Advances in Bioresearch
Adv. Biores., Vol 8 (2) March 2017:146-152

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.8.2.146152

Advances in Bioresearch

ORIGINAL ARTICLE

Application of Satellites Imagery in Detecting and Mapping *Striga hermonthica* in a Sugar Cane Field

Yasir A. Qurashi[1]; E. S. Ganawa[2]; A. F. Kheiralla[2];A. A. Hassaballa[3*]
[1]Sennar Sugar Factory, Sudan
[2]University of Khartoum, Sudan
3Precision Agriculture Research Chair (PARC), King Saud University, Saudi Arabia
* Corresponding Author address:Precision Agriculture Research Chair (PARC), King Saud University, Saudi Arabia
E-mail: ahassaballa@ksu.edu.sa, Tel.: +966542053994

ABSTRACT
This paper presented the applications of remote sensing imagery and GIS on Striga hermonthica weed mapping in a sugar cane fields at Sennar sugar factory where located in the southeast region of the Sudan. In this work, a remote sensing system was developed and implemented for detecting and mappings triga in selected fields. The developed system used satellite images and differential global positioning system (DGPS) points as inputs to determine the striga infestation level through supervised classification technique. It was noticed that the striga population density was allocated to the field's boundary. The study also intended to examine the impact of striga development on sugar cane yield during seasons 2009, 2010 and 2011. A considerable negative relationships between striga extent and sugar cane yield were noticed where an average infestation area increase of 34- 40 % caused yield drop of 150 – 200 tons over the studied fields during the three mentioned seasons. These results drew the attentions to the severity of striga expansion over Sennar sugar cane fields.
***Keywords**: Striga hermonthica, Sugar cane, Remote sensing, GIS, Weed mapping.*

Received 01/11/2016 Revised 12/01/2017 Accepted 19/02/2017

How to cite this article:
Yasir A. Qurashi; E. S. Ganawa, A. F. Kheiralla; A. A. Hassaballa. Application of Satellites Imagery in Detecting and Mapping *Striga hermonthica* in a Sugar Cane Field. Adv. Biores., Vol 8 [2] March 2017: 146-152.

INTRODUCTION

Weed management is an important practice in crop production, since weed infestation in agricultural fields causes high yield losses. Based on the worldwide estimates, the potential crop loss due to all pests is 40%– 80%, varying for different crops, and the potential of yield losses due weeds is estimated at34% of all pests [1].Precision plant protection often uses maps for decision support, and these maps are frequently produced from discrete sampling datasets. Maps are usually essential in a target-oriented pesticide application because it is widely accepted, particularly for weeds that are heterogeneously distributed in arable land [2-4]. A noxious weed location map with information on size and density of an infestation is also critical for planning control efforts. Integrated weed management involves using the most efficient control methods. It is very difficult to determine what methods are the most effective and efficient without documentation of the problem. This documentation is also critical for designating priority control areas, identifying infested areas and determining the budget required to do the job. Maps are also a critical component of developing contracts and cooperative agreements that identify areas of responsibility for all parties and define each partner's obligation.

Striga is a parasitic weed which attaches itself to the roots of cereals and other plants, not only robbing them of nutrition but also causing various debilitating effects which have earned them their common name of "Bodah". The two most important species (*Striga Hermonthica* and *Striga Asiatica*) parasitize cereal crops, particularly sorghum and millets, but also maize, upland rice and sugarcane. Another, (*Striga Gesnerioides*) attacks cowpeas. Striga produces numerous tiny seeds which remain viable in the soil for many years and do not germinate unless a sorghum, millet or maize root grows very near to it. Once established, it is therefore very hard to eradicate, and in some areas where infestation is heavy, there may be total crop failure in some years.

