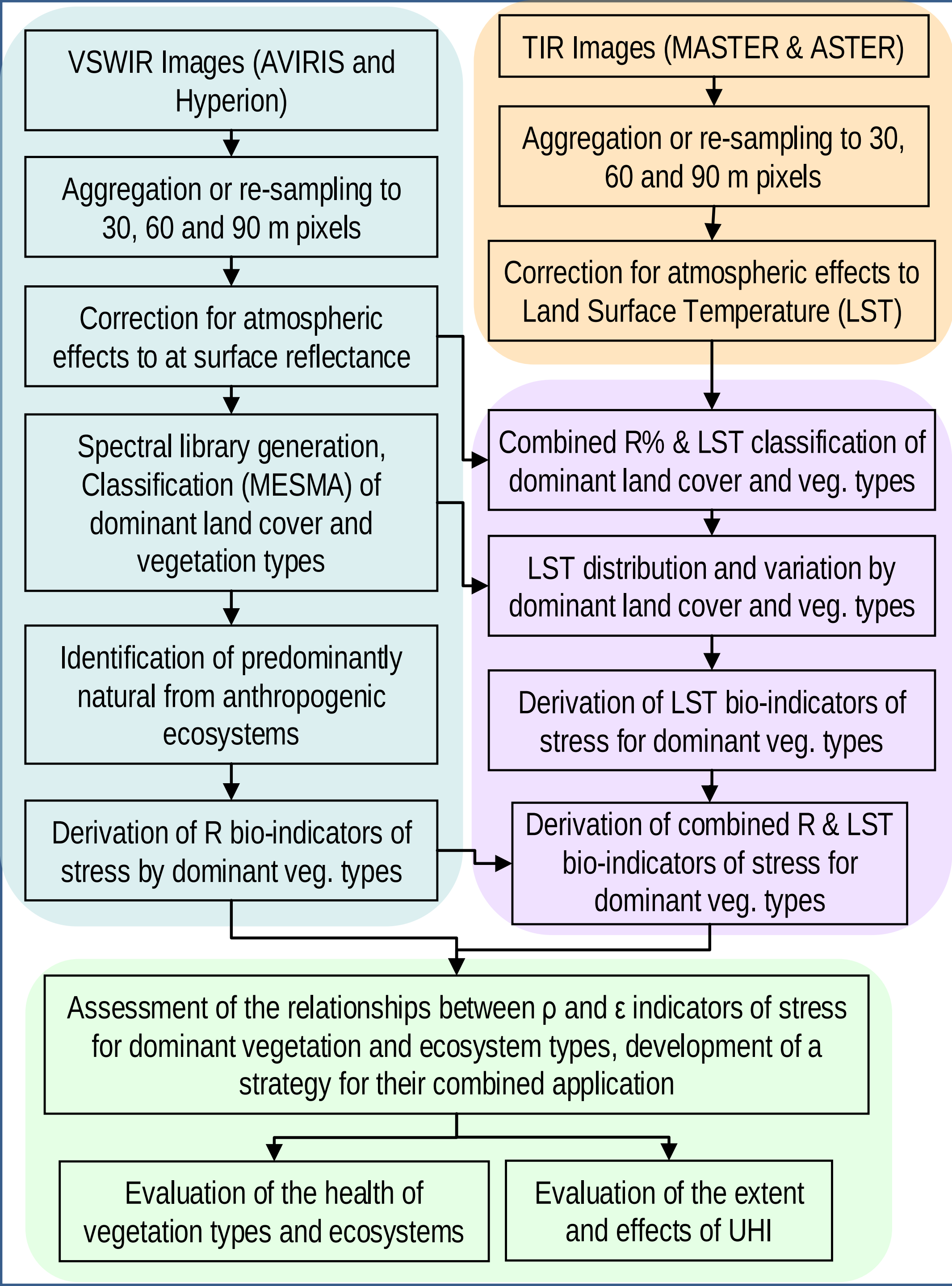
The *Ivanpah Playa* test site is approximately 3 km by 7 km in size with excellent spatial uniformity, hence its use for the vicarious calibration of reflective bands.

Sample MASTER imagery from the Ivanpah, test site, reflectance (left), vegetation in green; thermal (right) side.

