# Vegetation Dynamics with Elevation in Southern European Russia

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# Vegetation Dynamics with Elevation in Southern European Russia

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**Abstract**. In this research work vegetation dynamics was examined for spring-summer (may-august) season based on Moderate Resolution Imaging Spectroadiometer (MODIS) satellite data generated Normalized Difference Vegetation Index (NDVI) with elevation from 2014 to 2018 in Southern part of European Russia. The resulting divergent groups with respect to decreasing, increasing or no trends presented significant differences in vegetation dynamics and correlation between elevation and NDVI values. Results indicate that in the year 2016, vegetation was highly degraded with low NDVI values from less than 0 to 0.20. In comparing of elevation maximum vegetation was present from 100 to 250 m elevation, below and above this range was very low vegetation. In high elevation from 100 to 250m, low NDVI values slightly shift in high NDVI values, which show healthy vegetation on high altitude. Field observation also conform high NDVI values to high elevation. The MODIS time series with 250m resolution is appropriate for vegetation dynamics study for a large, inaccessible area with low coast, within less time for long term changes in vegetation growth.

## 1. Introduction

Vegetation dynamics is an important phenomenon in response of varying environmental conditions and terrestrial information for biodiversity and ecosystems functioning [1, 2, 3]. Vegetation dynamics is a visible relationship with environmental conditions and terrestrial topography because it's directly effects on plant biophysical components such as evapotranspiration and photosynthesis and later on plants growth [4, 5, 6]. Environmental conditions and terrestrial topography effect on vegetation at variety of different scales as local to global, seasonal to annual and decadal [7]. However, these effects cannot be study by tradition methods at large spatial and temporal scale. Fortunately, advance remote sensing technology resolve this problem by finding correlation in between NDVI and vegetation dynamics. Thus, this study emphasis on vegetation dynamics changes and growth at different elevation for spring-summer (may-august) season on annual basis from 2014 to 2018 based on MODIS satellite data generated NDVI in Southern part of European Russia [8].

Regular remote sensing satellite data can help to mapping and monitoring of vegetation dynamics with environmental and terrestrial information at different spatiotemporal scale [9, 10] by NDVI. NDVI is a band combination or ratio of red (visible) and infrared bands and resulted range from 1 to -1. Positive NDVI values represent greenness and negative values represent no or little vegetation.

Values which are close to zero from -0.1 to 0.1 represent degraded vegetation such as rock, sand or snow vegetation. Low positive values approximately 0.2 to 0.4 represent less vegetation such as shrubs and grassland. High values above 0.5 and close to 1 represent healthy vegetation such as tropical rainforest [11]. NDVI also represent photosynthesis, which is associated with plant biomass and water stress conditions so can be used for early warning system [12]. Now days globally, scitific communities have been widely using NDVI for vegetation growth and dynamics analysis with terrestrial information [13] as NDVI is the first useful tool to measure these relationships. However satellite generated NDVI have its own limitations associated with side situation, resolution and climatic conditions [14].

The specific objective of this research work was to examine spatiotemporal vegetation dynamics with elevation based on NDVI in southern part of European Russia for spring-summer (may-august) season from 2014 to 2018. To better understand the spatiotemporal changes in vegetation a trend analysis on NDVI change was executed at pixel and provincial level [15]. In addition we derive vegetation characteristics with elevation by NDVI trends with fine resolution and later on discuss vegetation growth [16].

