



**University of Nairobi**  
**School of Computing and Informatics**

**AUTOMATED RAINFALL DATA EXTRACTION FROM  
SATELLITE IMAGERY FOR CROP INDEX  
INSURANCE**

**BY**

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## **Abstract**

Crop insurance uses rainfall as one of the indices on which farmers can be insured. The rainfall data can be obtained locally from the weather stations but it is limited to only 30 kilometres radius from a station. Though there are many sources of rainfall data, satellite data has not been explored in depth within the Kenyan context and by any insurance firm as a reference point. This project presents an automation prototype that extracts rainfall data from satellite imagery for crop index insurance. The prototype is implemented using python, .NET, PHP, HTML and PostGres/PostGIS. The prototype encompasses download module, data extraction and database storage modules. Mosaic algorithm is implemented using the pixel traversal algorithm. The output product is created using the supplied reprojection information and output parameters such as pixel size and easting and northing. The input products being satellite image products, the processing parameter used is a shape file to map out the desired regions and rain gauge stations.

Once an output product has been written it can be updated with an unlimited number of new input products. The "filling" of the final product follows the principle of fetching pixels from source products. The Mosaic Processor loops over all cells in the target grid and determines whether a pixel from a source product may be suitable to read into it. The pixel RGB value is referenced to an accompanying CLR file to determine the rainfall value the pixel holds. Rainfall data was extracted from bil images of April 2006 for each day. The rainfall data extracted from the satellite imagery was compared to the recorded meteorological data for the same period (mean monthly rainfall) for April 2006. The research concludes that rainfall can be extracted from satellite imagery and used for rainfall index insurance. The .bil images provide rainfall information for a radius of 8kms which can be improved with higher resolution images. With this, the crop insurers can have a larger pool of farmers to insure as there will be no need of being 30km radius from a rain gauge station. This research presents alternative source of rainfall data from the traditional rain gauges to be provided to farmers and insurance companies. The research concludes by recommending further work to be done with level 0 imagery to be used as input and higher resolution images to reduce the 8km by 8km to even a shorter distance.

## DECLARATION

This research project, as presented in this report, is my original work. This research work has not been carried out nor presented to any institution for academic or other purposes.

Signí í í í í í í í í í í ..

Dateí .....

**Wilberforce Daniel Wafula Wanjala**

**P56/73063/2012**

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This project has been submitted to the School of Computing and Informatics in partial fulfillment of the requirement of the Master of Science in Information Systems of University of Nairobi with my approval as the University Supervisor.

**Sign.....**

**Date.....**

**Dr. Daniel Orwa**

School of Computing and Informatics

## **DEDICATION**

This project is dedicated to my wife Linda Awuor and my sons Naeto and Keita, for their tremendous support and understanding when I had to put in long hours and effort into this project.

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## **Definitions**

AOI ó Area of Interest

BIL - Band Interleaved by Line (Image format)

FEWSNET- Famine Early Warning System Network

GIS ó Geographical Information System

HTML5 - HyperText Markup Language version 5

IFAD ó International Fund for Agriculture Development

KMD ó Kenya Meteorological Department

MPE - Multi-Sensor Precipitation Estimate

MSG - Meteosat Second Generation

NCSA - National Center for Supercomputing Applications

NOAA - National Oceanic and Atmospheric Administration

RCMRD ó Regional Centre for Mapping of Resources for Development

RFE ó Rainfall Estimates

RIEI - Rain Intensity Erosion Index

WFP ó World Food Programme

## CHAPTER 1: INTRODUCTION

### 1.1 Background

Rainfall index insurance is a microinsurance product designed to help farmers cope with the risk of uncertain rainfall. Its payouts are based not on individual outcomes of its customers, but instead on rainfall measured at a nearby reference weather station. This contract structure eliminates moral hazard, adverse selection, and costly claims adjustment, facilitating sale to small-scale farmers. Despite vast theoretical promise and extensive policy development, demand for rainfall index insurance has been low, especially when offered at market rates (S Cole, et al, 2012)

Weather indexed based insurance is a new form of insurance taking place in Kenya. Most Kenyan farmers depend on rainfall as the main source of water for their crops. In recent years, rainfall has been variable with long dry spells experienced in some parts of the country. The high risks involved with farming limits the willingness of farmers to engage in farming activities. This prompted insurance companies to come up with a product that would make farmers go about their farming activities without necessarily worrying about the end yield status.

An index (also known as 'coupon') policy operates differently. With an index policy a meteorological measurement is used as the trigger for indemnity payments. These damaging weather events might be:

- a certain minimum temperature for a minimum period of time;
- a certain amount of rainfall in a certain time period - this can be used for excess rain and also for lack of rain (drought) cover;
- Attainment of a certain wind speed - for hurricane insurance.

The classic insurance policy is replaced with a simple index. Instead of the usual policy wording, which would give the indemnity, or range of indemnity levels, on say a per hectare basis for a given crop, for losses from specific causes, the index merely gives a monetary sum which becomes payable on certification that the named weather event, of

specified severity, has occurred. The face value of the coupon may be standard, to be triggered once the weather event has taken place for the area covered. Alternatively it could be graduated, with the value of the coupon then being proportional to the severity of the event (R.A.J. Roberts, 2005).

## **1.2 Problem Statement**

Traditionally, crop indexed insurance is based on physically measuring the loss at the specified farm. An assessor from the insurance firm has to physically visit the site once an insured farmer reports the loss. Due to the vast acreage of the country, at times it takes weeks for an assessor to visit a specified area. It is also not possible to have assessors all over the country as it will be a big wage bill for the insurance companies.

Crop index insurance is limited by the availability of rainfall information for each square kilometer of the country. UAP insurance provides cover to farmers within 30km radius of a rain gauge station listed by KMD (UAP, 2010). This has denied a large group of farmers from accessing the insurance product hence losses are not mitigated in cases of drought or intense rainfall.

There exist large repositories of satellite imagery for rainfall information that has not been exploited for crop index insurance in Kenya.

## **1.3 Rationale of the study**

Insurance companies depend solely on rainfall measurements at the nearest rainfall gauge station. This has also made insurance cover for crops to be applicable at a specific radius from a KMD approved rainfall gauge. In addition, insurance companies undertaking crop insurance in Kenya send assessors to the insured farmer's farm to physically determine the damage brought about by rain or not.

## **1.4 Main Objective**

The main objective of this research was to develop a prototype that can automate rainfall extraction from satellite imagery provided by Famine Early Warning Systems Network for crop index insurance.

## **1.5 Specific Objectives**

1. To evaluate various rainfall extraction techniques from satellite imagery.
2. To implement pixel traversal of mosaicking algorithm for rainfall extraction from satellite imagery.
3. To design and develop a prototype that automatically downloads and processes satellite data to determine: the rainfall (index), location and time.

## **1.6 Research Questions**

The main output of this research was a prototype that can be used to automatically extract rainfall data from satellite imagery and use the extracted data as a reference point for paying out claims of crop index insurance. Such a prototype can be used to develop a fully-fledged system that can automatically download, process, disseminate rainfall data. This can further enable insurance companies cut costs by having the information readily available and not sending an assessor to the field. Insured farmers will also benefit from the historical information stored on the system to determine rainfall patterns

1. Can rainfall information be automatically extracted from satellite imagery by extracting pixel values through pixel traversal?
2. What are the techniques that can be used for rainfall data extraction from satellite imagery?
3. In what format can the extracted information be presented for easier dissemination to farmers and crop insurers?

## **1.7 Limitations**

- i) Lack of storage for each of the satellite imagery pass as each image is around 1gigabyte.

## **1.8 Scope**

This study covered the problem of automatically extracting rainfall data from satellite imagery. It also covered the problem of how to disseminate the information to the insurance company as well as farmers. A prototype was developed to cater for the problem.

## **1.9 Assumption**

Some of the assumptions of the study were:

1. Targeted Insurers and farmers have access to internet.
2. Data will continue being hosted by FEWSNET. FEWSNET uses extensive data types, including gridded rainfall data and vegetation data from satellite imagery, to summarize current climatic situations (Ross, et al 2009).

## CHAPTER TWO: LITERATURE REVIEW

### 2.0 Introduction

Index based crop insurance uses weather observations as proxies for losses in production or quality and does not require loss assessments. It can be stated that index based crop insurance are contingent claims contracts for which payouts are determined by an objective weather parameter (such as rainfall, temperature, or soil moisture) that is highly correlated with farm-level yields or revenue outcomes.(Marc Sadler, et al 2011)

Rainfall index insurance is a microinsurance product designed to help farmers cope with the risk of uncertain rainfall. Its payouts are based not on individual outcomes of its customers, but instead on rainfall measured at a nearby "reference" weather station. (Cole et al., 2010).

UAP has partnered with Syngenta to offer *Kilimo Salama* an insurance product designed for maize and wheat farmers so they may insure their farm inputs against drought and excess rain. The product is available to farmers in five regions across Kenya: Bungoma-Busia, Oyugis-Homa Bay, Nanyuki-Timau, Embu and Eldoret. Kilimo Salama is a product launched under the Agricultural Index Insurance Initiative, a partnership between UAP Insurance and the Syngenta Foundation for Sustainable Agriculture (SFSA). The product is furthermore implemented in partnership with the agri-businesses MEA Limited and Syngenta East Africa Limited, the telecommunications company Safaricom, the Kenya Meteorological Department, and the NGO CNFA/AGMARK. The insurance uses automated weather stations to monitor the rainfall. Based on the stations measurements and a predefined formula of crop rainfall needs, payouts are made. This method enables farmers as small as one acre to be insured. This method of using weather stations measurement in combination with a predefined crop growth formula is often referred to as "index based insurance." (UAP, 2010).

The World Bank, in close collaboration with Malawi's National Association of Small Farmers (NASFAM), developed an index-based crop insurance contract that is more efficient and cost-effective than traditional crop insurance and can easily be distributed to

individual smallholder farmers to increase their access to finance and to protect farmers and loan providers from weather risk. The program was piloted in 2005. The weather-based crop insurance contracts were initially offered to farmers as a pilot program in the areas of Kasungu, Nkhokotakota, Lilongwe North, and Chitedze. The contracts were designed to provide compensation when rainfall during a crop growing cycle was insufficient for farmers to grow and to optimize their yields. Weather index insurance does not measure changes in yields; instead, it measures changes in rainfall, assuming that if rainfall is low, then farmers' yields will also be poor.

The Malawi index-based crop insurance measures the amount of rain recorded at local meteorological stations. In case of severe drought, it is assumed that all farmers within a 20-30 kilometer radius will be similarly affected. The insurance contract is bundled with loans to farmers that cover the cost of high-quality seeds. The insurance pays off part or the entire loan in case of severe drought. The sum insured is the loan amount and interest payable. Payouts are automatically made to the bank if the index hits the specified contract threshold at the end of the contract. (Marc Sadler, et al, 2011)

From 1998 to 2000, the NOAA/CPC produced Version 1.0 of the satellite-based rainfall estimates using the algorithms of Herman et al. (1997), while Version 2.0 has been in production since January 2001 (Xie and Arkin, 1997; Love et al., 2004). The basic inputs for the creation of the satellite-based rainfall estimates are geostationary thermal infrared (IR) satellite imagery, passive microwave (PM) imagery, and daily raingauge reports from the Global Telecommunications Systems (GTS) of the World Meteorological Organisation (WMO). For Version 1.0, rainfall was estimated from cold-cloud duration (CCD) calculated with a temperature threshold of 235K from the IR imagery, ingested on a 30-minute basis and aggregated on a daily time-step, with bias removed from IR-based estimates using interpolated GTS rainfall fields (Herman et al., 1997). The Version 2.0 estimates incorporate additional satellite data from the Special Sensor Microwave/Imager (SSM/I) satellite precipitation estimates acquired at a frequency of up to 4 times a day and the Advanced Microwave Sounding Unit B (AMSU-B) satellite rainfall estimates acquired twice a day (Love et al., 2004). In Version 2.0, rainfall is first estimated

separately from 3 satellite sources with a maximum likelihood approach that uses weighting coefficients inversely proportional to the square of individual data random errors. Finally, the satellite rainfall estimates are merged with interpolated rainfall from available GTS data (approximately 1 000 usable stations in Africa) so that the satellite data provide the rainfall, unlike any other hydrological parameters, is highly discontinuous both in space and time. Instantaneous rain rates may vary from fractions of mm to over 100mm per hour and the variations of rainfall intensity with duration can be large from one rainfall event to another as well as from region to region. Thus the performance of satellite rainfall estimation is very important in order to use satellite data for water resources assessment (Ochieng, 2009).

## **2.1 Different sources of rainfall data**

Rainfall data can be obtained from meteorological stations situated around the country. Traditionally rainfall is measured using rain gauges. A rain gauge is simply an instrument that is designed to measure the amount of rain that reaches the ground surface during a storm. Rain gauges are considered the most traditional method for measuring rainfall. They have been used historically to provide rainfall quantities and rates at a single point in space. The basic idea of most rain gauges is to collect rainwater into a cylindrical vessel of a fixed diameter. Rainfall measurements are usually provided in units of water depth (inches or millimeters). The volume of collected water is divided by the area of the cylinder opening and converted into a depth or rain. There are different types of rain gauges that can be classified into two main categories: non-recording gauges, and recording gauges (AMS Glossary, 2000).

An Automatic weather station (AWS) is an automated type of traditional weather station, either to enable measurements from remote areas or to save human labour. The system may report in several different ways. It may be in real-time via a local link to a computer system or via telecommunications or satellite systems. GSM mobile phone technology has also been known to be used. An alternative is the storage of the information in local data storage such as flash memory for retrieval at a later stage. Most automatic weather



stations have Thermometer for measuring temperature, Anemometer for measuring wind speed, Hygrometer for measuring humidity, Barometer for measuring pressure. Some of them even have rain gauge for measuring rainfall, ceilometers for measuring cloud height, present weather sensor or visibility sensor (AWSWebsite, July 2014).

## **2.2 Precipitations Imagery**

There are different types of satellite data (imagery) that provides precipitation information.

### **2.2.1 Rainfall Estimates – RFE**

The RFE imagery combines Meteosat infrared data, rain gauge reports from the global telecommunications system, and microwave satellite observations to provide daily rainfall estimate in mm at an approximate horizontal resolution of 10 km. These products provide input for hydrological and agrometeorological models as well as climate information e.g. compare the current state of rainfall with previous time periods (E. Bartholome, 2010).

### **2.2.2 Multi-Sensor Precipitation Estimate - MPE**

The MPE is an instantaneous rain rate product (in mm/hr) which is derived from the IR-data of the geo-stationary EUMETSAT satellites. The product is only suitable in convective weather situations. MPE is used for operational weather forecasting in areas with poor or no radar coverage (E. Bartholome, 2010).

### **2.2.3 Rain Intensity Erosion Index - RIEI**

The RIEI is a qualitative index with isolines combining short terms rain intensities (3 hours) and medium term rainfall amounts (3days, 10 daysí etc.). It is of great importance for flood risk and land degradation (E. Bartholome, 2010).

## **2.3 Satellite Data formats**

Satellite image data files consist of two parts: a header and the data. The header contains information about the data such as when it was acquired, which satellite produced it, the amount and organization of the data, and the name of the latitude/longitude file that applies to it. The user is given the option of including the latitude/longitude data within the satellite image file, or putting it in a separate file, and referencing this separate file through the header. Latitude/longitude data tends to be large and is often common to multiple data sets. Putting it in a separate file is a good way to save disk space.

### **2.3.1 HRIT/LRIT**

High Rate Information Transmission (HRIT) and Low Rate Information Transmission (LRIT) are the CGMS standards agreed upon by satellite operators for the dissemination of digital data originating from geostationary satellites to users via direct broadcast. The distinction between the two standards, as their names suggest, is the data rate (bandwidth) necessary to convey the data content. LRIT data are typically disseminated at speeds up to around 256 Kbps while HRIT data are typically disseminated at speeds up to 10 Mbps. Commonly the content of LRIT data streams are subsets of the equivalent HRIT data, with subsampling and lossy compression applied (Dang, 2012).

### **2.3.2 HRPT/LRPT**

High Rate Picture Transmission (HRPT) and Low Rate Picture Transmission (LRPT) are the CGMS standards agreed upon by satellite operators for the dissemination of digital data originating from low earth orbit satellites to users via direct broadcast. In a very similar way to HRIT/LRIT, described above, the distinction between the two standards is the data rate (bandwidth) necessary to convey the data content. LRPT data are typically disseminated at speeds less than 150 Kbps while HRPT data are typically disseminated at speeds greater than 0.5 Mbps (Dang, 2012)

### **2.3.3RFE**

Rainfall Estimate is available in RFE 2.0. RFE2.0 uses additional techniques to better estimate precipitation while continuing the use of cold cloud duration, or CCD (derived from cloud top temperature), and station rainfall data. Meteosat 7 geostationary satellite infrared data are acquired in 30-minute intervals, and areas depicting cloud top temperatures of less than 235K are used to estimate convective rainfall. WMO GTS data from ~1000 stations provide station rain gauge totals, and are taken to be the true rainfall within 15-km radii of each station. Two new satellite rainfall estimation instruments are incorporated into RFE 2.0, namely, the Special Sensor Microwave/Imager (SSM/I) on board Defense Meteorological Satellite Program satellites, and the Advanced Microwave Sounding Unit (AMSU) on board NOAA satellites. SSM/I estimates are acquired at 6-hour intervals, while AMSU rainfall estimates are available every 12 hours. RFE 2.0 obtains the final daily rainfall estimation using a two part merging process. All satellite data are first combined using the maximum likelihood estimation method, then Global Telecommunication System (GTS) station data are used to remove bias.

