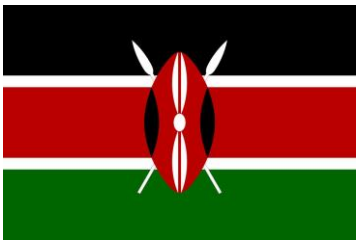
NDVI TECHNOLOGY FOR FOOD SECURITY AND BETTER HEALTH IN KENYA



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Research report submitted to GLOBE 2020 – Middle School Category
February, 2020.

Shree Swaminarayan Academy
Teach Through Expounding of Themes

ABSTRACT

Normalized Difference Vegetation Index (NDVI) is a remote sensing technology that is used to determine the amount of vegetation cover on the earth's surface. It is important to determine vegetation cover on the earth's surface because any changes on vegetation cover affects our health, economy and environment. In an effort to monitor major fluctuations in vegetation and understand how they affect the environment, 20 years ago Earth scientists began using satellite remote sensors to measure and map the density of green vegetation over the Earth. Using NOAA's Advanced Very High Resolution Radiometer (AVHRR), scientists have been collecting images of our planet's surface.

NDVI is useful for farmers as it helps them monitor and manage their farms remotely, and can predict climate changes such as drought. Since NDVI determines vegetation cover, it can also be correlated with incidences of vector borne diseases such as malaria, which is transmitted by the mosquito.

In this study, normalized data from Homa Bay County was used to determine whether there was a correlation between NDVI and malaria occurrence with weather conditions (precipitation, humidity and temperature) in Homa Bay County during the period between January, 2017 and February, 2018.

From the results, it was clear that both NDVI and malaria occurrence were highest during the month of May, 2017, which is the peak of the long rainy season in Kenya. The month of May, 2017 recorded the highest precipitation, humidity, malaria occurrence and the moderately high temperature. This month coincides with the growth of the maize crop, one of the most common food crops grown in Homa Bay. Hence, there is high vegetation cover during this month, which also encourages mosquito breeding. The levels of NDVI, precipitation and humidity steadily dropped between June and July 2017. This coincides with the harvesting season, whereby the maize stalks turn yellow in color, causing the NDVI values to drop. The NDVI value peaks again during the short rains, i.e. November, 2019, which also recorded relatively high precipitation and humidity. This coincides with the second growth season for the maize plant.

Malaria occurrence was found to be very high during the month of May and November, 2017, when there was high precipitation, high humidity and low temperature. During these months, the NDVI value was at its highest, which means the vegetation cover was very high. High vegetation and warm temperature encourages mosquito breeding, which results in high malaria transmission. Notably the adult female mosquitoes look for vegetation to rest on after laying their eggs- and thus the vegetation is an important variable.

NDVI is therefore a promising technology for monitoring vegetation cover, which in turn can provide information on vector borne diseases such as malaria. This information is useful to farmers as it will help to improve productivity.

TABLE OF CONTENTS

RESEARCH QUESTIONS

1. Whether there is a correlation between the weather conditions and NDVI
2. Whether there is a correlation between the weather condition and malaria occurrence
3. Whether there is a correlation between the Vegetation cover and malaria occurrence
4. What are the problems facing the farmers?
5. How can NDVI value help farmers improve their annual yields per hactre?

INTRODUCTION

NDVI stands for **Normalized Difference Vegetation Index** (Sentera, 2019)
It is a simple graphical indicator that can be used to determine the amount of vegetation cover on the surface of our planet remotely using a space platform (GIS Lounge, 2017). Plants and trees are important to human life as they provide us with food, oxygen, building materials, medicines. They also absorb carbon dioxide so they help clean up the air we breathe.

It is important to determine vegetation cover on the earth's surface because any changes on vegetation cover affects our health, economy and environment. To determine the density of green on a patch of land, researchers observe the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants. **Chlorophyll** is a color pigment in plant leaves that strongly reflects near-infrared light (from 0.7 to 1.1 μm), while it strongly absorbs red (visible) light (from 0.4 to 0.7 μm) for use in photosynthesis. NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red (visible) light (which vegetation absorbs, Earth observatory, NASA, 2000).

The instrument used for determining NDVI is called the **Advanced Very-High-Resolution Radiometer (AVHRR).** This instrument is a space-borne sensor that measures the reflectance of the Earth in five spectral bands:

- two centered on the red (0.6 micrometres) and near- infrared (0.9 micrometres) regions
- third one is located around 3.5 micrometres
- two more measure thermal radiation emitted by the planet, around 11 and 12 micrometres

The **AVHRR** is carried by the **National Oceans and Atmospheric Administration** (NOAA) platform and the European **MetOp** satellites.

