

**War, drought, and phenology:
Changes in the land surface phenology of Afghanistan since 1982.**

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War and resulting institutional changes can be important drivers of land use and land cover change. We explore how war, its consequences, and drought have affected the land surface phenology (LSP) of Afghanistan. Afghanistan offers the unique case of a semi-arid country with multiple institutional changes during the past two decades.

Long image time series characterizes the seasonal development of Afghanistan's vegetated land surface. We apply a statistical framework to four governance periods and compare the average AVHRR NDVI 8km data across periods, and calculate trends within study periods. We focus on significant changes in LSP in the region around Qandahar. Finally, we assess changes in LSP between 2001 (a drought year) and 2003 (a year with sufficient precipitation) using MODIS NDVI 1km data. Results reveal the strengths and limitations of LSP modeling in an environment characterized by high interannual and spatial variability as well as by socio-economic turbulence.

Keywords: Afghanistan; Pathfinder AVHRR NDVI; MODIS Terra NDVI; Land Surface Phenology; Institutional Change.

1 Introduction

About 12 million farmers in Afghanistan (Maletta and Favre 2003) have been affected by both political instability and drought over the past two decades. Drought decreased sheep abundance on average from 21.9 to 2.9 sheep per family between 1995 and 2003 (Maletta and Favre 2003). Winter wheat is Afghanistan's primary grain crop, averaging about 2 million ha in 1998. Due to persistent poverty, many farmers have returned in recent years to poppy farming, a practice outlawed by the Taliban in July 2000 (Medler 2005). Establishment of a new Afghan government has resulted in a period of relative stability and the 2002-03 crop season brought sufficient rainfall to most of the country (Maletta and Favre 2003). With political stability it becomes increasingly important to monitor changes in land cover and to enable assessment of the agricultural performance and growth.

A baseline study is critical to enable monitoring of current conditions and assessment of future changes. Current information about the Afghan agricultural sector is sparse and often outdated in the absence of an institutionalized agricultural census (Maletta and Favre 2003). Most of the available information is based on estimates from FAO surveys. In this study we try to determine whether the institutional changes and drought episodes have been of sufficient magnitude to be detectable in time series of imagery characterized by coarse spatial (8km/5km/1km) but fine temporal (10day/16day) resolutions.

Analyses of long image time series have increased our understanding of changes in the vegetated land surface. Vegetation indices, like the Normalized Difference Vegetation Index (NDVI), are surrogate measures for the density of green vegetation at the land surface. Land surface phenology (LSP) is defined as the spatio-temporal patterns of the vegetated land surface as revealed by synoptic sensors. We distinguish LSP from vegetation phenology which is the

study of the timing of recurring biological phases, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species (Menzel 2003).

We have previously shown that the collapse of the Soviet Union had significant influence on the LSPs of various land cover types in Kazakhstan (de Beurs and Henebry 2004, 2005). Here we will apply a similar methodology to characterize observable changes in the LSP of a key agricultural region of Afghanistan. In addition, we use MODIS 1km data to investigate the countrywide changes that have occurred between 2001 and 2003.

2 Data

2.1 Pathfinder AVHRR NDVI data

We used the Pathfinder AVHRR Land (PAL) maximum Normalized Difference Vegetation Index (NDVI) 10-day (dekad) composites (<http://daac.gsfc.nasa.gov/>) which have a nominal spatial resolution of 8×8 km. NDVI is calculated based on the red (0.58 – 0.68 μm) and near infrared (0.725 – 1.0 μm) reflectances of the NOAA AVHRR sensors as follows:

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

NDVI values for vegetation typically range from about 0.05 to about 0.7, with higher values for denser vegetation. NDVI for bare soil and rock is usually near zero and NDVI for water is typically negative. The total PAL-NDVI dataset is recorded by sensors on four different satellites: NOAA-7 (1981-1985), NOAA-9 (1985-1988), NOAA-11 (1989-1994), and NOAA-14 (1995-2000). There are 36 composites per year and we used all composites for 13 years (1982-1988 & 1995-2000). These periods fall within the observational spans of NOAA-7, NOAA-9, and NOAA-14 and these data exhibit no significant influences of sensor artifacts that would impair

change analyses (de Beurs and Henebry 2004). The final dataset results in 36 10-day composites for the years from 1982-1988 (NOAA-7 and NOAA-9, 252 images) and from 1995 to September 2001 (NOAA-14, 243 images). These PAL NDVI data can be divided according to a three-part timeline:

1982 – 1986: Data from the NOAA-7 satellite and the beginning of the NOAA-9 satellite fall in the ‘Soviet’ period that spans from 1979 to 1986.

1987 – 1988: Data from the NOAA-9 satellite fall in the ‘Afghan independence’ that spans from 1987 to 1992.

1995 – 2000: Data from the NOAA-14 satellite capture the ‘Taliban’ period that spans from 1994 until 2001. This period also overlaps the extended drought that started in 1998.