The data is obtained from <http://earlywarning.usgs.gov/fews/africa/index.php> in the form of zip files. FEWSNET RFE has a resolution of 1km. The RFE files are distributed in BIL (Band Interleaved by Line) format, an uncompressed file containing the actual pixel values of an image together with the image description, header file, statistics file, the resolution file and color file.

### **2.3.4 Shape file (vector)**

A shapefile is vector data format from Environmental Systems Research Institute (ESRI). All satellite data are first combined using the maximum likelihood estimation method, then Global Telecommunication System (GTS) station data are used to remove bias. Shapefiles spatially describe vector features: points, lines, and polygons, representing, for example, water wells, rivers, and lakes. Each item usually has attributes that describe it, such as name or temperature. The shapefiles will be obtained from the Regional Centre for Mapping of Resources for Development (RCMRD).

### **2.3.5 WMO binary data exchange formats - BUFR, GRIB**

The WMO Binary Universal Form for the Representation of meteorological data (BUFR) is a binary code designed to represent any meteorological data set employing a continuous binary stream. It has been designed to achieve efficient exchange and storage of meteorological and oceanographic data. It is self-defining, table driven and very flexible data representation system, especially for huge volumes of data ([www.wmo.int](http://www.wmo.int)).

Similarly, another widely used bit-oriented data exchange scheme is the WMO GRIddedBinary (GRIB) format. GRIB is an efficient vehicle for transmitting large volumes of gridded data to automated centers over high-speed telecommunication lines using modern protocols. An updated version of GRIB, commonly abbreviated to GRIB-2, is currently being introduced and is most relevant for use with satellite data (WMO GRIB Edition 2).

### **2.3.6 NetCDF, HDF, XML**

NetCDF (Network Common Data Form) is a machine-independent, self-describing, binary data format standard for exchanging scientific data. The data format is "self-describing". This means that there is a header which describes the layout of the rest of the file, in particular the data arrays, as well as arbitrary file metadata in the form of name/value attributes. The format is platform independent. The data arrays are rectangular, not ragged, and stored in a simple and regular fashion that allows efficient subsetting (Dey, 2007).

Hierarchical Data Format, commonly abbreviated HDF, HDF4, or HDF5 is a library and multi-object file format for the transfer of graphical and numerical data between computers. It is created and maintained by the NCSA. The freely available HDF distribution consists of the library, command-line utilities, test suite source, Java interface, and the Java-based HDF Viewer (HDFView). HDF supports several different data models, including multidimensional arrays, raster images, and tables. Each defines a

specific aggregate data type and provides an API for reading, writing, and organizing the data and metadata. New data models can be added by the HDF developers or users. HDF is self-describing, allowing an application to interpret the structure and contents of a file without any outside information. One HDF file can hold a mixture of related objects which can be accessed as a group or as individual objects (WMO website).

The Extensible Markup Language (XML) is a general-purpose markup language. Its primary purpose is to facilitate the sharing of data across different information systems, particularly via the Internet. More details of XML and its potential role in the exchange of binary data may be found in the web pages of the W3C organisation (WMO website).

## 2.4 Raster Data

A raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid), as shown below, where each cell contains a value representing information, such as temperature.

Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.

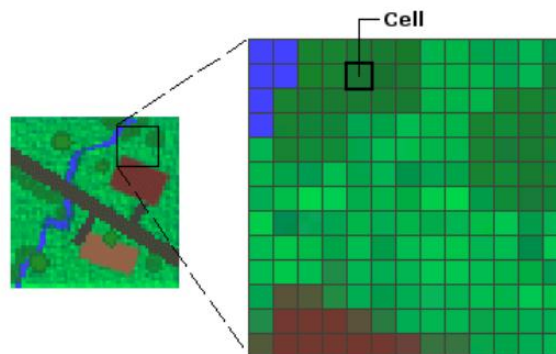


Figure 1 - Raster File (Source, fire.org)

Images are stored as raster because additional features e.g. points, measurements (rainfall) can only be stored as either a raster or a feature (vector) data type.

The advantages of a raster include:

- A simple data structure ó A matrix of cells with values representing coordinate and sometimes linked to an attribute table
- A powerful format for advanced spatial and statistical analysis
- The ability to represent continuous surfaces and perform surface analysis
- The ability to uniformly store points, lines, polygons, and surfaces
- The ability to perform fast overlays with complex data sets

The graphic below illustrates a raster data set with attribute table. The NoData values are not calculated in the raster attribute table. There are also three columns that are calculated by default; the other columns can be added individually or by using a join operation.

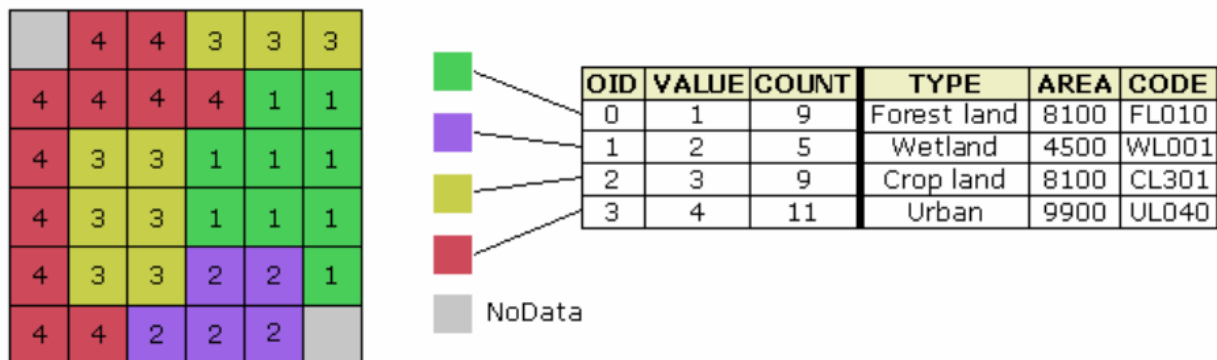


Figure 2 - Raster data set with attribute table (Source Arcgis 9.3 Desktop help)

When a raster attribute table is generated, there are three default fields created in the table: OID, VALUE, and COUNT. It is not possible to edit the content in these fields. The ObjectID (OID) is a unique system-defined object identifier number for each row in the table. VALUE is a list of each unique cell value in the raster data sets.

COUNT

represents the number of cells in the raster data set with the cell value in the VALUE

column. Cell values represented by NoData are not calculated in the raster attribute table (ArcGIS 10 Desktop Help).

### 2.4.1 Raster Image Formats

There exists many raster file formats but for the purpose of this study we shall consider only two:

#### ESRI BIL format

Each raster image is provided as four main files, with the extension of each file defining the file type (see table below). Additionally, basic metadata information is provided both in XML format (.xml) and in HTML format (.htm) following the FGDC standard. Projection information is provided in an ASCII text file (.prj). All raster data are in geographic (latitude/longitude) projection, referenced to datum WGS84.

**Table 1 - Bil Image files**

<b>Extension</b>	<b>File Type</b>
.bil	Raster data file
.hdr	Header file
.blw	World file
.stx	Statistics file

#### Raster data file (.bil)

The raster data for each layer are provided as unsigned integer data in a simple binary raster format (8-bit, 16-bit, or 32-bit). There are no header or trailer bytes embedded in the image. The data are stored in row major order (all the data for row 1, followed by all the data for row 2, etc.)

## Header file (.hdr)

The raster data header file is an ASCII text file containing size and coordinate information for the layer. Many standard software packages require the header file to provide important geo-referencing information for the image. The following keywords are used in the header file:

**Table 2 - bil Image keywords**

BYTEORDER	byte order in which image pixel values are stored I = Intel byte order (least significant byte first)
LAYOUT	organization of the bands in the file BIL = band interleaved by line
NROWS	number of rows in the image
NCOLS	number of columns in the image
NBANDS	number of spectral bands in the image (1 for all raster layers)
NBITS	number of bits per pixel (8, 16 or 32)
BANDROWBYTES	number of bytes per band per row (twice the number of columns for the 16-bit image; four-times for the 32-bit image)
TOTALROWBYTES	total number of bytes of data per row (twice the number of columns for the 16-bit image; four-times for the 32-bit image)
BANDGAPBYTES	the number of bytes between bands in a BSQ format image (0 for all raster layers)
NODATA	Value used for masking purposes (-9999 for all elevation images DEM and CON; -9 for all drainage direction maps DIR; 0 for all flow accumulation maps ACC)
ULXMAP	longitude of the center of the upper-left pixel (decimal degrees)
ULYMAP	latitude of the center of the upper-left pixel (decimal degrees)
XDIM	x-dimension of a pixel in geographic units (decimal degrees)
YDIM	y-dimension of a pixel in geographic units (decimal degrees)



### **World file (.blw)**

The world file is an ASCII text file containing coordinate information. It is used by some packages for geo-referencing of image data. On the next page is a table with the parameters provided in the world file (Dang, 2012).

**Table 3 - Worldfile parameters**

<b>XDIM</b>	<b>x-dimension of a pixel in geographic units (decimal degrees)</b>
Rotation term	always zero
Rotation term	always zero
Negative YDIM	negative y-dimension of a pixel in geographic units (decimal degrees)
XMIN	longitude of the center of the upper-left pixel (decimal degrees)
YMAX	latitude of the center of the upper-left pixel (decimal degrees)

### **2.5 PERSIANN Algorithm**

Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), provides global precipitation estimates using combined GEO-IR and PMW precipitation data from multiple GEO and LEO satellites.<sup>366</sup> The algorithm uses an artificial neural network to extract cold cloud pixels and their neighboring textures from the GEO-IR imagery, and associates variations in each pixel's brightness with temperature to estimate the pixel's surface rain rate. GEO-IR-based precipitation estimates are further adjusted by the PMW precipitation estimates, using the data from LEO satellites. A feedback process using the PMW estimates as the reference surface precipitation for the adjustment may further improve estimate quality.

The recently developed PERSIANN Cloud Classification System (PERSIANN-CCS), implements image processing and pattern classification techniques based on analysis of GEO-IR cloud images.<sup>8610</sup> Rainfall estimation from the PERSIANN-CCS is shown in Figure 1. First, image segmentation is used to separate cloud patches from their image background using a watershed delineation process. This is followed by extraction and

classification, in which cloud patches are treated as independent objects and described by object features such as patch coldness, size, shape, and texture. Classification of cloud-patch objects is achieved through an unsupervised self-organizing feature-map clustering scheme. When patch rainfall is assigned to a classified patch group, it establishes an interpretative relationship between the cloud-patch property and rainfall. The classified patch group's rainfall distribution is described by a set of GEO-IR brightness temperature and rainfall rate (Tb-R) functions. Parameters of the nonlinear Tb-R functions are calibrated from the spatial and temporal co-located satellite image and radar/PMW rainfall images (Kuolin Hsu et al, 2012).

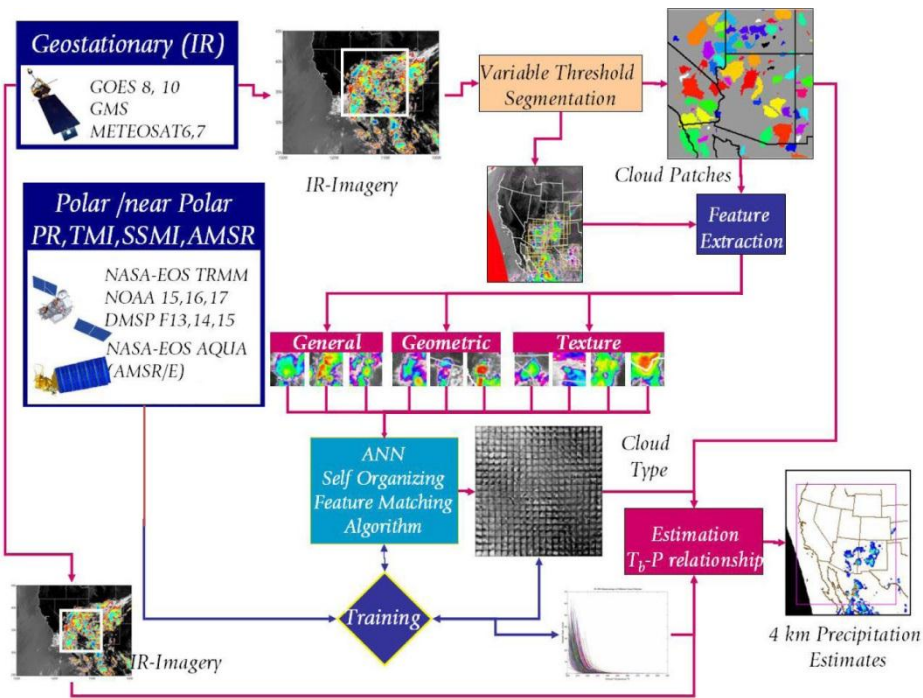


Figure 3 - PERSIANN-CCS (Source, Kuolin Hsu et al, 2012)

Table 4—Research Input Products

Input Product	Meaning for Research	Source of Data
Bil image .BIL	Image indicating a decadal (10 day series) of rainfall within the horn of Africa (Kenya, Uganda, Tanzania, Somalia, Rwanda & Burundi)	FEWSNET - <a href="http://earlywarning.usgs.gov/fews/africa/index.php">http://earlywarning.usgs.gov/fews/africa/index.php</a>

Machakos and Abardares Shape file .SHP	A shapefile with coordinates to provideclipping of the desired region from the .BIL image.	Regional Centre for Mapping of Resources for Developmenet (RCMRD)
Rainfall per Rain stations in the study areas (tabulated Excel file)	The rainfall will be used as a control measure to determine if the results obtained from the .BIL image have a corellation.	Kenya Meteorological Department

## 2.6 Mosaic Algorithm

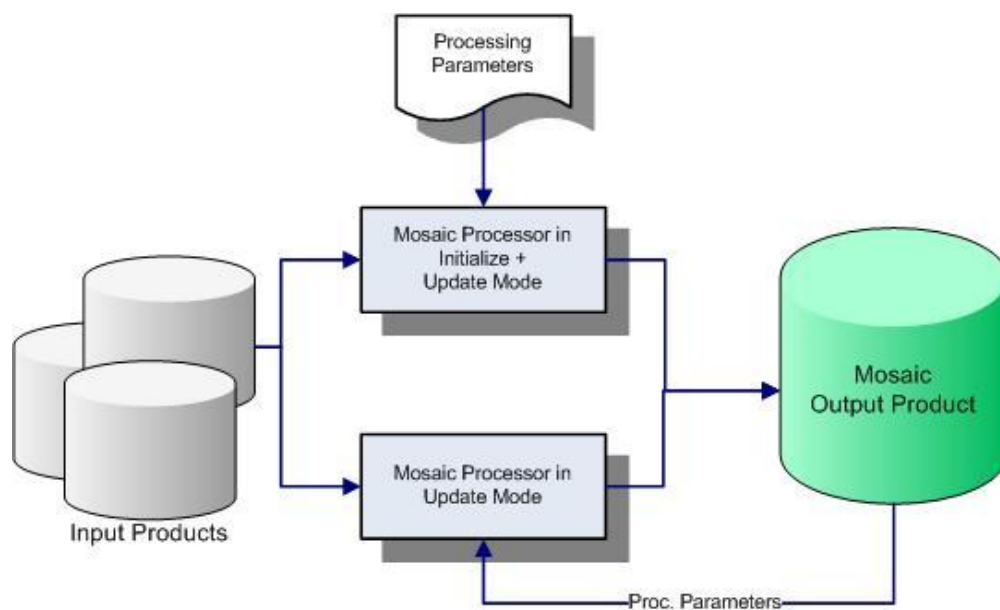


Figure 4 - Data flow of the Mosaic Processor (Source Herman et al., 1997)

- In the first step the output product is created using the supplied reprojection information and output parameters such as pixel size and easting and northing. The input products in this case are satellite image products.
- The Processing parameter used is a shape file to map out the desired regions.
- Once an output product has been written it can be updated with an unlimited number of new input products. The "filling" of the final product follows the principle of fetching pixels from source products. The Mosaic Processor loops over all cells in the target grid and determines whether a pixel from a source product may be suitable to read into it. This is done by looking up the nearest

neighbour pixel in the input product that contains the geographical center coordinate of the current output pixel being handled.

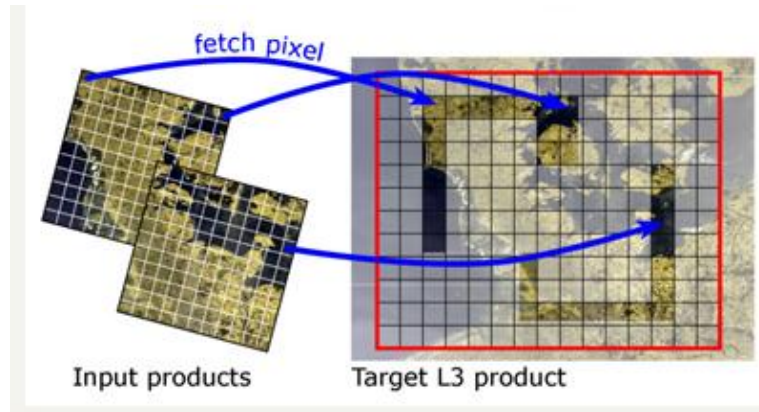


Figure 5 - Principle of Mosaicing (Source Herman et al., 1997)

The red rectangle marks the geographic boundary of the image; black lines are target grid cells. The bands of the output products are defined by output variables.

- Pixel values are accumulated using the arithmetic mean of all valid input pixels of all input products found for a given output pixel. An output variable has a name and an expression comprising mathematical operators, functions and symbols referencing the flags and bands defined in the input products.

Whether or not a pixel value is valid is determined by a set of valid pixel criteria. A valid pixel criterion is a boolean expression comprising mathematical operators, functions and symbols referencing the flags and bands defined in the input products. The mosaic processor can take any number of valid pixel criteria which can be either AND or OR combined. If no valid pixel criterion is given, all pixels are assumed as being valid (Herman et al., 1997).

