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# Development of a Web Mapping Application for grazing resource information in Kordofan, Sudan, by downloading MODIS data automatically via Python

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Jessica Ahlgren (2016)

***Development of a Web Mapping Application for grazing resource information in Kordofan, Sudan, by downloading MODIS data automatically via Python***

***Utveckling av en internetbaserad kartapplikation för information om betesresurser i Kordofan, Sudan, genom att ladda ner MODIS data automatiskt via Python***

Master degree thesis, 30 credits in *Geomatics*  
Department of Physical Geography and Ecosystem Science, Lund University

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Disclaimer

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# Development of a Web Mapping Application for grazing resource information in Kordofan, Sudan, by downloading MODIS data automatically via Python

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Master thesis, 30 credits, in *Geomatics*

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## **Abstract**

In Sahel livestock stands for an important resource. Since livestock is dependent on vegetation as food supply it is important to monitor biomass within the area to be able to assess and adapt to different situations regarding the livestock. Optimally such approximations should be available as early as possible in order for the owners to be able to make decisions while it still makes a difference. If patterns of annual NPP is detected and is identified due to different factors, mitigation can be discussed and food shortage for the livestock be prevented at an early stage. The overall aim of this thesis was to develop a web mapping application that can be used to disseminate grazing resource information as an aid in planning as well as a source for policy and decision making. MODIS data, containing NPP, was downloaded and processed automatically from the United States Geological Survey website through a Python script and was uploaded to ArcGIS Online where the Web Mapping Application is available. Long-term patterns of NPP could be detected by using long term accumulate values of NPP and gives an indication of how the vegetation and relative resource availability fluctuates each year and when there is expected to be the most vegetation and vice versa. The Web Mapping Application developed in this thesis do disseminate grazing information but requires some further implementations before it is a trustworthy aid in planning and decision making. This thesis can, nevertheless, be built upon for further implementation and provide some inspiration in the process.

**Keywords:** Web Development, Python, NPP, MODIS, Kordofan, Sahel, Grazing resources, Web GIS and ArcGIS Online.

## **Svensk sammanfattning**

I Sahel är boskap en viktig resurs och eftersom de i sin tur är beroende av vegetation som näringskälla är det viktigt att övervaka biomassa inom området för att kunna anpassa sig till olika situationer gällande boskap. Information från en sådan övervakning bör vara tillgänglig så tidigt som möjligt så att ägarna till boskapen kan fatta beslut medans de fortfarande kan göra skillnad. Om mönster kan detekteras gällande årlig NPP och i sin tur identifierad av olika faktorer kan dessa diskuteras och i sin tur användas för att förhindra matbrist för boskapen i ett tidigt skede. Det övergripande syftet med detta examensarbete var att utveckla en internetbaserad kartapplikation som kan användas för att sprida information om betesresurser som ett hjälpmedel i planering samt en grund för politik och beslutsfattande. MODIS data, som innehåller NPP, laddades ned och bearbetades automatiskt från United States Geological Survey webbplats via ett Python-skript och laddades sen upp till ArcGIS Online där kartapplikationen finns tillgänglig. Långsiktiga mönster kunde detekteras med hjälp av långtidsvärden av NPP och ger en indikation på hur vegetation och relativ tillgång på resurser varierar varje år samt när det förväntas att vara mest vegetation och vice versa. Kartapplikationen som utvecklats i denna avhandling visualiserar betesresurser, men kräver flera implementeringar innan det är en pålitlig hjälp i planeringen och beslutsfattandet. Detta examensarbete kan dock byggas vidare för ytterligare implementering och ge lite inspiration i processen.

## **Acknowledgements**

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# 1 Introduction

## 1.1 Background

The Sahel is a region that is known for recurring disastrous droughts (Nyong et al. 2007) and has in several occasions been considered as a high interest topic regarding global environment and climate change (Brandt et al. 2014a). It is located in Africa and extends from the Atlantic Ocean to the Red Sea which is roughly a distance of 6000 km (Brandt et al. 2016). Scientists have warned that large areas of the Sahel region could possibly be permanently degraded land (Ayoub 1998; Dregne 2002) but since an increase in rainfall have been observed starting from the 1990s, it has been proved from satellite-measurements that vegetation greenness are in fact increasing (Herrman et al. 2005; Olsson et al. 2005). This knowledge has led to what is known today as the (re-)greening Sahel phenomenon which is still stable and continuous in current time (Fensholt et al. 2012).

Studies involving remote sensing have confirmed via satellite analysis of time series that there is a positive trend in vegetation growth in the Sahel over the last decades (Anyamba and Tucker 2005; Fensholt et al. 2013). Several studies (Seaquist et al. 2009; Huber et al. 2011; Anyamba et al. 2014) state that the recorded increase of precipitation is one of the main factors causing the (re-)greening Sahel phenomenon; however, they also state that further studies are needed to validate such statements (Seaquist et al. 2009; Huber et al. 2011; Anyamba et al. 2014). Moreover, it has also been speculated whether livelihood has a relation to the (re-)greening of Sahel (Nyong et al. 2007; Mertz et al. 2008; Reenberg et al., 2013), and if there are some consequences on ecosystem health and carbon sequestration due to the increase in biomass productivity (Woomer et al. 2004; Luedeling and Neufeldt 2012). It is possible that human factors could be one reason for the observed (re-)greening. There has been recorded a general increase in population as well as it has been noticed that there is occurring migration to cities or even abroad. Thus it is unclear if a rising population are demanding more resources or if the recorded increase is stabilized by occurring mitigation (Rasmussen and Reenberg 2012; Romankiewicz and Doevenspeck 2015). Recent studies indicate that it is both climatic and anthropogenic factors that are driving the changes in Sahel. The theory is that higher temperatures and thus extended dry periods in combination with grazing, selective felling etc. have and are all parts of the changing of Sahel during the last 50 years (Miehe et al. 2010; Brandt et al. 2014b). Livestock is not only important for the Sahel, but it is a well spread human activity. In rangeland ecosystems it is the most common land use (Alkemade et al. 2012). It provides food for millions of people as well as income for many people (Herrero and Thronton 2013). In Sahel livestock stands for the primary renewable resource (Dicko et al. 2006) and may be related to precipitation since e.g. droughts sometimes results in food shortage for the animals (Fensholt et al. 2004). Because livestock is dependent on vegetation as food supply it is important to monitor biomass within the area to be able to assess and adapt to different situations regarding the livestock (Mbow et al. 2014). Optimally such approximations should be available as early as possible in order for the owners to be able to make decisions while it still makes a difference (Atzberger 2013).

## 1.2 Framework and problem statement

There is currently a project called the Grazing Resource Information for Sahel (GRIS). The projects overall aim is to develop a monitoring system quantifying supply and demand of grazing resources in the Kordofan region of the Sudan. This region is the home for the largest remaining pastoralist population in the African Sahel. The project includes data assimilation, processing and information distribution to the end user (pastoralist and regional manager). The data and information that have already been collected as well as future data should be available through a web mapping application compliant to the OGC Web Map Service (WMS) specification (de La Beaujardiere 2006). Such application has currently not been implemented. The supply of grazing resources shall be displayed in terms of Net Primary Productivity (NPP) with an 8-day temporal resolution and 1x1 km spatial resolution. The web mapping application should provide tools for different spatial analysis on resources or possible connections to e.g. watering points. A web mapping application was chosen because it will then be reachable using the internet which in turn ascertains flexibility and portability with mobile phones. Particularly regarding the demand aim in which resources could then be updated instantaneously and in a later stage herd movements could be mapped using Global Positioning System (GPS) collars. The nomads and transhumance pastoralists migrate to secure food and water for the animals; thus, the patterns vary from year to year due to resource availability. During the cropping season, grazing is not allowed in cropping areas in order to protect the harvest and to avoid conflicts (Ardö 2011). Overall, the project is associated to key questions regarded sustainable resource utilization, information communication and handling as well as managing prospects in agro-ecosystems in Africa that are predicted to suffer from climatic change (Neely et al. 2009; Olsson and Ardö 2002; Snyman 1998). As mentioned in section 1.1 monitoring biomass is important to enable future decision makings, in this specific thesis so the nomads can plan the movement of their livestock to beneficial areas. The aim of this thesis is therefore to create a web mapping application where such beneficial areas may be mapped and thus function as a support in planning as well as be a resource for policy and decision making.

Two methods using different types of data have been tested regarding the supply aim so that the supply of NPP (grazing resources) can be estimated, 1) using MOD17 or 2) using EVI or NDVI (Ardö 2011). This thesis will be based on the first one. MOD17 is the first satellite-driven dataset that observes vegetation productivity on a global scale. The goal of the dataset is to make GPP/NPP estimates available continuously over Earth's whole vegetated land surface. The algorithm for MOD17 is based on Monteith (1972) logic about original radiation use efficiency, which proposes that the annually accumulation of crops during good conditions is linearly related to the amount of absorbed solar energy, explicitly the amount of absorbed Photosynthetically Active Radiation (APAR). The transformation of APAR to the estimation of actual productivity is made through a translation efficiency parameter ( $\epsilon$ ) and varies by climate conditions and vegetation type. Thus MOD17 includes differences in maximum  $\epsilon$  among vegetation types as well as it reduces  $\epsilon$  under colder conditions and/or vapor pressure deficit (VPD). When calculating NPP it also estimates daily leaf and fine root maintenance respiration ( $R_{lr}$ ), annual growth respiration ( $R_g$ ) and annual maintenance

respiration of live cells in woody tissue ( $R_m$ ). The following three outputs are available for MOD17:

- 8-day GPP ( $GPP = \epsilon_{max} * Temperature\_Scalar * Water\_Stress\_Scalar * APAR$ )
- 8-day Net Photosynthesis ( $PSNet = GPP - R_{lr}$ )
- Annual NPP ( $NPP = PSNet\_Sum - R_g - R_m$ ) (NTSG 2016)

Since there are available data of MOD17 from the year 2000 to the present, both short and long term values of NPP can be used for various calculations. Possibly this will further aid planning as well as be a resource for policy and decision making. If patterns of annual NPP are detected and are identified due to different factors, mitigation can be discussed and food shortage for the livestock can be prevented at an early stage.

### **1.3 Aim and research questions**

The overall aim of this thesis is to develop a web mapping application that can be used to disseminate grazing resource information as an aid in planning as well as a source for policy and decision making, including information of vegetation productivity (NPP), for the Kordofan region of the Sudan.

The first question of this thesis is how MODIS satellite data can be downloaded, processes and uploaded automatically in a web mapping application. The second question is how short and long term values of NPP can be used for detecting long-term patterns of NPP and if it is possible to use it as an indication of relative resource availability.

### **1.4 Limitations**

Because it is costly to upload data to ArcGIS Online as a server, some limitations have been made regarding the amount data that has been uploaded as well as the resolution/scale available. The result in this thesis is therefore a limited version of what actually exists and can be seen as examples of possible implementations. Moreover the point data containing information about water sources and villages used in this thesis are not complete and should therefore also be seen as an example of implementation.

## **2 Literature review**

This section reviews 1) Net Primary Production (NPP) which the thesis is based on to monitor grazing resources; 2) mobile services which should be implemented in a future step in the web mapping application regarding the demand criteria of grazing resources (section 1.2); 3) the sensor Moderate Resolution Imaging Spectroradiometer (MODIS) that collects the data used in the thesis; and 4) Web GIS implementations for resource distribution.

### **2.1 Net Primary Production (NPP) and resource management**

One of the key factors in environmental resource management is to monitor terrestrial plant productivity (Churkina and Running 1998; Zhao and Running 2010). It is plant productivity

that regulates the extent of energy accessible to sustain all organisms (Chapin et al. 2011). Predictions as early as possible in changes of productivity are very useful both in local and regional perspective. Climate change can also be monitored via variation in vegetation productivity since ecosystems and climate interacts, thus influencing each other (Nemani et al. 2003b). In ecosystems photosynthesis is termed Gross Primary Productivity (GPP). Approximately half of the GPP is respired by plants and Net Primary Productivity (NPP) stands for the difference between GPP and plant respiration. This is the net carbon gain by plants (Chapin et al., 2011) and is an ecological variable used on global scale, often used in different models making it relatively comparable to other studies and projects (Kooistra et al. 2009). NPP is usually measured at the ecosystem scale, generally over a long period of time as a year ( $\text{g biomass or g C m}^{-2} \text{ year}^{-1}$ ). On the other hand, NPP does not give information if the circumstances regarding photosynthesis decrease the amount of carbon that is available to support growth or if the circumstances are making the growth rate regulate the amount of photosynthesis. NPP correlates mostly with precipitation and when the temperature rise NPP increases exponentially (Chapin et al. 2011). Chapin et al. (2011) state that there can be errors in studies analyzing NPP since many only consider the new plant biomass that is produced which most likely underestimates the true result with 30 %. Another source of errors can be that herbivores eats some vegetation before it is measured leading to a misleading result. Overall some components of NPP are hard to measure, for example root production, which sometimes is solved by making it a constant ratio of aboveground production (Chapin et al. 2011). Less than 10 % of studies related to terrestrial NPP in fact measured belowground production (Clark et al. 2001). Sometimes aboveground NPP disregard understory shrubs or mosses, thus excludes possibly large proportions of NPP in some ecosystems. Published work of NPP seldom state what mechanisms of NPP that have been involved in their results as well as the units are usually not defined (grams of carbon or grams of biomass). Therefore comparisons between different data on NPP or biomass among studies should be done with substantial caution (Chapin et al. 2011).

## **2.2 Mobile GIS services for obtaining and accessing field data**

Attaining field data on biomass dynamics is seldom done for the Sahel and is an inept task that has limited the success regarding methods for vegetation trend analysis (Brandt et al. 2014a). Many real-time field mapping activities regarding environmental and monitoring tasks usually need accurate positional information. Traditional field mapping is generally time consuming, difficult to carry out (Angold et al. 1996) and are also often limited to hard-wire network communications as well as desktop computers. There have been suggestions of implementing mobile Geographic Information System (GIS) services which can integrate GIS, global positioning systems (GPS) as well as remote sensing capabilities so that geospatial data can be accessed from mobile devices (Brandt et al. 2014a). This solution have some clear advantages, such as the ability for field workers to collect data, perform validation tasks (Pundt 2002) and then update centralized map services with real-time data as they are working. Mobile GIS has been a promising technology for a while and was early stated as a help in optimization of field-based collection, analysis and resource management tasks (Tsou 2004a). In current time (2016) there have been few attempts to include ground-based data

collections for a long-term period (Mbow et al. 2014), thus existing conclusions regarding growth in biomass remain only a theory so far (Brandt et al. 2014a). In future studies it is necessary to include adaptations to different changes in vegetation for the livelihood. Such changes could be in land use as farming or as an increase in livestock numbers due to the land possibly has higher capacity in resources for the animals. Overall the connection between land management, climate change and demographic pressure are all of interest since such previous studies are quite limited (Brandt et al. 2014a).

