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Modeling Aromatic Resins and Gum Arabic Resources from a Combination of High and Medium Spatial Resolution Satellite Imagery - A Case Study of Burco District, Northern Somalia

Gicheha R. W[1], Ngigi T. G[2], Kuria A. G[3]

[1]Jomo Kenya University of Agriculture and Technology, Department of Geomatic Engineering and Geospatial Information Systems (GEGIS) P.O Box 62000-00200 Nairobi, Kenya

[2]Jomo Kenya University of Agriculture and Technology, Department of Geomatic Engineering and Geospatial Information Systems (GEGIS) P.O Box 62000-00200 Nairobi, Kenya

[3] Tropical Biological Association - Nature Kenya, P.O Box 44486-00100 Nairobi-Kenya

Abstract: ***Northern Somalia has high potential for gums and resins production due to its suitable climatic conditions and soil type. These resources are found within the dry lands and do well in areas with sandy soils. Gum Arabic is produced by Acacia Senegal while Gum Resins is produced by Commiphora Myrrh. These resources have great value in that they are used as stabilizers in the food industry, used as medicine, in perfume industry and for raw materials. Northern Somalia being a dry land and where people are nomadic with few options for alternative sources of livelihood due to the difficult environmental conditions resulting from scanty and erratic rainfall and poor soils, this research will be used to assess the availability of these resources within Burco area. Remotely sensed satellite images both high spatial resolution World view images (0.5m resolution) and medium spatial resolution landsat images (30m resolution) were used to map the 2 resources. Two sites were identified (Site A and B), using one site i.e. Site A, the two resources were carefully mapped using the high spatial resolution Worldview image. Using Python scripting, resource percentages per grid cell was computed for the 2 resources plus "Other resources". Linear regression models were developed that compared the relationship between the medium resolution components i.e. landsat reflectance bands, PCT and NDVI with the resource as mapped using the high resolution. Resource percentage for site B was computed using the linear regression models and the medium resolution components i.e. landsat reflectance bands, PCT and NDVI. The percentage resource mapped using the high spatial resolution image was compared with the one computed using regression models and the relationship analyzed using SPSS, statistics software which showed a significant relationship. The results obtained from this research could be improved through use of complex models e.g. Parabolic models and through ground truthing which was difficult due to insecurity situation in Somalia.***

Keywords: Remote sensing, Gums and Resins, GIS, Python programming

1. Introduction

Sub-Saharan region is referred to as “the gum belt” of Africa due to the high volumes of gum Arabic the region produces [4]. These resources (gums) have great potential to generate wealth and uplift the living standards of the local community in the dry lands. Being a renewable resource, gums are sustainably exploited to supplement household income while increasing the overall productivity of drylands [5]. Gums and resins serve as raw materials for enterprise development thus providing opportunities for trade and employment for rural. In addition to commercial exploitation, gum belt help hold the sandy soils in place and prevent desertification thereby supporting the conserving biological diversity and sustaining ecosystem functions in drylands[3].

Research shows that *Acacia senegal* and *Commiphora myrrh* are among leading sources of gums and resins resources in the gum-belt of Africa [9]. These resources make for an important livelihood activity for the nomadic people of Somalia, as the dry lands where they live offers few alternative sources of livelihood [1]. As a country, Somalia is the third highest producer of gums and resins after Sudan and Ethiopia exporting large quantities of these resources to the Middle East [2]. Much of the gums and resins from the Somali states of Somali Land and Punt Land come from *Commiphora myrrh* (key source of gum resins) and *Acacia Senegal* (that provides gum arabic) [8].

In Somalia, commercial exploitation of gums and resins is greatly hampered by insecurity and the sparse distribution of gum producing trees. Coupled with poor accessibility, the situation makes it difficult and expensive for gum trappers to access market, but more importantly easily find suitable area offering high trap returns. In addition, the situation makes it difficult to rely on ground data collection methods to generate the required information on resource distribution. However, a remote sensing technique provides a reliable alternative approach that is convenient for generating the much needed information for government, researchers and other interested parties [7].

The remote sensing approaches used in this project helped overcome the major gap of lack of detailed maps of resources on the ground. The integration of remote sensing with programming techniques in python, made it possible to reliably compute percentages of *Acacia senegal* and *Commiphora myrrh* resources. This is because the combination of both medium and high resolution satellite data produced high quality results; the latter allowed the identification of individual (gum-producing) tree bushes and extrapolate to a large area. This was cost effective since cost for buying high resolution to cover the entire study area would have been prohibitive [10].

