Land Surface Phenologies in Central Asian Highlands

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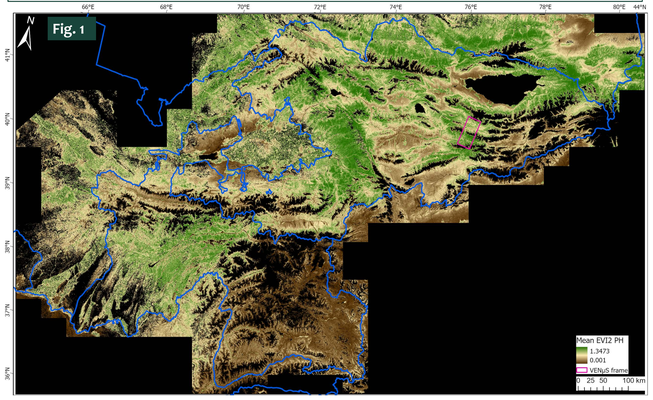
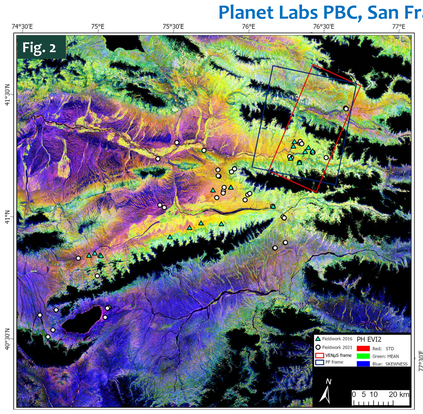
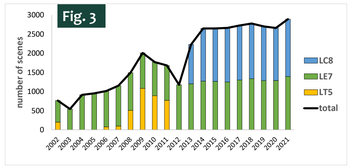
Across the mountains of Central Asia, agro-pastoralism is the dominant livelihood and the basis of the rural economy. It is characterized by vertical transhumance of livestock (sheep, cattle, horses, goats, yaks, donkeys) to higher elevation summer pastures and return to winter pastures at lower elevations near villages. Seasonality and intensity of pasture use is key to sustainable management of forage resources. However, herds have been increasing due, in part, to the remittances sent by labor migrants home to bank "on the hoof". Here we explore the use of higher spatial and temporal resolution data streams to characterize land surface phenologies (LSPs) from pasture areas.

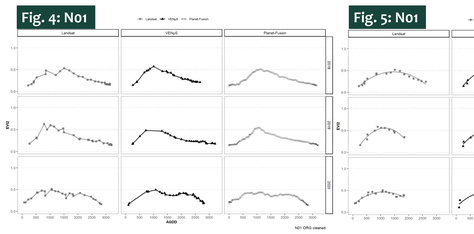


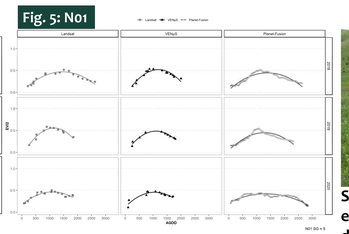
[Fig. 1] **Average EVI2 Peak Height (PH) based on LSP modeling using Landsat surface reflectance & MODIS LST products from 2002-2021. This map was based on more than 34K Landsat scenes, as shown by the bar chart** [Fig. 3, at right].

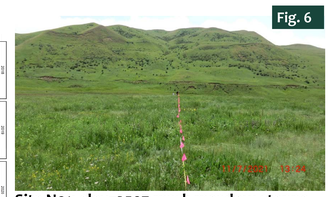


[Fig. 2] **False color composite of the descriptive statistics for EVI2 Peak Height annual series from 2002-2021 for Naryn & At-Bashy rayons. Symbols indicate locations visited during the July 2016 & 2021 field campaigns.**