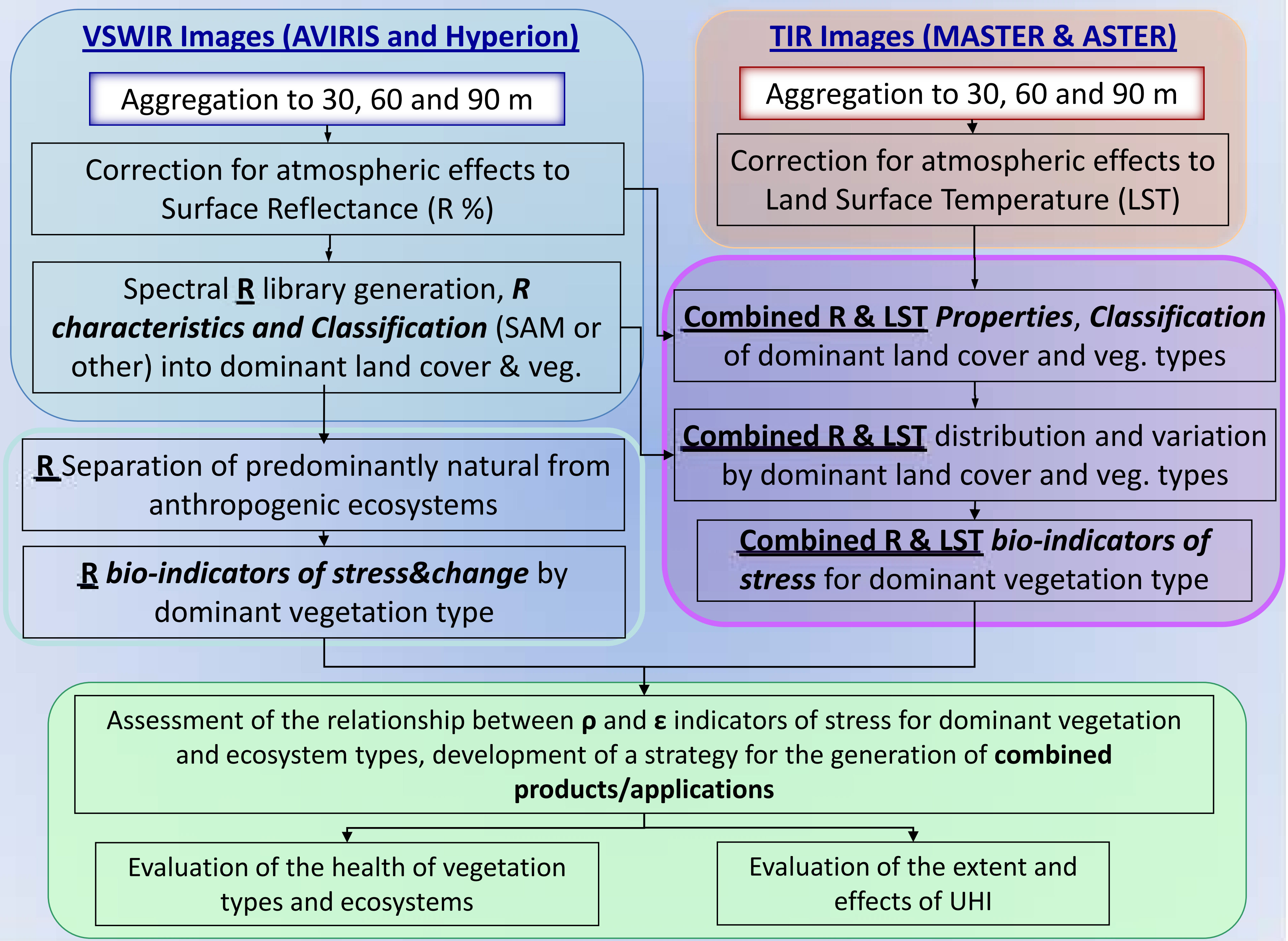
Data

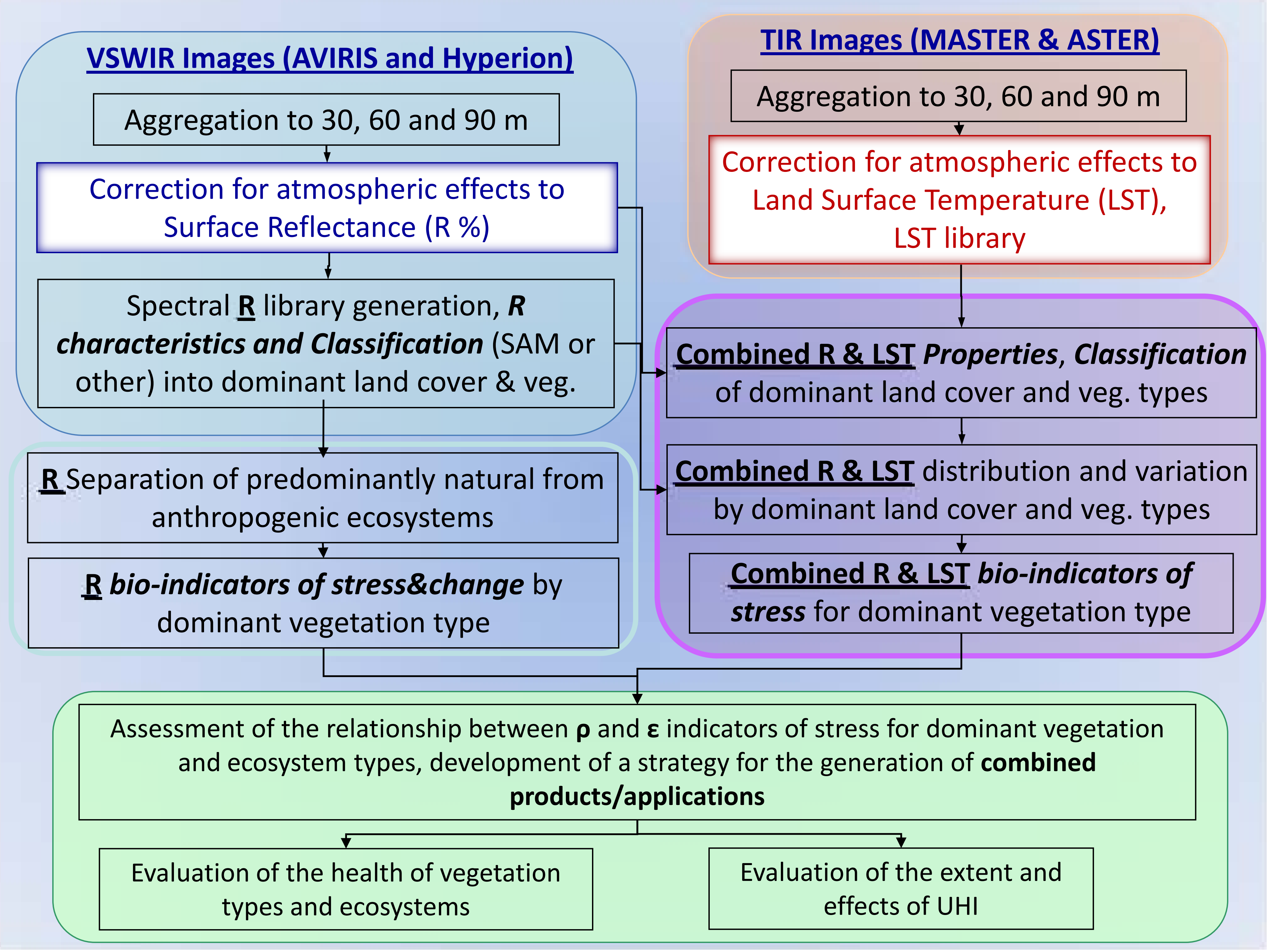
Parameters	*HyspIRI VSWIR*	AVIRIS	EO-1 Hyperion
Spectral range	*0.38 - 2.5 µm*	0.4 - 2.5 µm	0.4 - 2.5 µm
Band width	*10 nm*	10 nm	10 nm
number of bands	*~ 220*	224	220 (196 calibrated)
Spectral Coverage	*contiguous*	contiguous	contiguous
Spatial resolution	*60 m*	20 m	30 m
Swath width	*145 km*	11 km	7 km
Thermal infrared emission instruments and data characteristics (summary/overview)			
HyspIRI TIR	**Number of bands**	**Spectral bands (discrete)**	**Spatial resolution**
TIR channel centers	*8*	*3.98, 7.35, 8.28, 8.63, 9.07, 10.53, 11.33, 12.05 µm*	*60 m*
Swath width	*600 km*		
ASTER	**Number of bands**	**Spectral bands (discrete)**	**Spatial resolution**
Spectral range 0.5 - 12 µm	14		vary
VNIR channel centers	4	0.54, 0.66, 0.81, 1.65 µm	15 m
SWIR channel centers	5	2.17, 2.21, 2.26, 2.33, 2.40 µm	30 m
TIR channel centers	5	8.30, 8.65, 9.10, 10.60, 11.30 µm	90 m
Swath width	60 km		
MASTER	**Number of bands**	**Spectral bands (discrete)**	**Spatial resolution**
Spectral range 0.4 - 13 µm	50		5-25 m (B200) 10-30 m (DC-8) 50 m (ER-2)
0.45-2.39 µm	25	0.05 µm a part	
3.15-5.27 µm	15	0.15 µm a part	
7.75-12.87 µm	10	0.40-0.80 µm a part	
Total field of view	85.92°		

Capability of HyspIRI data for assessments of vegetation type and function



The analysis will be conducted using the native data resolution (~ 30 m), and aggregated to 60 and 90 m images, comparing the results.


VSWIR Images (AVIRIS and Hyperion)
Aggregation to 30, 60 and 90 m
Correction for atmospheric effects to Surface Reflectance (R %)
Spectral R library generation, R characteristics and Classification (SAM or other) into dominant land cover & veg.
R Separation of predominantly natural from anthropogenic ecosystems
R bio-indicators of stress&change by dominant vegetation type
TIR Images (MASTER & ASTER)
Aggregation to 30, 60 and 90 m
Correction for atmospheric effects to Land Surface Temperature (LST)
Combined R & LST Properties, Classification of dominant land cover and veg. types
Combined R & LST distribution and variation by dominant land cover and veg. types
Combined R & LST bio-indicators of stress for dominant vegetation type
Assessment of the relationship between ρ and ε indicators of stress for dominant vegetation and ecosystem types, development of a strategy for the generation of combined products/applications
Evaluation of the health of vegetation types and ecosystems
Evaluation of the extent and effects of UHI



