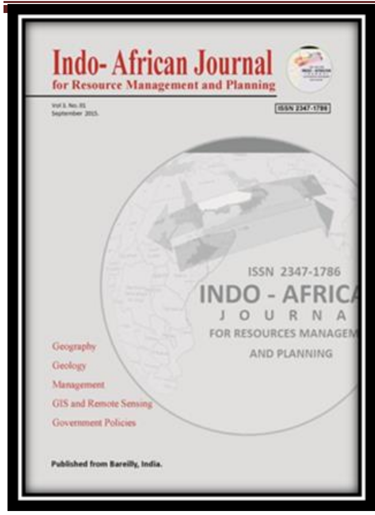

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Change Soil Moisture Content from 2015 to 2016 during Rainy season in the Nile Basin of Ethiopia.

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In this paper soil moisture within 0 to 10cm of depth was compared in between 2015 and 2016 during Kirmet season in the Nile Basin of Ethiopia. This time period was chosen to observe the impact of El-Nino event on soil moisture in the basin. Kirmet is the rainy season in Ethiopia; it starts in June 1 and end in September last. This season is very important for the most dominant crop Teff. The Dataset FLDAS Noah Land Surface Model L4 monthly 0.1 x 0.1 degree for Eastern Africa (GDAS and RFE2) V001 (FLDAS_NOAH01_A_EA_M) at GES DISC was used for this study. The same dataset was collected covering Nile basin for the Kirmet season (rainy) months June, July, August and September of the years 2015 and 2016. To find the change in the content of soil moisture the dataset 2016 was subtracted from 2015. The images representing the change were converted to point data. Finally to identify statistically significant spatial clusters of high values (hot spots) and low values (cold spots) Getis-Ord Gi statistic was applied with Hot Spot Analysis tool of ArcGIS. The result shows during June, July, August and September Nile basin received less moisture content in the El-Nino year (2015) than the year 2016 as13.0%, 15.1%, 13.3%, and 14.5% of its total area respectively with 99% of confidence level.*

Key words- Nile basin, Soil moisture, El-Nino

Introduction

In the Horn of Africa region, a drought exacerbated by El Niño has directly affected the region, leading to an increase in food insecurity and malnutrition. As of August 2016, close to 24 million people in the region are facing critical and emergency food insecurity levels, a doubling of numbers compared to August 2015. In Ethiopia alone, 9.7 million people require emergency food assistance to meet their basic food needs, and some 420,000 children suffer from severe acute malnutrition (SAM) and 2.36 million children from moderate acute malnutrition (MAM) (OCHA, 2016).

In late March, the United Nations Office for Coordination of Humanitarian Affairs (UNOCHA) in Ethiopia, together with its humanitarian partners, launched a 90-day campaign to raise money to finance urgently required food aid for Ethiopia. This campaign aimed to bridge the US$700 million gap between what is needed and what has so far been secured to aid the millions affected by a drought identified as the worst *El Niño* in recorded history (MFA, Ethiopia).

In Ethiopia the government estimates that 10.2 million people, on top of the 8 million that will receive support through the governments' safety net programme, will need humanitarian assistance this year at a cost of $1.4 billion, due to a drought that's been exacerbated by El Niño (OXFAM).

El Niño is a local warming of surface waters that takes place in the entire equatorial zone of the central and eastern Pacific Ocean of the Peruvian coast and which affects the atmospheric circulation worldwide (Kiladis and Diaz, 1989).

The current 2015-2016 El Niño cycle has been one of the strongest on record and has had significant impacts on agricultural production and food security across the globe (FAO, 2016)

Ethiopia is strongly dependent on agriculture, which supplies employment for 81% of the population and accounts for 40% of its gross domestic product (Äthiopien - Wirtschaft).

Overall, rainfall rates are highest during summer, with 65–95% of the All Ethiopian annual rainfall associated with Kiremt (Segele and Lamb 2005).

