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The Changes in the Natural Woody Vegetation in Some Yemeni Villages: Basics for Restoration Policies and Afforestation Programs

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Abstract: The aim of the study is to detect the changes in the natural woody vegetation (NWV) of rural areas of Yemen and analyze the patterns of these changes. Three villages around Sana'a city were selected. To detect the changes, satellite images of different dates (2004 and 2012) for each village were obtained from the Yemeni Center for Remote Sensing. The result showed an increase of 53%, 49% and 90% for Anagah, Dhbir Khairh and Bait Hambus respectively. The differences among years were significant using a paired- samples *t* test. The study declined the general consensus by experts who consider that land vegetation cover is declining. Identification of plants' species that exist in the area showed a low biodiversity of only 6 species where two *Acacia* species as well as the shrub *Lycium shawii* represent 95%. Furthermore, comparing NWV among the villages and within plots presented valuable information for plantation strategies such as selecting trees with regenerative criterion and seeding each barren land with some regenerative trees. The study also noted the possible negative influence of industrial expansion and signified the importance of developing land-use plans to protect the natural vegetation.

Keywords: Woody Plant Cover, Natural Vegetation, Renewable Resources, Woodland, Yemen

1. Introduction

Earth existing natural biological capital is declining by deforestation which is proceeding in an alarming rate over the globe [1]. Over the last three centuries, earth has lost more than 1200 million ha of forests and wood lands also grassland and pastures have diminished by about 560 million ha [2]. The demand for resources to support the continuous growth of human population increases each year and consequently intensifies the deforestation process. According to FAO [3] 13 million ha of forest and woodland is lost each year.

The consequences of deforestation are most severe in developing countries, especially those that are located in arid and semiarid zones. Yemen is an example, where poverty of rural communities has forced individuals to overexploit the natural vegetation cover in order to secure income to maintain a mere living [4]. In the same time, government's lack of financial resources has hindered their capacity to plan and implement rural development projects. ROY/FAO/UNDP [4] noted that Yemen has considerable difficulties in allocating funds for the acquisition of reliable and timely geo-spatial data which is considered the first step for appropriate planning and implementation. These two factors among other natural and human induced factors have lead some researchers to conclude that by the year 2000, the total available woody biomass of Yemen would be exhausted [5,4]. There has not been any recent literature on regard of the NWV of Yemen since then, but a general perception among scientists that a persistent reduction continues. .

Misana et al. [6] noted to the fact that land cover change is a complex process involving situation specific interactions among a large number of factors at different spatial and temporal scale. In some cases, these factors have lead to positive changes. In recent decades, some researchers have reported an increase in the NWV in certain parts of the world [7,8,9] and ;therefore, opens hope for recovery trends. Finding those areas and understanding the amount and the rate of this positive change can provide valuable information for restoration efforts in different parts of the world.

A keen visual observation by the author of some rural areas surrounding Sana'a city in recent years, also suggests a

positive change which fetch a contrary view to the general supposition. Therefore, this study will test the hypothesis which states that there has been an increase in the NWV of some rural areas of Yemen in the recent years. It will further analyze and explain those changes. The study will consequently provide a basis for governmental policy and programs which targets preservation and plantation in order to mitigate environment problems and help in alleviation of rural poverty.

2. Study Areas

Within a 25 Km radius from Sana'a city, there are approximately 27 villages out of which three villages were randomly selected (Figure 1). The following table gives more information about their location:

Table 1. *Detailed information about the villages used in the study*

Village name	Latitude	Longitude	Altitu'de	Distance from Sana'a
Anagah	15°18'57.7"	44°25'09.8"	2598 m	20 Km
Dhbir Khairh	15°07'60.0"	44°16'05.1"	2408 m	25 Km
Bait Hambus	15°15'55.6"	44°08'45.5"	2783 m	12 Km

Records for the weather conditions for each village are unavailable but the closest area that is documented is Sana'a city which has a mean annual temperature of 18 C and an average precipitation of 200 mm per year and usually has low humidity averaged of approximately 43% [10].