## 2. Study area
We choose Southern part of European Russia (ER) as a study area, which cover following 13 states of Russia: Astrakhan, Belgorod, Kalmyk, Kursk, Lipetsk, Penza, Rostov, Samara, Saratov, Tambov, Ulyanovsk, Volgograd, and Voronezh (fig. 1).
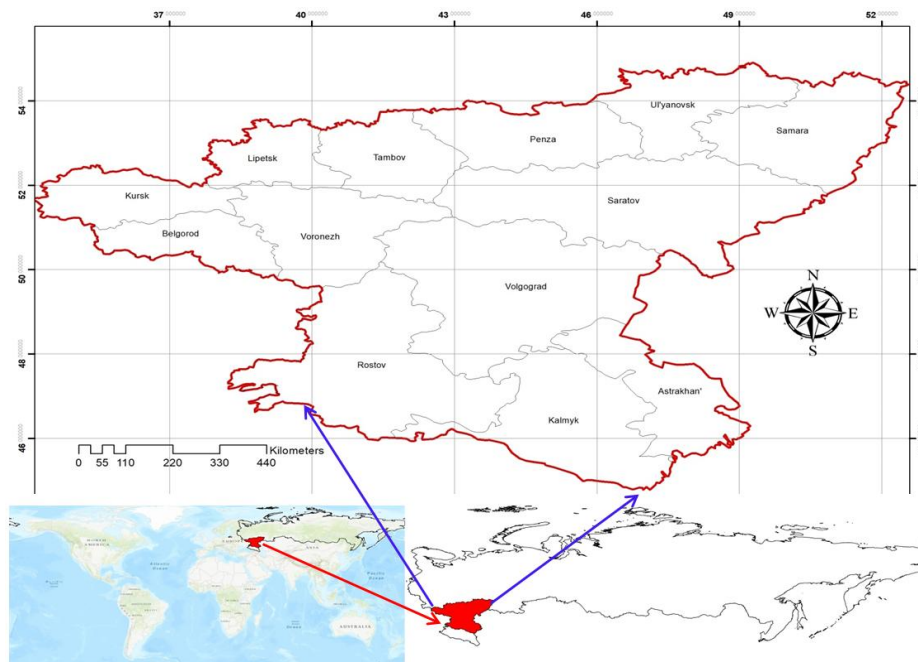


**Figure 1.** Geographic location of Southern Part of European Russia with 13 states of Russia.

## 3. Materials and methodology

### 3.1. Data
To obtain a sufficient spatial and temporal coverage of the study area on a yearly basis and at low data costs, multispectral and ground data were incorporated such as: Advance Very High Resolution Radiometer (ASTER), and Moderate Resolution Imaging Spectroadiometer (MODIS) [17]. This study focus on vegetation health based on NDVI values so consider spring-summer (may-august) season data as this time period, there is no snow cover and vegetation is on its peak growth stage. During field

work we used high quality hand held GPS for ground truth and georeference of the satellite imagery. For GIS analysis and image processing work we used ArcGIS, ER-Mapper and ERDAS software's and prepare thematic maps. So to take the dual advantage in this research work, we used both primary (satellite data) and secondary data (field and socio-economic data) [18]. To know topography information, we used Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER-GDEM) from the Ministry of Economy, Trade and Industry of Japan (METI) and the National Aeronautics and Space Administration (NASA) at 30 meter resolution data for elevation, slop and aspect information.

*3.2. Methodology*
This research work was benefited from ground-based information collected in region during field work. Than completed image pre-processing steps such as remove all radiometric, geometric distortions and project all datasets in WGS-1984 UTM projection with the help of ground control points (GPS) so that all noise or sensors related errors such as droplines was removed and each pixel was geocoded as its exact location on globe and then used best band combination and enhancement techniques to identify specific features in composite images. After it all field data were vectorise and interpolated as grid datasets so that it was combine with satellite data and later on easy to use in GIS format analysis, which was great help to derive meteorological information, phonological information and vegetation based indices for vegetation dynamics.

Following the streamlines in methodology, after image processing, all satellite data was processed for the mapping of NDVI trend change with elevation at pixel level. NDVI was calculated from MOD13Q1-MODIS data based on red and near infrared bands combination as following to estimate greenness:

$$Normalized\ Difference\ Vegetation\ Index\ NDVI = \frac{NIR-Red}{NIR+Red}$$

Where NIR is reflectance in near infrared band and Red is red band reflectance. MOD13 have 16 days repeat cycle so first 16 day time series was resampled to a monthly time series and then averaging for spring-summer (may-august) season for the study area from 2014 to 2018.

