ASSESSMENT OF SAVI AND NDVI VEGETATION INDICES POTENTIAL TO DETECT CHANGES OF VEGETATION COVER IN THE STATE OF KUWAIT

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ABSTRACT

This study aimed to assess the potential of SAVI (Soil-Adjusted Vegetation Index) and NDVI (Normalized Difference Vegetation Index) to determine vegetation cover using medium spatial resolution remote sensing imagery in the arid region of Kuwait. Both indices are simple to deploy and uses spectral bands in the red and near infrared portion of the electromagnetic spectrum. However, although NDVI has limitation in low and medium density vegetation cover but still many agencies prefer it because it is straightforward to use. A study area of about 40 sq.km was selected in the "Sulaibiya Area" due to the variety in natural vegetation cover densities and also for the presence of irrigated agricultural area. A Worldview-2 image was acquired on April 14, 2012 over this area and used to compare both vegetation indices. The first step was to simulate NDVI and SAVI at the spatial resolution of two widely used Earth Observation sensors, SPOT and Landsat, at 10 and 30 meter. Then, a radiometric correction was conducted to convert digital numbers into ToA reflectance and Ground Reflectance. Meanwhile, WV2 image was Pansharpened into 50 cm resolution and classified to get a reference of vegetation cover. The value of the indices was compared to the equivalent proportion of its area covered by vegetation. A complete fieldwork was done simultaneously to Worldview image acquisition for accuracy assessment purpose. Results showed that SAVI with a soil factor of 0.2, 0.5 and 0.9 was comparable to NDVI result when the spatial resolution is 10 meters. Nevertheless, a SAVI with soil factor of 0.9 is best suited to be used with resolution of 30 meter. In fact, where NDVI gave an R^2 of only 0.67 at 30 meter resolution, SAVI using DN leads to R^2 of 0.89 while using ground reflectance values gave an R^2 of 0.98. Hence SAVI is more adequate to use in this arid zone even though it requires an atmospheric correction but still gives very good result using DN only compared to NDVI.

Keywords: Landsat, Pansharpned, SPOT, Sulaibiya area, Worldview-2

1. INTRODUCTION

As most arid and semi arid zones, state of Kuwait is vulnerable to degradation of its vegetation cover due to a variety of reasons. In fact, climate change and global warming lead to significant fluctuations of temperature and precipitation in the last decades. Anthropogenic pressure including urban growth, camping, overgrazing and agriculture has reached disturbing levels. Furthermore, the excessive use of ground water for irrigation significantly increase the soil salinity which leads to vegetation cover deterioration. In this context, am adequate national program of monitoring vegetation cover over time and space is of prominent relevancy (Soleiman and Kamal, 2002). Remote sensing and other geoinformatics techniques such as GIS modeling and spatial analysis plays a major role to produce vegetation cover maps (Abu Sayed and Sadiq, 2002; Ait Belaid, 2010). Nevertheless, even though remote sensing has been widely used to monitor vegetation cover but still the use of different vegetation indices with different satellite imagery may mislead when performing vegetation change detection (Hadjimitsis *et al.* 2010; Lu *et al.* 2004; Ait Belaid, 2003). In Kuwait state, there is historical remote sensing imagery data available at different national organizations. However there is no unified methodology to retrieve vegetation cover from them. Some use classification, others vegetation indices or even basic image interpretation. Hence, this study focuses on the comparison of two Vegetation indices, NDVI and SAVI. Both are used worldwide at various spatial scales (Huete, 1988). However, in Kuwait there is a need to evaluate the performance of both of these indices at different spatial resolution to assess the potential one to be used for national scale vegetation mapping/monitoring.

2. MATERIAL AND METHODS

A very high resolution WorldView-2 image (Digital Globe, 2009) was acquired on 14 April 2012 over *Sulaibiya* area; (figure 1). The study area was selected because it has vegetation density from very low to very high. The area has also a very well variety of vegetation species such as *Tamarix Aphylla, Conocarpus Erectus, Prosopis, Zygophyllum Aatarense, Phoenix Dactylifera, Medicago Sativa*. The Sulaibiya is an agricultural area and obviously has large parcels of irrigated cash crop with a very high vegetation density. Figure 2 represents the general methodology flowchart, where the first step consisted to use the panchromatic band to pansharpen the multispectral bands. Hence enhancing their spatial resolution from 2 m to only 50 cm. Pansharpned image was use to classify vegetation cover using a hybrid unsupervised-supervised classification. Only vegetation class was retained for subsequent analysis and it has been transformed from a raster format to a vector-polygon one. During the second step, original WorldView-2 image was also been radiometrically corrected to convert DN to ToA reflectance and next an Atmospheric correction was done to obtain the ground reflectance for each pixel. Resulting images of second step were then degraded to obtain pixel size of 10 and 30 meter, The fourth step concerned the computation of NDVI and SAVI vegetation indices (equations 1 and 2) for all produced images.