Striga spp., root parasitic plants are considered the most serious biotic factor that threatens cereals (sorghum, maize, pearl millet and rice) production in the rain fed agriculture of the semi-arid tropics including Sudan. About 21 million hectares of cereals production area in Africa are estimated to be infested by Striga, causing an annual grain loss of about 4.1 million tons. Losses in grain yield due to striga infestation vary from 5 to 75%, depending on the level of infestation, susceptibility of the crop, climatic conditions and nature of the soil. Grain yield losses can reach 100% in susceptible cultivars under a high infestation level and drought conditions. In Sudan, more than 500,000 hectares under rain fed cultivation are heavily infested with striga, which commonly results in significant yield losses of 70-100%. Severe infestation by striga may force farmers to shift to less economic crops such as millet, to abandon the land when infestation is too heavy or even to migrate from their location to other locations. *Striga hermonthica* and S*triga asiatica* are the major biotic constrains to crop production, especially in the non-fertile semi-arid region of Africa, whereas *striga aspera* and *striga forbesii* are of lower economic importance. *Striga hermonthica* is the most serious biotic problem to cereal production, it attacks sorghum, maize, pearl millet and rice [5].

Striga hermonthica is suggested to originate from the same area as sorghum (*Sorghum bicolor L. Moench*), and it is thought to have coevolved with wild relatives of sorghum during domestication in the Sudan-Ethiopian region of Africa [6]. With the introduction of sorghum into new regions in Africa, it may have spread by crop seed contamination. It is thought that new areas and fields are still being colonized by contaminated crop seeds [7]. *Striga hermonthica* parasitizes, not only, on sorghum but also on other cereals, e.g., maize and millet [8]. Also *striga hermonthica* has been reported to parasitize rice, finger millet and sugarcane and recently barley [9]. *Striga hermonthica* is one of the most biological constraints to the production of millet, sorghum and maize in sub Saharan Africa despite more than 50years of research. Some fields have become so badly infested with Striga that farmers are forced to abandon them or grow other crops [9]. *Striga hermonthica* grows in sub-tropical areas with an annual rainfall ranging from 300 –1200mm. However, it may be able to adapt to agro climatic conditions outside its current distribution range and to other crop species.

Geographic information system (GIS) and remote sensing technologies have been integrated for a variety of natural resource applications [10-14], including mapping the distribution of noxious weeds [15-17]. Remote observations in georeferenced formats help to assess the extent of infestations, develop management strategies, and evaluate control measures on noxious plant populations.

Recently, remote sensing technology has received considerable interest in the field of biological invasion. It is a tool that offers well documented advantages including a synoptic view, multispectral data, multitemporal coverage and cost effectiveness [18, 19]. It is now widely applied on collecting and processing data. Weed survey data can be related to other digital data layers such as precipitation, temperature, soils and vegetative cover. These data can provide information for evaluating weed management plans, predicting areas vulnerable to weed invasion, understanding the biology of the invasion process and for assessing the economic impact of weed invasion [20].

Many researchers suggest that a so-called integrated striga control or management approach would be the best strategy for short and long term striga control and crop yield improvement. However, the concept of integrated striga management, like integrated pest management also implies that choices of control options must be based on a sound knowledge of the biology and population dynamics of the pest [21]. The life cycles of the economically important striga species are very closely linked to the growing seasons of their hosts.

A field study was conducted at the sugarcane farm of Sennar Sugar Factoryin order to apply remote sensing and GIS techniques to (1) achieve a more cost-effective method for mapping the extent of striga weed distribution, (2) to assess the impact of striga weed on sugar cane yield and (3) to gain a greater understanding of the factors governing the distribution and spread of striga infestation.

MATERIAL AND METHODS

Study Area

The study was conducted at the farm of Sennar Sugar Factory in the state of Sennar (Sudan), 40 km north-west of Sennar city, 300 km south of Khartoum. It is located between the latitudes of 13^{o}34’ 22”.6 – 13^{o} 54’ 0”.36 N and the longitudes of33^{o} 23’ 45”.0 – 33^{o}34’ 1”.2E with an elevation of 418 above MSL(Fig. 1).

Agriculture is the main economic activity, followed by livestock raising in the traditional seasonal transhumance pattern, village livestock raising and, as a recent element, livestock raising by large scale mechanized merchant farmers investing surplus wealth in cattle.