NDVI is calculated by near-infrared radiation (NIR) minus visible radiation (Red) divided by near-infrared radiation plus visible radiation (Earth observatory, NASA, 2000)

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

The result of this formula generates a value between -1 and +1.

A value of zero means no vegetation (e.g. tundra or desert) and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves (e.g. forest).

LITERATURE REVIEW

Homa Bay is a county located in south western Kenya with about 74% of the labor force employed in agriculture (MoALF, 2016). Despite this, half of the population is food insecure (GoK, 2013). The main food crops produced in the county are maize, beans, sorghum, millet, kales, sweet potatoes and peas. About 80% of the farmers grow maize and beans (GoK, 2014). In total, 104,464 hectares are dedicated to food crops, 12,277 hectares to cash crops, 6,000 hectares to horticulture and 54 hectares to aquaculture. Therefore, most of the vegetation cover in Homa Bay county is from the food crops.

What are the problems facing the farmers?

- extreme weather and climate shocks e.g. drought and floods
- unsustainable natural resource management
- high prevalence of HIV/AIDS (21.7%) and general poor health
- limited access to farm inputs and poor and obsolete farming methods
- limited water availability
- attack by crop pests and diseases
- lack of labor
- poor transport and communication
- deterioration of soil nutrients
- population increase, resulting in less land available for farming

How can NDVI value help farmers?

Satellites monitor how "green" different parts of the planet are and how that greenness changes over time.

- NDVI is used to measure plant growth. This can help us decide which areas of land to focus on agriculture, conservation or rehabilitation
- NDVI has been used to measure agricultural yield and compare with previous years. This helps to predict future yields.
- NDVI is also a good indicator of drought. It can help predict seasonal droughts to help farmers plan their farming.

Farmers can use NDVI based satellite imagery applications to:

- subdivide their farms into paddocks
- manage and plan their farming activities
- monitor their fields and crops

Western Kenya is also a malaria endemic region. Incidences of malaria among the population affect the health of farm workers, which results in reduced agricultural production, thereby causing food shortage in the region. Environmental factors affect the life cycle of the mosquito vector and the parasite that causes malaria, *Plasmodium falciparum*. Remote sensing data on environment have been used to predict or forecast malaria occurrences in malaria endemic regions of the world including Africa and South America. In this study, we wanted to determine whether there is a correlation between NDVI and malaria occurrence with weather conditions (precipitation, humidity and temperature) in Homa Bay County during the period between January, 2017 and February, 2018.

HYPOTHESIS

1. There is correlation between NDVI and weather conditions
2. There is a correlation between malaria occurrence and weather conditions.

PROCEDURE

Normalized data from the weather station located at Homa Bay High School (0.5379° S, 34.4600° E) between January 2017 and February 2018 was obtained. The data included temperature, humidity, precipitation, pressure, radiation, wind speed, NDVI and malaria occurrence and is presented in Table 1 below.

Automatic Weather Station Data(aggregated to Montly)								
dateTimeUTC	site	name	humidity	precipitation	pressure	radiation	temperature	windspeed
2017 Jan	TA00031	Homa Bay High School	57.9623656	0.623655914	87.899543	239.81289	24.8295968	-12.287
2017 Feb	TA00031	Homa Bay High School	65.1354167	0.611607143	87.915327	248.952396	24.5785268	-102.993
2017 Mar	TA00031	Homa Bay High School	68.7873486	1.043068641	87.924024	262.354159	24.5963526	-510.126
2017 Apr	TA00031	Homa Bay High School	69.5833333	0.656944444	87.968722	239.305056	24.0676667	-360.028
2017 May	TA00031	Homa Bay High School	77.077957	1.619623656	88.109664	221.121223	22.8539919	-200.732
2017 Jun	TA00031	Homa Bay High School	68.5888889	0.411111111	88.112083	229.314514	23.5965417	-165.588
2017 Jul	TA00031	Homa Bay High School	71.6451613	0.049731183	88.19539	200.973293	22.8053226	-429.14
2017 Aug	TA00031	Homa Bay High School	69.7459677	0.25672043	88.089126	216.338065	23.2080511	0.876909
2017 Sep	TA00031	Homa Bay High School	72.6652778	0.670833333	88.087861	219.730306	22.9022361	-818.487
2017 Oct	TA00031	Homa Bay High School	71.6760753	0.364247312	87.981008	238.099503	23.6264247	-509.855
2017 Nov	TA00031	Homa Bay High School	75.1625	0.75	87.958028	213.115069	22.5164722	-485.099
2017 Dec	TA00031	Homa Bay High School	66.2554167	0.344086022	36.418737	241.109503	24.2449866	-39.1162
2018 Jan	TA00031	Homa Bay High School	63.6842608	0.158602151	46.543212	207.753414	23.6970027	-2364.19
2018 Feb	TA00031	Homa Bay High School	58.8020536	0.438988095	63.534583	239.577991	25.6070536	-9998

