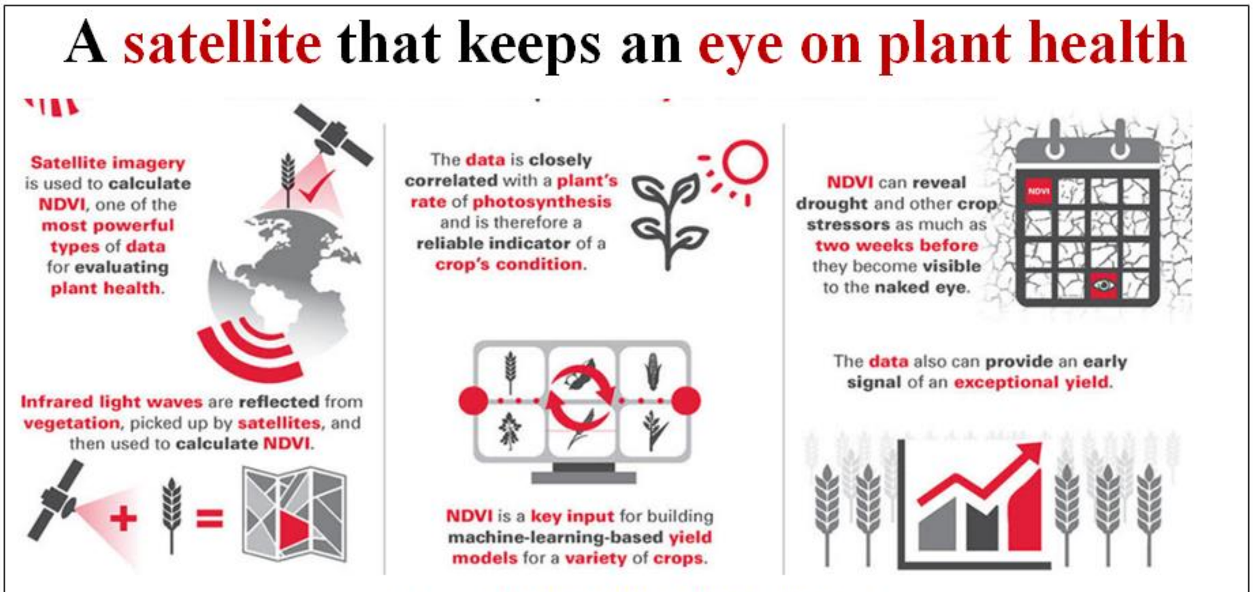
DETERMINING HOW WEATHER CONDITIONS AFFECT MALARIA OCCURRENCE AND MAIZE YIELDS IN HOMABAY, KENYA USING NDVI.



Source: GIMMS MODIS NDVI Intelligence

International Virtual Science Symposium 2021

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RESEARCH REPORT SUBMITTED TO MISSION MOSQUITO 2021

6TH MARCH, 2021.

Shree Swaminarayan Academy
Teach Through Expounding of Themes

Declaration

We declare that;

- This project is our own original work
- This project is not a reproduction of any other published or presented work from any other source, local or international.
- The results presented herein were obtained from experiments, research or trials that we have undertaken ourselves
- That this is the first time that these results are being presented to the International Virtual science symposium 2021 for judgement.

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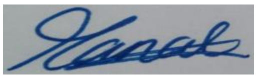
Signature  Date: 1st March,2021

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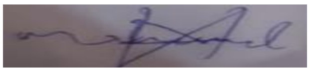
Signature  Date 1st March, 2021

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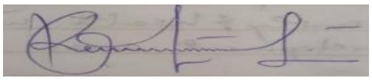
Signature  Date: 1st March,2021

Acknowledgements

In the present world of competition there is a race of existence in which those who have will, come forward to succeed. Project is the bridge between theoretical and practical working. With the will, we joined this particular project.

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Secondly, we feel obliged in taking this opportunity to sincerely say a word of 'thank you' to our School Principal Mrs. Lazar Anu and special heartfelt gratitude to our worthy supervisor Mr. Kennedy Otieno for his patience, belief in us and the enthusiasm that inspired us throughout the project.