2. Methodology

Burco is a cool but dry area with temperatures that range from 200 C to 240 C and rainfall from 200mm to 300mm [6]. Burco comprises mainly Yermisols soils which are rather poor for agriculture where Acacias and Commiphora are the dorminant species.

Remote sensing technology which is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object area or phenomenon was used to do the mapping.

Mapping of gums and resins resources requires high resolution satellite images up to cm accuracy to determine tree species. Landsat medium resolution image for Burco was acquired. The image was processed into a composite of 6 bands (blue, green, red, near infra-red, mid infra-red, and Shortwave Infra-red). A second set of Worldview high resolution images with a resolution of 0.5cm was acquired.

The high resolution images were overlaid with field data on distribution of Acacia senegal and Commiphora myrrh in Burco. An area of 243km2 with highest concentration of each of Acacia senegal and Commiphora myrrh selected for this study. An equal extent of Worldview high resolution images and landsat medium resolution image was clipped out. Worldview high resolution image was classified into 3 resource classes: Acacia Senegal, Commiphora myrrh, and "other resources".

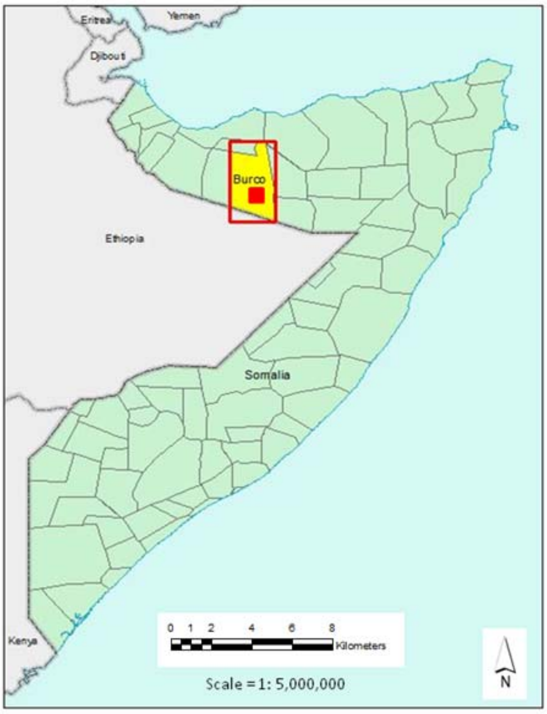

Figure 1: Study Area

using Erdas 2013 hybrid classification as shown in figure 2. This involved performing a combination of both supervised and unsupervised classification and was informed by ground knowledge of the distribution of target resources. The classification was at 0.5m spatial resolution allowing identification of individual resource bushes. Fishnet modeling tool was used to extract a 30 x 30m grid that matched the Landsat medium resolution pixel resolution Figure 3.

Landsat was also used to extract other component used in the model i.e Digital numbers from reflectance bands i.e. Band 1 (The Blue band), Band 2 (Green Band), Band 3 (Red Band), Band 4 (Near Infra-Red band), Band 5 (Mid Infra-Red band) and Band 7 (Microwave Band). Other Landsat components extracted included Principal Component Transformation (PCT) which compresses data reducing redundancy and eliminates bands that's are highly correlated. six PCT components (12345 and 6) were computed.

Normalized Difference Vegetation Index (NDVI) was computed using Red and Near Infra Red bands using the formula below:

$$\frac{NIR - RED}{NIR + RED}$$

If NDVI > 1 The area has more vegetation
NDVI < 1 The area has little or no vegetation