### **2.3 Moderate Resolution Imaging Spectroradiometer (MODIS)**

Moderate Resolution Imaging Spectroradiometer (MODIS) is a sensor that collects data from two satellites called Terra and Aqua. Its spatial resolution varies from 250 to 1000m and it was designed to provide global coverage information every two days for the Earth's biosphere and its dynamics. This kind of data is valuable for natural resource and land management, global carbon cycle analysis, ecosystem status assessment and environmental change monitoring (NTSG. 2016). However, recent studies have indicated that current  $\epsilon_{max}$  could be too low, particularly for drier locations in Africa, thus MOD17 are possibly underestimating GPP results (Sjöström et al. 2013). Ferreira et al. (2007) used MODIS data in an automated deforestation mapping system where they point out an important advantage of the sensor: data is atmospherically corrected, cloud screened and geocoded, thus in a "ready-to-use" format. However, when using orbital images that are automatically processed uncertainties can occur since there may be some false detection, which in turn can create errors in further studies (Ferreira et al. 2007). Information provided from the sensors are used in different scientific models to predict results which in turn are given to end users possibly as an assist in decision making processes (Kooistra et al. 2009). Modelling with satellite data can not only provide results to the end user in actual situation but also be used as a forecast for the future vegetation productivity (Nemani et al. 2003a).

### **2.4 Web GIS implementations for resource distribution**

Risk situations linked to natural hazards have been studied in Africa to help local governments in their work. Those studies usually contributed to geospatial data containing information that is valuable for future work when trying to decrease risks and mitigate the effects of disasters (Balbo et al. 2013). Visualizing data by maps can make interpretation faster, patterns can be detected, and support in planning as well as be a resource for policy and decision making (Evans and Sabel 2012). Evans and Sabel (2012) developed a web based GIS/spatial visualisation tool from a combination of open source software packages for the health and environment sectors to be used as a support tool. It provides the users the possibility to visually explore data online without any need of additional software. The authors state that creating an entirely new system is a clear advantage in form of designing; by making it fit to the task and a user friendly environment that does not have to require that the user has any experience in GIS to run it. To make their system as user-friendly as possible they created buttons which when clicked upon visualised data spatially. Thus the users could instantaneously get insight in different results and explore the spatial data. Because data were obtained regularly, a command procedure was implemented so that the data was automatically

published without requiring anything from the user. Another advantage of the system is that even a low-end budget computer with internet access can use it since all the heavy processes are carried out on the server and not on the client side (Evans and Sabel 2012).

The Worldwide Web Consortium (W3C) has developed web standards which are rules and guidelines that should encourage consistency of the web pages based on the design code behind (W3C 2016). The Open Geospatial Consortium (OGC) is a consortium that develops standards specifically for a GIS supported web. They are specified through three different interfaces in OGC which are Web Map Service (WMS), Web Feature Service (WFS) and Web Coverage Service (WCS). In short terms WMS is a visualisation service while WFS and WCS are geographic data services. Even though all are intended to distribute geographic information in web-computing environment, WMS is the most popular one; possibly due to its simple interface (Wu et al. 2011). There is over a thousand of examples where a WMS are set up and upheld by companies, governmental sectors, organizations and university institutions.

Geographers have by combining layers of spatially referenced data with remotely sensed aerial or satellite images made such computer mapping a powerful tool regarding decision-making (Gewin 2004). Boulos and Honda (2006) state that one of GIS most powerful capability is to share and publish geo-spatial information on the Internet where many people can reach it. It is an effective way of sharing geo-spatial information and users are generally able to choose what kind of information or layers they want at the moment, thus making it appropriate to their own requirements (Boulos and Honda 2006). However, one mentioned drawback from using an online modelling toolbox is that it requires the user to know how to interpret the results (Evans and Sabel 2012).

### 3 Materials and method

The following sections describe how the web mapping application was implemented. According to section 1.2, MOD17 data was chosen to visualize changes and calculate supply of NPP and grazing resources.

#### 3.1 Study area

The study area of this thesis is Kordofan in Sudan (figure 1). Kordofan lies about 500 meters above sea level and is largely an undulating plain. In the north in the steppe land the inhabitants are concentrating on cattle breeding while the inhabitants in the south live of agriculture. The area is known for its problem with erosion due to e.g. grazing (SNL 2014). Sudan is a part of the Sahel which is overall characterized by open and sparse grasslands and shrublands in the northern parts while open woody vegetation, deciduous shrubland and cropland characterize the southern parts (Fensholt 2013). The precipitation pattern is mainly driven by the S-N movement of the Intertropical Convergence Zone (ITCZ) (Lebel and Ali 2009) and the rainy season is connected to the West African Monsoon which usually lasts between 1 -4 months with a peak in August. The overall length differs from the north and south and usually the length decreases with increasing latitude, e.g. lasting 1 – 2 months in the north and ~4 months in the south (Nicholson 2000).

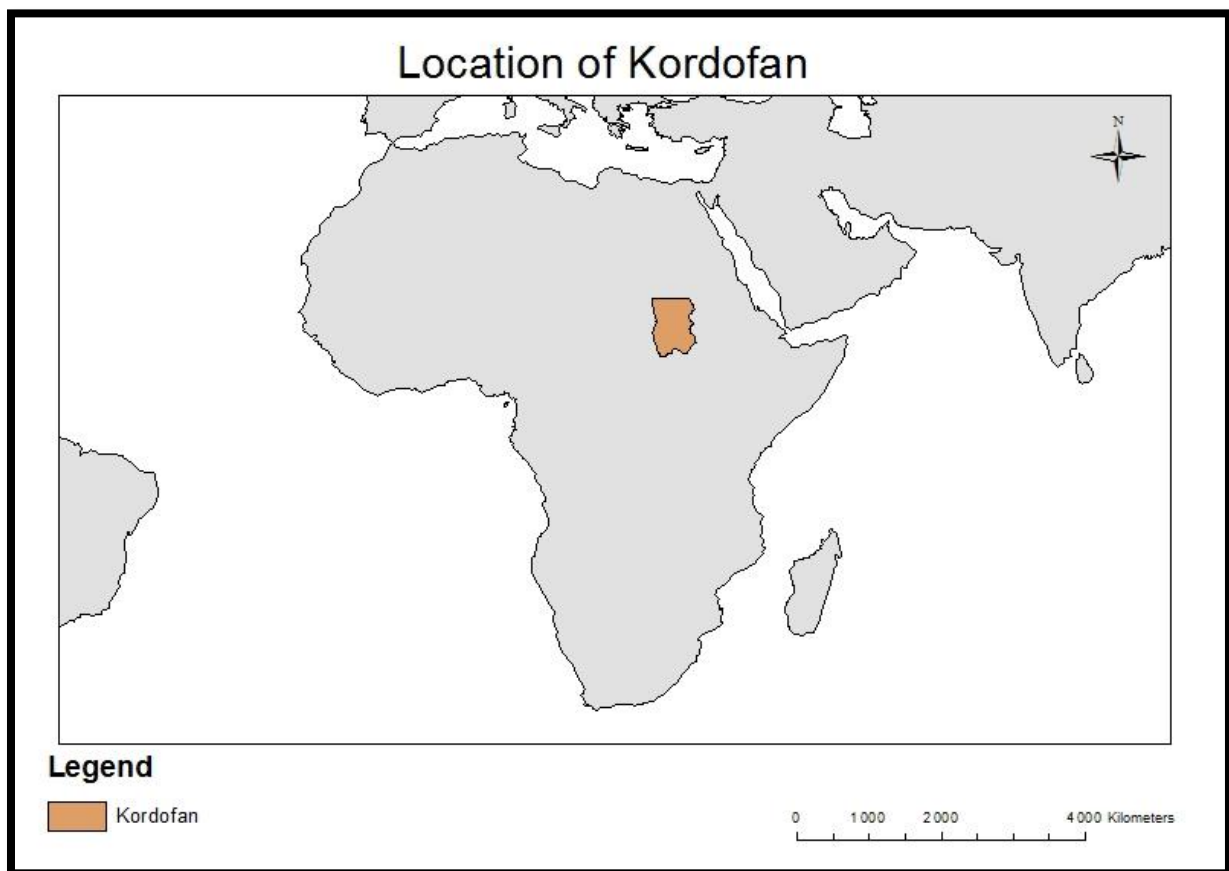


Figure 1. The location of the Kordofan region that were used as the study area

## 3.2 Data

MOD17A2H: MODIS/TERRA Gross Primary Productivity 8-Day L4 Global 500 m SIN Grid V006 was downloaded from the United States Geological Survey website (<http://e4ftl01.cr.usgs.gov>). MOD17A2H is based on the radiation-use efficiency concept and produce an image every 8-day with cumulative values with 500 meter pixel size. The Net Photosynthesis (PSN) layer used in this thesis is the result of GPP minus the maintenance respiration (MR) and can be seen in detail in table 2. MOD17A2H have assigned fill values which are described in table 3 (Running et al., 2015).

Table 1. Collection and granule information for MOD17A2H

Characteristic	Description
Number of Science Dataset (SDS) Layers	3
Rows/Columns	2400 cols x 2400 rows
Pixel Size	500 m
Temporal Extent	February 2000 - Present
Spatial Extent	Global
File Size	~3.2 MB
Coordinate System	Sinusoidal
Datum	N/A
File Format	HDF-EOS
Geographic Dimensions	1200 km x 1200 km

Table 2. Data layer characteristics

SDS Layer Name	Description	Units	Data Type	Fill Value	Valid Range	Scaling Factor
GPP_500m	Gross Primary Production	kg C m <sup>2</sup>	16-bit unsigned integer	32767	0 to 3000	0.0001
PsnNet_500m	Net Photosynthesis	GPP-MR	16-bit signed integer	32767	-30000 to 30000	0.0001
Psn_QC_500m	Quality Control bits	Bit Field	8-bit-unsigned integer	255	0 to 240	N/A

Table 3. Assigned fill value to MOD17A2H

Assigned Fill	Description
32767	Fill Value
32768	Land cover assigned as perennial salt or inland fresh water
32769	Land cover assigned as barren, sparse veg (rock, tundra, desert)
32770	Land cover assigned as perennial snow, ice
32771	Land cover assigned as "permanent" wetlands/inundated marshland
32772	Land cover assigned as urban/built-up
32773	Land cover assigned as "unclassified" or (not able to determine)

The data described in table 4 were obtained from Dr. Abdelrahman A. Khatir at the ARC-Agricultural Research Corporation, Sudan, and originate from the National Rural Water Association (NRWA) in North Kordofan State (NRWA 2016). The data were collected using GPS devices. The water point data contain information about the position of each water source in the Kordofan, as well as the type of the water source (e.g., deep well, shallow well, hand pump etc.). The villages point data contain information of the name of each village as well as the type of village (e.g. settlement, camp, building etc.). The Kordofan polygon data contain information on the boundaries for the region of Kordofan.



Table 4. Shapefiles obtained from Dr. Abdelrahman A. Khatir

Name	Description
Water point	Point layer, WGS_1984, units: meter
Villages	Point layer, WGS_1984, units: meter
Kordofan	Polygon layer, WGS_1984, units: meter

### 3.3 System requirements

To fulfil the aim, the system needs to have some specific features. Due to a restricted time frame for the development of the web mapping application the development was divided into two categories, high priority and additional features (table 5). The features under high priority are features that are necessary for the user to be able to visualize and interact without any further knowledge about GIS. If the web mapping application is functional without any knowledge of GIS it gets a wider target audience which is a clear advantage further on when decisions will be made. In other words the user should only have to click on different buttons to visualize different layers and spatial data, thus immediately gain some insight into the results. The additional features are tools for performing various local spatial analyses, but which may not be necessary for this specific thesis.

Table 5. Features of the system divided into high priority and additional features

High priority	Additional features
Download data automatically	Local spatial analysis
Process data automatically	
Style data automatically	
Upload to server automatically	
Visualize data with relevant legend and basic functions	
Get additional information (statistics and recent change)	

### 3.4 System design and software selection

The MODIS data was downloaded from the United States Geological Survey website and thus functions as this systems database. ArcGIS Online was used as a server and is also where the Web Mapping Application is available. Python was chosen as a programming language since it is well compatible with ESRI software, and it functions as a link between the database and server. The system design is visualized in figure 2. First a Python script is run which downloads the MODIS data automatically from the USGS website as well as processes the data. All files and calculations are downloaded to the computer the script is run on. From this working folder on the computer the files are uploaded to ArcGIS Online via the python script. In ArcGIS Online the layers are added to a web viewer where pop ups etc. can be configured. The web viewer is later on the foundation for the web app viewer (function on ArcGIS Online) which is the final step (the Web Mapping Application) in the system design where legend and other basic functions are added. If the web viewer is updated with new layers the web app viewer will also be updated.

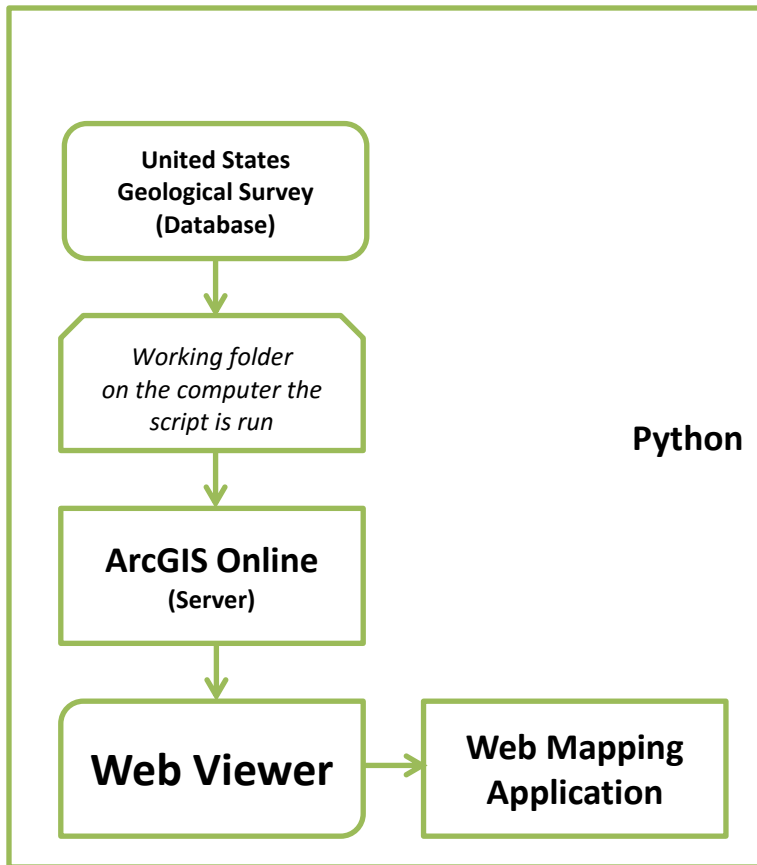


Figure 2. System design and data flow from downloading data at USGS website to final step of visualization on ArcGIS Online.