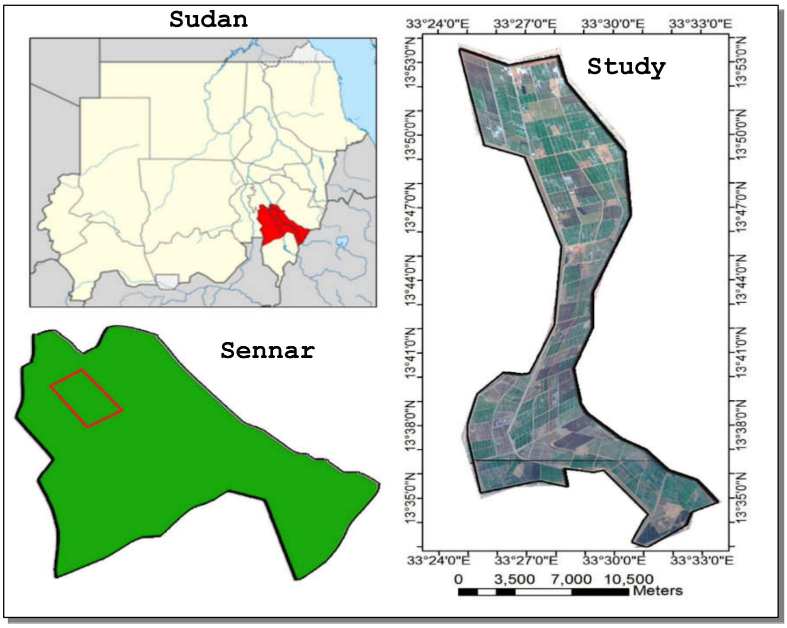

Fig. 1.Study area (Sennar Sugar Factory)

Data collection:

High resolution satellite images were procured from the Indian Remote Sensing satellite (IRS-P6 resourcesat-1),which is the state-of-art satellite mainly for agriculture applications with a 3-band multispectral LISS-IV camera and a spatial resolution of less than 6 m and a swath of around 25 km with across track steer ability for selected area monitoring. Three IRS images were acquired for the years 2009, 2010 and 2011 over the sugarcane farm of Sennar Sugar Factory. Geometric correction was conducted to adjust the images to a real word reference using WGS-1984-UTM projection system. Image subset was masked surrounding the study field beside the initial pre-processing steps applied using remote sensing software. Image classification was also applied in order to generate a monitoring map of the striga weed. ArcGIS software, in addition, was used to process, edit and manipulate the attribute data and prepare the maps layout. Differential global positioning systems (DGPS) in turn was linked to the GIS applications to improve the capacity of images, maps, aerial photos and site specific information integration [22].

Data processing:

The experimental sugarcane field was divided into two main sectors (A and B) andeach division was divided into five divisions (A1, A2,…A5 and B1, B2,…B5)as well. The flow chart shown in Fig. 2 below represents the steps followed to create a map of striga extent and to examine the striga impact on sugarcane yield. Images acquired from IRS sensor were pre-processed and then classified through a supervised classification mechanism using striga samples, collected at the field, as training and testing datasets for the classification. Supervised classification task was performed in order to develop mechanism that distinguishes the striga weed among the growing sugarcane. Striga sample locations were spotted at field using the DGPS device for building a classification matrix as well as for the validation process.

Two outputs were gained from the process:

1. Striga monitoring map, in which the spatially distributed striga regions within the classified image were masked through digitization process, and then striga monitoring map was generated for herbicide application purposes.
2. All pixels which were identified as striga-infested were counted then the infested area was assessed based on the image pixel-size's specifications. The estimated infested area was then correlated with the sugarcane yield for each sector.