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SUMMARY

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.

In accordance to t-test between NDVI and Crop Yield, when NDVI values increase, so does the Crop Yield and vice-versa. We thus concluded that there is a strong correlation between NDVI and Crop Yield. The reason for this is because healthy plants, crops are green in colour, due to chlorophyll. The green in the plants and crops resonates with NDVI. This is why there is higher NDVI when Crop Yield is healthy and promising good harvest.

CHAPTER ONE: INTRODUCTION AND REVIEW OF LITERATURE

1.1. Background Information

NDVI stands for **Normalized Difference Vegetation Index** (Sentera)
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). 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, while it strongly absorbs red (visible) light 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).

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

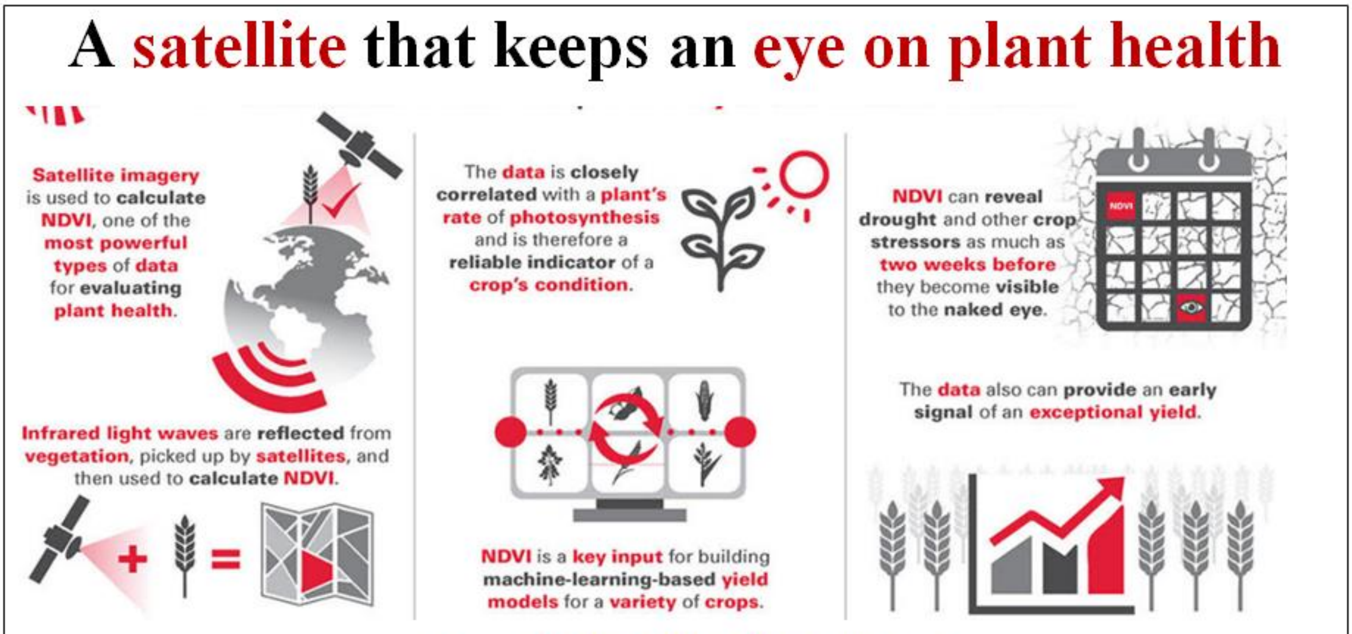
NDVI is calculated by near-infrared radiation (NIR) minus visible radiation (Red) divided by near-infrared radiation plus visible radiation (Earth observatory, NASA, 2000)

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

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).

CONCEPTUAL FRAME WORK



Source: GIMMS MODIS NDVI Intelligence

Homa Bay is a county located in south western Kenya with about 74% of the labour 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.

