Detection of Change in Vegetation Cover Caused by Desert Locust in Sudan

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Abstract: the problem of desert locust infestation increased as a consequence of rainfall increase in several areas suitable for desert locust breeding. In 2012, several desert locust outbreaks were reported in Africa mainly in Libya, Niger, Mali and Chad. The main objective of this research was to detect changes in vegetation state caused by desert locust infestation in the Sudan, using remote sensing (RS) and geographical information System (GIS). Enhanced vegetation index (EVI5) data, from MODIS satellite image and ancillary ground survey data, were integrated and three maps were produced. These maps were Sudan desert locust damaged-vegetation assessment map in 2012, Subset map of Khartoum State where desert locust activity took place in vegetated area in 2012 and vegetations damaged temporal change detection map. Zonal attribute analysis, post-classification change detection approach and image classification were performed. The results of desert locust damaged-vegetation map 2012 showed that the mean pixel value of infested areas is significantly different from healthy areas (p ≤ 0.02). The means pixel values of infested vegetation were 68.600, 66.839 and 73.770 during years of 2010, 2011 and 2012, respectively. Those of non-infested vegetation were 65.790, 65.006 and 77.600 during the years of 2010, 2011 and 2012, respectively. These results were used as guide for producing Sudan desert locust damaged-vegetation assessment map in 2012. In subset of Khartoum State, a temporal change in vegetation damage was detected and a total loss of 520.15 hectares of vegetation in three months, as result of desert locust activity in 2012 was recorded. It is concluded that Sudan is threatened by desert locust; it could be detected and monitored using RS and GIS. Real time monitoring approach is recommended to solve any coming problems. Therefore, RS and GIS techniques are recommended to be part of the existing Early Warning System and control strategy in Sudan.

Key words Desert locust, Sudan, GIS, RS

1- Introduction
Pest infestation is a major disaster affecting most of the African countries. Plants, crops and pastureland are subjected to damaged or poorly stand. As result significant impact on people livelihood and welfare is occurred (Nur, 2007). Large number of various pests attack crops in several states of the Sudan. In 2009 the most important pests recorded are Dura antad, Desert locust, Sesame seed bug, African boll worm, Melon bug, Qualia Qualia bird, Rodents and other minor pest. The Desert Locust, Schistocerca gregaria (Forskål, 1775) is a member of the grasshopper family Acrididae, It is a widely distributed pest which poses a recurrent threat to agriculture throughout Africa north of the Equator, the Middle East and South West Asia. Rainfall is critical for reproduction it’s the most devastating pests of agriculture worldwide. The Desert Locust plague of (1986-1989) and the upsurge in (1992 – 1995) have caused considerable and widespread concern Sudan had been affected with a severe drought during 2007-2011 this limited pest appearance. But in 2012 heavy rain hit several Sudan states and desert locust start breeding. Some desert locust breeding site buckets are noticed in Khartoum state. According to experts entomologists to avoid extensive and costly desert locust control operations, it is necessary to detect populations at the outbreak or early upsurge stages before they can expand into full-scale plagues. To achieve this at an early stage, potential breeding areas must be surveyed to assess the condition of the habitat and the state of any Desert Locust populations. Locust breeding areas are distributed in most of Sudan states. To survey these areas considerable preparation and travel...
time, costly transport, as well as significant financial and staff resources needed. The use of Remote Sensing and Geographical Information System technologies (satellite images combined with ground data information) could help and provide an early warning system beside useful maps. Using these technologies and maps, the survey teams could be directed towards regions with a high potential for Desert Locust infestation and to estimate control measures required (Cecato, et al, 2004). Our hypothesis is that vegetation at areas infested by desert locust is different from that at non-infested areas. To test this hypothesis, a method will be developed to compare these areas and the extracted Information will be coupled with the ground data to produce maps. The objectives of this research are to assess and monitor desert locust damage based on monthly image enhanced vegetation index version 5 (evi5) algorithm, analyze risk areas posed by desert locust swarms in Sudan, understand current situation (where, when and how the desert locust population grow, move, and decline) and informing recommendation for future interventions in summer and winter breeding areas in the Sudan. Classification of the vegetation cover state using MODIS image satellite enhanced vegetation index version 5 (EVIS). Vegetation monitoring for growth and losses during rainy season in the desert locust summer breeding area and identification of the hazard associated with desert locust activity related to land use.