The system implementation from Python to ArcGIS Online is described in more detail in figure 3. Each step is further described in section 3.5

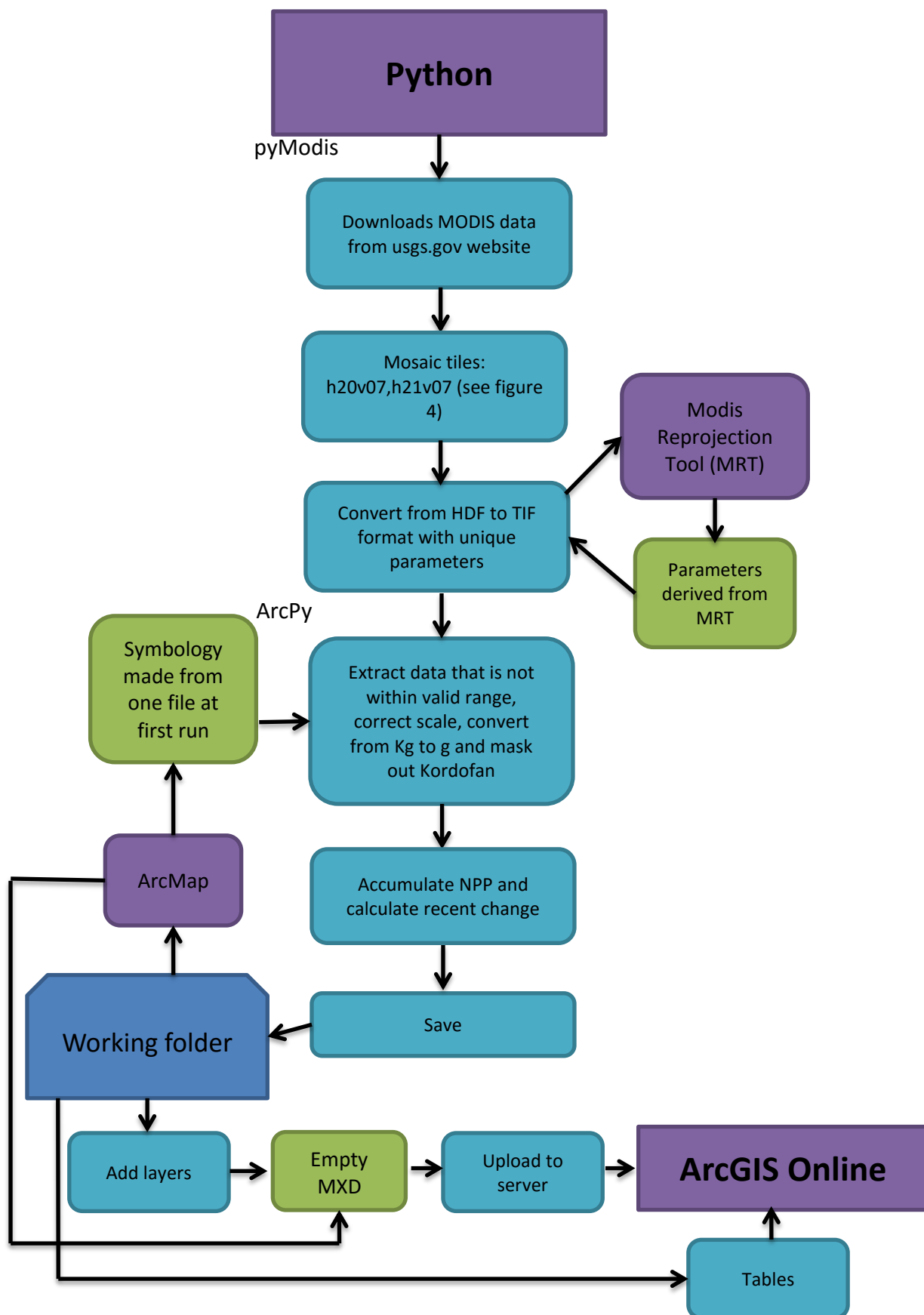


Figure 3. Workflow of the system implementation from the python script to the local server on ArcGIS Online. The purple squares represent software, green squares represent objects created outside the python script and the turquoise squares describes what is written and done in the code.

## 3.5 System implementation

### 3.5.1 Python code

Python is a commonly used and supported free open-source programming language. It has been the scripting language of choice for geoprocessing users since it was introduced to the ArcGIS community with ArcGIS 9.0 (Python 2016). The python script in this thesis is a stand-alone script and is run outside ArcGIS from Scientific PYthon Development EnviRonment (Spyder). The entire code is provided in Appendix I and the workflow of the system implementation from the python script to the local server on ArcGIS Online is described in figure 3.

### 3.5.2 Downloading MODIS data automatically

Python has a library called pyModis which allows the user to work with MODIS data. It provides functions for downloading data in larger volumes for different time ranges, mosaicking MODIS tiles, reproject from Sinusoidal to other desired projections, convert HDF format to other formats and extract data quality information (Delucchi 2015).

The tiles representing Kordofan was chosen (h20v07 and h21v07 in figure 4).

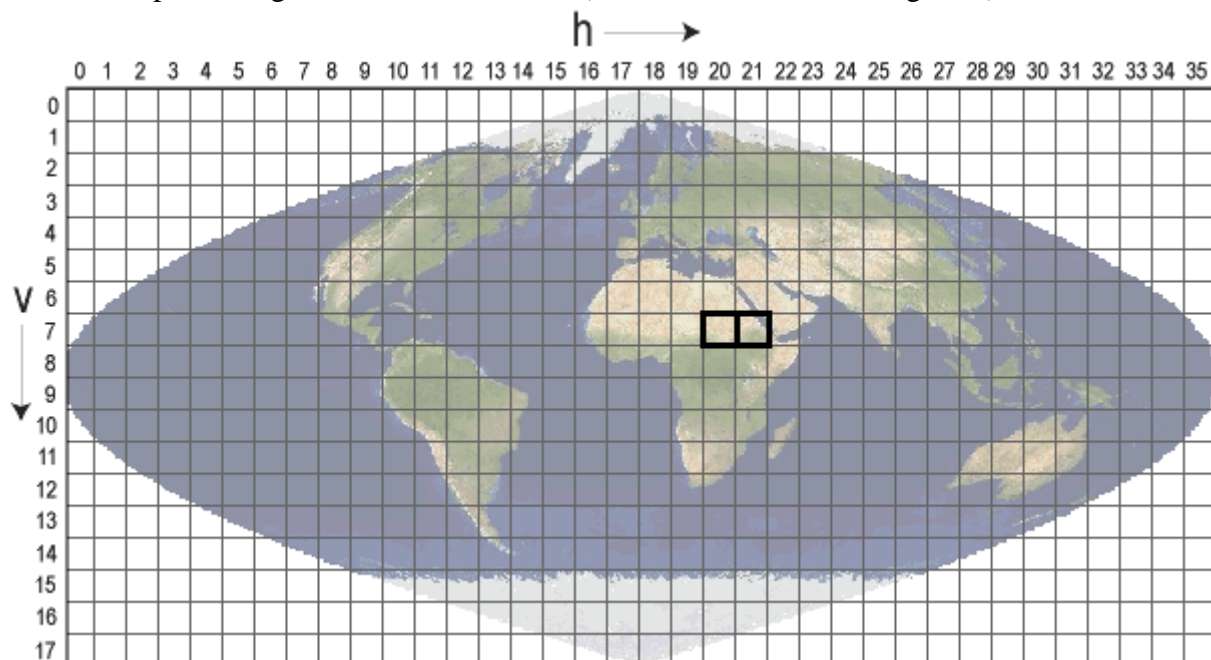


Figure 4. Sinusoidal Tile Grid where MODIS land data products have been produced and distributed in adjacent non-overlapping tiles which are about 10 degrees square at the equator (NASA, 2015).

A function was created and called “download” (part 1.5 in Appendix I). This function extracts data via the pyModis library class for downloading from the MOD17A2H folder from The United States Geological Survey (USGS) website. First all files for the given tiles from the earliest date to current time are added to a list. Because it is set on current time the script will download the latest and newest available data. In order to prevent everything being downloaded again when a new file is available, a function checks if the data already exists and thus only add files that do not exist, updating the preexisting list with the new data automatically. From this list Hierarchical Data Format (HDF) and Extensible Markup

Language (XML) files are then downloaded to a given folder on the computer. After the files according to the list have been downloaded they are mosaicked into one image for each date. Thereafter, the original sinusoidal projection of the data is converted to WGS84 as well as converted from HDF format to GeoTIFF format. This is done through the pyModis library class for converting. It requires that the computer the script is run on has the Modis Reprojection Tool (MRT) installed because the resampling is done from the MRT tools (Delucchi 2015). The convert class also requires a unique parameter file for each downloaded file, thus a parameter file had to be created for each date/file. This was done by creating an empty parameter file (prm file) and in write mode this file was edited in a loop so an input and output value are stored for each date. The parameter file defines which bands should be downloaded (in this case band number two which represents NPP), the resampling method which was chosen to nearest neighbor (recommended to avoid mixing categorical values) and the output projection which was chosen to WGS84.

### **3.5.3 Processing the data**

Python also have a library called ArcPy which allows the user to access all geoprocessing tools as well as other functions useful when working with GIS data. The package provides different ways to analyze data, convert, manage and automate it. With Python and ArcPy, programs that run on geographic data can be developed (Python 2016).

From the TIF files created in Section 3.5.2 a raster file in the ESRI's GRID format is made. First the raster is masked according to the shapefile over Kordofan. This raster file is then processed according to the valid range in table 2 and thus at the same time removing the assigned fill values in table 3. This results in pixels not containing NPP, e.g. urban areas are removed and set to NoData which will not be visualized in the Web Mapping Application later on. The scale is also scaled according to the scaling factor in table 2. The units are  $\text{kg C m}^2$  according to table 2 and are transformed to gram to provide a clearer visualization in the map. The raster layer is then updated with a predefined symbology layer created in ArcMap. Brown color indicates negative NPP and green indicates positive NPP. Then the raster is transformed to a layer file and saved on the computer the python script is executed on. In a predefined MXD (file extension for a map document used by ArcMap) the saved layer file are added and are finally saved within the MXD. Due to storage cost on the server only the most current file is saved to the MXD and thus only one file is uploaded to the server.

For each year a total accumulation of NPP is calculated by adding all the 46 files with 8 days cumulative values, where all pixels have been added within each file. From this a mean value is calculated for each year and presented in a table. In order to visualize the current change in vegetation a "recent change" is calculated and also saved in a table. The recent change is calculated from the accumulated NPP at day of year (DOY) minus the accumulated NPP at DOY 24 days ago. Positive values means that the total vegetation has increased compared to 24 days ago and negative values indicated that there is a decrease in vegetation compared to 24 days ago. To see the recent change pixel by pixel the most current layer is subtracted with the layer 24 days ago, this results in a second layer available in the Web Mapping Application where the user can see where in Kordofan NPP has increased /decreased. This second layer

has its own predefined symbology where red color indicates a decrease and green color indicates an increase. This second layer is added to another MXD since when uploading it to the server a tile layer is created and they cannot be uploaded in the same mxd.

### **3.5.4 Uploading the script to the server**

The final step of the Python script involves the uploading of the layers to the server, in this case ArcGIS Online. First a service draft definition has to be created in the working folder and if it does not contain any errors the service based on the saved MXD is uploaded to ArcGIS Online. This section of code (row 326 and forward in Appendix I) is part of the arcPy library and therefore, specific terms related to ESRI software are used here. To enable the uploading of the MXD the computer the script is being run on must have ArcMap open and signed into “ArcGIS sign in” where login for ArcGIS Online is required. Previous versions of the service (when everything is uploaded to ArcGIS Online) do not overwrite so the script begins with removing possible previous ones. The entire code for uploading to the server is also based on the ArcPy library.

### **3.5.5 ArcGIS Online**

In order to visualize spatial data from a database and provide analyze tools on such data a map server is required (Evans and Sabel 2012). This thesis is based on ArcGIS Online as the server. ArcGIS Online is a cloud-based mapping platform hosted by ESRI which also has chosen Python as the main programming language (ESRI 2016), making it compatible with the python script for downloading and processing the MODIS data.

When the script has been uploaded to ArcGIS Online the service is available and has published a “Tile Layer”. Before being able to add it in a web viewer, it has to be managed. As mentioned before the storage on the server cost and therefore this step is deliberately manual so no unnecessary costs occur due to bugs etc. When managing the tiles the scale it should be available in has to be decided by the user. This is also a question of cost and because the larger scales cost the most, the six smallest scales was chosen which range from 1:9,244,649 to 1:1,4,514 (meter) and will therefore be the visible range in the Web Mapping Application. When this has been done it can be added to a web map which is the web viewer for this thesis. In the web viewer the tile layers uploaded from the script based on the saved layers in the MXD files is added. The shapefiles for villages and water points in Kordofan and the tables created in the script are uploaded to the account in ArcGIS Online manually and are also added to the web map. The web map is set to be shared with everyone and is therefore made public and can be accessed from any device with internet connection. In the edit mode for the web map pop ups for the shapefiles and tables are configured so only relevant attributes are shown when the user clicks on them in the map. ArcGIS Online provide free basemaps distributed as map services. They are freely accessible to everyone and the one chosen as default in this thesis are the World Imagery.

In ArcGIS Online it is possible to make a custom Web Mapping Application without any programming that is also compatible with mobile devices. Based on the web map created in

the previous step the Web Mapping Application is created by ArcGIS Online function Web App Viewer (figure 2). In the Web AppBuilder the user can use predefined templates for themes and choose from different widgets. Widgets that are used for this thesis are: header controller, attribute table, coordinates, scale bar, zoom slider, legend, layer list, home, about and basemap gallery. The basemap gallery makes it possible to change the background map to another available basemap provided by ESRI. In the about widget a description of the web map and its functions is described and thus functions as a help and information function.

### **3.5.6 Long-term patterns of NPP**

In the web map and its application the tables created in the script are available. Due to the restricted time frame there was not enough time to create a function that transforms this data into charts for clearer visualization. Therefore charts were made manually in Microsoft Excel to provide examples of visualization implementation. First a chart was created to visualize the annual cumulative NPP for each year so resource availability overall could be compared. Since the current year (2016 in this thesis) is not yet completed a chart for average annual cumulative values were created as well so the current year could be compared to previous years. Finally a chart was made to visualize if there is any long-term patterns by plotting all 46 files (with cumulative values for an 8-days period) each year so seasonal variations also were visualized. To test if there were similar patterns and seasonal variations for all years, 2002, 2008 and 2014 were plotted on the same chart. A chart over the latest (completed) years were also made and compared to the patterns detected in previous chart.

