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Assessment of trends in land cover and crop type change over two decades in Yatta sub county, Kenya

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Abstract

Assessment of the distribution and dynamics of vegetation is becoming increasingly important in predicting the effects of climate change especially in the ASALs. It is therefore important to determine the effects of climate change on the crop type and land cover of the semi-arid regions hence the current study was carried out to assess the changes in crop type and land cover between 1986 – 2000 and 2000 – 2012 in Yatta District, Kenya. The LANDSAT TM, ETM and ETM+ satellite images of the years 1986, 2000 and 2012 in Yatta Sub-county were classified using ENVI 4.7 under supervised classification into different crop types and land cover. False colour composite using different reflective indexes (Bands 4, 3, 2) were used for the visual examination and interpretation of the images and maximum likelihood method of classification used. The percentage changes of crop types between 1986 – 2000 and 2000 – 2012 were determined using ENVI EX by comparing two images of different times. Questionnaires were administered to establish change detection from traditional (crops grown in the past but have been abandoned and underutilized) to introduced (crops grown as a result of technological advancement and economical advantage) crops in specific locations within the respondents farms. In 2012, maize and beans covered 72% while traditional crops (Sorghum, finger millet, cassava, dolichos, sweet potatoes, green grams, cowpeas, pigeon pea, and pumpkins), shrub land, bare land and riverine forest covered 14, 6, 3 and 5% of the study area, respectively. There was a significant (P=0.000) decline in the area under traditional crops (10.44 and 11.93 %), and a significant (P=0.000) increase in maize (4.70 and 22.73%), beans (23.83 and 2.6%) and bare land (3.42 and 1.03%) between the years 1986 – 2000 and 2000 – 2012 respectively. However, there was a significant (P=0.006) decrease in riverine vegetation (2.7 and 3.13 %) as well significant (P=0.000) decrease in shrub land (18.81 and 11.3 %) between the years 1986 – 2000 and 2000 – 2012 respectively. The observed trends will be important in guiding capacity builders on the crop type and land cover changes in the region who will in turn sensitize the community on the importance of traditional crops in view of the increasing climate variability and help in development of strategies for reintroduction of traditional crops in view of climate change and dwindling land resources as well as inform policies that will promote their reintroduction to achieve food security.

Keywords

Crop Type Change, Climate Change, Introduced Crops, Landsat Images, Traditional Crops

1. Introduction

Climate change is predicted by scientists to have the main impact on agriculture, economy and livelihood of the populations of under-developed world and mainly in sub-Saharan Africa (Kandji *et al*., 2006). Changes in land cover and land use have become recognized as important global environmental changes in their own right (Turner, 2002).

To understand how these changes affect and interact with global earth systems, information is needed on what changes occur, where and when they occur, the rates at which they occur and the social and physical forces that drive these changes (Lambin *et al*., 2003). Comprehensive information on the spatial distribution of the land use/land cover categories and the pattern of their change is a prerequisite for planning, utilization and management of the land resources.

The land use/land cover pattern of a region is an outcome of natural and socioeconomic factors and their utilization by man in time and space. Information on land use /land cover and possibilities for their optimal use is hence, essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare activities. This information is necessary in monitoring the dynamics of land use resulting out of changing demands of an increasing population particularly in the arid and semi-arid lands (ASALs) (Singh and Khanduri, 2011)

Over 80% of Kenya's landmass is classified as ASALs (Oshahr and Viner 2006). Farmers in the ASALs cultivate a variety of economically important crops such as maize, sorghum, green grams, beans and cowpeas under rain-fed agriculture as well as horticultural crops such as mangoes, bananas, tomato, onions, kale, capsicum, pawpaw and citrus. This is however not the case for the farmers in Yatta sub - County who mostly cultivate introduced crops such as maize and beans that are however not adaptable to the harsh climate conditions of the area (Ministry of Agriculture, 2007).

