

HOW CUBE SATELLITE TECHNOLOGY CAN DETERMINE THE DISTRIBUTION AND SOCIO- ECONOMIC IMPACTS OF DROUGHT IN NORTHERN KENYA USING CUBE SATELLITE DATA

**GLOBE INTERNATIONAL VIRTUAL SCIENCE SYMPOSIUM
2022 SENIOR CATEGORY**

PARTICIPATING STUDENTS:

**MOHAMED HAJI
SAHIL PATTNI
MANAL AHMED
LAKHSIMRAN SAGOO
ANUHYA DHALL**

**PROJECT MENTORS:
MR. NICODEMUS MOSE
MR. BERNARD MABELE
MRS. DORCAS NEMA**

Research report submitted to GLOBE IVSS 2022



Shree Swaminarayan Academy
Teach Through Expounding of Themes

TABLE OF CONTENTS

ABSTRACT	2
LITERATURE REVIEW	4
INTRODUCTION	4
Use of satellite imaging for identification and spread of desert conditions in Northern Kenya.	6
Use of satellite imaging to determine socio-economic impacts of drought in Kenya	
WHAT ARE CUBESATS?	8
PROBLEM STATEMENT - WHY CUBESATS?	8
MATERIALS AND RESEARCH METHOD	9
Materials and electronics used:	9
Study site:	9
Component principles and method:	9-17
DATA AND RESULTS	18-19
CONCLUSION	19-20
BADGES	20
BIBLIOGRAPHY	21

ABSTRACT

Desertification is a major problem in Africa. Deserts such as the Sahara continue to spread, and the effects of desertification are felt in countries all across Africa, including Kenya. Cubesat (cube satellite) technologies are a very viable tool that can be used to identify and predict these calamities. The purpose of this project was to research the viability of CubeSats, effects of desertification and drought in Northern Kenya and implement some of the complex technologies used by cubesats into building a small prototype that can be used in third world countries.

- In this study, we first conducted research on how cubesats collect temperature, humidity data, and how cubesats conduct imaging from space. We then designed and built a small prototype cubesat, which was fitted with sensors and a camera. We implemented arduino boards to control our electronics on board the prototype. We used our prototype cubesat to collect temperature and humidity data in Mombasa County during the second half of 2021 and early 2022.

The month of February 2022 reported having the highest temperature statistics during our study

With this project we therefore demonstrated the viability of designing and engineering a prototype cubesat that can be used locally to collect data.

LITERATURE REVIEW

INTRODUCTION

Climate change has led to very many drastic changes globally, all of them negatively impacting our day to day lives. The severity of climate change varies, but there is no doubt that Kenya has been hit the hardest. The constant threat of famine, drought and inefficient security of food has led to countless deaths. According to Simanyula (2021), the Kenyan government announced that 3 million Kenyans in Northern Kenya are at risk of starvation due to a severe drought sweeping the region.

Use of satellite imaging for identification and spread of desert conditions in Northern Kenya.

Desertification refers to the slow and steady encroachment of desert-like conditions over an area of formally productive land. It can also be defined as land degradation in arid and semi-arid areas due to climatic conditions.

Desertification is caused by various human activities such as;

- Deforestation
- Poor agricultural practices
- Urbanisation
- The exploitation of land and its resources

When identifying desertification, we can look for predominant features/ characteristics over a given topography

Desertification can be identified using satellite imaging by identifying;

- High relief
- Lack of vegetation cover
- Increase surface temperature
- Reduction in rainfall

Using satellite image we can identify the distinct changes in vegetative cover, and come to the conclusion that the particular area in question is at high risk of drought and famine caused by desertification

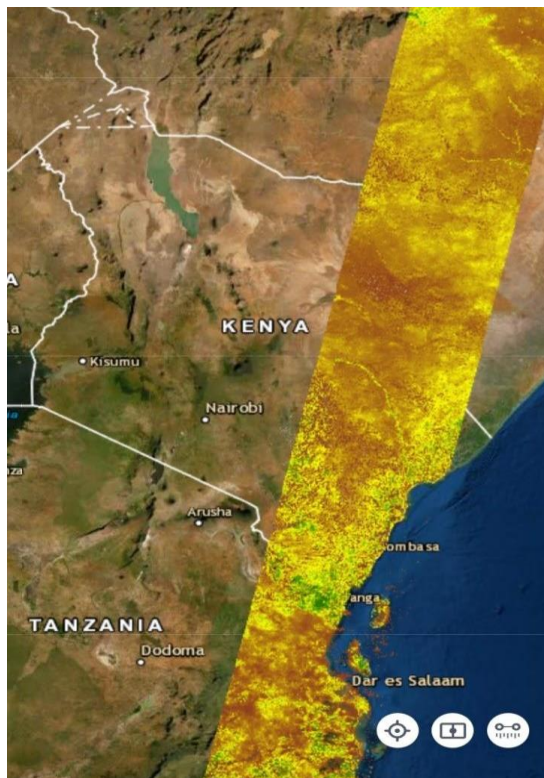


Figure 1: Image of East Africa captured by the Sentinel 2 satellite using imaging technology. Source: <https://maps.digitalearth.africa/>

