Greener Journal of Agricultural Sciences
ISSN: 2276-7770
Vol. 15(2), pp. 85-92, 2025

https://gjournals.org/GJAS
DOI: https://doi.org/10.15580/gjas.2025.2.012123009

Mapping of *Acacia senegal* (L.) Wild, *Acacia tortils and Leptadenia pyrotechnica* in North Kordofan, Sudan by using Remote Sensing-based Methods

Hatim Abdalla M. ElKhidir[1*], Abdelaziz K. Gaiballa[2], Nancy Ibrahim A. Khiralla[2], Abdelrahman A. Khatir[1]

[1] Agricultural Research Corporation, ElObeid Research Station. ElObeid, Sudan.

[2] Sudan University of Sciences and Technology, College of Forestry and Range Sciences. Khartoum, Sudan.

ARTICLE'S INFO

Article No.: *012123009*
***Type*:** *Research*
Full Text: *PDF, PHP, HTML, EPUB, MP3*
DOI: *10.15580/gjas.2025.2.012123009*

Accepted: *27/01/2023*
Published: *05/11/2025*

Keywords: *Acacaia senegal, Mapping, MODIS, Time series, NDVI*

Corresponding Author

Hatim Abdalla M. ElKhidir

E-mail: *guzaia@ hotmail.com*

Article's QR code

List of Abbreviations

NDVI	Normalized Differences Vegetation Index
MODIS	Moderate Resolution Imaging Spectroradiometer
LAI	Leaf Area Index
GIS	Geographical Information System
GPS	Global Positioning System
LULC	Land Use Land Cover
LIDAR	Light Detection and Ranging
IES	Institute of Environmental Studies
IIED	International Institute of Environment and Development
CBS	Central Bureau of Statistics

ABSTRACT

The development of remote sensing technology has made it possible to map the distribution of tree species in a timely and accurate manner. At present, a large amount of remote sensing data have been accumulated, including high-spatial-resolution images, time-series images, light detection and ranging (LiDAR) data, etc. This study was conducted in North Kordofan State, Sudan to map *Acacia seneal* (L.) Wild which is known as gum arabic tree "Hashab" that found in many types of pure stands or associated with other tree species such as *Acacia tortils "Seyal"* or *Leptadinia pyrotechnica* "Marakh". The objectives of this study was to understand means of identification and mapping of *A. senegal* trees (Hashab) in gum belt using remote sensing techniques e.g time series MODIS imagery in North Kordofan Region, the Sudan. And recognizing means of differentiating between *Acacia senegal* (Hashab), *Acacaia tortilis* (Seyal) and *Liptadenia pyrotechnica* (Marakh) covers using time series remote sensing-based techniques and mapping of *Acacia senegal* cover using RS-based means that express spatial and temporal variations of vegetation cover. The MOD13Q1v006 product from MODIS was acquired for this study. The MOD13Q1 product provides a 250 m resolution of 16-day imagery including the red (620-670 nm) and infrared bands (841-876 nm) wavelength. This product provides Normalized Difference Index (NDVI). Fifteen years from 2000 to 2014 MODIS data were studied. The analysis of MODIS data was done and all NDVI images were resized to fit the study area frame. The NDVI data were layer stacked for all years using all months to study the NDVI patterns in dry and rainy seasons. All stands were overlapped in study area frame to get the NDVI mean of all Hashab, Seyal and Marakh in selected sites. The results showed that the values of NDVI are significantly different between the three species during the wet months while it almost the same in dry months of the year. It's clear from the results that Hashab has higher NDVI values compared with other two species. NDVI is high sensitive to the rainfall and Hashab species is highly response to the rainfall and season start. From the results, NDVI values ranking is Hashab followed by Marakh and Sayal but, in 2002 and 2010 Marakh gave NDVI values higher than Hashab. MODIS time series have been successfully used as input features to classify land-cover classes characterized through differing phenological patterns and mapping Hashab, Marakh and Sayal.