1.1 Economical Importance

Desert locust plague caused by heavy and wide spread rainfall. Desert locust plagues threaten the food security of up to 1 billion people in over 60 nations (Cressman, 1997, Lecoq, 2003). More than 60 countries are affected at varying degrees during desert locust plague in Asia and Africa, this is equivalent to about 20% of the land mass of the Earth (Cressman, 2008). African Desert Locust outbreaks meet an accepted environmental hazard definition (Smith, 2004). In 1958 Ethiopia lost 167000 tons of grain due to locust infestation, the amount lost was enough to feed one million persons for one year. In 1954 Sudan lost 55000 tons of grain because of locust infestation (Nur, 2007). In 1989 Tokar Delta was attacked by locust and caused 55% damage in Dura grain (Nur, 2007). Large plagues have historically survived a decade. In 1998, African Desert Locust reached the Caribbean but failed to breed (Lorenz, 2009). Plaque Swarms strip vast areas of all vegetation within hours, destroying security of whole communities. In solitary phase at recession areas (West Africa to Northern India) no economic threat reported. Potential damage to vegetations will occur if a high density populations gregarious swarms settled under favorable bioclimatic conditions in upsurges and plagues areas as shown in Figure (1) (Anymba et al, 2005). damage to standing crops could be occurred even several hundred kilometers away from desert locust origin (invasion areas) (Dutta et al., 2004).

Figure (1): African Desert Locust recession and invasion areas. Source: (Anymba et al,2005)

Single swarms of 80 billion locusts can cover 1,000 km2 (Showler, 2002). Swarms eat daily thousands of tons of vegetation (Vander et al., 2005). Gregarious locust swarms can grow 10-fold per generation, therefore, hundreds or thousands of swarms can merge into plagues that capable of invading a fifth of the planet’s land surface (Showler, 2002 and Lorenz, 2009). Upsurges and plagues are characterized by the presence of large numbers of hopper band and swarms in both the recession and invasion areas (Symmons and Cressman 1994). The species are capable of long distance downwind migration within and between countries.

1.2 Biology, Ecology and control

The life cycle of the Desert Locust passes through three stages: egg, nymph (hopper) and adult. Eggs are laid by females (Symmons and Cressman, 1994). Adults that can fly are initially sexually immature, but eventually become sexually mature and can copulate and lay eggs (Symmons and Cressman 1994). Following copulation the female Desert Locust will select a site to lay her eggs (Symmons and Cressman 1994). Soil moisture is critical for egg development rate of development is dependent on temperature. 24-30 days at high (summer) temperatures this can be extended to 45-55 under lower (winter) temperature regimes. Individual locusts concentrated by large scale meteorological features such as wind
convergence, rainfall and green vegetation (Figure 2).

Figure 2. A: Damaged vegetation by Desert locust Gregerization Source: Chember (2011).

Desert Locust plagues have been known to last between four and 22 years, while recession periods have been recorded extending from one to ten years (Cheke and Tratalos, 2007). Diminishing vegetation drives solitary locusts into “bands” Figure (2), (Desplan et al., 2003). Above a population density threshold they undergo “phase shift”. They start the “gregarious” phase transformation (Anstey et al., 2009). The control strategy aims to reduce populations to prevent plagues and damage to crops and pastures. Negative effects on resident predatory species that are known to consume huge amounts of locusts during the outbreaks control is reported (Culmsee, 2002). Control efforts in Mauritania during 2004 were primarily carried out with organophosphate chemicals (mainly chlorpyrifos and malathion) applied in small concentrated doses (referred to as ultra low volume, ULV, formulation). These compounds are potentially harmful for humans (Reichhardt, 1998) and toxic effects have been demonstrated on aquatic organisms, honeybees and other insects of economic value (Mullié and Keith 1993; Krall 1995). No regularity was found in the intervals between the onsets of successive plagues, which fluctuated irregularly in all regions (Waloff, 1976).

1-3 RS and GIS technologies

Geographic Information System (GIS) uses satellite data, field data and historical records to monitor sites of actual or potential high-density Desert Locust activity. Desert locusts Geographic Information Systems (GIS) use data set to monitor sites of actual or potential high-density (DL) activity to maintaining a recession by minimizing swarms and preventing plagues through selective pesticide spraying (Lecoq, 2003). The International Research Institute for Climate and Society (IRI) has summarized the challenges (IRI, 2010, a, b). Locust hotspot prediction minimizes unnecessary field study and spraying; reduces environmental and financial costs; and optimizes strategic deployment of equipment and humanitarian aid. The (IRI) displays the most recent decadal rainfall, vegetation map. FAO identifies areas of concern. From IRI and monthly locust reports from each (NLCC), e.g. (PPD Sudan). National Weather Center, 2010 Satellite images from IRI are used in this study to detected where and when rainfall to correspond the ground data with the Satellite vegetation images.