Soil moisture content is a measure of the amount of water in the soil. Knowing how much water is held in the soil is useful for many applications, including improving agricultural productivity, assessing drought and flood conditions, and even estimating groundwater supplies (NASA).

Though Nile basin does not face as problems as in the eastern part of Ethiopia due to El-Nino, but this region is supposed to be important from the view point of Agriculture. So It was chosen to study soil moisture difference in 2015 and 2016.

Site Description

In this paper, the Nile basin (from latitude 7.712500 dd to 12.758333 dd north and from longitude 34.488333 dd to 39.810833 dd east, shown as Figure 1), located in western part of Ethiopia, was selected as the study area.

Fig.1

Data

FLDAS Noah Land Surface Model L4 monthly 0.1 x 0.1 degree for Eastern Africa (GDAS and RFE2) V001 (FLDAS_NOAH01_A_EA_M) at GES DISC data was used for this study.

This data set contains a series of land surface parameters simulated from the Noah 3.3 model in the Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS). The data are in 0.10 degree resolution and range from January 2001 to the present.

The temporal resolution is monthly and spatial coverage is Eastern Africa (11.8S, 22.0E, 23.0N, 51.4E). The files are in NetCDF format.

Data analysis

To identify statistically significant spatial clusters of high values (hot spots) and low values (cold spots) Getis-Ord Gi* statistic was applied with Hot Spot Analysis tool of ArcGIS.

This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). It creates a new **Output Feature Class** with a z-score, p-value, and confidence level bin (Gi_Bin) for each feature in the **Input Feature Class**.

The Getis-Ord local statistic is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}} \quad (1)$$

where x_j is the attribute value for feature j, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (2)$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2} \quad (3)$$

The G_i^* statistic is a z-score so no further calculations are required.

The Gi_Bin field identifies statistically significant hot and cold spots regardless of whether or not the FDR correction is applied. Features in the +/-3 bins reflect statistical significance with a 99 percent confidence level; features in the +/-2 bins reflect a 95 percent confidence level; features in the +/-1 bins reflect a 90 percent confidence level; and the clustering for features in bin 0 is not statistically significant. Without FDR correction, statistical significance is based on the p-value and z-score fields.

The Gi* statistic returned for each feature in the dataset is a z-score. For statistically significant positive z-scores, the larger the z-score is, the more intense the clustering of high values (hot spot). For statistically significant negative z-scores, the smaller the z-score is, the more intense the clustering of low values (cold spot).

Results

Table 01 shows the maximum, minimum, mean values and standard deviation in the soil content from surface to 10 cm of depth. Maximum values indicate that there was more soil moisture during 2016 than 2015. Figures 2, 3, 4 and 5 shows the amount of soil moisture in Nile Basin at wereda level.

Table 01 Soil Moisture Content in [m^3 m-3] during 2015 & 2016 in the Nile Basin of Ethiopia.

Months	Max		Min		Mean		Standard deviation	
	2015	2016	2015	2016	2015	2016	2015	2016
June	0.4096	0.4459	0.0713	0.0786	0.25	0.3	0.07	0.09
July	0.4111	0.4457	0.0721	0.0955	0.26	0.36	0.07	0.07
August	0.4153	0.4470	0.0838	0.0816	0.27	0.36	0.06	0.07
September	0.4190	0.4453	0.0692	0.0668	0.26	0.33	0.08	0.08