2.2 MODIS NDVI data

To understand the development of the Afghan land surface since 2000 we downloaded both the MODIS/Terra BRDF/Albedo Model-1 16-Day L3 Global 0.05 GCM Grid data (MOD43B4) from the Land Processes Distributed Active Archive Center (LPDAAC; <http://edcdaac.usgs.gov/>) for 2000 through 2005 and the MODIS/Terra Vegetation Indices 16-Day L3 Global 1km SIN Grid data (MOD13A2) for 2001 (a drought year) and 2003 (a year with sufficient precipitation). MOD43B4 consists of seven MODIS bands, from which the first two are the red and the near infrared. The spatial extent of the data is global and the spatial resolution is 0.05° (~5km). The data comes as 16-day composites and there are 23 composites per year. We selected the spatial extent of Afghanistan and calculated the NDVI as described above (equation 1) for all composites from 2001 to 2005.

MOD13A2 is a tiled data set (with tiles of $\sim 10^\circ$ by 10° lat/long). We downloaded the tile that had the largest overlap with Afghanistan (h23v5) for 2001 and 2003 and applied the MODISTool to reproject the data to a geographic coordinate system. Afterwards we created two separate time series of 23 16-day composites for 2001 and 2003.

2.3 MODIS Landcover data

We selected the MODIS IGBP Landcover data from 2001 with a spatial resolution of 1km to generate a general overview of the Afghan land cover.

2.4 Palmer Drought Severity Index

To identify the spatial and temporal distribution of drought events we used the Palmer Drought Severity Index (Dai *et al.* 2004). This monthly index with a 2.5° spatial resolution from 1870 to 2002 is derived using historical precipitation and temperature data for global land areas. PDSI measures the cumulative departure in atmospheric moisture supply and demand at the land surface (Dai *et al.* 2004). In theory, PDSI ranges from -10 (dry) to +10 (wet). PDSI values less than -3 are considered very dry and values greater than 3 considered very wet. Figure 1 gives the average PDSI for Afghanistan, and shows severe drought periods from about 1983-1987 and from about 1987 to 2003.

[Insert figure 1 about here]

2.4 Accumulated Growing Degree Day data

To overcome the lack of reliable weather data we decided to use the daily minimum and maximum temperature from the NCEP/NCAR CDAS/Reanalysis Project (http://wesley.wwb.noaa.gov/ncep_data/). These data have daily measurements on a $\sim 2^\circ \times 2^\circ$ grid, which is fairly coarse compared to the rough Afghan terrain, which has high spatial variability in elevation. We decided to interpolate the data based on the lapse rate (6.5°C decrease for each 1000 meter increase in elevation). We used the GTOPO30 (E060N040) as the elevation data source and interpolated the available minimum and maximum temperature to the 1km spatial resolution of the MODIS/Terra dataset.

The thermal regime of the growing season can be measured as accumulated growing degree-days by summing growing degree-days from some consistent start date until a specific subsequent date. Assuming a northern hemisphere start date of January 1st and an effective temperature threshold of 0 °C, we calculated the accumulated growing degree-days for each pixel as follows:

$$GDD = \frac{(T_{\max} + T_{\min})}{2}$$
$$AGDD = \sum_{i=GDD01Jan}^{i=GDD31Dec} GDD, \text{ if } GDD > 0 \quad (2)$$

The AGDD were summarized into 10 and 16-day composites to allow for an easy comparison with the 10 and 16-day composites from the PAL NDVI data and the MODIS/Terra NDVI data.

3 Methods

We filtered the PAL NDVI dataset by replacing outlying pixel values (mean $\pm 4 \times$ standard deviation) with the average annual value for the respective pixel. In this study our focus is on changes in agricultural regions and thus we masked the areas that do not have any composite with NDVI greater than 0.4. In the next step we divided Afghanistan in nine agricultural regions according to the classification by ICARDA (ICARDA 2006) (see figure 2). For each region we determined the average NDVI and coefficient of variation (CV=standard deviation/mean) of the pixels that remained after masking. We analyzed the time series separately by region. We omitted the east central region (EC) from our analysis since the available sample of NDVI pixels was too small. To allow for comparability between the PAL NDVI data and other data sources, such as the Palmer Drought Severity Index, we have summarized the 10-day NDVI composites into monthly composites by determining the maximum value among the three composites for a particular month.

[Insert figure 2 about here]

3.1 Step Changes

Step changes in image time series may be visualized as differences in the overall averages between the three (Afghan) political periods. Discontinuities can occur due to differences in drought impact and/or can be caused by sudden events in the land surface environment. The image time series for most selected regions in Afghanistan do not follow a normal distribution and the three study periods do not span an equal amount of time. Thus, the statistical methods

employed to determine the step changes must be capable of handling non-normal data and unequal numbers of observations (Dunnet 1980, Day and Quinn 1989, Keselman *et al.* 1998). Here we will apply the Fligner-Policello test that we have previously proposed for the testing of step changes in image time series with non-normal distributions, unequal period lengths, and unequal variation between groups (de Beurs and Henebry 2005).