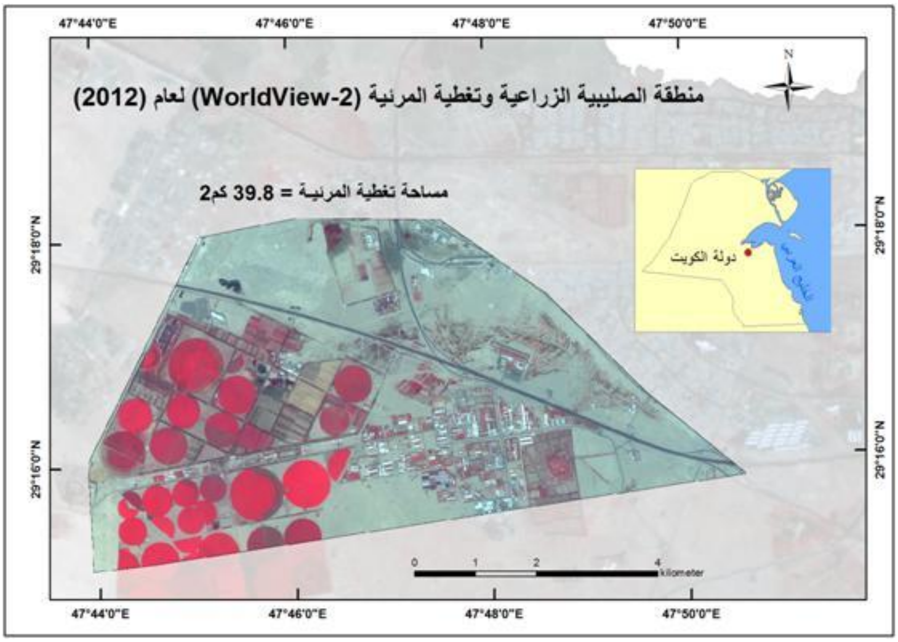

Figure 1: WorldView-2 Image of Sulaibiya Area on 14 April 2012 (False colours composite; RGB=7, 5, 2), Inset: Study area in State of Kuwait

$$NDVI = \frac{\rho_n - \rho_r}{\rho_n + \rho_r}$$

$$SAVI = \frac{(\rho_n - \rho_r) \times (1 + L)}{(\rho_n + \rho_r + L)}$$

Where: ρ_n = *Near Infra Red (NIR) Band,*
ρ_r = *Red Band ,*
L = Correction Factor (from 0 to 1)

Three values of the soil factors (L) were retained for SAVI; 0.2, 0.5 and 0.9. Hence 24 new raster layers were obtained for both NDVI and SAVI at two spatial resolution (10 and 30 meter) and at three radiometric status, respectively, DN, ToA reflectance and Ground Reflectance. Finally, NDVI and SAVI layers were transformed into vector-polygon and overlaid with the vegetation vector produced from classification. Identity function was used to determine vegetation indices values in function of the percentage of vegetation cover in each pixel.

