An overview of vegetation health in the North West Province, South Africa, between 2010 and 2020

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Abstract. The North West Province in South Africa is an important contributor to the country’s economy with agriculture and mining the main drivers. Droughts regularly affect the region and impact greatly on farming which in turn has negative socio-economic consequences. Multi-temporal satellite remote sensing data is well suited to study changes in vegetation health. Vegetation and temperature indices from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor and rainfall data from the Climate Hazards group Infrared Precipitation with Stations (CHIRPS) between 2010 and 2020 showed good vegetation health in 2010 and 2020, but gradually worsening drought condition in the intervening years. Although the entire North West Province is affected by drought, the central and western portions experience the worst conditions. The vegetation condition index, temperature condition index and vegetation health index show a faster recovery along the western edge of the province in 2018 than the rest of the province, a detail not easily visible in the conventional enhanced vegetation index and land surface temperature data. They also show a gradual decrease in vegetation health between 2010 and 2014. A comparison with geology shows that vegetation health is, in part, also linked to the underlying rock types.

1. Introduction
The North West Province (NWP) is one of nine provinces in the Republic of South Africa (figure 1a) and is an important contributor to the South African economy through agricultural and mining activities. It falls in the summer rainfall part of the country with an annual rainfall of about 500 and 600 mm [1]. It falls within savanna and grassland biomes [2] (Figure 1b). Vegetation varies with soil type which in turn is derived from the underlying geology. The savannah biomes correspond to low-lying areas covered by younger sediments (Figure 1c and d). Grasslands cover the more weather-resistant quartzites, and lavas of the Witwatersrand, Ventersdorp and Transvaal Supergroups.

Approximately 50% of the land area is used for commercial agriculture, comprising mainly grazing land used for livestock and game farming, followed by arable land used for crop production [3]. Many of the farmers in the NWP rely on rainfall for agriculture activities and are therefore severely affected by periods of drought. Unfortunately, droughts routinely affect South Africa, and between 1981 and 2018, four very dry periods occurred, namely 1981-1982, 1992, 2016, and 2018 [4]. This study investigated the vegetation conditions in the province between 2010 and 2020.
Figure 1. (a) Locality of the North West Province in South Africa; (b) Biomes in the NWP [2]; (c) Digital elevation map extracted from the AW3D30 data set [5]; (d) Simplified geological map derived from the 1:1000 000 geological map [6].

2. Materials and methods
Changes in the vegetation condition were studied through vegetation indices, land surface temperature and rainfall data provided by and derived from satellite remote sensing data. These data sets were obtained for two-year intervals starting in 2010 and ending in 2020, and possible relationships between them were identified. To understand the changes in vegetation health for specific land cover types, published land cover maps were used to delineate major zones. Effects of drought conditions on these were then analysed through comparing statistics of the satellite data and products for each of the zones.

2.1. Land cover maps
Three South African National Land Cover (SANLC) data sets were available from South Africa’s Department of Environmental Affairs for the 10-year study period. The 2013-2014 data set was generated from digital, multi-seasonal Landsat 8 multispectral imagery, acquired between April 2013 and March 2014 [7]. It has a resolution of 30 m. The data set for 2018 used 20 m resolution Sentinel-2 data collected between 1 January and 31 December 2018 to generate 73 classes of information [8]. The SANLC 2020 dataset was also produced from 20 m resolution Sentinel-2 data but used automated mapping methods as opposed to conventional image classification procedures [8]. The classification used the full temporal range of available imagery acquired by Sentinel 2 during the period 01 January 2020 to 31 December 2020.
2.2. Satellite remote sensing data
The MODIS (Moderate Resolution Imaging Spectroradiometer) sensor onboard the Terra satellite provides a suite of data sets that is especially applicable to environmental change studies on a regional scale. Data sets used in this study (Table 1) are the enhanced vegetation index (EVI), land surface temperature (LST), evapotranspiration (ET) and potential ET (PET). Rainfall data were obtained from the CHIRPS (Climate Hazards group Infrared Precipitation with Stations) data set [9].

The normalized difference vegetation index (NDVI) is also provided by MODIS, but the EVI is better suited to dealing with atmospheric and background (soil) effects [10] and was therefore selected for use.