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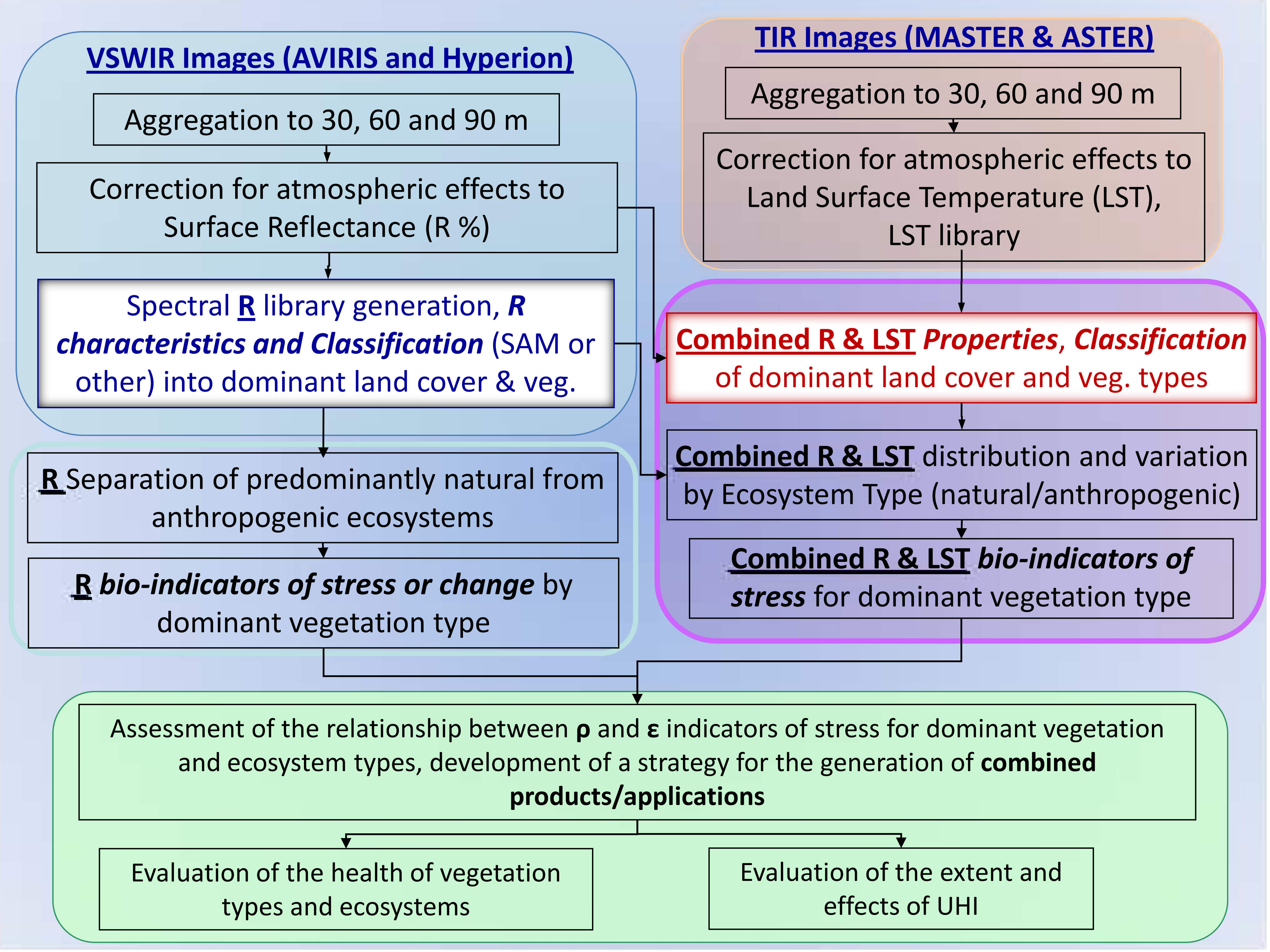