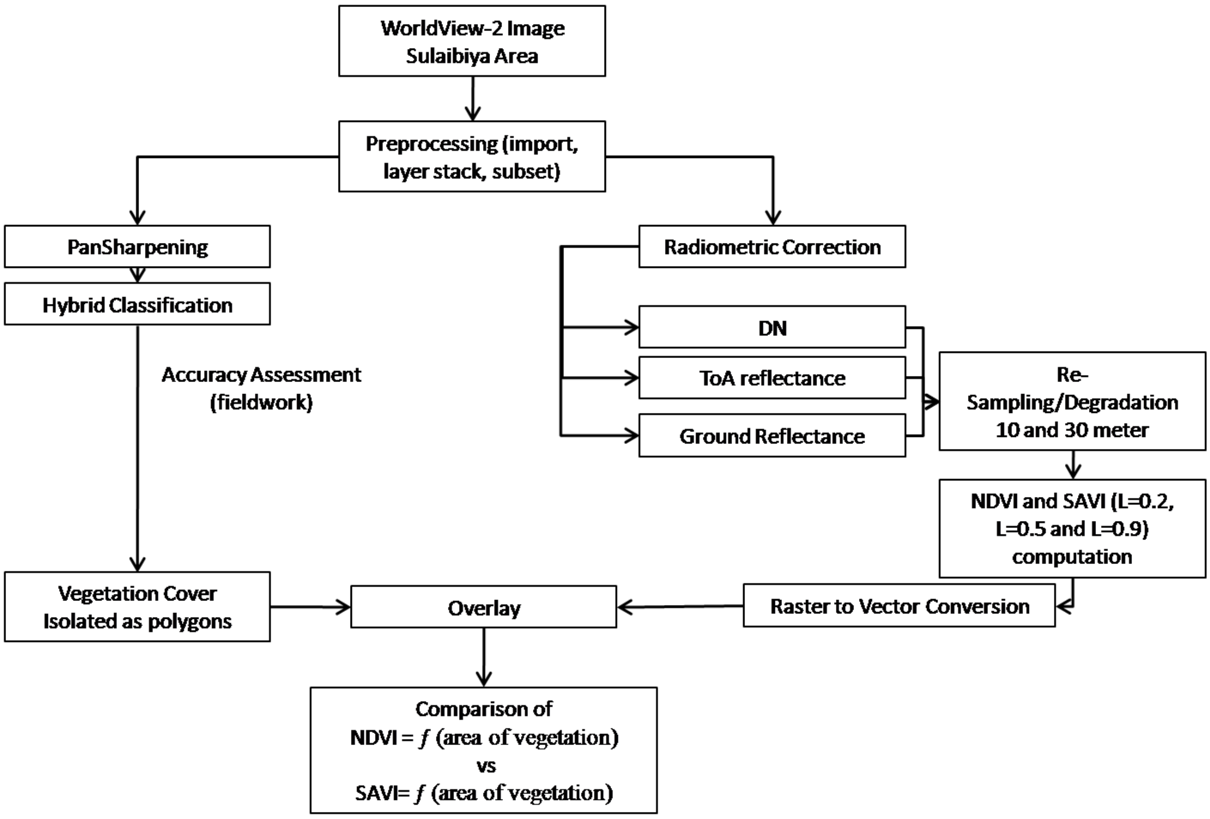

Figure 2: General Methodology Flowchart

In this study, ATCOR module of PCI Geomatica 2013, and ERDAS imagine 2011 were used as commercial packages for raster image processing; while ArcGIS10 was used for vector overlay.

3. RESULTS AND DISCUSSION

Figure 3 represents a zoom in for the result of Worldview-2 image degradation from 2 meter spatial resolution (figure 3A) to 10 and 30 meters (figure 3B and 3C respectively). The hybrid classification results is shown in figure 3D where vegetation is seen in green. Accuracy assessment was done via using a hundred check point, figure 3E giving an overall accuracy of 89%. The agriculture area is very clear in the circles with very high density while on the North and East parts of the image ther is a low density. The medium density is in the eastern vicinity of the agricultural area.

