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Determining the Magnitude of High Spot Lands by using Remote Sensing in Irrigated Schemes Case Study: Al Rahad Agricultural Scheme-Sudan

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Abstract: ***High spot lands are one of the most serious problems facing the irrigated agricultural production sector of the Sudan. As well, water and wind erosion, and silt deposits are the major environmental hazards causing land degradation in most parts of the irrigated sector. An understanding of the extent and magnitude of these hazards on various field surfaces is essential for the selection of appropriate control measures. The objective of this study was to identify and investigate the magnitude of high spot lands. Data from satellite images for four different years (1987-2013) were used to measure and quantify the high spot areas at four selected sites under the study areas.Also, personal communication with farmers in the study area was carried out.The satellite images showed variations of land cover in the study areas during years 1987-2013.The high spot lands covered 1.4 % of the total area till 1987 and increased to 3.3 %, 4.2% and 6.3 % in 2000, 2005 and 2013, respectively. Data from satellite images for the year 1987 and 2013 showed that the density of uneven spots in 2013 was higher than that in 1987.The analysis showed that some changes in orientation of Abu XX at some sites were initially made to accommodate some of the natural elevation differences. The general trend of uneven area was randomly distributed. The results of the analysis of different remote sensing data using GIS proved the presence of high spots and elevation differences within the scheme.It seems that the continuous plowing pattern by the ridger in most cases without considering elevation and slope differences have largely contributed in the creating more high spot lands by the transportation of the soil by the plowing implements. The laboratory soil analysis showed similar soil characteristics of samples collected from high spot lands compared with the nearby original soils of even areas. It can be concluded that high spot lands increased at an annual rate of 0.2% and accordingly, it threatens agricultural production in the study area by the loss of potential yield of the left-out high spot areas. Detailed soil and land survey investigations based on remote sensing and GIS techniques are highly recommended to identify all high spot areas in the irrigated sector in terms of location, size and soil characteristics.***

Keywords: High spot lands, Remote sensing and GIS techniques**,** Potential yield

1. Introduction

The main causes of deterioration of the soil surface elevation are the farming operations and silt deposition, especially with ponding irrigation. Land forming is the process of reshaping the soil surface for purpose of better control of irrigation water (land leveling), better surface drainage (land grading) and erosion control (land shaping)(Nazar, 1994).Uneven soil surface has a major impact on the germination, stand, and yield of crops due to inhomogeneous water distribution and soil moisture.(https://shivkumardas.wordpress.com). In Sudanese irrigated projects, the raise of the field levels especially at the area adjacent to irrigation canals and to a distance of 30 m by 30 m relative to the center of the field are due to; accumulation of silt, long term cultivation in one direction, and long term swelling of subsoil with the slow but steady increase in the subsoil moisture to depth and width around canals. The high elevation at the headland and the tail of the field usually result in poor crop compared to the centre, as it cannot be fully irrigated without flooding the centreof the field to unacceptable depth (Mohamed, 1982). The increase in high spot levels affected the design and operation of the whole irrigation system (water head and capacity to command the irrigated area). Under conditions of irregular field surfaces the tenant are currently choosing one of two options, either to stop irrigation when the bulk of the field (85%) is watered, leaving high spot dry, especially with use of open-plan method; or continue irrigation in order to cover the high spot, ignoring the overwatering in the remainder parts. However, the general tendency is to adopt the first option.

In the Sudan, the use of remote sensing technology is a cost effective way for surveying natural resource in large areas. Starting from 1971 remote sensing has been used in natural resources surveying, mapping, planning and development (Dafalla, 2007). There are four types of resolution when discussing satellite imagery in remote sensing: spatial, spectral, temporal, and radiometric (Campbell 2002).The resolution of satellite images varies depending on the instrument used and the altitude of the satellite's orbit. For example, the Landsat archive offers repeated imagery at 30 meters resolution for the planet, but most of it has not been processed from the raw data. Landsat 7 has an average return period of 16 days. For many smaller areas, images with resolution as high as 41 cm could be available (Grayaudio, 2010). Aerial photography is sometimes supplementing the satellite imagery, which has higher resolution, but is more expensive per square meter. Satellite imagery can be combined with vector or raster data in a GIS if the imagery has been spatially rectified so that it will properly align with other data sets.This study aims to identify and investigate the distribution and magnitude of high spot lands at Al Rahad irrigated project, Sudan using remote sensing and GIS techniques.