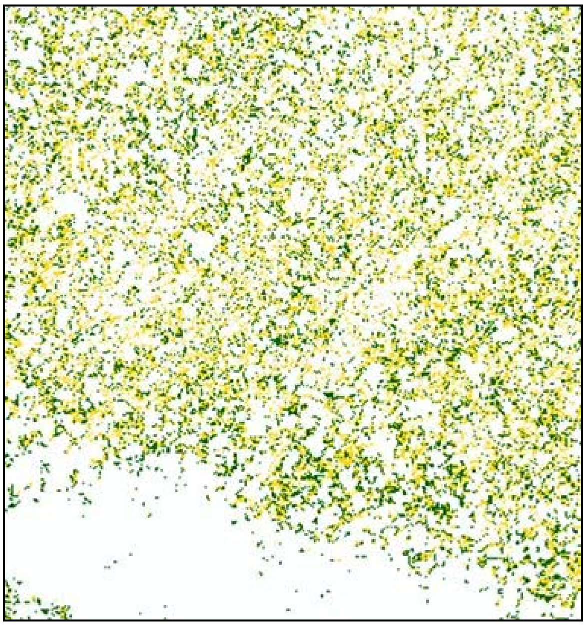

Figure 2: Classified image showing distribution of Acacia Senegal (green), Commiphora myrrh (yellow) and other resources (white).

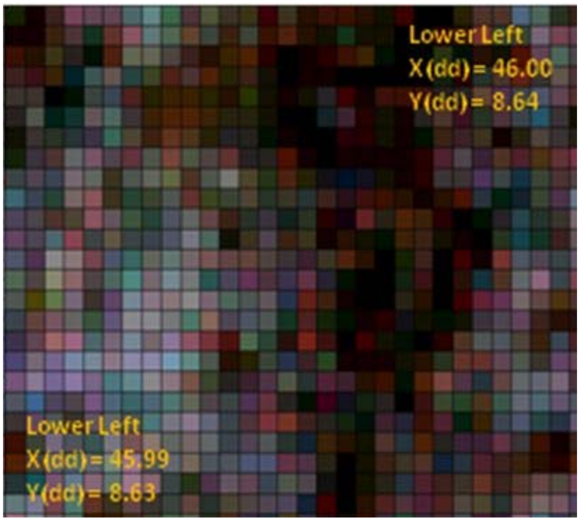

Figure 3: 30mx30m grid matching Landsat image Pixel

3. Data Analysis

Two sites were identified (Site A and B) Using one site i.e. Site A, percentage resources for Acacia Senegal, Commiphora myrrh, and "other resources" was computed per 30m x 30m grid cell using python scripting. Data from site A was used to compute mathematical models of percent resources against each of the landsat components based on the best-fit line y= mx + c, where

y = percent resources;

x = the landsat component used to predict 'y';

m = slope of the line showing the direction of the relationship between y and x, and

c = intercept, or the value of 'y', when "x" = zero

Data from site B was used to test the mathematical models developed out of the data from site A. Using landsat components data for site B, a new set of percent resources were estimated for each for the 30m x 30m cell. Only those mathematical models that explained a significant variation of 'y' were tested. The new estimated percent resources were compared with worldview percent resources computed using python script for site B.

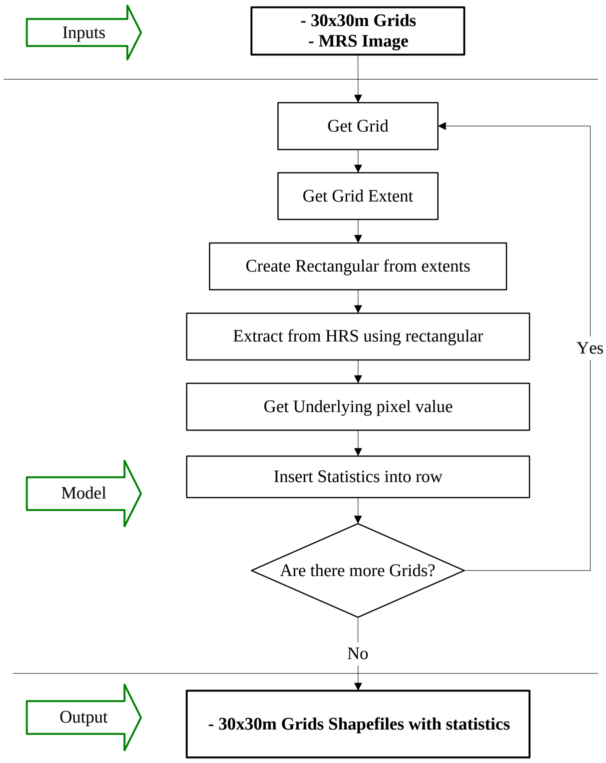

Figure 4: Process applied in the python script to extract landsat components

4. Results and Discussions

Regression result indicated that a highly significant amount of variation in both percentages Acacia Senegal and Commiphora myrrh was explained by each of the landsat bands, PCT1 and PCT4, and NDVI as shown in Table 1 and 2 as well as in figure 5 and 6.