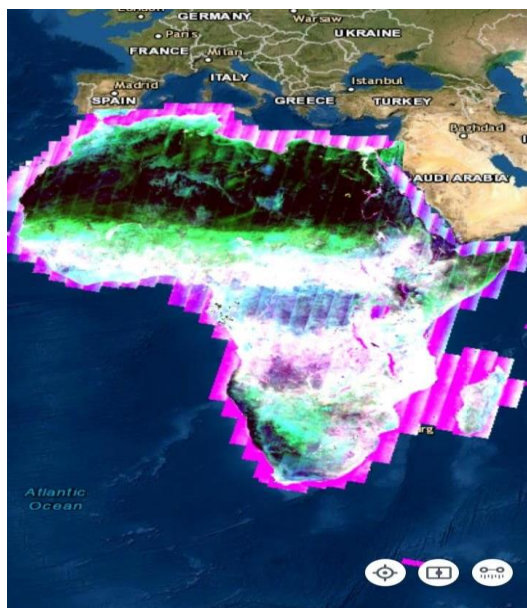


Figure 2: Image of Africa taken by the Sentinel 2 satellite which shows areas with heavy desertification. Source: <https://maps.digitalearth.africa/>

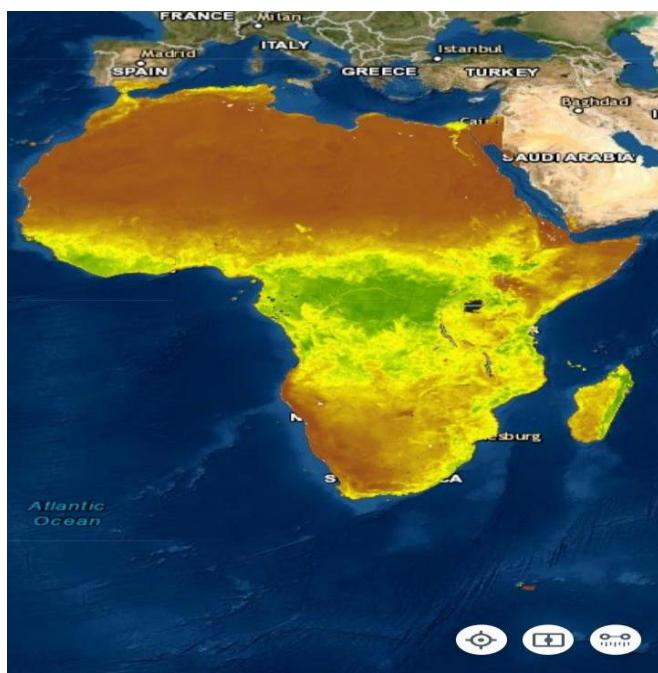


Figure 3: Image of Africa from the Sentinel 2 satellite showing NDVI cover.

Source: <https://maps.digitalearth.africa/> - Website link

Use of satellite imaging to determine socio-economic impacts of drought in Kenya

The socio-economic effects of desertification in Northern Kenya would affect the most popular activity in that region. Raising livestock. The arid, unsustainable pasture put local farmers at risk, by not having enough resources to graze cattle. This can lead to the economic status of the north diminishing, having greater impacts on the country's total GDP.

Lack of favourable pastures, ideal farming land and unreliable supply of water can lead to a lot of mental instability for the people living in these particular regions. The inability to sustain their families and themselves put a great deal of stress on an average farmer in this region

"Kenya, like many other nations in the world, is threatened by desertification, land degradation, and drought. In areas like North-Eastern, the deserts have once eaten the once potential landscapes turning it into an inhabitable landscape that cannot support humans, livestock, and even wildlife," (NEMA, 2020).

Figure 4 below gives a very good look at the microclimate of northern Kenya. We can see a dryer area of land which is less favourable for agricultural activities. These areas include Turkana, Marsabit, Wajir and Mandera. This contrasts with the fertility and favorability of farm lands in the Rift Valley region of Kenya.

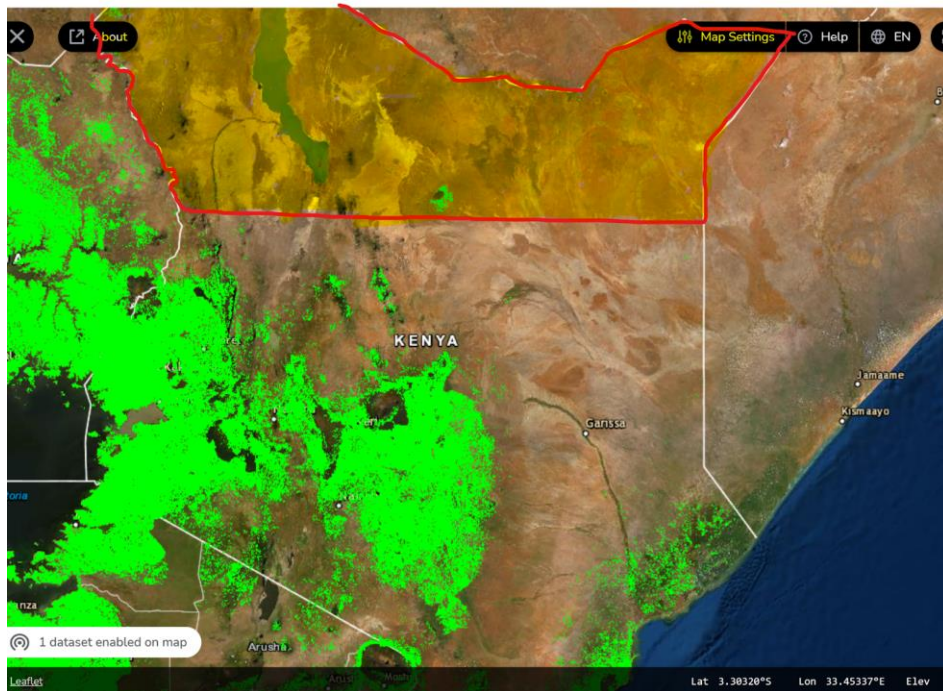


Figure 4: Satellite image showing microclimate of northern Kenya.