The North West Province is a naturally dry area, and in order to study vegetation, satellite remote sensing data were selected for the summer rainfall months of January and February when vegetation should be in the best condition.

| Data set            | Index/data type | Temporal resolution | Spatial resolution |
|---------------------|-----------------|---------------------|--------------------|
| MOD13Q1v6[11]       | EVI             | 16 day average      | 250 m              |
| MOD11A2v6[12]       | LST             | 8 day average       | 1000 m             |
| MOD16A2v6[13]       | ET, PET         | 8 day average       | 500 m              |
| CHIRPS[9]           | Rainfall        | 2 months            | 0.5° (~5 km)       |

Additional indices that were derived from the MODIS data were the vegetation condition index (VCI) (equation 1) [14], temperature condition index (TCI) (equation 2) [15], vegetation health index (VHI) (equation 3) [16] and the evaporative stress index (ESI) (equation 4) [17].

\[
VCI = 100 \times \frac{\text{EVI} - \text{EVI}_{\text{min}}}{\text{EVI}_{\text{max}} - \text{EVI}_{\text{min}}} \tag{1}
\]

where \(\text{EVI}_{\text{max}}\) and \(\text{EVI}_{\text{min}}\) are the minimum and maximum values of EVI for a pixel over the observation period.

\[
TCI = 100 \times \frac{\text{LST}_{\text{max}} - \text{LST}}{\text{LST}_{\text{max}} - \text{LST}_{\text{min}}} \tag{2}
\]

where \(\text{LST}_{\text{max}}\) and \(\text{LST}_{\text{min}}\) are the minimum and maximum values of land surface temperature for a pixel over the observation period.

\[
\text{VHI} = \alpha \text{VCI} + (1 - \alpha) \text{TCI} \tag{3}
\]

where \(\alpha\) is the contribution of each condition index to the VHI. This is normally unknown and a value of 0.5 is commonly used.

\[
\text{ESI} = 1 - \frac{\text{ET}}{\text{PET}} \tag{4}
\]

3. Results and discussion

3.1. Land Use Land Cover (LULC) maps
The land-cover change assessment results for the NWP are based on a comparison of SANLC 2014, SANLC 2018, and SANLC 2020 data sets three to four dominant types of land cover, namely shrubland (specifically in 2013-2014), grassland, commercial farms, and woodlands (Figure 2). On a provincial scale urban and mining areas are limited. The woodlands in the northeast correlate with the Bushveld Complex (Figure 1d) which is known for its mineral wealth, and a large number of platinum and chrome mines are located in this area. A comparison with the biomes (Figure 1) shows that the farmlands mostly fall within the grassland biome, and woodlands, shrublands, and grasslands correspond to the savanna biome.
Reported change statistics ([https://egis.environment.gov.za/](https://egis.environment.gov.za/)) show increases in mining areas, total pivot irrigated cultivation area, total commercial cultivation, total urban footprint, and total plantation footprint (Table 2). However, the change maps show the largest changes to be increases in grassland from 2014 to 2020 and increases in natural woodlands (Figure 3). The change from shrublands to grasslands between 2014 and 2020 is most likely to a reassignment of the class since the 2013-2014 land cover map was made by a different company [7]. The agricultural area remained largely unchanged.

**Table 2.** Significant land cover changes between 2014 and 2020, and between 2018 and 2020.

| Description                               | 2014 - 2020 | %    | 2018 - 2020 | %    |
|-------------------------------------------|-------------|------|-------------|------|
| Increase in mining area                   | 14727       | 24   | 7485        | 18   |
| Increase in pivot irrigated cultivation area | 25423       | 29   | 8374        | 8    |
| Increase in total commercial cultivation area | 123342      | 6    | 54172       | 3    |
| Increase in total urban footprint         | 60940       | 28   | 10697       | 4    |
| Increase in total plantation footprint    | 30446       | 179  | 5573        | 13   |
Figure 3. Most prominent changes in land cover types between 2014 to 2020, and 2018 to 2020. A summary of the most important land cover zones is shown on the right as a reference.

The SANLC datasets highlight four zones in the NWP (Figure 3). In the west there are largely grasslands and shrublands. Agriculture dominates in the centre and to the south. Built-up areas are present north of the farmlands, and finally in the northeast, mining in the Bushveld Complex is common.

3.2. Satellite remote sensing data
The rainfall figures for January and February clearly show the droughts in 2016 and 2018 (Figure 4). A more localized drought affected the NWP during 2012 [18] to such an extent that the premier of the province declared a state of disaster in 2013.

