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Assessing and Monitoring Agriculture Crop Production for Improved Food Security in Machakos County

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Abstract: ***Agriculture productivity has been a challenge to food security in Machakos County, Kenya. The area is semi-arid with scanty rainfall amounts irregularly distributed. Population pressure in high agriculture potential areas has pushed human settlement to fragile ecosystems. The objective of this study was to assess state of land cover and land use with keen interest on agriculture land use. Eco-climatic variables are known to influence agriculture crop production, thus crop condition was assessed using normalized difference vegetation index. Rainfall amounts and distribution was analyzed to show its impact on crop production. The methodology was based on satellite data processing. Land use and land cover was derived from Landsat satellite imagery while normalized difference vegetation index was computed from SPOT vegetation satellite data; time series analysis of biomass health and vigor for 2010 and 2011 cropping season in Machakos was analyzed. FEWSNET rainfall data was used to compute cumulative rainfall amount and average for the growing season. The Analysis revealed that Agriculture occupies 64% of the total land mass, and most land in high potential areas of the district is under agricultural production. During March 2011- September 2011 the region received total rainfall of 81-250 mm. Crop condition in 2010 was better than 2011 season, this can be attributed to decline in soil moisture content and nutrients. Agriculture assessment using earth observation data is a viable technology especially when working in a relatively large area with limited resources (time/finances) or when you need to study change over time as with the normalized difference vegetation index. This study proposes use of very high resolution data to capture detailed land use for crop production assessment. Long term change analysis of land cover using Geo information and Remote Sensing would further help in current and future analysis of agriculture crop production in Machakos.***

Keywords: Semi-arid, Remote Sensing, Geo information, Crop production

1. Introduction

Productivity is low in Africa because research has not been able to address the most limiting factors to increased production. The soils of the Sahelian and sub-humid zones are sandy (20% sandy texture), poor in nutrients, and subject to intense erosion. The soils of the lowland tropics (18 %) are acidic, with low absorptive capacity, and also poor in nutrients. The occurrence risk for drought is high for 66 % of the area (FAO, 1986). The agricultural sector is the mainstay of Kenya's economy. The sector directly contributes 24% of the Gross Domestic Product (GDP) and 27% of GDP indirectly through linkages with manufacturing, distribution and other service related sectors (KFSSG, 2008).

Kenya's agriculture is mainly rain-fed and is entirely dependent on the bimodal rainfall in most parts of the country. A large proportion of the country, accounting for more than 80 per cent, is semi-arid and arid with an annual rainfall average of 400 mm. Droughts are frequent and crops fail in one out of every three seasons. Kenya's agriculture is predominantly small-scale farming mainly in the high-potential areas. Production is carried out on farms averaging 0.2–3 ha, mostly on a commercial basis. This small-scale production accounts for 75 per cent of the total agricultural output and 70 per cent of marketed agricultural produce (KFSSG, 2008).

In Machakos County, The environment and natural resources have in recent years been under threat due to increased dependence on natural resources to meet basic needs. The natural resources in the district include land and soils, water, forestry and wildlife as well as commercial minerals. The district is generally dry making rain fed agriculture difficult in many areas. The situation is further aggravated by frequent droughts that deplete any surplus food in the district while affecting pastures. The county faces inadequate water for domestic, livestock, crop and industrial use. Other issues include destruction of water catchment areas, persistent droughts, destruction of existing earth dams and pans, collapse of community water committees etc. The climatic and human factors are causing serious threats of desertification. Poor farming methods and increased population pressure on the land have led to clearing of land which was originally reserved for forests. The county has less than 2% of its area under forest (Machakos DEAP, 2009-2013). Unsustainable farming methods and increased population pressure on the landhave led to clearing of land which was originally reserved for forests in the County. The main threats to food security in Machakos remain to be poor performance and early cessation of rainfall, low adoption rate of drought tolerant crops, use of uncertified seeds and poor access to farm inputs especially in the low lands of the county. Therefore the main objective of this study is generally to assess agricultural crop production using GIS and Remote Sensing, but more specifically to identify extent of agricultural land and general land use/land cover, assess seasonal crop health using vegetation indices, estimate seasonal rainfall amounts and distribution and map soil characteristics related to crop production in Machakos County.