Source: Study

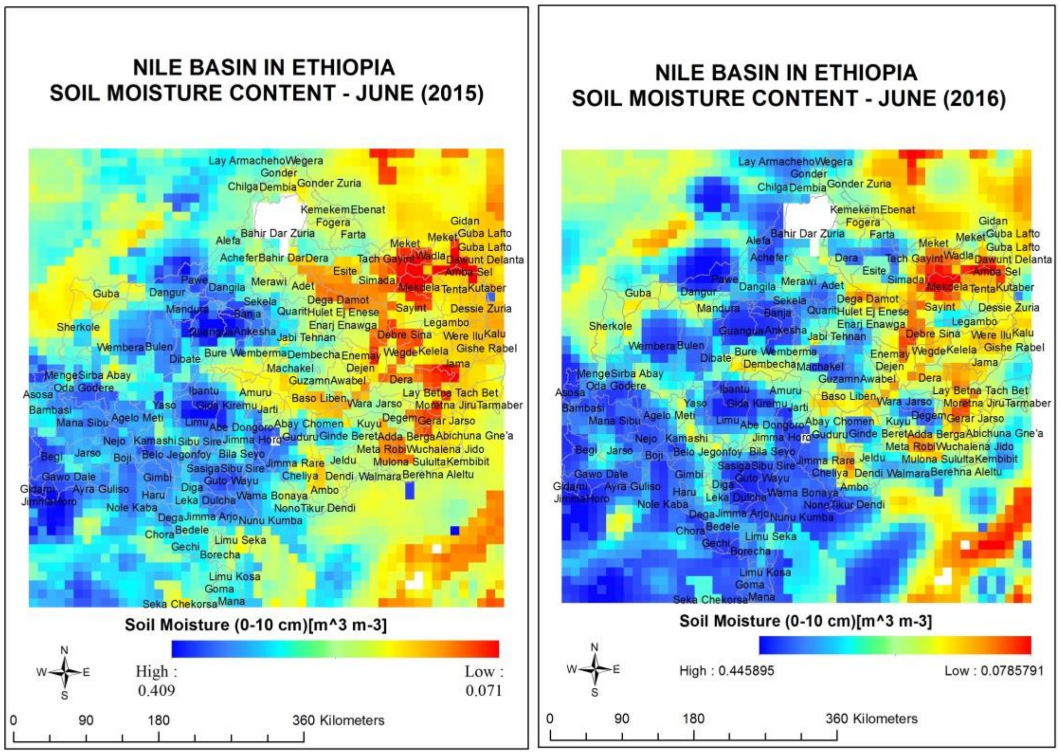
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - JUNE (2015)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.409
Low : 0.071
0 90 180 360 Kilometers
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - JUNE (2016)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.445895
Low : 0.0785791
0 90 180 360 Kilometers

Fig. 2

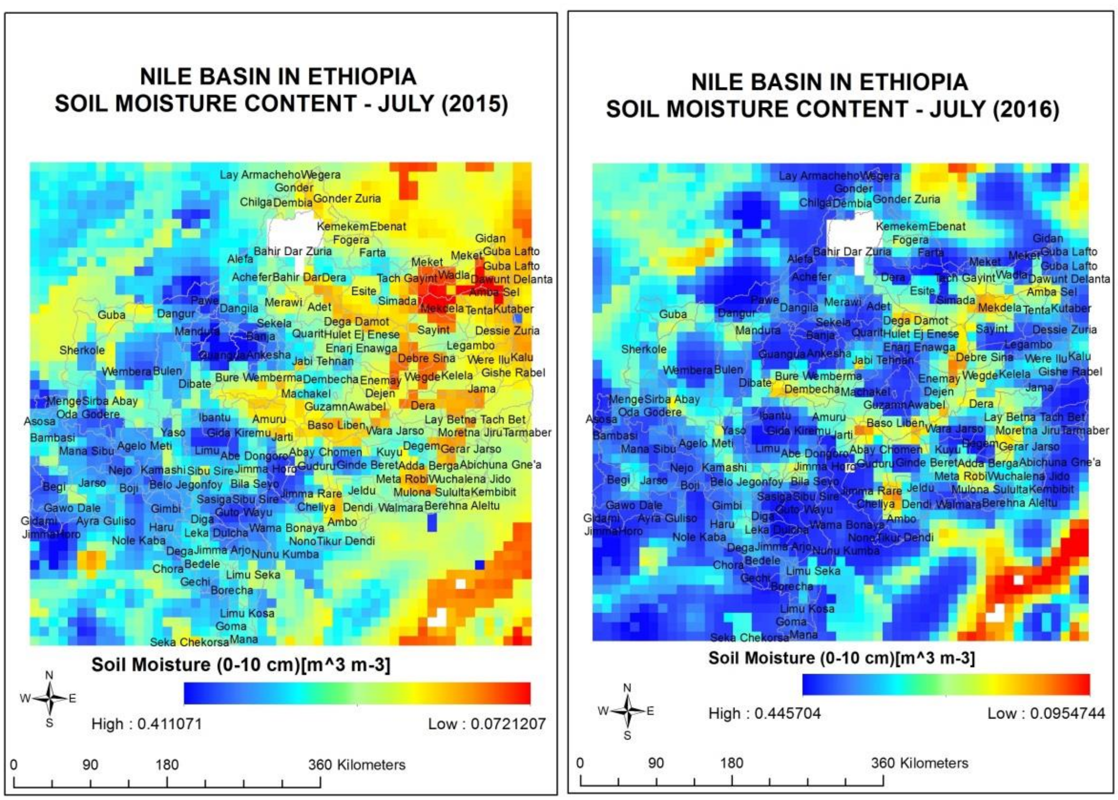
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - JULY (2015)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.411071
Low : 0.0721207
0 90 180 360 Kilometers
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - JULY (2016)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.445704
Low : 0.0954744
0 90 180 360 Kilometers