NDVI is a proxy for photosynthetic activity and primary production from vegetation biomass and is a common index for monitoring vegetation growth. To identify NDVI trend change with elevation over a period of time, we use [18] method that change in NDVI values are proxy of change in vegetation condition. According to this we classify NDVI values in terms of very healthy to no vegetation class as in table 1:

**Table 1.** Vegetation classes according to NDVI values.

| Class name | NDVI range | Class level I | Class level II | Class level III | NDVI range | Subclass name |
|---|---|---|---|---|---|---|
| 1 | 0.9 to 1 | | Dense vegetation | Very healthy vegetation | 0.85 < | A |
| 2 | 0.5 to 0.8 | Vegetation | Open vegetation | Temperate and tropical rainforests | 0.79 – 0.84 | B |
| | | | | | 0.66 – 0.78 | C |
| | | | | | 0.51 – 0.65 | D |
| 3 | 0.2 to 0.4 | | Degraded vegetation | Shrub and grassland | 0.41 – 0.50 | E |
| | | | | | 0.31 – 0.40 | F |
| | | | | | 0.20 – 0.30 | G |
| 4 | -0.1 to 0.1 | No-Vegetation | | Barren areas of rock, sand, or snow | 0.00 – 0.19 | H |
| 5 | -0.1 to -1 | | | Water | 0.00 – -0.50 | I |
| | | | | | -0.51 > | J |

Subsequently superimposed all NDVI images on DEM by this way we overlap mean NDVI values of spring-summer (may-august) season on different elevation intervals of 50m. Than were extracted NDVI values on different heights from 0 to 350 meter with 50 m intervals as maximum elevation in the study area is 390m. So first we calculate total vegetation and non-vegetation area and then subclass level vegetation area according to NDVI values as table 1 from 2014 to 2018 for Southern part of ER to know the NDVI trend change at pixel level (fig. 2) on different elevation. Finally calculate total area change in different NDVI values on different elevation. As atmospheric condition were different for the different years during the image capturing so field work was an important task to increase accuracy in sub class level vegetation area calculations on different elevation based on NDVI trend change. So we also carried out field visits during July 2018 for field verification and ground trothing. We noticed healthy and dense vegetation on high elevation. For accuracy assessment of the all yearly NDVI maps with elevation from 2014 to 2018, we derive user accuracy, producer accuracy and overall accuracy, which was higher than 91% for all images. Here we also did some key interview with old peoples who living in the study area for a long time (more than 25 years).

## 4. Results

Figure 2 represent NDVI trend change for spring-summer (may-august) season from 2014 to 2018 in Southern Part of ER. In 2014 north part is with very high NDVI values (0.7 to 1) and southeast part is with lowest NDVI values (0.1 to 0.0>) but in 2015 lowest NDVI values convert into moderate to high NDVI values in southeast part and vice-versa in northeast and southwest part of the study area. In 2016 maximum central part of the study area show low to very low NDVI values with some moderate NDVI values patches in north and south. In 2017 north part was convert into very low NDVI values and in 2018, it was the similar situation like 2014 but with little bit high NDVI values (fig. 2).