1-4 Monitoring of vegetation

Field researchers of survey team target accessible rain-induced new vegetation where (DL) hotspots normally found. Sometimes remote from rainfall sites, these are identified from MODIS enhancement difference vegetation index (EVI) images. The 250 m spatial resolution provides distinct advantages over the 1 km resolution of SPOT-VGT datasets (DLCC, 2006). Detailed spectral signature analysis at sufficient spatial resolution can reveal disease states in identifiable plant species (Hatfield, et al., 2008), but no methods specifically identify (DL) crop damage (FAO 2004). Accuracy of vegetation detection is dependent on spatial resolution. Since pixel size ranges from approximately 30 meter (Landsat generations) to more than 250 meter (MODIS), this will affects degree of detectability and identification. On the other hand temporal resolution has also a predominant effect on monitoring of vegetation, health, growth and development dependent (16 days for MODIS). However, Seasonal and annual vegetation characteristics are also considered an important factor that governs the level of accuracy attained in vegetation detection (Yuchen, et al., 2006). New product of MODIS enhanced vegetation index (EVI5) released by IRI in 2012 for free accesses. EVI is a modified NDVI with a soil adjustment factor (Huete and Justice, 1999). EVI correlate well with rainfall and could be used for detecting locust breeding areas (Abaker, 2011).

1-5 Change Detection

Change detection is used by (Jensen, 1996) in early studies. Recently several methods are used in agriculture for predicting crop yields and for global monitoring of food and fiber production, Forestry applications such as inventory updating, fire and damage detection. Vegetation can be stressed or unhealthy because of a change
(toxic elements, disease and insect damage). Fit model of the spectral reflectance of vegetation changes according to the structure and health of plants could be studied as in figure (2.B) (Philpot, 2011). Elsafi (2011) study and classify the damaged caused by tree locust in hashab gum Arabic Belt in Sudan. Five major classes were reported; none defoliated hashab trees, light, moderate and high defoliated hashab trees and swarm of tree locust.

**Figure 2.B:** change of spectral reflectance of vegetation Source: (Philpot, 2011).

1-6 FAO Monitoring System of (DL)
FAO notifies National Locust Control Centre (NLCCs) of concerns through monthly bulletins, direct communications and customized datasets for national GIS use. NLCCs, send their FAO-trained field workers to investigate figure (3.A,B). The self-explanatory data requirements have remained constant for years but are now recorded and transmitted electronically in many countries for rapid GIS integration (E-locust series). This accelerates response times to problems. eg: According to FAO reports the situation in Sudan is that; No surveys were carried out and no locust were reported in May 2012. But the forecasting is that; low numbers of adults are likely to appear in parts of the summer breeding areas in the interior and breed on small scale in areas of recent rain fall and those areas that receive rain during forecast period. Consequently, locust numbers will increase slight but remain below threatening levels (FAO, 2012, A). In Aug 2012, FAO received a report indicated that no surveys were carried out in June. However, there was a report from North Darfur of an immature group of adults North West of Mellit (1047N/2543E) on the 24th. During July, mature solitarious adults were present in North Kordofan between Um Badir (1413N/2758E) and Nile river, in southern Baiyuda Desert, and in north near Dongla (1910N/3027E).

**Figure 3.A:** Desert Locust breeding sites January 2012 Source: (FAO, 2012).

Egg laying was in progress in the east between kassala (1527N/3623E) and Derudeb (1731N/3607E). Groups of immature adults were reportedly present in West and north Darfur (FAO, 2012, B). Immediate FAO uses SWARMS. It is a Powerful and regularly upgraded GIS for operational, monitoring and early warning (Cressman, 1999, Cressman and Hodson, 2009).

**Figure 3.B:** Desert Locust breeding sites September 2012 Source: (FAO 2012).

2-Material
2.1. Study Area
The study areas are desert locust breeding sites in Sudan. These sites are found in Kordofan, White Nile, River Nile, Red Sea area and Northern State (El Toum, 2013). The sub set area of Khartoum State was included for interpretation and further investigation as confirmatory set of research finding and detect temporal changes.