3.2 Trends

Using linear regression to estimate a trend from a time series of observations is a practice widespread in the remote sensing literature. However, we have shown that image time series exhibit four complications that usually result in the violation of linear regression assumptions (de Beurs and Henebry 2004): (1) the observations are not mutually independent but related in time; (2) the residuals are not random and do not follow a random distribution; (3) the mean of the residual distribution is not equal to zero; and (4) the variances of the residuals are not constant over time. Ignoring violations of these assumptions can lead to the discovery of spurious trends. The seasonal Mann-Kendall (MK) trend test corrected for autocorrelation is a nonparametric test that is routinely used in the analyses of meteorological time series (Dietz and Killeen 1981, Hirsch and Slack 1984, von Storch and Navarra 1999). The MK test is robust against all four violations (Hirsch and Slack 1984) and more robust in estimating trend significance than simple linear regression (de Beurs and Henebry 2004). While the MK test does not provide an estimate of the magnitude of the detected trend, it does give indication of whether a significant trend is positive or negative.

While the main advantage of the MK test compared to simple linear regression is the robustness against the previously mentioned violations, an additional advantage is the fact that all the available observations are incorporated in the test statistic. Thus, in case of 7 years of

observations, the MK test used all 84 (monthly) composites. This is a major increase over the seven yearly observations often used when simple linear regression is applied. To understand the drought influence on NDVI trends, we applied the MK test on both the monthly NDVI and monthly PDSI data. We also applied the partial MK test, where we corrected the NDVI test statistic for trends found in the PDSI data (Libiseller and Grimvall 2002). To increase the number of observation, we combined the first two periods (1982-1986 and 1987-1988) into one set. Thus, we tested the trends for two sets of seven year PDSI and NDVI time series with 84 and 72 observations respectively.

We also apply the SMK test to the individual MODIS (0.05 degree) pixels to determine the spatial distribution of land surface trends since 2001.

3.3 Land surface phenology

To understand the changes in the land surface phenology, we summarized the observed NDVI and CV for the three study periods. We plotted the 10-day NDVI and CV for the three periods against the accumulated growing degree days (AGDD base 0°C). In this way we attenuate interannual AGDD variability while examining LSP. In the first step we demonstrate the development of the land surface phenology of the Southwest in a detailed study. In the second step we compare the development of the phenology between 2001 and 2003. To do so, we first fit quadratic land surface phenology models to the NDVI data from all MODIS 1km pixels for 2001 and 2003 and the AGDD.

$$NDVI = \alpha + \beta AGDD + \gamma AGDD^2 \quad (3)$$

Based on the parameter coefficient estimates we determine three phenological indicators: 1) the NDVI at the beginning of the growing season; 2) the NDVI at the peak of the growing season;

and 3) the amount of AGDD (and corresponding calendar days) that is necessary to reach the peak NDVI.

4 Results and Discussion

The recent history of Afghanistan is complex and highly dependent upon geographical location. Some areas in Afghanistan put up stronger resistance to the Soviet Army than other and thus saw heavier fighting and damage impacts. During the period of Afghan independence and civil war (1987-1994), the control of the country was divided among numerous warlords. Basic activities of civil society, such as health care facilities, schools and agricultural production, functioned more or less well depending on the regional warlord. The Taliban started their 1994 uprising in Qandahar in southern Afghanistan. While the Taliban uprising was relatively smooth and effortless during 1995 for the Southern part of the country, they were met with considerable resistance in the Northern areas, including Kabul which they did not capture until 1996.

On top of all the civil turmoil in Afghanistan, the country has frequently been hit by droughty periods over the last 20 years. The spatial and temporal distribution of drought impacts was highly variable.

4.1 Step changes and trends

The effects of the complex interaction of drought and institutional changes should be studied for each region separately. In addition, to understand the effect of institutional changes in each region, it is necessary to examine the socio-economical background and the major events that have occurred during the last 20 years.

Table 1 shows significant increases in NDVI between 1982-86 and 1987-88 for *Northeast2*, *East* and *Southeast*. These three regions are adjacent in the Northeastern part of the country, north and east of Kabul.

[Insert table 1 about here]

Table 2 shows the SMK trend statistics. We found significant trends in PSDI in every region, except for Southwest and Herat. While we found no significant trends in NDVI, it is clear that the direction of the trends follow the PDSI data. In the first time periods the trends are fairly low and have both positive and negative signals depending on the region. However, we found a negative trend in the NDVI in every region from 1995 to 2001, which is mostly a result of widespread drought that hit the country in the latter part of this time period. In almost every case the strength of the NDVI trend is greatly diminished when corrected for drought severity using the partial MK test (table 2, last two columns).

[Insert table 2 about here]

Figure 3 gives the trend in the MODIS 0.05° data from 2001 to 2005. We only indicate the areas with significant trends ($\alpha < 0.05$). Most significant trends are positive (green), with only some negative (purple) areas in the Herat region and in SE southeast of Kabul. SW and Herat have especially large positive trends at the southwestern extremities. Also the eastern part of the N and most of the NE1 show significant positive trends. Parts of the grainbelt do not exhibit significant trends.

[Insert figure 3 about here]

4.2 Changes in land surface phenology

As discussed previously there is a wide range of factors that played a role in each period and region in Afghanistan. It is too complicated to discuss concisely the LSP changes in every region of Afghanistan across the complete time period. Thus, we restrict our attention here to the interesting case of observed changes in the Southwestern region around Qandahar.