NDVI_2014



NDVI_2015
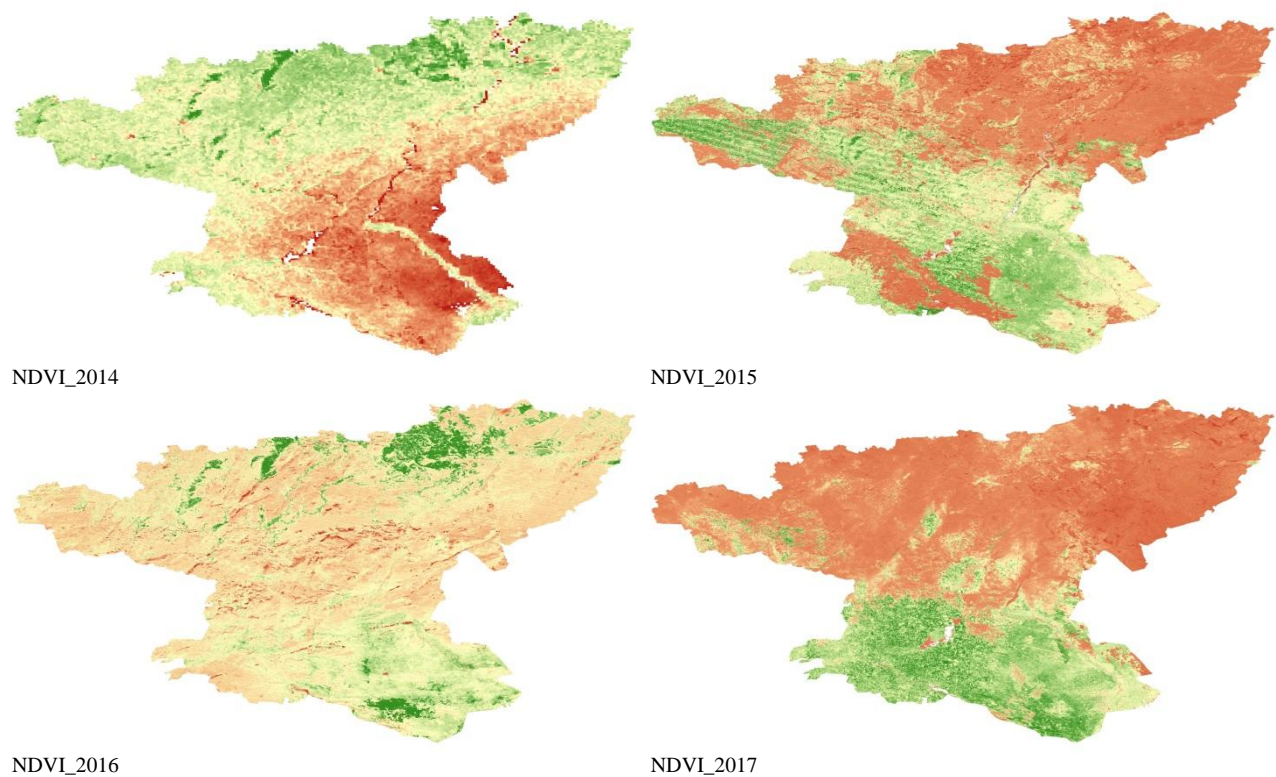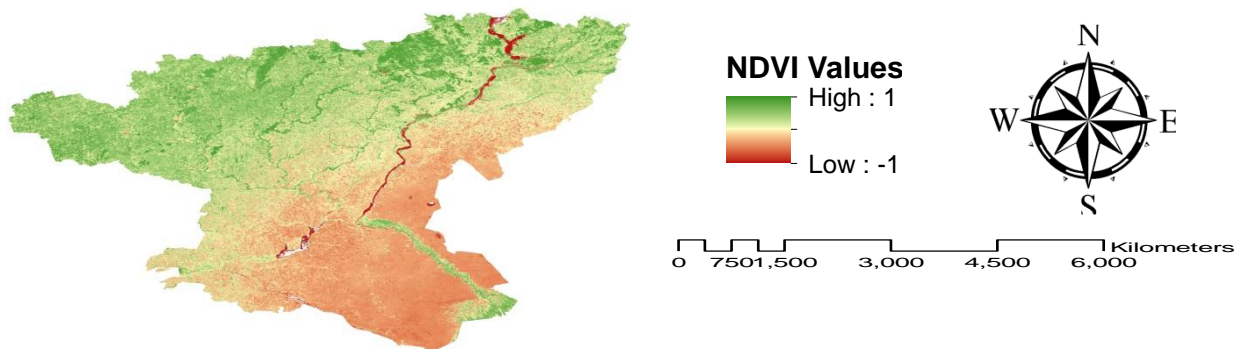


NDVI_2016



NDVI_2017

NDVI_2018

**Figure 2.** NDVI change trends for spring-summer (may-august) season from 2014 to 2018 in Southern Part of European Russia.

When we compare yearly changes in area based on NDVI values, we find in 2018 have high NDVI (>.85-.4) to moderate NDVI avles (0.4-0.2) but in 2017 maximum vagetation (55%) have 0.0 to 0.2 NDVI values and around 28% area with