Overall, the rainfall increases from west to east in the province (Figure 4), and this is mimicked by the LST with temperatures decreasing from west to east (Figure 5).

Figure 4. Total rainfall during January and February over the NWP during the study period.
Figure 5. Land surface temperatures over the NWP during the study period.

Zonal means of the LST are consistently higher for the grasslands and shrublands (table 3, Figure 6a). This is probably due to this zone falling in the west of the province which is generally warmer than the rest of the province (Figure 5) and not related to the type of land cover. Except for 2018, the difference ranges from about 3°C to 8°C in 2020. There is no direct link between LST and rainfall for agricultural, built-up, and mining areas (Figure 6b). Low temperatures were observed in drier years and in the wettest years, while the highest temperatures occurred during years with average rainfall. Temperatures in grassland and shrublands generally decrease with increasing rainfall. It appears that in areas where human activity takes place, droughts do not necessarily correlate with higher temperatures, while in natural areas they are inversely linked.

Table 3. Mean and standard deviation (σ) of the land surface temperature (°C) for the four land cover zones shown in Figure 3.

| Years | Agriculture | Built-up | Grassland/shrubland | Mining |
|-------|-------------|----------|---------------------|--------|
|       | Mean°C | σ°C | Mean°C | σ°C | Mean°C | σ°C | Mean°C | σ°C |
| 2010  | 32.23  | 2.44 | 33.40  | 1.37 | 36.85  | 1.99 | 30.97  | 1.97 |
| 2012  | 34.66  | 3.16 | 34.11  | 2.29 | 41.95  | 2.62 | 31.70  | 2.37 |
| 2014  | 38.93  | 2.85 | 38.61  | 2.34 | 43.61  | 2.65 | 39.66  | 3.54 |
| 2016  | 36.48  | 2.08 | 37.14  | 2.34 | 40.79  | 2.39 | 38.57  | 3.76 |
| 2018  | 39.17  | 2.63 | 40.27  | 1.72 | 41.41  | 2.83 | 41.54  | 3.43 |
| 2020  | 32.77  | 2.01 | 32.14  | 0.93 | 38.88  | 2.74 | 30.98  | 1.84 |
Figure 6. (a) Mean values for the land surface temperature and (b) LST versus rainfall for the four zones shown in Figure 3.

The EVIs for the two wettest years (2010 and 2020) (Figure 7) are overall higher over larger areas than for the dry years but do not correlate exactly with the rainfall patterns (Figure 4). In 2010 the southwest experienced high rainfall during January and February, but the EVI is below 0.2. The land cover data show the west to be mostly covered by grass- and shrublands (Figure 2) and these types of vegetation are generally not very green, thus will not have high EVI values.

Figure 7. EVI averaged over 16 days over the NWP during the study period.
Looking more closely at the changes within the four land cover zones a good correlation between the EVI and rainfall pattern can be found (Table 4, Figure 8a). In the dry period between 2012 and 2018, the EVIs are mostly below 0.25. The very dry 2012 corresponds to local minima in the agricultural and built-up areas. In all the zones, the EVI increases with increasing rainfall and decreasing temperature (Figure 8b, c).

Table 4. Mean and standard deviation (σ) of the EVI for the four land cover zones shown in Figure 3.

| Years | Agriculture Mean | Agriculture σ | Built-up Mean | Built-up σ | Grassland/shrubland Mean | Grassland/shrubland σ | Mining Mean | Mining σ |
|-------|------------------|---------------|--------------|-----------|--------------------------|-----------------------|-------------|----------|
| 2010  | 0.32             | 0.10          | 0.30         | 0.06      | 0.23                     | 0.05                  | 0.33        | 0.06     |
| 2012  | 0.25             | 0.07          | 0.24         | 0.04      | 0.19                     | 0.04                  | 0.29        | 0.08     |
| 2014  | 0.24             | 0.07          | 0.23         | 0.05      | 0.18                     | 0.03                  | 0.25        | 0.07     |
| 2016  | 0.22             | 0.07          | 0.20         | 0.05      | 0.16                     | 0.03                  | 0.23        | 0.07     |
| 2018  | 0.21             | 0.07          | 0.20         | 0.05      | 0.18                     | 0.03                  | 0.23        | 0.08     |
| 2020  | 0.33             | 0.08          | 0.35         | 0.06      | 0.25                     | 0.06                  | 0.37        | 0.07     |

Figure 8. (a) Mean values for EVI, (b) EVI versus rainfall, and (c) EVI versus LST for the four zones shown in Figure 3.