Key:

Green area = plotted land

Yellow area = Desertification spread

Figure 5 below shows us the microclimate within Kenya. Similar to the previous image we can see that the North part of Kenya has very arid desert-like tundra conditions compared to the greener parts of Kenya towards the rift valley area.

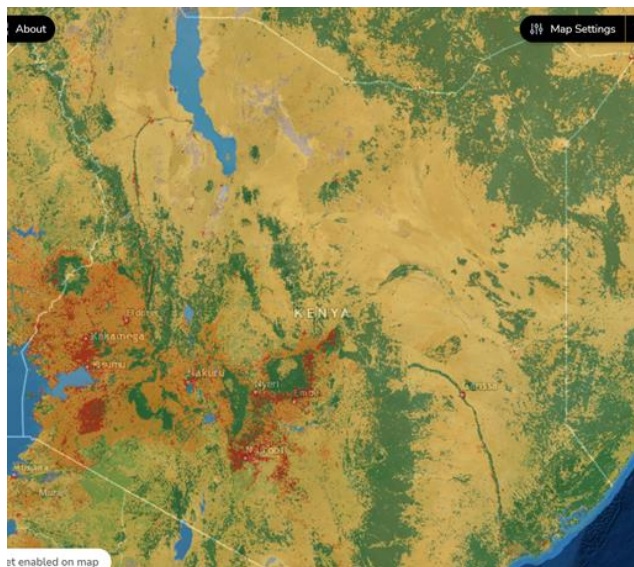


Figure 5: Satellite image of Kenya showing the microclimate in the country.

Source: <https://maps.digitalearth.africa/>

Key:



Using such satellite imaging, we can identify areas that require a higher degree of aid and attention and help minimise wastage of resources.

Images extracted via:

<https://maps.digitalearth.africa/>

WHAT ARE CUBESATS?

A CubeSat is a type of miniature satellite used for space research and Earth tracking, imaging and mapping that is made up of multiple cubic modules 10 cm (3.9 in) per side. CubeSats have a mass of no more than 1.33 kg (2.9 lb) per unit, and often use commercial off-the-shelf (COTS) components for their electronics and structure. CubeSats are put into orbit by deployers on the International Space Station, or launched as secondary payloads on a launch vehicle. As of August 2021, more than 1600 CubeSats have been launched

PROBLEM STATEMENT - WHY CUBESATS?

Large satellites are a common technology used to view and analyse the Earth and its various deserts, oceans etc. The issue lies in building and deploying these satellites, a typical weather satellite costs USD \$290 million, compare this gigantic price tag to the average cost of a cubesat which lies around USD \$20,000 to \$200,000. Therefore we realised that poorer nations may not have the funding to budget such large projects and therefore the country's geography cannot be analysed to great detail leading to the spread of degradation processes such as desertification, drought and famine. Cubesats have a lower price tag than conventional satellites due to their low weight and size.

This major threat can be treated using CubeSat imaging. CubeSat imaging can diagnose various causes and effects of desertification. Cubesat imaging can identify the lack of vegetation cover. In Northern Kenya, this allows us to pinpoint areas at high risk of drought and famine such as Turkana, Marsabit, and Isiolo. Identifying agricultural land using CubeSat imaging, we can assess the sustainability of farming practices, and intervene where necessary. As poor agricultural practices such as overgrazing, overuse of pesticides, etc, can lead to poor soil fertility over time.

Designing and implementing remote sensing technology into a CubeSat that will undertake a Low Earth Orbit (LEO). This is done due to the fact the closer proximity to the ground eliminates major

delays between the communications. To add on further, a sun-synchronous orbit will ensure optimal lighting to extract data of greater accuracy. Not to mention that, a good number of CubeSat missions fail upon launch. Implementing hardware that can withstand the harsh environment of space is also another challenge. New research on satellite technology is always welcomed so as to further improve the capabilities of these engineering marvels.