2. Methodology

This study is based on eco-climatic variables within Machakos county-Kenya, specific target population comprises: vegetation cover (type and condition), rainfall amounts andsoil properties. These are the most important variables in crop assessment as they determine productivity and yield. Vegetation index and rainfall amount will beassessed during the March to September wet season in 2010 and 2011; general soil characteristics such as soil texture will also be sampled from satellite imagery for Machakos County. Main data source includes satelliteimagery acquisition, interpretation and analysis. The satellite data of focus includes: Landsat ETM (Enhanced Thematic Mapper), Spot Vegetation NDVI (Normalized Difference Vegetation Index), Fewsnet RFE (Rainfall Estimate) and HWSD (Harmonized World Soil Database) soil data- as described in Table 1:

Table 1: Input Data Sources

Data	*Image/Vector Type*	*Resolution*
Land Use Land	LANDSAT TM	30m
Rainfall	FEWSNET RFE	8 km
Ndvi	SPOT VGT	1 km
Soil	HWSD	1KM

3. Data Processing and Analysis

The data is processed guided by the log-frame in figure 1. Software used to do image analysis and interpretation includes: ArcGIS, Erdas, Ilwis and Microsoft Access/ Excel. Spectral Bands 2, 3, 4 were selected to bring out the vegetation type as illustrated in table 2: Supervised classification was done to identify extent of agricultural land and crop type.

Table 2: Landsat Image Band Combination

Band	Wavelength	Use in mapping
Band 2 - green	0.52-0.60	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 3 - red	0.63-0.69	Discriminates vegetation slopes
Band 4 - Near Infrared	0.77-0.90	Emphasizes biomass content and shorelines

Vegetation Index was derived from SPOT VGT NDVI and a time series of the 2 wet seasons (March-Sept. 2010 and 2011) analyzed; six hotspots were selected for this analysis namely: Mavoko, Machakos town, Kathiani, Matungulu, Masinga and Yatta. Seasonal cumulative and mean Rainfall amounts was analysed and their distribution mapped, besides, trend analysis was conducted to see how rainfall behaved throughout the season and its impact on crop production. Soil data was used to derive parameters such as texture and moisture using Microsoft Excel and ArcGIS software. The HWSD contains soil raster data and database (in MS Access format) which is linked together to select and obtain soil attribute.

4. Results

The classified image in figure 5 shows that the central region is highly vegetated and most agricultural activities take place in this zone. However there are