Figure 4 shows the changes in LSP over the last two decades for Qandahar. Before the Soviet invasion the oasis town of Qandahar was famous for its fruit orchards which produced almonds, figs, grapes, melons, mulberries, peaches, pistachios, and pomegranates. These orchards could persist in the hot and dry deserts due to a well-maintained and complicated system of irrigation. However, during the Soviet war, both the Mujaheddin and the Soviet Army mined these fields heavily, which led to widespread abandonment of the orchards and a large migration of the local population to Pakistan. There was especially heavy fighting in 1985. Later, the Soviets cut down thousands of trees and destroyed large parts of the irrigation system to find the Mujaheddin who were mainly hiding in the orchards (Rashid 2001).

Many of the refugees returned after 1990 when the Soviets left Afghanistan. However, since it would take years to rebuild the orchards, many farmers grew opium poppies to sustain a living (Rashid 2001). In 1996, the Qandahar province alone counted more than 3160 hectares of poppy fields. While the Taliban prohibited the smoking of opium in 1996, they allowed the cultivation of poppies and trafficking of opium to protect their support base (UN 1996).

[Insert figure 4 about here]

Figure 5 maps the modeled intercept, which is the parameter coefficient corresponding to the NDVI at the start of the growing season, for 2001, 2003, and the difference image (2003-2001). NDVI in the grain belt in the North of Afghanistan is high at the beginning of the growing season. This is most likely a result of the fact that the grain belt is mostly winter wheat. Winter wheat is planted in the fall and greens up as soon as there is sufficient heat and moisture. The quadratic model for these regions starts out high and decreases after this first high point. The difference image shows that there has been an increase in NDVI early in the growing season in most of the grain belt, along the northern border. The higher altitudes of Afghanistan are mostly black in these images because a quadratic model of phenology does not fit well in these areas. The elevation of central Afghanistan rises to about 3000 m and in Northeastern Afghanistan to 5000 m. Since we do not expect much vegetation in these regions, we are not concerned about the lack of model fit. It is interesting to see the intercept decrease in the irrigated region in the SW around Qandahar. Also, just south of the cereal belt there is a large area with a decrease in intercept. The north central part of the southwest region shows an increase in intercept. It is this location that is considered one of the main poppy producing areas in 2003.

[Insert figure 5 about here]

Figure 6 maps out the parameter coefficient that corresponds to the peak NDVI for 2001, 2003, and the difference (2003-2001). The NDVI in the northern grain belt is lower during the peak than at the beginning of the growing season because the phenological model starts out high

with very green winter wheat green up, and decreases to a low during the summer after harvest. The difference in NDVI between those two years is far less than the difference at the beginning of the growing season.

[Inset figure 6 about here]

Figure 7 gives the day of the year that the peak position of the growing season is reached. When we compared the peak timing for 2001 and 2003 we can see that there is really a mixture of areas with earlier and later peaks. Most of the grain belt has a later peak. We suspect that the peak of the growing season is later in these regions because of drought recovery in 2003. In 2001 Afghanistan was in the middle of a long lasting drought that had started in 1999 (cf. Figure 1).

5 Conclusions

Before the Soviet war, Afghanistan was self-sufficient with respect to cereal production and had a thriving export market in horticultural products (Kelly 2003). The destructive effects of the Soviet invasion and subsequent civil war have been dramatic. The agricultural sector (horticulture and cereal as well as the livestock industry) suffered great losses. In this study we have used a very coarse spatial but long temporal resolution image series to analyze the dynamics of land surface phenology. The results demonstrate that the socio-economic turbulence that has affected Afghanistan over the last twenty years has been sufficiently large to influence

significantly the land surface phenology as observed with 8km pixels. This is a spatial resolution that is coarse relative to land use decisions, but one that is highly relevant to interactions between the land surface and the lowest layer of the atmosphere (Bonan 2002). We have found that the effect of war and civil conflicts can mimic long term drought effects with similar de-vegetation and reduction in the spatial variation of the land surface phenology in agricultural areas. Afghanistan's recent history demonstrates the importance of war and civil conflicts as drivers of land cover and land use change. Of broader significance is the fact that freely available long image time series with coarse resolution are able to monitor phenological changes caused by civil conflicts and war. These image time series can provide a fast (almost real time, MODIS data from July 2006 is now available) overview of changes and of recovery efforts on the surface. Some authors have shown the power of remote sensing and GIS as counterterrorism tools to identify certain regions with terroristic activities (Beck 2003, Shroder 2005). This paper, however, focuses on a larger perspective and the long-term consequences and recovery efforts in war-torn Afghanistan.

Acknowledgments

Research supported by an American Institute of Afghanistan Studies (AIAS) Postdoctoral Fellowship to KMdB and by NASA NEWS funding to GMH. Among the data used are some produced through funding from the Earth Observing System Pathfinder Program of NASA's Mission to Planet Earth in cooperation with NOAA. The data were provided by the EOSDIS DAAC at Goddard Space Flight Center which archives, manages, and distributes this data set. NCEP Reanalysis data were provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, CO from their website at <http://www.cdc.noaa.gov/>. The land cover data were distributed by the

Land Processes Distributed Active Archive Center (LP DAAC), located at the U.S. Geological Survey's EROS Data Center <http://LPDAAC.usgs.gov>. Portions of this paper were published in the online proceedings of the 2006 International Geoscience and Remote Sensing Symposium (IGARSS) and presented for the 2006 conference of the Central Eurasian Studies Society (CESS).