Condition indices comparing the values of an index at a specific time to the minimum and maximum experienced over the whole study period enhance variations in an index. Values for the VCI are generally classified into drought hazard severity classes (Table 5) The VCI confirms that 2010 and 2020 experienced fewer drought conditions compared to the intervening years (Figure 9), however, it also shows that in the dry years of 2016 and 2018, the drought was less severe in localized areas in relation to the other years. For example, along the western boundary there is no drought in 2018. Rainfall extended further west in 2018 which may explain this. Land cover data shows open woodlands to have increased in this area compared to 2013-2014, and this may also contribute to the higher values. However, woodlands in the rest of the area correspond to drought conditions in 2018 so the possibility exists that the drought was not as severe in the west.

Table 5. Drought classification of the VCI values (from [14]).

| Drought Hazard Severity Class | VCI value (%) |
|------------------------------|---------------|
| No drought                   | > 40          |
| Mild drought                 | 30 - 40       |
| Moderate drought             | 20 - 30       |
| Severe drought               | 10 - 20       |
| Extreme drought              | < 10          |
Figure 9. VCI over the NWP during the study period.

Statistics for the four land cover zones also show the enhanced response of the VCI to ambient conditions. In the wettest years of 2010 and 2020, the VCI is higher than 0.7 (Table 6, Figure 10a). The VCI for grasslands and shrublands in 2018 is 0.33 which indicates a mild drought, while for the other zones it is 0.2 and less, signalling severe drought. Since the grassland and shrubland zone falls in the west, the statistics agree with the previous observation that the drought was not as severe in the west as in the rest of the province. However, the standard deviations for the VCIs are significant thus revealing uncertainty in the results.

Comparing the VCI with rainfall and LST (Figure 10b, c) reveals a more distinct inverse relation between the VCI and LST than between the VCI and rainfall. When the rainfall is low, the VCIs are higher than for moderate rainfall which seems contrary to the general assumption that drought leads to decreasing vegetation health.

Table 6. Mean and standard deviation (σ) of the VCI for the four land cover zones shown in Figure 3.

| Years | Agriculture | Built-up | Grassland/shrubland | Mining |
|-------|-------------|----------|---------------------|--------|
|       | Mean σ      | Mean σ   | Mean σ              | Mean σ |
| 2010  | 0.73 0.29   | 0.72 0.23| 0.72 0.30           | 0.73 0.24 |
| 2012  | 0.42 0.27   | 0.36 0.20| 0.46 0.29           | 0.53 0.28 |
| 2014  | 0.34 0.29   | 0.33 0.27| 0.28 0.27           | 0.30 0.25 |
| 2016  | 0.23 0.27   | 0.16 0.22| 0.13 0.19           | 0.17 0.20 |
| 2018  | 0.18 0.23   | 0.15 0.18| 0.33 0.31           | 0.20 0.27 |
| 2020  | 0.84 0.25   | 0.94 0.15| 0.82 0.25           | 0.91 0.17 |
Figure 10. (a) Mean values for VCI, (b) VCI versus rainfall and (c) VCI versus LST for the four zones shown in Figure 3.

The TCI derived from the LST (equation 3) is used in conjunction with the VCI to assess drought conditions. It is usually assumed that higher temperatures cause more vegetation stress, thereby reducing the EVI[19]. The formula also uses the reverse ratio to the VCI (equation 2), and consequently, low TCI values reflect high temperatures, and high values indicate lower temperatures [20]. This inverse relation between the TCI (Figure 11) and the VCI (Figure 9) is visible on a regional scale in the NWP, but localized variations occur. The higher temperature-more vegetation stress assumption may therefore not hold true for specific areas.

Figure 11. TCI over the NWP during the study period.

The mean TCIs for the agricultural, built-up, and mining zones follow a similar trend through the 10 years (Table 7, Figure 12a). For the grassland and shrubland, the TCI in 2012 is only 0.3 compared to 0.64 and higher for the other zones and in 2018 it is higher (0.4) than in the other zones (0.04 to 0.18).
There is no discernible relation between TCI and rainfall (Figure 12b), but since the TCI is calculated from the LST, their relation is clear (Figure 12c).