2. Materials and Methods

Materials

The Study Area

The study area is located within Group 8as part of the nine groups making Al Rahad Scheme. The dominance of high spot lands at Group 8 has encouraged the selected of this group for this research study. The Al Rahad Agricultural Scheme (RAS) is located about 276 km South Khartoum, on the eastern bank of the River Rahad (a tributary of the Blue Nile). It is subtended by latitudes 13° 08 N and 14° 05 N and longitudes 33° 06 E and 34° 01 E. The climate is semi-arid; the rainy season is from early June to early October with an annual rainfall ranges from 300 mm in the north to more than 500 mm in the south. The mean temperature ranges from 30°C to 40°C in summer and from 10°C to 25°C in winter.The soil was classified as Vertisol with high clay content (50–60 %). The soil is characterized by its low organic matter (0.03%), and moderate alkalinity with pH ranges from 8.8 to 9.4.

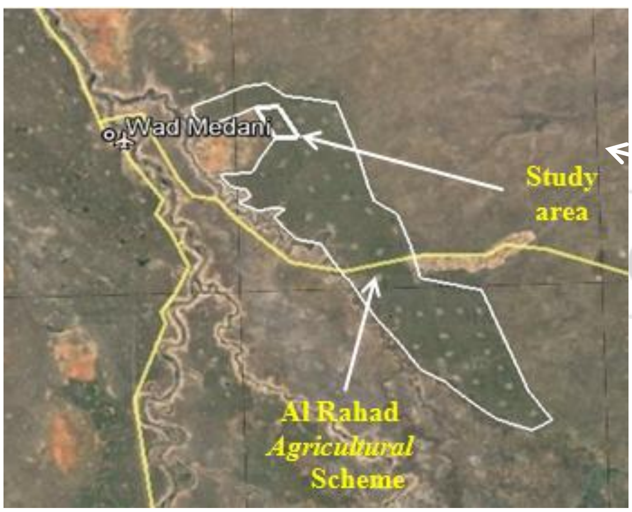


Figure 1: The study Area at Northwestern Parts of Al Rahad scheme, Sudan

Satellite Imagery

Four sub images from Landsat covering the selected sites 2989.8 ha (7115.72 fed) were used in this study. They are composed of three bands (1, 2, 3) for four time intervals, 1987 (Thematic Mapper) and 2000, 2005 and 2013 (Enhanced Thematic Mapper plus). The characteristics of these images were listed in Table 1.

Table 1: Characteristics of imageries used in the study

Image	Path/ Row	Sensor	Band	Resolution	Scale	Area (km^2)	year
1	172/50	TM	1-3	30m	1:1000000	109×109	1987
2	172/50	ETM+	1-3	30m	1:1000000	109×109	2000
3	172/50	ETM+	1-3	30m	1:1000000	109×109	2005
4	172/50	ETM+	1-3	30m	1:1000000	109×109	2013

Source: Satellite images 1987, 2000, 2005 and 2013.

Methods

Geometric Correction of Landsat Data

The Landsat data covering the same area from the different dates were geometrically corrected to cut out areas of interest and get the same size and exactly the same area. Every pixel in the Landsat TM data from 1987 was converted to the projection of the Landsat ETM data from (2000, 2005 and 2013). The reason that the TMs were corrected to the ETMs is for finding the field data collected during the field survey corresponding better to the ETMs that were taken more recently. Finally subsets of areas that surround the study areas were cut out.

False Colour Composite (FCC):

Images are usually composed of colour bands; the bands may be 1 to 3, 1 to 5 or 1 to 7. For the images of this study, Bands 2, 3 and 4, which represent the green, red and infrared respectively, were used to develop False Colour Composite (FCC) image. The colours assigned to each of the bands are in the same order blue, green and red. This combination of colours gives various shades or tones of red for the healthy chlorophyll-rich vegetation in an FCC image.