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Figures

Figure 1: Average PDSI for Afghanistan from 1982 to 2003. Periods with a shortage of moisture are indicated as black squares. Periods with a surplus of moisture are indicated a white circles. Periods with PDSI below -3 are considered as extreme droughts. There is a short period of extreme drought between 1984 and 1988. There is an extended and very severe drought from 1998 to 2003.

Figure 2: MODIS (1 km) 2001 IGBP land cover classification overlaid with the nine agricultural regions. Yellow is classified as agricultural area. Red is urban. Green is grasslands. Dark brown is desert and light brown is open shrublands. Some of the agricultural areas are so scattered and dry in 2001 that they do not appear in this classification.

Figure 3: Trend in the MODIS NDVI data 2001-2005. Areas with significant ($\alpha < 0.05$) positive (or negative) trends are indicated in green (or purple), with more highly significant trends appearing in darker tones. Bright green circles indicate key cities. There were especially widespread significant increases in NDVI in southwestern Herat region, the southern half of the Southwestern region, and in the Northeast. Significant negative trends occurred in tight clusters across the central part of the country.

Figure 4: Top images: Qandahar as observed by Landsat MSS and Landsat TM in 1973 and 2001. The geographical distribution of the agricultural areas is largely confined to the irrigated regions along rivers in this desert area. It is difficult to observe the repeated changes that occurred in Qandahar between 1973 and 2001 with sporadic Landsat images. Middle and Lower

panels: LSP as observed in the PAL NDVI time series describe the story of Qandahar in greater detail. NDVI in 1985 shows a slight drop compared to previous and following years. The extreme drought that had an especially large influence on the NDVI in 2000 and 2001 showed a large decrease in NDVI compared to previous periods. The CV showed a large difference from 1000 to 3500 AGDD between the area at the beginning on the Soviet occupation and the subsequent periods. Heavy fighting in 1985 and extreme drought in 2000 and 2001 show a similar pattern of an even lower CV.

Figure 5: Top: NDVI at the start of the growing season in 2001. Middle: NDVI at the start of the growing season in 2003. Bottom: Difference of the NDVI at the start of the growing seasons of 2001 and 2003. A median filter has been applied to clarify the spatial distribution of the observed changes. Purple areas indicate decreased NDVI at the beginning of the growing season (2003<2001). Green areas show increased NDVI at the beginning of the growing season (2003>2001). The wheat belt showed the most obvious increase in NDVI, while NDVI in the irrigated areas in Southern Afghanistan decreased. The black areas in the middle of Afghanistan are at very high elevations and did not fit well the quadratic phenology model for either year.

Figure 6: Top: NDVI peak in 2001. Middle: NDVI peak in 2003. Bottom: Difference of the NDVI at the peak of the growing seasons of 2001 and 2003. A median filter has been applied to clarify the spatial distribution of the observed changes. The lighter areas had little difference in the NDVI peak between 2001 and 2003. Darker purple areas had a higher NDVI peak in 2001 than in 2003. Green areas had a higher NDVI peak in 2003.

Figure 7: Peak timing for 2001 (top) and 2003 (middle) with the difference in peak timing between 2001 and 2003 (bottom). Redder areas had a later peak in 2003, while blue areas had an earlier peak in 2003 than 2001. Black areas in all images have a very high elevation and the quadratic phenology model fit poorly in these regions.