Fig. 3

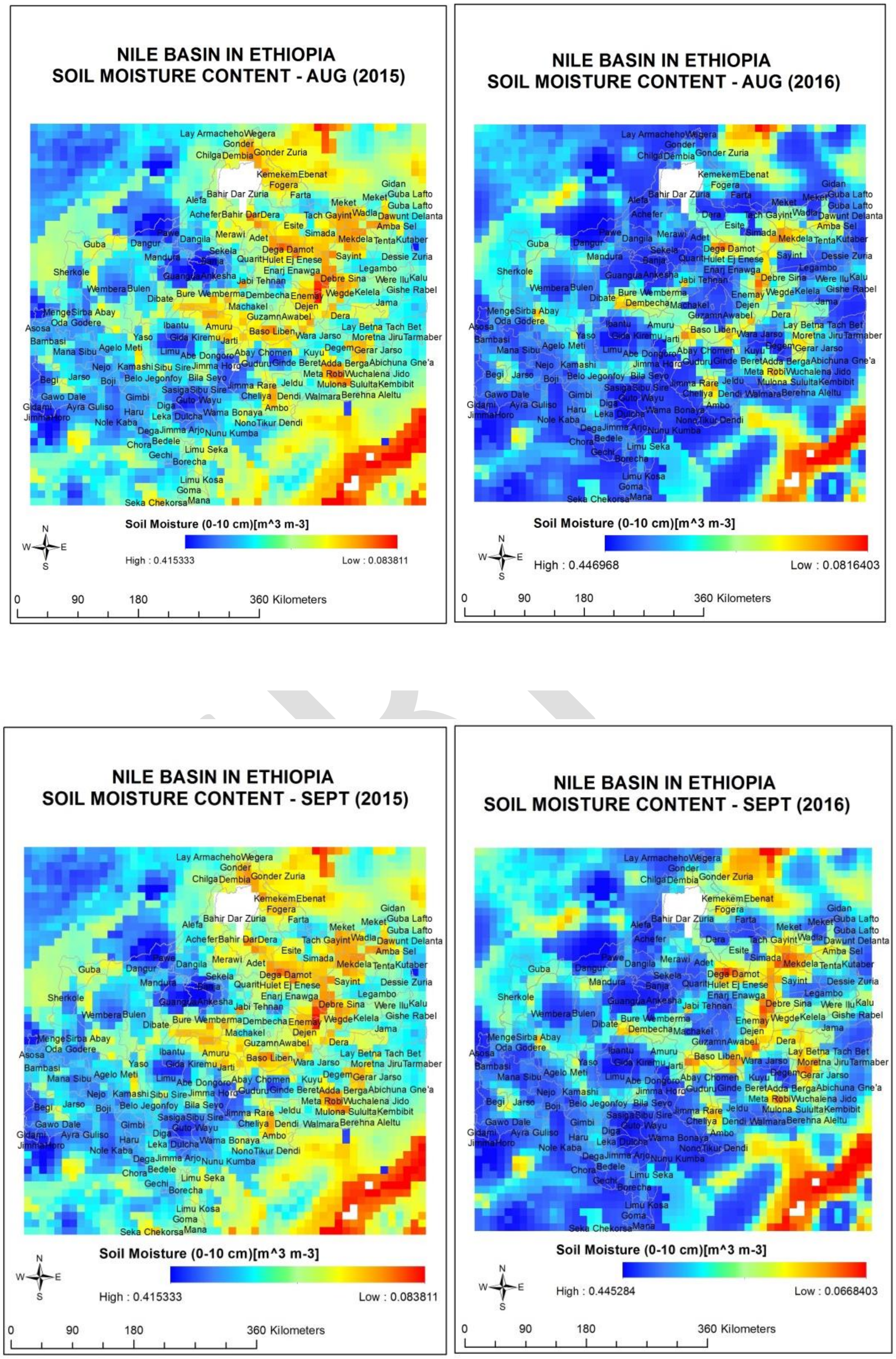
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - AUG (2015)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.415333
Low : 0.083811
0 90 180 360 Kilometers
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - AUG (2016)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.446968
Low : 0.0816403
0 90 180 360 Kilometers
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - SEPT (2015)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.415333
Low : 0.083811
0 90 180 360 Kilometers
NILE BASIN IN ETHIOPIA
SOIL MOISTURE CONTENT - SEPT (2016)
Soil Moisture (0-10 cm)[m^3 m-3]
High : 0.445284
Low : 0.0668403
0 90 180 360 Kilometers