MATERIALS AND RESEARCH METHOD

Materials and electronics used:

- High spatial resolution camera/CAM - Onboard camera- ESP32 CAM Board
- Arduino Uno/COM - Communication system
- ESP32 Board
- Micro SD Card for external data storage
- 3D printed frame to house parts and electronics
- Arduino sensor, the DHT11 to collect temperature and humidity data
- Power source
- Arduino IDE for uploading of code/sketches on to boards

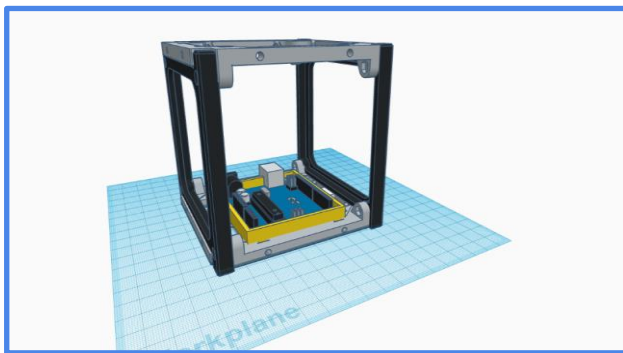


Figure 6: 3D model of CubeSat prototype

Study site:

Shree Swaminarayan Academy grounds

Component principles and method:

a. ESP32 Arduino

This is the brain of the operation. The ESP32 allows us to relay real-time information about variables and receive processed data. This microcontroller is connected to the sensor.



Figure 7: ESP32 Arduino

Image courtesy of:

https://ce8dc832c.cloudimg.io/v7/ cdn /EE/B6/90/00/0/617454_1.jpg?width=640&height=480&wat=1&wat_url= tme-wrk %2Ftme new.png&wat scale=100p&ci sign=d3711bfc7b01cfc40330b791c4dedda4b056ff5c

b. DHT11 Sensor

The DHT11 sensor allows for capturing data on temperature and humidity

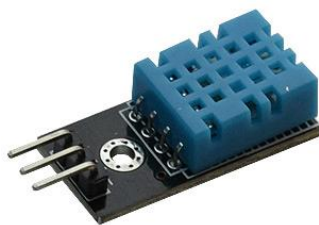


Figure 8: DHT11 Sensor

Image courtesy of:

<https://homedevice.pro/wp-content/uploads/2015/03/SNS-DH11-1.jpg>

Build up

Using the DHT11 Sensor we have manage to capture humidity and temperature of the the December climate in Mombasa. Figure 9 below shows the set up while Figure 10 is a sample of the data captured.

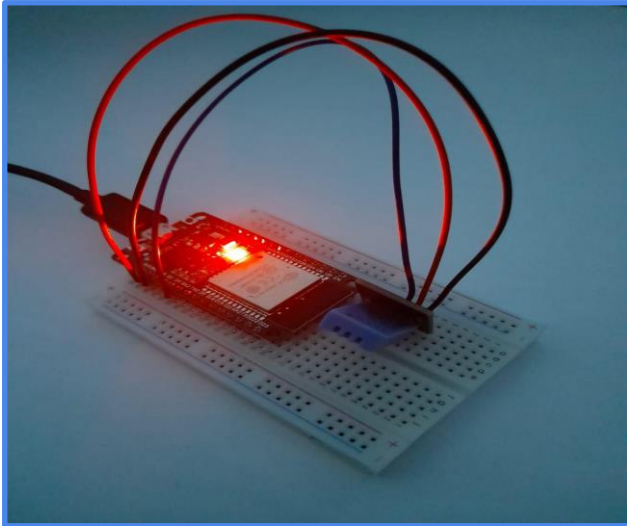


Figure 9: Setup module of ESP32 and DH11 Sensor



Figure 10: Sample of data recorded.

c. Camera Module

The Camera control system is shown in Figure 11 below.



Figure 11: Camera control system

This control system is located on a web server. By entering a distinct IP address on a web browser, the camera can be controlled via our smartphones.

Of course, we don't only rely on this web server to collect images, the camera automatically takes a picture every 20 min and saves it on the micro SD card which is connected to the ESP32 CAM Board.

An example of an image of a plant taken using the OV7670 camera which is inbuilt in the ESP32-CAM module is shown in Figure 12 below.

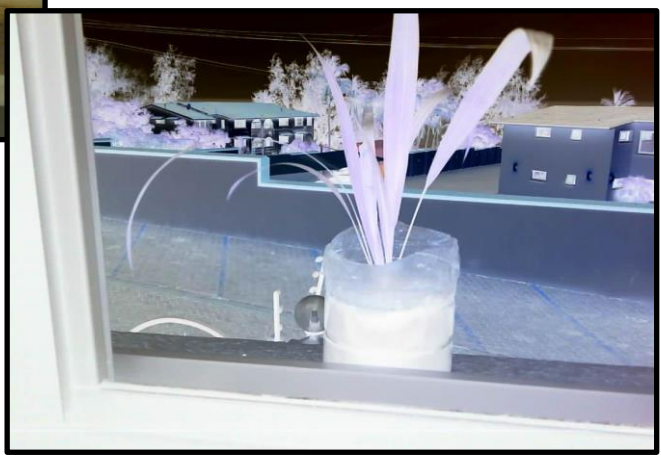


Figure 12: Image of plant taken using the OV7670 camera.

c. Camera with ESP32 CAM board

The Camera plus ESP32 CAM board which controls it is shown in Figure 13 below.