Severe droughts, increasing competition, and the instability of global grain markets have underscored the importance of obtaining accurate and timely information on crop conditions and potential yield. The benefits include improved inventory, revenue, cost, and risk management along the entire value chain, from producers, to processors (fertilizer, pesticide, and farm chemical manufacturers) and marketing agencies such as the Kenya cereals & produce board (KCPB). Governments, crop insurance companies, and universities also stand to benefit strategically from such advance information.

Two major survey techniques are currently in use for crop yield forecasting and estimation. The most common is the use of list or multiple frame based sample surveys of farm operators. Farmers selected in the statistically based sample are asked to report their final harvested yield or their best evaluation of potential yield, based on current conditions. The second is objective yield surveys which utilize plant counts and fruit measurements from random plots in selected fields. Data from multiple years are used to build models that relate pre-harvest counts and measurements to the final post- harvest yield (Allen et al. 2002).

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. We also wanted to determine whether there was correlation between NDVI and crop yield in Homa Bay.

Hopefully, with time, farmers all over the world will be using NDVI technology to monitor the health of their crops and manage their farming activities.

1.2 Justification of study

The results from this study will provide information on how NDVI technology can help the local people of Kenya by monitoring the health of crops and incidences of vector borne diseases that can cause food insecurity.

NDVI technology is useful for monitoring health of crops and to monitor incidences of vector borne diseases such as malaria.

Adopting the technology in Kenya will help improve agricultural yield and food security and result in a more healthy and productive nation.

1.3 Research questions

1. Is there correlation between NDVI and weather conditions?
2. Is there a correlation between malaria occurrence and weather conditions?
3. Is there correlation between NDVI and crop yield?

1.4 Objectives

1. To find out if there is a correlation between NDVI and weather conditions.
2. To investigate the correlation between malaria occurrence and weather conditions.
3. To determine if there is correlation between NDVI and crop yield.

1.5 Study Area

The study area is Homa Bay County (0.6221° S, 34.3310° E), Kenya as shown in Figure 1 below.

Figure 1: Satellite image of Homa Bay County, Kenya.

CHAPTER 2: RESEARCH METHODS AND MATERIALS

2.1 Data collection for NDVI, weather parameters and malaria occurrence.

Raw and 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 from the Regional Centre for Mapping of Resources for Development (RCMRD). The data included temperature, humidity, precipitation, pressure, radiation, wind speed, NDVI and malaria occurrence. Raw data is presented in Table 1 while the normalized data is presented in Table 2 below. The raw data was normalized using the formula:

Normalized = (x-min)/(max-min)

where:
x is the value to be normalized within a particular data set
min is the minimum value within the data set
max is the maximum value within the data set

Table 1: Raw data of weather parameters and malaria occurrence from Homa Bay (Source:RCMRD)

Automatic Weather Station Data(aggregated to Montly)									
DateTime	Site	Name	huHidity	Precipitation	Pressure	Radiation	Temp	Windspeed	Malaria
2017 Jan	TA00031	Homa Bay High	57.96236559	0.62365591	87.89954	239.8129	24.8296	-12.286976	48195
2017 Feb	TA00031	Homa Bay High	65.13541667	0.61160714	87.91533	248.9524	24.57853	-102.99347	35020
2017 Mar	TA00031	Homa Bay High	68.78734859	1.04306864	87.92402	262.3542	24.59635	-510.12552	32924
2017 Apr	TA00031	Homa Bay High	69.58333333	0.65694444	87.96872	239.3051	24.06767	-360.02821	32599
2017 May	TA00031	Homa Bay High	77.07795699	1.61962366	88.10966	221.1212	22.85399	-200.73246	52231
2017 Jun	TA00031	Homa Bay High	68.58888889	0.41111111	88.11208	229.3145	23.59654	-165.5884	31620
2017 Jul	TA00031	Homa Bay High	71.64516129	0.04973118	88.19539	200.9733	22.80532	-429.14035	25961
2017 Aug	TA00031	Homa Bay High	69.74596774	0.25672043	88.08913	216.3381	23.20805	0.8769086	17897
2017 Sep	TA00031	Homa Bay High	72.66527778	0.67083333	88.08786	219.7303	22.90224	-818.48678	20148
2017 Oct	TA00031	Homa Bay High	71.67607527	0.36424731	87.98101	238.0995	23.62642	-509.85464	17773
2017 Nov	TA00031	Homa Bay High	75.1625	0.75	87.95803	213.1151	22.51647	-485.09922	30703
2017 Dec	TA00031	Homa Bay High	66.25541667	0.34408602	36.41874	241.1095	24.24499	-39.116156	25341
2018 Jan	TA00031	Homa Bay High	63.68426075	0.15860215	46.54321	207.7534	23.697	-2364.1936	44842
2018 Feb	TA00031	Homa Bay High	58.80205357	0.4389881	63.53458	239.578	25.60705	-9998	33645