### **3.5.7 Additional features**

As stated in section 3.3 System requirements, there are additional features which are local spatial analysis. Such additional features did not get implemented in the thesis but likewise the statistics and the charts it was done manually in ArcMap to provide examples of visualization for the web map when implemented. From the water points the idea was to create a function so the user can decide on a radius and then the function would create a circle and calculate the cumulative biomass within that given area. This is related to reasonable walking distances for different types of animals since they need to drink daily and at regular intervals. Thus watering points could be compared and possibly provide information on seasonal patterns, which watering point is most useful at specific times at the year etc. In ArcMap this was done by first create a buffer around the water points and then use zonal statistics to sum the biomass within the new circles.

## **4 Results**

This section describes the finished Web Mapping Application which can be found at the following link:

<http://lund.maps.arcgis.com/apps/webappviewer/index.html?id=af2d4540cdcd4748af31ae997067983e>.

The following figures are print screens from the link above.

## 4.1 Web Mapping Application

In figure 5 the web application can be seen and is based on the data added in the web viewer in the step before. If the web viewer is edited the web application will also be updated. However the titles and information in the about widget (number 2 in figure 5) has to be edited in the web application.

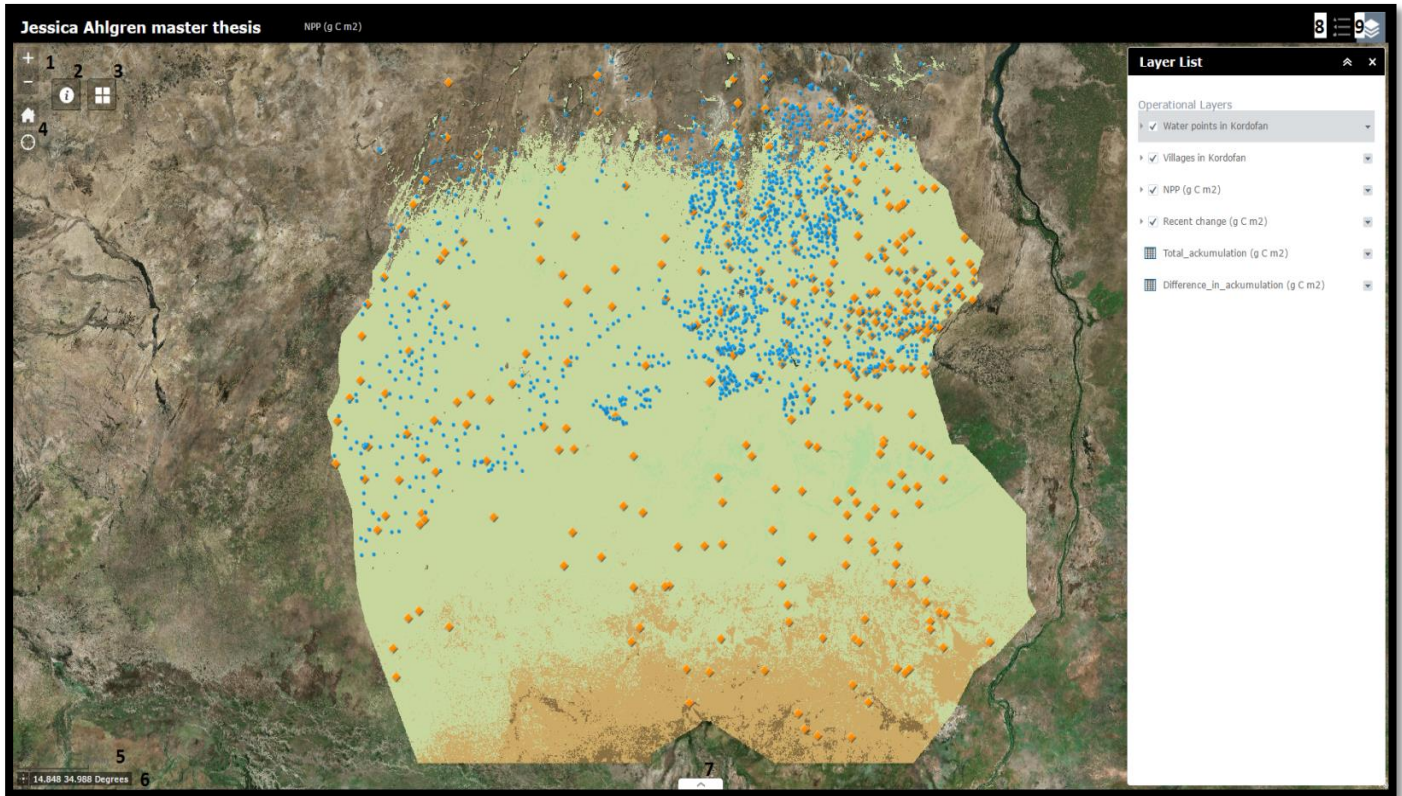


Figure 5. Print screen showing the web mapping application when first opened. The numbers in the figure specify different function in the web mapping application. Number 1 is the zoomslider widget, number 2 the about widget, number 3 the basemap gallery, number 4 the home widget, number 5 the scalebar, number 6 is the coordinates, number 7 is the attribute table, number 8 the legend and number 9 the layer list.

In figure 6 the NPP for the date 2016-02.02 is visualised in the web mapping application. In the layer list (number 9 in figure 5) water points, villages and NPP is checked and are thus shown in the legend as seen in figure 6. As the legend states the units are in  $\text{g C m}^{-2} \text{ year}^{-1}$  and brown colour indicate negative values and the greener colour the more NPP.



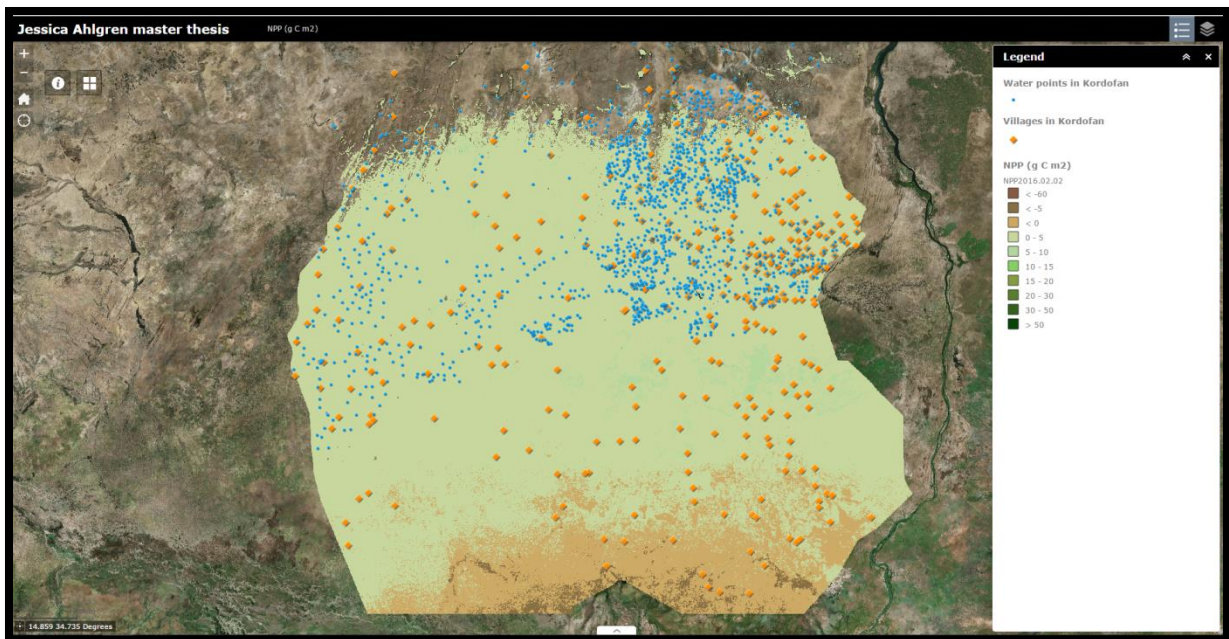


Figure 6. Print screen for the layer of the latest date as well as the villages and water points in Kordofan.

In figure 7 the recent change of NPP for the date 2016-02.02 compared to 24 days ago is visualised in the web map. In the layer list (number 9 in figure 5) water points, villages and recent change is checked and are thus shown in the legend as seen in figure 6. As the legend states the units are in  $\text{g C m}^2$  and red colour indicate negative values (those specific pixels indicate a decrease in NPP) and green colour indicate positive values (those specific pixels indicate an increase in NPP). Yellow colour indicates no change for those pixels compared to 24 days ago.

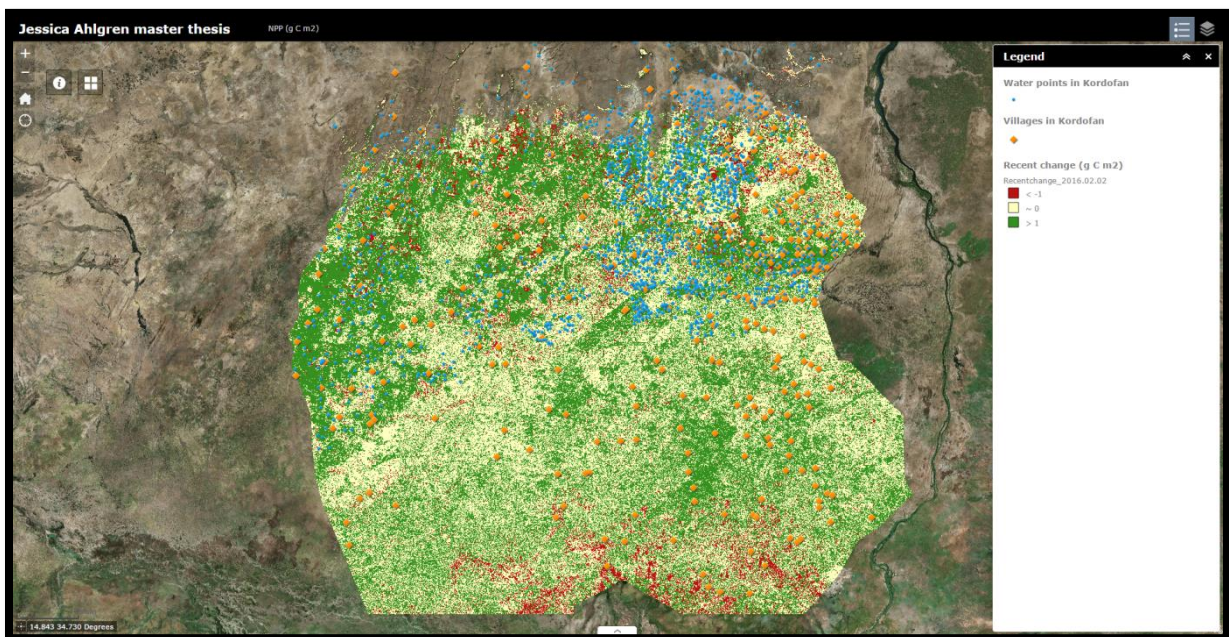


Figure 7. Print screen for the layer of recent change for the latest date (compared with the layer 24 days ago) as well as the villages and water points in Kordofan.



In figure 8 the recent change in cumulative values are presented in table form. All positive values indicates that the vegetation has overall increased  $X \text{ g C m}^2$  compared to 24 days ago and all negative values indicated that the vegetation has decreased  $X \text{ g C m}^2$  compared to 24 days ago.

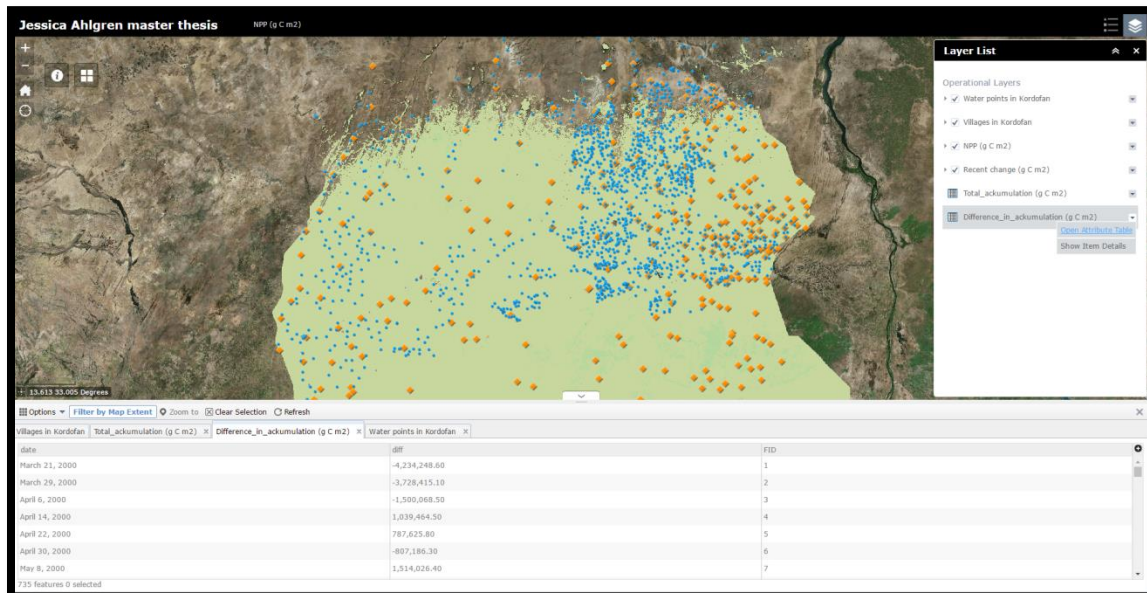


Figure 8. Print screen of an example for one of the tables: the difference in accumulation. When the user click on the table from the layer list and chose open attribute table is will open from number 7 in figure 5.

In figure 9 an example of the pop ups is shown. For the villages the name of the village appears and for the watering points the name and kind of watering service (e.g. hand pump) is shown.