**Table 5 -Mosaic algorithm items**

<b>Item</b>	<b>Component</b>	<b>Remarks</b>
Rainfall Product .Zip file	Input Product	The products are initially downloaded as a zip file and stored on a local drive
Rainfall product .Bil Image (extracted from zip file)	Input Product	The rainfall image (.Bil) extracted from the zip file.
Shapefile	Processing Parameters	The shape file used to clip the area of interest for the project
Rainfall indices	Mosaic Output product	This is the final data that will be stored onto a database to enable referencing in future.

## **2.7 Why Mosaic Algorithm over PERSIANN Algorithm**

This study incorporates mosaic algorithm because of the following advantages it has over the PERSIANN Algorithm:

- Mosaicking involves pixel replacement with an average value rather than pixel removal for the case of PERSIANN while doing a cloud reduction analysis.
- Pixel Values are averaged from other products giving the nearest mean
- Mosaicking is sequential while PERSIANN is random, the user is able to know at what point the algorithm is at any time.
- Mosaic Algorithm provides means to implement the binning technique using maximum likelihood, arithmetic mean, Minimum/Maximum.

## **2.8 Review of Existing Systems**

Most of the satellite imagery processing is undertaken by using GIS or Remote Sensing software e.g ArcGis, Envi, Erdas. The software are very efficient and require a background in the two fields to be able to get basic information as rainfall precipitation

from the satellite data. The European Union funded the Joint Research Centre (JRC) to develop an automated system that is very compressive only to vegetation satellite imagery. Novice users will require writing additional scripts of code to extract rainfall information. Basically there is no implementation of a system that provides rainfall as an index to insurance companies in our context but there exists systems that extract weather information from satellite imagery.

Below is a comparison of the proposed system and the E-Station:

**Table 6 - Comparison of the E-Station and proposed Automated Rainfall Index Extraction System**

	<b>E-station</b>	Proposed System
Product's Source	Mainly EUMESAT	FEWSNET
Operating System	Linux	Windows
Interface	Command based	GUI
Hardware Structure	3 separate computers undertaking separate processing	1 computer
Visualization Interface	One of the computer s used for visualization, requires a micro-LAN	Centralized machine
Image Processing	Uses NDVI mean for final product production	Pixel by Pixel value as per the Mosaicking algorithm.

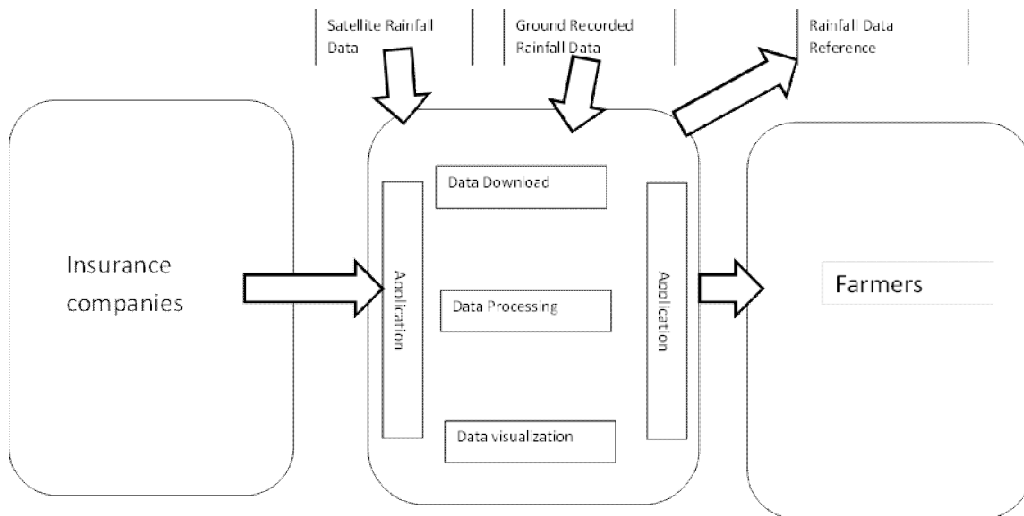
## **2.9 Relevance of the algorithm to the study**

Mosaicking involves first of all extraction of an area of interest using the geographical extents of the given location. For this research the area of interest will be county/district. The extracted area will be traversed and values extracted into a matrix of values detailing the rainfall data.

The system implementation was mainly depended on the algorithm as applicable to the Kenyan insurance scene, applicable to an area that has high rainfall values and a sparse one.

## 2.10 Conceptual Framework

The role of the prototype was to process automatically the rainfall data received from FEWSNET to provide rainfall data in areas where there are no gauge stations for purposes of index insurance. The whole system consists of data downloading, extraction, processing, storage and dissemination component as indicated in figure 6 below.



**Figure 6-Conceptual Framework for rainfall data extraction from satellite imagery**

## CHAPTER 3: RESEARCH METHODOLOGY

### 3.0 Introduction

Methodology presents an overview of the methods to be used in the study. Research is defined as a human activity based on the intellectual investigation and aimed at discovering, interpreting and revising human knowledge on different aspects of the world.

The objective of research methodology was to provide a standard method and guidelines to ensure that the project was completed on time and was conducted in a disciplined, well-managed, and consistent manner that promotes the delivery of quality product and results. This research consisted of three tasks. The first task was to evaluate various rainfall extraction techniques from satellite imagery. Second task was to implement pixel traversal of mosaicking algorithm for rainfall extraction from satellite imagery and finally the last task develop an automated system to extract rainfall information from satellite imagery.

This chapter therefore provides an understanding of how this project was conducted and organized in order to obtain information that could be helpful for studying and developing a simple prototype for rainfall information extraction from satellite images. Satellite images provide data for various uses. Data extracted from satellite imagery provide information that assist in making decisions from past experiences. Computer applications are used to extract the data from various types of satellite images. Pixel traversal is a mosaicking mechanism used to read pixel by pixel value from an image. Pixel by pixel value reading is intuitive but slow. This prompts a reference file to be used to obtain specific pixel values from the larger raster file. Since Pixel traversal requires an intelligent software its also important to consider what software development methodologies are used to build the final software prototype.



### **3.1 Research Design**

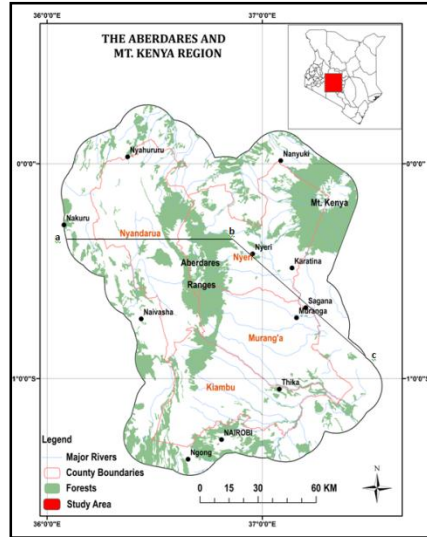
The approach had qualitative dimensions in determining highly rainfall receiving areas (highlands) as well as a semi arid area. The qualitative aspect used focus group discussion (student, lecturer) to determine the two diverse areas within the country in terms of weather, and from recent media reports as well as application of the *Kilimo Salama* product from UAP insurance. The Aberdares is a source of many rivers and

#### **3.1.2 Study Area**

This research considered two study areas with diverse rainfall patterns. The areas were picked due to their proximity to each other but with diverse rainfall patterns. There has been a lot of study on the two areas in recent past with focus on food security, frost and forest cover (Malaso, 2013). This studies have provided a good reference source for this research. One area was the Aberdares and Mt Kenya region to be in a position to assert the value of the system.

##### **Aberdares**

This study area is located within the Kenyan highlands, one of the major water towers in Kenya and consisting the Aberdare forest and national park. Spatially, the area covers four counties, Nyandarua, Kiambu, Murang'aa and Nyeri counties (figure 7 below). The area is located between the latitudes: 0016'53.51"N and 01027'44.71"S and longitudes: 3603'25.51"E and 37033'24.90"E. The study area is approximately 21399km<sup>2</sup>. The altitudes of the study area range from 948m to 5065m in Mt. Kenya and 3900m in the Aberdares.



**Figure 7 -Study area, Aberdares and Mt Kenya Region (Source RCMRD)**

The topography of the study area is characterized by mountain ranges (the Aberdare ranges), strong local variations and feature elevations resulting in an undulating topography including valley systems. The variations in topography and altitude make this region a suitable choice for the study since altitude is an important determinant when it comes to choice of crops to cultivate, and frost occurrence, as well as the amount of rainfall, and wind patterns.

The average annual rainfall of the region varies across the plains and ranges from 400mm in the low eastern plains to 2200mm on the southeastern windward side of the Nyandarua Range in 2200 ó 2700 m asl (the rainfall data is recorded from the Nyeri, Thika and the Nyahururu stations respectively). It is within this altitude range of between 2200-2700 that condensation and rain from the clouds of the South East Trade winds take place (Jaetzold, et al., 2007).

The distribution of rainfall is typically bimodal with two distinct rainy seasons. The first rainy season has its peak in April and the second has its peak in November. The intervening dry season is distinct, except in the misty and cloudy altitudes above 1800 m, and west of the Aberdare Range and Mt. Kenya where rains induced from Western Kenya occur (Jaetzold, et al., 2007).

**Machakos**

The district has a variety of topographical features. The landscape is largely a plateau that rises from 700m to 1700 m above sea level and is interrupted by an escarpment and a series of hill masses, the highest of which is Kilimambogo or Ol Donyo Sabuk, which rises to 2,144m above sea level. The district is bound in the western part by the Kapiti and Athi Plains, in the north by the Athi River which curves round the solitary hill of Ol Donyo Sabuk to flow to the south east. Rising steeply to the north east of Athi River is the Yatta Plateau, which is broken by occasional hills. This plateau extends into the basin of River Tana. In the central part of the district is a striking series of hill masses that stretch in a roughly north-south axis. This series includes the Ol Donyo Sabuk, Kanzalu ranges, Kangundo, Mua, Mitaboni, Iveti and Kiima Kimwe.

The district is generally hot and dry. It has two rainy seasons, the long and the short rain seasons. The long rains seasons starts at the end of March and continues up to May, while the short rains season starts at the end of October and lasts till December. The annual average rainfall ranges between 500mm to 1300mm. There are significant regional and seasonal variations within the district and rainfall reliability is quite low. The high altitude areas of Matungulu, Kangundo, Kathiani, Central and Mwala divisions receive slightly higherrainfall than the low land areas.

Mean monthly temperatures vary between 180C and 250C. The coldest month is July while October and March are the hottest. The highland areas which receive higher rainfall are more suitable for rain-fed agriculture than the lowland areas, while the plains support ranching (Machakos District Environmental Action plan, 2013).



Figure 8- Study Area, Machakos County (Source RCMRD)

### 3.1.3 Data

The project encompasses different data inputs namely rainfall estimates (in the form of bil images), shapefile and a rain gauge data collected over the years (source Kenya Meteorological Department).

#### Data Download

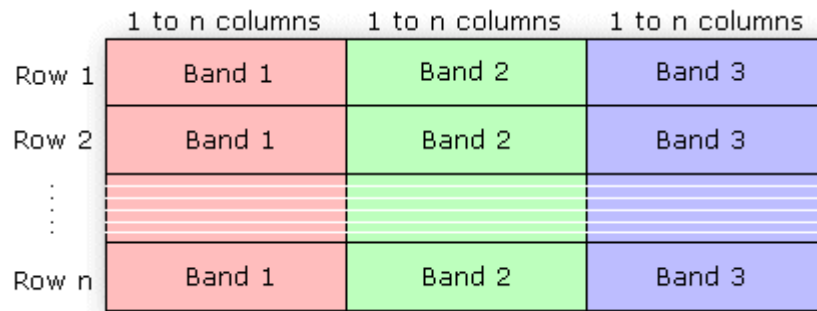
The system data download component connects to FEWSNET ftp site and access the data archive available in zip format. The zipped data is downloaded into a folder on the local computer. The downloaded data is unzipped to an input folder to facilitate manipulations.

#### Data Processing and analysis

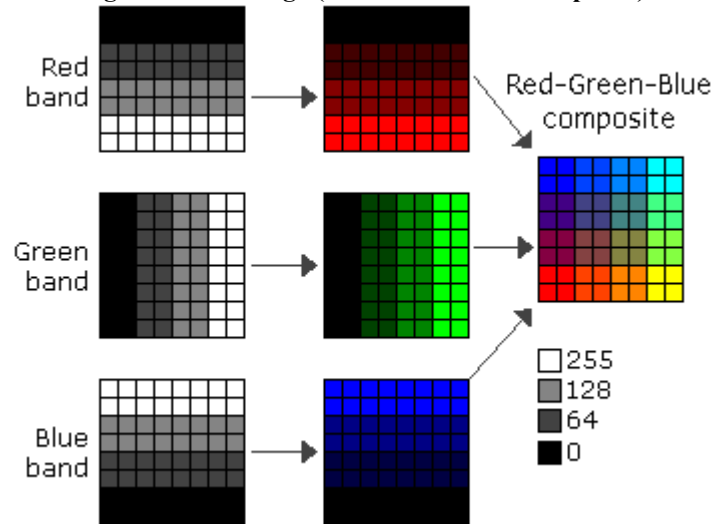
The second part of the system is the processing part. The processing scripts access the input folder and read the data. Each unzipped BIL file is read pixel by pixel. The pixel

value is referenced to the available resolution file and describes the height and width of each cell and the coordinate position of the top left cell of the data. It gives the Resolution information with the following lines:

- resolution in x-dimension
- rotation factor (always zero for GPW)
- rotation factor (always zero for GPW)
- resolution in y-dimension
- x-coordinate of the center of the upper-left cell
- y-coordinate of the center of the upper-left cell



**Figure 9 - Bil Image (source ArcGis 9.3 Help File)**



**Figure 10- Bil image (source ArcGis 9.3 Help File)**

The prototype was implemented using postgres Database as the data store. Implemented by storing pixel values in a table that is, one pixel value per record along with corresponding (x; y) coordinates for that particular pixel.

### Image processing algorithm

The method that closely fits this study is the Mosaicking method proposed by: NASA VISAT team. The different precipitation areas on the raster image are mosaicked out using the K and each pixel value recorded. The value will be referenced to the accompanying bil files to obtain geo coordinates, pixel ó precipitation mapping, and associated RGB values.

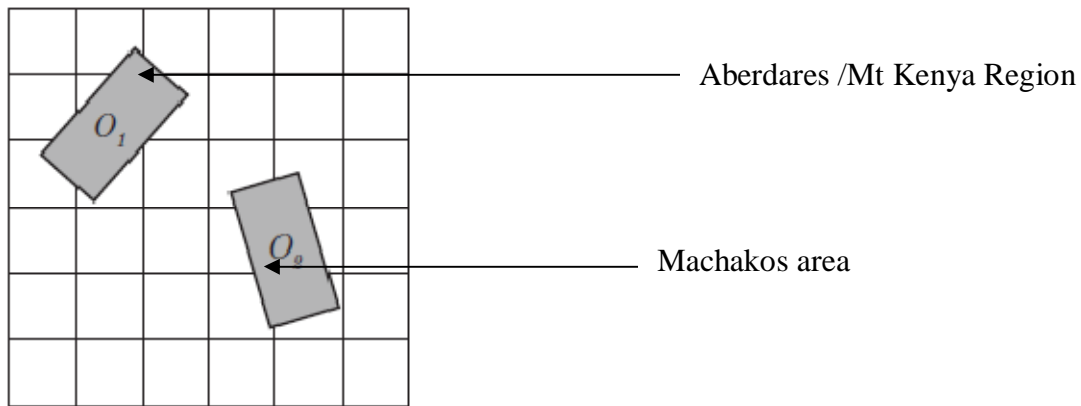


Figure 11 - Area of Interest on raster file (Source Firebrand Systems)

The extracted pixel values are stored in a bin. Each bin is a category of the intensity of the rainfall. Campbell et al (1995) defined the binning algorithm to involve the following steps:

- Select one of three possible binning algorithms (Maximum Likelihood, Arithmetic Mean and Minimum/Maximum)
- Predefine a subset region as minimum/maximum latitude/longitude. All pixels outside this region are rejected.
- Define the bin size without restrictions.
- Update long term means step by step as the input data becomes available.
- Binning and flux-conserving as independent resampling methods.
- Process multiple bands with different Bitmask expression and different binning algorithms at the same time.

This research implemented the Minimum/Maximum algorithm tracing the minimum and maximum value of the measurements for the bin. The final product matrix was composed as follows:

$$\min_i = \text{MIN}(X_{i,j})$$

$$\max_i = \text{MAX}(X_{i,j})$$

Where i,j is the pixel location (Campbel etal, 1995)

### Data Validation

Validation of the extracted rainfall measurements was done against the actual rainfall data recorded via guage stations for each studyarea. The gauge stations are used as a source of rainfall data up to a radius of 30Km to actual rain gauge measurements for a farmer to be insured. The image resolution usedhas an 8km by 8km resolution per pixel hence the rain gauge measurement falls within the 30Km radius.