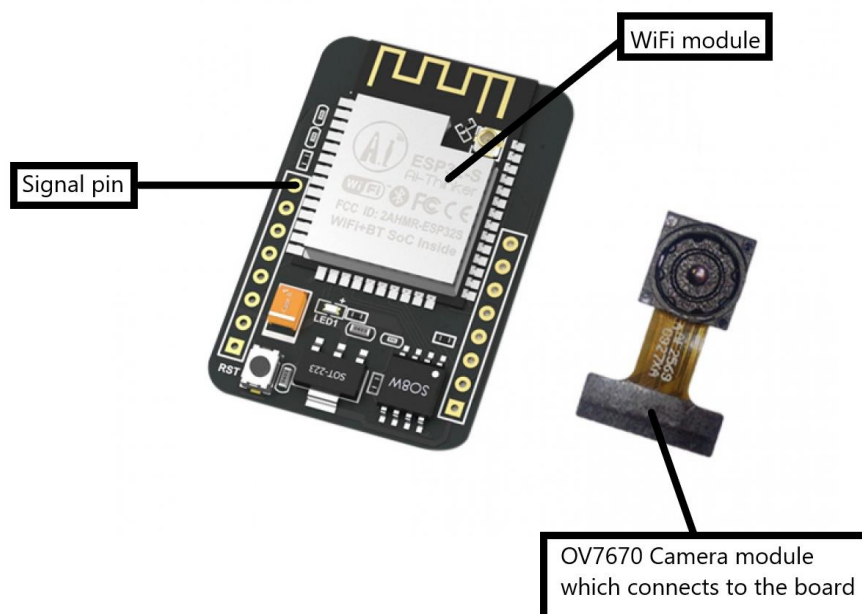


Figure 13: Camera with ESP32 CAMoard control

d. Micro SD Card (External Storage)

Image of micro SD card inserted into SD card slot in ESP32 CAM board is shown in Figure 14 below. An SD card is an additional measure to save any images taken by the camera. The board works on a timelapse basis, taking pictures every 20 minutes, along with additional control via a web interface to collect pictures and videos.

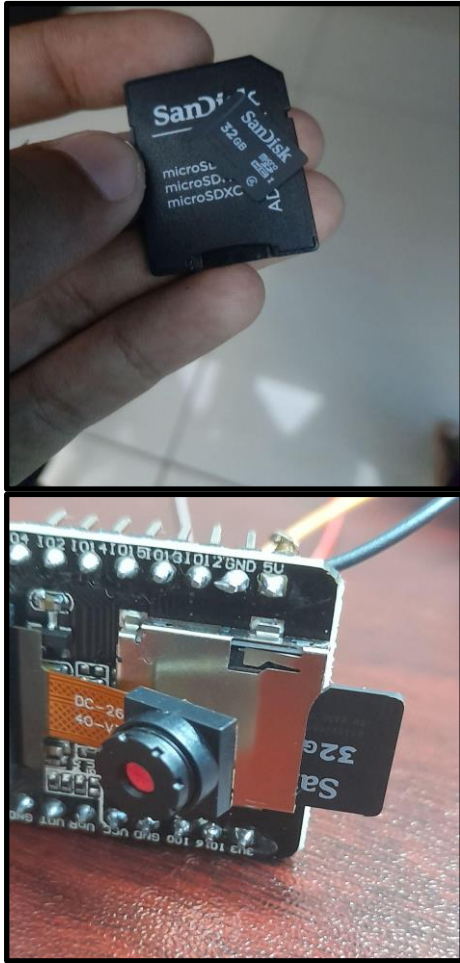


Figure 14: Micro SD Card (External Storage) inserted into the ESP32 CAM board.

e. Arduino Uno Board

The arduino uno is a common board used for many projects among arduino enthusiasts. In our case, we used the arduino uno to connect the ESP32 CAM to a power source, as the ESP32 CAM board does not have a direct power plug in (Figure 15).

The arduino uno also has built in resistors which means we can connect the set up to any power source without frying the ESP32 CAM board.

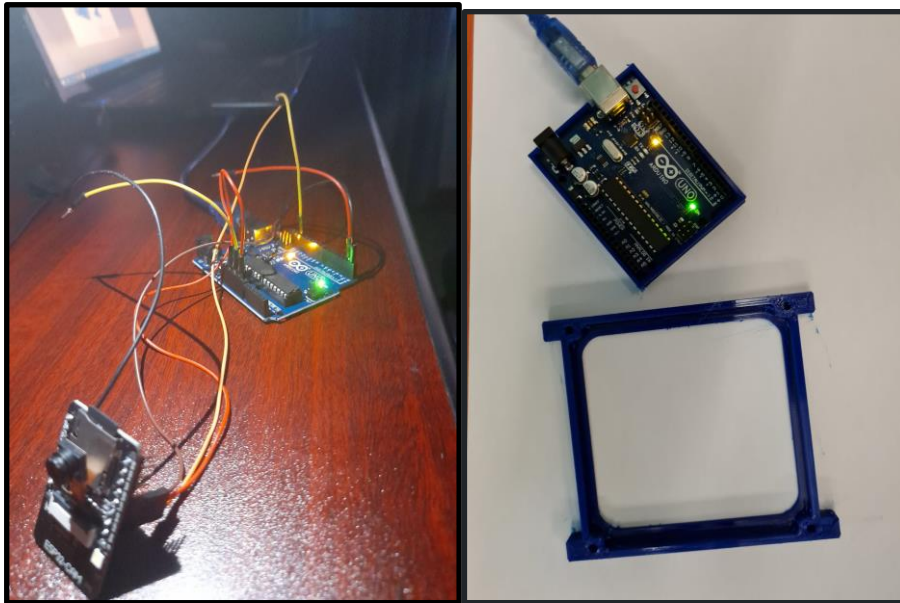


Figure 15: The picture on the left shows the plug in of the arduino uno and ESP32 cam, the picture on the right shows the arduino uno clearly in a frame.

f. Arduino IDE and project coding

Arduino IDE is an environment where sketches (code) can be written, verified and uploaded to various arduino boards and supported boards e.g ESP series.'