Table 2: Normalized data of weather parameters, NDVI and malaria occurrence in Homa Bay county (Source: RCMRD)

Normalized (x-min)/(max-min)					
DateTime	Humidity	Precipitation	Temperature	Malaria Occurence	NDVI
Jan, 17	0	0.365582192	0.748443185	0.882871902	0.401
Feb, 17	0.3752461	0.35790729	0.667206048	0.500522375	0.391
March, 17	0.56629077	0.632742353	0.67297384	0.439694701	0.413
April, 17	0.60793137	0.386786529	0.501910247	0.430262929	0.437
May, 17	1	1	0.109209136	1	0.446
June, 17	0.55590869	0.230194064	0.34947129	0.401851529	0.424
July, 17	0.71579243	0	0.093461497	0.237622613	0.414
Aug, 17	0.61643932	0.131849315	0.223769829	0.003598584	0.442
Sept, 17	0.76915811	0.395633561	0.124819199	0.068924488	0.437
Oct, 17	0.71740965	0.200342466	0.359140364	0	0.431
Nov, 17	0.89979609	0.446061644	0	0.375239422	0.456
Dec, 17	0.43383701	0.1875	0.559284531	0.219629694	0.444
Jan, 18	0.29933132	0.069349315	0.381976831	1	0.386
Feb, 18	0.04392686	0.247951321	1	0.70076699	0.3

2.2 Data collection on Maize crop yield

Crop yield estimation is of great importance to food security. Normalized Difference Vegetation Index (NDVI), as an effective crop monitoring tool, is extensively used in crop yield estimation. However, there are few studies focusing on the aspect of mixed crops grown together. In this study, a correlation-based approach for crop yield estimation is applied to three small villages (Kananga Lakeshore, Katuma & Nyalkinyi) in Homa Bay County and the main food crop (maize) in these areas are selected. Based on the correlation analysis between MODIS-NDVI data and crop yield, the crop planting areas as well as the best periods for a reliable estimation are identified.

Fifteen (15) farmers were randomly sampled from Homa Bay School and its environs. Data on field-observed maize yields of four growing seasons (2017–2018) were collected in 2019 by means of interviews with the selected farmers who had records of their production. The size of sampled plots varied between 20 and 41 ha. Crop yield was calculated as kg/ha.

Normalization of crop yield data was done in MS Excel using the same formula that was used for normalization of other data, i.e. **Normalized = (x-min)/(max-min)**.

2.3 Data analysis

The normalized data from RCMRD and data on crop yields from the selected farmers was used to plot line graphs using MS Excel 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
3. Whether there is a correlation between the NDVI and crop yield.

A correlation matrix is a table showing correlation coefficients between variables. Each cell in the table shows the correlation between two variables such as NDVI and crop yield, NDVI and humidity, NDVI or correlation between malaria occurrence and precipitation. A correlation matrix value is used to determine the degree of linear correlation between two variables. If the value is near **±1**, then it said to be a perfect **correlation**: as one variable increases, the other variable tends to also increase (if positive) or decrease (if negative). High degree: If the coefficient value lies between ± 0.50 and ± 1, then it is said to be a strong **correlation**. Therefore;

- **(-1)…** indicates a perfectly negative linear **correlation** between two variables.
- **(0)** …indicates no linear **correlation** between two variables.
- **(+1**)… indicates a perfectly positive linear **correlation** between two variables.