Image Classification:

An unsupervised classification is performed using the ERDAS 8.5 Imaging. An unsupervised digital image classification was used to fine the relationship between pixel values and land cover types; and classify the all features in the satellite imagery.

The spatial data management are :

a) **Importation of digital data:**
   Importation of digital data was done to import raster images (Landsat TM 1987, Landsat ETM from dates 2000, 2005 and 2013).
b) **Map projection:**
   Data on the study area in form of map exist with different coordinates, is a function performed to transform map coordinates.

Image Enhancements:

Contrast enhancement(global enhancement) was also used for:

a) Transformation of raw data using the statistics computed over the whole data set,
b) Linear stretching and histogram equalization to enhance specific data ranges showing certain the cover of land, and

c) Special enhancement procedures that results in image pixel value modification, (based on the pixel values) in its immediate vicinity (local enhancement) to emphasize low frequency features and to suppress the high frequency component of an image using low paths filters.

Land Cover Change Assessment

Quantity assessment of land use change was performed through map calculation option. Map calculation was used to calculate the occurrence and extent of changes on land surface during the study period (1987 to 2013). Map calculation was used for change detection assessment to compare between the satellite images depending on area calculations and a planometer were used to correct the areas.

3. Results and Discussions

Land Cover and Land Use Changes

Land cover in the study area during the study period 1987–2013, showed several changes. These changes divided into two categories:

1) Vegetation (Agricultural lands)
2) High spot lands

The interpretation of the satellite images for 1987 showed ahigher percentage of vegetation density as compared to the years 2005 and 2013. This may be attributed to the increase of high spot lands of some agricultural lands specifically in 2013.The comparison between the sub satellite images (Fig. 3and4) showed a higher density of vegetation in the years 1987, 2000 and 2005 compared to that of the year 2013..Figure 3 shows the original image in year 1987. The unsupervised classification in Figure 4the shows the change in land cover mainly vegetation covers during the periods 1987-2000, 2000-2005 and 2005-2013 respectively.

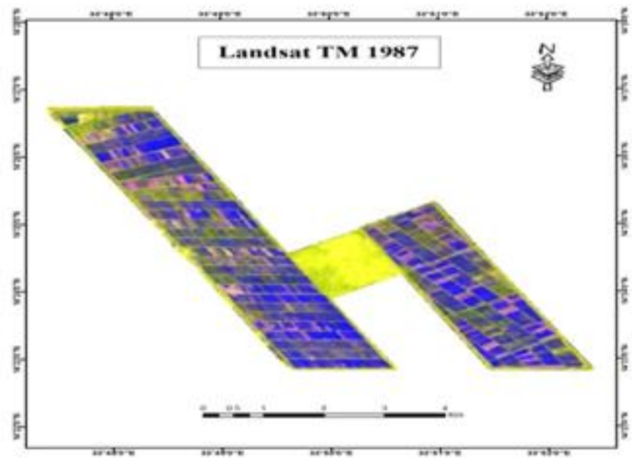
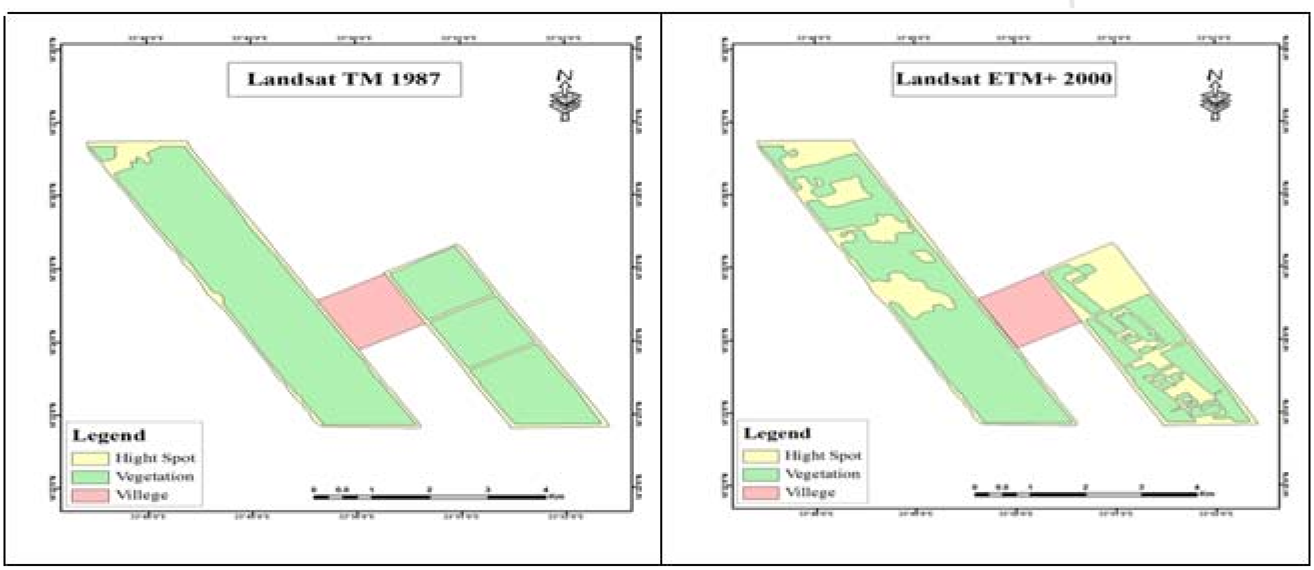