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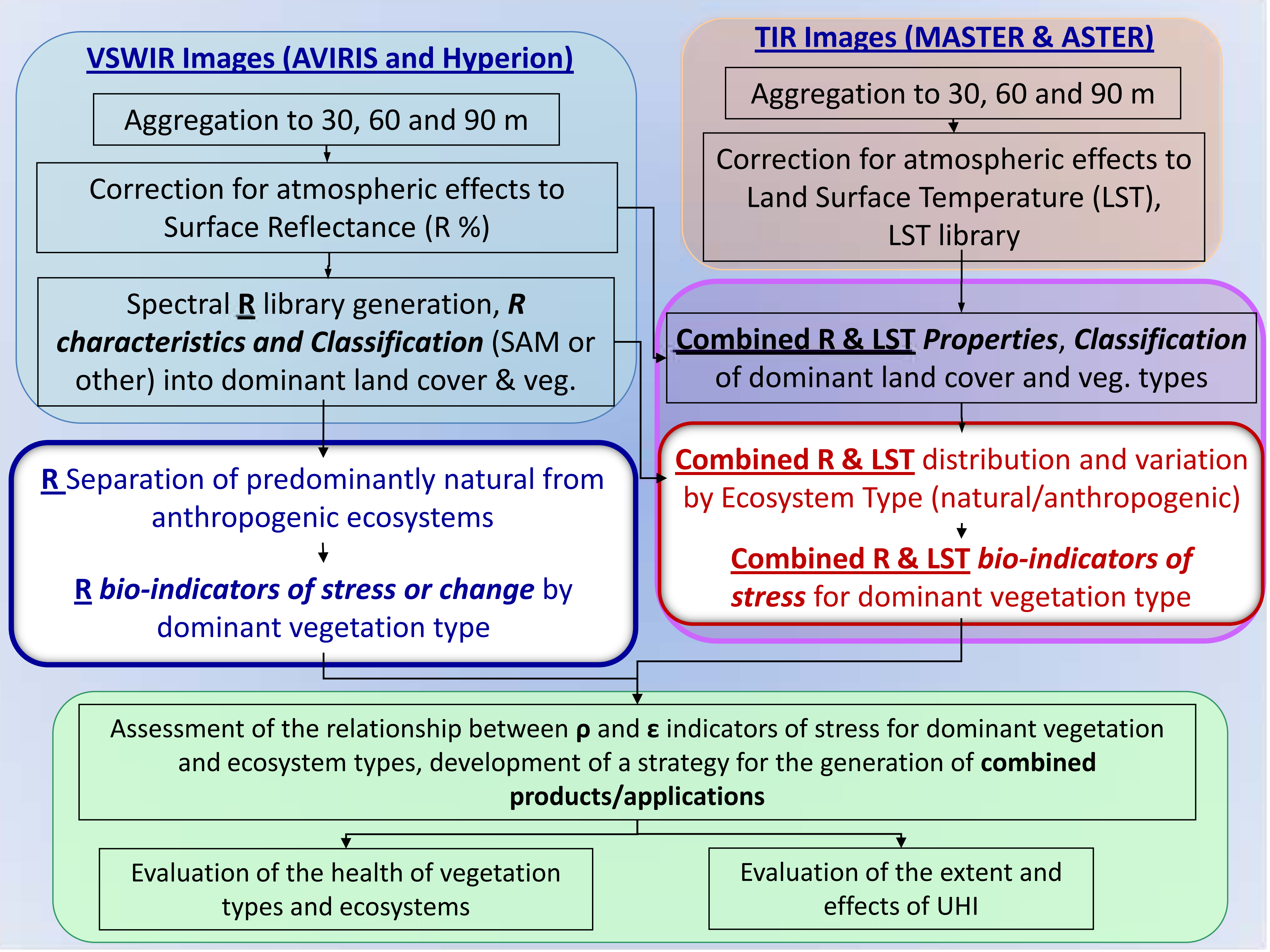
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