verly low NDVI avlues (fig. 3). Year 2016 show a water stress year and 55% vegetation cover have loweast NDVI values with below than 0.0. 29% area with 0.0 to 0.19 and 11% area cover with 0.2 to 0.3 NDVI values. In 2015 maximum area shifted moderate to low NDVI values with highest range around 40% area with NDVI value of 0.0 to 0.2 (fig. 3). In 2014 situation is better than 2015 and NDVI values shifted from low to moderate NDVI values (0.2 to 0.5).
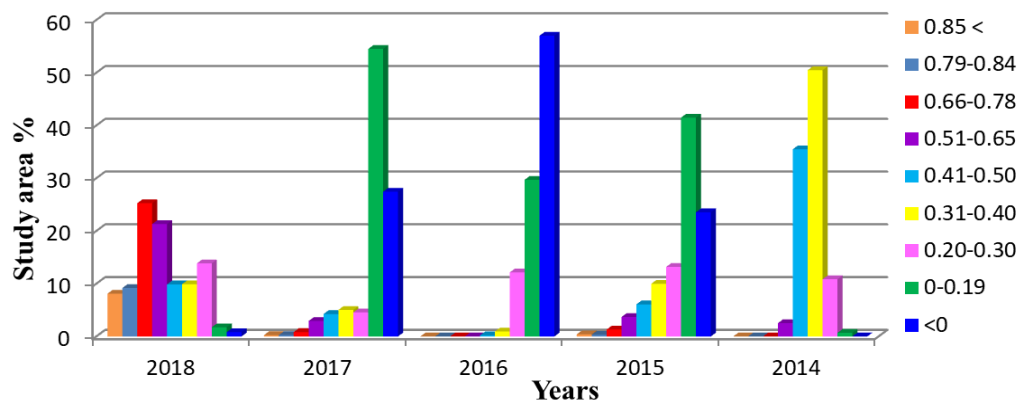