INTRODUCTION

One of the most important forest types in the Sudan is the gum Arabic belt, which lies within the low rain Savanna zone. The term gum Arabic belt is used to indicate a region of approximately 520,000 km^2 which extends across Central Sudan between 10° and 14° North latitudes (Map 1) and which accounts for roughly one-fifth of the country total area (IIED and IES, 1989), now and after separation of the South Sudan States, Gum belt area almost equal one-third of the country total area. *Acacia senegal*, the tree commonly known as "hashab", grows naturally in this belt. The tree has an important role in fulfilling households' wood energy and fodder demands, besides enriching the soil fertility, possibly also through biological nitrogen fixation (Ballal, 1991). *Acacia senegal*, which produces gum arabic, is a very important tree. For instance, in 1995, Kordofan region produced almost 50% of total gum production in Sudan **(**Seif el Din and Zarroug, 1998).

In Sahel in general and in North Kordofan in particular, it is rare to find herbaceous and woody species in pure stands. What one founds is vegetation communities or vegetation associations. Distributions of rainfall and soil types are major factors determining these communities or associations. Examples for such communities in North Kordofan were given by various authors (Harrison and Jackson, 1958 and Fadl Elmula, 1997). Based on a classification by Harrison and Jackson (1958), *A. senegal* occurs in a number of vegetation types ranging from the semi-deserts and grassland zone in the north of the Sudan to the Terminalia-*Sclerocarya-Anogeissus*- savanna woodland in the south of the country.

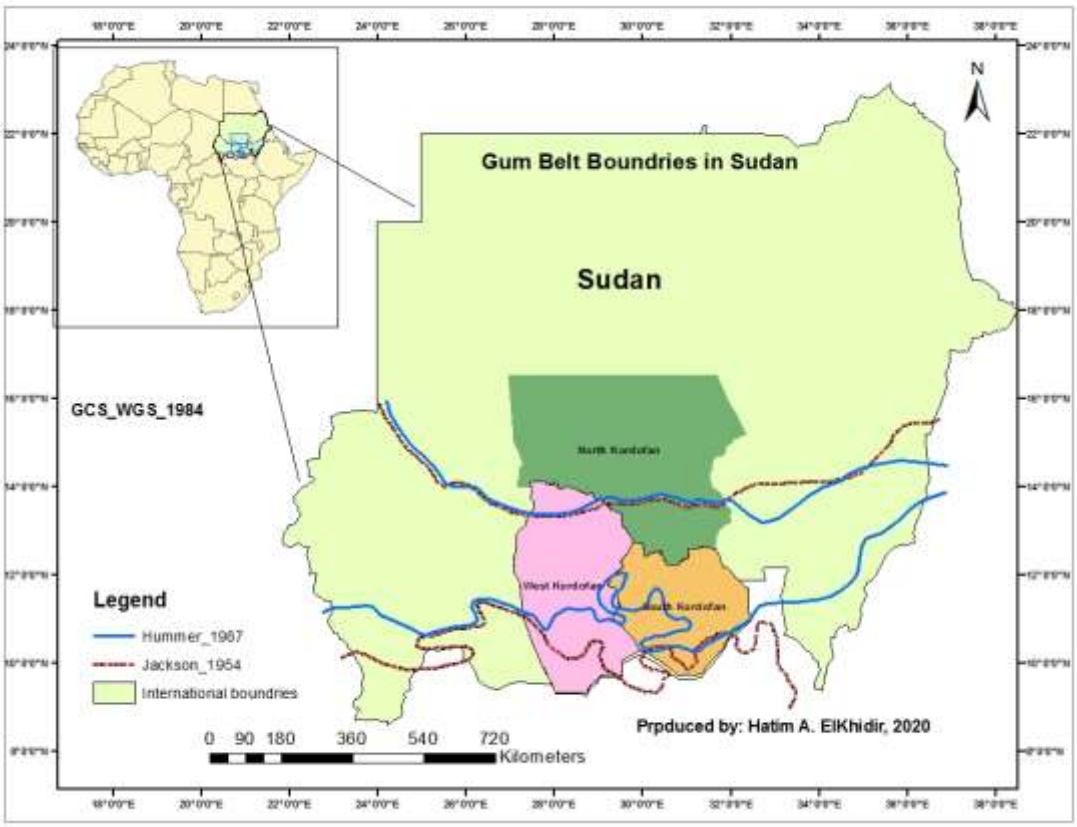

Figure 1: Gum belt boundaries in Sudan
Source: Harrison & Jackson, 1958; Hammer, 1987

The distribution of Hashab in the gum belt is variable and patchy depending on soil types, rainfall and human". IIED and IES (1989) also reported that, the current boundaries of the gum belt differed from the previous ones (Harrison & Jackson, 1958; Hammer, 1987) (Figure 1).