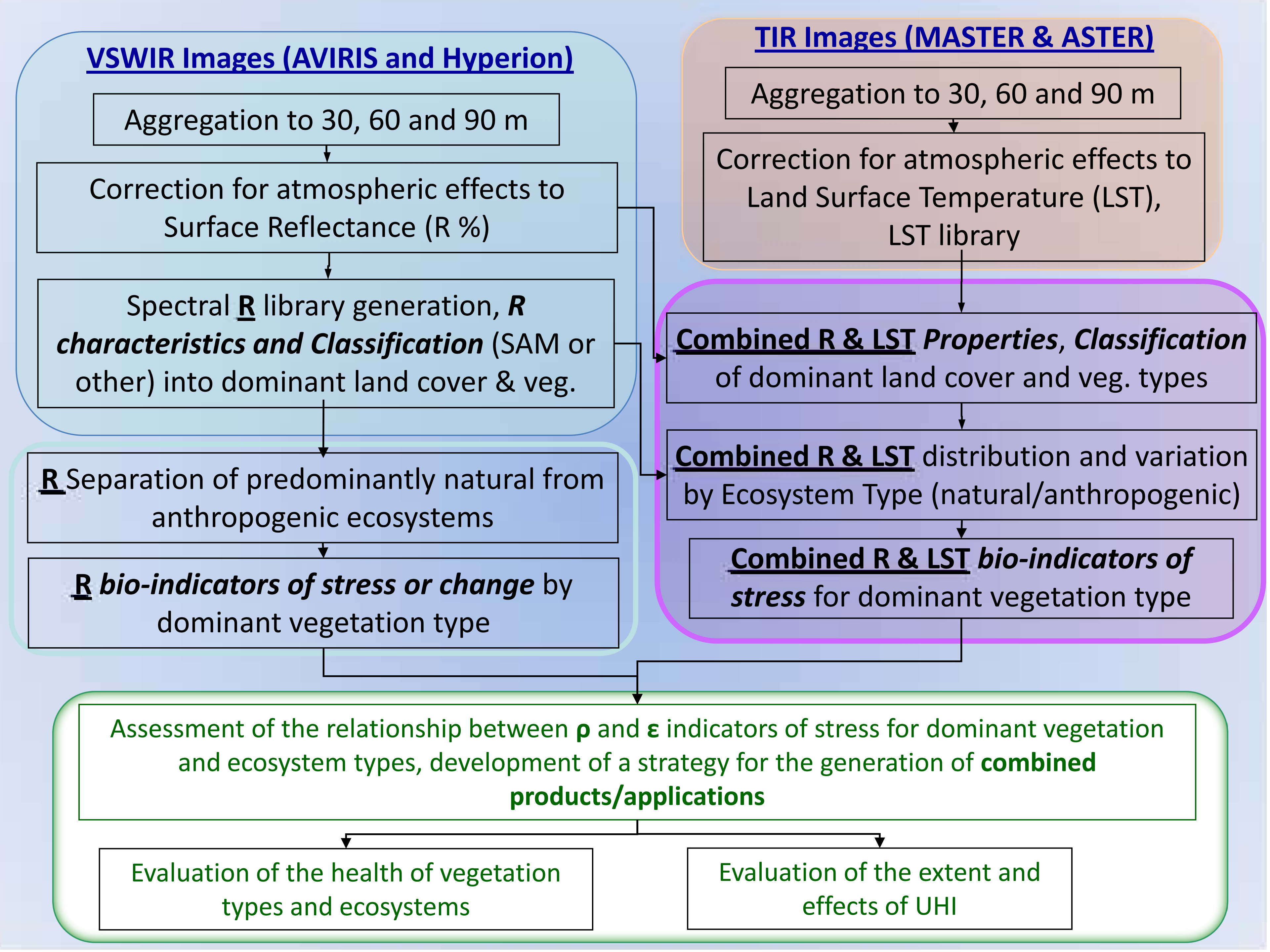
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