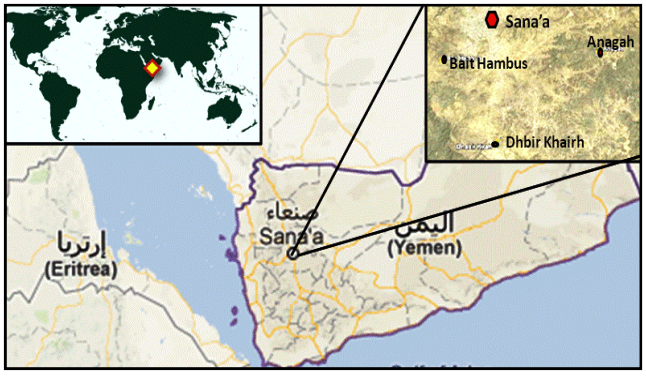

Figure 1. *The geographic location of the study area.*

3. Methodology

3.1. Satellite Images and GIS Analysis

The three villages were observed in different dates for change detection which is defined as the process of identifying differences in the state of an object or phenomenon by observing it at different times [11]. The study looked at the NWV of those three villages in the year of 2004 and the year of 2012 with 8 years interval using QuickBird satellite images with 60 cm resolution and Blue, Green, Red, NearIR bands. For each village two images with the different dates were obtained from the Yemeni Center for Remote Senescing and Geographical Information System. Folega et al. [12] stated that The moderate resolution of satellite images is suitable for mapping the status of land cover features and can enable planners to quantify the pattern of land cover changes that have occurred over time. Due to the small size of the areas, the low density of the vegetation and the importance of the accuracy, the following simple method was adopted.

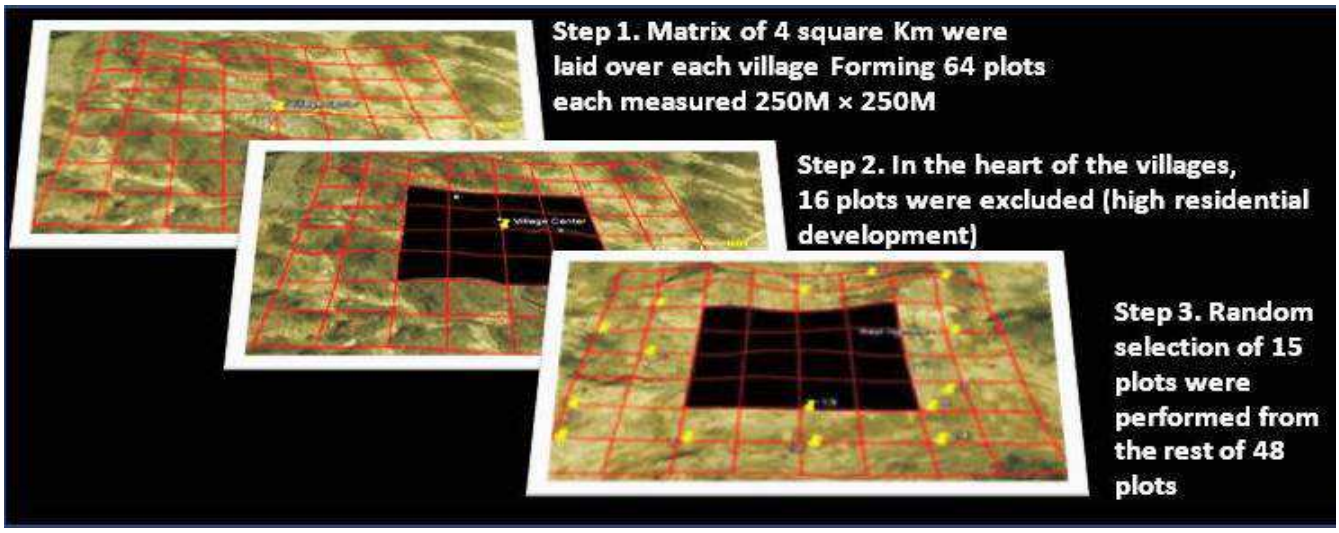

Figure 2. *Methodology steps for randomized data collection using satellite images.*

A matrix of 4 square Km was laid over each village and formed 64 plots where each plot measured 250 M × 250 M. In the heart of the villages were residential development is high, 16 plots were excluded. A random selection of 15 plots

were performed from the rest of the 48 plots (Figure 2). Overlapping of two layers for each village one with the year 2004 and the second with the year of 2012 using GIS (ArcMap version 9.3), we were able to trace the fate for each single vegetation and observe any appearance of new vegetation by changing the transparency of the upper layer and the result was recorded (Table 1). To test the accuracy of the recorded result from satellite images of year 2012, a site visit for the plots was performed using GPS device. To estimate the accuracy of the 2004 satellite images, trees and shrubs' ages were observed. Another task which was also performed during the site visit is identifying and counting the types of vegetation that existed in those plots.