2.2. Data collection
Data regarding vegetation status and levels of infestation were collected using satellite images correlated with ancillary ground surveys conducted by Plant Protection Directory (PPD). For the ground surveys (FAO) standard method were flowed survey area per kilometer and density per square meter were recorded. Threshold level was counted for insecticide spraying. In addition presence and absent of the
desert locust in the surveyed area were registered as desert locust presented and not presented (absent). Detailed database was maintained at PPD.

2.3. Satellite data
MODIS images were freely downloaded from (IRI). MODIS images during the rainy season in the summer breeding areas in 2010, 2011 and 2012. The MODIS Enhanced Vegetation Index (EVI) images version 5 were used in this study. 

2.4 Ancillary Ground survey data
Datasets from the Locust Division, Plant Protection Directorate Khartoum North - Sudan, were used. The dataset was collected in the same time of MODIS images. It is in form of excel spreadsheets. The data indicates geographical location (longitude, latitude) and entomological data for the same period span (2007 – 2012). The local data accuracy was checked against the situation data of the FAO monthly reports available at the desert locust information website www.FAO.org/ag/locusts .

2.5 Hardware and Software
A Laptop Computer provided with Software, ERDAS 8.5, ARC GIS10, and OFFICE 2010 were used to collect, integrates and analyze information extracted from satellite images and (PPD) ground survey.

3- Method
3.1 Correlation between satellite and ground data
The ancillary ground points, from the PPD data file, were overlaid over Sudan MODIS satellite images using ArcGIS 10, spatial analyst. Suitable projection GCS_WGS_1984, Datum: D_WGS_1984 were used. Zonal attribute was performed to extract pixels value from raster images (MODIS) satellite image with use of vector shapefile of the ground data survey. The exported output was used in tabulating area. This final step creates the mean of pixels value for each points. Student t-test was performed using MINITAB 16 to compare means of infested, non-infested and interactions areas in years 2010, 2011 and 2012. To confirm the finding one way ANOVA test was performed for the whole dataset. For intermediate levels above non-infested and under healthy, an arbitrary threshold was identified after analysis to indicate moderately healthy and heavily infested areas using percentage means plot.

3.2 Validation of the model
To validate the model, subsets of Khartoum from the MODIS satellite images were selected for temporal change analysis. The obtained values of damaged and non-damaged pixels from previous analysis were used to identify the status damage in the selected sites.

3.3 Change Detection
Post classification change detection approach was adopted to identify the changes in vegetation status as result of desert locust infestation in a subset of Khartoum State. Firstly an image was rectified and classified based on pixel by pixel approach (Jensen, 1996). Each group was counted and separated as class. Multi-date visual composite image change detection technique was applied to calculate change between classes in images of different date for the same location. Accordingly growth and losses estimated as negative and positive change.

4-Results and Discussion
In this study to detect damaged vegetation by locust, remote sensing and geographical information system techniques were used. Data were integrated to extract information.

4.1 Desert locust infestation and ground surveying data map during 2012
Figure (4) showed vegetation status during summer season of the desert locust breeding in 2012. The vegetation could be classified into main four groups healthy, moderately infested, and heavily infested and others plant vegetation

![Figure(4): Sudan Desert locust vegetation damage and ground surveying (data 2012)]
The mean pixel’s values in Table (1) were used as guide for representing the infested damage vegetation. Statistic Analysis shows that there is significant difference (p < 0.02) between infested and non-infested areas. Mean pixel digital numbers of 68.6, 66.8 and 73.8 for infested areas in years 2010, 2011 and 2012, respectively. For non-infested areas, mean pixel digital numbers of 65.8, 65.0 and 77.6 were recorded for years 2010, 2011 and 2012, respectively.

Table.1: Mean pixel’s digital numbers of infestation levels

<table>
<thead>
<tr>
<th>Infestation Level</th>
<th>Year 2010</th>
<th>Year 2011</th>
<th>Year 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>65.7 ± 11</td>
<td>65.00 ± 10</td>
<td>77.60 ± 17</td>
</tr>
<tr>
<td>1</td>
<td>68.6 ± 9</td>
<td>66.83 ± 8</td>
<td>73.77 ± 15</td>
</tr>
</tbody>
</table>