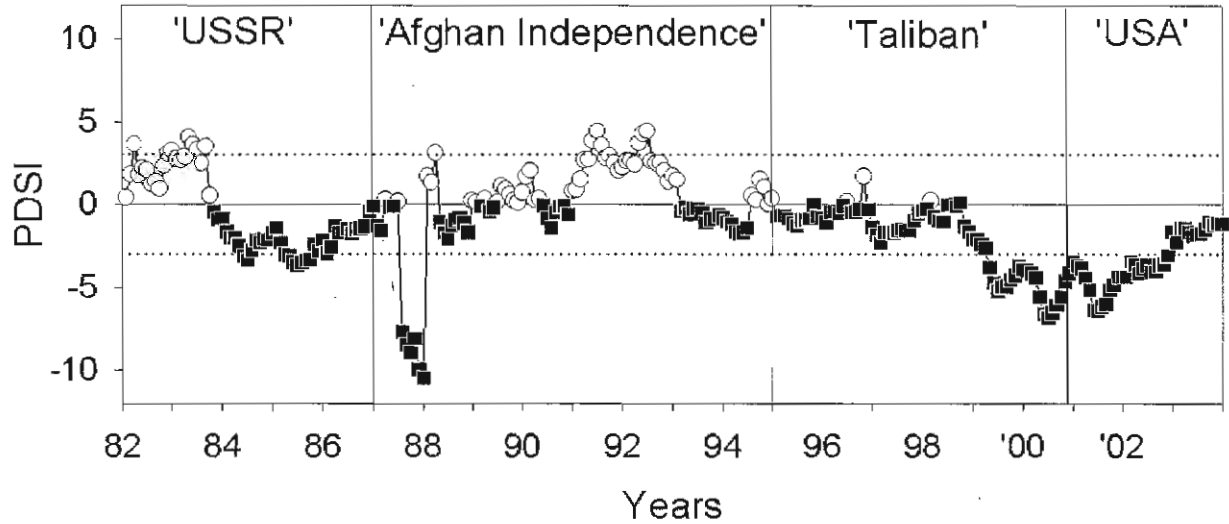


Figure 1

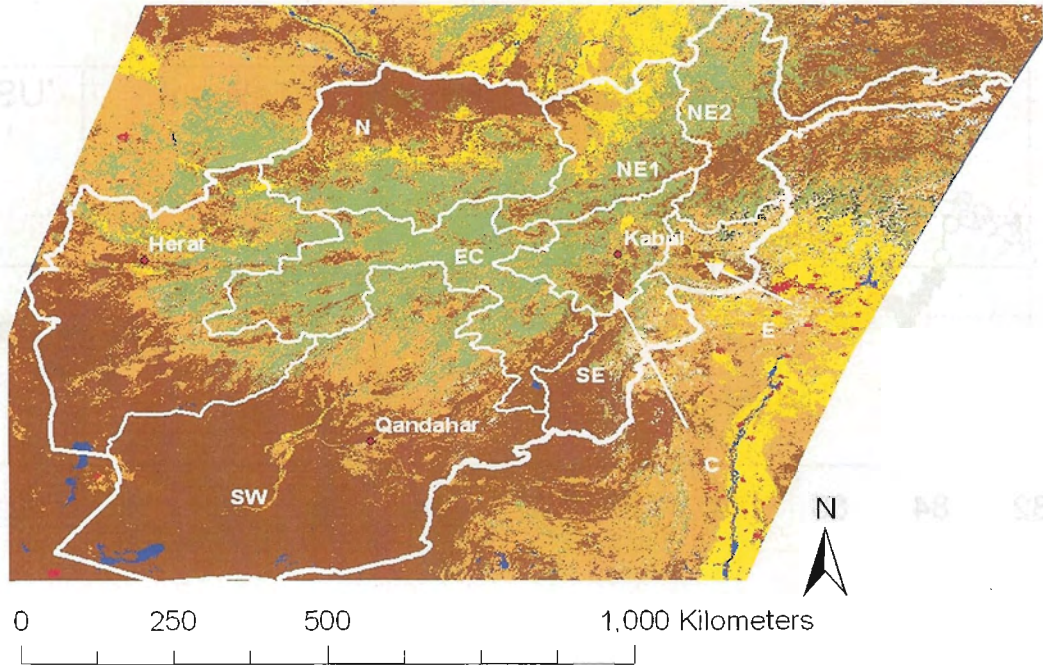


Figure 2

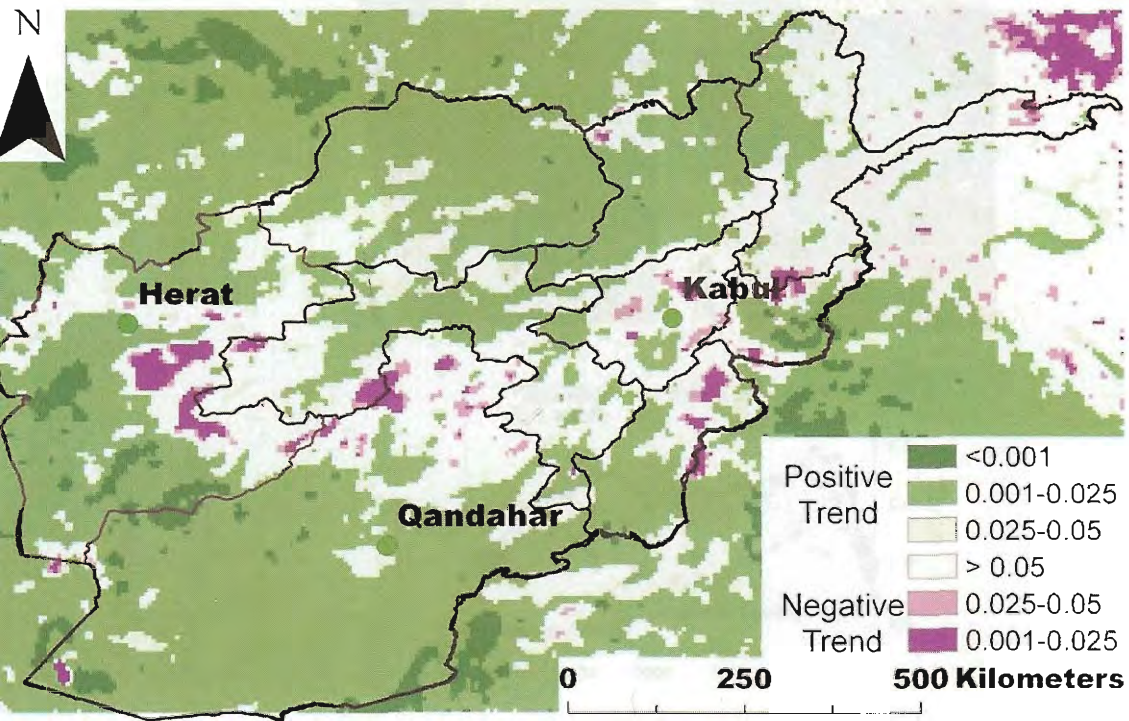


Figure 3

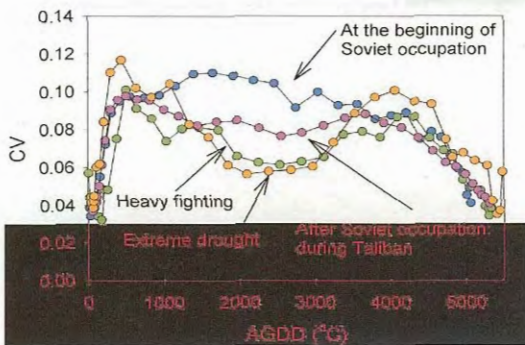