Figure 3: The Landsat TM original image in 1987



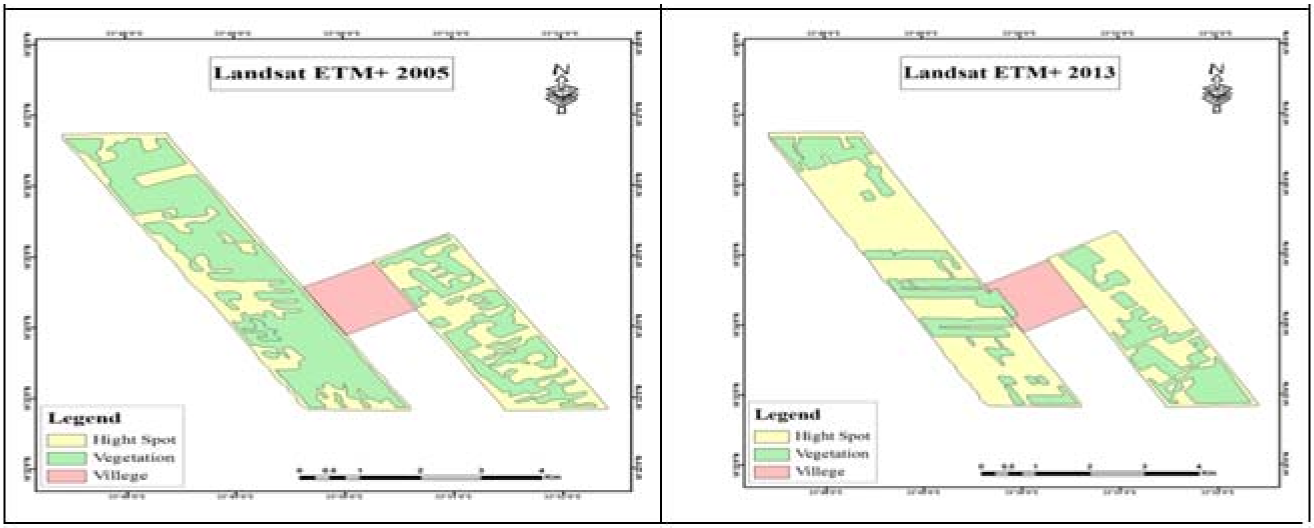


Figure 4: Land Cover of the study area in(1987-2013)

Table 2: Coverage of vegetation and High Spots in the study area during1987 – 2013in Hectares and Percentage