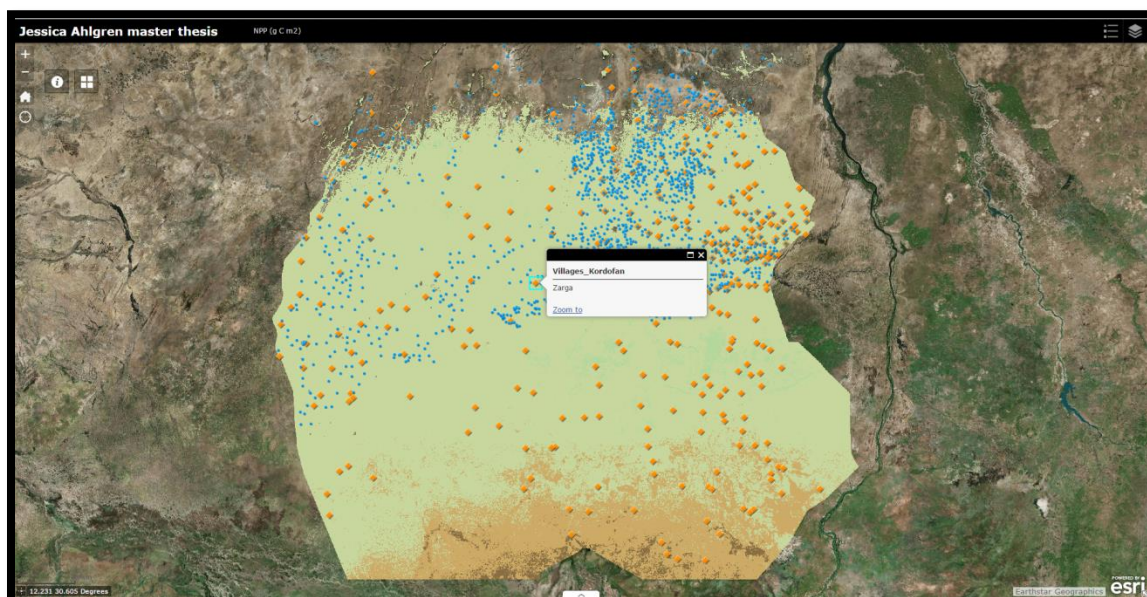


Figure 9. Print screen of an example if the user clicks on the map, specifically a village. A pop up will appear with information about the name of the village.

## 4.2 Mobile devices

Mobile devices can access and visualize the information and through ArcGIS Online's Web AppBuilder tool, the Web Mapping application provides previews for a total of 18 different devices including iPads (figure 10).

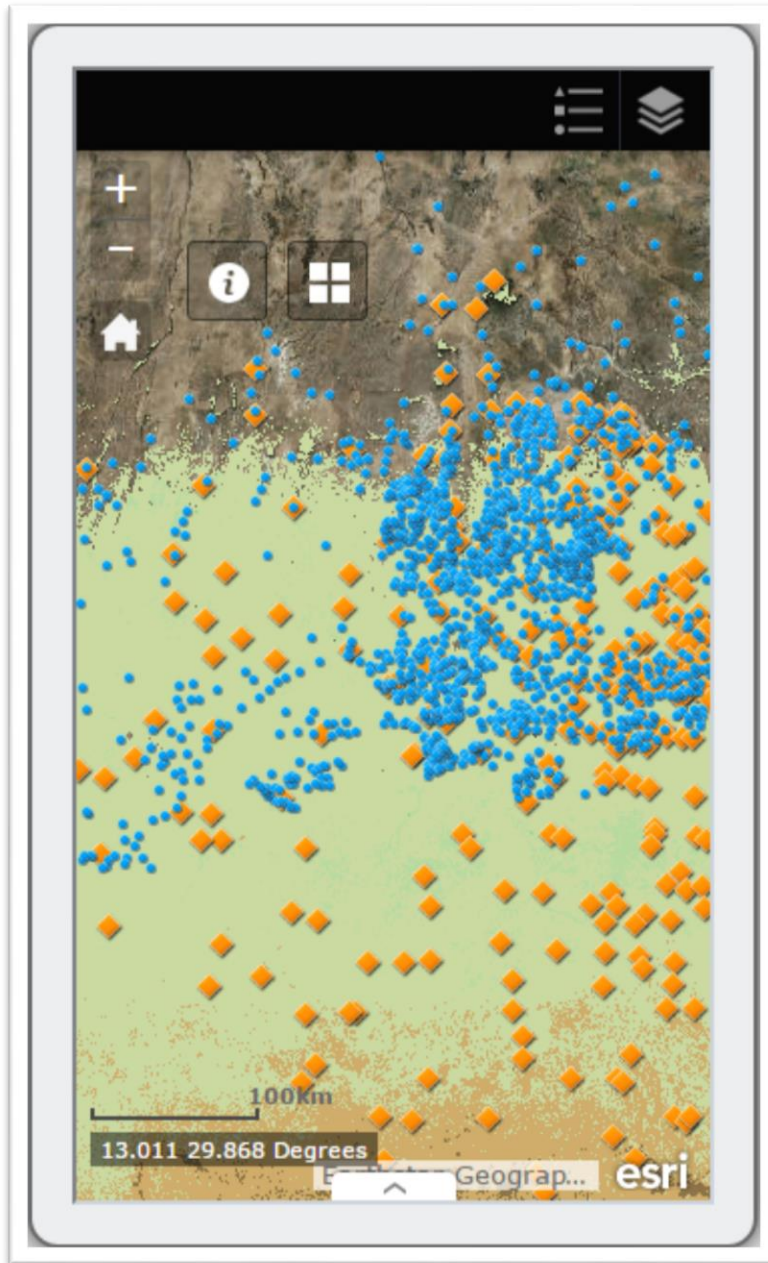


Figure 10. Example of the web mapping application on a mobile phone, specifically an iPhone5/5C/5S 320 x 568.

### 4.3 Long-term patterns of NPP

Figure 11 shows an example of a possible implementation of charts in the web mapping application when being based on the table (part 1.6, 1.7 and 1.12 in Appendix I) for total accumulation of NPP for each year. The total accumulation for each year is based on the cumulative values for each date (8-days period) and then sums all 46 files that year. However, each year does not have the exact same amount of dates and satellite images thus the years are not comparable to each other. It is more an indication of how much NPP that was recorded for each year.

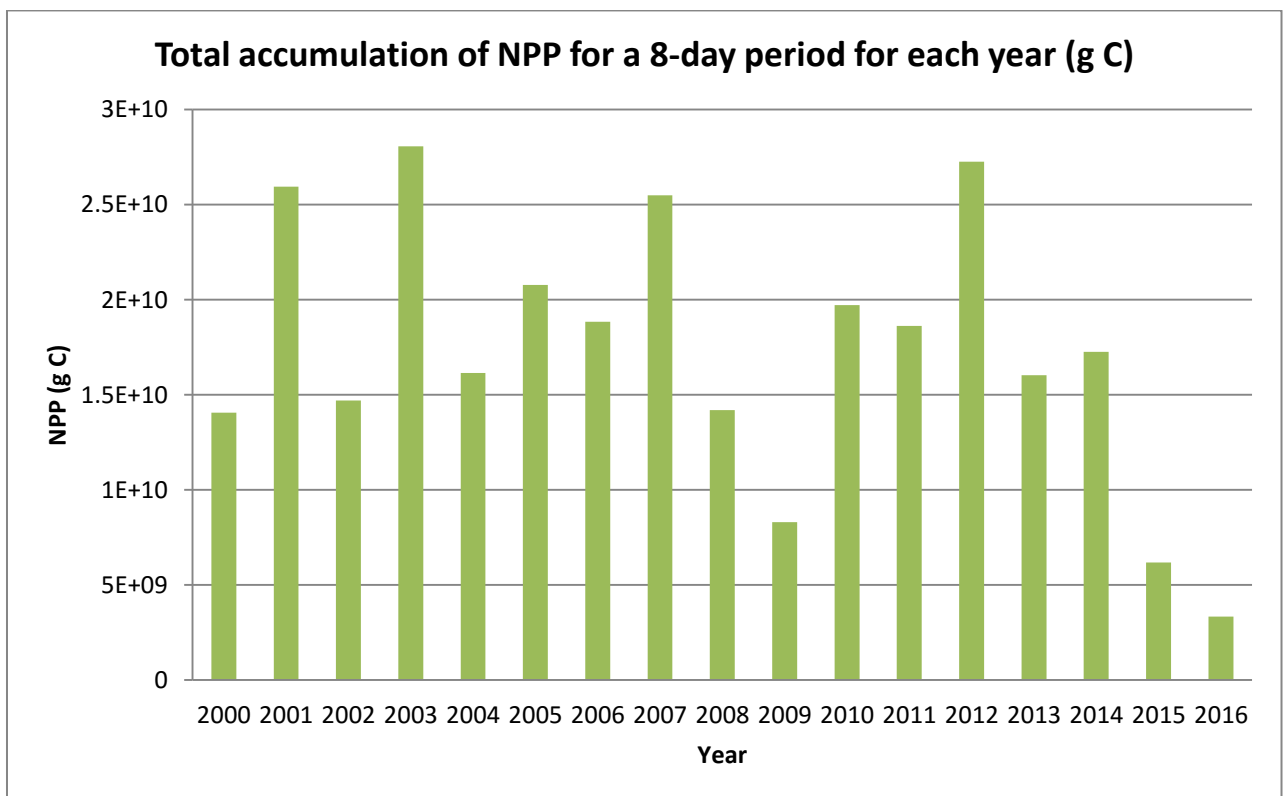


Figure 11. Total accumulation of NPP (g C) for each year in the Kordofan area. The bars represent the sum of all pixel values in all of the MOD17A2H files produced every 8<sup>th</sup> day within a year (in total 46 files)

Figure 12 shows an example of possible implementation of charts in the web mapping application when being based on the table (part 1.6, 1.7 and 1.12 in Appendix I) for total accumulation for each year but with average values instead. The average values are calculated by taking the total accumulation values seen in figure 11 and divide them by the number of dates/files downloaded for each specific year. Therefore the average values for each year could be compared, but with some caution.

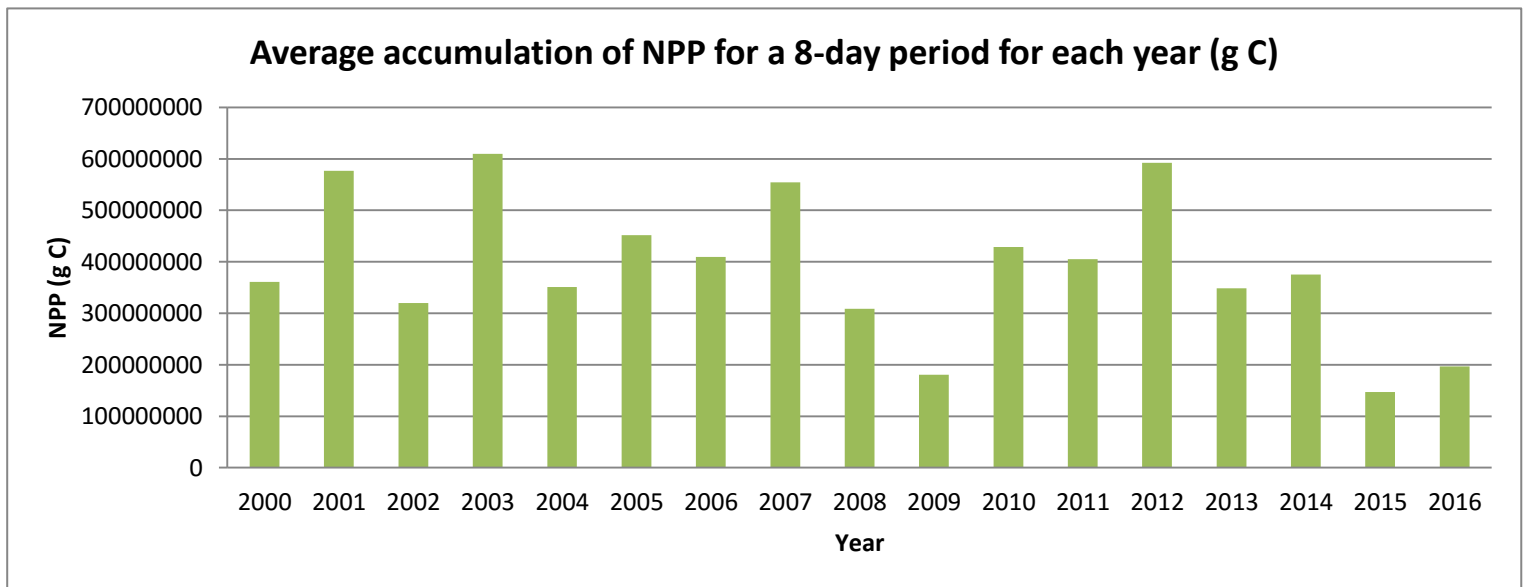


Figure 12. Average accumulation of NPP (g C) for MOD17A2H files produced every 8<sup>th</sup> day with 500 meter pixel size, for each year.

In figure 13 the flow of accumulation (PSNet = GPP - maintenance respiration) of NPP is visualised for the years 2002, 2008 and 2014. Each year has 46 dates/files that NPP has been calculated for, evenly distributed over the year and months. The values represent the amount NPP (cumulative values for each file of an 8 days period). The figure shows a similar pattern for all the years with a peak in NPP during the summer in August. In December-January the NPP increases again and is rather steady and low for March-May.

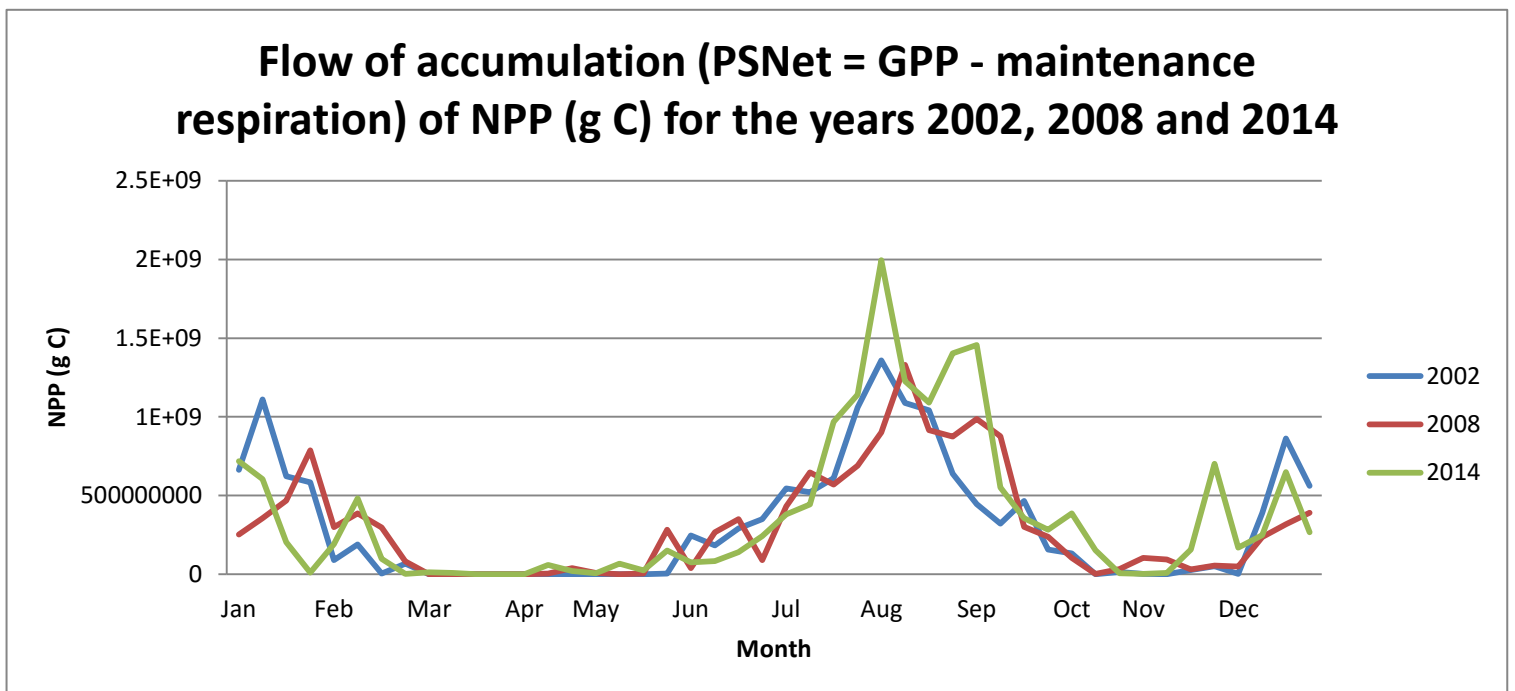


Figure 13. The flow of accumulation (PSNet = GPP - maintenance respiration) of NPP in the Kordofan region with the years 2002, 2008 and 2014 as examples. Each year has 46 files evenly distributed over the year which has been plotted to detect long-term patterns.