3.2. Statistical Procedures

The alternative hypothesis states that there is a difference in the NWV of some rural areas of Yemen between year 2004 and year 2012. To prove that a difference exists and to evaluate its significance, a paired- samples *t* test were used in which the means of year 2004 and year 2012 were compared. The tests were two tailed and at alfa level of .05. The SPSS program (IBM SPSS statistics, version 21) was used for the analyses.

4. Results and Discussion

The result of the satellite images showed an increase in woody plants cover between year of 2004 and 2012 (Table 1). The increase was 53%, 49% and 90% for Anagah, Dhbir Khairh and Bait Hambus respectively.

Table 2. *Change % of NWV between year of 2004 and 2012 among villages and within plots.*

Plot #	Anagah			Dhbir Kharah			Bait Hambus		
	2004	2012	% change	2004	2012	% change	2004	2012	% change
1	6	9	50	33	38	15	75	105	40
2	3	3	0	3	9	200	63	95	51
3	2	3	50	13	23	77	2	15	650
4	4	14	250	20	29	45	10	26	160
5	7	11	57	16	31	94	19	37	95
6	0	0	0	15	31	107	17	42	147
7	0	0	0	20	37	85	11	29	164
8	11	25	127	4	10	150	27	60	122
9	56	64	14	76	69	-9	1	3	200
10	0	0	0	9	20	122	29	43	48
11	5	8	60	3	20	567	0	0	0
12	1	5	400	15	21	40	1	4	300
13	1	0	-100	11	19	73	0	6	600
14	1	7	600	25	19	-24	0	5	500
15	1	1	0	41	77	88	11	36	227
TOTAL	98	150	53	304	453	49	266	506	90

When *t* test was performed, the result showed that these increases were significant at alfa level of (.05) for each village independently and for all villages together (Table 2). This result is in the contrary to the general consensus by some Yemeni experts and scientists who consider that land vegetation cover is declining. Their supposition is supported by previous studies. Millington [5] indicated the negative impact of fuel-wood collection on the woody biomass and predicted that by the year 2000, the total available woody biomass in Yemen will have been exhausted. Another study estimated that the total fuel-wood consumption in Yemen was 5 million m3 (3 million tons) in 1982 and projected that fuel-wood consumption would reach 8.5 million m3 by the year 2000, at which time the fuel-wood supplies will have disappeared [4]. The researchers reached this conclusion because Yemenis used to relay on wood as their main source of energy. In the early years of this century, gas prices were affordable and in the same time there was a scarcity of wood; therefore, a shift toward gas energy was made. The shift relieved the stress on the NWV and a notable recovery took place.

Table 3. *Average count of NWV, % change and t-test results @ α =.05.*

	2004	2012	% Change	Paired Samples *t*-Test	
				Df	*P*-value
Anagah	6.5	10	53	14	0.008
Dhbir Kharah	20.3	30.2	49	14	0.002
Bait Hambus	17.7	33.7	90	14	0.003
All Villages	14.8	24.6	64	44	0.000

The provision of alternative energy source proved to be practical solution for deforestation and the Yemeni government should take it to account when it sets prices for gas. A solution for deforestation which had been proposed generally by some researchers [13] and specifically to Yemeni rural areas by others [4].

Another study of the vegetation cover between years of 1990 and 2000 which covers all Sana'a governance, stated a decline by 34% [14]. The study used NDVI technique and included agriculture crop cover while ours only focused on natural trees and shrubs cover. The possible explanation is that both studies are true for their certain timeframe studied. Meaning that there had been a decline before year of 2000

and an increase afterward. A fact that can be explained by the shift in the energy demand from woodfuel to gasfuel. A decreased trend in early years followed by an increase in recent years has been reported by some researchers. For example, Doner [9] who showed a decrease of forest trees between 1978 and 1987 and an increase between 1990 and 2000 in Gumushane, Turkey. The increase took place in Turkey earlier than Yemen probably because it is more developed and the energy shift could have been earlier.