Years	1987	2000	2005	2013
Details	Area in ha			
Vegetation area	2030.2	1991.12	1972.59	1928.73
High spots area	28.83	67.95	86.48	130.34
Total Farming area	2059.2			
Percentage High spots	1.4%	3.3%	4.2%	6.33%

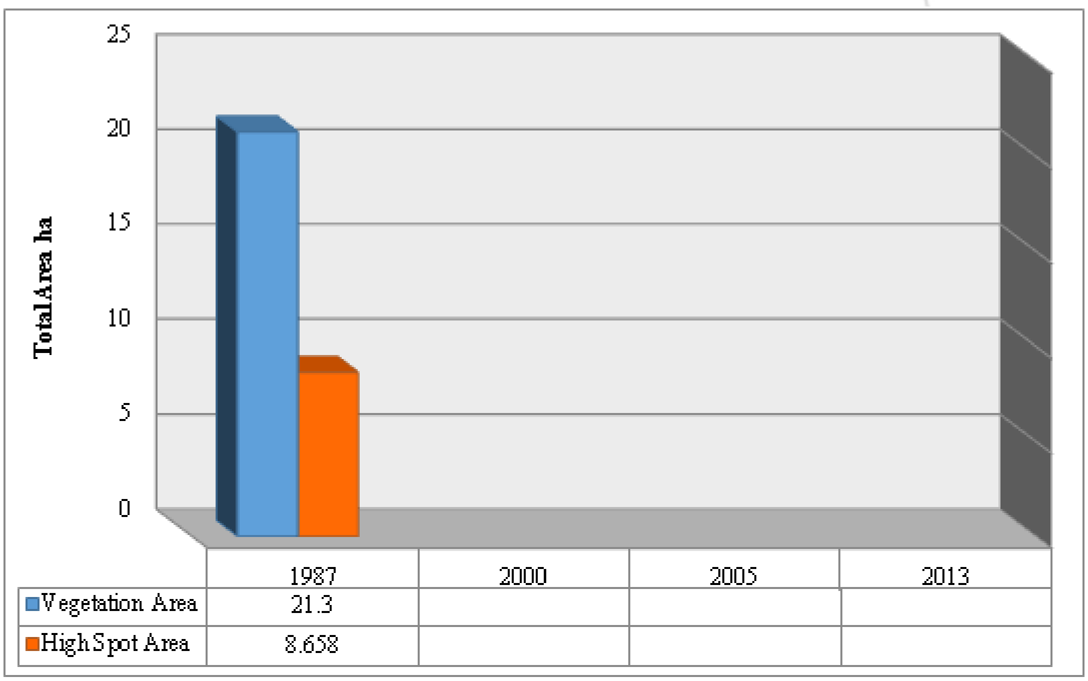


Figure 5: Vegetation and High Spots coverage in study area for the period 1987 - 2013

