FINDING THE RELATIONSHIP BETWEEN VEGETATION INDEX AND COHERENCE SIGNATURE TO UTILIZE THE PRODUCT OF RADAR INTERFEROMETRY IN LAND COVER APPLICATION

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ABSTRACT:

The phase coherence derived from SAR (Synthetic Aperture Radar) Interferometry has recently been proven its usefulness in classification of remote sensed imagery. On another hand, vegetation index has been employed for a long history as a basic indicator in any application related to land cover. This paper establishes a significant relationship between NDVI (vegetation index) and the CC (coherence signature) via illustration in the forest area of the active volcano Mayon, Philippines. The result of this research asserts an outstanding support for the fusion of radar sensor derived information and other remote sensed information as optical data. In this paper, wavelet analysis was predominantly applied to filter disturbing factors in the graph, which symbolizes the relationship between NDVI and CC before setting up the mathematical relationship.

1. INTRODUCTION

SAR interferometry is based on processing the phase difference between coincident SAR images (Gen et al., 1996; Zebker et al., 1992; Madsen and Zebker, 1998). A typical geometry of SAR interferometry is depicted in Figure 1.

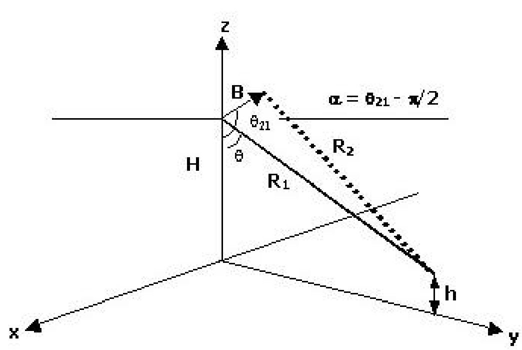


Figure 1. Radar interferometry geometry

The successful generation of interferogram from two SAR images heavily depends on the coherence nature of these two images (Zebker et al., 1992; Gen et al., 1996). The possible factors affecting the quality of interferometric data can be satellite orbit, atmospheric or objects on the Earth surface. Wehr et al. (1996) illustrated the effect of different kind of land cover on the accuracy of interferometric data. This effect can be utilized as a clue in land cover classification as well as change detection (Wegmüller and Werner, 1996). This paper is an initial step for the attempt to find out the relationship of phase coherence and land cover that is represented through vegetation index. In the first step, only forest area, which deserves high value of NDVI, is investigated. Furthermore, wavelet filtering was applied as a supporting method to set up any mathematical relationship between two factors. The fundamental idea of wavelet is to analyze the signal at different scales or resolutions. The implementation of wavelet that was applied in this paper is referred to Starck, and Murtagh, (1994) in which the redundant *a trous* algorithm with B3 spline wavelet function was stated.

2. STUDY AREA AND DATA USED

Mayon is located in the Alabay province of Philippines, 300 km SE of Manila (13°15.4'N – 123°41.1'E). The slope of the upper part of Mayon is covered by bare land comprising lava flows and other loose air-fall deposits. Middle slopes are mostly sited with spares and bush lands followed by grassland, while coconut can generally been seen in the gentle slopes. The lower foothills are extensively cultivated with rice; these areas are highly susceptible for mudflow and pyroclastic flow. There are approximately only two main seasonal differentiations of wet season during June to November and dry season December to May.

Two experiments were carried out by two ERS1&2 tandem data sets (see Table 1). They are different in system parameters, i.e. baseline, ascending or descending, and were acquired in two different seasons. The investigation of the two sets consequently can exclude factors that are instigated by weather and systems. Moreover, Landsat TM was used to calculate vegetation index. The accurate DEM derived from topographic map and updated with recent aerial photo was employed to extract ground control points that were necessary for ortho-rectification SAR scenes.

Table 1 – Data used

Data	Date	Characteristics
ERS1&2 Tandem	20 and 21May 1996	Ascending, baseline 90m
ERS1&2 Tandem	10 and 11 October 1997	Descending, baseline 400m
Landsat TM	18 February 1994	Geocoded
DEM (DEMtopo)	Topographic map, updated by airphoto	Geocoded

3. DATA PROCESSING

The complete processing to find out the relationship between CC and NDVI is illustrated in Figure 2.