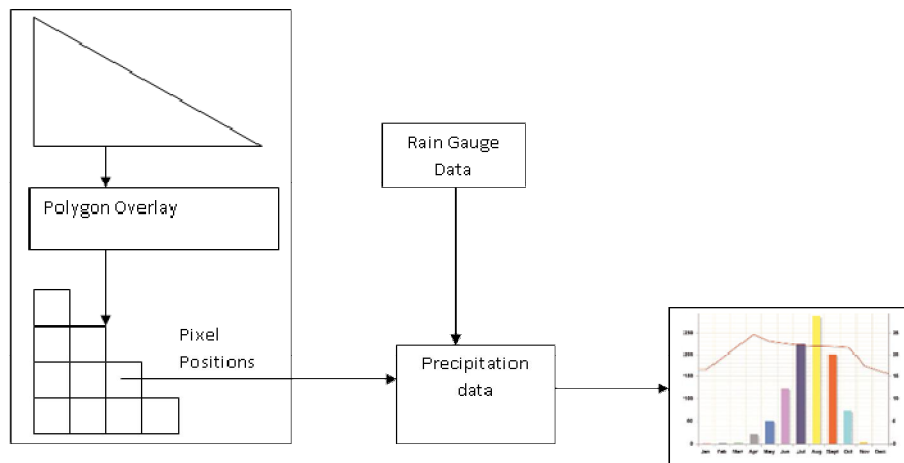


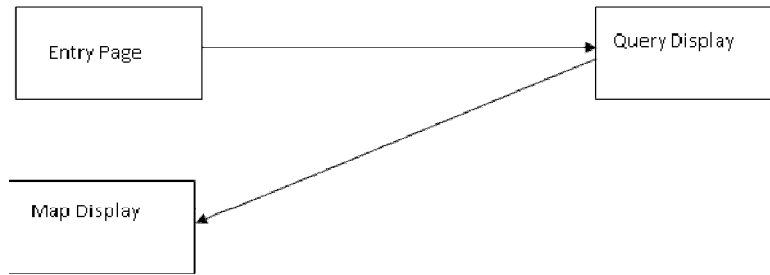
Figure 12 - Data Validation diagram (source own)

### Data Storage

Once the data was extracted, the corresponding precipitation information is stored in a Postgres database with geo-reference capabilities (PostGIS plugin). A symbolically generated image was stored in the output folder for reference purposes.

### Dissemination

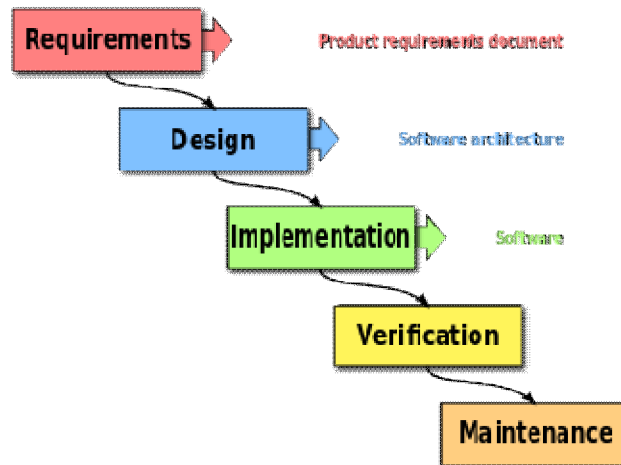
The dissemination component was designed using html5, javascript and php. A symbolically generated image was stored in the output folder for reference purposes.



**Figure 13- Layout of the dissemination web structure**

### 3.1.4 Software Development Life Cycle

The waterfall lifecycle was used as the software development methodology, since the software to be developed required a thorough understanding of the requirements before the prototype could be developed. The software development process therefore follows a simple requirements analysis, design, coding, testing and implementation.



**Figure 14 -Waterfall lifecycle (Source Wikipedia)**

## 3.2 SYSTEM DESIGN

### 3.2.1 Algorithm

Step 1: Download of satellite image

Step 2: Unzipping of compressed file.

Step 3: Extraction of pixel values with reference to a gauge station shapefile

The extraction cycle can be summarized as follows:

- a. Load bil image into memory
- b. Overlay a shapefile (with rain gauge stations) onto the bil image



- c. extract pixel values at each of the georeferenced rain gauge stations
- d. reference pixel value to bil to .clr file to determine rainfall in mm
- e. while not (termination condition) do step (a) to (e)

$$\text{Pixel} = \text{pixel} + 1$$

After performing operation the data was output in the format below:

**Table 7- Extracted Data output format**

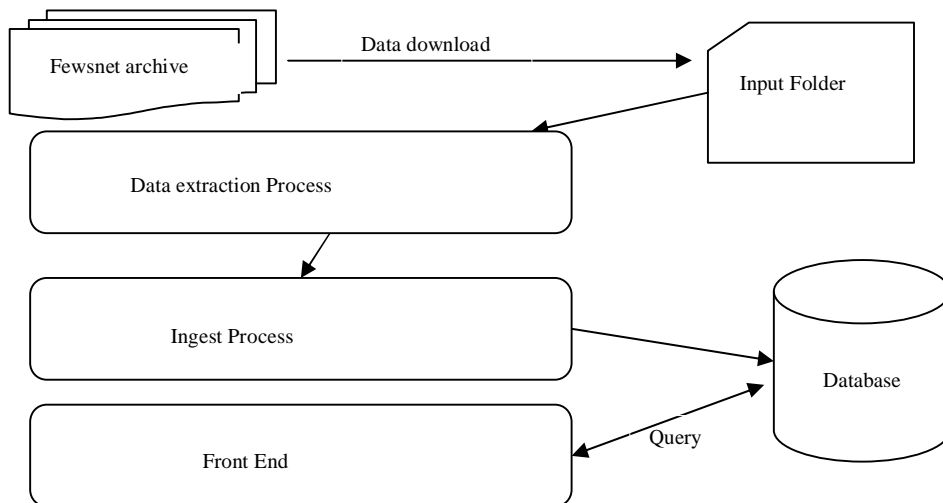
ID	longitude	latitude	Rainfall value	Gauge Station Locality

Some of the Termination Conditions:

- i) all the pixels of an image have been read (end of file)
- ii) A shapefile for reference purposes is not loaded
- iii) Image contains errors, or noise.

### 3.2.2 System Architectural Overview

The system comprises of a web user interface that is the point of interaction between the farmers and staff from an insurance company with the system. The system data is stored in a database; queries are used to search for specific rainfall data. The user interacts with the system through a network.

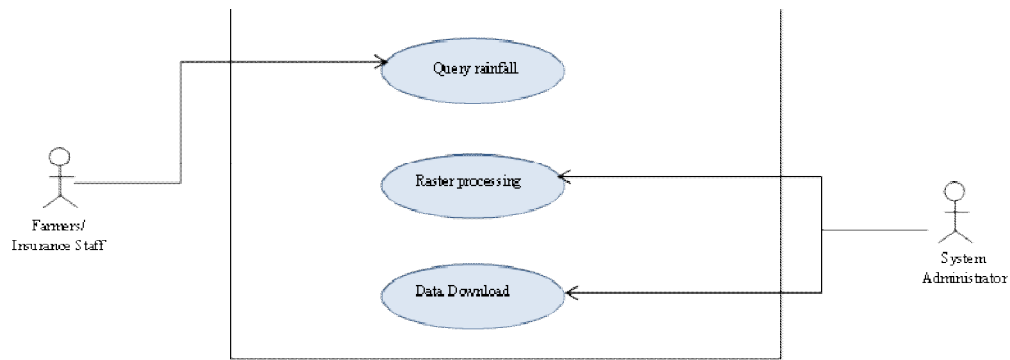


27  
**Figure 15 - Prototype Overview**

### 3.2.3 Use Case Diagram

The figure below shows the actors and cases in the automated rainfall extraction system. The actors are farmers, insurance staff and a systems administrator. The farmers and insurance staff load the web front end of the system to query rainfall data for specified periods. The system administrator ensures the automated processing is uninterrupted by other operating system services and the database is coherent.

**Figure 16 - Use Case Diagram**



**Table 8 - Rainfall Query Use Case**

<b>Use-Case</b>	Query Rainfall
<b>Actor</b>	Farmers / Insurance Staff
<b>Description</b>	This use-case occurs when the users interact with the front end webpage. They provide parameters to query the database for specific rainfall data by inputting year and month.
<b>Stimulus</b>	End user loads the website and enters fills in the forms
<b>Response</b>	The system loads rainfall data for the specified month

**Table 9 - Raster Processing Use Case**

<b>Use-Case</b>	Raster Processing
<b>Actor</b>	System Administrator
<b>Description</b>	This use-case occurs when the system admin interact with the backend. On start-up he points the system onto download the fewsnet RFE data
<b>Stimulus</b>	The System Admin loads the specified directory .The system loads all .bil images in recursive sub directories.
<b>Response</b>	System processes the raster data and stores the rainfall data into a database.

**Table 10 - Data Download Use Case**

<b>Use-Case</b>	Data Download
<b>Actor</b>	Administrator
<b>Description</b>	This use-case occurs when the administrator loads points the system to download data from fewsnet website.
<b>Stimulus</b>	Administrator selects source of data
<b>Response</b>	The system changes downloads the data and stores in a specified folder

### 3.3 Database Design

A postgres/Postgis database was designed and called AREFSI. Below is the individual table structure.

**Table 11 - Stations Table structure**

<b>Stations</b>		
<b>Name</b>	<b>Data Type</b>	<b>Description</b>
station_id	integer	primary key
station_name	variable character	
locality_id	integer	
Latitude	real	
Longitude	real	

**Table 12 - Locality Table structure**

<b>Locality</b>		
<b>Name</b>	<b>Data Type</b>	<b>Description</b>
locality_id	integer	foreign Key
locality_name	char	

**Table 13 - Satellite Rainfall Table structure**

<b>Satellite Rainfall</b>		
<b>Name</b>	<b>Data Type</b>	<b>Description</b>
ID	integer	
Month	integer	(checks for 1 to 12)
Year	integer	
satellite_precipitation	real	
latitude	real	x value of pixel
longitude	real	y value of pixel

**Table 14 - Gauge Rainfall Table structure**

<b>Gauge Rainfall</b>		
<b>Name</b>	<b>Data Type</b>	<b>Description</b>
ID	integer	
Date	date	Format yyy-mm-dd
station_id	integer	
recorded_precipitation	real	
latitude	real	x value of pixel
longitude	real	y value of pixel

Before the table was designed, data normalization was done removing redundancies and data anomalies in the database. The database consists of four tables which are stations, locality, satellite\_rainfall, gauge\_rainfall.

Stations ó this table stores the information about the rain gauge stations

Locality ó this table stores the information about the study area / district.

Satellite\_rainfall ó stores derived precipitation data from satellite images

Gauge\_rainfall - stores the actual recorded rainfall data (monthly mean) for the specified rain gauge stations within the study area.

It was decided to have two different tables for gauge data and satellite data as gauge stations give the actual rainfall amount that was recorded while the satellite imagery give pixel values of the precipitation. This enabled the research to show the disparities if any.

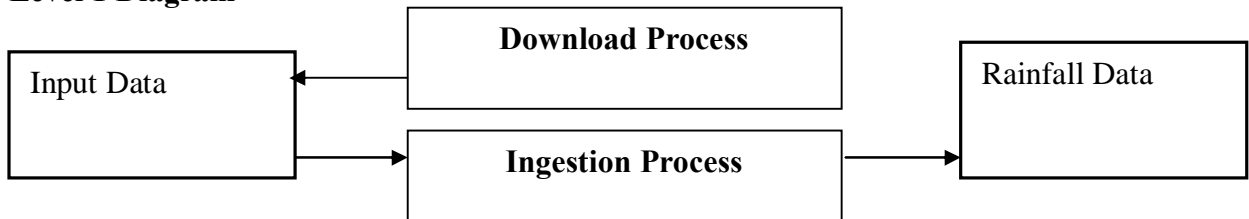
### 3.4 Pseudocode:

```
Ingest image:
Load ao1, ao2 (combined aoi);
Clip image as per outer boundaries of ao1, ao2;
Load shapefile
for (int row = 0; row < rint.NumRows; row++)
{
    for (int col = 0; col < rint.NumColumns; col++)
    {
        int pixel_value = rint.Data[row][col];
    }
}
```

### 3.5 System Architecture

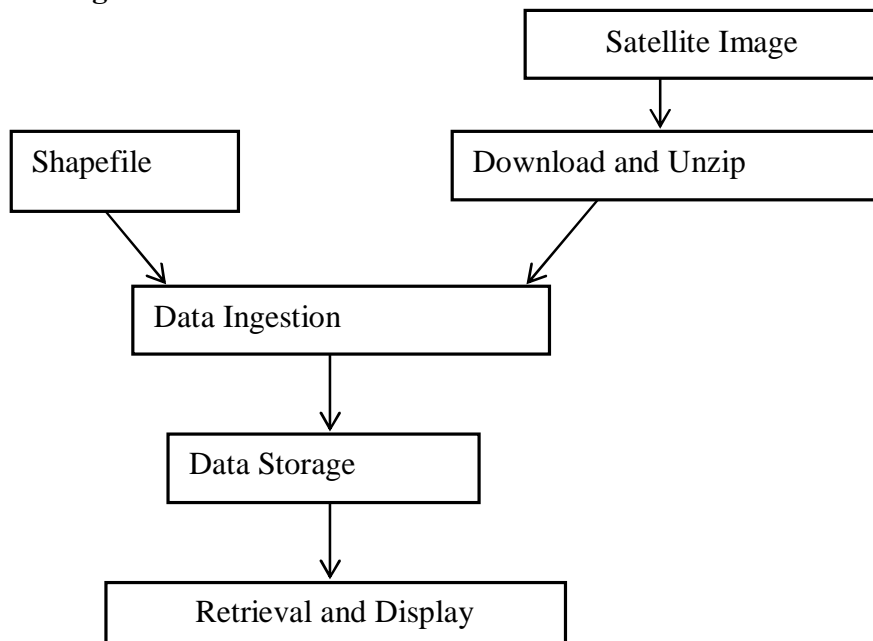
#### 3.5.1 Interactive Diagram

##### Level 1 Diagram



Top level interaction shows the main processes and the data that goes in on the left and comes out on the right. The prototype consists mainly of the download and ingestion processes.

##### Level 2 Diagram



Input data was a shapefile and a satellite image. Once the data was processed (ingested) they were stored for future reference.

### 3.5.2 Functional Requirements

- 1) The system should be able to download .zip files (contents are bil images)
- 2) The system should be able to unzip a zipped file
- 3) The system should be able to read rainfall data from bil image
- 4) Insert the rainfall data into a database.
- 5) The system should be able to display rainfall data from a database on a webpage

### 3.5.3 Scenarios:

#### S.1: download satellite data

- connect
- download
- Disconnect
- Unzip

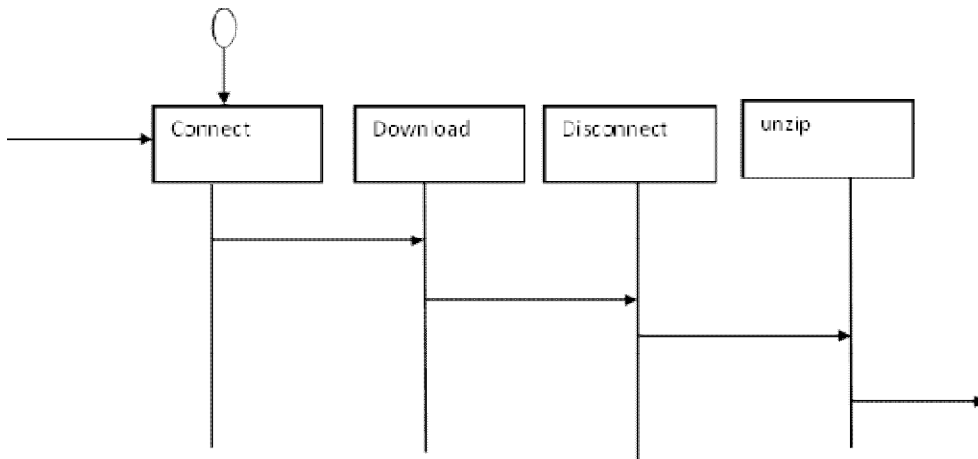


Figure 17 - Download Satellite data Scenario

S 2: Application of Rainfall Extraction Algorithm

- Load satellite image into memory
- Load and overlay satellite image with Shapefile of rain gauge stations
- Read row, column starting from the left top most corner, left to right
- Read the next row first column (row++)
- Output data

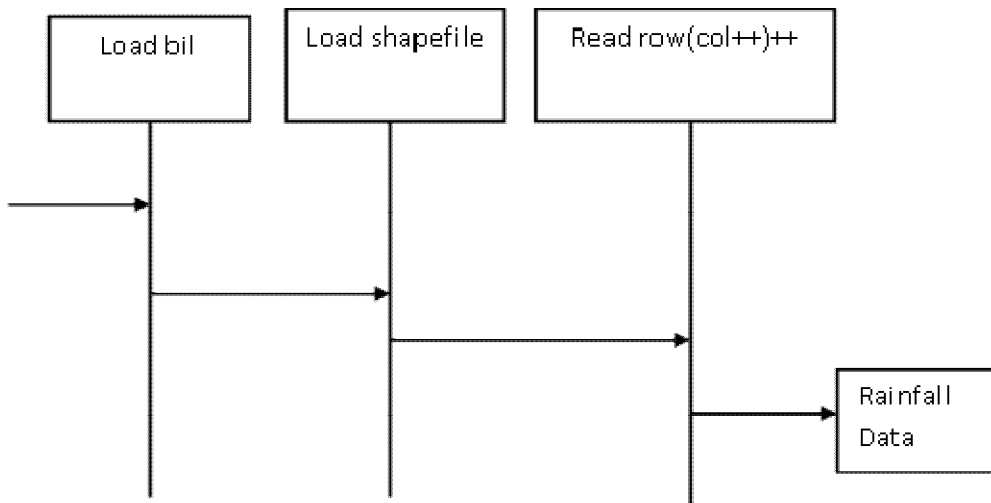


Figure 18 - Rainfall Extraction Algorithm



## CHAPTER 4: RESULTS AND DISCUSSION

### 4.0 Overview

This research involved a prototype development for extraction of rainfall data from satellite imagery. The end product was a prototype and web frontend that displays rainfall data. The rainfall data is analyzed to show variance with the traditional recorded rain gauge data.