There is a strong need to map Hashab and distinguish it from some spatially related trees.). Land use and land cover studies were carried out on different scales for different users using remote sensing technologies. Although RS provides useful information but most of the studies conducted didn't provided detailed information that answer some specific research issues like assessing Today additional and more accurate information can be obtained as techniques are becoming more advanced as with the Moderate Resolution Image Spectroradiometer (MODIS) satellite data. The MODIS sensor provides "ready to use" ecosystem variables such as Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI) and Net Primary Production (NPP) at several spatial and temporal resolutions (Fensholt, 2003).Tree species mapping in forest areas is an important topic in forest inventory. In recent years, several studies have been carried out to map tree species using different types of hyperspectral sensors under various forest conditions (Dalponte *et al.* 2013 and Ghosh *et al.* 2014). The latest trends and advances studies of tree species classification have recently been summarized in Fassnacht *et al.*, (2016).

The main objective of this study is to understand means of identification and mapping of *A. senegal* trees (Hashab) in gum belt using remote sensing techniques in North Kordofan Region, the Sudan. And the specific objectives are recognizing means of differentiating between *Acacia senegal* (Hashab), *Acacaia tortilis* (Seyal) and *Liptadenia pyrotechnica* (Marakh) covers.

MATERIALS AND METHODS

This study was conducted in North Kordofan State which situated in the central part of Sudan extending from 11.15°N to 16.40°N latitudes and from 27.30°E to 32.25°E longitudes The State covers an area of approximately 245,000 km^2, representing two third of the Greater Kordofan Region area. (CBS, 2008).

Soils in the area range from sandy in the north to clay and *gardud*[1] in the south. The sandy soils cover an area of about 60% of the cultivable area, while the clay and sandy/clay (*gardud*)[1] cover 40%.

Annual rainfall ranges from less than 50 mm on the northern border to more than 600 mm on the southern border. The length of the rainy season varies from about one month or less in the north to about three months in the south. Rains occur between June-October with the peak in August. Within and

[1] The "*Gardud*" soil is a type of land that is mixed between Clay and Sand in varying proportions, it has a hard top layer with poor water percolation and for this difficult to cutivate

between seasons variation in rainfall amount and distribution is common. The average daily temperature ranges between 10-35ºC with an annual variation of 15ºC. April, May and June are the hottest months of the year, and December, January and February are the coolest ones. (Van der Kevie, 1973).

Methodology

The research methodology based on remote sensing techniques to identify and distinguish between *Acacia senegal* (L. WILLED) "Hashab", *Leptadenia pyrotechnica* "Marakh" and *Acacia tortilis* "Seyal" using MODIS imagery. These plant species supposed to have different patterns and characteristics of growth. Occurrences of Hashab tree can be pure Hashab stands or mixed with some other tree species like Marakh or Seyal. In this study pure Hashab stand were presented in ElHimaira Forest, Marakh presented in Umgalgy and Seyal in Mieliha stand. Table (1) showed the sites and their information.

Table (1). Study areas sites

Site	Tree Species	Area (km^2)	Village
1	*Acacia Senegal*	1.76	ElHimaira
2	*Acacia tortilis*	0.4	Mieliha
3	*Leptadinia pyrotechnica*	1.98	Umgalgy

Site selection was done using GPS logger and Arc GIS to make shapefiles for the selected stands. (Figure 2; Plates 1, 2 and 3).