In our study, we used the normalized data of NDVI, weather parameters and malaria occurrence (Table 2) to compute a correlation matrix using CORREL formula in MS Excel**.**
To determine the correlation between crop yield and NDVI, a t-test Two-Sample Assuming Equal Variance from MS Excel was used.

CHAPTER 3: RESULTS

3.1 Trends 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 2 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.

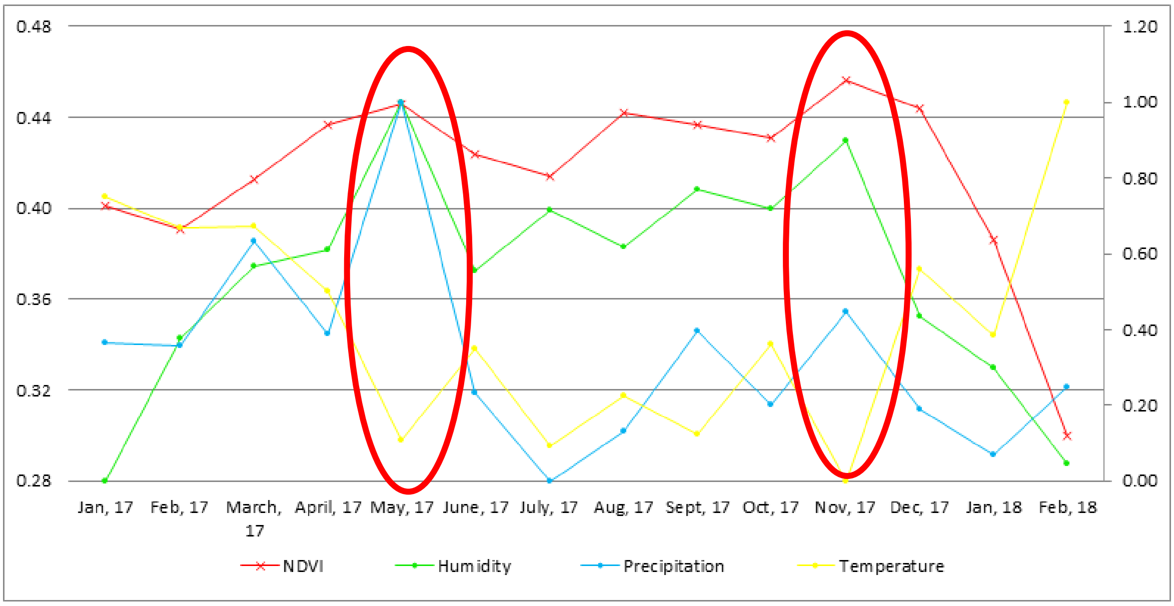


Figure 2: Graph showing trends between NDVI and weather conditions

3.2 Trends 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 3 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)