This chapter provides details of the aims and objectives of the implementation portion of the project, and also discusses the methodologies and design principles that were considered whilst developing the prototype.

### 4.1 Pixel traversal of Mosacking algorithm Implementation

The pixel traversal of mosaci algorithm was implemented using python 2.6 and loaded modules of gdal 1.0. Gdal is important in this study as it presents libraries to enable interaction with georeferenced raster files.

The researcher used Vb.NET to create the GUI which facilitated the interaction with the download module. Python was used for the back end while php, HTML 5 and Javascript were used for the front end.

Once the data download module was ready, it was used to download sample zipped files containing the .bil images and accompanying files from the FEWSNET website. The files were observed on the local drive and each file extracted to ensure the data stream was not broken during the download process and the download was successful.

The extracted zipped files were stored on a local directory to be used as a reference for the backend development using python.

The python code was designed to use one bil image as a test and the data was extracted from it. The bil image was loaded andn an area of interest shapefile loaded onto the

image so that rainfall was extracted from specific points the rain gauge stations lie. The test results were obtained and the same bil image was opened on QGis 1.7 to determine the actual image data.

## Test Results

**Table 15 - Test Results of Machakos using 23rd July 2013**

Station ID	Name of Station	Area of Interest	Latitude	Longitude	Rainfall (mm)
9137115,	ROHET RANCH,	MACHAKOS,	37.0333,	-1.3667,	0
9137109,	NDOVOINI LUKENYA RANCHING F.CO OP SOCIETY,	MACHAKOS,	37.15,	-1.35,	0
9137209,	MAVUKO TOWN COUNCIL - SEWAGE T/WORKS,	MACHAKOS,	37.0833,	-1.3333,	0
9137199,	MBIANI KOMA ROCK,	MACHAKOS,	37.1833,	-1.3167,	0
9137064,	KAMORU LIMITED - ATHI PLAINS,	MACHAKOS,	37.0667,	-1.2833,	0
9137108,	KOMA ROCK RANCH OFFICE,	MACHAKOS,	37.2167,	-1.2833,	0
9137204,	SENGANI SECONDARY SCHOOL,	MACHAKOS,	37.3167,	-1.25,	0
9137074,	KANGUNDO KITHIMANI D.O'S OFFICE,	MACHAKOS,	37.45,	-1.2,	0
9137015,	LA FINCA - DONYO SABUK,	MACHAKOS,	37.3,	-1.1667,	0
9137126,	MISELENI AGRICULTURAL OFFICE,	MACHAKOS,	37.35,	-1.1667,	0
9137054,	KIANZABE COFFEE ESTATE - DONYO SABUK,	MACHAKOS,	37.3,	-1.15,	0
9137055,	MUKA MUKUU FARMERS CO-OP SOCIETY,	MACHAKOS,	37.2667,	-1.1333,	0
9137162,	YATTA FIELD UNIT (N.Y.S.),	MACHAKOS,	37.3833,	-1.1167,	0
9137197,	MAMBA TREE NURSERY,	MACHAKOS,	37.4167,	-1.1167,	0
9137103,	THIKA YATTA FURROW,	MACHAKOS,	37.3333,	-1.1,	0
9137090,	NGOLIBA ESTATE - DONYO SABUK,	MACHAKOS,	37.35,	-1.1,	0
9137121,	NGOLIBA SCHEME,	MACHAKOS,	37.35,	-1.1,	0
9137174,	NDALANI CHIEF'S CENTRE,	MACHAKOS,	37.4833,	-1.1,	0
9137123,	MANGU HIGH SCHOOL,	MACHAKOS,	37.0333,	-1.0833,	1
9137034,	MBOONI AFRICAN INLAND MISSION,	MACHAKOS,	37.0833,	-1.0833,	1
9137007,	DONYO SABUK ESTATE LTD,	MACHAKOS,	37.25,	-1.0833,	1
9137122,	KILIMAMBOGO COLLEGE,	MACHAKOS,	37.2333,	-1.0667,	1
9137178,	KWAKULU PRIMARY SCHOOL.,	MACHAKOS,	37.4,	-1.05,	0
9137198,	MBEMBANI IATINENI PRIMARY SCHOOL,	MACHAKOS,	37.5,	-1.05,	0
9037244,	KITHYOLO PRIMARY SCHOOL,	MACHAKOS,	37.45,	-0.9833,	0
9037246,	EKALAKALA CHIEF'S CAMP,	MACHAKOS,	37.45,	-0.9833,	0
9037095,	KAMBURAINI - NAROMORU,	NYERI,	37.0833,	-0.6833,	0

**Table 16- Test Results of Machakos using 23rd July 2013**

Station Id	Station Name	District	Latitude	Longitude	Rainfall (mm)
9036280,	CHANIA RIVER - ABERDARES NAT. PARK,	NYERI,	36.7167,	-0.45,	2
9036157,	KIANDONGORO HYDROMET SITE - NYERI,	NYERI,	36.8333,	-0.45,	2
9037084,	MURUA PWD CAMP - KARATINA,	NYERI,	37.05,	-0.45,	1
9036141,	WHITE RHINO HOTEL - NYERI,	NYERI,	36.9167,	-0.4333,	2
9036163,	NYERI AGRICULTURAL OFFICE,	NYERI,	36.95,	-0.4333,	2
9036210,	R.A. LITTLE - NYERI,	NYERI,	36.95,	-0.4333,	2
9036225,	NYERI PROVINCIAL AGRICULTURAL OFFICE,	NYERI,	36.95,	-0.4333,	2
9036288,	NYERI METEOROLOGICAL STATION,	NYERI,	36.9667,	-0.4333,	2
9037101,	IHWAGI - KARATINA,	NYERI,	37.15,	-0.4333,	0
9036246,	ZAINA FOREST STATION,	NYERI,	36.8167,	-0.4167,	2
9036030,	KABAGE FOREST STATION - OLD,	NYERI,	36.8333,	-0.4167,	2
9036159,	KABAGE FOREST STATION - NYERI,	NYERI,	36.85,	-0.4167,	2
9036282,	NYERI HILL,	NYERI,	36.9,	-0.4167,	2
9036017,	MINISTRY OF WORKS - NYERI,	NYERI,	36.95,	-0.4167,	2
9036223,	NYERI PRISONS,	NYERI,	36.95,	-0.4167,	2
9036316,	NYERI BAPTIST HIGH SCHOOL,	NYERI,	36.9667,	-0.4167,	2
9037203,	NGORANO CHIEF'S CAMP - KARATINA,	NYERI,	37.0667,	-0.4167,	1
9036247,	KABAGE FOREST STATION - NEW,	NYERI,	36.8167,	-0.4,	2

## 4.2 Test Results Analysis

The test results indicated that the rainfall values extracted from the image were equal to the values extracted by Argis software. This was essential as the data was obtained from the pixel values. The pixel being 8km by 8km ensures the prototype records the actual data captured by the satellite cameras. With the confirmation of test results using third party softwares like ArcGis and QGIS, the prototype was able to be programmed to work with large datasets and came up with the final results.

### 4.3 Screen Shots

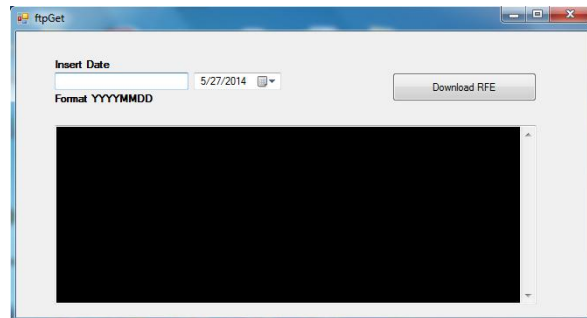


Figure 19 - Dialogue box to download satellite data

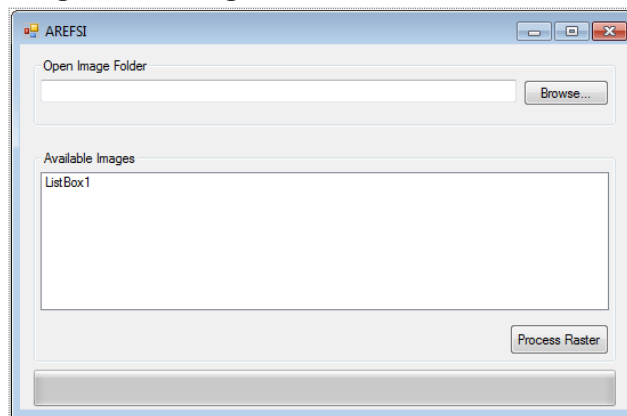


Figure 20 - Dialogue box to load images

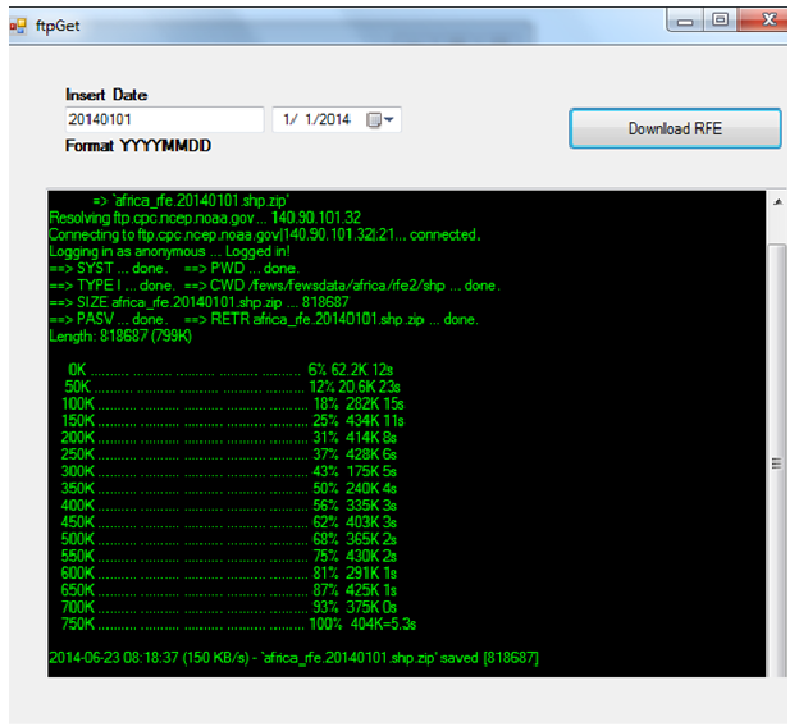
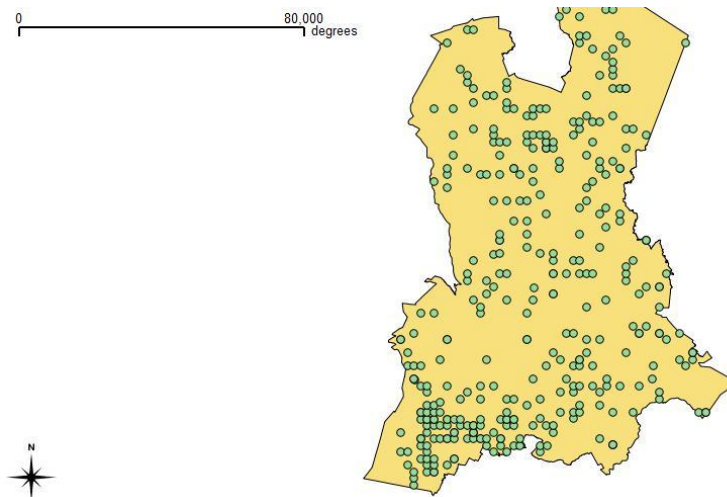
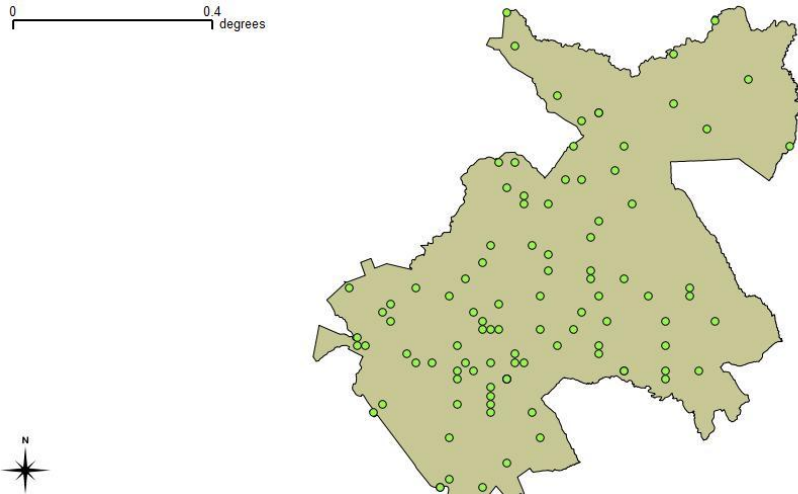


Figure 21 - FTP Download



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Figure 22 - Rain Gauge distribution of Aberdares area (viewed in QGIS)



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Figure 23 - Figure 23 - Rain Gauge distribution of Machakos area (viewed in QGIS)