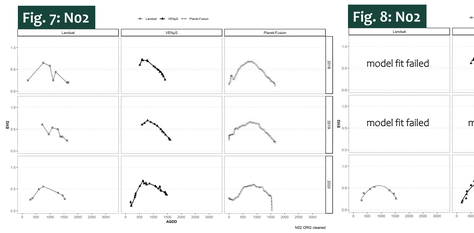


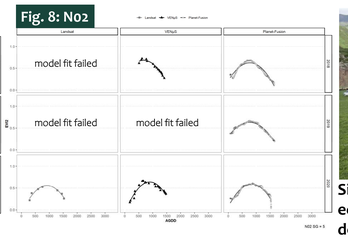




Site N01: elev=2507 masl; meadow-steppe ecozone; spring & fall grazing; forb-dominated degraded pasture.

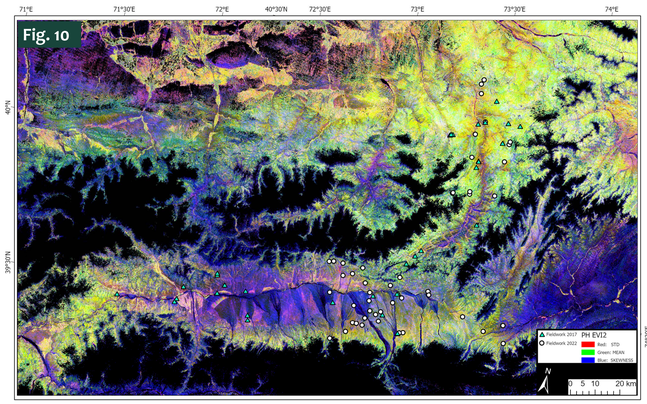
Variations in LSP modeling using different input data: Landsat, VENμS, and Planet Fusion for points N01 [Figs. 4-5, above] and N02 [Figs. 7-8, below]. Site N01 [Fig. 6, above], located near a main road into summer pastures, is degraded transitional (spring and fall) pasture. Site N02 [Fig. 9, below] is in a remote, higher elevation (3150 m) summer pasture. Both pasture sites are degraded, but in different specific ways due to ecozones, grazing histories, and changing environmental conditions. Both exhibit substantially higher coverages of unpalatable species. Figs. 4 & 7 show the original series available for LSP modeling and Figs. 5 & 8 show the model fits along with filtered series used for fitting. Note that the LSP fitting procedure failed at N02 for Landsat in 2018 & 2019 and for VENμS in 2019 [Fig. 8].



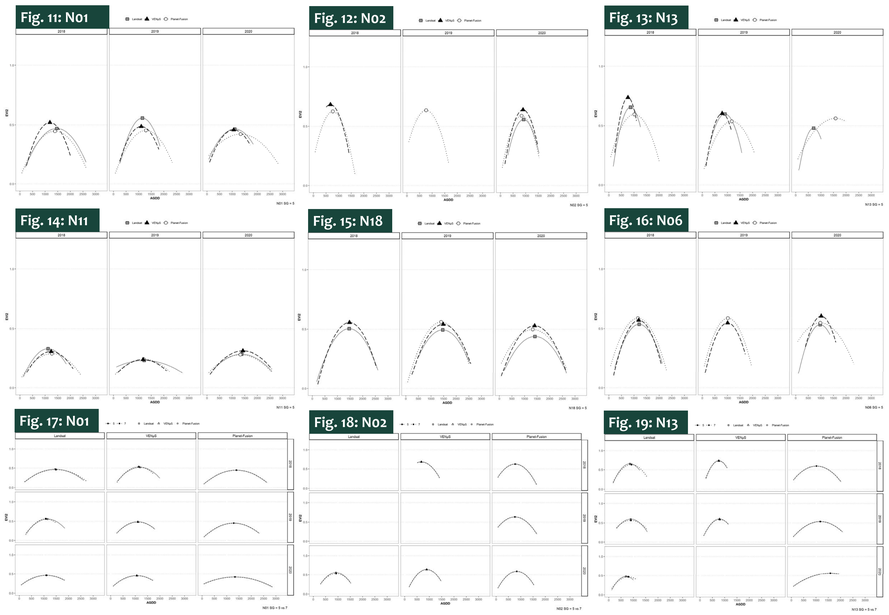


Site N02: elev=3150 masl; alpine meadow ecozone; summer grazing; forb-dominated degraded pasture.