The change in land area under introduced crops from traditional ones can be attributed to many of the landraces being lost with the "green revolution" that introduced high-yielding varieties of crops to boost food self-sufficiency in famine-prone countries. The high-yield crop varieties were widely distributed, often with government subsidies to encourage their adoption, and they displaced local traditional crops from many farmland areas (Padulosi *et al*., 2000; IPGRI., 1998). The "pushing forward" of high-yielding crops in developing countries through subsidies in the widest sense has quite often eliminated farmers' economic rationale. Now, "there is an increasing endorsement at national and international level of the important role in sustainable farming systems and human well-being of less-used (abandoned or orphaned) crops and species, particularly in less favorable and marginal lands" (Padulosi *et al*., 2000; IPGRI 1998). It is therefore important to establish the trend in crop abandonment as well as the reasons for the same to found basis for reintroduction. It has been widely accepted that land use land cover change in an area is as a result of the complex interactions between driving forces. Population increase, intensive and extensive agricultural practices, urbanization as well as economic development (Kelarestaghi and Jeluodar, 2009) are among the forces that cause changes in land use land cover change which lead to severe environmental problems such as droughts, floods, landslides (Giri *et al*., 2003). Researchers (Rahman et al., 2005, Rouchdi *et. al*., 2008) have therefore acknowledged the advantages of remote sensing coupled with Geographic Information Systems (GIS) in mapping, monitoring and detecting land use land cover dynamics.

In this study, an effort was made to map and detect vegetation cover and crop type changes over two time periods, 1986 – 2000 and 2000 – 2012 in Yatta sub- County using Landsat remote sensed data and GIS technology to examine and establish the trend in the change of crop cover over the years from traditional crops to introduced crops.

2. Materials and Methods

2.1. Study Site

The study was conducted in Yatta sub- County located in Machakos County, Kenya which lies between 1.50^0 S and 37.25^0 E. The sub - county has three administrative divisions namely; Ikombe, Yatta and Katangi. The total land area of the study site is 372.17 km^2. The sub-county is mainly in agro-climatic zone IV which is classified as semi-arid land (Landon, 1984).

The mean annual temperature ranges from 17ºC at night to 24ºC during the day and experiences bimodal rainfall pattern; with long rains (LR) commencing end of March to May (about 400 mm) and short rains (SR) from end of October to December (500 mm). The major soils in Yatta sub - county are a combination of Ferric Luvisols, Lithisols and Rhodic Ferralsols (USDA, 1978; WRB, 2006). These soils are well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay with high moisture storage capacity and low nutrient availability (Kibunja *et al.,* 2010). The majority of the farmers in the sub - county are small-scale farmers practising mixed farming (crops and livestock) with low investment for agricultural production. The most prevalent cropping system is maize, beans, and cowpea intercrop (Macharia, 2004).

2.2. Data Collection

One Thematic mapper (TM) for year 1986, one Enhanced Thematic Mapper (ETM) for year 2000 and one Enhanced Thematic Mapper plus (ETM+) for year 2012 were obtained from Regional Centre for Mapping of Resources for Development (RCMRD), Kenya. These LANDSAT imageries were used to assess crop type and land cover changes in the study area. The selected years of the images were purposively chosen considering the effect of cloud cover especially in the study area and temporal sensitivity.

2.3. Land Cover and Crop Type Classification

ENVI 4.7 software (ESRI, 2009) was used to process the LANDSAT imagery for the years 1986, 2000 and 2012.

Maximum likelihood method of supervised classification was used to get different crop types and land cover. False colour composite using different reflective indexes (Bands 4, 3, 2) were used for the visual examination and interpretation of the images. To avoid uncertainties, the selected images were acquired within the same season of the years (December). The images were then classified into different land cover and crop types using supervised classification. Classification of different crops (introduced and traditional crops) was based on the information provided by the farmers regarding their past and current spatial crop production. A total of 60 farmers selected by proportion in line with the population size of the sub-County based on the Cochrane formulae (Cochran, 1977) were interviewed. Specific locations where these crops used to be grown in the year 1986, 2000 and currently 2012 were recorded using a GPS receiver with the guidance of the farmers. False colour composite using different reflective indexes (Bands 4, 3, 2) were used for the visual examination and interpretation of the images and maximum likelihood method of classification (Dutta and Sharma 1998) was used. Six main land cover types were classified according to Anderson (1998) guidelines and selected to carry out statistical analysis. The crop types included; traditional crops (Sorghum, finger millet, cassava, dolichos, sweet potatoes, green grams, cowpeas, pigeon pea, pumpkins), maize and beans while the other types of land cover were riverine forest, shrub land and bare land.

Thematic change detection was established using ENVI EX Software (ESRI, 2009 by comparing two images of different times (1986-2000 and 2000-2012 image changes). The software identified differences between the images with a resultant classification image and statistics. The statistics on image changes were examined and analysed for land cover and crop type changes and their percentage changes subjected to Chi-square test to establish significance levels.