**Figure 3.** Percentile study cover change based on NDVI values for spring-summer season from 2014 to 2018 in Southern Part of European Russia.

To know the vegetation variation on different elevation based on NDVI values, we define vegetation on different contour lines with 50m elevation differences as show in figure 4. Figure 4 shows NDVI images from 2014 to 2018 for the spring-summer season with elevation information for a small specific sample site in the center of the study area marked as blue line in figure 4. From 2014 to 2015 Lowest NDVI values (0.0-0.4) represented by red, orange and pink were changed in high NDVI values (0.5-0.8) represented by sky-blue, light and dark green at high elevation. 2015 to 2016 was a driest period so all healthy vegetation (NDVI values 0.5-0.8) convert into lowest NDVI values (<0.0-0.1) at all elevation represented by blue and red color. From 2016 to 2017 lowest NDVI value shifted into moderate value (0.2-0.5) on high elevation. In 2017 to 2018 at high elevation moderate NDVI class represented by yellow, pink and orange color (NDVI 0.2-0.5) changed to the high NDVI values (0.5-0.8) represented by green and sky blue color areas (fig. 4). So generally on high elevation low NDVI values shift into high NDVI values.
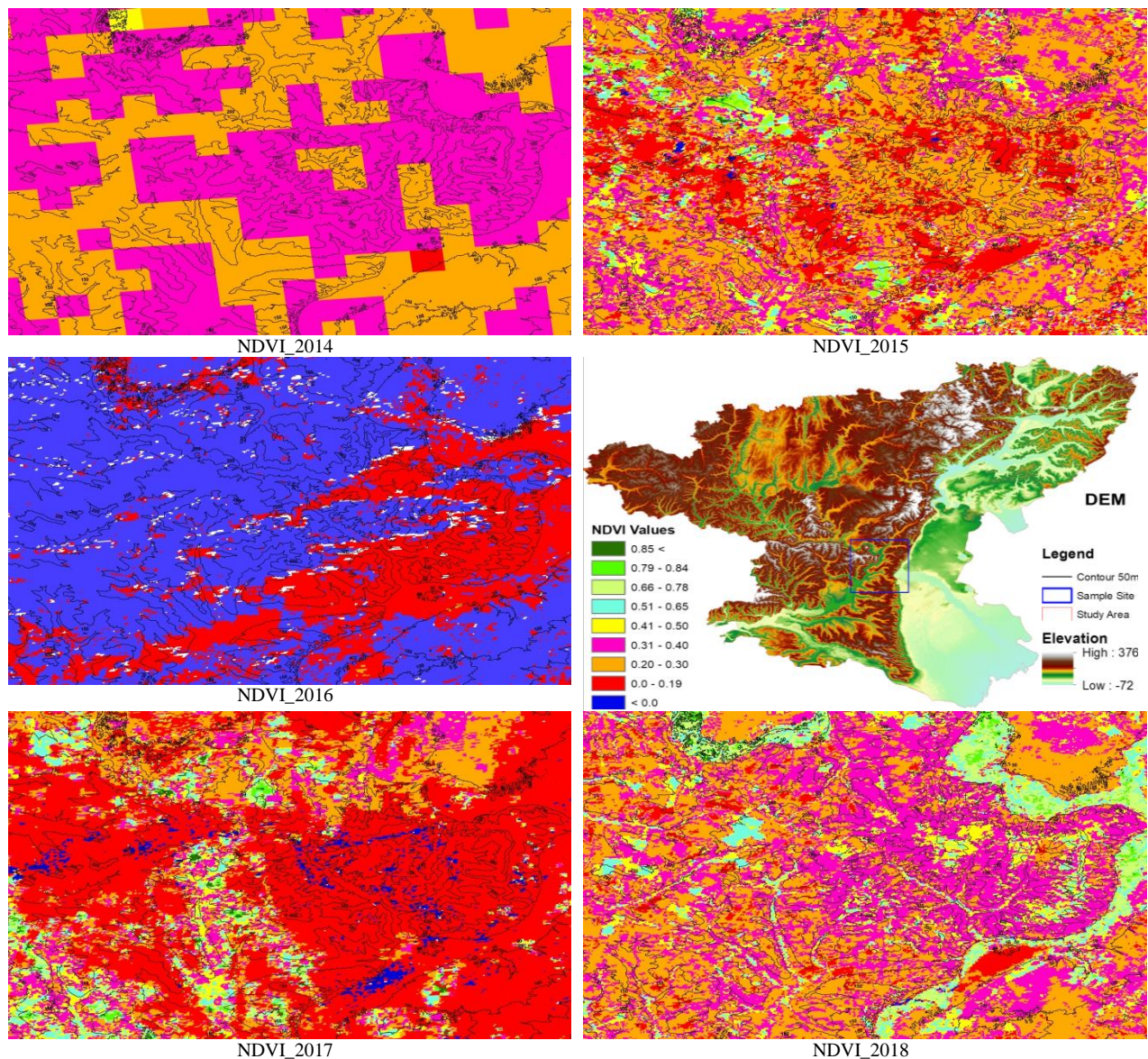
**Figure 4.** NDVI images for spring-summer season from 2014 to 2018 in sample site of Southern Part of European Russia with contour lines.