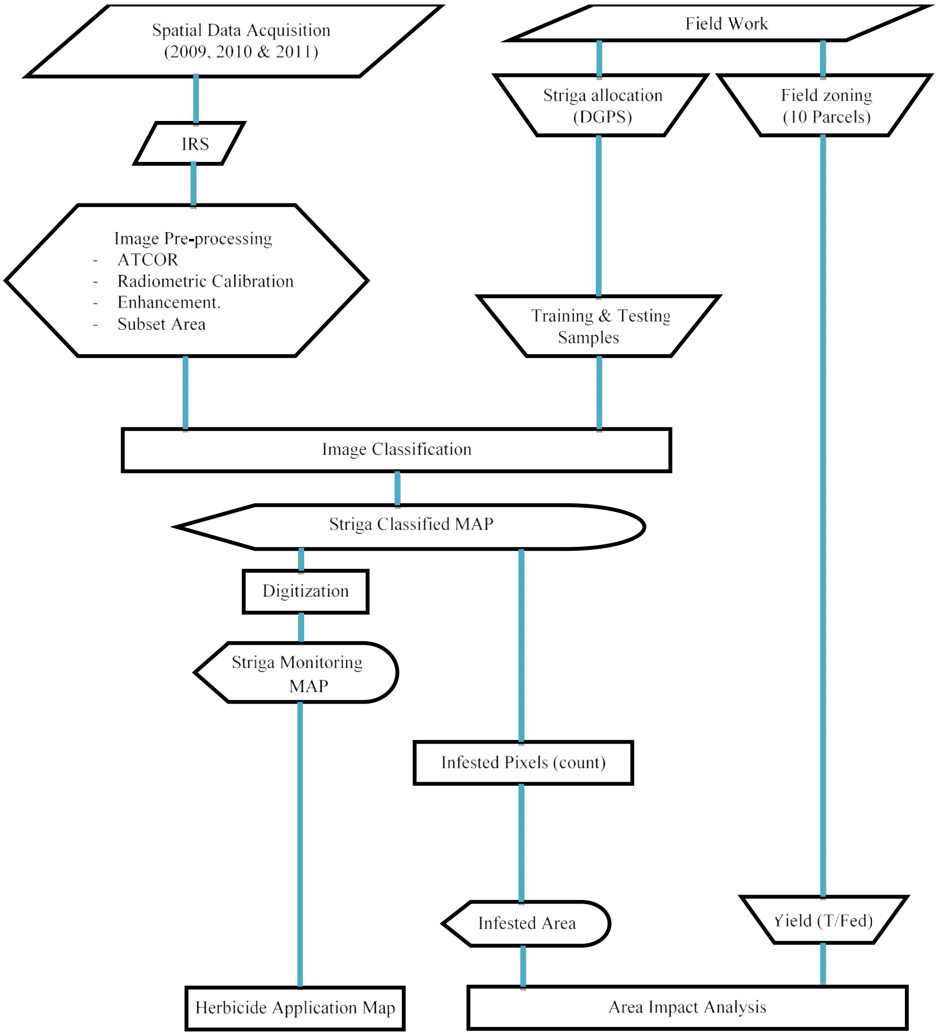

Fig. 2.Steps for creating the digital maps and their analysis

RESULTS AND DISCUSSION

Herbicide Application Maps

Herbicide application maps were developed to assist in selecting the optimum treatments for striga, where its distribution was identified based on the classification process. The proposed optimum herbicide treatments were suggested as assigning herbicide rates to each location according to infestation level, in which chemical treatments will be used. For this option, a direct chemical injection system will be utilized. This system was based on GPS data for positioning the sprayer and then applying treatments at the infested zone.

The spatial distribution of the striga along the study area reflects (through the map) the impact of the water irrigation system allocation on striga density and distribution; as it can be seen in the sample figures (Figs. 3 & 4) of seasons 2009 and 2011. It could be noticed that the higher population density of striga is always allocated around the field boundaries. This could be attributed to the high rate of water logging at conduits outlets on the field and also areas prior to drainage systems.

The ability of using DGPS in geo-locating striga was found to be twofold, first; it was used to accurately record points of infested sites and second; it was used in integration with GIS and remote sensing's outputs to accurately locate striga infestations. The resultant map also showed much variability in the size, morphology, and distribution of striga patches both within and between agricultural fields.

