

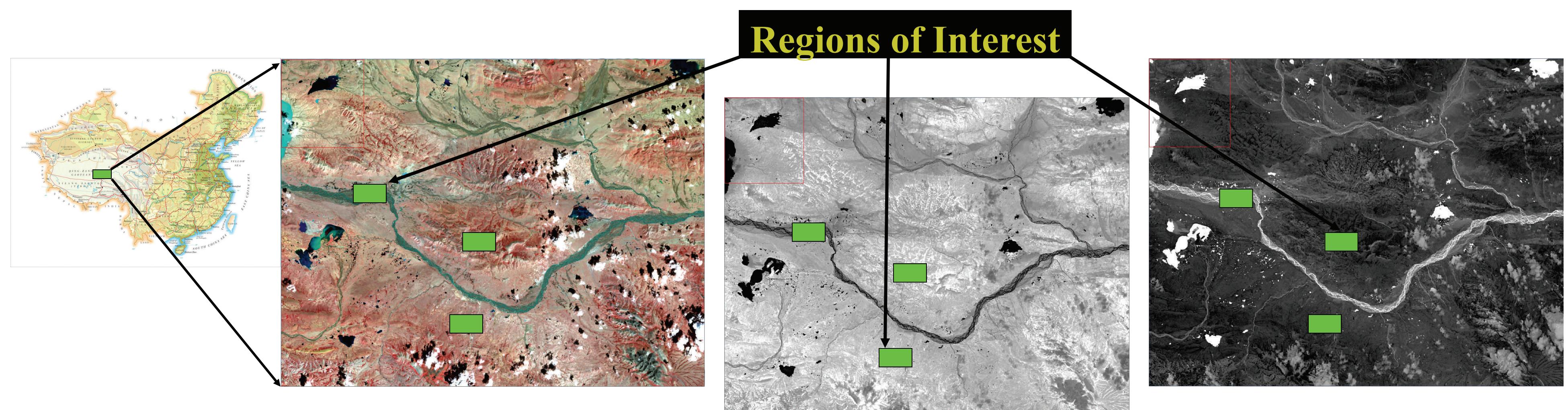
Vegetation and Water Change on the Tibetan Plateau: Case Study of Sanjiangyuan

Background

Sanjiangyuan, the source region of the Yellow, Yangtze, and Mekong rivers, is the highest cold marsh climate in the world. Located in the center of the Tibetan Plateau, Sanjiangyuan is not heavily studied given its remoteness, restricted access, and harsh climate. A 2001 study released by researchers at China's Northwest Normal University used Landsat TM imagery from 1986 and 2000 to show significant losses in ecologically productive land types such as grassland and wetlands, and increases in, predominantly, "unused" or barren lands. Since then, few studies have assessed the quality of land in Sanjiangyuan from the perspective of vegetation health and availability of water. This study attempts to assess the change in level of vegetation health and water levels over the period 2000 to 2010 using Landsat TM imagery. Specifically, this study employs the indexes NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) and compares their results over time to show changes in vegetation and water levels, respectively.

Methodology

NDVI (calc: $NDVI = (NIR-R)/(NIR+R)$) highlights the absorption of sunlight by chlorophyll in the red band (R) of the electromagnetic spectrum and the reflectance of plant mesophyll in the near-infrared region (NIR). High NDVI values indicate abundant and healthy vegetation. Similarly, NDWI (calc: $NDWI = (G-NIR)/(G+NIR)$) combines the reflectance of water picked up by low wavelengths of NIR and the reflectance of water in the green band. NDVI and NDWI are combined as $NDVI-NDWI$ to eliminate the low values of NDVI that water bodies reflect and corresponding high values of NDWI. This calculation allows improves delineation of water and non-water land cover. Finally, a regression of reflectance values at the 0.86μm wavelength on NDWI exposes the degree to which soils have lost (or gained) moisture over time. This is possible because reflectance at or below 0.86μm in the NIR band exposes water, and if soils contain water then NDWI values should be positive. Negative NDWI values, therefore, indicate dry and barren land.