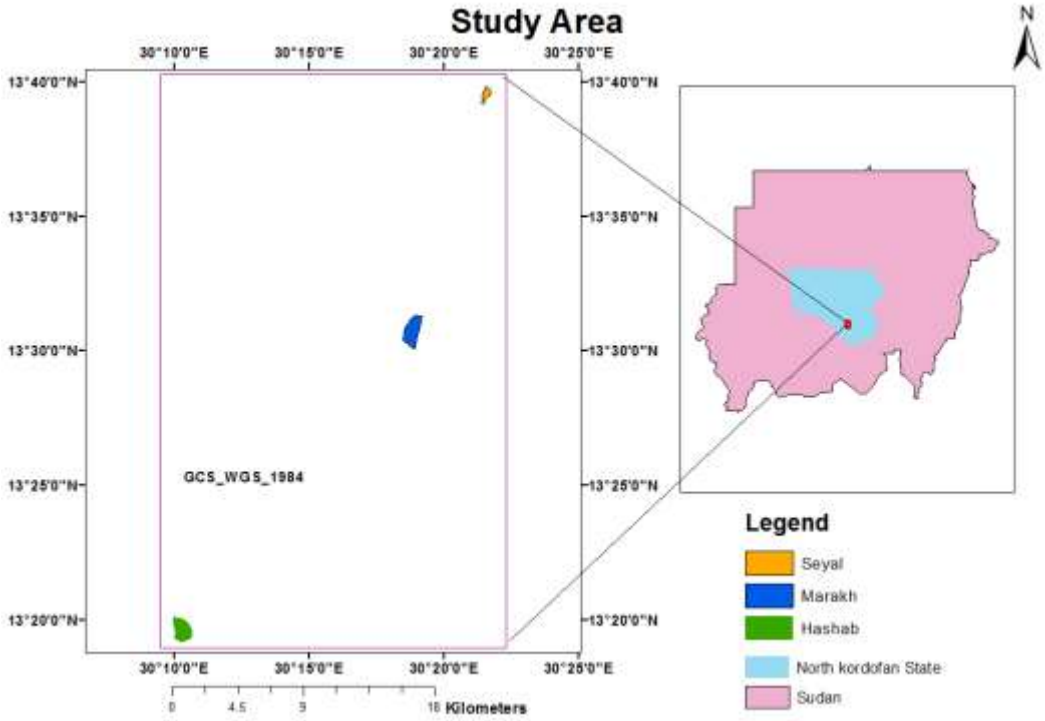

Figure 2. Study Area

Plate (1). Hashab in Himaira Forest

Plate (2). Seyal in Meileha

Plate (3). Marakh in Umgalgy

The MOD13Q1v006 product from MODIS was acquired for this study. The MOD13Q1 product provides a 250 m resolution of 16-day imagery including the red (620-670 nm) and infrared bands (841-876 nm) wavelength. This product provides Normalized Difference Index (NDVI).

MODIS data were downloaded from MODIS data site (http://daacmois.orl.gov/cgi-

bin/MODIS/GLBVIZI_GIb/Modis_subset_order_global_col5.pl). Fifteen years from 2000 to 2014 MODIS data were studied. MODIS NDVI data of years 2000 to 2012 was already calculated and ready when downloaded but data of years 2013 and 2014 were downloaded in bands and NDVI calculated using below formula with a remote sensing software applying the following equation:

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

NDVI = (float(b2)-(b1))/(float(b2)+(b1))

The analysis of MODIS data was done and all NDVI images were resized to fit the study area frame. After that NDVI data were layer stacked for all years using all months to study the NDVI patterns in dry and rainy seasons. All stands were overlapped in study area frame to get the NDVI mean of all Hashab, Seyal and Marakh in selected sites.
Formula below was used to calculate NDVI means over all fifteen years.

NDVI average =
(float(b1)+float(b2)+float(b3)+float(b4)+float(b5)+
float(b6)+float(b7)+float(b8)+float(b9)+float(b10)+
float(b11)+float(b12)+float(b13)+float(b14)+float(b15))
/15
Where: b1= red and b2= near infrared

RESULTS AND DISCUSSIONS

The NDVI time series for 15 years (2000-2014) for Hashab, Marakh and Sayal are presented in figure (3). The results showed that the values of NDVI are significantly different between the three species during the wet months while it almost the same in dry months of the year. *Acacia senegal* (L. WILLD) "Hashab" gave mean of NDVI values of 0.204, 0.313 and 0.320 in July, August and September, respectively. *Leptadenia pyrotechnica* "Marakh" gave mean of NDVI values of 0.18, 0.28 and 0.28 in July, August and September, respectively. *Acacia tortelis* "Sayal" gave the lowest NDVI mean values in compared with the other two species (0.17, 0.22 and 0.23) in July, August and September, respectively.

From these results, the NDVI time series imagery can be one of the methods to classify and identify tree species. The availability of no-cost MODIS NDVI data and automated data processing techniques that provide high quality continuous time series data, represent a major advancement for the automated monitoring annual land-cover change and vegetation condition over large geographic regions as reported by Lunetta *et al*. (2006). Recently, satellite imagery has been used in many studies for several purposes such as estimation of cultivated land, identification of crop types, yield forecast, developing of hydrological model (Jakubauskas and Legates, 2002; Sakamoto *et al*., 2005). Crop type identification maps are known the most important data source in crop management and yield assessment (Zhao *et al*., 2017; Ustuner *et al*., 2014). For crop mapping purpose seasonal parameters such as the starting, middling, ending of the season, seasonal length, seasonal amplitude etc., can be obtained from several time series vegetation indexes (Zhao *et al*., 2017).