3. Results and Discussion

3.1. Trends in Crop Type Change between the Years 1986, 2000 and 2012

A significant (P<0.05) decrease in area under traditional crops (Sorghum, finger millet, cassava, dolichos, sweet potatoes, green grams, cowpeas, pigeon pea, pumpkins) while that under maize and beans increased over the 1986 – 2000 and 200 – 2012 period (Figure 1). The greatest crop type and land cover change occurred after 2000 with rapid increase in introduced crops grown, shrub land and bare land and decrease in traditional crops and riverine forests.

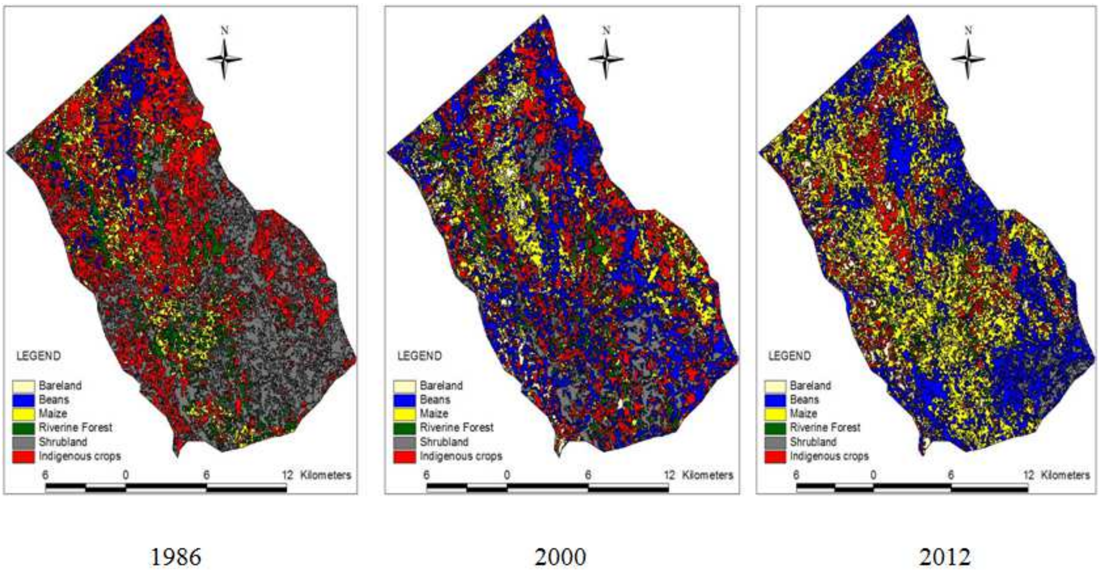

Figure 1. *Crop type and land cover change in the years 1986, 2000 and 2012*

Shrub land decreased from 35.94% in 1986 to 17.13% in 2000 and 5.83% in 2012 while bare land increased from 0.18% in 1986 to 3.60% in 2000 and to 4.63% in 2012. In contrast, the riverine forest decreased from 9.14% in 1986 to 6.44% in 2000 to 3.31% in 2012. There was significant decrease (Table 1) in cultivation of traditional crops in the years 1986 – 2000 and 2000 – 2012 (P = 0.000) with corresponding significant increase in the maize crop (P = 0.000) as well as beans (P = 0.000). Significant decrease in shrub land (P = 0.000) and riverine forest (P = 0.006) and consequent significant increase in bare land (P = 0.001) were also observed (Table 1).

The change in crop type and vegetation change (from traditional crops to introduced crops, riverine forest and shrub land decrease and bare land increase) is attributed to low unreliable rainfall (92%), population increase (42%), low inputs (42%) and poverty(37%) as per results from the farmer suvey. The decreasing shrub land and riverine forest and increasing bareland is mainly as a result of increased population hence increased human activities such as agricultural activities coupled with the changing climate (Kioko and Okello, 2010; Mutie *et al.,* 2006; Pelikka *et al.,* 2005; Gunlycke and Tamala, 2011; Ochego, 2003). Studies have shown that population growth is the major driver of land use/land cover over time owing to the increasing demand for productive land which is met by clearing more forest and shrub land and increased land degradation hence increased bare land (Barasa *et al.,* 2010; Ramankutty *et al.,* 2002). The rising population especially in developing countries imposes lots of pressure on the land resources in a country such as Kenya where approximately 75% of the populace engages in agriculture but only 20% of its land is arable. As a result, the shortage of arable land has led to expansion of cultivation into the wetter margins of rangelands, felling of forests and the declining savannas and grasslands due to overgrazing, charcoal burning and other unsustainable land use practices (Mwagore, 2002; Campbell et al., 2003).