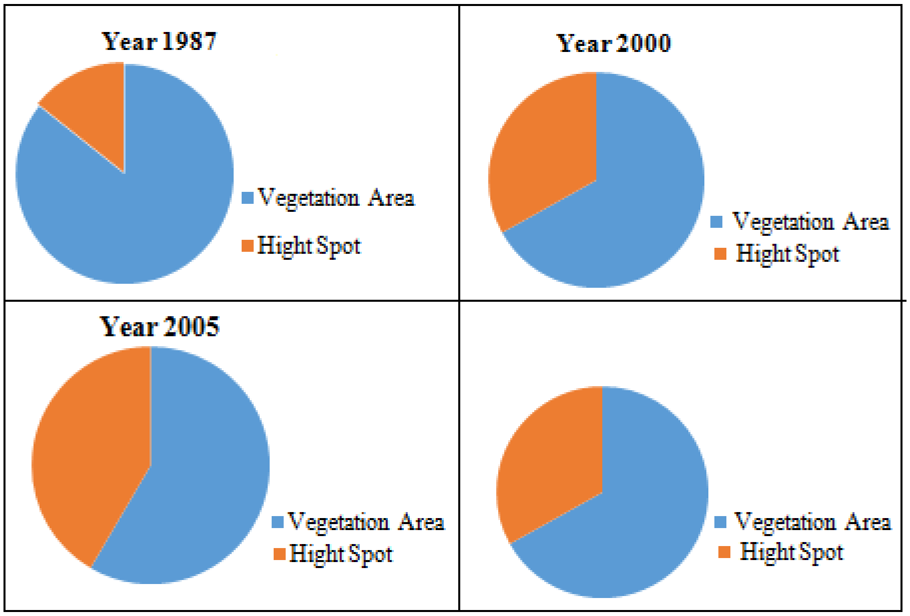


Figure 6: Land Cover in Study Area from 1987 to 2013

Table 2shows that from 1978 until 1987, the high spots covered 1.4 % of the total area, and that area covered by high spots increased to 3.3 % in 2000, to 4.2% in 2005 and to 6.33 % in 2013 respectively. The figures indicated that there is an inverse relation between vegetation and high spot land, the high spots increased with time while vegetation coverage declined. However, the rate by which vegetation declined, reported to about 1.9% from 1987 to 2000, 2.8% from 2000 to 2005 and 4.9% from 2005 to 2013, with a total of 9.6%, this was by large higher than the built up of high spot lands (Figure 5 and 6) .

Table 3 and Figure 7 show the results of the analysis of satellite images for high spots developed during four periods. The yearly average increasing rate of high spots for the periods 1978-1987, and 1987-2000 were almost steady, resulted in 0.16 and 0.15 percent respectively. The rate increased to 0.18% for the period 2000-2005 and also increased to 0.27% for the period 2005-2013, the increase during the last period showed about 0.68% more increase than the average of the first period.Figure 7 showed the average yearly development of high spots buildup during the period from the start of the scheme in 1978 until 2013.

Generally, the study sitesmakes an area of2030.2ha (4831.876 fed). Because of high spots development, this area was reduced annually to about 0.15 % in year 1987 until 2000 that is equivalent to 3.05 ha (7.25 fed). Since the total area of scheme 126,050ha (300,000 fed), then the high spots may represented 189.075 ha (450 fed) in years 1987 to 2000. During years 2000-2005 the study area was decreased annually by rate 0.18% which equivalent to 3.65 ha (8.70fed) of high spots. However, in total area of scheme the high spots may represent226.89ha (540.0 fed). During the period 2005-2013 the study area decreased annually by about 0.27% this represented 5.48154 ha (13.05 fed) of high spot. Nevertheless, in total area of scheme the high spots may represent 340.33 ha (810.00 fed).The preliminary investigations started by interpreting of high spots by Google Earth and using AutoCAD to calculation and drawing of total area of high spots and percentage in study area, the results indicated that high spots occupy about 6% of the study area, which are shown in figure (8).

Table 3: The Rate of High Spots Buildup through years 1987 to 2013 in StudyArea

Years and periods	*1978*	*1978-1987*	*1987-2000*	*2000-2005*	*2005-2013*
Elements					
Years elapsed	0	9	13	5	8
Periodical Build up %	0	1.4	1.9	0.9	2.13
Periodical average %	0	0.16	0.15	0.18	0.27
Cumulative ratio %	0	1.4	3.3	4.2	6.33

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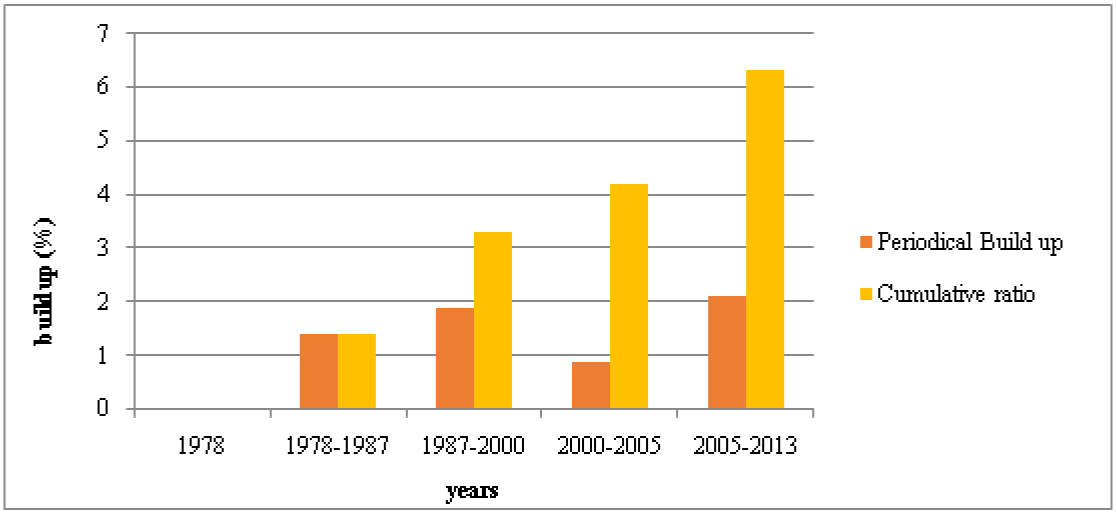