### Table 7. Mean and standard deviation (σ) of the TCI for the four land cover zones shown in Figure 3.

| Years | Agriculture Mean | σ | Built-up Mean | σ | Grassland/shrubland Mean | σ | Mining Mean | σ |
|-------|-----------------|---|--------------|---|----------------------------|---|-------------|---|
| 2010  | 0.92            | 0.12 | 0.83        | 0.13 | 0.94                       | 0.12 | 0.92        | 0.10 |
| 2012  | 0.64            | 0.25 | 0.73        | 0.22 | 0.30                       | 0.23 | 0.86        | 0.12 |
| 2014  | 0.19            | 0.23 | 0.24        | 0.22 | 0.11                       | 0.19 | 0.19        | 0.16 |
| 2016  | 0.45            | 0.23 | 0.40        | 0.24 | 0.46                       | 0.24 | 0.29        | 0.17 |
| 2018  | 0.18            | 0.23 | 0.06        | 0.11 | 0.40                       | 0.30 | 0.04        | 0.07 |
| 2020  | 0.87            | 0.16 | 0.97        | 0.07 | 0.70                       | 0.28 | 0.91        | 0.12 |

**Figure 12.** (a) Mean values for TCI, (b) TCI versus rainfall and (c) TCI versus LST for the four zones shown in Figure 3.

Combining the VCI and TCI into the VHI (equation 4) also reveals a slightly more complex situation with localized areas showing healthy vegetation (Figure 13). For example, healthier vegetation is visible in the centre of the province. This area contains agricultural activities. It also appears that the impact of drought on vegetation health in 2012 was not as severe as in 2016 and 2018, but a decrease in vegetation health is evident from 2012 to 2018, suggesting drought conditions were prevalent for most of the decade.

Mean values of the VHI for three of the zones show the lowest vegetation health conditions in 2018, but for the grassland and shrubland zone the worst condition was in 2014 (Table 8, Figure 14a). Since the VHI is a combination of the VCI and TCI, the relations between it, rainfall and LST mimic those for the VCI and TCI (Figure 14b, c).
Figure 13. The VHI over the NWP during the study period assuming even contributions from the VCI and TCI.

Table 8. Mean and standard deviation ($\sigma$) of the VHI for the four land cover zones shown in Figure 3.

| Year | Agriculture | Mean | $\sigma$ | Built-up | Mean | $\sigma$ | Grassland/shrubland | Mean | $\sigma$ | Mining | Mean | $\sigma$ |
|------|-------------|------|----------|----------|------|----------|---------------------|------|----------|--------|------|----------|
| 2010 | 0.83        | 0.17 |          | 0.77     | 0.14 |          | 0.83                | 0.18 |          | 0.83   | 0.14 |
| 2012 | 0.53        | 0.20 |          | 0.55     | 0.13 |          | 0.38                | 0.21 |          | 0.70   | 0.17 |
| 2014 | 0.26        | 0.22 |          | 0.29     | 0.22 |          | 0.20                | 0.18 |          | 0.24   | 0.18 |
| 2016 | 0.34        | 0.21 |          | 0.28     | 0.20 |          | 0.29                | 0.18 |          | 0.23   | 0.16 |
| 2018 | 0.18        | 0.17 |          | 0.10     | 0.12 |          | 0.37                | 0.26 |          | 0.12   | 0.15 |
| 2020 | 0.85        | 0.17 |          | 0.96     | 0.09 |          | 0.76                | 0.23 |          | 0.91   | 0.12 |
Figure 14. a) Mean values for VHI, (b) VHI versus rainfall and (c) VHI versus LST for the four zones shown in Figure 3.

The evaporative stress index (ESI) has been proposed as a better drought indicator since soil responds quickly to moisture changes [17]. Values close to 0 indicate abundant moisture and values close to 1 indicate water stress [21]. The western half of the province is almost constantly experiencing dry conditions (Figure 15). This is concerning as agricultural activities take place in parts of this region. Another, or additional reason for the low moistures content can be the young sediments of the Kalahari Group that underlay much of the western area. Sandy soils derived from these sediments will not be as good at retaining moisture as the more clayey soils derived from lavas, gabbros and mudstone that are more prevalent in the eastern half of the province. In extremely dry conditions the more clay-rich areas are also deprived of moisture.