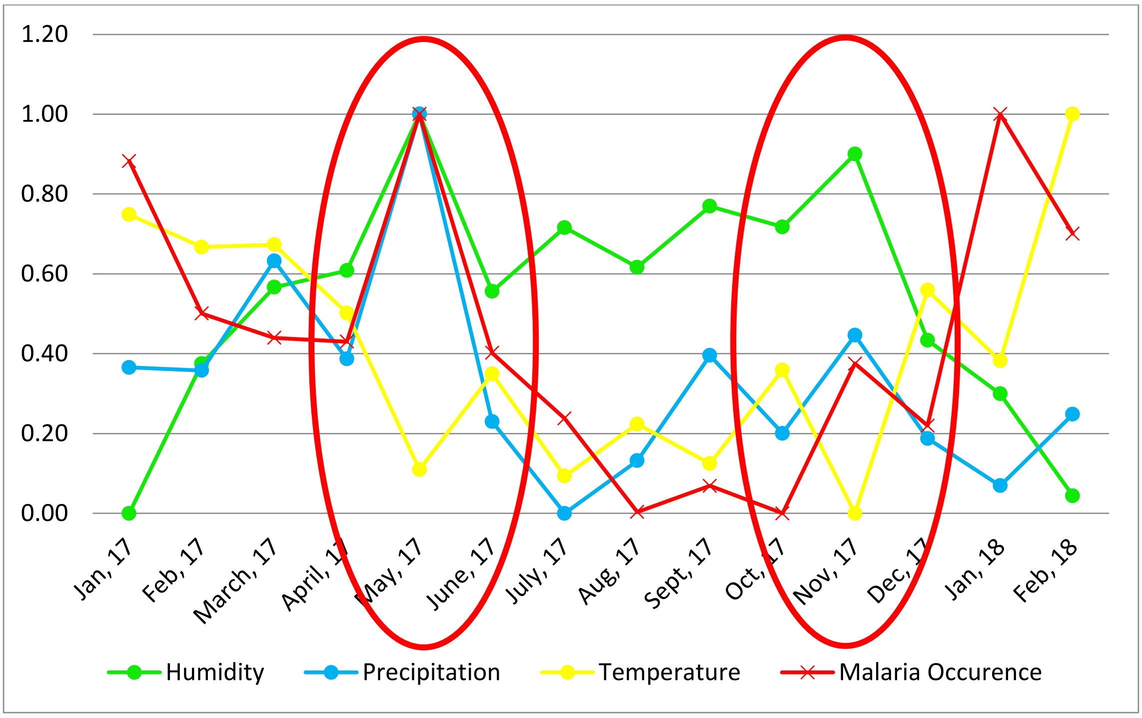


Figure 3: Graph showing correlation between malaria occurrence and weather conditions

3.3 Correlation between NDVI, malaria occurrence and weather conditions

A correlation matrix value is used to determine the degree of linear correlation between two variables. If the value is near **±1**, then it said to be a perfect correlation: as one variable increases, the other variable tends to also increase (if positive) or decrease (if negative). High degree: If the coefficient value lies between ± 0.50 and ± 1, then it is said to be a strong correlation.

A correlation matrix showing the correlation between the different parameters was generated using MS Excel. The matrix is presented in Table 3 below. Of particular interest was how NDVI correlated with the weather parameters, malaria occurrence and crop yield.

NDVI had a strong positive correlation with humidity **(0.767)** and low positive correlation with precipitation **(0.271)**. This means that NDVI increased with increase in humidity and precipitation. On the other hand, NDVI had a strong negative correlation with temperature **(-0.752)** and very low inverse correlation with malaria occurrence **(-0.378)**. This means that NDVI decreased with increase in temperature, and to a much lesser extent, increase in malaria occurrence.

Table 3: Correlation matrix

	Humidity	**Precipitation**	**Temperature**	**Malaria Occurrence**	**NDVI**
Humidity	**1**				
Precipitation	**0.386**	**1**			
Temperature	**-0.855**	**-0.073**	**1**		
Malaria Occurrence	**-0.378**	**0.392**	**0.311**	**1**	
NDVI	**0.767**	**0.271**	**-0.752**	**-0.378**	**1**

Table 3 shows that the correlation coefficients for NDVI and humidity (**0.767**) were higher than those for NDVI and temperature (**-0.752**). NDVI correlated strongly with humidity since an increase in moisture leads to increase in green and leafy vegetation. The correlations with precipitation was moderate precipitation (**0.271**) in the same period. However, temperature has strong negative correlation coefficients (**-0.752**). for NDVI.

The greenness values derived through remote sensing have been used as a surrogate environmental variable to help monitor and predict occurrences of a number of vector-borne and zoonotic diseases, including malaria. Often, relationships NDVI, and disease occurrence are established using temporal correlation analysis. However, the strength of these correlations can vary depending on type and change of land cover during the period of record as well as inter-annual variations in the climate drivers (precipitation, temperature) that control the NDVI.

In Table 3, there is a strong negative correlation coefficient **(-*0*.378)**. between NDVI and malaria occurrence. This observation reveals one of the major drawbacks with using NDVI as a precipitation surrogate for prediction of infectious diseases linked to climate like malaria. Over the study period, NDVI continues to show irregular correlations with malaria occurrence. The contrast in correlation values between times of high and low malaria occurrence also helps to interpret the effects of moving mosquito life cycles and wet/dry seasons.