Sketches are the language by which boards are known to carry out functions. In our project, two major sketches were implemented: one to control the CubeSat's sensors, and another to handle all camera operations. A small snippet of the code used in this study is shown in Figure 16 below.

```

CameraWebServer | Arduino 1.8.16
File Edit Sketch Tools Help

CameraWebServer app_httpd.cpp camera_index.h camera_pins.h

void startCameraServer();

void setup() {
  Serial.begin(115200);
  Serial.setDebugOutput(true);
  Serial.println();

  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
  config.ledc_timer = LEDC_TIMER_0;
  config.pin_d0 = Y2_GPIO_NUM;
  config.pin_d1 = Y3_GPIO_NUM;
  config.pin_d2 = Y4_GPIO_NUM;
  config.pin_d3 = Y5_GPIO_NUM;
  config.pin_d4 = Y6_GPIO_NUM;
  config.pin_d5 = Y7_GPIO_NUM;
  config.pin_d6 = Y8_GPIO_NUM;
  config.pin_d7 = Y9_GPIO_NUM;
  config.pin_xclk = XCLK_GPIO_NUM;
  config.pin_pclk = PCLK_GPIO_NUM;
  config.pin_vsync = VSYNC_GPIO_NUM;
  config.pin_href = HREF_GPIO_NUM;
  config.pin_sscb_sda = SIOD_GPIO_NUM;
  config.pin_sscb_scl = SIOC_GPIO_NUM;
  config.pin_pwdn = PWDN_GPIO_NUM;
  config.pin_reset = RESET_GPIO_NUM;
  config.xclk_freq_hz = 20000000;
  config.pixel_format = PIXFORMAT_JPEG;

```

Figure 16: A snippet of the code used in this stud

g. CubeSat frame

Some components used to house our electronics and parts were 3D printed (Figure 17)

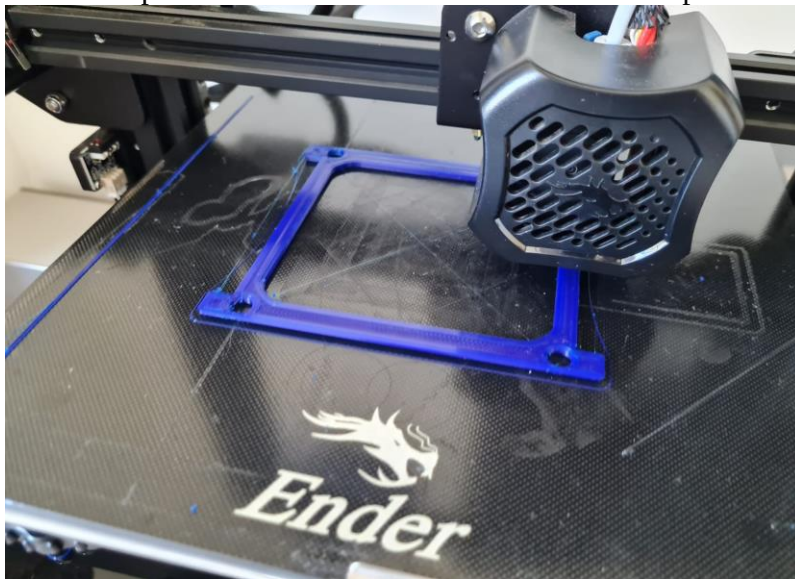
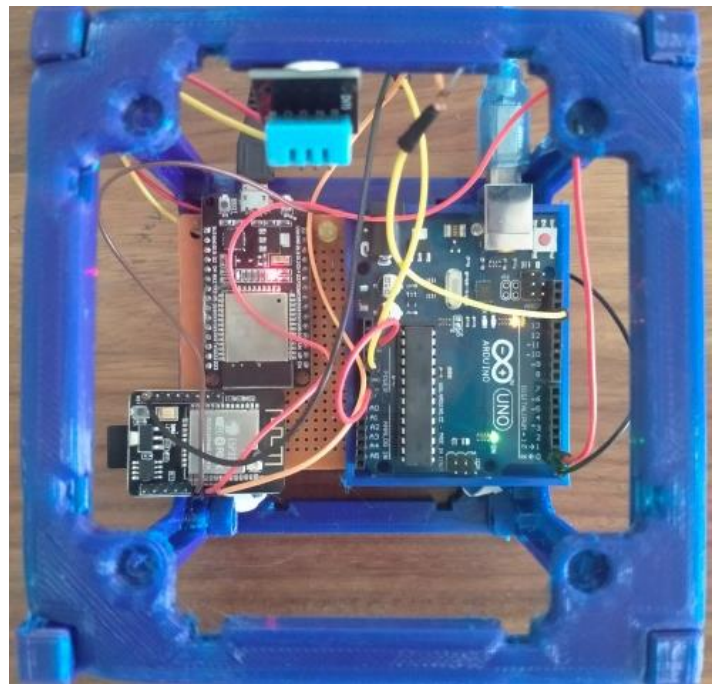
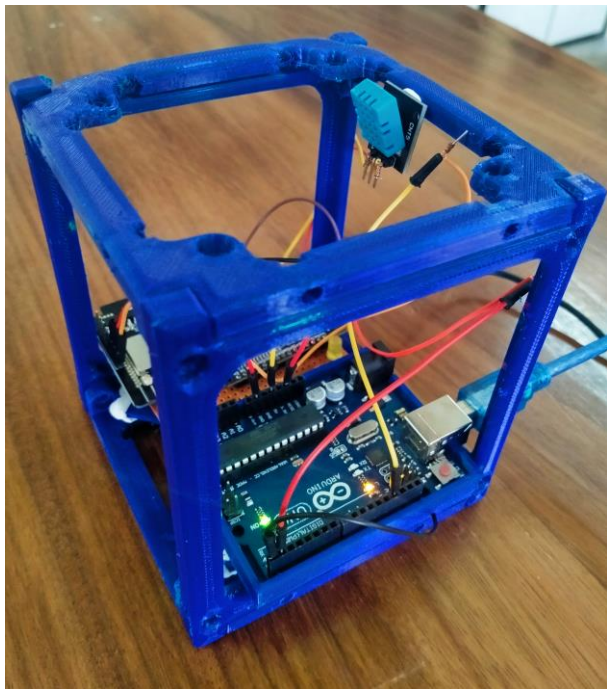