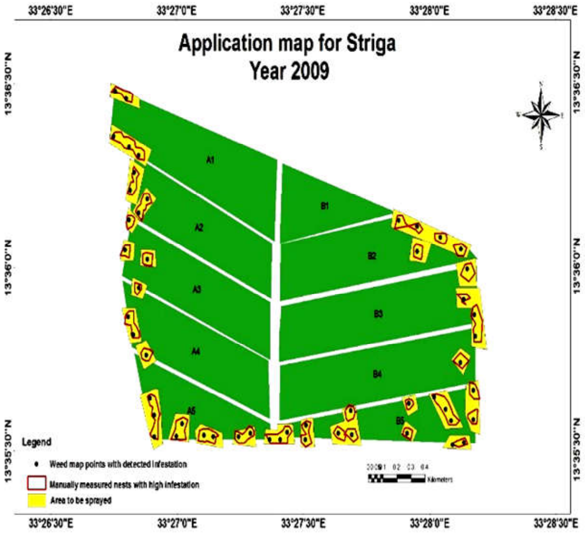

Fig. 3: Application map for Striga year 2009

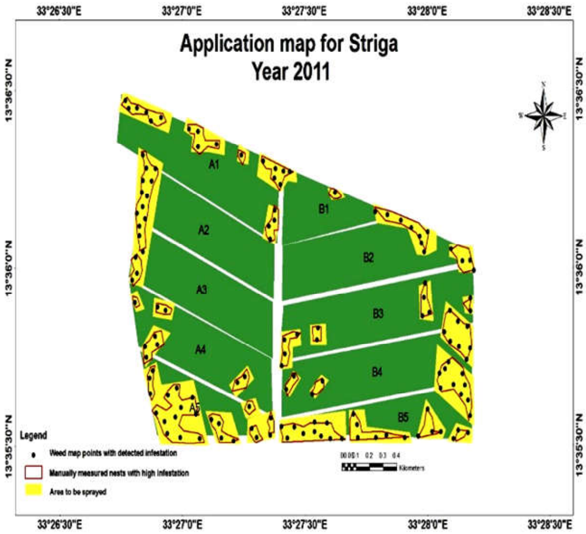

Fig.4: Application map for Striga year 2011

Impact of infested area on sugar cane yield

As a step to analyze the impact of the striga on sugar cane yield over different sections of the irrigated field. The density of the striga population was assessed in the form of counting infested pixels over the whole classified 10 sectors of the study area. Infested area was calculated according to the image pixel's specifications. Finally, the resultant infested areas were plotted against the measured yield taking into account that, the cultivated sugarcane area was maintained for each sector during the three study seasons.

By taking fields of sector B as examples (Figs. 5 (a &b)), a robust negative relationship was found between infested areas and the measured yield within the 5 divisions of sector B. As a result, it has been confirmed thatas the striga progresses over a certain sector, the yield decreases accordingly. This was found to be clearly obvious over sectors with relatively small areas which assure that the centralization and dominancy of populated striga was specifically close by water conduits and drains; which means around the field.

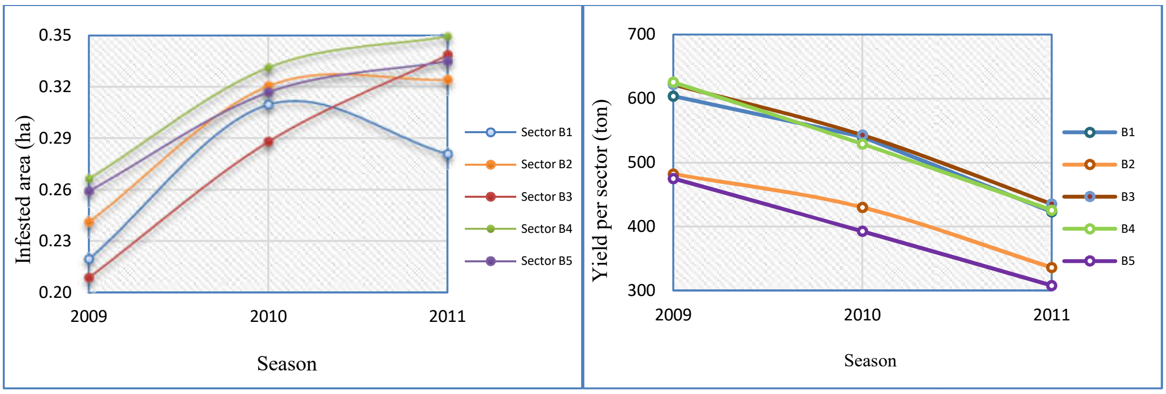

Fig. 5: Impact of striga expansion on sugarcane yield during seasons 2009, 2010 and 2011 for sectors: (a) A_5 and (b) B_5 as examples.