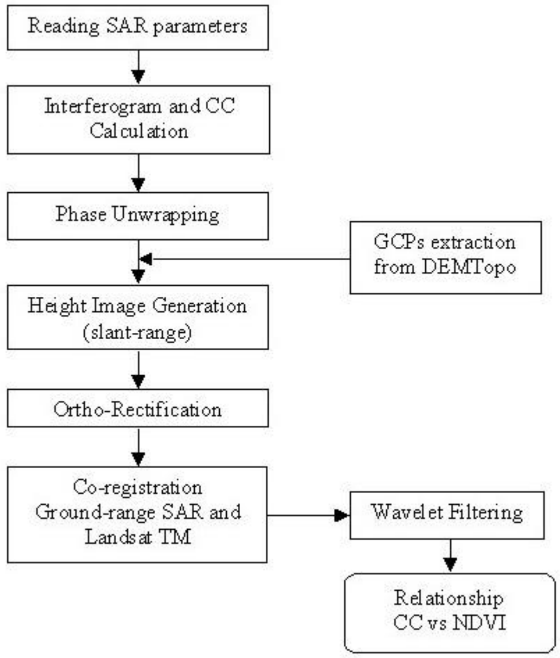


Figure 2. Processing flowchart

To investigate the relationship between two mentioned factors, an area in the gentle slope of volcano Mayon was selected. Figure 3 depicts the location of the study area by the false color composite of Landsat TM.

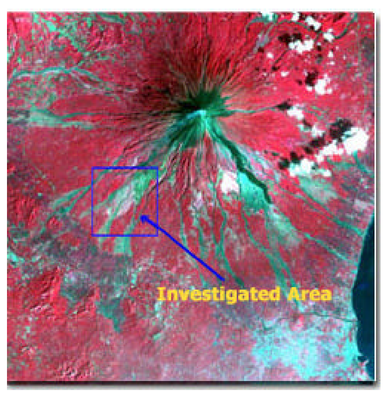


Figure 3. The investigated area

After being co-registered carefully by the cross correlation, two SAR images were consequently able to be employed for calculation the multi-look complex interferogram by the following equation.

$$\text{Complex interferogram} = \frac{< S_1 \times S_2^{*} >}{\sqrt{< S_1 \times S_1^{*} >< S_2 \times S_2^{*} >}}$$

where s1 and s2 are single look complex values of two co-registered images,
* stands for conjugate complex,
<> stands for ensemble average

Due to the side-looking geometry of SAR system, a portion of interferometric phase related to the imaging geometry should be removed out of interferogram based on the orbit information. After removal the Earth curve phase trend, flattened interferograms were formed, and based on these flattened interferograms, coherence was estimated with 5x5 local window and gaussian weighting function. The results in the investigated area are illustrated in Figure 4.

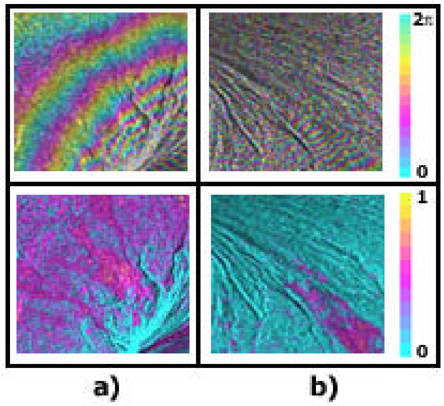


Figure 4. The flatten interferogram and the coherence images: (a) 1996 and (b) 1997 data

Figure 4 depicts clearly the point that the higher value of coherence, the clearer visibility of fringe in the interferogram. It is obvious that the fringes appear more clearly in 1996 data, which is clarified by the statistical results of coherence value (Table 2).