Thus, the NDVI trend is unlikely to correlate with malaria occurrence over longer time periods, but suggests that NDVI values may help predict the magnitude of case numbers once an active period is underway.

3.4 Correlation between NDVI and Crop Yield.

NDVI is information created from satellite sensors. The satellites are basically measuring how green a specific are is, and this indicates the health and growth of crops in that area. The NDVI values are as a result of growth of maize and responds to its development.

To determine the correlation between NDVI and Crop Yield, the normalized data was subjected to t-test 2-sample assuming equal variances using MS Excel. The normalized data that was used for the t-test and the t-test outcome are presented in Table 4a and 4b below.

In accordance to t-test between NDVI and Crop Yield, when NDVI values increase, so does the Crop Yield and vice-versa. We thus concluded that there is a strong correlation between NDVI and Crop Yield. The reason for this is because healthy plants, crops are green in colour, due to chlorophyll. The green in the plants and crops resonates with NDVI. This is why there is higher NDVI when Crop Yield is healthy and promising good harvest.

However, considering many possible factors such as temperatures, rainfall and soil conditions that contribute to beneficial or detrimental crop growing conditions. The correlation between NDVI and crop yield employs these factors to predict the end-season yield. At any given time, one input might be positively enabling yields to increase, such as when temperatures are perfect for growth, while at the other times an input might be negatively contributing to growth such as very low soil moisture.

Table 4a: Normalized NDVI and Crop Yield data

Homa Bay Crop Yields for 2017		
	Raw (kg/ha)	Normalized
Homa Bay High School	360	0.136
Odundu	1500	1.000
W. Adede	180	0.000
Rangkre	720	0.409
John Olungi	675	0.375
Jared Otiem	1080	0.682
Pius Odhimbo	540	0.273

Normalized data	
AVERAGE Crop yield 2017	0.411
NDVI average for 2017	0.428

Normalized NDVI	
DateTimeUTC	NDVI
Jan, 17	0.401
Feb, 17	0.391
March, 17	0.413
April, 17	0.437
May, 17	0.446
June, 17	0.424
July, 17	0.414
Aug, 17	0.442
Sept, 17	0.437
Oct, 17	0.431
Nov, 17	0.456
Dec, 17	0.444

Table 4b: Outcome of the t-test comparing NDVI and Crop Yield

t-Test: Two-Sample Assuming Equal Variances		
	Normalized crop yield	*NDVI*
Mean	0.410714286	0.415857
Variance	0.11417134	0.001565
Observations	7	14
Pooled Variance	0.037125145	
Hypothesized Mean Difference	0	
df	19	
t Stat	-0.057659885	
P(T<=t) one-tail	0.477310819	
t Critical one-tail	1.729132812	
P(T<=t) two-tail	0.954621637	
t Critical two-tail	2.093024054	

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 and crop yield

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).

In accordance to the correlation matrix computed using Correl formula in Ms excel, there is a positive coefficient (**0.270**) between NDVI and Crop Yield. This implies that when NDVI values increase, so does the Crop Yield and vice-versa. We thus concluded that there is a strong correlation c between NDVI and Crop Yield. The reason for this is because healthy plants, crops are green in colour, due to chlorophyll. The green in the plants and crops resonates with NDVI. This is why there is higher NDVI when Crop Yield is healthy and promising good harvest.

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
c) NDVI and crop yield

1. NDVI generally has a strong positive correlations with precipitation and humidity, while it has a moderately negative relationship with temperature.
2. Malaria occurrence has a moderately positive correlations 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. Therefore, NDVI has a perfect correlation with the malaria occurences.

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.

RECOMMENDATIONS

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.

- 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 Kenya, which relies on agriculture for economic growth, will help to improve agricultural yields and improve food security, minimize food shortage in the country, resulting in a more healthy and productive nation.

-There is need to collect NDVI data with weather parameters and crop yields for at least three years or longer in order to determine the correlations more confidently.

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