From the figures above, it was noticed that when the striga area expanded 30 % between 2009 and 2010, the yield dropped 30% over the same division.As an example if we consider division B3, as infested area expanded 0.12 ha, the yield at the division dropped 190 ton throughout season 2009 – 2010.

In order to assess the variability of the striga expansion during the three seasons, the study presented the five infested divisions in a spatial and temporal plotted showing the relative growing area changes time wise. As it can be seen in Fig. 6 below, in all divisions of sector B the striga expands in a similar manner with a slight difference in division B3 for season 2010-2011; this justifies that striga shares the host crop the whole available resources and grow according to the surrounding conditions.

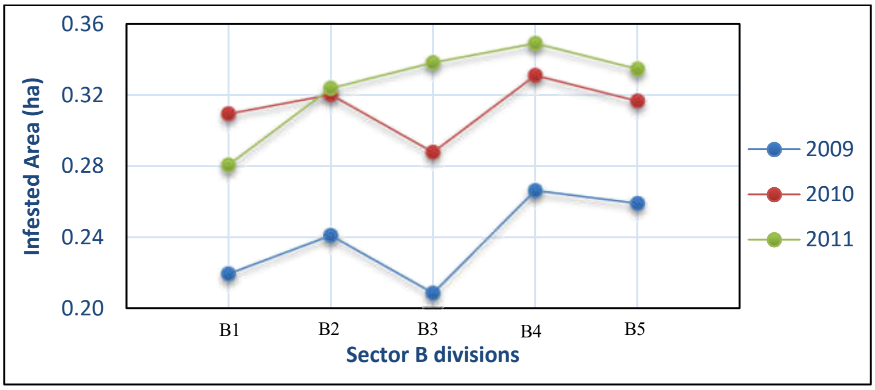

Figure 6: The trend of striga expansion throughout the three season.

Taking into account the sustainability of cultivated areas during seasons 2009, 2010 and 2011 beside all agricultural processing (land preparation, irrigation, fertilization, etc..), it could be highlighted that the striga weed is considered as one of the most invasive weeds that threaten sugar cane crop in the study area due to its harmful characteristics that have been studied and reported worldwide which state that:

- The damage caused by striga is a major and the harvest losses are always measurable [23]. The growth of the host plant is drastically slowed down by striga because it damages its photosynthesis and uses its nutrients, causing a high deficit [24].
- After striga has spread to a field the damage would increase every season if nothing is done to combat it [24].
- Competition for mineral nutrients is one of the strike points that striga has, so being hardy and vigorous in growth habit; it soon outgrows the crops and consumes large amount of water and nutrients. Thus causing heavy losses in yields.
- Striga competes for space both in the rhizosphere and atmosphere. In the striga presence, crop plants will have limited space to develop their shoots, which amounts to reduced photosynthesis in them.

In fact, many other harmful effects that striga causes to the host crops which should be considered when applying herbicides. An integrated approach to striga management that uses remote sensing and GIS techniques should be adopted to generate control strategies to manage striga populations so that it can reduce the treatment cost.

CONCLUSIONS

Striga hermonthica is an economically important parasitic weed of sugar cane. The infestation affects almost all stages of the crop growth. In this work, a system was developed and implemented for the striga detection in agricultural fields. The developed system used satellite images and DGPS points as an input to determine the striga infestation level through image processing and supervised classification. The infestation was measured on the plant level by class assignments for each visible plant in the image.The study led to conclude that:

- Remote sensing offered a low cost, frequent alternative mean for mapping and monitoring striga infestations over sugar cane fields.
- For the success of remote sensing technique, the targeted striga was allocated in-situ using DGPS system and supervised classification mechanism so as to identify the striga extent throughout the study area. Detection of striga was pending to the infestation density.
- Herbicide application map was generated based on the resultant classified map where, it was noticed that the striga population density was allocated to the field's boundary.
- The study also intended to examine the impact of striga development on the sugar cane yield during seasons 2009, 2010 and 2011. Considerable negative relationships between striga extend and sugar cane yield was noticed, which reflected the severity of striga as an invasive weed grown over Sennar sugar cane factory.

ACKNOWLEDGMENT

This project was financially supported by King Saud University, Vice Deanship of Research Chairs.

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