In examination of these indexes, this study completes the following regressions:

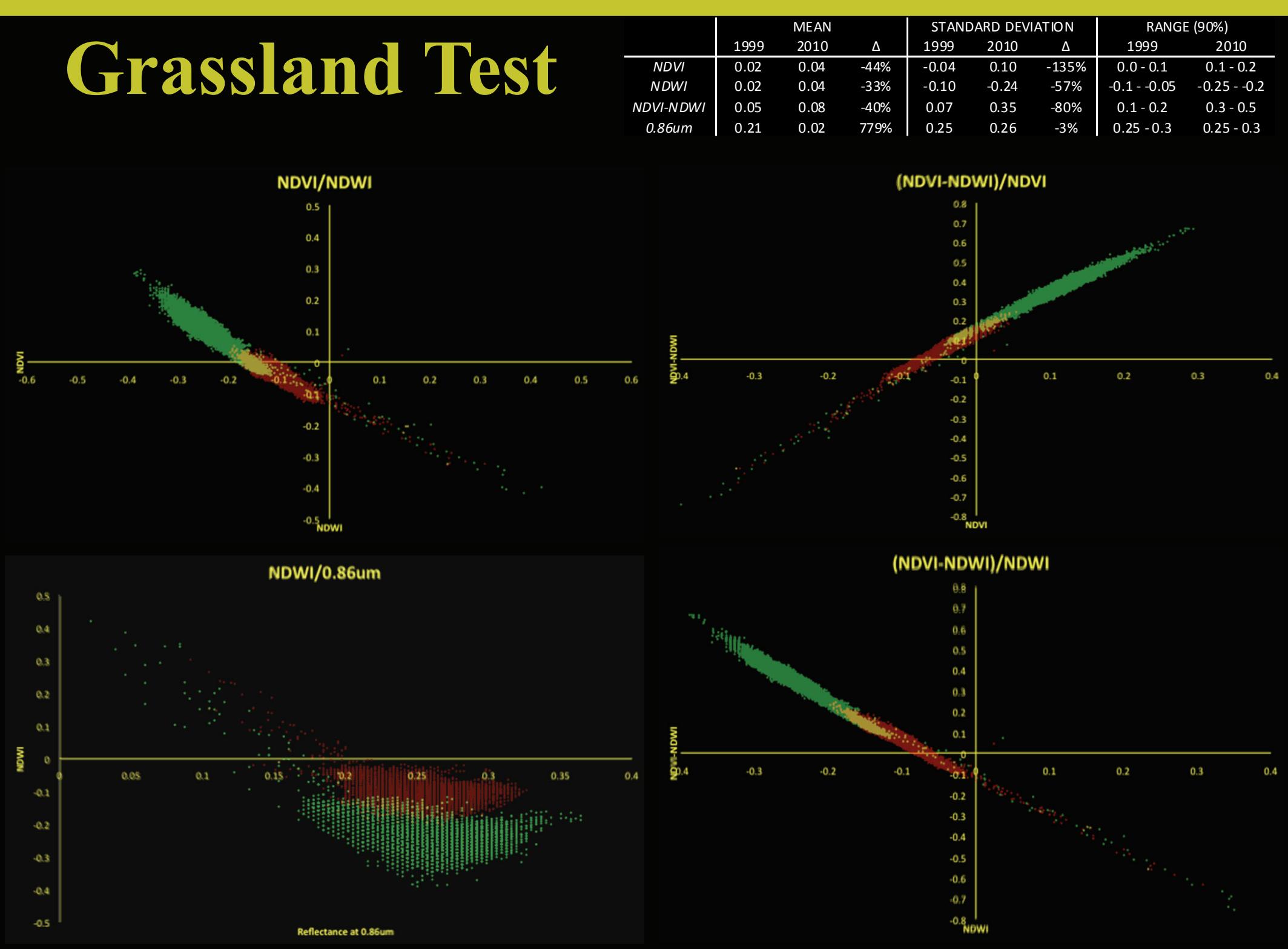
$NDVI$	$NDVI-NDWI$	$NDVI-NDWI$	$NDWI$
$NDWI$	$NDWI$	$NDVI$	$Reflectance \text{ at } 0.86\mu\text{m} \text{ Wavelength}$

Three regions of interest (grassland, riverbed, & low altitude mountains) are compared by index. The change in mean, standard deviation, and range of pixel values for each region is provided for NDVI and NDWI values.