As seen in figure 14 the same patterns appear for the years 2013 and 2015 as well (see figure 13).

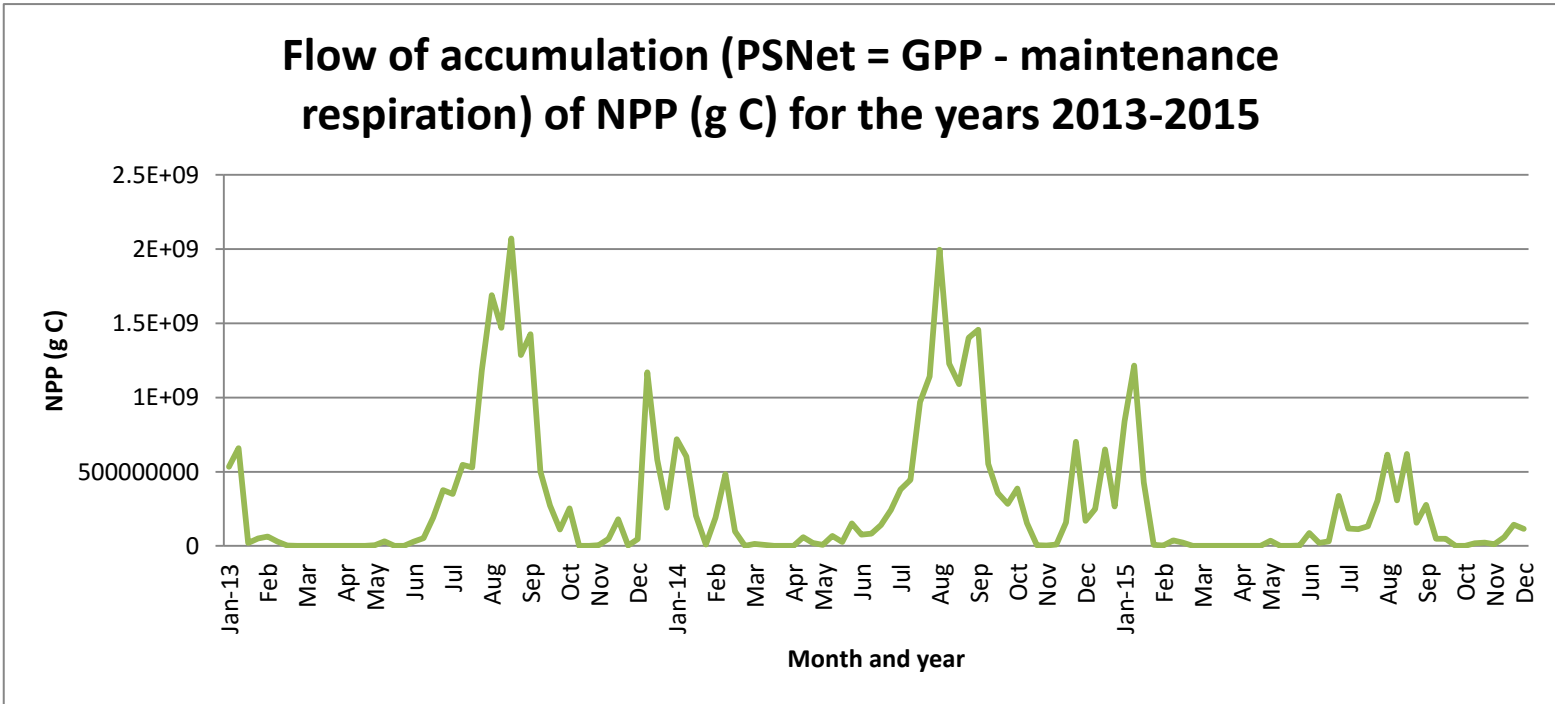


Figure 14. The time period of 2013-2015 for the accumulation flow of NPP (PSNet = GPP - maintenance respiration) in the Kordofan region for each MOD17A2H file produced every 8<sup>th</sup> day with 500 meter pixel size, (46 per year).

#### 4.4 Additional features

In figure 15 a radius in kilometres are chosen around each watering point for the data 2016-02-02 and then the cumulative NPP is calculated for each circle. In figure 15 ‘identity’ in ESRI’s software ArcMap is used to visualise the red circles pixel value which in this case is the cumulative value for that watering point.



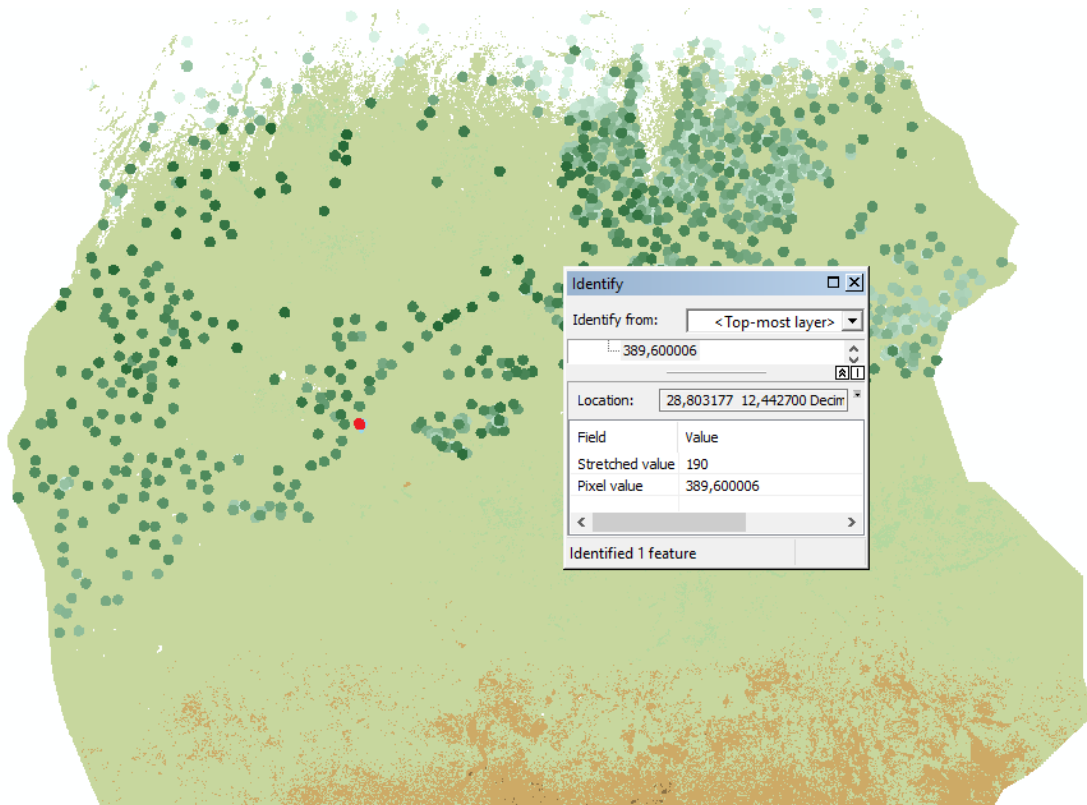


Figure 15. An example of how a local spatial analysis function could work. It shows the map from the web mapping application and has done a buffer around each watering point and from this buffer calculated the given biomass ( $\text{g C m}^{-2} \text{ year}^{-1}$ ) around that specific watering point which is visualized as a pop up in “pixel value”.

#### 4.5 Python script and system requirements

From the system requirements stated in table 5 the following results were obtained in the python script (Appendix I). ‘Download data automatically’ (part 1.5 in Appendix I) were solved by the library pyModis by first creating a list where all the files according to different given parameters (start date, end date, path, tiles etc.) were stored. The script then only downloads the files within that list. If the script has been run once and the purpose by running it again is to update the web mapping application with newer data, the script checks if all the files are stated within that list, if it exist in the list the file is thus not downloaded again and only the new, not existing in the list, files are downloaded when the script is run once again (on the same computer where nothing is deleted). ‘Process data automatically’ (part 1.8 in Appendix I) also uses the pyModis library. When the files are converted they require a unique parameter file which is used in the Modis Reprojection Tool. In order to convert each file automatically another list was created which stores the necessary parameters for each file. When the conversion is executed the unique parameters are derived from that list. Further processing (part 1.9 in Appendix I) was done by using the arcPy library in a loop so the same processing is done for each file. ‘Style data automatically’ (part 1.10 in Appendix I) is also done by using the arcPy library and is done for the layer that is going to be uploaded to ArcGIS Online. ‘Visualize data with relevant legend and basic functions’ were solved via ArcGIS Online Web AppBuilding tool where such functions (or widgets) are available as premade templates. ‘Get additional information (statistics and recent change)’ starts with

creating empty lists (part 1.6 Appendix I). The total yearly accumulation of NPP is calculated (part 1.7 Appendix I) and is stored in the premade list done in section 1.6. When each file is being processed (part 1.9 Appendix I) the total accumulation for each file (8 days) are calculated. This is also stored in a premade list in section 1.6. The recent change compared to 24 days ago is calculating by counting backwards 4 files (part 1.11 Appendix I). The difference is also stored in a list in section 1.6 as well as a new layer is created so local spatial changes in NPP can be visualized. The lists made in section 1.6 are finally printed to text documents in csv format in part 1.12 and 1.13 in Appendix I.

## **5 Discussion**

According to the system requirements in table 5 the results (section 4.5) indicate that the implementation has been successful. Furthermore the dissemination of grazing resource information has been solved by visualising the results uploaded to ArcGIS Online in a Web Mapping Application. ArcGIS Online supports Web Map Service (WMS) and Web Map Tile Service (WMTS) which are both OGC specifications (ESRI 2016). This means that OGC WMS layers can be added to the existing Web Mapping Application by adding it in the web viewer which is an advantage in further implementation. However, the existing Web Mapping Application cannot in turn be published as a WMS and is therefore not accessible for others, which is a disadvantage. This could be solved via ArcGIS Server (ESRI 2016), though it is most likely more expensive compared to ArcGIS Online.

### **5.1 Python script and web mapping application**

Python turned out to be well compatible with ESRI software and well suitable as a programming language for this kind of project. Some problems that occurred had nothing to do with Python itself, but rather because of the internet connection and that the database (the USGS website) was sometimes unavailable. The script (appendix I) can be modified to meet other criteria, for example the tiles (figure 4) could easily be changed to another extent and thus it could be used for the e.g. the entire Sahel. Because data are processed for the entire period 2000-2016 it takes several hours for the script to run from beginning to end. If the user only is interested for a given time period this could also be modified in the script and thus the running time will be shorter. Even if only the latest file of 8-days is shown in the web mapping application all files must be downloaded to calculate the statistics, tables and charts if a long-term pattern should be analysed. However, compared to do these tasks manually the user saves a lot of time with programming which is a clear advantage even though it takes a while to run. Problems that were encountered when working with the script were related to the internet connection, because the files are downloaded from the internet and the script then in turn uploads to a server on the internet the script will not work if there is no internet connection for the computer it is being run on. Therefore it is important to make sure there is a clear internet connection for the entire time the script is being run. Secondly, the script cannot work if the website for the files is currently out of service. During the time this thesis was under progress this happened three times. In the script the user will be notified by ‘the connection failed’. If this happens there is no more to do than to try later and hope the United States Geological Survey (USGS) website is up and running again later. At one point the



script was set to run at the same time as they were uploading new files at USGS, this resulting in strange results and is something you should be aware of when using/updating the web map by running the script. The USGS at that time uploaded several dates at the same time and when the script began to run not every file had been uploaded to the website which created confusion for the script. This only happened once under this project and it is thus unclear how common it is or if it was a one-time incident. Thirdly, only one tile layer can be visualized per MXD file uploaded to ArcGIS Online. Therefore, to enable the visualisation of two tile layers in the web map, two MXD files, containing one tile layer each, were uploaded to ArcGIS Online.

For the web mapping application developed in this thesis, ArcGIS Online was suitable as a server. Even though it caused some limitations as stated in section 1.4 it met up to all system requirements. It provides many functions that are advantages for this particular project, for example it is possible to use the web mapping application offline. This is likely a significant advantage since the web mapping application is probably going to be used where the internet connection may not be that trustworthy or accessible everywhere. The offline mode allows users to view, collect and updates different features when they are disconnected from the internet. When they are connected once again the map is synchronized and will send the updates the user have and at the same time update information from other users. The users in Kordofan thus only need a mobile device to update for example information of location of different animals, status on watering points etc. ArcGIS Online through its web mapping application provides such layouts for many mobile devices and thus is already ready to be used on any mobile device; an example can be seen in figure 9 where the layout for an iPhone5/5C/5S 320 x 568 is shown. ArcGIS Online provide premade widgets which the user can decide which ones to show in the web map. An example of such a widget is the analysis widget. Unfortunately, such widgets only work on vector data and were therefore not applicable to this study since the NPP layers are raster data. The web map visualises the current NPP for the latest date (see figure 6) and the recent change for the latest date compared to 24 days ago (see figure 7). 24 days were chosen since it represents 24-32 days ago which is approximately a month ago since the files are updated every 8 days. Another time step could be used to show an indication of recent change compared to the past and could be changes in the code (see row 244 and further in Appendix I). The web mapping application only visualises the change as negative, zero or positive since it is hard to state what a relevant increase or decrease in NPP is in a given unit as  $\text{gram C m}^{-2} \text{ year}^{-1}$ . The recent change map is thus only an indication to local differences and where the vegetation is changing at current time.