Table 2 – Basic statistic of coherence value

Data	Min	Max	Mean	Stdev
1996	0.01	0.87	0.36	0.14
1997	0.01	0.85	0.25	0.14

The investigation of the relationship between CC and NDVI required the co-registration between Landsat TM and ground range SAR images, which required the ortho-rectification of SAR. Another research was carried out in the same area (Vu and Tokunaga, 2000), which measured the effect of DEM coherence on the accuracy. The parameters for DEM ortho-rectification to ground range obtained from the particular research was utilized here again for the ortho-rectification of coherence images. The details of the processing are referred to the mentioned paper. Both coherence images of 1996 and 1997 were ortho-rectified and manually co-registered with Landsat TM. Subsequently, Band 4 (near infrared) and Band 3 (red) of Landsat TM were used to calculate the normalized difference vegetation index (NDVI) as usual. The summarized results of field survey, conducted by the ACRoRS team (1999), showed that three land cover types as shown in Table 3.

Table 3 – Land cover types and their associated NDVI

NDVI range	Land cover type
NDVI < 0.2	Bare land, Riverbed, Pyroclastic Flow
0.2 <NDVI < 0.4	Grass, Paddy field
NDVI > 0.4	Forest, Coconut

As mentioned earlier, in this paper, only the forest area was selected to investigate. Therefore, according to the field survey results, the investigation concern in the NDVI value greater than 0.4 only. It is recognized that some of the existed areas with no data in coherence images due to the used parameters from the generating DEM step including masking the low coherence areas in unwrapping phase to ortho-rectify images. Consequently, the NDVI image was also masked to exclude these areas. Overlaying NDVI in 1996 coherence and 1997 coherence, the relationship between NDVI and CC was generated sequentially in the graph as depicted in Figure 5.

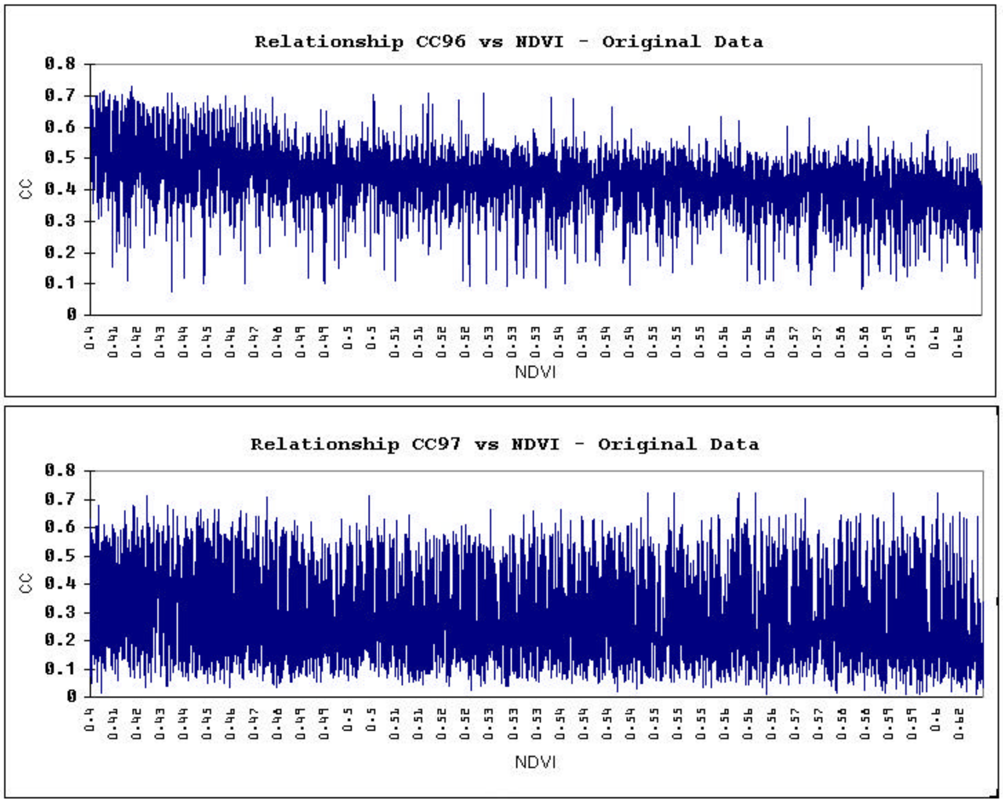
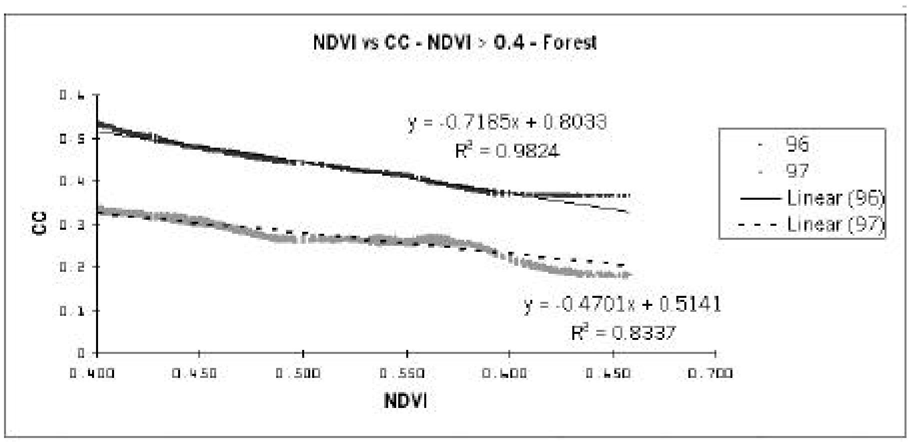