We have conducted four field campaigns in Kyrgyzstan: in Naryn oblast during July 2016 & 2021 [Fig. 2] and in Osh oblast during July 2017 & 2022 [Fig. 2]. In Naryn oblast, we surveyed pastures in Naryn and At-Bashy rayons. In Osh oblast, we surveyed pastures in Alay and Chong-Alay rayons in 2017 and only in Alay rayon in 2022. Here we present results of our modeling of LSPs at multiple spatial and temporal resolutions using surface reflectance time series from Landsat (30m, 8-16d), VENμS (5m, ~2-3d) and Planet-Fusion (3m, 1d) time series. Our LSP model links an EVI2 time series to a downward-arching convex quadratic function of accumulated growing degree-days calculated from MODIS LST products. An iterative fitting procedure follows outlier filtering (mostly a problem in VENμS) and Savitzky-Golay smoothing. Key phenometrics, calculated from the fitted parameter coefficients, are Peak Height (PH) and Thermal Time to Peak (TTP). We focus here on two contrasting locations within the region highlighted in Figure 2. We also compare and contrast LSP fits from the three sensors at additional sites [Figs. 11-14].

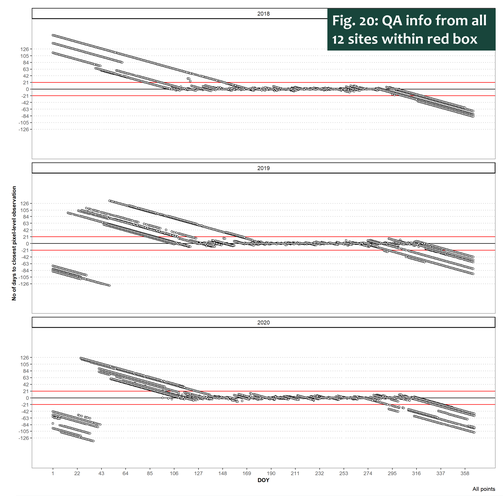


[Fig. 10] **False color composite of descriptive statistics for the EVI2 Peak Height annual series for Osh oblast for 2002-2021. Symbols indicate locations visited during the July 2017 & 2022 field campaigns.**



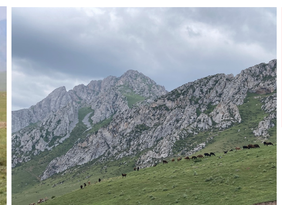
Comparing the phenometrics (PH, TTP) from successful fits across sensors [Figs. 11-16, above]. Note across sites that there is a general consistency to the phenometric values. Discrepancies in TTP are more important than in PH, since LSP is about timing. Site N13 [Fig. 13] posed a particular challenge with clear differences in phenometrics across sensors and years. Scanning across Figs. 11-16, there appears a tendency for the Planet-Fusion product to exhibit larger TTP values. Figs. 17-19 compare LSP fits from time series smoothed with a 5-day vs. 7-day Savitzky-Golay filter. Usually, there is little difference, but SG7 may yield a fit when SG5 fails.

[Fig. 20] **For Planet-Fusion products only, the number of days to closest pixel-level observation used to gap-fill (- is before, + is after prediction day). The P-F gap-filling strategy can lengthen the apparent growing season, thereby leading to TTP values larger than Landsat or VENμS.**



TAKE HOME MESSAGES:

- **High interannual variation of LSP in mountain pastures**
- **Phenometrics from EVI2 & LST often show agreement**
- **P-F gap-filling can distort signal early & late season**
- **Model fitting failures associated with sparser series**



Flag of KG
recalls the sky viewed through a yurt top