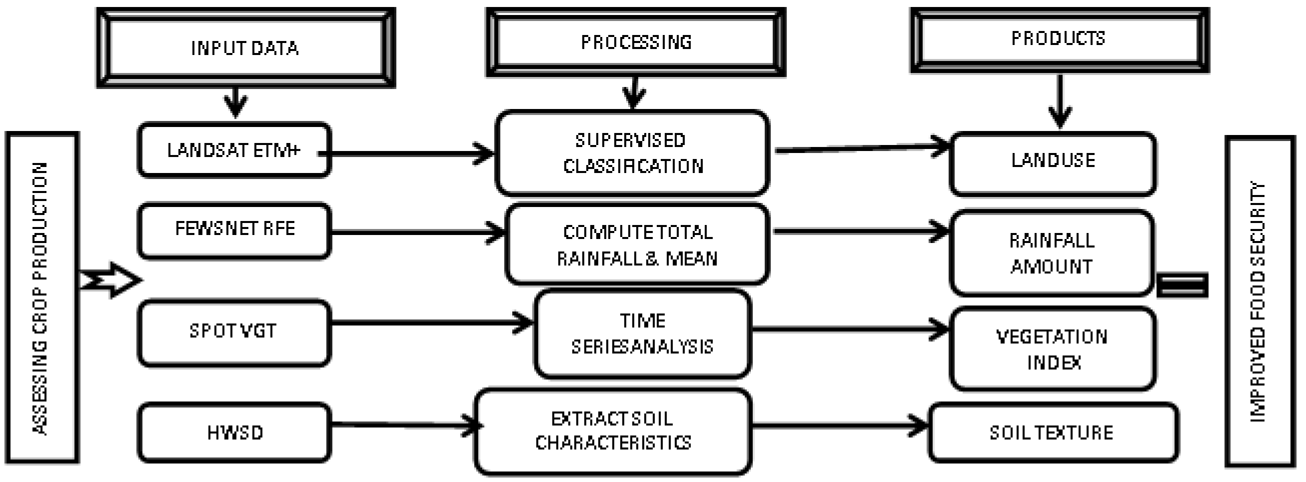

Figure 1: Data processing log-frame

some areas especially around the hill masses in Kathiani and Kangundo which are too steep for cultivation but cultivation is going on. There is also agricultural production in the low potential areas (Mwala, Katangi, Yathui, Kalama, Athi River, Masinga, Yatta and Ndithini divisions). There are soil erosion problems but farmers have put soil conservation structures in most of the farms. Use of fire for bush clearing to plant in Yatta, Katangi, Mwala, Yathui and Masinga is a major environmental concern because of loss of biodiversity.

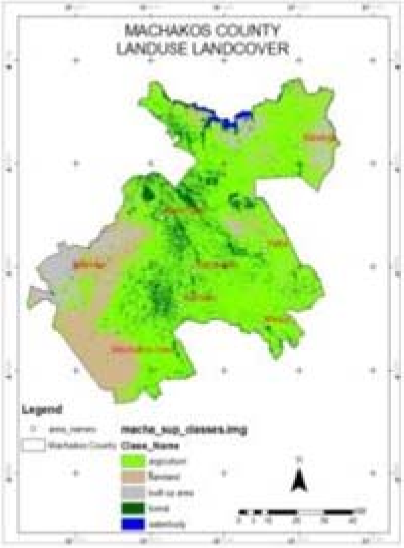

Figure 5: Machakos Land Use Land Cover classification

Supervised classification was done, this brought out agriculture as the main land use in the region, and areas around Machakos town and Mavoko are drier with sparse vegetation. Out of total area, Agriculture occupies 64% which is 3942 sqaure kilometers of the total land mass (See Figure 6): Environmental officers from the region informed this study that the main crops grown in the area include: Cereals (maize, sorghum, millet); Pulses (beans, pigeon peas, cowpeas, chicken peas, greengrams); Root and tubers (sweet potatoes, Irish potatoes, cassava, arrow roots). To a small extent some industrial crops are grown which include: Coffee, Cotton, tobacco and sisal.

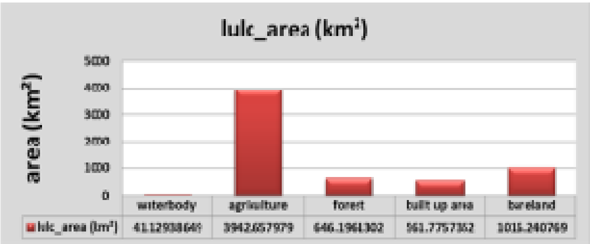

Figure 2: Machakos Land Use Land Cover (%) NDVI

NDVI (Normalized Difference Vegetation Index) from SPOT VGT satellite data was used to monitor the trend of biomass health and vigor. NDVI Maps area useful resource to view crop health variability, identify possible areas of poor plant stand, or show crop development status, helping advisors and producers to identify problem areas, and to make timely decisions.