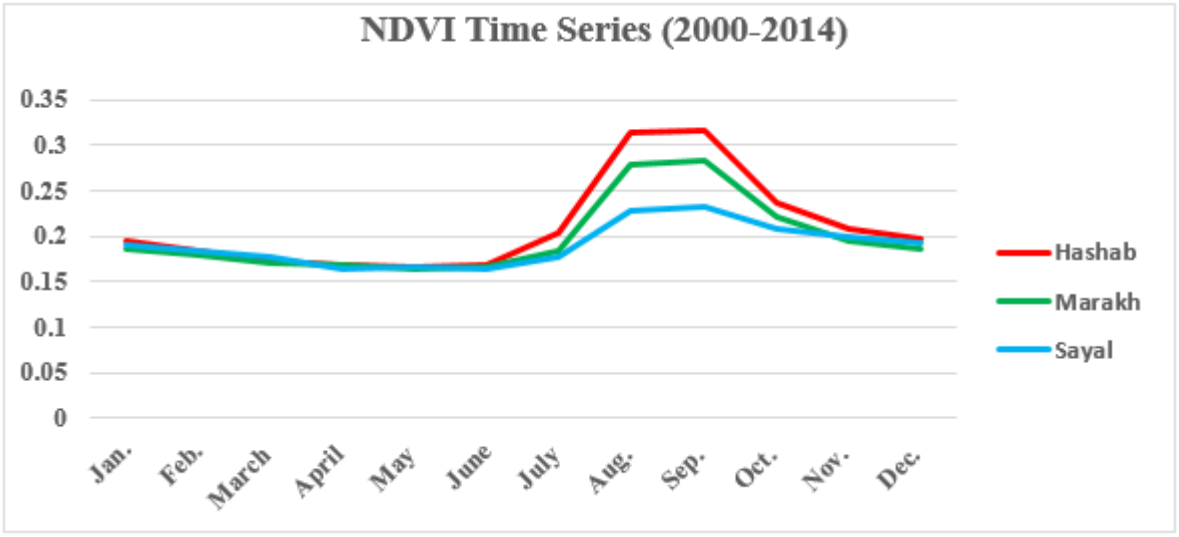

Figure (3). NDVI Time Series for Hashab, Marakh and Sayal through fifteen years (2000-2014).

NDVI time series for Hashab, Marakh and Sayal by year for the fifteen seasons are presented in figure (4). It's clear from the results that Hashab has higher NDVI values compared with other two species. The exceptions appeared in few years due to the climate change and low precipitation. NDVI is high sensitive to the rainfall and Hashab species is highly response to the rainfall and season start. Hashab tree begin to green early in rainy season. From the results and similar to the figure (3), NDVI values ranking is Hashab followed by Marakh and Sayal but, in 2002

and 2010 Marakh gave NDVI values higher than Hashab.

Wardlow *et al.* (2007) concluded that a time-series of the 16-day composite MODIS 250 m VI data had sufficient spectral, temporal, and radiometric resolutions to discriminate the region's major crop types and crop-related land use practices. For each crop, a unique multi-temporal VI profile was detected in the MODIS 250 m data that was consistent with the known crop phenology. Most crop classes were separable at some point during the growing season based on their phenology-driven spectral–temporal differences expressed in the VI data.

