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Mesquite Risk Mapping and Assessment in Tokar Delta-Eastern Sudan

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Abstract:
Tokar Delta is a name given to a small delta of approximately 161,000 hectares situated in the southern area of the Red Sea in Eastern Sudan. Beginning of 1980, mesquite species (*Prosopis chilensis & Prosopis juliflora*) were introduced to Tokar area to be planted as a shelterbelt for the city Tokar, but after while; it spread out to the delta area and became an invasive plant to the agricultural lands and along Khor Barak banks. Nowadays mesquite covers more than half of the delta area, decreased the cultivable land in the delta and created risk to the environment and livelihood of the people in the area. Therefore, this research study was an attempt to map and assess mesquite risk in the Tokar Delta and further provide guidance for possible solutions, control and management. The tools and methods used for the study were different multi-temporal satellite imagery, ground field survey and risk assessment models. The results showed that mesquite has increased by more than 50% during the period 1989-2001, while the expansion was about 10% during 2001-2013. Moreover, the assessment indicated that mesquite risk has many aspects ranging from management to environment and socio-economic.

***Key words*—Assessment, Mapping, Mesquite, Risk, Delta Tokar**

I. INTRODUCTION

Tokar Delta is a name given to a small delta of approximately 161,000 hectares situated in the southern area of the Red Sea in Eastern Sudan between the coordinates 18°25′31″N 37°43′45″E and 18.42528°N 37.72917, figure (1). Tokar area receives annual rainfall not exceeding 200 mm and exposing to winds blows for about 4 months a year which sometimes reached 20 km/hr with mean daily temperatures range from 20-40 °C [1]. Nevertheless, the region is environmentally and socially sensitive, as it falls in the arid Sahel zone and most of the populations are practicing agriculture and animal rearing [2]. The joint mission to the Tokar Delta Agricultural Scheme (TDAS) in 2008 reported that TDAS has a total of 5,724 landowners registered and 24,000 landless sharecroppers while the census showed a total population of 45581 inhabitants in Tokar administration unit plus the rural areas [3 and 4]. During the Colonial times Tokar delta was great source of wealth through the extensive production of cotton, but since then land usage has declined to less than 70,000 hectares. It has been estimated that more than 1400 ha of the delta can no longer be cultivated because of mesquite infestation [3 and 5]. Mesquite species now invade greater part of the Delta area and create risk to the environment and the population. Thus, this research is an attempt to assess, map and analyze mesquite risk in Tokar Delta aiming to have better understanding to the invasion dynamics and provide guidance for management plans.

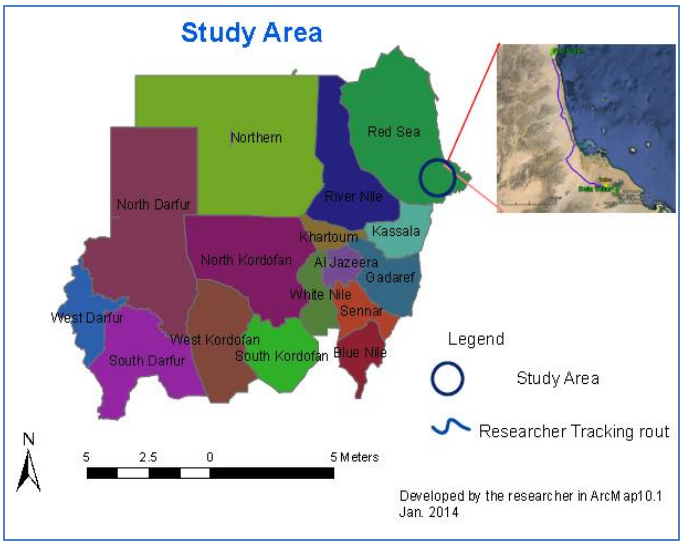


Fig. 1: The Study Area

II. PROBLEM STATEMENT

Just after a decay of introduction of mesquite species (Prosopis chilensis & Prosopis juliflora) to the Tokar area, it started expanding and competing with the agricultural crops and native plant species. This was due to many factors such as abundant of agricultural farms in the delta during the war and drought in eighties and also due to lack of flood and mismanagement of water irrigation system in the TDAS. Also, there was a lack of multi-sectoral linkage between the TDAS administration that changing from time to time. By now mesquite covering most of the fertile land in the Delta and