Figure 5 shows graphical representation of figure 4, means NDVI values variation at different elevation from 2014 to 2018 for spring-summer season in SER. All year's situation looks very different from each other's. Vegetation below 50m and above 300m elevation was unchanged or very less variant. From 100 to 250m elevation based on NDVI values vegetation condition is different based on specific year's climatic conditions.

In 2018 at 100m elevation maximum vegetation was moderate condition with 0.2-0.5 NDVI values. From 150 to 250m elevation maximum area was covered by high NDVI values from 0.51 to 0.78. In overall in 2018 whole vegetation was healthy with moderate to high NDVI values and very low vegetation below than 50 and above than 300m elevation.
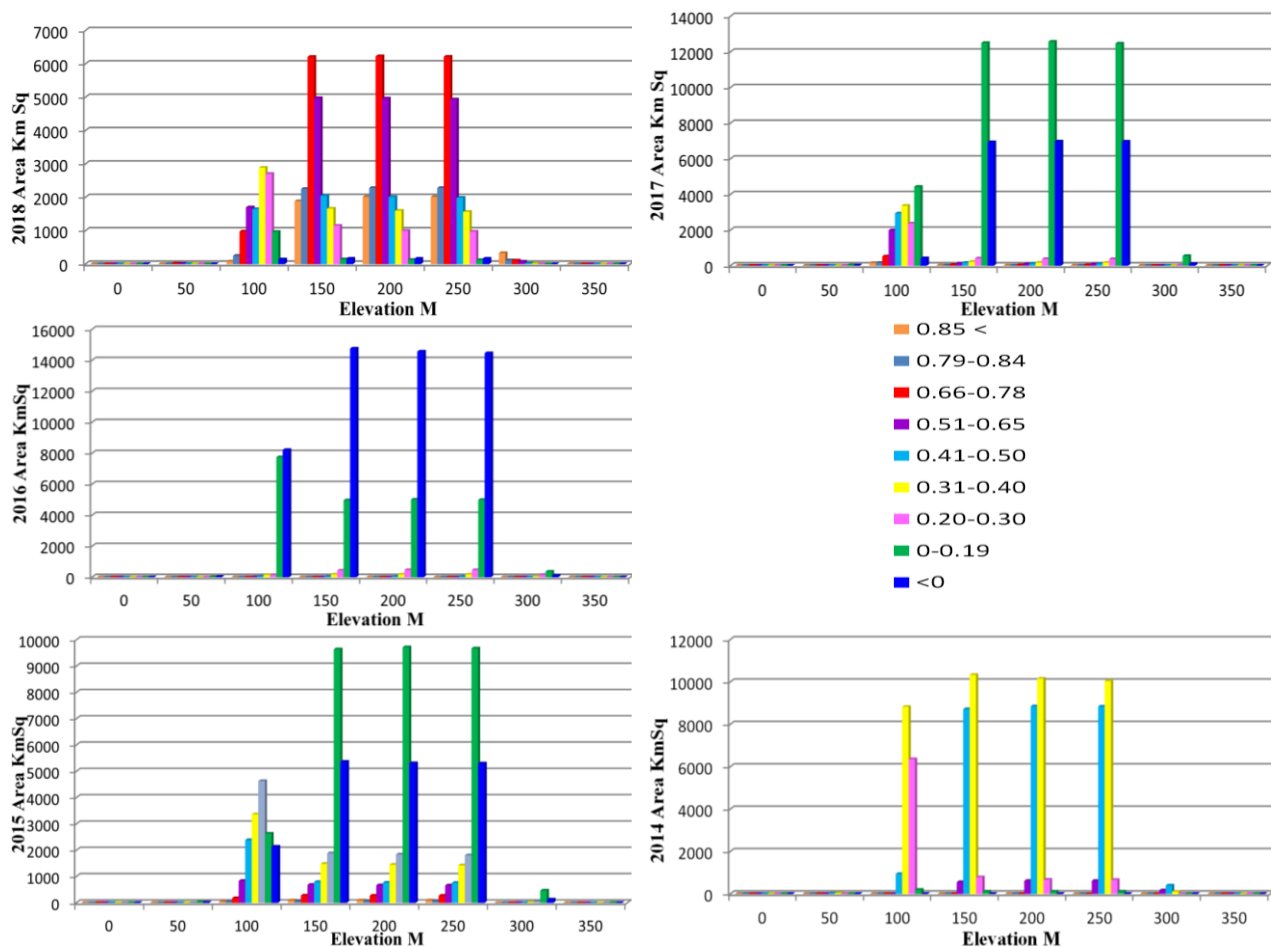
**Figure 5.** NDVI differences on different elevation for spring-summer (may-august) season from 2014 to 2018 in Southern Part of European Russia.

In the year 2017, at 100m elevation vegetation was moderate to low NDVI values from 0.65 to 0.19. There was less healthy vegetation from 150 to 250m elevation with NDVI values of 0.19 to less than 0.0. It's also unchanged or very less changes below than 50 and above than 300m elevation, same like 2018. Due to water stress situation in the year 2016, all vegetation was with lowest NDVI values below than 0.19.

In compare of 2016, vegetation condition was much better in 2015 and especially in 2014. As in 2016 lowest NDVI values due to water stress condition show low NDVI values but in 2014 it was moderate NDVI values from 0.3 to 0.5. In 2014 and 2015, vegetation was unaffected same like other years at below to 50m and above 300m elevation.

The results of this research work indicate vegetation variation depends on climatic condition on different elevation so to pressure ecosystem and biodiversity in Southern part of Europe responsible organizations must be care things. Generally low NDVI values indicate increased Red and decrease Near Infra-Red reflectance due to harsh climatic conditions, resulted squat photosynthetic activities. During field work we observe this harsh condition across the study area especially above 150m elevation. Finally satellite remote sensing based vegetation indices are an effective and low coast indication to identify inter and intra annual changes in vegetation growth.

## 5. Conclusions

In this research work MODIS satellite data generated NDVI values were examined for vegetation dynamics on different elevation from 2014 to 2018 for spring-summer (may-august) season in Southern part of European Russia. The summarized conclusions are given below:

1. NDVI values were increase with increasing elevation, especially in between 100 to 250m elevation, which show healthy vegetation on height.
2. The climatic variation and geography situation are the main cause for NDVI values variations in Southern part of European Russia.
3. Other than this during field work, find that socio-economic activities, government policies, environmental conservation and irrigation management schemes are also effect on vegetation condition in the study area.
4. For future scenario in the study area, water arability and land use/cover change would be instantly considered.
5. Furthermore vegetation dynamics study with elevation should be considering such problems in methodology and data uncertainties.

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