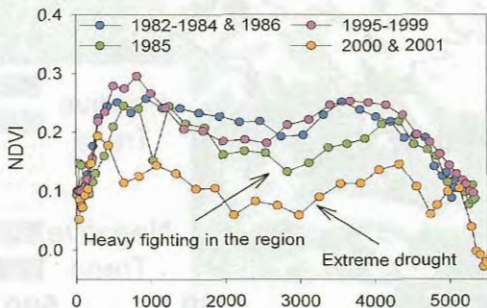
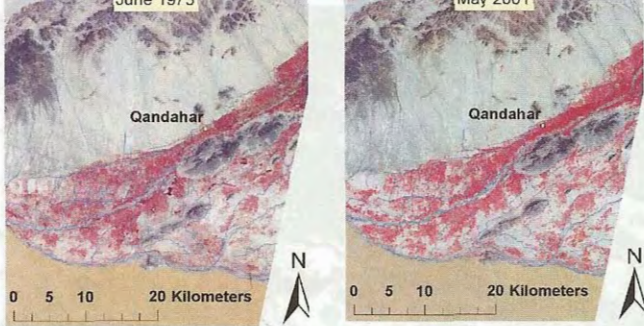


Figure 4

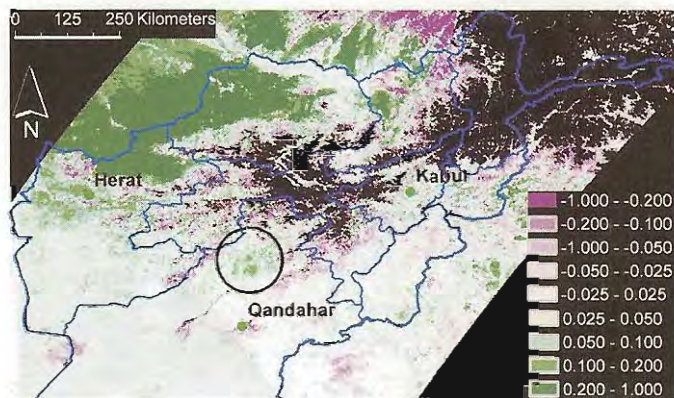
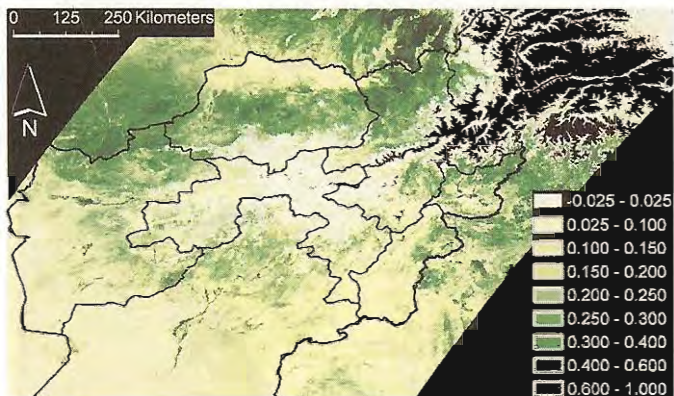