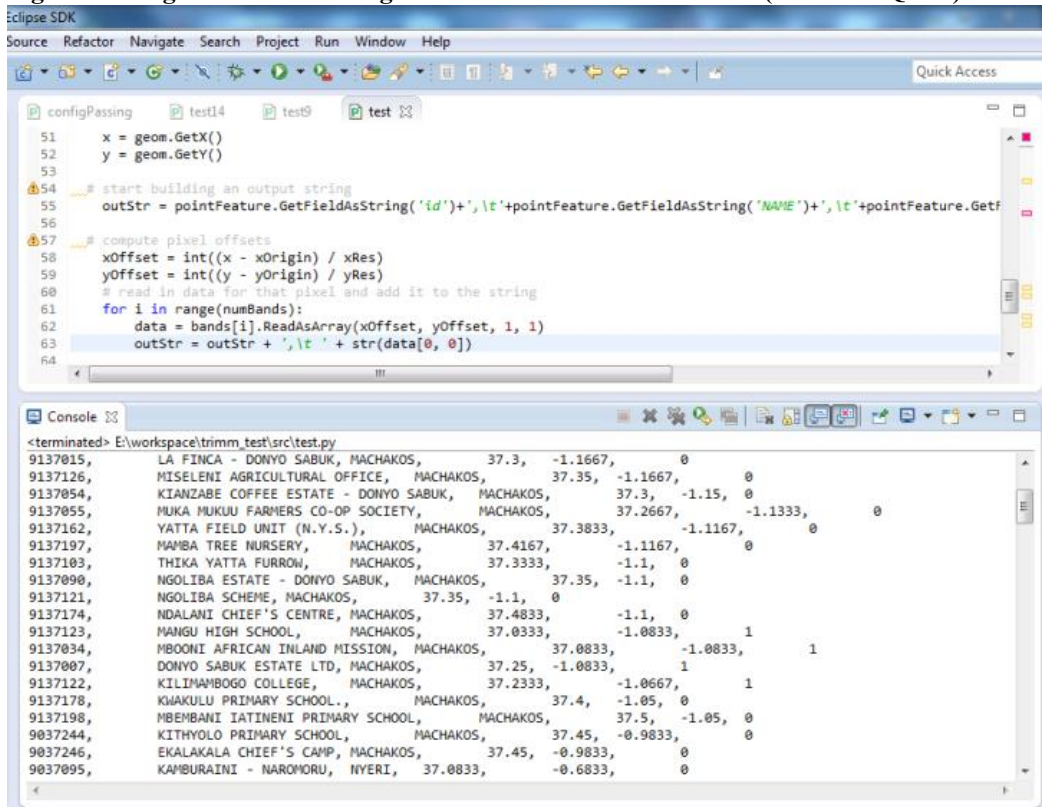


Figure 24 - Screenshot of test data results for Machakos

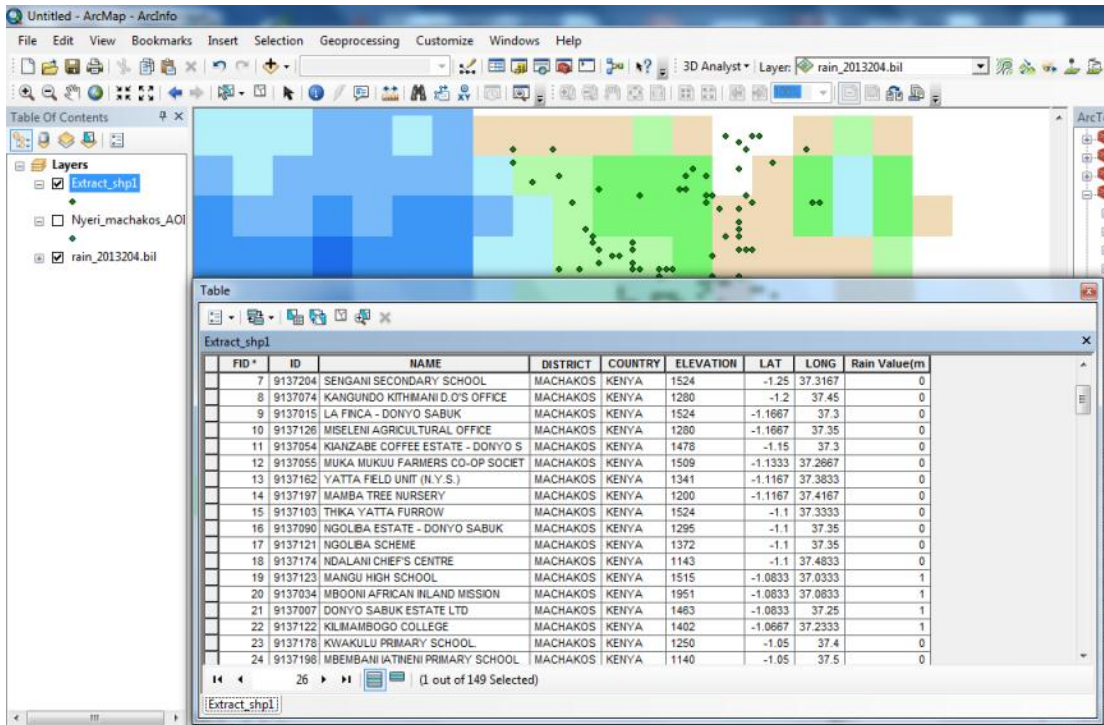


Figure 25 - Screenshot of test results on Arcmap

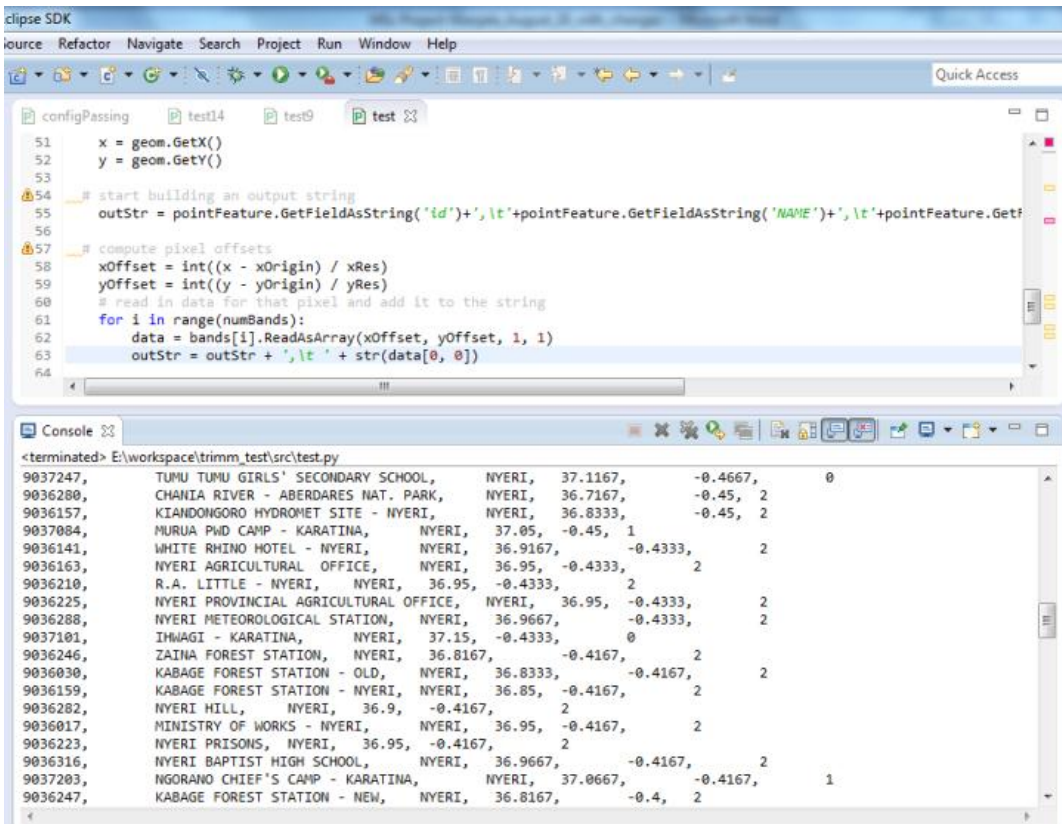


Figure 26 - Screenshot of test data results for Nyeri

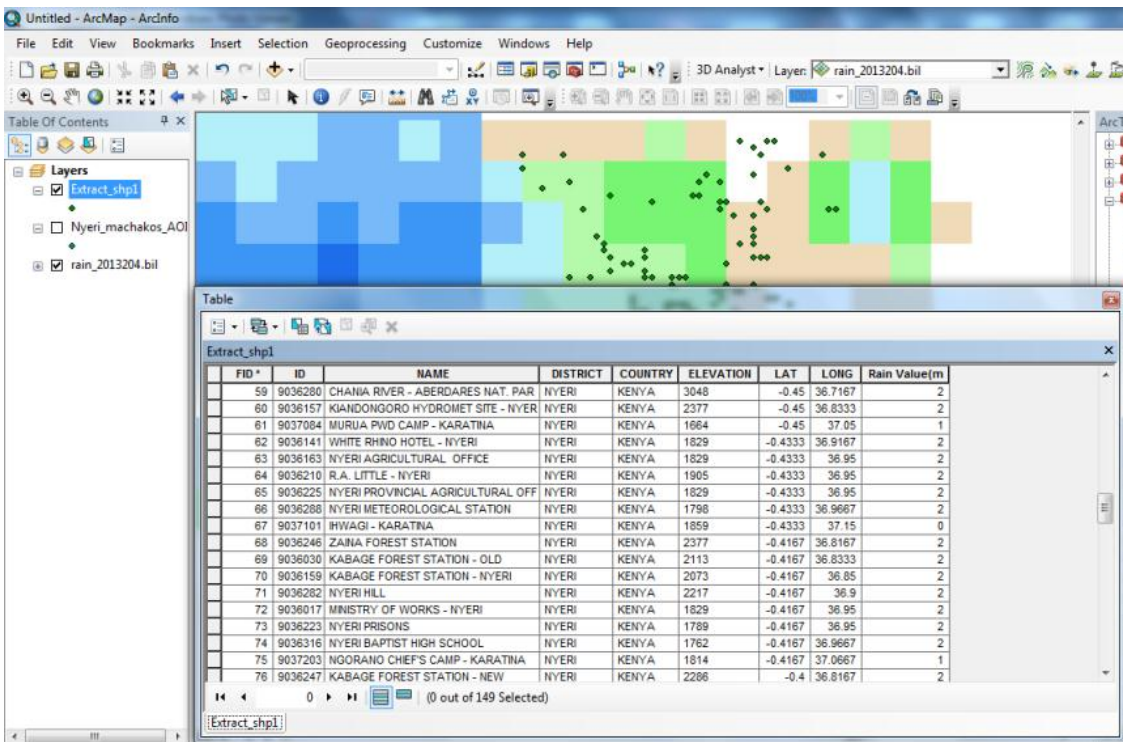


Figure 27 - Screenshot of the test data verified on Arcmap



#### 4.4 Sample Results

The rainfall data extraction technique, extracts rainfall from a bil image. The results below were obtained from bil image of 30<sup>th</sup> April 2006.

**Table 17 - Extracted Rainfall Data for Machakos AOI for 30th April 2006**

Rain Gauge Location Name	Latitude	Longitude	Rainfall Extracted from Image
ROHET RANCH	37.0333	-1.3667	1
NDOVOINI LUKENYA RANCHING F.CO OP SOCIETY	37.15	-1.35	2
MAVUKO TOWN COUNCIL - SEWAGE T/WORKS	37.0833	-1.3333	2
MBIANI KOMA ROCK	37.1833	-1.3167	2
KAMORU LIMITED - ATHI PLAINS	37.0667	-1.2833	2
KOMA ROCK RANCH OFFICE	37.2167	-1.2833	2
SENGANI SECONDARY SCHOOL	37.3167	-1.25	1
KANGUNDO KITHIMANI D.O'S OFFICE	37.45	-1.2	0
LA FINCA - DONYO SABUK	37.3	-1.1667	1
MISELENI AGRICULTURAL OFFICE	37.35	-1.1667	0
KIANZABE COFFEE ESTATE - DONYO SABUK	37.3	-1.15	1
MUKA MUKUU FARMERS CO-OP SOCIETY	37.2667	-1.1333	1
YATTA FIELD UNIT (N.Y.S.)	37.3833	-1.1167	0
MAMBA TREE NURSERY	37.4167	-1.1167	0
THIKA YATTA FURROW	37.3333	-1.1	1
NGOLIBA ESTATE - DONYO SABUK	37.35	-1.1	0
NGOLIBA SCHEME	37.35	-1.1	0
NDALANI CHIEF'S CENTRE	37.4833	-1.1	0
MANGU HIGH SCHOOL	37.0333	-1.0833	3
MBOONI AFRICAN INLAND MISSION	37.0833	-1.0833	3
DONYO SABUK ESTATE LTD	37.25	-1.0833	3

**Table 18 – Extracted Rainfall Data for Nyeri AOI, for 30th April 2006**

KAMBURAINI - NAROMORU	37.0833	-0.6833	12
KIAMBUTHIA SECONDARY SCHOOL	36.9	-0.6167	11
GARUWERU VILLAGE - NYERI	37.1333	-0.6167	13
GUMBA CHIEF'S CAMP	37.1333	-0.6	13
GEKONDI CATHOLIC MISSION - NYERI	37.0333	-0.5833	12
GIATHUGU CHIEFS' CAMP	37.1	-0.5833	13
CHINGA FOREST PLANTATIONS - NYERI	36.8167	-0.5667	10
MUCHARAGE SCHOOL - NYERI	36.85	-0.5667	11

IHURIRIO SCHOOL - NYERI	36.8833	-0.5667	11
CHINGA BOYS HIGH SCHOOL	36.9	-0.5667	11
MUKURUWEINI AGRICULTURAL OFFICE - NYERI	37.05	-0.5667	13
OTHAYA AGRICULTURE OFFICE - NYERI	36.9333	-0.55	12
BARICHO CATHOLIC MISSION KARATINA	37.2333	-0.55	15
KAHETI CATHOLIC MISSION	37.05	-0.5333	14
GURA FISHING CAMP - NYERI STATION	36.9167	-0.5167	12
KIARAHO PRIMARY SCHOOL	37.0667	-0.5167	14
LONG TERM R/GAUGE - ABERDARES 1	36.7833	-0.5	11
KAGUMO PLANTATIONS - NYERI	36.8	-0.5	11
LONG TERM R/GAUGE - ABERDARES 2	36.8333	-0.5	11
LONG TERM R/GAUGE - ABERDARES 3	36.8833	-0.5	12
NGUNGURU SECONDARY SCHOOL	37.1	-0.5	14
MUTUBIO GATE - ABERDARES N. PARK	36.6333	-0.4833	0
KIANDONGORO GATE - ABERDARES N. PARK	36.75	-0.4833	0

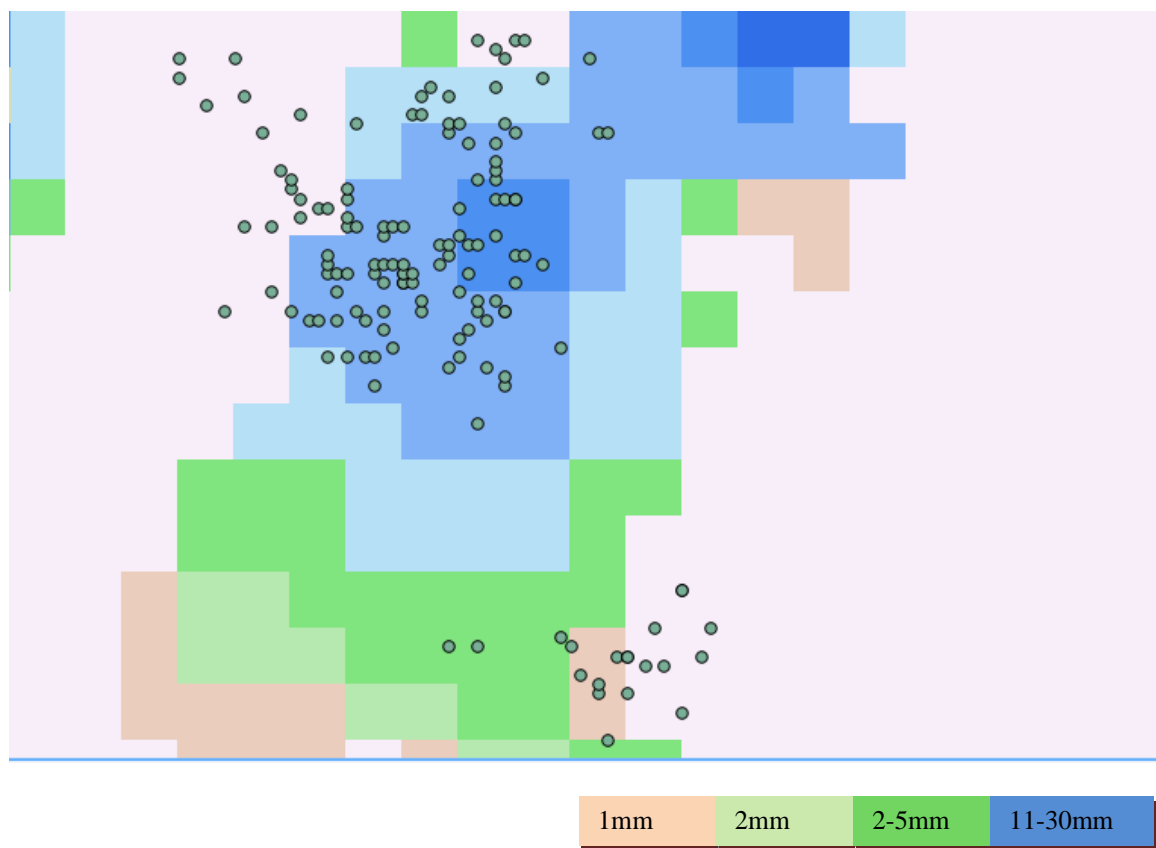


Figure 28 - Screen shot of rainfall distribution in mm within the AOI (as seen on QGIS)

**Table 19 - Rainfall Data for the month of April 2006(1<sup>st</sup> to 29<sup>th</sup>), sample 11 stations in Machakos**

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
ROHET RANCH	0	3	8	13	25	5	14	17	15	4	0	0	2	0	0	4	16	0	0	0	0	10	6	0	0	1	1	2	1
NDOVOINI LUKENYA RANCHING F.CO OP SOCIETY	0	1	12	13	15	12	20	19	23	0	0	0	3	0	1	8	9	0	4	0	1	1	5	0	0	1	0	3	2
MAVUKO TOWN COUNCIL - SEWAGE T/WORKS	0	2	13	14	20	8	17	14	21	1	0	0	2	0	1	7	9	0	1	0	0	4	5	0	0	1	0	3	2
MBIANI KOMA ROCK	0	1	12	13	15	12	20	19	23	0	0	0	3	0	1	8	9	0	4	0	1	1	5	0	0	1	0	3	2
KAMORU LIMITED - ATHI PLAINS	0	2	13	14	20	8	17	14	21	1	0	0	2	0	1	7	9	0	1	0	0	4	5	0	0	1	0	3	2
KOMA ROCK RANCH OFFICE	0	1	12	13	15	12	20	19	23	0	0	0	3	0	1	8	9	0	4	0	1	1	5	0	0	1	0	3	2
SENGANI SECONDARY SCHOOL	0	2	9	8	17	23	25	25	26	0	0	0	4	0	2	9	4	0	18	0	0	9	4	0	0	0	0	1	1
KANGUNDO KITHIMANI D.O'S OFFICE	0	3	5	7	15	27	31	22	24	2	0	0	4	0	2	9	5	0	23	0	0	7	4	0	0	5	0	0	0
LA FINCA - DONYO SABUK	0	2	9	8	17	23	25	25	26	0	0	0	4	0	2	9	4	0	18	0	0	9	4	0	0	0	0	1	1
MISELENI AGRICULTURAL OFFICE	0	3	5	7	15	27	31	22	24	2	0	0	4	0	2	9	5	0	23	0	0	7	4	0	0	5	0	0	0
KIANZABE COFFEE ESTATE - DONYO SABUK	0	2	9	8	17	23	25	25	26	0	0	0	4	0	2	9	4	0	18	0	0	9	4	0	0	0	0	1	1

**Table 20 - Rainfall Data for the month of April 2006, Sample 9 stations in Nyeri**

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
LONG TERM R/GAUGE - ABERDARES 3	0	1	5	15	4	22	24	5	5	2	3	0	0	0	1	4	9	3	10	0	16	6	4	26	13	3	0	5	12
NGUNGURU SECONDARY SCHOOL	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14
MUTUBIO GATE - ABERDARES N. PARK	0	2	10	9	3	19	13	11	5	2	5	2	2	0	1	5	13	0	15	0	17	3	6	9	7	0	0	0	0
KIANDONGORO GATE - ABERDARES N. PARK	0	2	10	12	4	21	15	10	7	2	4	2	1	0	1	6	13	1	13	0	17	2	7	17	7	0	0	0	0
IHITHE FARMERS CO-OP - NYERI	0	1	5	15	4	22	24	5	5	2	3	0	0	0	1	4	9	3	10	0	16	6	4	26	13	3	0	5	12
LONG TERM R/GAUGE - ABERDARES 4	0	1	5	15	4	22	24	5	5	2	3	0	0	0	1	4	9	3	10	0	16	6	4	26	13	3	0	5	12
GICHIRA CHIEF'S CAMP	0	0	2	20	1	18	25	0	2	1	3	0	0	0	0	0	7	2	7	1	29	16	2	29	16	6	0	8	13
TUMU TUMU MISSION - KARATINA	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14
KARATINA - NYERI	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14

#### 4.5 Analysis of Results

The results indicated that rainfall can be extracted from satellite imagery for historical purposes. The results were area specific and depended on the image resolution to determine the extent of the recorded precipitation information.