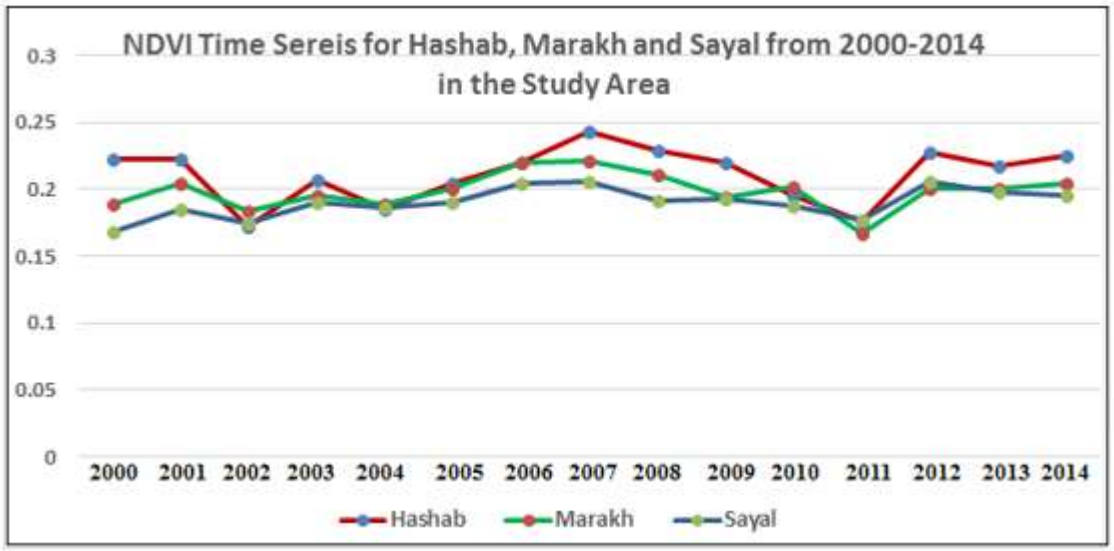

Figure (5). NDVI Time Series for Hashab, Marakh and Sayal from 2000-2014 in the Study Area.

Figure (6) presented the NDVI time series for Hashab, Marakh and Sayal for fifteen years during the wet season. Matching the previous figures, Hashab leads the two species and have highest NDVI values in all years except 2002 and 2010. In general, Hashab can clearly distinguished and identified from Sayal and Marakh as Hashab is distributed in its habitat almost with these species in North Kordofan.

Mapping forest types in a natural heterogeneous forest environment using remote sensing data is a long-standing challenge due to similar spectral reflectance from different tree species and significant time and resources are required for acquiring and processing the remote sensing data.

Phenological study of different species in the past has shown differences in the time and duration of phenophases of individual species. Bajpai *et al.* (2012). Performed an in-situ experiment to investigate phenophases of two dominant species, *Shorea robusta* and *Ficus hispida*, in deciduous natural forests along the Indo-Nepal order. Data collected from 160 twigs showed clear differences between the species. The variation in vegetation phenological properties opens the possibility of differentiating the specie types using spectral signatures over time. Time series data analysis with vegetation indices is Forests popular in Land Use Land Cover (LULC) classification as well as agricultural and forestry applications.

Yan *et al*. (2015) utilized normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) time series data to classify vegetation cover types in China. MODIS time series images have been used for particular crop identification (Zeng *et al.* 2016 and Wardlow *et al.* 2007), land cover classification (Xue *et al.* 2014) etc.

Statistical metrics computed on MODIS time series have been successfully used as input features to classify land-cover classes characterized through differing phenological patterns, such as Hansen *et al*. (2003) for mapping a global continuous fields tree cover and Gessner *et al*.(2009) for mapping fractional vegetation cover in Namibia on a regional scale.