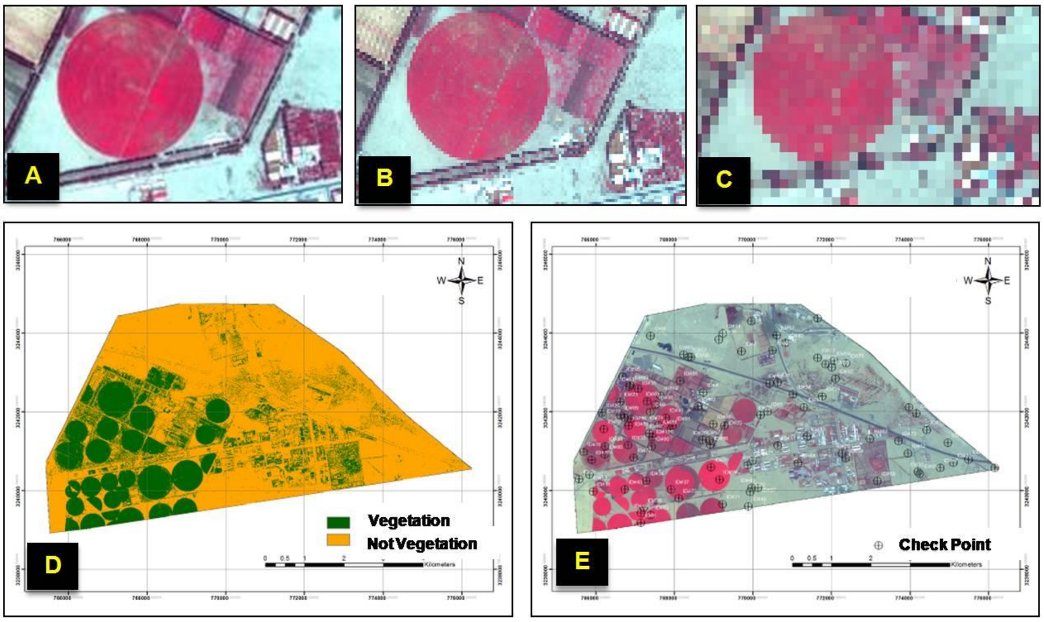

Figure 3: Worldview-2 image degradation and classification result, (A) example of original 2 meter resolution-RGB (7,5,3) (B) Degraded to 10 meter, (C) degraded to 30 meter, (D) Vegetation cover classsification and (E) accuracy assessment check points

Figures 4, figure5 and figure 6 depict the results obtained for the NDVI and SAVI comparison using the radiometric sets and spatial resolution of 10 and 30 m. These parameters were used among the 24 possibilities to match most common available SPOT and Landsat imagery. It turns that at 10 m pixel size, both vegetation indices (NDVI and SAVI) are highly correlated with the percentage of pixel's area covered by vegetation' values of R^2 are stable around 0.97. However, when spatial resolution is 30 m NDVI scored the less correlation with an R^2 of 0.66 only. On the other hand, the spatial resolution of 10 meters affected negatively the SAVI score but the lowest value obtained is R^2 = 0.82 for soil factor parameter L of 0.2. Also for SAVI as the soil factor increase (L=0.5 and L=0.9) the R^2 remains strong with values of 0.83 and 0.88 respectively. From a different aspect, it is clear that SAVI index is more sensitive to presence of vegetation when the spatial resolution is 30 m. In fact, the lowest percentage of vegetation cover detected using SAVI, at this resolution, is 7%, while the NDVI is start to reacts only when there is 15% of the pixel covered by vegetation. It means that for a pixel of 900 m^2 there is only 63 m^2 covered with vegetation the SAVI may detect it (L=0.9), but using NDVI the minimum vegetation area should be 135 m^2 nearly the double. Even though SAVI uses atmospheric corrected reflectance for Red and NIR bands but it still gives satisfactory results at 30 m using DN. To illustrate the role of atmospheric correction on SAVI performance, figure 4 shows the R^2 for SAVI (L=0.9) using ToA reflectance and ground reflectance. The values were respectively 0.97 and 0.98 with a sensitivity surface of 5% for both (45 m^2). Hence the radiometric correction has a significant role to get valuable information using SAVI index.