The actual rainfall data obtained from the Kenya Meteorological Department (depicting the monthly mean for April 2006) for Nyeri is as shown in the table below:

**Table 21 - KMD Rainfall mean for Nyeri**

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Nyeri	2006	21.4	52.5	119.4	229.7	102.6	24.2	30.2	27.5	41.8	145.8	344.8	210.9
	2007	49.9	39.3	42.7	130.3	138.5	53.4	87.0	66.7	58.9	210.3	57.1	41.1

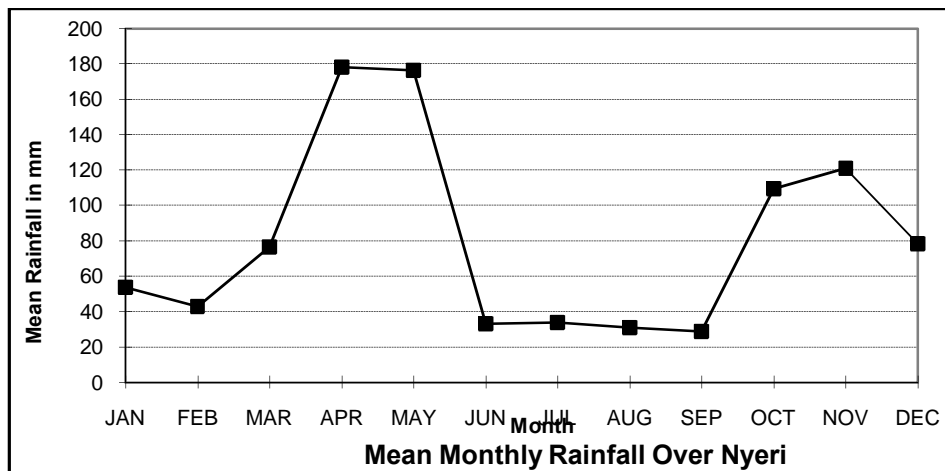


Figure 29 - Mean Monthly Rainfall Distribution over Nyeri (Source KMD)

#### 4.6 Comparison of raingauge data and Satellite imagery precipitation

This study indicates that rainfall data can be obtained from satellite imagery for crop index insurance. Historical data can give a glimpse on the actual effects of rainfall to a particular area for the farmer to both the farmer and the insurance company.

The data obtained was fully depended on:

1. Season (long rains, short rains and dry spells)
2. Altitude (high altitudes always record rainfall throughout the year)

Rain gauge data is inconsistent as there are months that KMD does not have any information regarding the rainfall for some areas/ station gauges.

## CHAPTER 5: CONCLUSIONS & RECOMMENDATIONS

### 5.0 Introduction

This research was based on finding out various rainfall extraction techniques from satellite imagery, to design and develop a prototype that automatically downloads and processes satellite data to determine: the rainfall (index), location and time and to provide an interface for querying of rainfall information in a format easily understandable by farmers and insurers.

### 5.1 Research objectives:

**First objective:** *To evaluate various rainfall extraction techniques from satellite imagery.*

The research question associated with this research objective was; Can rainfall information be automatically extracted from satellite imagery? We sought to establish and compare the mechanisms of extracting rainfall data from satellite imagery and the algorithms involved. The research indicated that the mosaicking, pixel traversal is the best method as it gives first priority to the AOI and covers all the pixels that fall within the stated area. This is an indicator that the objective was realized.

**Second objective:** *To design and develop a prototype that automatically downloads and processes satellite data to determine: the rainfall (index), location and time.*

To address this objective, we sought to find out if the research was successful in designing, developing and implementing a prototype to enable automatic data download and processing to extract rainfall information. The research was able to meet this objective as indicated in the indexes as well as screenshots of the system at various stages of data processing. The webpage can be viewed on any browser hence enabling both insurers and farmers to have access to the information.

**Third objective:** *To use pixel traversal to implement mosaicking algorithm for rainfall extraction from satellite imagery.*

The algorithm was successfully implemented with an input of 30 .bil images for the year 2006. The traversal algorithm was successful as rainfall data was extracted from the

images for our two areas of interest.

## **5.2 Research Assessment**

Crop index insurance is being adopted in various African countries, case point being Kenya and Malawi. The dependent index being rainfall whose information is limited to raingauge distributions within the stated countries (R.A.J Roberts (2005)).The output of this research tried to indicate a better and ready way of accessing rainfall information to be used for crop index insurance.

### **What is new? Does the research make a significant, value-added contribution to the current thinking?**

Crop index insurance will never be the same again as the insurers have three issues that has been solved: Pool of rainfall data stored as .bil images on FEWSNET website, a tool that has been developed to access the website, download and process the images to extract the information and finally a website that both farmers and insurers can access to obtain rainfall information. This in essence enlarges the domain of the farmers that are willing to be insured as well as giving the insurance companies a larger pool of a source of income.

### **So what? How will this research change crop index insurance?**

As the research has pointed out an index that can be obtained from satellite imagery, this has opened up opportunities to have temperature as well as landcover changes to be obtained from satellite imagery. This in essence means that crop insurance will never be the same again with accessibility to unlimited information pertaining the development of the crops as well as weather.

### **So what? How will the research change crop index insurance adoption?**

The research has enabled rainfall data to be availed at all areas within the country, thereby making the current requirement that a farmer to be within a 30km radius from an approved weather station not valid. This will enable more farmers to be insured, enabling the crop index insurance product to be spread wider within the countries.

### **Are the underlying logic and supportive evidence compelling?**

The study involved development of a prototype that extracts rainfall information from satellite imagery. The rainfall data was extracted from pixel values. The data is valid but only if the image does not contain noise or distortions. The raingauge pixels provided rainfall with a minimal error margin indicating the 8km by 8km radius value of the rainfall. The data can be improved with a higher resolution image.

### **How thorough was the study?**

The study established that crop index insurers don't have in place a rainfall information system that references satellite imagery. This was achieved through literature review with development of a prototype processing data from a highly rainfall area (Aberdares) and a sparingly one (Machakos).

### **Why now? Is it of interest to the people?**

The adoption of crop index insurance has picked up but limited to areas outlined by the insurance firms. The main factor being distance from a KMD approved rainfall gauge station and the ability of an assessor to visit the farm. The system will let insurance companies sell insurance products while roping in many farmers from diverse backgrounds and areas to buy the products. Any farmer with a browser on the phone can access historical data to assist him on the potential outcome.

## **5.3 Limitations and Recommendations for furtherwork**

The main limitation of this research was consideration of the input data.

The researcher looked at BIL extraction of rainfall data from bil images. The algorithms can be further enhanced to incorporate level 0 satellite products eg NOAA18, with further enhancing to determine top and bottom cloud temperature. This can also provide forecasting option to ensure that farmers can be warned in advance of adverse rainfall.

Further research can be undertaken to improve the efficiency of the proposed algorithm with trial on other satellite images with a higher resolution. Furthermore, researchers can incorporate beautiful GUIs and mobile to ensure a bigger audience is reached.

The model tuning can consider images with up to 100m resolution (width of a pixel) to ensure more precise location based data is obtained.



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## APPENDIX 1 – SOURCE CODE

### Data Download module

```
Imports System
Imports System.Diagnostics
Imports System.ComponentModel

Public Class ftpGet

    Private Sub Button1_Click(sender As System.Object, e As System.EventArgs) Handles
        Button1.Click
        Dim proc As New Process()

        With proc.StartInfo
            .FileName = "..\wget.exe"
            .Arguments =
                "ftp://ftp.cpc.ncep.noaa.gov/fews/fewsdata/africa/rfe2/shp/africa_rfe." +
                TextBox1.Text + ".shp.zip"
            .UseShellExecute = False
            .RedirectStandardError = True
            .RedirectStandardOutput = True
            .RedirectStandardInput = True
            '.CreateNoWindow = True
        EndWith

        proc.Start()
        TextBox2.Text += "downloading /----/----/---/---/---"
        TextBox2.Text += proc.StartInfo.RedirectStandardOutput.ToString
        TextBox2.Text += proc.StandardOutput.ReadLine()
        TextBox2.Text += proc.StandardError.ReadToEnd()

        proc.WaitForExit()

    EndSub
    Private Sub DateTimePicker1_ValueChanged(sender As System.Object, e As
        System.EventArgs) Handles DateTimePicker1.ValueChanged
        TextBox1.Text = Format(DateTimePicker1.Value, "yyyyMMdd")

    EndSub
End Class
```

## Data extraction Module

```
'''
Created on April 19, 2014

@author: WafuLa
'''
import os,struct,sys, psycopg2, glob
from datetime import datetime
from osgeo import ogr, gdal
from osgeo.gdalconst import *
import configparser,datetime,time
Config = configparser.ConfigParser()

Config.read("config.ini")

thePath = Config.get('config', 'BilFolder')
shapefile = Config.get('config', 'shapeFile')
csvOutputPath = Config.get('config', 'OuputFolder')
#DSN = Config.get('config', 'dbConn')
DSN="dbname=AREFSI_DB user=postgres password=admin2005"

print"Loading configurations\n"
print"-----\n"
print (Config.sections())
print"Bil Folder is: "+ thePath
print"RainuageShapefile: "+shapefile
print"Output Folder:"+csvOutputPath
#print "The database Connection is: "+ DSN
#function that processes the raster images
time.sleep(1)

#def rasterProcessor(filename, csvFileName):
def rasterProcessor(filename,shp):

    driver = ogr.GetDriverByName("ESRI Shapefile")
    dataSource = driver.Open(shapefile, 0)
    layer = dataSource.GetLayer()
    src_ds = gdal.Open(filename)
    gt = src_ds.GetGeoTransform()
    rb = src_ds.GetRasterBand(1)

#print filename
for feature in layer:
    geom = feature.GetGeometryRef()
    mx, my = geom.GetX(), geom.GetY()
#Convert from map details into pixel coordinates.
```

```

    px = int((mx - gt[0]) / gt[1]) # x pixel
    py = int((my - gt[3]) / gt[5]) # y pixel
    structval = rb.ReadRaster(px, py, 1, 1, buf_type=gdal.GDT_UInt16) #
use string 'UInt16' instead for data type, i.e 16 bit int or 'short'
intval = struct.unpack('h' , structval) # use the 'short' format code (2
bytes) not int (4 bytes)

defdateMambo(theDt):
#print theDt
    dt = datetime.datetime.strptime(theDt, '%Y%j')
#dt.strftime('%d-%m-%Y')
    d = dt.strftime('%Y-%m-%d')
return d

defbilProcessor(filename, shp):

    driver = ogr.GetDriverByName("ESRI Shapefile")
    dataSource = driver.Open(shp, 0)
    layer = dataSource.GetLayer()
    src_ds = gdal.Open(filename)
    gt = src_ds.GetGeoTransform()
    rb = src_ds.GetRasterBand(1)

print"Station Name" + "," + "Latitude" + ','+'Longitude',\t" + "Rainfall
value"
for feature in layer:
# print feature.GetField("ID")+" "+ feature.GetField("NAME")
    geom = feature.GetGeometryRef()
    mx, my = geom.GetX(), geom.GetY()

    px = int((mx - gt[0]) / gt[1]) # x pixel
    py = int((my - gt[3]) / gt[5]) # y pixel

    structval = rb.ReadRaster(px, py, 1, 1, buf_type=gdal.GDT_UInt16) #
Assumes 16 bit intaka 'short'
    intval = struct.unpack('h' , structval) # use the 'short' format code
(2 bytes) not int (4 bytes)

    csvF = filename.split('/')
    csvFile=csvF[len(csvF)-1]
    csvTime=csvFile.split('_')

#print csvTime
#sys.exit()
print"csvfile:"+csvFile

#csvName = csvOutputPath +
csvFile.strip(".bil")+str(datetime.datetime.now())+'.csv'
    csvName = csvOutputPath +
str(dateMambo(csvTime[1].strip(".bil")))+'.csv'

```

```

        date = str(dateMambo(csvTime[1].strip(".bil")))
        f = open(csvName, "a")
        f.write(str(feature.GetField("ID")) + ",\t"
+str(feature.GetField("DISTRICT")) + ",\t" + str(feature.GetField("NAME")) +
',\t' + str(mx) + ",\t " + str(my) + ",\t " + str(intval[0])+"\n")
        f.close()

        SQL = "INSERT INTO rainfall (sid, tarehe, latitude, longitude,
precipitation) VALUES (" +str(feature.GetField("ID")) + ",'" +str(date)+"',"+
str(mx) + ", " + str(my) + ", " + str(intval[0]) + ");"
print SQL
#dbConnect(DSN,SQL)
with psycopg2.connect(DSN) as conn:
with conn.cursor() as curs:
            curs.execute(SQL)

#directory walk to get file names
defdirWalk(thePath):
    theFiles=[]
    print"The path is: "+thePath+"\n"
    print"-----\n"
    for root, dirs, files in os.walk(thePath):
    for name in files:
        nm, ext = os.path.splitext(name)
        if ext == ".bil":
            thName = name
            theFiles.append(os.path.join(root+'/' +thName))

#print a

for a in theFiles:
print"processing..." +a+"\n"
        time.sleep(1)
        bilProcessor(a, shapefile)
return str(theFiles)
#end get files

defdbConnect(DSN, SQL):
try:
        conn=psycopg2.connect(DSN)
except:
print".....unable to connect to the database."
        cur = conn.cursor()
try:
        cur.execute(SQL)
print"Insert into satelliLite_Rainfall SUCCESSFULL..."

except:
print"Unexpected error:", sys.exc_info()[0]
#raise

```

```

defmain():
    start = time.time()# mark the time the script starts running
    #nlist=dirWalk(thePath)
    dirWalk(thePath)
    #print nlist
    time.sleep(5)
    #time the script finishes processing all the .bil images
    #time.sleep(4)

    print"Download + Insert Complete"+" it took: "+ str(time.time() - start)+'
seconds'
    time.sleep(5)

if __name__ == '__main__':
    main()

```

### Config File

```

[config]
;location of the folder containing bil images
BilFolder=E:/data/bil/rfe_200604/rfe_200604/

;location of the shapefile
shapeFile=E:/data/Shapefiles/Nyeri_machakos_AOI.shp

;Where to output the data
OuputFolder=E:/data/csv/

;Database Connection

dbConn="dbname=AREFSI_DB          user=postgres          password=admin2005"

```

## Installation

### 1. Python

- Download python from <https://www.python.org/download/> and install
- Add python directory to local system PATH
  - i. Open System Properties
  - ii. Switch to the Advanced tab
  - iii. Click Environment Variables
  - iv. Select PATH in the System variables section
  - v. Click Edit
  - vi. Add python's path to the end of the list (the paths are separated by semicolons). For example:  
C:\Windows;C:\Windows\System32;C:\Python27

### 2. Postgres

- Download postgres from <http://www.postgresql.org/download/> and install

### 3. WAMP

- Download and Install WAMP from <http://www.wampserver.com/en/>

## Usage

### 1. Data Download

- Extract Downloader from the package provided, run it
- Select the dates and click download
- Wait for download to complete.

### 2. The package contains **config.inf** file that entails the configuration details:

**[config]**

;location of the folder containing bil images

**BilFolder**=E:/data/bil/rfe\_200604/rfe\_200604/

;location of the shapefile

**shapeFile**=E:/data/Shapefiles/Nyeri\_machakos\_AOI.shp





**APPENDIX3 – Extracted data for April 2006**

**Table 22 - Rainfall Data for April 2006 (Machakos and Abaerdares)**

Name	Lat	Long	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
ROHET RANCH	37.0333	-1.3667	0	3	8	13	25	5	14	17	15	4	0	0	2	0	0	4	16	0	0	0	0	10	6	0	0	1	1	2	1	
NDOVOINI LUKENYA RANCHING F.CO OP SOCIETY	37.15	-1.35	0	1	12	13	15	12	20	19	23	0	0	0	3	0	1	8	9	0	4	0	1	1	5	0	0	1	0	3	2	
MAVUKO TOWN COUNCIL - SEWAGE T/WORKS	37.0833	-1.3333	0	2	13	14	20	8	17	14	21	1	0	0	2	0	1	7	9	0	1	0	0	4	5	0	0	1	0	3	2	
MBIANI KOMA ROCK	37.1833	-1.3167	0	1	12	13	15	12	20	19	23	0	0	0	3	0	1	8	9	0	4	0	1	1	5	0	0	1	0	3	2	
KAMORU LIMITED - ATHI PLAINS	37.0667	-1.2833	0	2	13	14	20	8	17	14	21	1	0	0	2	0	1	7	9	0	1	0	0	4	5	0	0	1	0	3	2	
KOMA ROCK RANCH OFFICE	37.2167	-1.2833	0	1	12	13	15	12	20	19	23	0	0	0	3	0	1	8	9	0	4	0	1	1	5	0	0	1	0	3	2	
SENGANI SECONDARY SCHOOL	37.3167	-1.25	0	2	9	8	17	23	25	25	26	0	0	0	4	0	2	9	4	0	18	0	0	9	4	0	0	0	0	1	1	
KANGUNDO KITHIMANI D.O'S OFFICE	37.45	-1.2	0	3	5	7	15	27	31	22	24	2	0	0	4	0	2	9	5	0	23	0	0	7	4	0	0	5	0	0	0	
LA FINCA - DONYO SABUK	37.3	-1.1667	0	2	9	8	17	23	25	25	26	0	0	0	4	0	2	9	4	0	18	0	0	9	4	0	0	0	0	1	1	
MISELENI AGRICULTURAL OFFICE	37.35	-1.1667	0	3	5	7	15	27	31	22	24	2	0	0	4	0	2	9	5	0	23	0	0	7	4	0	0	5	0	0	0	
KIANZABE COFFEE ESTATE - DONYO SABUK	37.3	-1.15	0	2	9	8	17	23	25	25	26	0	0	0	4	0	2	9	4	0	18	0	0	9	4	0	0	0	0	1	1	
MUKA MUKUU FARMERS CO-OP SOCIETY	37.2667	-1.1333	0	1	6	8	18	28	28	25	26	0	0	0	4	0	2	9	3	0	23	0	0	4	4	1	0	0	0	1	1	
YATTA FIELD UNIT (N.Y.S.)	37.3833	-1.1167	0	3	4	7	18	32	35	21	27	2	0	0	5	0	2	10	5	0	34	0	0	0	4	0	0	2	0	0	0	
MAMBA TREE NURSERY	37.4167	-1.1167	0	3	4	7	18	32	35	21	27	2	0	0	5	0	2	10	5	0	34	0	0	0	4	0	0	2	0	0	0	
THIKA YATTA FURROW	37.3333	-1.1	0	1	6	8	18	28	28	25	26	0	0	0	4	0	2	9	3	0	23	0	0	4	4	1	0	0	0	1	1	
NGOLIBA ESTATE - DONYO SABUK	37.35	-1.1	0	3	4	7	18	32	35	21	27	2	0	0	5	0	2	10	5	0	34	0	0	0	4	0	0	2	0	0	0	
NGOLIBA SCHEME	37.35	-1.1	0	3	4	7	18	32	35	21	27	2	0	0	5	0	2	10	5	0	34	0	0	0	4	0	0	2	0	0	0	