Table I. *Land cover and crop type changes in Yatta sub - County*

	1986		**2000**		**2012**		**Change (1986-2000)**		**Change (2000-2012)**		**(Chi-Square Test)**		
Land use/cover	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	%	Area (km^2)	%	X2		P Value
Indigenous Crops	136.80	36.76	97.95	26.32	53.55	14.39	-38.84	-10.44	-44.40	-11.93	35.799	0.000	0.000
Maize Crop	42.53	11.43	60.03	16.13	144.62	38.86	17.50	4.7	84.60	22.73	72.250	0.000	0.000
Bean Crop	24.39	6.55	113.06	30.38	122.76	32.98	88.67	23.83	9.69	2.6	68.546	0.000	0.000
Riverine Forest	34.01	9.14	23.98	6.44	12.33	3.31	-10.03	-2.7	-11.65	-3.13	10.400	0.006	0.006
Shrub Land	133.76	35.94	63.75	17.13	21.68	5.83	-70.01	-18.81	-42.06	-11.3	87.309	0.000	0.000
Bare Land	0.68	0.18	13.40	3.60	17.23	4.63	12.72	3.42	3.83	1.03	13.419	0.001	0.001
Total	372.17	100	372.17	100	372.17								

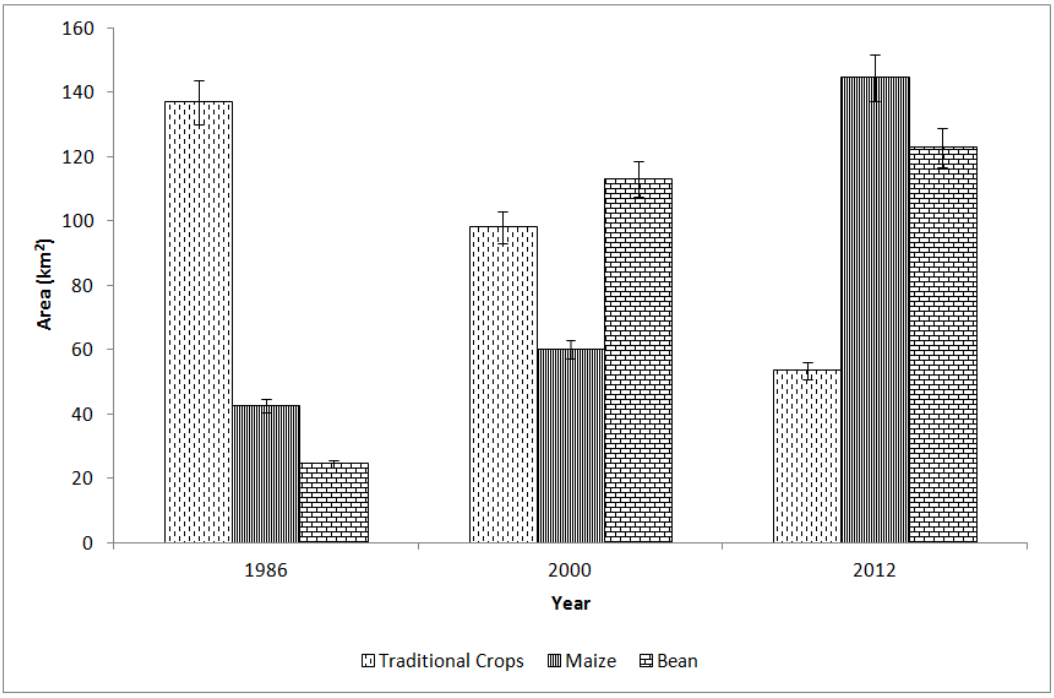

Figure 2. *Crop type change over the years*

3.2. Traditional Crops vs. Introduced Crops

The area (%) covered by traditional crops and introduced crops in the year 2012 were; traditional crops (Sorghum, finger millet, cassava, dolichos, sweet potatoes, green grams, cowpeas, pigeon pea, pumpkins) (14%), maize (39%) and beans (33%) (Table 1). The area under traditional crops decreased significantly from 36.76% in 1986 to 26.32% in 2000 and to 14.39%in 2012 while area covered by maize increased significantly from 11.43% in 1986 to 16.13% in 2000 and 38.86% in 2012 (Table 1). The area covered by beans also increased from 6.55% in 1986 to 30.38% in 2000 to 32.98% in 2012. Traditional crops decreased significantly while the introduced crops (maize and beans) increased significantly in the years 1986, 2000 and 2012, respectively (Figure 2).