Figure 7: The Ratio of High Spots Buildup through Time (periods 1978 to 2013)

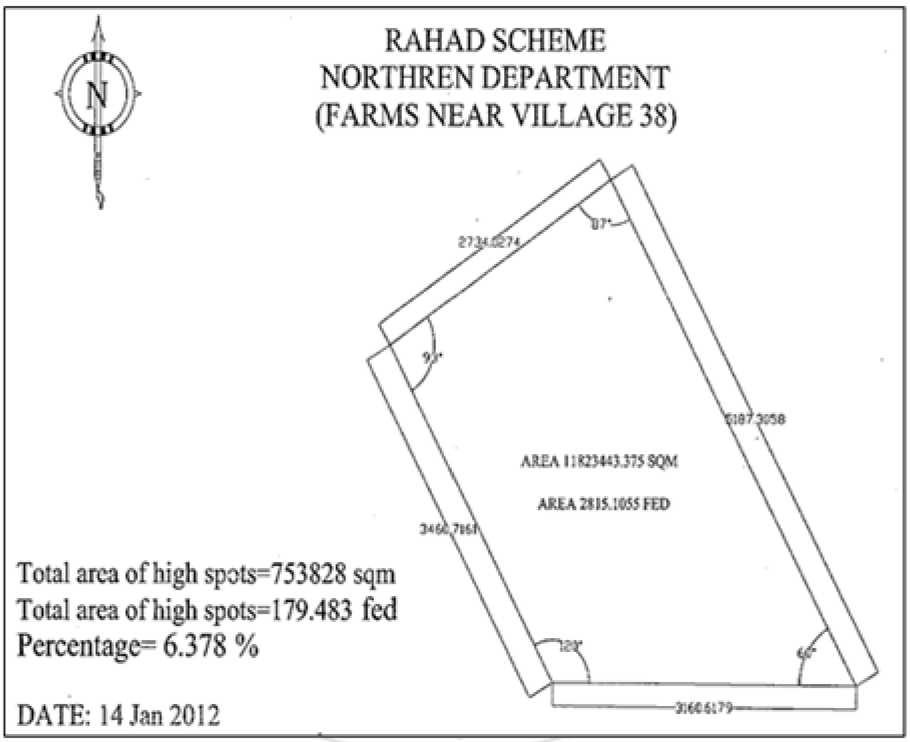

Figure 8: The Characteristics of the High Spot area by Using AutoCAD

Validation

The comparison between the secondary data of full Scheme in Al Rahad Agricultural Corporation and data of satellite image are shown in Table (4).

Table 4: Comparison of Secondary Data and Image Data

	Study Area		Full Scheme	
Area (Ha)	Secondary	Image	Secondary	Image
	data	Data	data	Data
Total Area (Ha)	1182.8	2030.2	130,721	126,050
High Spots Are (Ha)	75.4	125.96	9861.8	10140.8
High Spots %	6.378	6.33	7.54	8