Figure 17: 3D printing of the CubeSat frame

h. CubeSat Prototype Images



DATA AND RESULTS

The results of the temperature (Figure 18) and humidity (Figure 19) sensors are presented below.

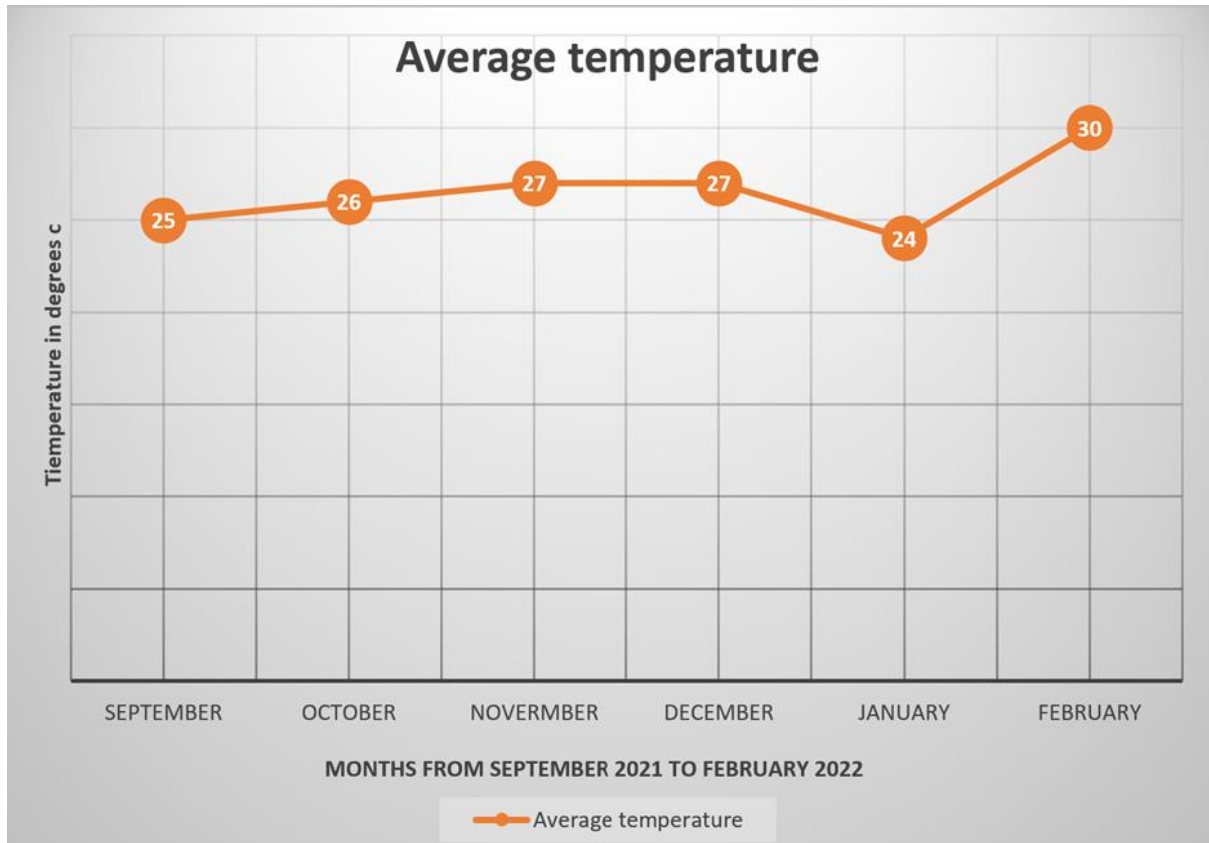


Figure 18: Average temperature detected between September 2021 and February 2022 for Mombasa County.

As you can see, average temperatures start rising in February, as the months of February- March have been known to be the warmest months in Kenya.