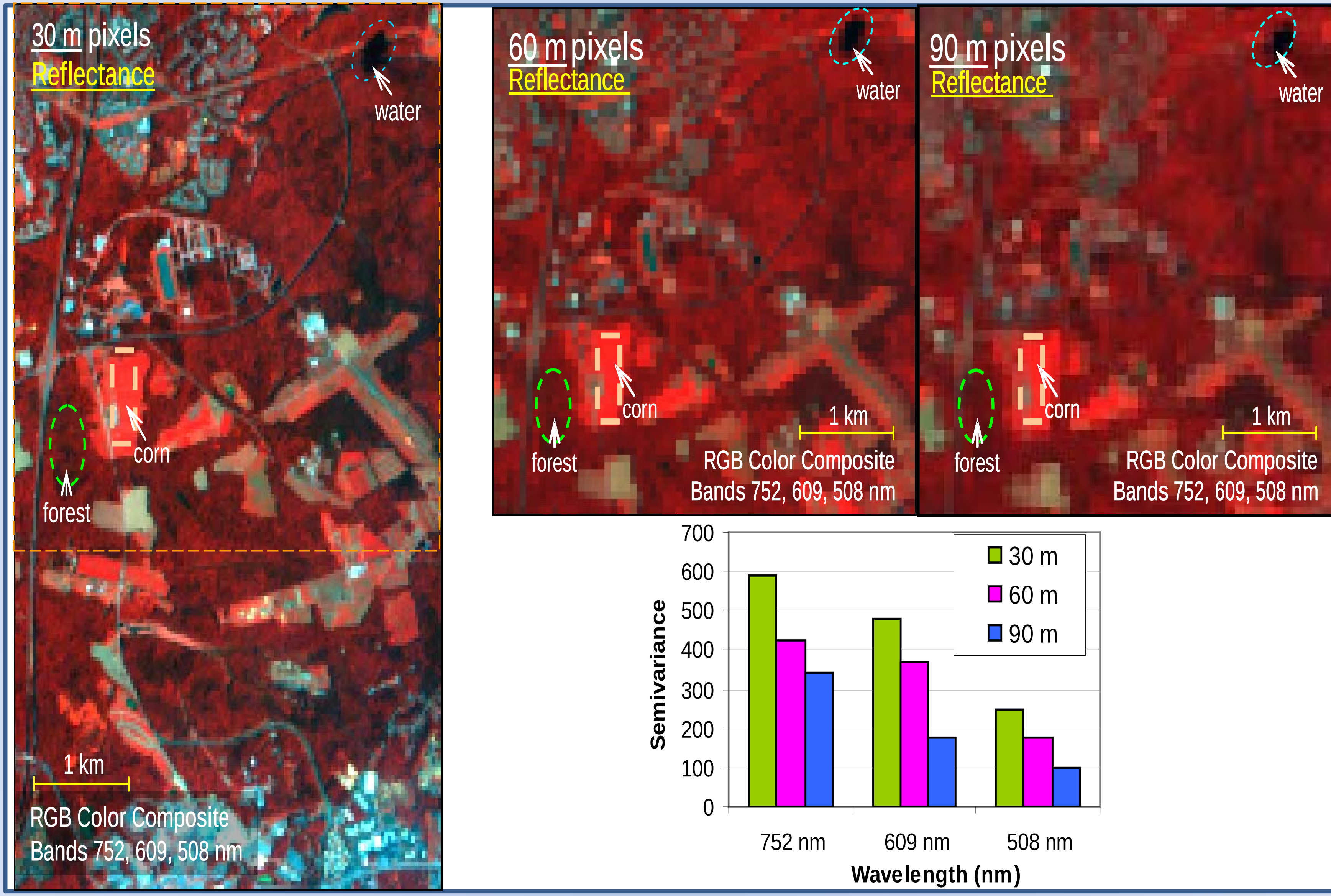
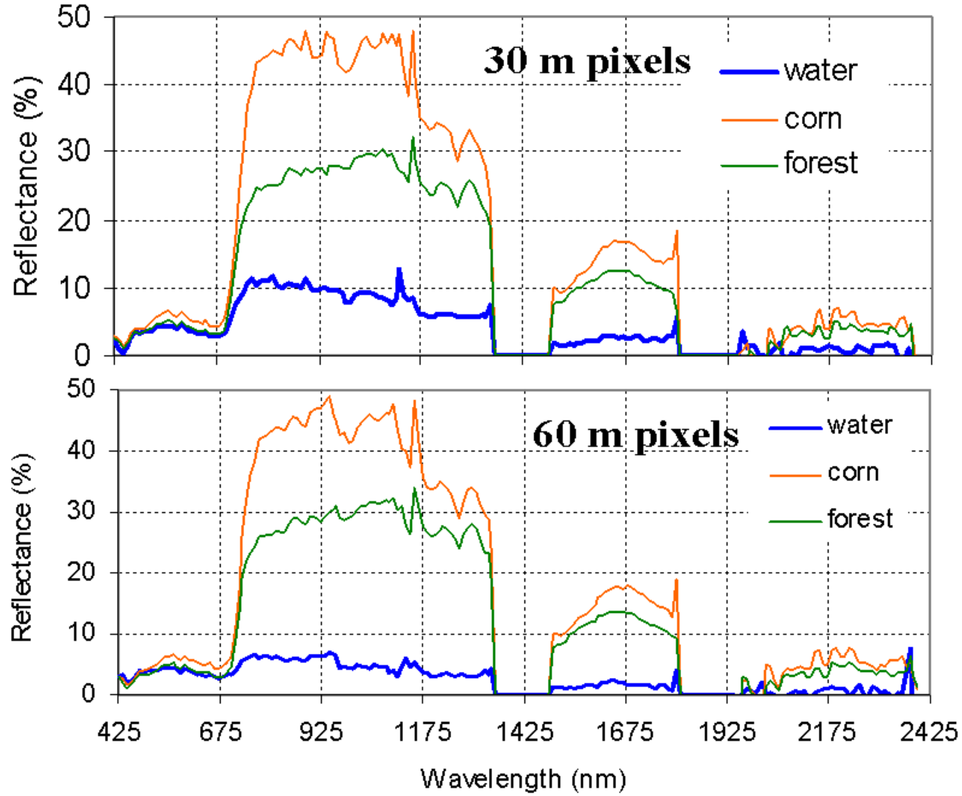
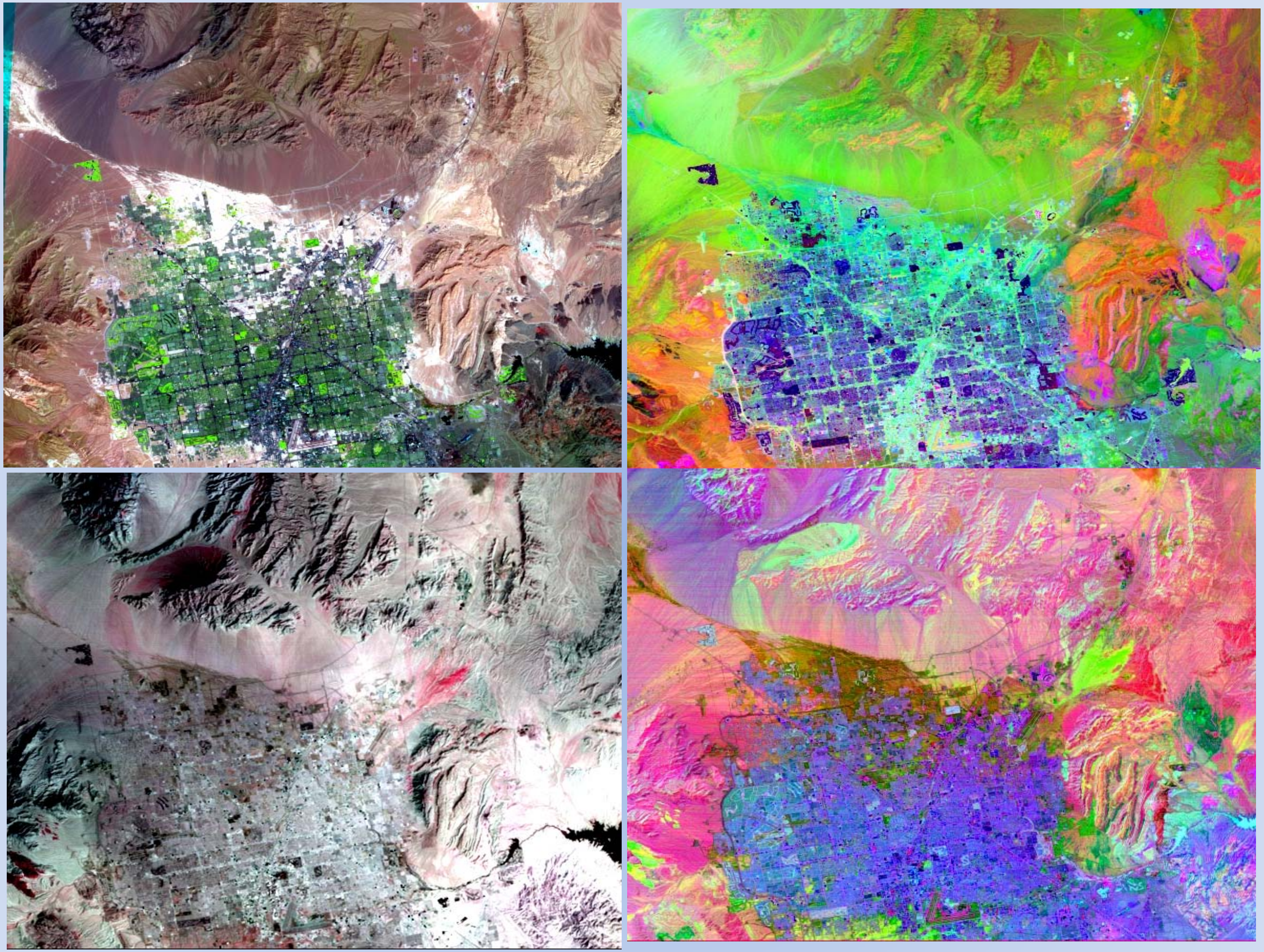