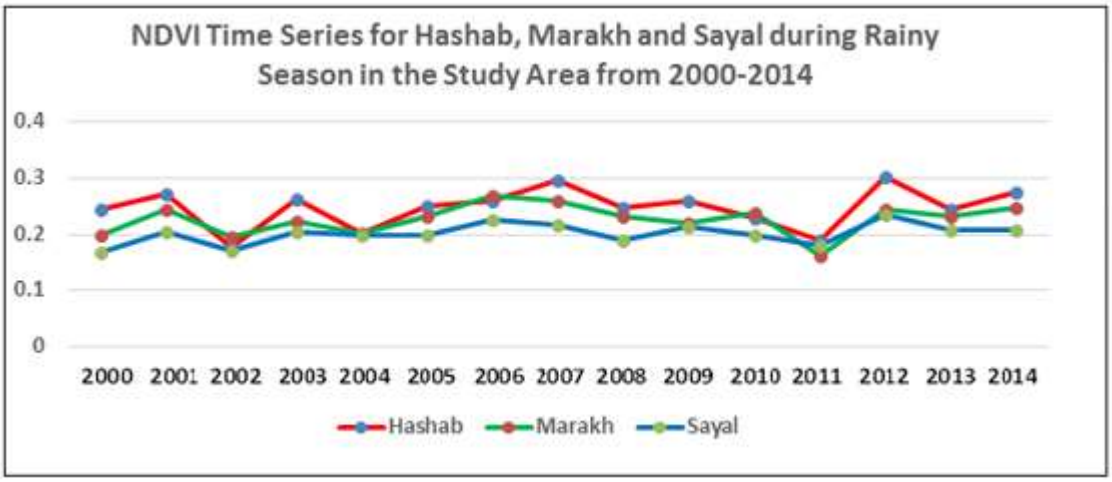

Figure (6). NDVI Time Series for Hashab, Marakh and Sayal during Rainy Season from 2000-2014 in the Study Area.

CONCLUSIONS

The findings of the study clearly showed that NDVI values for Hashab, Marakh and Seyal are significantly differences over fifteen years' time series data. Hashab always gave higher NDVI values followed by Marakh then Sesyal in 3rd place.

The overall average of NDVI values from 2000-2014 in the active growth period (May to October) showed that Hashab has high NDVI values (0.234) followed by Marakh (0.216) then Seyal (0.196). The results indicate that the three tree species have different growth characteristics and different NDVI values during the rainy season. These differentiations clear in some points as green startup, peak of growth and average of NDVI values.

MODIS time series imagery have been successfully used as input features to classify tree species and Hashab can clearly distinguished from Seyal and Marakh as Hashab is distinguished in its habitat almost with these species in North Kordofan.

AUTHORS CONTRIBUTIONS

Hatim Abdalla M. ElKhidir. The main and corresponding author who write the draft.

Abdelaziz K. Gaiballa. Supervising the study and edited the draft.

Nancy Ibrahim Khiralla. Help in analysis during the study.

Abelrahman A. Khatir. Help in analysis and edited the draft.

REFERENCES

Bajpai, O.; Kumar, A.; Mishra, A.K.; Sahu, N.; Behera, S.K. and Chaudhary, B.L. (2012). Phenological Study of Two Dominant Tree Species in Troppical Moist Deciduous Forest from the Northern India. Int. J. Bot. 8, 66–72.

Ballal, M.E. (1991): Acacia senegal: A multi-purpose Tree Species for Arid and Semi-arid Tropics. M.Sc., University of Wales, UK.

Barker, T.; Bashmakov, I; Bernstein, L.; Bogner, J.; Bosch, P.; Dave, R.; Davidson, O.; Fisher, B.; Grubb, M.; Gupta, S.; Halsnaes, K.; Heij, B.; Kahn Ribeiro, S.; Kobayashi, S.; Levine, M.; Nabuurs, G.J.; Najam, A.; Nakicenovic, N.; Holger Rogner, H.; Roy, J.; Sathaye, J.; Schock, R.; Shukla, P.; Sims, R.; Simth, P.; Swart, R.; Tirpak, D.; Urge-Vorsatz, D. and Zhou, D. (2007). Summary for Policymakers IPCC Fourth Assessment Report, Working Group III, Lawrence Berkeley National Laboratory.

CBS. (2008). Central Bureau of Statistics. Ministry of Councils of Ministries. Annual Report Statistical Book. Sudan.

Dalponte, M., Ørka, H.O., Gobakken, T., Gianelle, D., Næsset, E. (2013). Tree species classification in boreal forests with hyperspectral data. IEEE Trans. Geosci. Remote Sens. 51, 2632–2645. https://doi.org/10.1109/TGRS.2012.2216272.)

Fadl Elmula M. (1997). Soil and Vegetation Baseline Survey of CBRRCSB project area, UNDP, Khartoum, pp 4-33

Fassnacht, F.E., Latifi, H., Stereńczak, K., Modzelewska, A., Lefsky, M., Waser, L.T., Straub, C., Ghosh, A. (2016). Review of studies on tree species classification from remotely sensed data. Remote Sens. Environ. https://doi.org/10.1016/j.rse.2016.08.013.

Fensholt, R. (2003). Assessment of primary production in a semi-arid environment from satellite data. PhD thesis, Institute of Geography, University of Copenhagen.

Gessner, U.; Klein, D.; Conrad, C.; Schmidt, M.; Dech, S. (2009). Towards an automated estimation of vegetation cover fractions on multiple scales: Examples of Eastern and Southern Africa. In Proceedings of the 33rd International Symposium of Remote Sensing of the Environment, Stresa, Italy, May 4–8, 2009.