*Significant difference  * highly significant difference ± STD

For moderately where there is a damaged vegetation and no infestation of the desert locust registered in the ground surveying (infestation = 0) this could be for two reasons; either the infestation is less than the ground survey desert locust threshold level (desert locust density) or not registered by the surveying teams for other reasons. The pixels value of intermediate areas (moderate infested damaged vegetation areas) are extract from percentage plot of means Figure (5). For infested areas mean of 69.27±4.869 used as guide for classification of areas into moderate and heavily infested. The range of infestation is (62.5 – 77.5), with accuracy of 95%. For healthy vegetation Mean pixels value 65 could be used when pixel value are ≤ 69. The pixels values were applied directly in MODIS satellite images 2012. The finding in year 2012 is that; there is a positive correlation between EVI and pixel value of healthy vegetation (77.60 ± 17) and damaged vegetation (73.77 ± 15). When the pixel value ≥ 70, Pixel value of healthy vegetation was higher than the pixel value of damaged vegetation. This finding is similar to the study taken by Elssafi (2011) to classify Hashab belt (gum Arabic trees) affected by tree locust using spot images and land-sat ETM+ as very high resolution images. The finding of year 2010 and 2011 showed that pixel value of healthy vegetation was 65.006 ± 10 and 65.79 ± 11, respectively. While the pixel value of damaged ones were 66.839 ± 8 in year 2010 and 68.60 ± 9 in year 2011. This finding is contradicted with Elsafi (2011) and agreed with Yuchen, et al., (2006). Yuchen, et al. (2006) were attributed this extraordinary finding factors related with change in vegetation status (health and development), temporal resolutions of the Satellite Sensors (16 days for composite EVI MODIS vs 10 days for Landsat), spatial resolution, and seasonal and annual vegetation characteristics.

4.2 Result validation in Khartoum State

4.2.1 Classification of Vegetation status

Subset area in Khartoum State showed that plant vegetation can be classified into five main classes which are; healthy unsuitable plants for desert locust breeding, healthy suitable plants for desert locust breeding, highly infested vegetation, moderately infested vegetation and other vegetation Figure (6).

Others plant vegetation communities are those plants vegetation detected by MODIS satellite images and not classified by this research methods such as forest areas in Southern Sudan and different agricultural schemes in different states of Sudan.
4.2.2 Vegetation Damage Assessment and Extent

Three main classes were selected for detailed studies for the damaged assessment. These were healthy vegetations, moderate damaged (desert locust-infested vegetation) and heavily damaged (desert locust-infested vegetation) as shown in Figure (7) which represent vegetation status during three months of desert locust activities. Decrease in healthy and moderately infested areas are very clear on the other hand there is a linear increase in heavily damaged areas in the four images during the three months.

Accordingly areas were estimated for each class and the percentages were reported in Table (2). The result revealed that 81.25 hectares were healthy but heavily damaged by desert locust covers 87.5 hectares which constituted 16.68% of the total area in late July to early August, 350 hectares were moderately damaged 67.47% and 62.5 hectares were heavily damaged during early and late August, healthy vegetation were stable 56.25 hectares until mid September but heavily damaged area decreased to 75 hectares and moderately damaged area increased to 937.5 hectares in late August and decreased to 481.25 hectares in early September. Finally in late September to early October (end of the season) only 25 hectares were healthy (21.05%). There was a decrease in healthy vegetation. These findings agreed with Elsafi (2011). They stated that tree locust damaged could be detected and estimated using Spot and Landsat satellite images. Although these images are expensive and not suitable to cover large area; so in case of the desert locust infestation monitoring wide coverage is a prerequisite. However, high resolution image with low coverage is needed to increase data reliability. For example in the beginning of the rainy season, the damaged areas are small to be detected by the MODIS satellite. Also at the end of the season, when vegetation is completely dry, it is difficult to detect infested areas with such moderate resolution MODIS image. It is worth to mention that, decrease in moderately infested vegetation areas (31.25), (26.32%) at the end of rainy season could be caused by the fact that MODIS satellite could not detect dry vegetation at the end of the season. This agreed with Ceccato (2004), who stated that some sophisticated satellites and forthcoming civilian satellites could potentially detect locust swarms but these images are not yet operationally available.