became risk to the environment and livelihood of the people in the area. Not only that but also the Sudan National Forest Sector (FNC) reported that about 1.5 million ha in irrigated areas are affected by mesquite [6]. Therefore there is a need for methods of assessing and mapping of mesquite risk and having better understanding of its invasion dynamics and strategic impacts upon livelihood of the people.

III. Objectives

- To carry out mesquite risk mapping and assessment in Tokar Delta in order to better understand of its invasion strategy and dynamics.
- To assess the likelihood and risk of mesquite upon the environment and livelihoods of the people in Tokar Delta.
- Further to provide options and guidance for future management plans

IV. Tools and Methods

a. General

Three temporal satellite imagery were acquired and download for the USGS.gov website. These include Landsat 8 for the year 2013 and Landsat Thematic Mapper (TM) for the years 1989 and 2001. The Landsat 8 satellite consists of two science instruments; the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS), and provide coverage scenes at a spatial resolution of 30 meters (visible, NIR, SWIR); 100 meters (thermal); and 15 meters (panchromatic). Various image processing techniques have been implemented to the images using ERDAS Imagine 9.1, MultiSpec V.3.2 and ArcGIS10.1 software. These were including; image subset, spectral test, enhancement and classification. Besides that a model has been developed for risk mapping, evaluation and analysis. Moreover, some field data and secondary information were also used in the research. Finally, mapping results were integrated with risk model and risk maps were produced.

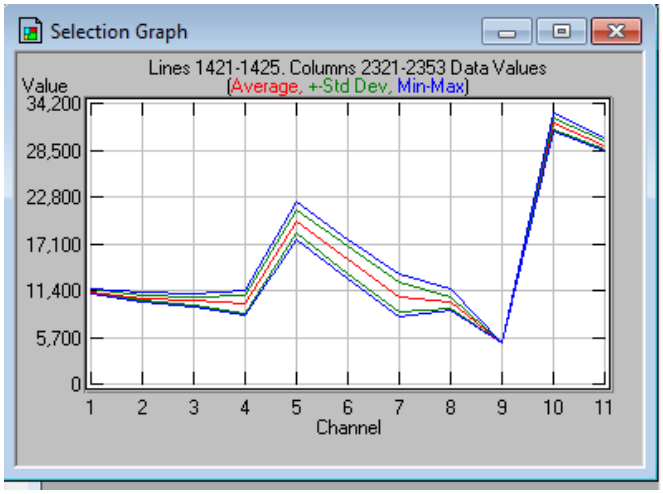


Fig. 2: Image processing: spectral test using MultiSpec 3.2.

b. Image Processing

Initially, subsets for the study area (Delta Tokar) were created from the satellite imagery. Then the several enhancement procedures were implemented, these include spectral test, PCA (Principle Components Analysis) for features and classes extraction; NDVI (Normalized Difference Vegetation Index) for vegetation identification and MSAVI2 (Modified Soil Adjusted Vegetation Index) for removal of soil effects (fig.2 and 3). Afterwards, unsupervised classification algorithm was used for production of mesquite invasion maps.