Ghosh, A., Fassnacht, F.E., Joshi, P.K., Koch, B. (2014). A framework for mapping tree species combining hyperspectral and LiDAR data: role of selected classifiers and sensor across three spatial scales. Int. J. Appl. Earth Obs. Geoinf. 26, 49–63. https:// doi.org/10.1016/j.jag.2013.05.017.

Hansen, M.; DeFries, R.; Townsend, J.; Carrol, M.; Dimeceli, C.; Sohlberg, R. (2003).Global percent tree cover at a spatial resolution of 500 meters: first results of the MODIS vegetation continuous field's algorithm. Earth Interact. 2003, 7, 1–15.

Harrison, M.N. and Jackson, J.K. (1958). Ecological Classification of the Vegetation of the Sudan. Forest Department, Forest Bulletin No. 2, Sudan.

IIED and IES. (1989). Gum Arabic Rehabilitation in the Republic of the Sudan. Ministry of Finance and Economic Planning. International Institute of Environment and Development (IIED) and Institute of Environmental Studies (IES).

Jakubauskas, M. E.; Legates, D.R. and Kasterns, J. H. (2002). Crop Identification using Harmonic Analysis of Time-series AVHRR NDVI Data. Computers and Electronics in Agriculture. 37 (1-3), 127-139.

Sakamoto T., Yokozawa M., Toritani H., Shibayama M., Ishitsuka N. and Ohno H. (2005). A crop phenology detection method using time-series MODIS data. Remote Sensing of Environment, 96(3–4): 366–374. https://doi.org/10.1016/j.rse.2005.03.008.

Lunetta, R.L., Knight, F.K, Ediriwickrema, J., Lyon, J.G., and Worthy, L.D. (2006). Landcover change detection using multi-temporal MODIS NDVI data. Remote Sensing of Environment, 105, 142-154.

Opdam, P.; Luque, S. and Jones, K. B. (2009). Changing landscapes to accommodate for climate change impacts: a call for landscape ecology. Landscape Ecol. 24: 715-721.

Seif el Din, A.G. and M. Zarroug. (1998). Production and Commercialization of Gum Arabic in Sudan. In: Non-Wood Forest Products 9. Nairobi, FAO, (Ed.). FAO, Kenya, Rome

SSA. (1975). Sudan Survey Authority. Annual Report. Sudan.

Stern, N. (2007). The economics of climate change. The Stern Review. Cambridge Universtity Press, Cambridge.

Ustuner M., Sanli F.B., Abdikan S., Esetlili M.T., Kurucu Y. (2014). Crop type classification using vegetation indices of rapideye imagery. In The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XL: 195–198. Istanbul, Turkey: ISPRS Technical Commission VII Symposium.
https://doi.org/10.5194/isprsarchives-XL-7-195-2014.

Van der Kevie, W. (1973). Climate Zones in the Sudan. Soil Survey Department, Wad Medani.

Xue, Z.; Du, P.; Member, S.; Feng, L. (2014). Phenology-Driven Land Cover Classification. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 7, 1142–1156.

Yan, E.; Wang, G.; Lin, H.; Xia, C.; Sun, H. (2015). Phenology-based classification of vegetation cover types in Northeast China using MODIS NDVI and EVI time series. Int. J. Remote Sens. 36, 489–512.

Zeng, L.; Wardlow, B.D.; Wang, R.; Shan, J.; Tadesse, T.; Hayes, M.J.; Li, D. (2016). A hybrid approach for detecting corn and soybean phenology with time-series MODIS data. Remote Sens. Environ. 181, 237–250.

Zhao X., Wang X., Cao G., Chen K., Tang W., Zhang Z. (2017). Crop identification by using seasonal parameters extracted from time series landsat images in a mountainous agricultural county of eastern qinghai province, China. Agricultural Science, 9(4): 116–127. https://doi.org/10.5539/jas.v9n4p116.

Cite this Article: Hatim, AME; Abdelaziz, KG; Nancy, IAK; Abdelrahman, AK (2025). Mapping of *Acacia senegal* (L.) Wild, *Acacia tortils* and *Leptadenia pyrotechnica* in North Kordofan, Sudan by using Remote Sensing-based Methods. *Greener Journal of Agricultural Sciences*, 13(1): 85-92, https://doi.org/10.15580/gjas.2025.2.012123009.