The web mapping application does not provide the user with information about any patterns or trends to take further action. Therefore spatial analysis is necessary and should be included in future developments. Due to the restricted time frame such spatial analysis were not included in the code but are further discussed under in Sections 5.3- 5.4.

## 5.2 Quality of data

The data obtained are a composite product of 8-days. Hence the maximum absorbed photosynthetic active radiation (APAR) is selected to represent the period; this could be misleading since there is an assumption that there is no variation within those 8 days regarding APAR. It could be beneficial when dealing with clouds since they could then be discarded. However if all days within an 8-days period are cloudy the result will be quite misleading nonetheless. Such overestimating is though most likely for e.g. tropical areas which in fact have frequently cloudy weather (Zhang et al. 2009). The MODIS algorithm has been studied by Turner et al. (2006) where they made the conclusion that MODIS products tends to underestimate in high productivity sites as well as overestimate at low productivity sites. The shift to spring greening could also possibly be earlier since as mentioned before the MODIS APAR are maximum value composites for over an 8 days period. However, they state that the magnitude of such effect would not be large (Turner et al. 2006). It is also discussed as mentioned before (section 1.2) that the results are overall underestimated about 30 % since only new biomass is considered as well as the results is sometimes misleading particularly concerning grazing since some vegetation is eaten before being measured (Chapin et al. 2011). Turner et al. (2006) also concentrated on validation of NPP, in their study from 2006 the validation of MODIS NPP turned out to be not dependent on flux tower measurements as they were analysing, nonetheless it showed to be beneficial when seeking validation of NPP (Turner et al. 2006). From the USGS website quality control data of NPP product (NPP\_QC) are available for downloading. Due to limited time frame this was not included for this thesis, although spatio-temporal pattern of NPP (based on the MODIS NPP data) has been done in Wuling mountainous area during 2001-2010. In this study by Sun et al. (2014) they used the NPP\_QC data to analyse the quality of NPP data. Likewise in this thesis they used Python programming and used the NPP\_QC and classified the data into four levels. Pixels with low credibility or fail in this classification were discarded and the remaining analyses were only based on quality checked pixels (Sun et al., 2014). Another type of validation is to compare with field data. This has been previously done in a study made by Zhang et al. (2009). Field data were compared with NPP/GPP ratio calculated from MODIS data and they came to the conclusion that they had similar patterns. It has also been discussed before that even though remotely sensed data may not be waterproof and entirely equal to field data, MODIS is the best NPP data available globally thus far and is not reasonable to maintain good results at a global level without remote sensing (Zhang et al. 2009).

## 5.3 Long-term patterns of NPP

A research question in this thesis was how long term average values of NPP can be used for detecting long-term patterns, and whether it was possible to use such patterns as an indication of relative resource availability. As seen in figure 13 and 14 there seems to be a long-term pattern regarding the flow of NPP (PSNet = GPP - maintenance respiration) with 8-day cumulative values with 500 meter pixel size in Kordofan with seasonal variation.

These findings would benefit from long-term meteorological data as precipitation and temperature so see if there is any connection or possibly explanations to the given pattern.

Concerning the total accumulation of NPP for each year it most likely is related to temperature and precipitation. Regarding precipitation a West African monsoon onset index was defined by Fontaine and Louvet (2006) based on the period of 1979-2004 where the mean dates of the occurrence is 28-29 June with a standard deviation of 8.5 days (Fontaine and Louvet 2006). According to figure 13 the peak of the flow in NPP starts in June and could thus possibly be related to the precipitation and more specifically the West African monsoon. Annual precipitation has also been studied by Fensholt et al. (2013) where they point out that even if it should be the same annual precipitation it could have very different impacts on relationships towards vegetation. It could depend on how heavy showers of precipitation there is and how well distributed they are over the pixels for the satellite images. The distribution could depend on terrain, soil-type and vegetation cover and up to 80 % of the precipitation could possibly run-off (Fensholt et al. 2013). This could be an explanation for why the total amount of NPP is not the same for every year but fluctuates a bit. It has previously been implied that precipitation is a stronger limiting factor compared to temperature (Churkina and Running 1998; Nemani et al. 2003b; Zhang et al. 2009). Water availability is not only important in dry areas but lack in precipitation could in turn decrease/increase other sources critical for vegetation growth such as radiation input, nutrient leaching or soil oxygen. If there is a decrease of soil oxygen the decomposition of organic matter will slow down and in turn reduce mineralization. Radiation could be affected by precipitation since it is related to clouds and thus could lead to a decrease in incoming solar radiation which is necessary for a high productivity (Zhang et al. 2009). For the year 2007 there were high precipitation in the eastern and northern parts of the Sahel compared to other years (Wagner et al. 2016). As seen in figure 11 and 12 it is not the year with the most accumulated NPP/highest average which is an indication that precipitation does not solely affect the net primary productivity in the region even though previous studies indicate that it is a main factor. As mentioned before the Sahel has higher precipitation in the south compared to the north and could be an explanation for local variations seen in the web mapping application. However in figure 6 it seems to be quite the opposite since there is higher vegetation in the north compared to the south. Possibly Kordofan is not affected by this studied distribution of precipitation.

Yan et al., (2013) has done a study where they analysed spatiotemporal aboveground biomass patterns in northern China over 2000–2012 including MODIS images as estimate. The causes for the variations in biomass they found are stated as both natural and human factors. Even here precipitation in particular showed a more or less uniform trend with the fluctuations of the total aboveground biomass. Human factors causing observed fluctuations were increase in population, livestock and even policies/environmental education. However, policies could also have positive effects and is stated as a reason why the biomass increased in 2008-2009 although the precipitation declined (Yan et al., 2013). Since it seems to be the same pattern in Kordofan over the time period 2000-2016 it is most unlikely that the reason is politics or a specific human factor. However it could be noticeable that politics have shown a positive result before and could be implemented to keep the accumulated NPP at a steady level disregarding natural factors as e.g. precipitation.

## **5.4 Future prospects**

The first step for continuing on this project would be to make the script run automatically and thus update the web mapping application with the latest date at a regular basis. This was as mentioned not done by purpose due to the limitations described in section 1.4. At the moment the data updating will have to be done manually. In appendix I row 109 the script checks if every file has been downloaded, in other words only the latest files will be downloaded and the running time will therefore be shorter compared to the first time the script was run. To compare the costs of various system implementations has, however, not been within the scope of this thesis.

Moreover, it may also be necessary to include information about the land cover classes in Kordofan since not every pixel is available for animals to graze upon. For example cultivated land could result in high NPP values but this is not very relevant for the animals since they are most likely not allowed to graze there. Thus the map should take this into consideration and possibly a specific layer only showing allowed grazing could be accessible. All animals do not eat the same type of vegetation and in an even further step the vegetation could be specified in the web mapping application and also be possible for the users to update to make it possible to figure out where each animal species should graze.

The long-term patterns of NPP discussed in section 5.3 could be available for the users in the web mapping application as a chart function. Basic spatial analysis, mentioned as additional features (figure 15), could also benefit the web mapping application and provide local information that could be relevant for the users. The watering points are of certain interest since water is sufficient for the animals and are as important as grazing resources. Therefore it could be an advantage if it is possible through the web mapping application to calculate which watering point that is most sufficient to move the animals to both regarding water status and the actual given biomass around that water resource. Figure 15 shows an example of how such spatial analysis could be applied. Furthermore, from the long-time data possibly an extrapolation could be made and provide the users with preliminary future predictions. Future studies will also have to find out if this is possible to implement or not.

## **5.5 Sources of error**

Since there is no validation for the NPP data the data quality is a clear source of error and should be taken into consideration. The United States Geological Survey sometimes has data delivery latency and could be the reason why the latest date is sometimes not that current. There could also be errors in the data if the script is run at the same time as new files are added to the website. Overall if the MODIS data has false detection all results in further studies will contain error (Ferreira et al. 2007) which is not unique for only this study but for all using those orbital images.

## **6 Conclusions**

The overall aim of this thesis was to develop a web mapping application that can be used to disseminate grazing resource information as an aid in planning as well as a source for policy and decision making. The Web Mapping Application developed in this thesis do disseminate grazing information but requires some further implementations before it is a trustworthy aid in planning and decision making. This thesis can, nevertheless, be built upon for further implementation and provide some inspiration in the process.

Long-term patterns of NPP could be detected by using long term accumulate values of NPP and it gives an indication of how the vegetation and relative resource availability fluctuates each year and when there is expected to be the most vegetation and vice versa.

## 7 References

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[https://lpdaac.usgs.gov/dataset\\_discovery/modis/modis\\_products\\_table/mod17a2h\\_v006](https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod17a2h_v006)

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## APPENDIX I

```
1. #-*- coding: utf-8 -*-
2. """
3. Author: JessicaAhlgren
4. Last updated: 2016-05-02
5.
6. """
7. #####
8. #1.1 Importing modules
9. #####
10.
11. import pymodis
12. import os
13. import sys
14. import arcpy, arcinfo
15. from arcpy.management import Delete, SaveToLayerFile
16. from arcpy.sa import *
17. import re
18. import numpy
19. import csv
20.
21. #####
22. #1.2 Will have to be changed when run on a different computer
23. #####
24.
25. #Workspace where all files will be stored on the computer the script is run on
26. arcpy.env.workspace = "C:\\Users\\user\\Documents\\Exjobb\\Python\\"
27.
28. #Folder where e.g the files will be downloaded to
29. destinationFolder = "C:\\Users\\user\\Documents\\Exjobb\\Python\\downloads\\"
30.
31. #Pathway to Modis Reprojecting Tool (MRT) that has to be installed on the computer
32. mrtpath = 'C:\\Python27\\MRT\\'
33.
34. #Symbology files, one for each mxd
35. symbology = 'C:\\Users\\user\\Documents\\Exjobb\\Python\\test\\symbology.lyr'
36. symbology2 = 'C:\\Users\\user\\Documents\\Exjobb\\Python\\test\\recentchange.lyr'
37.
38. #Shapefile over Kordofan which will be used as a mask
39. mask = 'C:\\Users\\user\\Documents\\Exjobb\\webdata\\Kordofan.shp'
40.
41. #####
42. #1.3 Created by the script when it is run
43. #####
44.
45. #Create an empty file(.prm), will be updated in the script when the tiles are mosaic
    ked
46. confile = destinationFolder + 'params.prm'
47.
48. # Creates map document and dataframe variables.
49. mxd = arcpy.mapping.MapDocument(r"C:\Users\user\Documents\Exjobb\Python\JESSICA.mxd"
    )
50. df = arcpy.mapping.ListDataFrames(mxd,"*")[0]
51. mxd2 = arcpy.mapping.MapDocument(r"C:\Users\user\Documents\Exjobb\Python\JESSICA2.mxd"
    d")
52. df2 = arcpy.mapping.ListDataFrames(mxd2,"*")[0]
53.
54. ##Used in the section where it is uploaded to the server
55. ##Two of each are necessary since two lyr files can not be uploaded in the same mxd
56.
57. sddraft = destinationFolder + 'Jessica.sddraft'
58. sd = destinationFolder + 'Jessica.sd'
```

```

59. sddraft2 = destinationFolder + 'Jessica2.sddraft'
60. sd2 = destinationFolder + 'Jessica2.sd'
61.
62. ##Will be the names of the services on ArcGIS Online
63. service = 'Jessica'
64. service2 = 'Jessica2'
65.
66. #Each file requires an individual "confile"/parameter file, in other words one unique
67. #for every file, when they are being converted from HDF to TIF. The Modis Reprojecting
68. #will project the entire input file using the Bounding Box coordinates defined in the
69. #Archive metadata (here lat/long). SPECTRAL_SUBSET is the available bands, here we are
70. #interested in the second band (eg. NPP) of a total of three existing bands.
71. ##See below in the script how/when param1, param2 and param3 are used
72. param1 = '\n\nSPECTRAL_SUBSET = ( 1 )\n\nSPATIAL_SUBSET_TYPE = INPUT_LAT_LONG\n\nSPATIAL_SUBSET_UL_CORNER = ( 19.999999998 21.283555447 )\n\nSPATIAL_SUBSET_LR_CORNER = ( 9.999999999 40.617064472 )\n\n'
73. param2 = '\n\nRESAMPLING_TYPE = NEAREST_NEIGHBOR\n\nOUTPUT_PROJECTION_TYPE = GEO\n\n' #Nearest neighbor default
74. param3 = 'OUTPUT_PROJECTION_PARAMETERS = ( \n 0.0 0.0 0.0\n 0.0 0.0 0.0\n 0.0 0.0 0.0\n 0.0 0.0 0.0\n 0.0 0.0 0.0 )\n\nDATUM = WGS84\n' #Reprojecting to WGS84
75.
76. #####
77. #1.4 Following can be changed for other results
78. #####
79. tileIDs = 'h20v07,h21v07' #selected tile(s): http://modis-land.gsfc.nasa.gov/MODLAND_grid.html
80. endDate = '2000-02-18' #from date, the day to end downloading (the downloading happens in reverse order)
81. startDate = None #most current change to 'Today'
82.
83. arcpy.env.overwriteOutput = True #overwrite the outputs
84.
85. #####
86. #1.5 Download satellite data automatically (pyModis)
87. #####
88.
89. def download():
90.     print 'Starting'
91.     #Create an object called dm, this is how the files are derived from the usgs.gov website/database.
92.     #Password and user default values/not used since server is an HTTP server
93.     dm = pymodis.downmodis.downModis(destinationFolder, password=None, user='anonymous', url='http://e4ftl01.cr.usgs.gov',
94.                                     tiles=tileIDs, path='MOLT', product='MOD17A2H.006', today=startDate, enddate=endDate,
95.                                     delta=1, jpg=False, debug=True, timeout=30)
96.
97.     #Connect to the server according to the object dm, 20 is the maximum number of attempts to connect to the HTTP server before failing
98.     dm.connect(ncon=20)
99.
100.    print "Connection Attempts: " + str(dm.nconnection) #Prints how many connection attempts that has been done
101.
102.    #Get all/decide which files to download, for each day of interest
103.    downloads = [] #create an empty vector
104.    for day in dm.getListDays(): #Return a list of all selected days (endDate and startDate)
105.        print "Date: " + day #Print the day
106.