NDALANI CHIEF'S CENTRE	37.4833	-1.1	0	3	5	5	17	23	37	19	20	3	2	0	4	0	2	7	9	0	21	0	0	0	3	0	0	22	0	0	0
MANGU HIGH SCHOOL	37.0333	-1.0833	0	1	9	8	25	13	15	26	21	0	0	0	1	0	1	11	2	0	2	0	0	2	4	0	0	0	3	5	3
MBOONI AFRICAN INLAND MISSION	37.0833	-1.0833	0	0	13	8	24	11	16	25	26	0	0	0	2	0	2	11	3	0	4	0	0	3	5	0	0	0	2	3	3
DONYO SABUK ESTATE LTD	37.25	-1.0833	0	0	12	7	19	14	23	25	26	0	0	0	3	0	2	12	2	0	8	0	0	4	5	1	0	0	2	3	3
KILIMAMBOGO COLLEGE	37.2333	-1.0667	0	0	12	7	19	14	23	25	26	0	0	0	3	0	2	12	2	0	8	0	0	4	5	1	0	0	2	3	3
KWAKULU PRIMARY SCHOOL.	37.4	-1.05	0	2	8	8	20	20	35	21	22	0	1	0	4	0	2	7	4	0	17	0	0	0	5	4	0	0	0	0	0
MBEMBANI IATINENI PRIMARY SCHOOL	37.5	-1.05	0	3	7	6	19	16	36	19	20	0	3	0	4	0	2	8	8	0	12	0	0	0	4	4	3	17	0	2	0
KITHYOLO PRIMARY SCHOOL	37.45	-0.9833	0	2	8	8	20	20	35	21	22	0	1	0	4	0	2	7	4	0	17	0	0	0	5	4	0	0	0	0	0
EKALAKALA CHIEF'S CAMP	37.45	-0.9833	0	2	8	8	20	20	35	21	22	0	1	0	4	0	2	7	4	0	17	0	0	0	5	4	0	0	0	0	0
KAMBURAINI - NAROMORU	37.0833	-0.6833	0	0	6	13	11	12	21	16	8	5	2	0	0	0	1	8	17	2	7	0	17	43	7	22	9	0	1	6	12
KIAMBUTHIA SECONDARY SCHOOL	36.9	-0.6167	0	0	8	13	6	35	23	9	6	4	0	0	0	0	1	6	11	2	10	0	11	8	10	24	12	1	0	6	11
GARUWERU VILLAGE - NYERI	37.1333	-0.6167	0	0	5	14	6	8	23	12	6	5	2	0	0	0	1	5	16	2	7	0	17	31	7	20	11	1	1	6	13
GUMBA CHIEF'S CAMP	37.1333	-0.6	0	0	5	14	6	8	23	12	6	5	2	0	0	0	1	5	16	2	7	0	17	31	7	20	11	1	1	6	13
GEKONDI CATHOLIC MISSION - NYERI	37.0333	-0.5833	0	0	6	16	6	22	22	9	6	4	2	0	0	0	1	3	12	2	9	0	17	22	7	24	12	2	0	7	12
GIATHUGU CHIEFS' CAMP	37.1	-0.5833	0	0	5	14	6	8	23	12	6	5	2	0	0	0	1	5	16	2	7	0	17	31	7	20	11	1	1	6	13
CHINGA FOREST PLANTATIONS - NYERI	36.8167	-0.5667	0	1	10	10	5	36	21	12	8	4	1	0	0	0	1	6	17	2	9	0	15	0	9	25	11	0	0	7	10
MUCHARAGE SCHOOL - NYERI	36.85	-0.5667	0	0	8	13	6	35	23	9	6	4	0	0	0	0	1	6	11	2	10	0	11	8	10	24	12	1	0	6	11
IHURIRO SCHOOL - NYERI	36.8833	-0.5667	0	0	8	13	6	35	23	9	6	4	0	0	0	0	1	6	11	2	10	0	11	8	10	24	12	1	0	6	11
CHINGA BOYS HIGH SCHOOL	36.9	-0.5667	0	0	8	13	6	35	23	9	6	4	0	0	0	0	1	6	11	2	10	0	11	8	10	24	12	1	0	6	11
MUKURUWEINI AGRICULTURAL	37.05	-0.5667	0	0	5	14	6	8	23	12	6	5	2	0	0	0	1	5	16	2	7	0	17	31	7	20	11	1	1	6	13



TUMU TUMU MISSION - KARATINA	37.0833	-0.4833	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14
KARATINA - NYERI	37.1333	-0.4833	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14
KARATINA AGRICULTURAL OFFICE	37.1333	-0.4833	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14
KAGUMO COLLEGE - NYERI	36.9833	-0.4667	0	0	2	20	1	18	25	0	2	1	3	0	0	0	0	0	7	2	7	1	29	16	2	29	16	6	0	8	13
KAIYABA CHIEF'S CAMP - KARATINA	37.0833	-0.4667	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14
TUMU TUMU GIRLS' SECONDARY SCHOOL	37.1167	-0.4667	0	1	4	15	5	8	26	10	4	2	3	0	2	0	1	6	8	0	6	0	19	14	3	21	12	3	0	7	14
CHANIA RIVER - ABERDARES NAT. PARK	36.7167	-0.45	0	1	5	20	3	8	13	9	3	0	6	3	3	0	1	5	12	1	17	0	15	8	5	17	7	0	0	0	0
KIANDONGORO HYDROMET SITE - NYERI	36.8333	-0.45	0	2	5	20	5	10	20	9	5	0	5	0	1	0	1	5	10	3	11	0	11	1	3	29	11	5	0	0	13
MURUA PWD CAMP - KARATINA	37.05	-0.45	0	2	4	14	7	7	31	11	6	0	3	0	4	0	1	9	3	0	4	1	11	5	2	22	11	5	0	6	16
WHITE RHINO HOTEL - NYERI	36.9167	-0.4333	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI AGRICULTURAL OFFICE	36.95	-0.4333	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
R. A. LITTLE - NYERI	36.95	-0.4333	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI PROVINCIAL AGRICULTURAL OFFICE	36.95	-0.4333	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI METEOROLOGICAL STATION	36.9667	-0.4333	0	2	4	15	3	9	28	7	6	0	4	0	2	0	0	5	2	4	7	1	13	6	0	24	12	6	0	6	14
IHWAGI - KARATINA	37.15	-0.4333	0	1	6	12	7	3	35	11	7	0	2	0	5	0	1	11	4	0	6	0	13	1	3	21	10	0	0	6	17
ZAINA FOREST STATION	36.8167	-0.4167	0	2	5	20	5	10	20	9	5	0	5	0	1	0	1	5	10	3	11	0	11	1	3	29	11	5	0	0	13
KABAGE FOREST STATION - OLD	36.8333	-0.4167	0	2	5	20	5	10	20	9	5	0	5	0	1	0	1	5	10	3	11	0	11	1	3	29	11	5	0	0	13

KABAGE FOREST STATION - NYERI	36.85	-0.4167	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI HILL	36.9	-0.4167	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
MINISTRY OF WORKS - NYERI	36.95	-0.4167	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI PRISONS	36.95	-0.4167	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI BAPTIST HIGH SCHOOL	36.9667	-0.4167	0	2	4	15	3	9	28	7	6	0	4	0	2	0	0	5	2	4	7	1	13	6	0	24	12	6	0	6	14
NGORANO CHIEF'S CAMP - KARATINA	37.0667	-0.4167	0	2	4	14	7	7	31	11	6	0	3	0	4	0	1	9	3	0	4	1	11	5	2	22	11	5	0	6	16
KABAGE FOREST STATION - NEW	36.8167	-0.4	0	2	5	20	5	10	20	9	5	0	5	0	1	0	1	5	10	3	11	0	11	1	3	29	11	5	0	0	13
MWERU WORKS CAMP - NYERI	36.9	-0.4	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI HIGH SCHOOL	36.9167	-0.4	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NYERI FOREST STATION	36.9333	-0.4	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NARINGATO ESTATE - NYERI	36.95	-0.4	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
KAGUMO HIGH SCHOOL - KIGANJO	37.0167	-0.4	0	2	4	15	3	9	28	7	6	0	4	0	2	0	0	5	2	4	7	1	13	6	0	24	12	6	0	6	14
CHEHE FOREST STATION - KARATINA	37.2	-0.4	0	1	6	12	7	3	35	11	7	0	2	0	5	0	1	11	4	0	6	0	13	1	3	21	10	0	0	6	17
RUHURUINI GATE - ABERDARES N. PARK	36.8167	-0.3833	0	2	5	20	5	10	20	9	5	0	5	0	1	0	1	5	10	3	11	0	11	1	3	29	11	5	0	0	13
THEGO FORD - NYERI	37.0333	-0.3833	0	2	4	15	3	9	28	7	6	0	4	0	2	0	0	5	2	4	7	1	13	6	0	24	12	6	0	6	14
KAGOCHI TEA FARM - KARATINA	37.15	-0.3833	0	1	6	12	7	3	35	11	7	0	2	0	5	0	1	11	4	0	6	0	13	1	3	21	10	0	0	6	17
RAGATI FOREST STATION - NYERI	37.1667	-0.3833	0	1	6	12	7	3	35	11	7	0	2	0	5	0	1	11	4	0	6	0	13	1	3	21	10	0	0	6	17
NYERI STATION - KIBERIRE	37.0167	-0.3667	0	2	4	15	3	9	28	7	6	0	4	0	2	0	0	5	2	4	7	1	13	6	0	24	12	6	0	6	14
LITTLE SAGANA - NYERI STATION	37.0333	-0.3667	0	2	4	15	3	9	28	7	6	0	4	0	2	0	0	5	2	4	7	1	13	6	0	24	12	6	0	6	14
SAGANA STATE LODGE	37.0667	-0.3667	0	2	4	14	7	7	31	11	6	0	3	0	4	0	1	9	3	0	4	1	11	5	2	22	11	5	0	6	16
TROUT BIOLOGICAL STATION - SAGANA	37.0833	-0.3667	0	2	4	14	7	7	31	11	6	0	3	0	4	0	1	9	3	0	4	1	11	5	2	22	11	5	0	6	16

MWEIGA ESTATE - NYERI	36.9167	-0.35	0	2	4	17	4	9	24	5	5	0	5	0	0	0	0	4	4	7	10	0	12	3	0	25	12	5	0	5	13
NGONDI - NYERI	37.05	-0.35	0	2	4	14	7	7	31	11	6	0	3	0	4	0	1	9	3	0	4	1	11	5	2	22	11	5	0	6	16
KARATINA HOMBHE FOREST STATION	37.1167	-0.35	0	2	4	14	7	7	31	11	6	0	3	0	4	0	1	9	3	0	4	1	11	5	2	22	11	5	0	6	16
KURASE HILL - ABERDARE PARK	36.6667	-0.3333	0	2	4	20	3	5	13	10	3	0	5	2	2	0	0	4	8	1	13	0	13	10	4	18	7	3	0	0	0
MIOGO RIVER - ABERDARE PARK	36.7167	-0.3333	0	2	4	20	3	5	13	10	3	0	5	2	2	0	0	4	8	1	13	0	13	10	4	18	7	3	0	0	0
ARK GATE - ABERDARE PARK	36.85	-0.3333	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
AMBONI AGRICULTURE CAMP	36.8667	-0.3333	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
MWEIGA HQ. - MT. NATIONAL PARK	36.9167	-0.3333	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
ABERDARE COUNTRY CLUB	36.9333	-0.3333	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
BLUE LINE FARM	36.95	-0.3333	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
WANDARE GATE - ABERDARE PARK	36.7667	-0.3167	0	2	5	20	5	8	19	10	4	0	4	0	1	0	1	5	5	3	10	0	9	5	2	20	11	5	0	0	0
BONDENI FARM - NYERI	36.85	-0.3167	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
KAHOHERU ESTATE	36.8	-0.3	0	2	5	20	5	8	19	10	4	0	4	0	1	0	1	5	5	3	10	0	9	5	2	20	11	5	0	0	0
TALAU FARM - MWEIGA	36.8167	-0.3	0	2	5	20	5	8	19	10	4	0	4	0	1	0	1	5	5	3	10	0	9	5	2	20	11	5	0	0	0
KADUNIE - NYERI	37.05	-0.3	0	2	6	14	7	6	31	11	9	0	2	0	4	0	1	9	0	0	2	2	0	3	3	21	10	10	0	6	17
UASO NYIRO FARM - NARO MORU	36.7667	-0.2833	0	2	5	20	5	8	19	10	4	0	4	0	1	0	1	5	5	3	10	0	9	5	2	20	11	5	0	0	0
LAWRENCE MWANGI'S FARM - UASO NYIRO	36.85	-0.2833	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
KIMAHURI PRIMARY SCHOOL	37.1167	-0.2833	0	2	6	14	7	6	31	11	9	0	2	0	4	0	1	9	0	0	2	2	0	3	3	21	10	10	0	6	17
THEGO RIVER ESTATES - NYERI	37.1333	-0.2833	0	2	6	14	7	6	31	11	9	0	2	0	4	0	1	9	0	0	2	2	0	3	3	21	10	10	0	6	17
KABARU FROUT HATCHERY - NYERI	37.15	-0.2833	0	1	10	15	6	3	33	10	11	0	2	0	6	0	1	10	2	0	3	0	4	4	4	19	10	0	0	6	17
KABARU FOREST STATION	37.15	-0.2833	0	1	10	15	6	3	33	10	11	0	2	0	6	0	1	10	2	0	3	0	4	4	4	19	10	0	0	6	17

WATUKA MET. STATION	36.75	-0.2667	0	2	4	20	3	5	13	10	3	0	5	2	2	0	0	4	8	1	13	0	13	10	4	18	7	3	0	0	0
GWATHI MARKET - NDUNYU	36.85	-0.2667	0	3	4	17	5	8	24	9	6	0	4	0	1	0	1	5	1	4	11	0	6	3	1	21	12	6	0	7	14
ENDARASHA SECONDARY SCHOOL	36.75	-0.25	0	3	4	21	6	5	14	12	4	0	2	0	1	3	0	3	1	0	7	0	14	9	2	12	6	2	0	0	0
NARO MORU GIRLS' SECONDARY SCHOOL	37.0833	-0.25	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
THAGA FARM - NYERI	37.1167	-0.25	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
GATARAKWA CHIEF'S OFFICE	36.7333	-0.2333	0	3	4	21	6	5	14	12	4	0	2	0	1	3	0	3	1	0	7	0	14	9	2	12	6	2	0	0	0
WARAZO PRIMARY SCHOOL	37.1167	-0.2333	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
NARO MORU FOREST STATION	37.1167	-0.2167	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
NARO MORU SETTLEMENT SCHEME	37.0667	-0.1833	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
NARO MORU FOREST GUARD POST	37.1167	-0.1833	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
MUGUNDA PRIMARY SCHOOL	36.7	-0.1667	0	3	4	21	6	5	14	12	4	0	2	0	1	3	0	3	1	0	7	0	14	9	2	12	6	2	0	0	0
METEOROLOGICAL STATION LODGE	37.0333	-0.1667	0	3	6	21	7	10	26	12	5	2	1	0	3	0	0	5	0	1	11	5	8	11	4	6	8	6	0	4	11
NARO MORU GATE	37.15	-0.1667	0	1	13	23	7	5	28	11	5	0	1	0	6	0	0	8	1	0	0	1	1	10	7	12	7	7	0	4	11
TELEKI CAMP	37.3	-0.1667	0	1	19	29	6	1	25	10	10	0	1	0	4	0	1	8	4	0	0	0	2	3	6	14	5	9	0	3	12
CHOGORIA GATE	37.3167	-0.1667	0	1	19	29	6	1	25	10	10	0	1	0	4	0	1	8	4	0	0	0	2	3	6	14	5	9	0	3	12
LAMURIA LTD - NAROMORU	36.8667	-0.15	0	3	3	21	7	10	22	14	5	0	1	0	3	3	0	3	1	1	15	4	12	13	2	4	8	4	0	4	8
OLTARAKWAI - NARO MORU	37.0333	-0.15	0	3	6	21	7	10	26	12	5	2	1	0	3	0	0	5	0	1	11	5	8	11	4	6	8	6	0	4	11
OLTARAKWAI - (RACE COURSE)	37.05	-0.15	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
UPPER NARO MORU FOREST POST	37.1333	-0.15	0	2	10	20	7	10	28	12	4	1	0	0	5	0	0	8	0	0	5	4	4	14	6	7	7	6	0	3	11
KAREMENO	36.7667	-0.1333	0	3	4	22	8	11	17	15	3	0	1	0	3	6	0	2	7	0	11	3	22	11	1	0	7	3	0	4	0