Figure 5

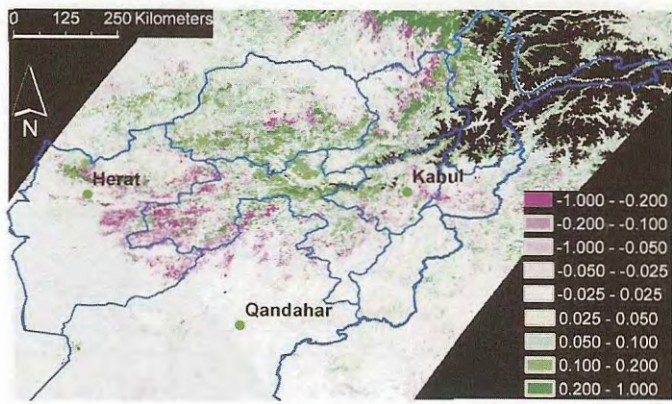


Figure 6

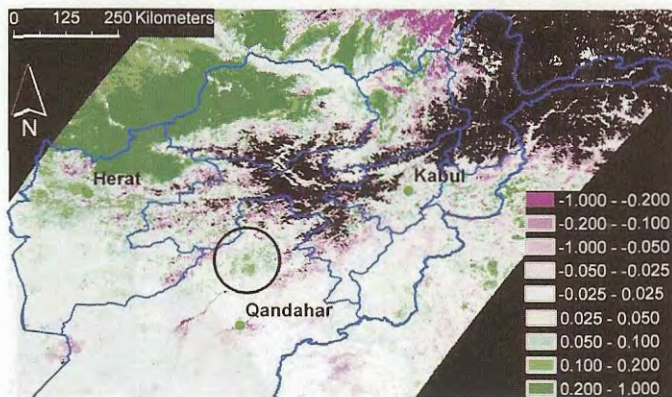


Figure 5

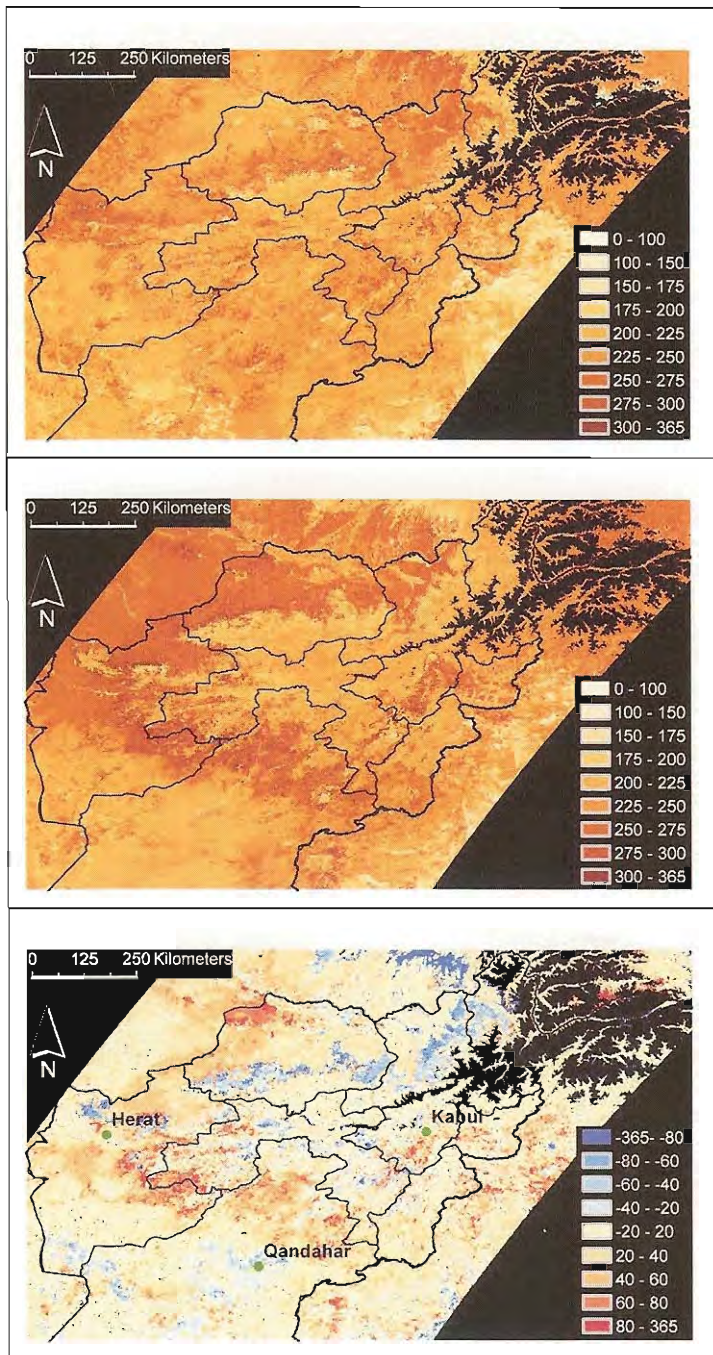


Figure 7

Table 1: Step Changes for the three selected study periods with actual α –level at 0.05 (bonferroni level for three comparison: $(1-(1-\alpha)^{1/3})$). Significant differences are in bold.

Region	NDVI differences for the period comparisons		
	82-86 / 87-88	82-86 / 95-01	87-88 / 95-01
Northeast2	0.039	0.017	-0.022
Northeast	0.017	0.013	-0.004
North	0.016	0.017	0.000
Central	0.022	0.012	-0.011
East	0.030	0.018	-0.013
Southeast	0.019	0.008	-0.012
Southwest	0.004	-0.012	-0.017
Herat	0.009	-0.003	-0.013

Table 2: Seasonal Mann-Kendall trend test statistics for the monthly PDSI and NDVI data. Last column gives the NDVI trends corrected for trends in drought severity (PDSI). Significant trends ($\alpha < 0.05$) are in bold. Higher/lower trend statistics indicate stronger positive / negative trends.

Region	PDSI trend		NDVI trend		Corrected NDVI trend	
	82-88	95-01	82-88	95-01	82-88	95-01
Northeast2	56	-186	28	-46	15	-24
Northeast	56	-186	46	-36	18	-24
North	-56	-142	-14	-87	-27	-85
Central	-74	-176	50	-34	14	-10
East	-76	-166	64	-54	14	-15
Southeast	-116	-120	43	-50	18	-40
Southwest	-88	-88	-33	-26	-5	17
Herat	-34	-94	-28	-72	-21	-42