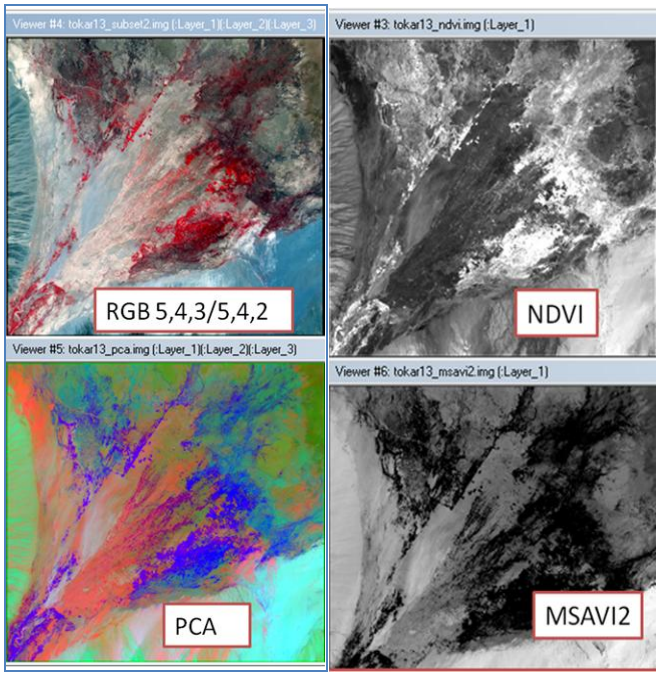


Fig. 3: Image processing output using ERDAS Imagine 9.1 and MultiSpec 3.2.

The MSAVI2 is a useful method for image enhancement. It is very efficient method for vegetation identification especially in areas with imprecise vegetation factor. The formula was obtained from [7], and then builds in ERDAS Spatial Modeler then used for Equi.1).

Equi.1:

$$MSAVI2 = \frac{\left(2*NIR+1-\sqrt{(2*NIR+1)^2-8*(NIR-RED)}\right)}{2}$$

c. Mesquite Risk Assessment Process

In order to map and assess the risk of mesquite in the study area, a hypothetical model has been developed using

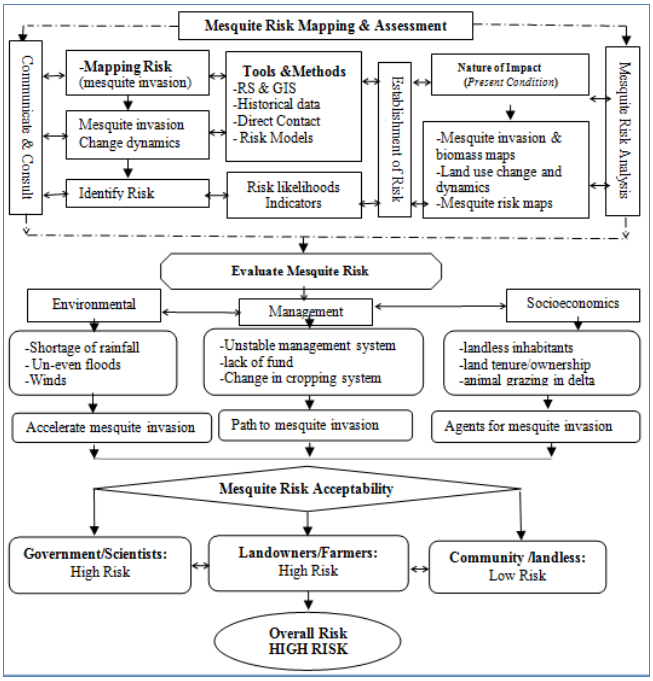


Fig.4: Mesquite Risk Mapping & Assessment Model.
Developed by: the author from: [8, 9, and 10].

secondary available literature, (fig. 4). The model process started with communication and consultation of mesquite risk parameters such as invasion using various mapping methods and tools. Then the next step, the model used to establish mesquite risk picture in order to find out the likelihood and nature of mesquite impacts its present condition for further analysis. Further driven and referenced parameters were used to evaluate the risk from environmental, management and socioeconomic point of view. Finally, the model process resulted in production of risk acceptability and current levels.