In 1986, the traditional crops mostly grown were pigeon pea (24%), cowpea (21%), green grams (19%), sorghum (16%) and millet (11%) while in 2000 the common traditional crops grown were pigeon pea (21%), sorghum

(21%), cowpea (19%) and green grams (19%). In 2012, the common traditional crops were pigeon pea (23%), sorghum (22%), green grams (22%) and cowpea (21%). Other traditional crops grown though not in significant proportions were dolichos, cassava, millet, sweet potatoes, pumpkins and yams. From these observations, pigeon pea, sorghum and cowpea were the most planted traditional crops across the two decades. In Kenya, following the Green Revolution and the push to use modern agriculture to improve food production and security, a high proportion of farmers grew introduced crops. Traditional crops however offer a huge potential for building resilience and adapting to climate change especially in ASALs. Crop choice is very climate sensitive (IIED, 2011; Kurukulasuriya and Mendelson, 2006).

Change from traditional crops to introduced crops can be attributed to the economic importance attached to these crops hence the abandonment of the traditional crops that are more adapted to the local climate of the area. Studies have shown that there is a decrease of area under production of other crops in preference to high value crops of economic importance such as maize. This is as a result of both natural and socio-economic factors and their utilization including population increase and modernisation and commercialization of agriculture (Choudhury and Saha, 2003; Sharma, 2011)

Poverty and population increase are the major drivers behind increased economic importance attached to cash crops and are therefore the major causes for the change resulting in increased land area under agriculture. Research by Agatsiva and Oroda (2001) in Eastern Kenya revealed that the main crops grown in the area were maize and beans usually intercropped while food crops such as sorghum were also grown but at a lower scale. However, most of the farmers were achieving less than 10 bags of maize per acre due to droughts (climate change). Another study by Maeda *et al*. (2010) in Taita Hills showed that maize and beans were the predominant crops grown in the area while crops that are more resistant to drought such as cassava, pigeon peas and cowpeas were grown on a much smaller scale.

Climate variability is another factor contributing to the changing crop type due to the fact that over the years, crop yields have been reducing as a result of climate change translating to reduced economic returns and hence the need for farmers to increase their economic returns by planting introduced cash crops even though they are not adapted to the region. De bie et al. (2008) found that disparity between the crop types and the changing crop intensities were attributed to major droughts faced in India during the period of study. A similar study by Punithavathi, *et al*. (2012) to assess agricultural cropping concentration and crop wise changes, showed changes in crop types grown as a result of migration of people and poor climatic conditions due to climatic changes.

4. Conclusion

A tremendous change in crop types and land cover within the last two decades in Yatta sub – County was noted. A clear trend was established in the shift in crop types grown over the two decades with major significant ($P<0.05$) changes observed from traditional crops that are more adaptable to the regions' local climate to introduced crops, preferred due to their economic advantage. The riverine forests and shrub land also significantly ($P<0.05$) reduced while bare land increased. These changes can be majorly attributed to population growth, human activity, poverty and climate change. This study is therefore likely to be used for future generations monitoring methods especially for crop type change. As traditional systems and land husbandry are rapidly being abandoned, an alternative approach is essential in view of the changing climate.

This study will inform government policies that will cater for the abandoned crops and encourage there re-adoption especially in the ASALs where they are more adapted as compared to the modern crops. It will also aim to enlighten the community to better understand the crop trends in their region, the reasons for their abandonment and the importance of the abandoned crops as well as their reintroduction thus creating more opportunities for research in these areas.

From this study, it would be important to look at the economic impact of the crop type change and possibility of producing a multi-year cropping pattern map for use in future spatial crop distribution prediction in view of the current climate changes. Future research efforts should be put into new crops that are more suitable for the semi - arid regions as well as making the current crops more resilient to the local climate as this would go a long way in improving the farmers' economic welfare as well as food security.

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