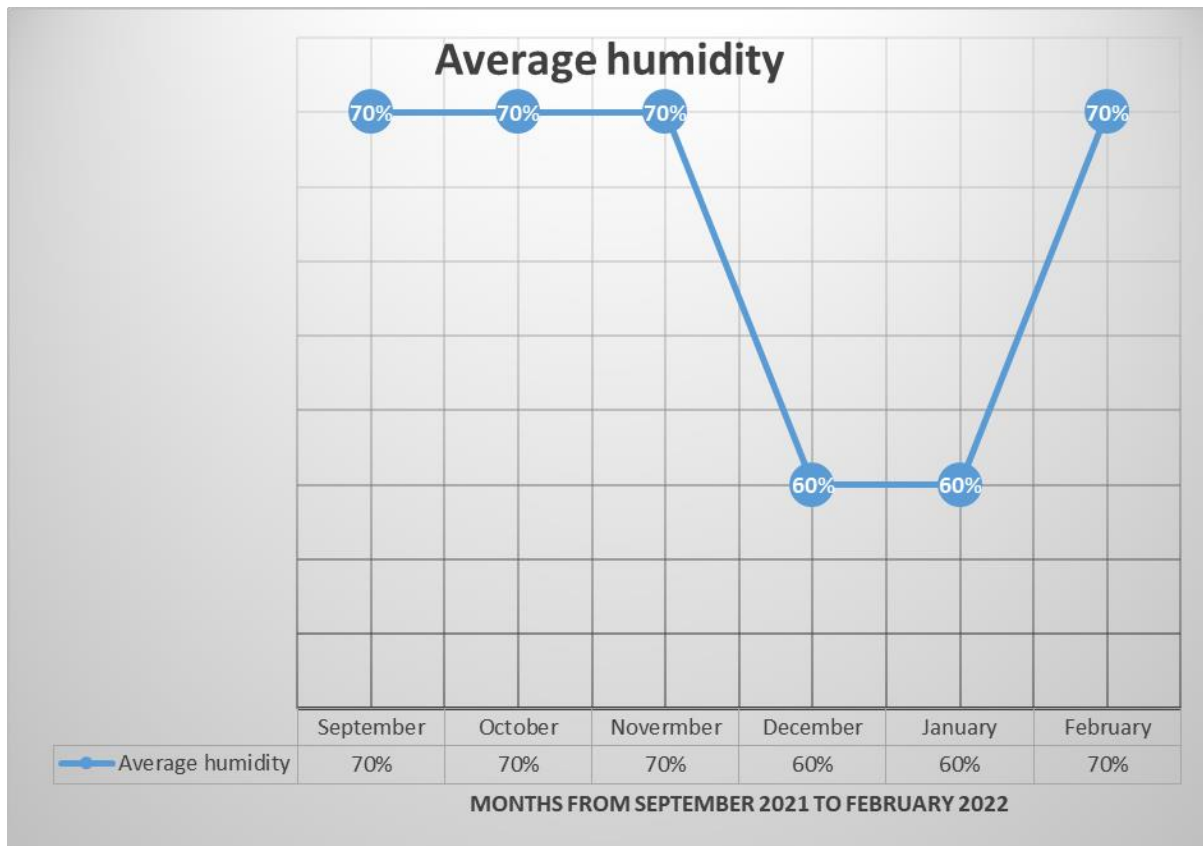


Figure 19: Average humidity detected between September 2021 and February 2022 in Mombasa County.

CONCLUSION

By the end of the study, we have come to a greater understanding of what cubesats are, how they work, and their potential in being implemented more in the aerospace field of engineering.

The engineering and building of a cubesat model helped us understand the different structures and components that go towards building these nanosatellites

We have gained towards working with arduinos and writing code for these microcontrollers.

Our project mentors greatly aided us throughout the process of researching, data collection and engineering.

BADGES

I am an engineer- Students have incorporated remote sensing technology and satellite imagery by engineering a cube sat.

The data is then used to identify distribution of droughts by identifying key determinants such as vegetation cover, areas of high relief, change in surface temperature and changes in precipitation and humidity.

The students programmed and calibrated temperature and humidity sensors into a model of a cube sat to showcase different environment variables that help identify desert like conditions and the fertility of the land

I am a data scientist- the student have collected data from satellite images from [digitalearth.africa.com](https://digitalearth.africa/). The students have also collected data from the temperature and humidity sensor.

The pictures taken by the integrated camera module operated by the students show various results and can help compare states and area of vegetation cover

I made an impact- the student research positively impacted the local community by incorporating satellite imaging technology in relation to humidity and temperature sensors to give an idea on how farmers can use this tool to aid with agricultural activities. This information can be used to conserve resources and target specify land for the best probability of increase crop yield

BIBLIOGRAPHY

NEMA, 2020. Desertification and drought day, 2020.

https://www.nema.go.ke/index.php?option=com_content&view=article&id=314&catid=10&Itemid=469

Simanyula, A. W. (2021). 3M Kenyans at risk of starvation due to severe drought. Dying livestock in Turkana, Marsabit, Mandera counties rings alarm bells. <https://www.aa.com.tr/en/africa/3m-kenyans-at-risk-of-starvation-due-to-severe-drought/2289146>

<https://www.conserve-energy-future.com/causes-effects-solutions-of-desertification.php>

<https://maps.digitalafrica.org>

<https://www.globe.gov>