```

```

107.         files = dm.GetFilesList(day) #Returns a list of files to download. HDF
           and XML files are downloaded by default.
108.         ##Check if a file already exists in the local download directory, if i
           t doesn't exist it will be added to the list of files and thus be downloaded
109.         newFiles = dm.checkDataExist(files, move=False)
110.         print newFiles #Print the files
111.         #Make list of all the files
112.         if len(newFiles) != 0 :
113.             print "Adding files to the list"
114.             ##Only create a file if it actually exists
115.             newListFile = open(destinationFolder + day + ".fileList.txt", 'w')
           #Creates a file(newListFile) with a list over the files per date
116.             for f in newFiles:
117.                 downloads.append((f,day)) #store them in empty vector download
           s
118.             newListFile.write(destinationFolder + str(f) + '\n') #Write al
           l files for specific day to newListFile
119.             newListFile.close()#Close newListFile as we are done with it
120.
121.         numDownload = len(downloads) #Counts the number of rows, aka number of file
           s
122.         print "Files to Download: " + str(numDownload) #Total amount of files that
           should be/have been downloaded
123.
124.         #If there are no files to download, no further code is necessary to execute
           and therefore return is used
125.         if len(downloads) == 0:
126.             print "No new files. Exit function. "
127.             return
128.
129.         ##Download all files stated in downloads and put in destinationFolder
130.         for filename, day in downloads:
131.             print "Downloading: " + filename
132.             dm.downloadFile(filename,destinationFolder+filename,day)
133.             print "Files downloaded"
134.
135.         #####
136.         #1.6 Calculating statistics
137.         #####
138.
139.         years = [] #List with the available years
140.         accumulationsTotal = [] #list where the total accumulation for each year is
           stored
141.         accumulationsAverage = [] #list where the average accumulation is stored
142.         accumulationsPerDay = [] #list where the total accumulation per file (8days
           ) is stored
143.         summa = 0 #variable used to calculate the total yearly accumulation
144.         counter = 0 #variable used to count the number of days, used to calculate t
           he total accumulation. Used to calculate the average accumulation
145.         onlyLatest = True #Change this is you do not/do want all files (False/True)
146.
147.         first = True
148.         for day in dm.getListDays(): #Return a list of all selected days
149.             date = day.split(".") #Split dates in year, month and date
150.             files = dm.GetFilesList(day)
151.             print files #Print the files
152.
153.             #Make list of all the files
154.             if len(files) == 0 :
155.                 continue #Go directly to the next date
156.
157.         #####
158.         #1.7
           Gather yearly statistics. i.e. Total accumulation per year and average accumulation
           per year

```

```

159. #####
160.         year = date[0]
161.         if not year in years : #check if the year is not present in the list o
f available years. If it is not, we have a new year to append to the list
162.             years.append(year) #append the year to the list
163.             if not summa == 0 : #The sum will not be zero unless it is the fir
st one (i.e. it is the first year)
164.                 akumulationsTotal.append(summa) #append the sum to the list

165.                 ave = float(summa)/counter #calculate the average
166.                 akumulationsAverage.append(ave) #append the average to the li
st
167.
168.                 summa = 0 #reset the sum
169.                 counter = 0 #reset the counter
170.
171. #####
172. #1.8 Mosaic the tiles, convert them to TIF and reproject to WGS84 (pyModis)
173. #####
174.
175.         arcpy.CheckOutExtension("spatial") #Retrieves the license from the Lic
ense Manager
176.
177.         ##convert the tiles into a mosaic
178.         pymodis.convertmodis.createMosaic(destinationFolder + day + ".fileList
.txt", 'mosaic.' + day, mrtpath, subset='010').run()
179.
180.         #Creates a config file used to convert
181.         print 'Writing config file'
182.         f = open(confile, 'w')
183.         f.write('\nINPUT_FILENAME = ' + destinationFolder + 'mosaic.' + day +
'.hdf') #assign input
184.         f.write(param1)
185.         f.write('OUTPUT_FILENAME = ' + destinationFolder + 'converted.' + day
+ '.tif') #assign output with tif instead of hdf
186.         f.write(param2 + param3)
187.         f.close()
188.         print 'Converting file to tif'
189.         convert('mosaic.' + day, confile)
190.
191. #####
192. #1.9
Convert TIF to raster, extract attributes (valid range), correct scale and further c
alculate statistics
193. #####
194.
195.         print "Extracting attributes"
196.         tiffile = destinationFolder + 'converted.' + day + '.PsnNet_500m.tif'
#Defining each tif file and its location
197.         tempras = arcpy.Raster(tiffile) #Making a raster of the tiffile
198.         outExtractByMask = ExtractByMask(tempras, mask) #Masking out Kordofan

199.         ras = ExtractByAttributes(outExtractByMask, "value < 30000") #Extracti
ng all values below 30000 according to the metadata file with valid range
200.         newras = ras * 0.1 # correcting scale by multiplying with 0.0001 and a
t the same time transform from kilogram to gram, thus 0.1 instead.
201.
202.         ##Calculating total akumulation
203.         array = arcpy.RasterToNumPyArray(newras, nodata_to_value = 0)
204.         summa += array.sum() #Incerase the sum variable
205.         counter += 1 #increase with 1, as we have 1 more day with data
206.         print "Total: "
207.         print summa
208.
209.         akumulationsPerDay.insert(0, (day, array.sum(), newras)) #append all
data to the list for later calculations.

```

```

210.
211. #####
212. #1.10 Transform raster to ArcGIS layer and add to map document (mxd)
213. #####
214.
215.     print 'Transforming raster to ArcGIS layer'
216.     #Transforms raster to ArcGIS layer
217.     result = arcpy.management.MakeRasterLayer(newras, "NPP" + day)
218.     addLayer = result.getOutput(0) #Returns a layer
219.     #Applies symbology from model layer
220.     print 'Applying symbology'
221.     arcpy.management.ApplySymbologyFromLayer(addLayer, symbology)
222.     #Saves layer and adds to map
223.     #Creates an output layer file (.lyr) that references geographic data s
tored on disk
224.     arcpy.management.SaveToLayerFile(addLayer, destinationFolder + 'layer.
' + day + ".NPP.lyr")
225.     print day
226.     #Due to cost on server we only want to upload the latest file
227.     if onlyLatest == True : #check if we only want the latest file
228.         if first == True : #check if the current day is the latest day
229.             print "This is the latest!"
230.             print day
231.             first = False
232.             arcpy.mapping.AddLayer(df, addLayer, "AUTO_ARRANGE") #if so, a
dd the file
233.         else:
234.             arcpy.mapping.AddLayer(df, addLayer, "AUTO_ARRANGE") #all files wa
nted, so just add
235.
236.     arcpy.RefreshActiveView() #Refreshes the active view and table of cont
ents of the current map document
237.     arcpy.RefreshTOC() #Refreshes the table of contents
238.     print 'Raster layer saved to map'
239.
240. #####
241. #1.11 Calculating statistics and add to a second map document (mxd2)
242. #####
243.
244.     #The following is based on the fact that there are 8 days between each day in
the list
245.     #going back 4 files, would therefore give us the values from 24 days ago
246.     #So if we are currently on day 25th of march e.g.
247.     #Then we want the file from the 1st of march. The list of days are (1, 9, 17,
25 ...)
248.     #That is 4 files back
249.
250.     first = True
251.
252.     diffCounter = 1 #Counts upp to 4. When we have 4 files, we have enough days
to calculate the difference 24 days back
253.     akumulationsDiff = [] #list with the akumulation differences
254.     index = 1 #starting index, used to fetch correct files (i.e. 24 days back)
255.     for (day, value, ras) in akumulationsPerDay: #loop previously saved data to
calculate recent changes
256.         if diffCounter%4 == 0 and diffCounter != 0 : #We have reached 4, which
means we have enough data to calculate the recent changes
257.             (prevday, prevvalue, prevras) = akumulationsPerDay[index -
4] #Retrived data from 24 days ago from the list
258.             print "This: " + day
259.             print "Prev: " + prevday
260.             akumulationsDiff.append((day, (value -
prevvalue))) #add to list a tuple with the day, and the diff from 24 days ago
261.             #The raster is subtracted so we get a new file containing the diff
erence

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```

262.         newras = prevras - ras
263.         #Transforms raster to ArcGIS layer
264.         result = arcpy.management.MakeRasterLayer(newras, "Recentchange_"
+ day)
265.         addLayer = result.getOutput(0) #Returns a layer
266.         #Applies symbology from model layer
267.         arcpy.management.ApplySymbologyFromLayer(addLayer, symbology2)
268.         #Saves layer and adds to map2
269.         arcpy.management.SaveToLayerFile(addLayer, destinationFolder + 'la
yer.diff.' + day + ".NPP.lyr") #Creates an output layer file (.lyr) that references
geographic data stored on disk
270.         if onlyLatest == True : #check if we only want the last file (if n
ot add it)
271.             if day == dm.getListDays()[0]: #Checks if the date we are on i
s the latest day in the list with dates
272.                 print "This is the latest!"
273.                 print day
274.                 first = False
275.                 arcpy.mapping.AddLayer(df2, addLayer, "AUTO_ARRANGE") #if
so, add the file
276.             else:
277.                 arcpy.mapping.AddLayer(df2, addLayer, "AUTO_ARRANGE") #all fil
es wanted, so just add
278.
279.             else: #we have yet not gotten enough files to calculate the recent cha
nges
280.                 diffCounter += 1 #increase the counter
281.
282.                 index += 1 #increase index so we know what value to take when going ba
ck 24 days (4 files)
283.
284.         #####
285.         #1.12 Prints the recent changes to text document in csv formatted file
286.         #####
287.         f = open(destinationFolder + "akumulationDiffs.txt", 'wb') #open the file
288.
289.         writer = csv.writer(f) #create a csv writer (as we want it in csv format)
290.         headers = ['date', 'diff'] #make the headers of the table
291.         writer.writerow(headers) #write the headers to the file
292.         for (day, value) in akumulationsDiff: #for all recent changes, write it t
o the file
293.             row = [] #empty list
294.             row.append(day) #append the day to the list
295.             row.append(str(value)) #append the recent change to the list
296.             writer.writerow(row) #write the data to the file
297.
298.         f.close() #we are done, so we close the file
299.
300.         #For the last year available, append the sum and average to the lists
301.         akumulationsTotal.append(summa) #append the sum
302.         ave = float(summa)/counter #calculate the average
303.         akumulationsAverage.append(ave) #append the average
304.
305.         #####
306.         #1.13
307.         Prints the total, average akumulations per year to a text document in csv formatted
file
308.         #####
309.         f = open(destinationFolder + "akumulations.txt", 'wb') #open the file
310.         writer = csv.writer(f)#create a csv writer (as we want it in csv format)
311.         headers = ['year', 'total', 'average']#make the headers of the table
312.         writer.writerow(headers)#write the headers to the file
313.         for i in range(len(years)): #for each year, write the total and average ack
umulatons to the file
314.             row = []#empty list
315.             row.append(years[i]) #append the year to the list

```

```

314.         row.append(str(accumulationsTotal[i])) #append the total to the list
315.         row.append(str(accumulationsAverage[i])) #append the average to the list
316.     writer.writerow(row) #write the data to the file
317.     f.close() #we are done, so we close the file
318.
319.     arcpy.RefreshActiveView()
320.     arcpy.RefreshTOC()
321.     mxd.save() #Save the maps
322.     mxd2.save()
323.     print 'done'
324.
325.     #####
326.     #1.14 Uploading the map documents (mxd) to ArcGIS Online (server)
327.     #####
328.
329.     print "Uploading to server"
330.     # This code block creates a service draft definition, stages it and uploads
331.     # it to the server. For it to work, you need to first
332.     # open ArcMap, and use file -
333.     > sign in to log on to ArcGIS online. It does not overwrite, so previous versions of
334.     # the service
335.     # definition must be removed before new ones can be added.
336.     arcpy.management.Delete(sd)
337.     arcpy.management.Delete(sd2)
338.
339.     ##Upload the first mxd
340.     summary = 'Jessica master thesis'
341.     tags = 'NPP, Kordofan, Sudan, MODIS'
342.     #Convert Map Document (.mxd) file to Service Definition Draft (.sddraft) file
343.     analysis = arcpy.mapping.CreateMapSDDraft(mxd, sddraft, service, 'MY_HOSTED
344.     _SERVICES', None, True, None, summary, tags) #My Hosted Services server type for Arc
345.     GIS Online or Portal for ArcGIS
346.
347.     # Stages and uploads the service if the sddraft analysis did not contain er
348.     rors
349.     if analysis['errors'] == {}:
350.         arcpy.server.StageService(sddraft, sd)
351.         # Upload the service. The OVERRIDE_DEFINITION parameter allows you to over
352.         ride the
353.         # sharing properties set in the service definition with new values. In thi
354.         s case,
355.         # the feature service will be shared to everyone on ArcGIS.com by specifyi
356.         ng the
357.         # SHARE_ONLINE and PUBLIC parameters. Optionally you can share to specific
358.         groups
359.         # using the last parameter, in_groups.
360.         arcpy.UploadServiceDefinition_server(sd, "My Hosted Services", service,
361.         "", "", "", "", "OVERRIDE_DEFINITION"
362.         , "SHARE_ONLINE",
363.         "PUBLIC", "SHARE_ORGANIZATION", "")
364.
365.     print "Uploaded to service1"
366.
367.     else:
368.         # If the sddraft analysis contained errors, display them and quit.
369.         print analysis['errors']
370.
371.     ##Upload the second mxd
372.     summary = 'Jessica master thesis2'
373.     tags = 'NPP, Kordofan, Sudan, MODIS'
374.     #Convert Map Document (.mxd) file to Service Definition Draft (.sddraft) fi
375.     le

```



```

364.         analysis = arcpy.mapping.CreateMapSDDraft(mxd2, sddraft2, service2, 'MY_HOS
TED_SERVICES', None, True, None, summary, tags) #My Hosted Services server type for
ArcGIS Online or Portal for ArcGIS
365.
366.         # Stages and uploads the service if the sddraft analysis did not contain er
rors
367.         if analysis['errors'] == {}:
368.             arcpy.server.StageService(sddraft2, sd2)
369.             # Upload the service. The OVERRIDE_DEFINITION parameter allows you to over
ride the
370.             # sharing properties set in the service definition with new values. In thi
s case,
371.             # the feature service will be shared to everyone on ArcGIS.com by specifyi
ng the
372.             # SHARE_ONLINE and PUBLIC parameters. Optionally you can share to specific
groups
373.             # using the last parameter, in_groups.
374.             arcpy.UploadServiceDefinition_server(sd2, "My Hosted Services", service
2,
375.                                                 "", "", "", "", "OVERRIDE_DEFINITION"
, "SHARE_ONLINE",
376.                                                 "PUBLIC", "SHARE_ORGANIZATION", "")
377.
378.             print "Uploaded to service2"
379.
380.         else:
381.             # If the sddraft analysis contained errors, display them and quit.
382.             print analysis['errors']
383.
384.         #Function for converting the files from HDF to TIF, used in the code above
385.         def convert(filename, conf):
386.             """Exec the conversion process"""
387.             import subprocess
388.             execut = mrtpath + 'bin\\resample.exe';
389.             if not os.path.exists(execut):
390.                 raise Exception('The path {name} does not exist: it could be an '
391.                                 'erroneus path or software'.format(name=execut))
392.             else:
393.                 subprocess.call([execut, '-p', conf])
394.             return "The hdf file {name} was converted successfully".format(name=filena
me)
395.
396.         if __name__ == "__main__":
397.             download()

```

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