NDVI = (NIR - RED)/(NIR + RED)

As can be observed in figure 8, the region has NDVI value of 0.22 - 0.42 (normal) and 0.12 - 0.22 (poor) occupying almost the whole region. In 2010, 'poor' NDVI was more distributed than in 2011. This means that crop vigor/health slightly improved in that period of 2010 and 2011. This could be attributed to an increase in crop moisture and nutrients. Sites were selected for comprehensive NDVI trend analysis of the region, these include Machakos town, Mavoko, Matungulu, Kathiani, Masinga and Yatta. These sites were selected based on their potential for Agriculture whereby some fall in high while others low production zones. Matungulu area is illustrated in Figure 9:

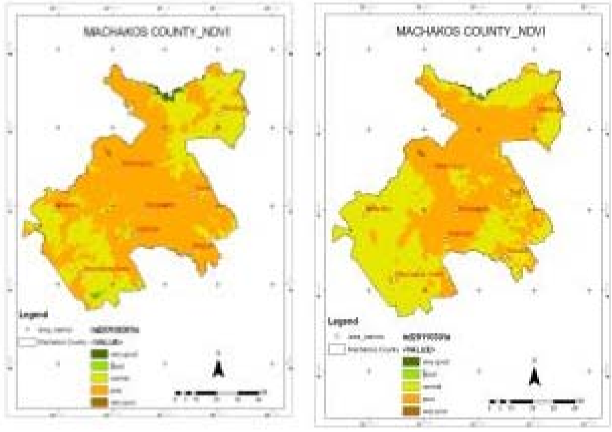

Figure 8: Machakos NDVI Maps (March 2010 & March 2011)

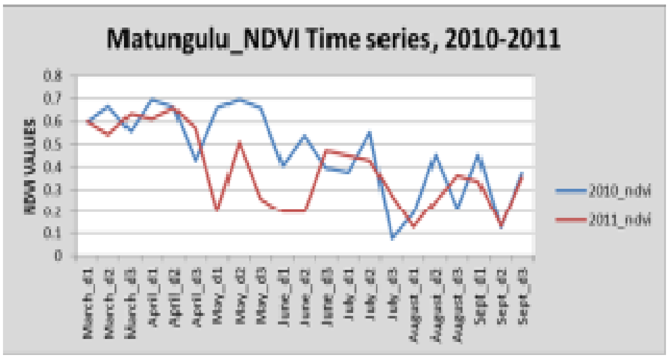

Figure 9: NDVI Time Series, 2010-2011

Predominant crop types in Matungulu are basically cereals and pulses. From figure 9, it's vivid that there is a steady increase of NDVI at the beginning of the growing season, as the crop begins to grow then a sharp decline towards crop harvest. The difference between NDVI trend in 2010 and 2011 is attributed to moisture content, nutrients, pests and diseases, whose increase or decrease affects biomass health and maturity. The results in figure 10 shows that the cumulative rainfall amount in 2010 cropping season was ranging between 215-324mm while in 2011 the amount was 81-251mm, this is lower compared to the previous year. It can therefore be argued that rainfall contributed greatly to better crop health/vigor as was witnessed earlier in the 2010 NDVI graphs. Also rainfall seems evenly distributed in 2010 from the Mua Hills flowing down to Mavoko and Machakos Town. In 2011 rainfall was scanty with little showers being experienced in Mavoko and North West Matungulu. Kenya Meteorological Officer informed this study that the County experiences erratic and unpredictable rains of less than 500mm annually, with short rains in October through to December and the long rains in late March to May. Well from the previous rainfall and NDVI figures, this is true, and it can be argued that the area receives low rainfall that is unsustainable for agriculture. Agriculture production is through rain fed agricultural system. The County is largely semi-arid and the amount and frequency of precipitation is quite irregular.