Table 1: Regression of worldview % Acacia senegal (y), against landsat components (x) and corresponding model (y= mx + c) statistics.

Landsat components (x)		Slope(m)	Intercept (c)	Regression statistics			
				R	R^2	$F_{(1,1146)}$	P value
Band	1	0.296	(8.551)	0.171	0.029	34.66	0.000
	2	0.454	(7.741)	0.264	0.070	86.16	0.000
	3	0.244	(7.996)	0.339	0.115	148.55	0.000
	4	0.334	(19.977)	0.374	0.140	186.87	0.000
	5	0.154	(17.235)	0.393	0.154	209.15	0.000
	7	0.195	(11.611)	0.395	0.156	212.20	0.000
PCT	1	0.103	(15.357)	0.386	0.149	200.09	0.000
	2	(0.063)	9.786	0.034	0.001	1.34	0.247
	3	(0.825)	16.589	0.247	0.061	74.26	0.000
	4	(0.293)	21.250	0.100	0.010	11.52	0.001
	5	(0.098)	11.320	0.029	0.001	0.99	0.320
	6	0.010	13.237	0.002	0.000	0.00	0.951
NDVI		(65.970)	17.611	0.210	0.044	52.98	0.000

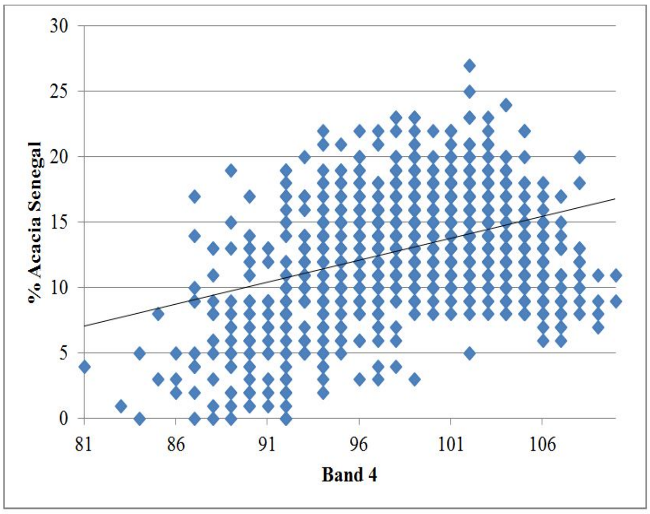

Figure 5: Relation between Modeled Acacia Senegal with Landsat band 4 showing positive correlation

Table 2: Regression of worldview % Commiphora myrrh (y), against landsat components (x) and corresponding model (y = mx + c) statistics.

Landsat components (x)		Slope (m)	Intercept (c)	Regression statistics			
				R	R^2	$F_{(1,1146)}$	P value
Band	1	1.506	(97.011)	0.595	0.354	628.488	0.000
	2	1.684	(64.283)	0.671	0.450	936.642	0.000
	3	0.713	(48.576)	0.677	0.458	967.318	0.000
	4	0.936	(79.570)	0.717	0.514	1,210.731	0.000
	5	0.398	(65.376)	0.694	0.482	1,067.129	0.000
	7	0.501	(50.428)	0.694	0.482	1,066.492	0.000
PCT	1	0.276	(62.850)	0.703	0.494	1,119.963	0.000
	2	(1.088)	(44.059)	0.401	0.160	218.942	0.000
	3	(0.065)	13.412	0.013	0.000	0.204	0.652
	4	(0.754)	34.060	0.176	0.031	36.430	0.000
	5	(0.981)	(4.989)	0.202	0.041	48.663	0.000
	6	0.252	15.917	0.030	0.001	1.015	0.314
NDVI		(205.056)	27.093	0.447	0.199	285.401	0.000