Results

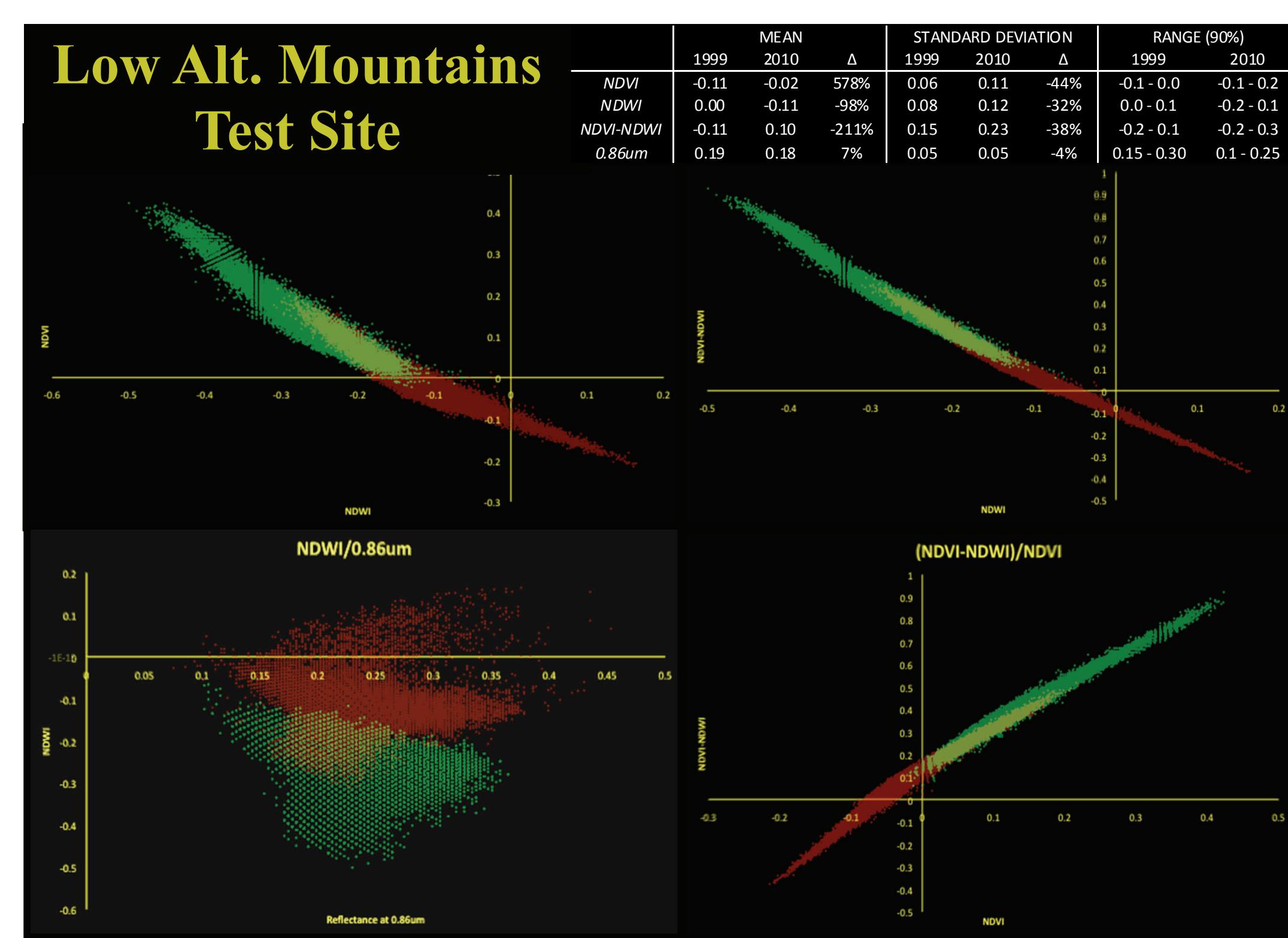
This study is a hybrid of two techniques that utilize NDVI and NDWI to determine levels of vegetation and water cover of land. Lacking in the two techniques derived from a literature review was that time series comparison. In determining whether or not a change in vegetation and water levels had occurred, time series comparison was successful in six test sites in the Sanjiangyuan region, and significant in five of the six. Understanding the causes of the significant changes observed in this study are outside the scope of the study itself, but a literature has been developing over the past twenty years pertaining specifically to the Tibetan Plateau's climate. Given the body of research examining precipitation levels over the past two decades, it is unlikely changes in indexes are due to changes in precipitation on the Tibetan Plateau.¹³ With no significant irregularities in rainfall, there remain a number of possible reasons for the drying of the Sanjiangyuan region. Two categories; human-induced degradation and climate change, seem to be the leading suspects. In Sanjiangyuan, with an average altitude of over 4000 meters above sea level and very little human inhabitance, many point to the warming climate as the culprit. Hopefully this study will provide a new approach to studying vegetation and water cover change that can help us better determine the causes before Sanjiangyuan becomes irreparably barren.