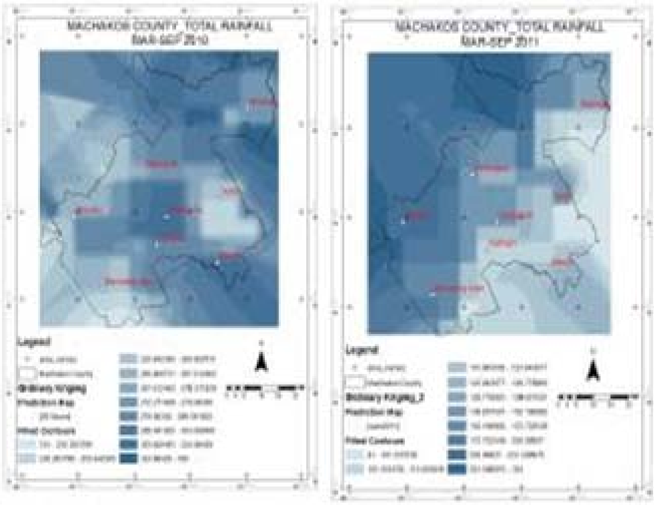

Figure 10: Total Rainfall Amounts (March-Sept 2010 and 2011)

The Harmonized World Soil Database (HWSD) raster data was used to derive soil texture. Figure 11 shows Soil texture Map of Machakos. From the soil texture it's clear that the land is mainly characterized by fine texture soil (clays, silty clays, sandy clays, clay loams and silty clay loams with more than 35 percent clay.) Medium texture soil comes second and basically refers to sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and clay loams. This classification is very important for crop production since Soil texture strongly influences the infiltration of water, the ability of the soil to retain moisture (water holding capacity), its general level of fertility, the tendency to form clods and ease of cultivation.

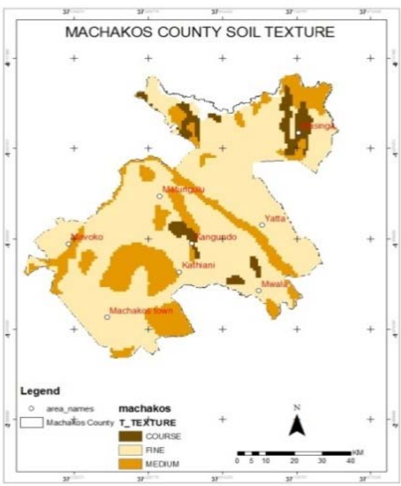

Figure 3: Soil Texture for Machakos County

5. Conclusion

Monitoring NDVI is very essential in crop assessment since the trend can be analyzed to observe when periods of dryness or drought stress occurred during the growing season. These could be caused by reduced moisture content, nutrients, or pests and diseases infestation. Vegetation index is not only useful in past and current growth assessment but also forecasting and early warning. The area has a predominant non mechanized rain-fed agriculture as opposed to irrigated agriculture; this has posed great challenge to crop production as the amount, frequency and distribution of rainfall is not sufficient. Remote sensing and GIS is a useful tool in assessing agriculture crop production especially in large areas where immediate results are needed. Spatial resolution of satellite imagery is important when details are needed, therefore this study proposed use of higher resolution satellite imagery for a more detailed crop assessment. This will give room for individual crop assessment and monitoring thus give more comprehensive result. Long term change detection (ten to thirty years ago) of land use and land cover with keen interest on agriculture land use in Machakos would enhance understanding of current and future trends in crop production. Crop yield forecasting could also be generated from the NDVI time series analysis presented above together with current data on crop yield. This would be useful for food security plans. With geospatial analysis farmers may have the ability to visualize their land, crops, and management practices in unprecedented ways for precise management of their businesses. Today, accessing spatial data has become an essential farm practice. Governments may need to host web sites that deliver valuable information to help farmers better understand their land and make more informed decisions. This data can be accessed on the Internet and used to create intelligent maps for better farm business practices.

6. Acknowledgement

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