V. RESULTS AND DISCUSION

a. Imagery Classification

The preliminary results of unsupervised classification of landsat8 showed that mesquite species have increased rapidly by more than 50% during the 1st period 1989-2001, while increased only by about 10% in second period 2001-2013 (Fig. 4). This could be refereed to that in earlier period of introduction of mesquite, there were more bare lands with good moisture in the delta area which gave chance for rapid spread of mesquite; while in the later period the moist areas have already been invaded by mesquite, so that the invasion was limited. In addition to that there was some control measures applied to reduce mesquite expansion in the Delta such as clear cutting and eradication which also has impact in invasion. The same results have been approved in Gash Delta which has the same condition by [11], and stated that mesquite invade only the moist soils on the buffer zone of 500-1000 meter from river banks and canals.

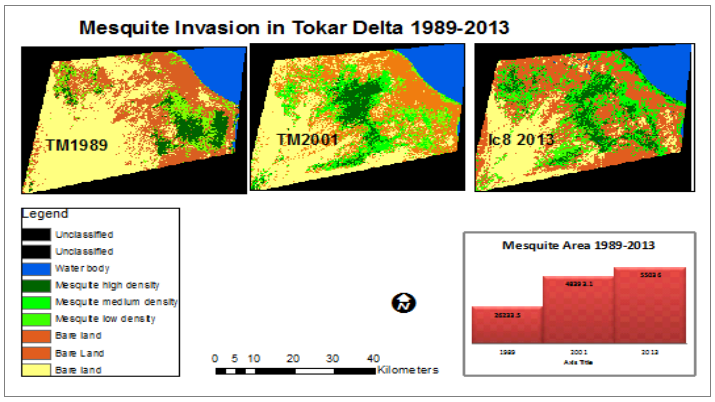
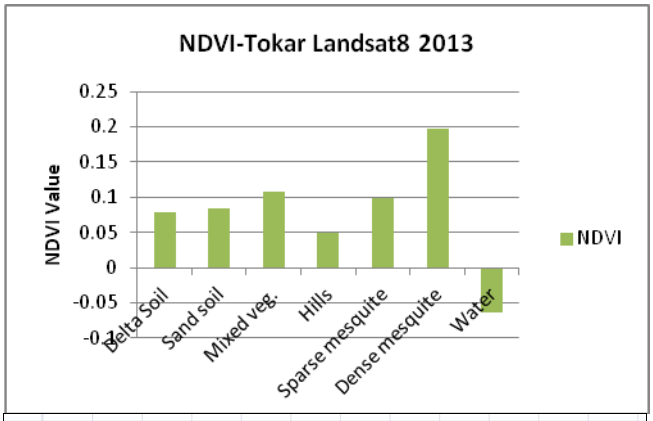


Fig.5: Unsupervised Classification of Mesquite in Tokar Delta 1989-2013



Cluster	Pixels	Channel Means										
		1	2	3	4	5	6	7	8	9	10	11 NDVI
1	14177.8	14286.7	15992.6	18460.4	21617.5	25102.7	22260.2	16745.2	5058.1	34280.8	30985.8	0.078774
2	13547.2	13477.6	14808.2	16955.8	20089.9	23219.1	20371.7	15473.6	5053.7	34549.4	31123.7	0.084601
3	12601.6	12311.8	13247.1	15153.4	18816	22306.1	19030.6	13821.9	5049.5	34817.2	31103.8	0.107821
4	13625.7	13482.1	14436	15876.6	17505.1	19954.1	18302.8	14871.2	5049	34853.3	31343	0.048784
5	12598.9	12229.3	12767	14077.7	17149	19465.8	16668.9	13156.6	5047.4	34471.2	30892.9	0.098355
6	12040.3	11503.1	11652.2	12231	18233.5	17913.1	13890.3	11761.2	5047.5	33637.8	30332.9	0.197033
7	11959.4	11250.7	10054.3	8369.3	7354	6686.2	6272.2	9354.3	5023.2	28246.6	26734.7	-0.06457