Grassland Test



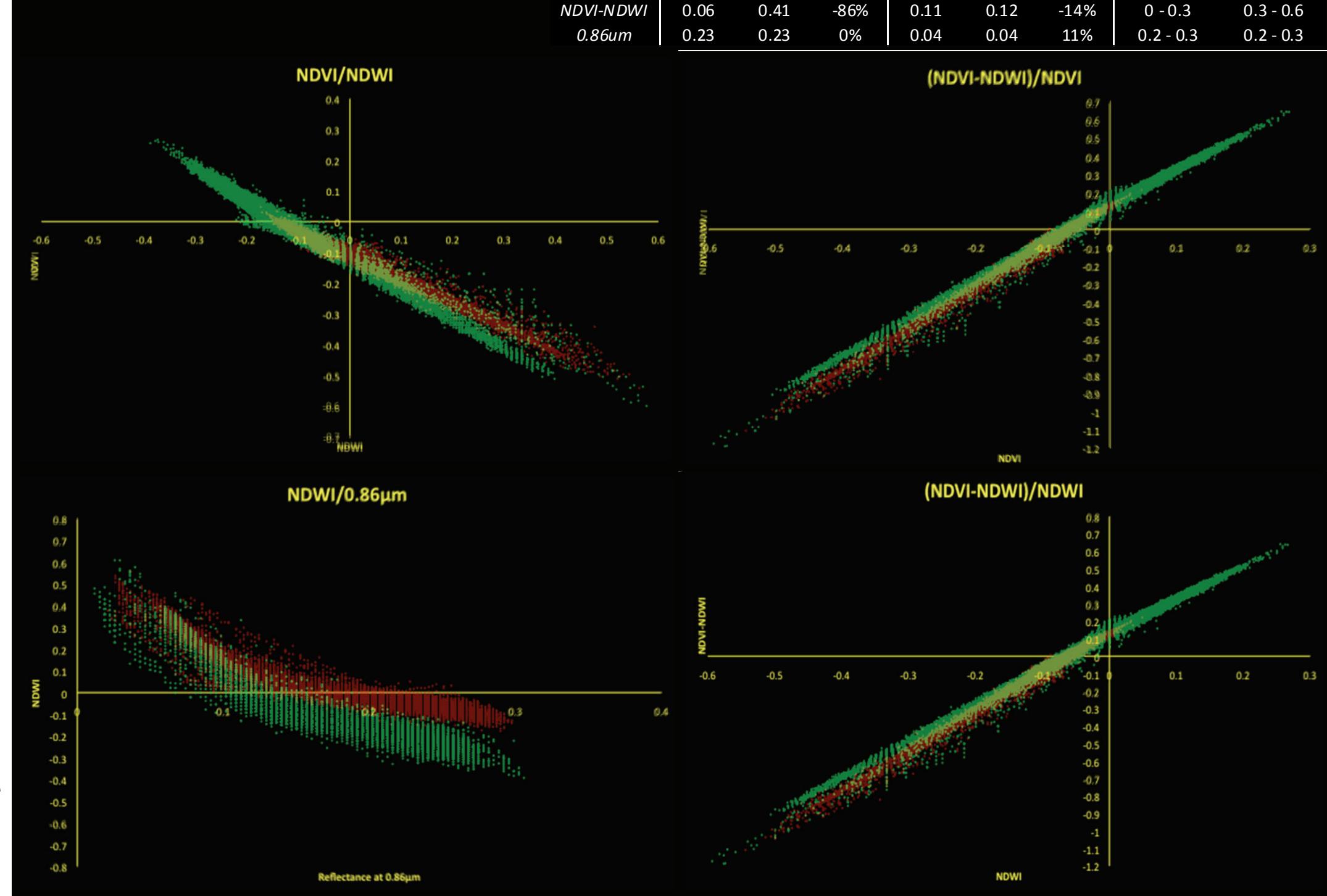
Analysis of NDVI/NDWI provides evidence that the region is losing water. NDVI values have increased over the period, yes, but more importantly the standard deviation of all indexes suggests a greater dispersion of both levels of vegetation and water. The increase in NDVI and decrease in NDWI values suggests, therefore, that between 1999 and 2010 the grassland has become drier but more vegetated. Essentially, the grassland has become a drier prairie with less moisture and surrounding water bodies. The NDWI/0.86μm index provides additional evidence of drying, as a negative shift in NDWI values has occurred.

Low Alt. Mountains Test Site



A large increase in the mean NDVI suggests a greater abundance of vegetation in 2010 compared to 1999 in the low mountains. Negative changes in already largely negative NDWI and NDVI-NDWI values point towards loss of water in the area, however, which means that the low mountains are becoming increasingly dry. In addition, the scarcity of water is best shown in the NDWI/0.86μm index, where a large negative shift between 1999 and 2010 indicates a loss of water in the low mountains.

Riverbed Test



A sharp decrease in the mean NDWI suggests a loss of water in and around the riverbed between 1999 and 2010. Decreases in standard deviation values indicate that each index is more disaggregated in 2010 compared to 1999. We also observe a shift in the range of the three indexes that point to a greater degree of vegetation growth amidst significant water loss. The NDWI/0.86μm index shows a negative shift in NDWI values over the period with relative uniformity in the 0.86μm wavelength reflectance values. This suggests a drying of the riverbed has occurred. Importantly, however, this test site should be re-evaluated over time as seasonal rains and other temporal changes may impact the water level as much as any long-term drying.