The data was used to plot line graphs in order to determine the following:

1. Whether there is a correlation between the weather conditions and NDVI

2. Whether there is a correlation between the weather condition and malaria occurrence

RESULTS

1. Correlation between NDVI and weather conditions

A line graph showing the correlation between NDVI and weather conditions at Homa Bay between January, 2017 and February, 2018 is presented in Figure 1 below.

The highest recordings of NDVI obtained were during the months of May, 2017 (0.45) and November, 2017 (0.46). During the month of May, 2017, humidity and precipitation also recorded the highest values of 1.00, while temperature recording was very low (0.11). In November, 2017, humidity value was also high at 0.90 while precipitation was at 0.45. During this month, the lowest temperature value of 0.00 was recorded.

Between May and July, 2017, NDVI recordings steadily decreased from 0.45 to 0.41. During this period, there was also a decrease in precipitation, from 1.00 in May, to 0.00 in July, 2017. The temperature recording was also quite low at a value of 0.09.

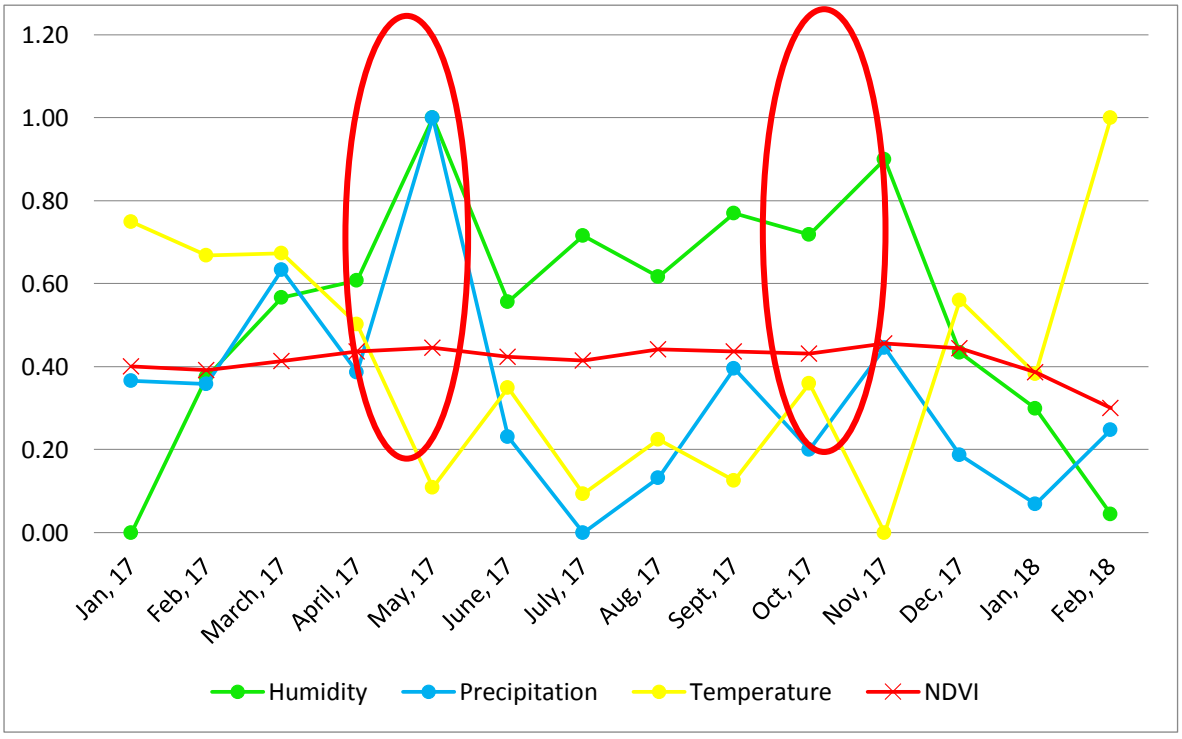

Figure 1: Graph showing correlation between NDVI and weather conditions

2. Correlation between malaria occurrence and weather conditions

A line graph showing the correlation between malaria occurrence and weather conditions at Homa Bay between January, 2017 and February, 2018 is presented in Figure 2 below.