Fig. 5

Variation in Soil Moisture from 2015 to 2016

Table 2 shows Soil Moisture Content change from 2015 to 2016 in the Nile Basin of Ethiopia.

In the table first column Gi_Bin field shows statistically significant hot and cold spots. Area in the + 3, +2 and +1 bin represent more moisture content during 2016 than 2015 at 99%, 95% and 90% confidence level. On the other hand Area in the - 3, -2 and -1 bin represent more moisture content during 2015 than 2016 at 99%, 95% and 90% confidence level.

Area in the 0 bin represent not significant statistically to say the difference in between 2015 and 2016.

Table 2 Soil Moisture Content change from 2015 to 2016 in the Nile Basin of Ethiopia.

Gi_Bin	June		July		August		September	
	Area		Area		Area		Area	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%
-3.0	22133.1	13.0	20657.6	12.1	20165.7	11.8	20165.7	11.8
-2.0	9714.0	5.7	13156.9	7.7	12173.2	7.1	13156.9	7.7
-1.0	7377.7	4.3	9714.0	5.7	9468.1	5.6	8607.3	5.0
0.0	95049.5	55.7	86565.1	50.8	87302.9	51.2	86073.3	50.5
1.0	4426.6	2.6	5410.3	3.2	6148.1	3.6	7377.7	4.3
2.0	9591.0	5.6	9222.1	5.4	12665.1	7.4	10451.8	6.1
3.0	22256.1	13.0	25822.0	15.1	22625.0	13.3	24715.3	14.5
	170548.0	100.0	170548.0	100.0	170548.0	100.0	170548.0	100.0