Fig. 6: NDVI for Mesquite in Tokar Delta

Further on, with regard to the NDVI classification, the values calculated showed a range of 0.1-0.2 for areas of low and dense mesquite simultaneously (Fig.6). Similar results were obtained in a mesquite research in Atbara River by [11].

b. Mesquite Risk Evaluation and Assessment

Mesquite risk evaluation in Tokar Delta indicated that the risk has a complex background ranging from management to environmental and socio-economic factors. This is because, in principle the (TDAS) has been found for cultivation of cotton, but due to low income and increased needs for food grains, the farmers tend to cultivate sorghum and millet in addition to cotton (Table.1). Thus, from management point of view, the TDAS administration was facing lack in multi-sectoral linkage. This was clear when we looked back to the administration history of the scheme. It has been started with a Colonial administration in 1930s, then shifted to the national

government management, and afterwards changed to a private sector corporation and finally back to the government administration. These shifts created gaps in management especially with regard to the control of mesquite, irrigation and the cropping pattern.

Moreover, and due to poor administration and high cost of agricultural activities, farmers specially the sharecroppers (landless farmers) failed to remove sorghum stalks after harvesting their crops which triggered the accumulation of sand mounds that hinder floods flow to the farm [3]. As a result of these sand mounds no smooth and regular floods to many farms, and as a consequences those farms remained abundant and became favorable for mesquite invasion. Besides that previously animal grazing inside the TDAS was prohibited, but due to lack of management now animals are grazing in the delta and this lead to spread of mesquite seeds and contributed to the invasion.

Going on, the environment also played a considerable role in mesquite invasion. Because, Tokar area exposing to wind blow from South and Southeast to the north during July-September and from the North to the East during October-December. These winds positively help in floods flow in the delta but at the same time act in spreading mesquite seeds by water wash in the farms and also forming mounds that hindered flood sheets.

Moreover, mesquite risk has also social dimensions among these, was that the farms in the scheme were distributed on a tribal bases and only 5724 family owned farms while 24,000 landless farmers working as sharecroppers [3]. This created kind of conflict of interest as most of the cultivators were from the landless people. Besides that, the landowners established what so called Tokar Farmers Union (TFU) which had a role in advocating and disseminating information and enforce relationships between its members and resolve disputes. Also the TFU used to maintain linkages with Community Based Organizations (CBOs) based outside of the Delta. Another socioeconomic aspect in the delta was that the sharecroppers used to get very low income from their shared crops. As a result they didn't care about farm land after harvest which led to sand mounds and hindered flood flow. On the other hand, the landless used to work in mesquite wood marketing as charcoal or woods for their local use, so they have different perceptions regarding mesquite eradication. In fact, the landowners have the will to clear mesquite, but they don't have the financial capability and proper technical knowhow. This also could be lined to mesquite invasion history in Sudan which has has been reported by [12].

VI. CONCLUSION:

The study concluded that, there is clear mesquite invasion and risk in Tokar Delta for the period 1989-2013 with different acceptability levels. The famers or landowners categorized it as a high risk, while the landless people and the sharecroppers find it to be of low risk. The government and scientists specified mesquite as an invasive species with a high risk. However, neither the government, nor the famers have agreed guidance for how to get rid of or control mesquite.

VII. RECOMMENDATIONS:

- Identify clear management body and system for the Delta Agricultural Scheme.
- Activation of the Farmer Union and integrated it in the management body
- Mesquite eradication by clear cutting found to be not effective as if the land has not been irrigated after clearance, the mesquite will grow a again.
- Making use of results of relevant researches and studies carried out.
- Using best methods or techniques for management and/control of mesquite practiced in areas with the same conditions such as pruning to prevent seeds production and prevent animals grazing in the delta and initiation of marketing and processing of mesquite such as charcoal
- Rehabilitation of irrigation and flooding systems
- Extension, capacity building and technology transfer for the results obtained to the farmer and communities.
- Animal grazing need to be controlled in the Delta especially in the cultivable lands to avoid spread of mesquite seeds.

VIII. REFERENCES

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