Table 2: Extent of healthy and damaged vegetation

<table>
<thead>
<tr>
<th>Vegetation Status</th>
<th>Healthy</th>
<th>Damaged</th>
<th>Total Area (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heavily</td>
<td>Moderately</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ha</td>
<td>%</td>
<td>Ha</td>
</tr>
<tr>
<td>A: 28/07 – 12/08/2012</td>
<td>81.25</td>
<td>15</td>
<td>87.5</td>
</tr>
<tr>
<td>B: 12/08 – 27/08/2012</td>
<td>56.25</td>
<td>5.3</td>
<td>62.5</td>
</tr>
<tr>
<td>C: 28/08 – 12/09/2012</td>
<td>56.25</td>
<td>9.1</td>
<td>75.0</td>
</tr>
<tr>
<td>D: 28/09 – 4/10/2012</td>
<td>25.0</td>
<td>21.05</td>
<td>52.0</td>
</tr>
</tbody>
</table>

4.2.3 Change Detection of Vegetation Status

The study revealed temporal change in Khartoum subset area. Healthy vegetation was decrease. This might be caused by the desert locust infestation Figure (8). Noticeable vegetation change was detected in the North West part of subset area border to north kordofan state during early August image (B). The damage could be attributed to the desert locust activities. Although there was growth recovery in the same area by the end of
August the damaged vegetation area was expanded (C). This might be due to rain fall and insecticide treatment beside desert locust behaviour.

Table 3: Change detection of vegetation status (Khartom State)

<table>
<thead>
<tr>
<th>Vegetation status</th>
<th>Healthy (Ha)</th>
<th>Heavily Infested (Ha)</th>
<th>Moderately Infested (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image dates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A: 28/07/2012 - 12/08/2012</td>
<td>-25</td>
<td>-25</td>
<td>+21.31</td>
</tr>
<tr>
<td>B: 12/08/2012 - 27/08/2012</td>
<td>0</td>
<td>+12.5</td>
<td>-10.21</td>
</tr>
<tr>
<td>C: 28/08/2012 - 12/09/212</td>
<td>-31.25</td>
<td>-12.5</td>
<td>-450</td>
</tr>
<tr>
<td>D: 28/09/2012 – 14/10/2012</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2.4 Vegetation Monitoring for Growth and Losses

More investigation and ground truth is needed to explain the great amount of vegetation losses 520.15 hectares (Table 4). The vegetation type e.g. is it crops? What are the other factors that cause these losses? In contrast of this, if the area is a rangeland, why other plants communities give the sign of the desert locust damage? To answer these questions, high resolution satellite images and intensive study are needed or ground truth data. According to Anstey, et al. (2009) desert locust population density start phase shift (gregarious) transformation above the threshold level. The same case was found similar in this research. Also Obaid (2008) stated that, specific quality of food (plant vegetations), age and density were needed by the desert locust hoppers and nymphs to complete live cycle and to protect themselves from natural enemies. This gives the answer for why the distribution of the desert locust breeding areas related to specific land use.
Table 4: Vegetation monitoring for Losses and growth

<table>
<thead>
<tr>
<th>Image dates</th>
<th>Lose (Ha)</th>
<th>Recover (Ha)</th>
<th>Growth (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: 28/07/-12/08/2012</td>
<td>50.00</td>
<td>21.31</td>
<td>0.00</td>
</tr>
<tr>
<td>B: 12/08/-27/08/2012</td>
<td>10.21</td>
<td>12.5</td>
<td>2.29</td>
</tr>
<tr>
<td>C: 28/08/-12/09/2012</td>
<td>493.75</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sub Total</td>
<td>553.96</td>
<td>33.81</td>
<td>2.29</td>
</tr>
</tbody>
</table>

Total vegetation losses/h = 520.15

5- Conclusion and Recommendations

This study confirms the FAO monthly reports in 2012 and concludes the following:
1. Desert locust damaged vegetation could be detected and monitor using MODIS images integrated with ground survey data. The damaged vegetation area could be also computed.
2. Sudan is one of the desert locust risk areas. This is due to wide breeding areas in addition to two rainy seasons at different sites (summer one in most of the Sudan and winter in the Red Sea coast). The trend of rains in a mount and distribution will possibly lead to severe problem of desert locust. Consequently agricultural, famine and food security problems will threaten the country.
3. A Climate change such as sudden increase of rainfall intensity and distribution could be possible, this will trigger the desert locust population to multiply and migrate causing a severe damage to a agricultural sectors as that happened in august 2012 where the infested was jumped suddenly from thirty hectares to 1285 hectares.
4. Expected aerial application of insecticide will probably cause environmental hazard as result of huge application of insecticide.

For these reasons the study recommends the following:
1. Appropriate and real time plan to monitor desert locust to solve any coming problems.
2. Strengthen of cooperation with International Organization worked in the field of desert locust control.
3. Improvement of a national early warning center in the ministry of agriculture for appropriate monitoring and management of crops, plants, vegetations production and protection.

6- References


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