Source: Study

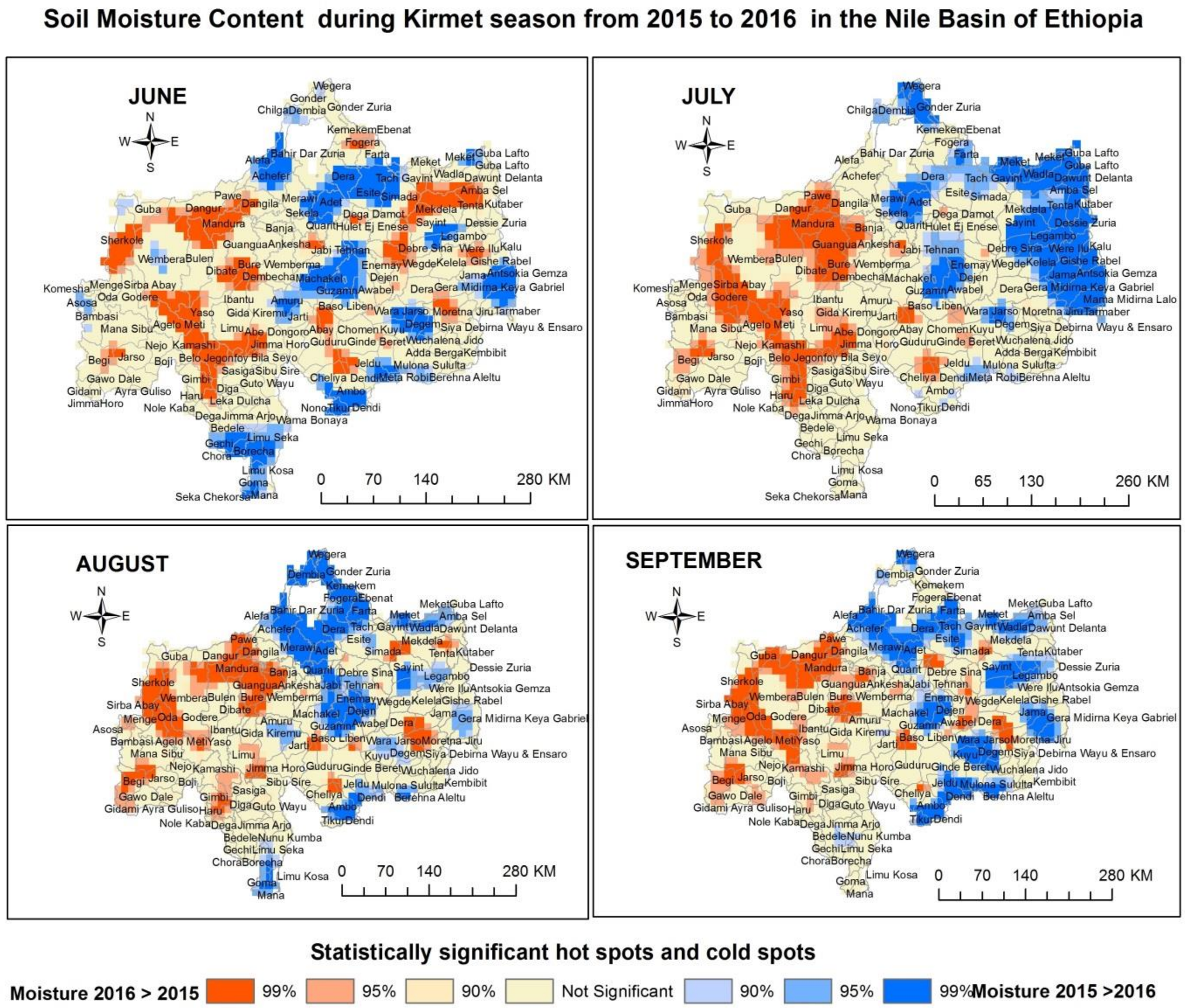

Fig. 6

Conclusion

The results headlights Eastern part of the Nile basin soil moisture was more in 2015 than 2016. While in western part of the basin soil moisture was less in 2015 than 2016.

This study is not enough to give an idea of moisture deficit woredas because of El-Niño 2015. For more scientific study data time range has to be expanded covering more El-Niño events. Fields survey will also be helpful for accuracy assessment of satellite data.

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