Peak malaria occurrence (with a value of 1.00) was recorded during the month of May, 2017, where humidity and precipitation were at their highest. During this month, the temperature was quite low at a value of 0.11. Malaria occurrence steadily decreased from May to July, 2017, where precipitation was at its lowest. This research suggests that there is a two-month "lag" between temperature and outbreaks of malaria being reported. That is because when the temperature is warm enough for mosquitoes to become active (usually at 20 degrees or higher for at least 10 days), then mosquitoes will breed and bite people to get a blood meal for their eggs. It takes about two months on average before people begin to show symptoms and get sick once active mosquito season begins. There is often a two-month lag with precipitation events- meaning there is either rain or drought and it takes about two months to notice that impact on when outbreaks occur.

Between August and October, 2017, malaria occurrence remained at lowest levels (0.00 to 0.07). In November, 2017, malaria occurrence increased from 0.00 to 0.38, while at the same time, precipitation also increased to 0.45. The month of November, 2017 also recorded a high value of 0.90 for humidity, and the lowest temperature value of 0.00.

Malaria incidence also gave a high value of 1.00 during the month of January, 2018, which recorded lower precipitation (0.07), humidity (0.30) and temperature (0.38)

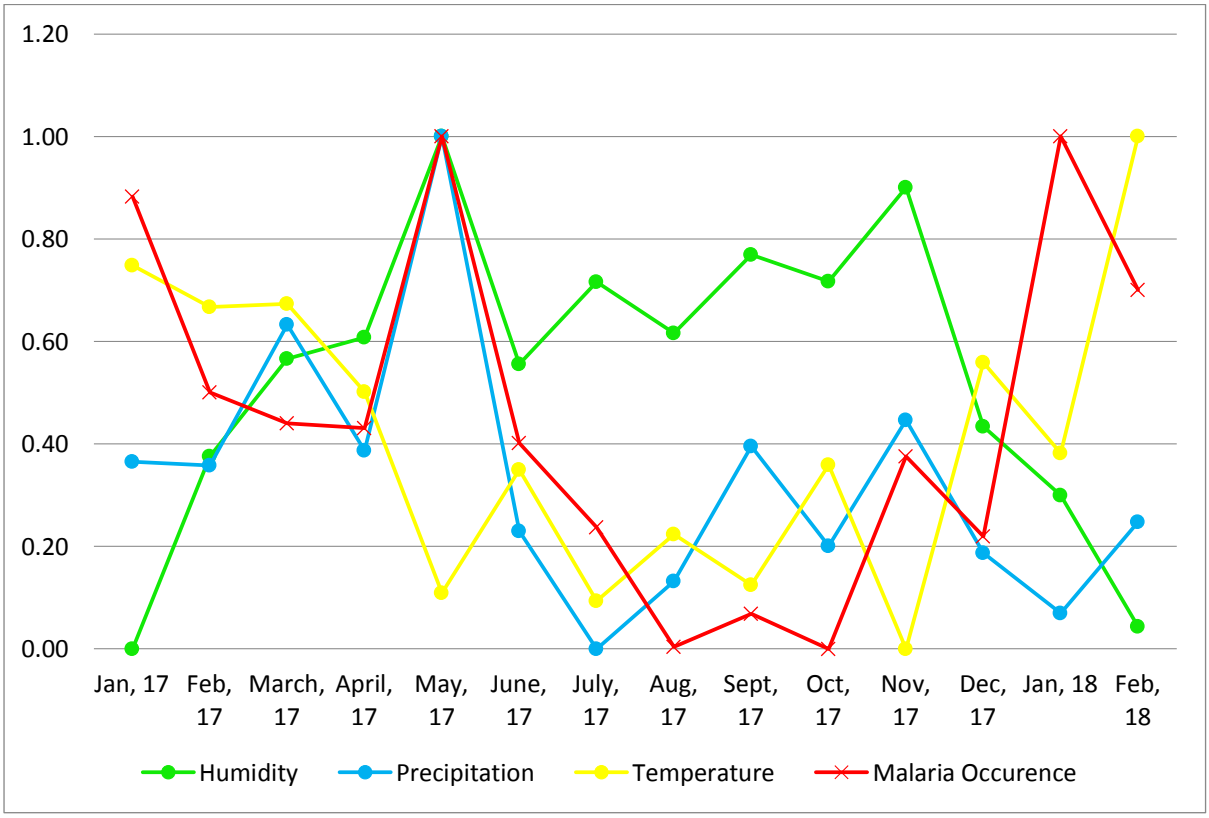

Figure 2: Graph showing correlation between malaria occurrence and weather conditions