Figure 15. The ESI over the NWP during the study period.
Table 9. Mean and standard deviation ($\sigma$) of the ESI for the four land cover zones shown in Figure 3.

| Years | Agriculture Mean | Agriculture $\sigma$ | Built-up Mean | Built-up $\sigma$ | Grassland/shrubland Mean | Grassland/shrubland $\sigma$ | Mining Mean | Mining $\sigma$ |
|-------|-----------------|---------------------|--------------|-----------------|--------------------------|-----------------------------|-------------|---------------|
| 2010  | 0.81            | 0.09                | 0.85         | 0.05            | 0.91                     | 0.03                        | 0.75        | 0.07          |
| 2012  | 0.88            | 0.07                | 0.90         | 0.05            | 0.95                     | 0.03                        | 0.79        | 0.06          |
| 2014  | 0.84            | 0.23                | 0.86         | 0.24            | 0.88                     | 0.28                        | 0.82        | 0.22          |
| 2016  | 0.91            | 0.06                | 0.94         | 0.04            | 0.97                     | 0.02                        | 0.90        | 0.06          |
| 2018  | 0.94            | 0.04                | 0.96         | 0.02            | 0.96                     | 0.02                        | 0.92        | 0.05          |
| 2020  | 0.77            | 0.09                | 0.77         | 0.06            | 0.90                     | 0.05                        | 0.68        | 0.08          |

The mean ESIs for the mining zone are the lowest of the four zones, and even during the very dry 2021, the ESI is lower indicating high moisture content (Table 9, Figure 16a). A reason may be that mining activities use substantial amounts of water, and this water can seep from tailings dams and other water storage facilities. The water often contains acid mine drainage, and certain grasses and reeds thrive in the acidic conditions.

As can be expected, there is an inverse relation between the ESI and rainfall (Figure 16b). Higher LST correlates with increased ESI which also makes sense as higher temperatures lead to more evaporation (Figure 16c).

Figure 16. (a) Mean values for ESI, (b) ESI versus rainfall and (c) ESI versus LST for the four zones shown in Figure 3.

Land cover data set the background for vegetation studies, but the vegetation and temperature indices provide critical insight into possible causes behind changes in land cover.

The EVI is persistently low in the west, even in wet periods such as 2010 and 2020 (Figure 7). This can be partly ascribed to the vegetation types but also to the young sedimentary cover that will not retain moisture very well. The agricultural lands generally have higher EVIs but these decrease during droughts for large swaths of this cover type which shows that many farmers are dependent on rainfall for farming. EVIs in built-up areas are somewhat affected by droughts, but not as severely as the previous two land cover types. Mining in the northeast takes place in an area characterized by abundant thorn trees. These trees have deep taproots through which they can sustain relative health during dry periods. This will explain why EVIs are still moderate in places in the northeast during 2016 and 2018. The soil derived from Bushveld Complex rocks are also better at retaining moisture.

VHI combines the VCI and TCI and shows the highest values in 2010 and 2020, before and after the drought. The VCI, TCI, and VHI show local trends that are otherwise not easily visible in conventional EVI and LST data. For example, the western edge of the province shows faster recovery in 2018 than the rest of the province, a detail not easily visible in EVI and LST data. They also show a gradual
decrease in vegetation health between 2010 and 2014. The demonstration of this index to show trends in indices may assist in possible drought planning in the future.

An interesting observation is that the EVI and ESI correlate with rainfall and LST, but the condition indices and VHI derived from them do not have an apparent relationship with rainfall.

4. Conclusions
Vegetation health indices derived from moderate resolution satellite data show that the entire North West Province is affected by drought, but mostly the central and western portions. Healthier vegetation in the mining areas even during dry spells show possible agricultural promise, once mining is complete in these areas. This is also dependent on successful rehabilitation post-mining, should any be necessary.

This study provided a baseline for further studies of ecological indicators and an ecological security assessment. The regional satellite data showed that the North West Province is prone to drought conditions. Since farming is a major component of the region’s economy, dry spells constitute a significant risk to the socio-economic well-being of the community. Soil types related to the underlying geology also control some of the vegetation health indicators and play an important role in moisture retention.

The province also hosts platinum mines in the north at Rustenburg and gold mines in the southeast around Klerksdorp (Figure 1). In 2017 mining contributed 31.3% to the region’s gross domestic product [22]. Mining contributes almost 25% to national mining GDP and roughly 33% to national mining employment [23]. A problem associated with mining is water pollution, e.g. acid mine drainage is a common problem in the gold mining industry [24]. Pollution of water resources can affect vegetation health. It is possible that changes in vegetation health around mines may in part be related to mining activities and not only to climatic changes. High-resolution remote sensing data will be used to study those.

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