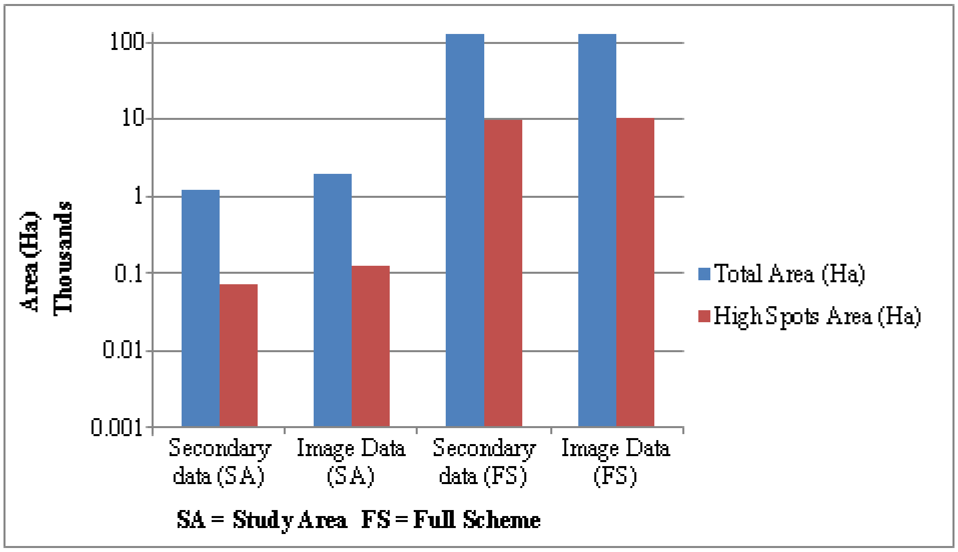

Figure 8: Comparison of Secondary data and Image data of Study Area and Full Scheme

The data of Image is same result of secondary data in evaluation of high spot lands that indicated the Image data is accurate results of evaluation of land losses. In addition, the remote sensing and GIS are effective tools for time and cost in land evaluation. The remote sensing and GIS are not only provides accurate results but also provides cost and time effective methods of analysis.

4. Conclusions

- The study proved the existence of high spots in the study area which was selected to represent the whole Al Agricultural Scheme. High spot areas do exist at heads and tails of fields and bordering Abu XX canals. They are mainly caused by tillage operations but some parts are due to poor levelling. The high spots are estimated to occupy about 7% of the farming land.
- The study explains the formation of high spots by suggesting that the traditional tillage practices often move the soil in one direction — outward from the center of the field. Over time, such soil movement creates an uneven soil surface resulting in a low spot in the center of the field and high spots at the head and tail of the field. The centre of the field often remains wetter and tillage operations are usually delayed by high incidence of weeds in these low areas.
- Remote sensing and GIS are time and cost–effective tools in characterization of land surface features and evaluation of land use land cover changes. The extensive spatial coverage, regular temporal coverage and reasonable cost of satellite imagery provide an opportunity to undertake routine natural resource monitoring. This can then contribute to efficient decision making in natural resource management. In order to monitor and map the land degradation over a large area and over a long time period, Landsat images should be used.
- GIS provides a great advantage to analyze multi-layers of geospatial and field quantitative data within a specific area like farm fields. The estimation of soil loss in farms and fields is a core capability of GIS. It does not only provide accurate results but also prove to be cost and time effective tool for analysis.
- The data available for this study was effectively employed for monitoring and mapping the prevailing land conditions in the study area. The hypothesis of this research that the ground observations and remote sensing data could be used to achieve reliable characterization of the high spot and land degradation proved to be correct.

5. Recommendations

- Research efforts are highly needed to combine the newly emerging technologies including the remote sensing data with ground observed data to monitor and evaluate the landscape condition in the area.
- Al Rahad Agricultural Scheme (RAS) administration should expand the use of the decision support tools like space technologies (GIS, RS and GPS) to plan for sustainable development and proper land management in the whole area of Al Rahad scheme.
- Detailed contour maps based on modern advanced technologies using RS and GIS are highly essential for all Irrigated Scheme in Sudan. Updated modern contour maps based on RS and GIS will enable revision and updating of the old irrigation designs. Periodical land leveling and adjusting of slopes in irrigatedfarming system is an essential task towards proper land management.

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