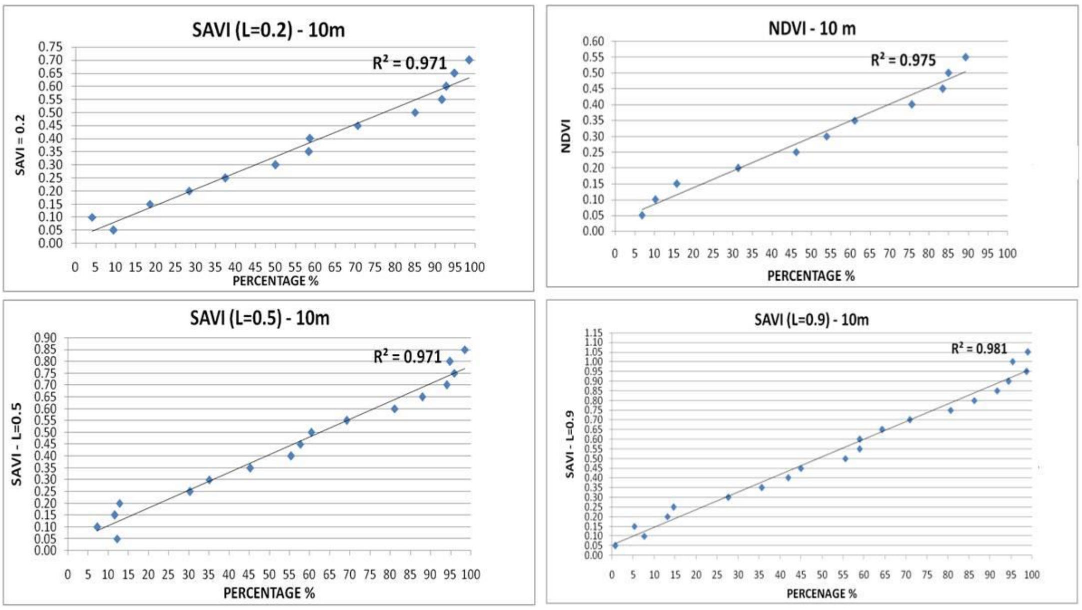

Figure 4: Comparison of NDVI vs SAVI at 10 m spatial resolution using DN

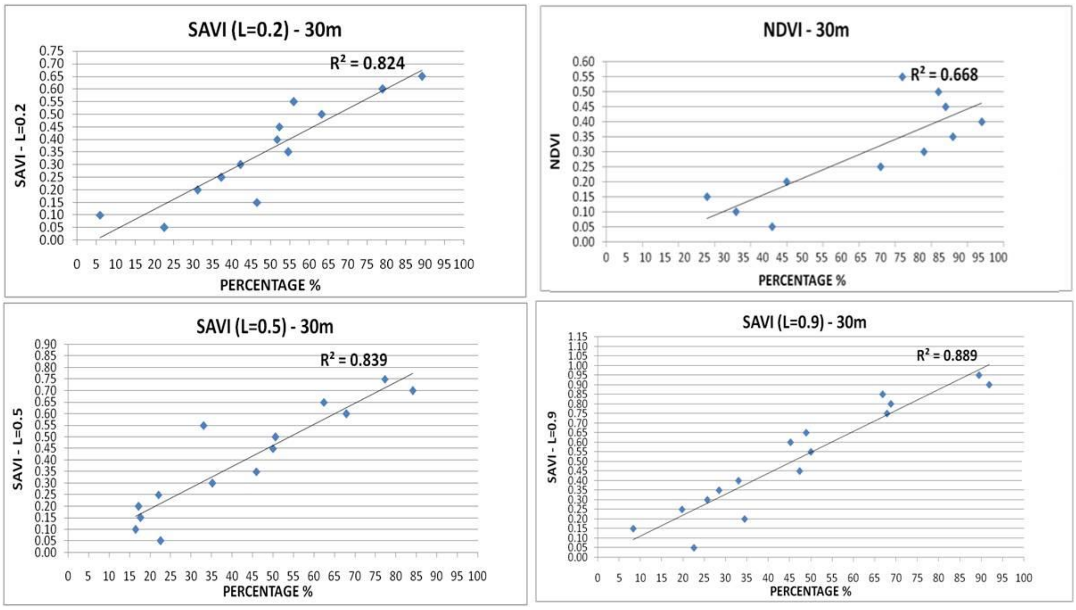

Figure 5: Comparison of NDVI vs SAVI at 30 m spatial resolution using DN

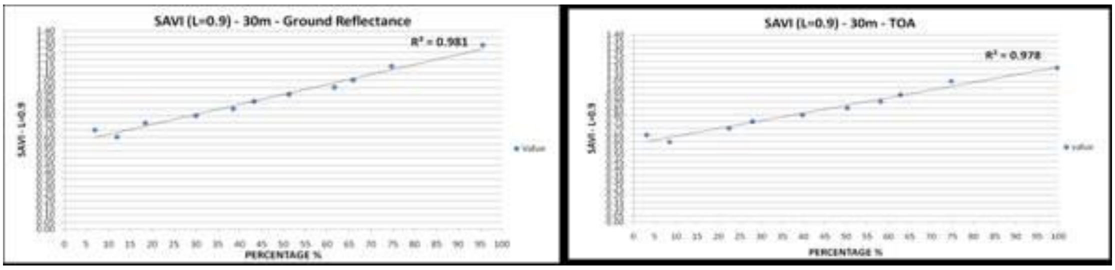

Figure 6: Comparison of SAVI at 30 m spatial resolution using ToA Reflectance vs Ground Reflectance

4. CONCLUSIONS

The methodology used in this study shows quantitatively that at 10 m spatial resolution both SAVI and NDVI have comparable performance to detect vegetation cover in the study area. Nevertheless, while the spatial resolution lowers, the SAVI with a soil factor of (L=0.9) is more robust even using digital numbers and without atmospheric correction. NDVI is still correlated to percentage of vegetation area in pixels but with much lower accuracy than SAVI. It has been shown also that despite the fact that SAVI is a vegetation index requiring atmospheric correction before being computed but it still gives good results even with DN. However, with atmospheric correction it is much more accurate. Hence, it is recommended to use SAVI index to produce vegetation maps for the State of Kuwait and it is reliable even for historical remote sensing data with medium spatial resolution of Landsat and SPOT earth observation satellites. Finally, this study confirmed the adequacy of SAVI vegetation index over the more popular NDVI in arid and semiarid zones especially in medium spatial resolution.

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