A comparison of wood cover within plots and among villages presents a valuable implication for plantation and preservation programs. Anagah has the least NWV cover in 2004 and consequently has an increase of only 52 count by 2012 while Bait Hambus has an increase of almost five fold more than Anagah. This is because plots that showed zero cover remain in most cases zero after 8 years while those that have some plants which have reproductive habits gave more plants cover over time. This fact explains why some huge distances of Yemeni landscape are empty from any trees and illustrate the importance of seeding all barren land with some regenerative trees.

Only two plots in Dhbir Khairh showed a decrease in number of plants between year of 2004 and 2012. This decrease was explained from observing satellites images by industrial and agriculture development that have reached to the area and consequently have cleared the NWV that had existed. This observation is important and denotes the possible impact of the future industrial and agriculture expansion. It also urges the concerned officials to establish land use plans for the whole area to protect NWV, especially watershed areas which are the most sensitive.

The study area has only 6 different species of NWV where both *Acacias* and *Lycium shawii* represent 95% (Table 3), a fact that can be generalized based on author's ground observation for the high mountain region of Yemen. This indicates the lack of biodiversity in the NWV of the region.

Table 4. *Existing plant species and their count per village and their percentage from whole NWV.*

	type	Dhbir Khairh		Anagah		Bait Hambus	
		2012	%	2012	%	2012	%
Acacia gerrardii	Tree	131	29	0	0	177	35
Acacia origena	Tree	170	38	0	0	215	42
Tamarx aphylla	Tree	0	0	53	35	0	0
Ziziphus spina-christi	Tree	13	3	3	2	0	0
Ficus carica	Tree	0	0	11	7	1	0
Lycium shawii	shurb	139	31	83	55	113	22
TOTAL		453	100	150	100	506	100

Selection and Introduction of new species for plantation program can help in improving biodiversity. The FAO reported three species that used to exist in Yemeni landscape and had been eliminated due to high exploitation [15]. Those can be a good choice for reintroduction.

Ziziphus spina-christi is another important indigenous species which exists in scars number and yet has a great value as an agroforestry tree [16]. Since this important plant already existed; therefore, proved practically to be suitable for the region. Furthermore, its ability to be multiplied by simple method of direct seeding [17], makes it another good suggestion for plantation program.

The study also illustrated the importance of tree reproductive character as a criterion for plant selection. Anagah which has *Tamarx aphylla* and *Ficus carica* which are both less reproductive showed less vegetation cover while Dhibr Khairh and Bait Hambus which have both *Acacias* that are highly reproductive showed better vegetation cover.

5. Conclusions

The result of the study proved a recovery in the NWV in the sample areas studied, and provide new notion which replaces the long held view of decline. One of the main causes of this change is the shift that took place in some parts of Yemen from the use of wood for fuel to the use of gas for fuel at a time where fossil fuel energy was made affordable and wood was scarce. The rate of the recovery process depended on two factors. The first is the amount of NWV cover that still exists. Those areas that still have a large NWV cover were able to recover easily, while those areas that have no NWV cover remain as they were. The second factor is the species type and its ability to regenerate. An important consideration which had been ignored in previous plantation effort and had resulted in a poor outcome as found in this study. Plots that have single or multiple exotic plants which were unable to regenerate in Yemeni environment, remain the same number after more than 8 years. Plantation programs are a must and lay an ethical obligation upon governmental and non-governmental organization. The study also denotes the importance of land-use plans for areas surrounding big cities in Yemen to protect intensive NWV as well as the importance of policy initiatives for sustainable use of this important natural resource.

The study were restricted to small area due to resources limitation. Yet its finding is important and provoke the attention of officials to allocate funds for the acquisition of reliable and timely satellite images for the whole Yemen. A large scale analysis that could confirm the consistency of those findings over the whole region should be also funded. Although Cover changes can be detected by remote sensing but in order to get a deep understanding of their causes, a

socio-economic analysis should be carried out. A further study is also suggested to cover this topic.

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