Examples of Hyperion reflectance image (30 m pixels) and the re-sampled to 60 and 90 m subset, demonstrate the spatial differences between HyspIRI-like data (60 m) and 30 and 90 m data.



Pixel size	Vegetation Indices: V1	PRI	REIP	Dmax	NDWI	NDVI	Albedo water	corn	forest
30 m	1.81	-0.14	721	0.749	0.14	0.81	0.03	0.20	0.14
60 m	1.88	-0.15	721	0.748	0.15	0.82	0.04	0.20	0.13

While there were significant differences in the spatial variability between the original 30 m and the aggregated to 60 and 90 m data, the spectral properties of the major land cover types did not significantly differ.



ASTER imagery, Las Vegas area: VSWIR aggregated to 90 m (upper left, vegetation in green) and TIR bands (lower left), principle components of reflective bands (upper right) and all VSWIR and TIR (lower right).

Bio-physical parameter	Spectral bio-indicators *(examples)*	References
VSWIR indicators		
Chlorophyll in crops	$(R_{NIR}/ R^{-1}_{720\text{-}730}) - 1$	Gitelson et al., 2005
Canopy greenness	$EVI = G * \frac{R_{NIR} - R_{red}}{R_{NIR} + C_1 R_{red} - C_2 R_{blue} + L}$	Huete et al. 2002
Chlorophyll concentration estimation	$TCARI / OSAVI = \frac{3*[(R_{700} - R_{670}) - 0.2*(R_{700} - R_{550})*(R_{700} / R_{670})]}{(1+0.16)*(R_{800} - R_{700})/(R_{800} + R_{670} + 0.16)}$	Haboudane et al. 2002, Zarco-Tejada et al. 2004
Efficiency of photosynthesis	PRI=(R570-R531)/(R570+R531)	Gamon et al., 1992, Suarez et al. 2008
Canopy foliar water content	$NDWI = \frac{R_{NIR} - R_{1240}}{R_{NIR} + R_{1240}}$	Gao, 1996
Canopy foliar water content	$SIWI = \frac{R_{NIR} - R_{1640}}{R_{NIR} + R_{1640}}$	Fensholt and Sandholt, 2003
Vegetation stress	Average (R675…. R705)	Vogelman, 1993
Veg. structure and foliar biomass	NDVI = (R800-R670)/(R800+R670)	Deering, 1978
Stress/Chlorophyll	D714/D705, where D is product of first derivative transformation of R	Entcheva, 2004
Stress/ Chlorophyll	Dmax/D705, where Dmax is the maximum of D in the 670-730nm region	Entcheva, 2004

Bio-physical parameter	Spectral bio-indicators *(examples)*	References
<u>TIR indicators</u>		
Water stress (100% vegetative cover)	CWSI = (ΔTcanopy – ΔTnws)/(ΔTmax – ΔTnws), where Tmax for non-transpiring and Tnws is “non-water-stressed” baseline temperature. 0 = no stress, 1 = maximal stress, Δ = (Tsurface - Tair)	Idso et al. 1981, Jackson, 1981
Irrigated vs. non-irrigated (100% veg.)	IG = (Tmax – Tcanopy)/(Tcanopy – Tnws),	Jones 1999
Increase in sensible heat due to UHI	Rn = G + LE + H, Rn + A = G + LE + H; where Rn is net radiation, G ground heat, LE latent heat, H sensible heat, A anthropogenic heat	Kato and Yamaguchi, 2005
<u>Combined VSWIR & TIR indicators</u>		
Relative water status (Veg. cover < 100%)	WDI trapezoid, defined by the fractional vegetation cover and Δ = (surface - air temperature); 0.0 well-watered (latent heat flux is limited only by atmospheric demand), 1.0 no available water	Moran et al. 1994
Water supply	WSVI=NDVI/Ts, where Ts is the brightness temperature at ~11 µm, the smaller this index is, the more severe the drought is	Hatfield et al. 2008
Temperature–vegetation dryness index	TVDI = (*T*s – *T*s_min)/(*a* + *b*NDVI – *T*s_min), where *T*s_min is the minimum temperature in the triangle; and *a* and *b* are the interception and slope of the dry edge, respectively	Wand et al. 2004
After WSVI and TDVI	Like WSVI and TVDI, but using VSWIR parameters sensitive to water stress, such as NDWI or SIWI.	New, to test

Deliverables and Milestones

- Best estimates of atmospheric properties needed to atmospherically correct the two HyspIRI-like data sets;
- Radiometric calibration coefficients for the sensors used to create the HyspIRI-like data sets;
- Algorithm to spatially convolve the airborne or spaceborne imager data sets to 30, 60, and 90 m spatial resolution;
- Classifications of HyspIRI-like data for a broad range of natural and anthropogenic ecosystems and vegetation functional types;
- Development of HyspIRI-like spectral bio-indicators of ecosystem health; and
- Presentation materials for the HyspIRI workshop and final report delivered one month prior to the completion of the project.

Expected Results

- Through the combined use of reflective and emissive data, the proposed work will evaluate the suitability of HyspIRI for delineating ecosystem functional types and tracking the conversion of land from rural to urban.
- The research will produce two HyspIRI-like data sets combining reflectance and thermal data, which will be used to assess the potential of HyspIRI data for delineating land cover and vegetation types, discriminating natural versus urban ecosystems, and assessing ecosystems diversity and health.
- In addition, the work will produce methods and tools for work with the HyspIRI data.

Thank You