DISCUSSION

NDVI is a useful technique for determining the vegetation cover of an area. In Kenya, we have two rainy seasons in a year: the long rains, between May and August, and the short rains between October and November. From the results presented from Homa Bay County, the two rainy seasons are clearly seen as the peaks of precipitation were in May, 2017 and November, 2017.

1. Correlation between NDVI and weather conditions

The main economic activity in Homa Bay is farming, with maize as the staple food.
Maize is usually planted just before the rains, during the months of February and March for the long rains, and September-October for the short rains. This explains why the NDVI is low just before the rainy season. At peak precipitation, i.e. in May and in November, highest values of NDVI were recorded. This is because, during this time, the maize plants are growing and appear very green in colour. They are harvested during the month of June, and in the month of July, the maize stalks are left to dry, and they turn yellow in color. This explains the lowered NDVI value during the month of July.

According to the Ministry of Agriculture, Livestock and Fisheries report of 2016, food insecurity in Homa Bay peaks between July and August and between December and March when harvested stocks have been depleted. This explains very well why the NDVI value drops during these months in Homa Bay. Food insecurity is linked to low productivity due to factors such as extreme weather, climatic shocks, unsustainable natural resource management, high prevalence of HIV/AIDS (21.7%) and limited access to farm inputs (MoALF, 2016).

2. Correlation between malaria occurrence and weather conditions

Malaria is transmitted by the *Anopheles* mosquito, which breeds in stagnant water during the rainy seasons. This explains why the malaria occurrence was at its highest peak during the long rainy season in May, 2017 in Homa Bay. Malaria occurrence steadily decreased from June to October, 2017. Thereafter, a high occurrence was recorded in November, 2017, which corresponded to an increase in precipitation due to the short rains. During this month, high precipitation, high humidity and low temperature was recorded.

From the data collected for the month of May, 2017, it is clear that, there was high vegetation cover (NDVI value of 1.00). With high vegetation cover, mosquito vector population is likely to be high. This may explain the high incidence of malaria during the month of May, 2017. Malaria occurrence also increased during the month of November, 2017, where precipitation and humidity were also higher than the previous months of June to September, 2017. In November, 2017, temperature was also at its lowest. This means that low temperatures increase rates of malaria transmission by the mosquito vector.

Between the months of August and October, 2017, malaria occurrence was at its lowest. This could be due to low vegetation cover, since this is the period that harvesting of the first season and planting of the second season of maize is taking place. The NDVI values during this month are also lower, indicating less healthy crop (yellowed maize stalks during harvesting) and less vegetation cover following harvesting.

The health of a community is important as it affects the economic activities of the community. High occurrence of malaria would imply that there are fewer healthy individuals to work in the farms, and this will lower the agricultural productivity of the area.

CONCLUSION

The results presented show that there is a correlation between:
a) NDVI and weather conditions
b) Malaria occurrence and weather conditions

The results presented are summarized as:
1. NDVI generally has a positive relationship with precipitation and humidity, while it has a negative relationship with temperature.
2. Malaria occurrence has a positive relationship with precipitation, humidity and also a negative relationship with temperature
3. NDVI can be correlated with malaria occurrence because it is dependent on weather conditions and gives a good indication of vegetation cover. High vegetation cover encourages mosquito breeding.

NDVI technology is therefore a very useful tool for monitoring health of crops by farmers and also to monitor incidences of vector borne diseases such as malaria. This is important, as, a healthy community will result in increased agricultural productivity.

Such information on NDVI and malaria occurrence of a given area can be used by the government to help its citizens on best agricultural and health practices, help in prediction of drought, floods and disease epidemics. Adopting NDVI technology in a country like Kenya, which relies on agriculture for economic growth, will help to improve agricultural yields and therefore improve food security, minimize food shortage in the country and result in a more healthy and productive nation.

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