Figure 5. The relationship between CC and NDVI before filtering

Both graphs show very high noisy relationship. While 1996 data introduced some trend behind the noisy background visually, the 1997 data did not demonstrate anything at all. Wavelet filtering was applied on both graphs to outline the possible relationships. Figure 6 illustrates the relationships after wavelet filtering; both data sets now show similar trend. The correlation analysis between NDVI and both coherence data 1996 and 1997 also yields the value of –0.93 and –0.92, respectively. With these high values of correlation, it is not impressive by the high value of R^2 when fitting the relationship with the negative-sloped line.



4. CONCLUSION

ERS1/2 Tandem C-band radar data was employed in the study to investigate the relationship between coherence data and land cover indirectly through vegetation index. The result showed very low coherence value for both of data sets used due to the highly effect by land cover type. The interesting result was found in the forest area with a negative-sloped trend line between coherence and vegetation index. Two experiments with two data sets yielded the same trend of relationship at different value of amplitude. Moreover, wavelet filter has been applied efficiently prior to the setting up the mathematical relationship. It is recommended to extend this study to valid the relationship with more data set, more land cover types and apply the result in a real land cover application.

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REFERENCES

ACRoRS, Final Report, 1999. Remote Sensing and GIS analysis for base data creation and change detection; the study on comprehensive disasterprevention around Mayon volcano in the Republic of The Philippines. (Source: Asian Center for Research on Remote Sensing, Thailand).

Gens, R. and Van Genderen, J. L., 1996. Review Articles SAR interferometry: issues, techniques, applications. Int. J. Remote Sensing, 17, 10, 1803-1835.

Madsen, S.N, and Zebker, H.A., 1998. Imaging Radar Inteferometry, Principles and Applications of Imaging Radar (John Wiley &Sons, Inc.).

Madsen, S.N, Zebker, H.A. and Martin, J.M., 1993. Topographic Mapping Using Radar Interferometry: Processing Techniques. IEEE Trans. GE and RS, 31, 1, 246-256.

Mallat, S., 1998. A wavelet tour of signal processing. Academic Press. pp 220-224, 303-310.

Starck, J.L., and Murtagh, F., 1994. Image restoration with noise suppression using wavelet transform. Astronomy and Astrophysics, 288, 342-348.

Vu, T.T., and Tokunaga, M., 2000. Effect of Coherence on DEMs Derived from SAR Interferometry, Asian Journal of Geoinformatics, 1, 2, 33-39.

Wegmüller, U. and Werner, C. L., 1996. Land applications using ERS- 1/2 Tandem data. Fringe 1996 - ESA Workshop on Applications of ERS SAR Interferometry, Zurich, Switzerland, September 30 – October 2, 1996.

Wehr, A., Wu, X. and Thiel, Karl-Heinz, 1996. The effects of different land covers on the accuracy of interferometric DEM. Fringe 1996 - ESA Workshop on Applications of ERS SAR Interferometry, Zurich, Switzerland, September 30 – October 2, 1996.

Zebker, H.A. and Villasenor, J., 1992. Decorrelation in Interferometric Radar Echoes. IEEE Trans. GE and RS, 30, 5, 950-959.