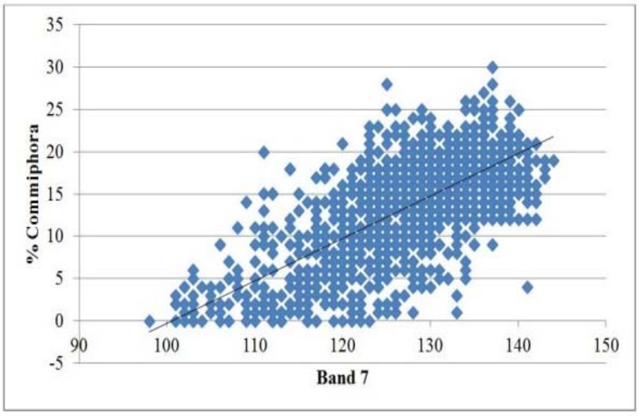

Figure 6: Relation between Modeled Commiphora with Landsat Band 7 showing positive correlation

Acacia Senegal mapped using high resolution was compared with results from the model, there were significant but negative associations for all models except PCT4. The model developed from NDVI returned a positive association that was also significant, as shown in table3.

Table3: Spearman's ranked correlation coefficients (rs) of worldview against mathematical model-estimated percentage Acacia Senegal resources (N=1148)

Model's landsat component	R_s	P value
Band1	-0.31	0.000
Band2	-0.311	0.000
Band3	-0.276	0.000
Band4	-0.396	0.000
Band5	-0.23	0.000
Band7	-0.214	0.000
PCT1	-0.255	0.000
PCT3	-0.071	0.016
PCT4	-0.042	0.150
NDVI	0.02	0.001

There were significant, but negative associations between Commiphora myrrh percentages mapped using the high resolution and the percentage amounts estimated from the mathematical model for band 4 and PCT2 (Table 4). However, the models developed from Bands 5 and 7 and NDVI returned positive associations that were also significant (Table 4).

Table 4: Spearman's ranked correlation coefficients (rs) of worldview against mathematical model-estimated percentage Commiphora myrrh resources (N=1148)

Model's landsat component	R_s	P value
Band1	-0.045	0.128
Band2	-0.03	0.305
Band3	0.16	0.589
Band4	**-0.11**	**0.000**
Band5	**0.062**	0.035
Band7	**0.07**	0.018
PCT1	0.037	0.209
PCT2	**-0.344**	**0.000**
PCT4	-0.04	0.176
PCT5	-0.047	0.112
NDVI	**0.232**	**0.000**

5. Conclusion

Remote sensing technology was found to be a very good tool for mapping resources especially tree species due to its uniform and regular image acquisition intervals and images coverage. This is suitable in Somalia context where the resources are scattered in the vast land and most areas are not accessible due to rough terrain and insecurity.

Tree mapping requires very high accuracy to distinguish between different species. The model developed was based on High resolution worldview 1 images with a resolution of 50cm; with this kind of resolution one is able to accurately delineate tree bushes therefore enhancing the accuracy of mapping. The model was used to extrapolate to larger areas using medium resolution landsat images. Combining high resolution and medium resolution provided a faster, accurate and cost effective means of mapping resources. Processing the medium resolution satellite image into Principle transformations and NDVI components helped extract more information which could not have been captured visually.

Remote sensing was further integrated with programming techniques which made it easier and accurate to compute percentages of both Acacia Senegal and Commiphora myrrh. Based on the models developed, it is clear there is a significant relationship between Landsat bands components and the resources mapped using high resolution images for both Acacia senegal and Commiphora myrrh.

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Authors Profile

Rispha Gicheha has a bachelor Degree in Information technology from Kenyatta University and a diploma in Land surveying and Mapping from Technical University of Kenya (TUK). Finalizing masters in GIS and Remote Sensing at JKUAT and awaiting graduation. With more than 10 years experience in Geospatial Science, she is currently working for FAO SWALIM as a remote sensing Expert where she is involved in landcover and landuse modeling and database development.

Thomas Ngigi obtained his B.Sc. in Surveying & Photogrammetry from the University of Nairobi in 1996. He has a M.Sc. in Image Informatics Chiba University, Japan and a PHD in Earth and Human Environmental Science from the same university. He is currently a Senior Lecturer in Remote Sensing and Digital Image Processing at Jomo Kenyatta University of Agriculture & Technology, Kenya.

Anthony Kuria is the Director of the Tropical Biology Association African office in Nairobi and plays a key role in Kenya Bird Map dealing with administrative issues and liaison with Nature Kenya. He holds a Masters' degree in Conservation Biology from the University of Cape Town, South Africa. He has 15 years capacity building expertise which has resulted in several cohorts of influential conservation managers in Africa. Kuria has co-authored several training manuals for conservation scientists, including the TBAs toolkit on scientific research