

Image mosaicing

The three georeferenced ERS SAR frames that cover the study area (Table 3) partially overlap. They have been attached overlapping the northern frame (3447) over the southern (3465).

From each of the three mosaics a strip containing the study area has been selected and extracted (Figure 1 and Table 2). These three strips have been used as reference images for further analysis, after geometric correction to ensure that they would perfectly overlay.

Inside the study area, three sites characterized by different kinds of shrimp farms have been selected to test the image processing procedures:

1. The area from Vidatamunai to Seguwantiyu, Manativu Division; it contains several groups of medium-sized shrimp farms and many smaller ones.
2. The Uppadaluwa area, in the Satapolai Division; it contains a group of large, industrial shrimp farms.
3. The northern part of the Dutch Canal. Large groups of small-sized shrimp farms cover all the islands in the Canal and its neighboring terrain.

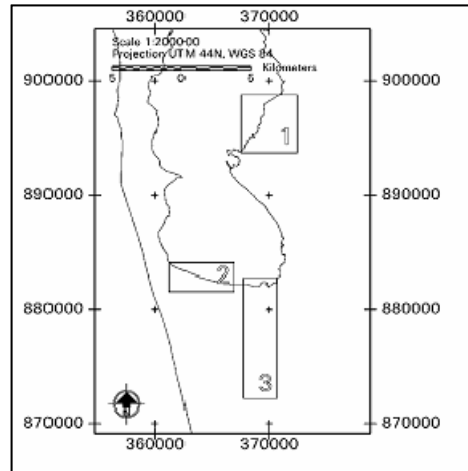


Figure 16 Location of the test sites

The location of the test sites is shown in Fig. 16, and their coordinates are listed in Table 4.

Table 4 Coordinates of the three test sites.

Test sites	Upper left corner		Lower right corner	
	UTM 44N, WGS 84 Northing (y)	Easting (x)	Northing (y)	Easting (x)
Manativu Division	898743.75	367506.25	893756.25	372493.75
Uppadaluwa	884043.75	361256.25	881556.25	366868.75
Dutch Canal	895618.75	381881.25	889993.75	387506.25

Speckle removal

SAR images are affected by a kind of noise called speckle. The speckle causes randomly scattered pixels to have particularly high or low values, thus increasing the error in classifying low-reflecting surfaces as water-covered surfaces.

The speckle is minimized by applying speckle suppression filters to the image. A filter is a matrix of values (also called template, box, window or kernel), whose dimensions are chosen by the operator. The filter matrix is moved over the image row by row and column by column. The pixel values covered by the matrix at a particular position are then used to define a new value for the pixel corresponding to the central element of the matrix (Richards, 1993). The noise reduction is generally accompanied by a loss of details; therefore the choice of the filter depends both on the characteristics of the image and on the kind of subsequent analysis.

The aim of the present study is to identify shrimp ponds, which may be small in extension, thus the loss of detail must be kept to a minimum. Also, the presence of noise may be partially tolerated as part of the analysis is performed visually by an operator. Finally, the entire image processing procedure must be as simple as possible, including the noise reduction technique, to allow for its use by people not highly trained in SAR image analysis and interpretation.

In order to choose the speckle removal procedure that satisfies those requirements, the following speckle suppression filters provided by ERDAS IMAGINE (version 8.3) have been tested:

- *Lee-Sigma filter*: replaces the pixel of interest with the average of all DN values within the moving matrix that fall within the selected range of standard deviation.
- *Local Region filter*: divides the moving matrix into eight regions based on their angular position respect to the pixel corresponding to the central element of the matrix (North, South, East, West, NW, NE, SW, and SE). Then selects the region in which the pixels have the lowest variance, and average their values to obtain the new value of the central pixel.
- *Lee filter*: is based on the assumption that the mean and variance of the pixel of interest is equal to the local mean and variance of all pixels within the user-selected moving matrix.
- *Frost filter*: is a minimum mean square error algorithm which adapts to the local statistics of the image to preserve edges and small features.

These filters are generally applied iteratively until the desired effect is reached. Three combinations of filters have been applied to the three test sites and their results have been visually analyzed to choose the one which satisfies the balance between noise reduction and identification of the smallest shrimp ponds:

1. Three applications of Lee-Sigma filter, increasing the window size (3 x 3, 5 x 5, 7 x 7) and increasing the coefficient of variation multiplier (0.5, 1, 2);
2. Application of Lee and then Local Region filters at constant window size (5 x 5);
3. Three applications of Frost filter, at increasing window sizes (3 x 3, 5 x 5, 7 x 7).

Analysing each passage of the three filtering sequences on the test sites it has been noted that the smallest shrimp ponds are still visible only after a single application of the Frost filter, using a 3 x 3 moving matrix. Therefore the three images of the study area have been subjected to this filter to conclude the preprocessing procedure.

The images obtained from the sequential application of the Frost filter to the Seguwantiyu test site are shown as example in Figure 17.

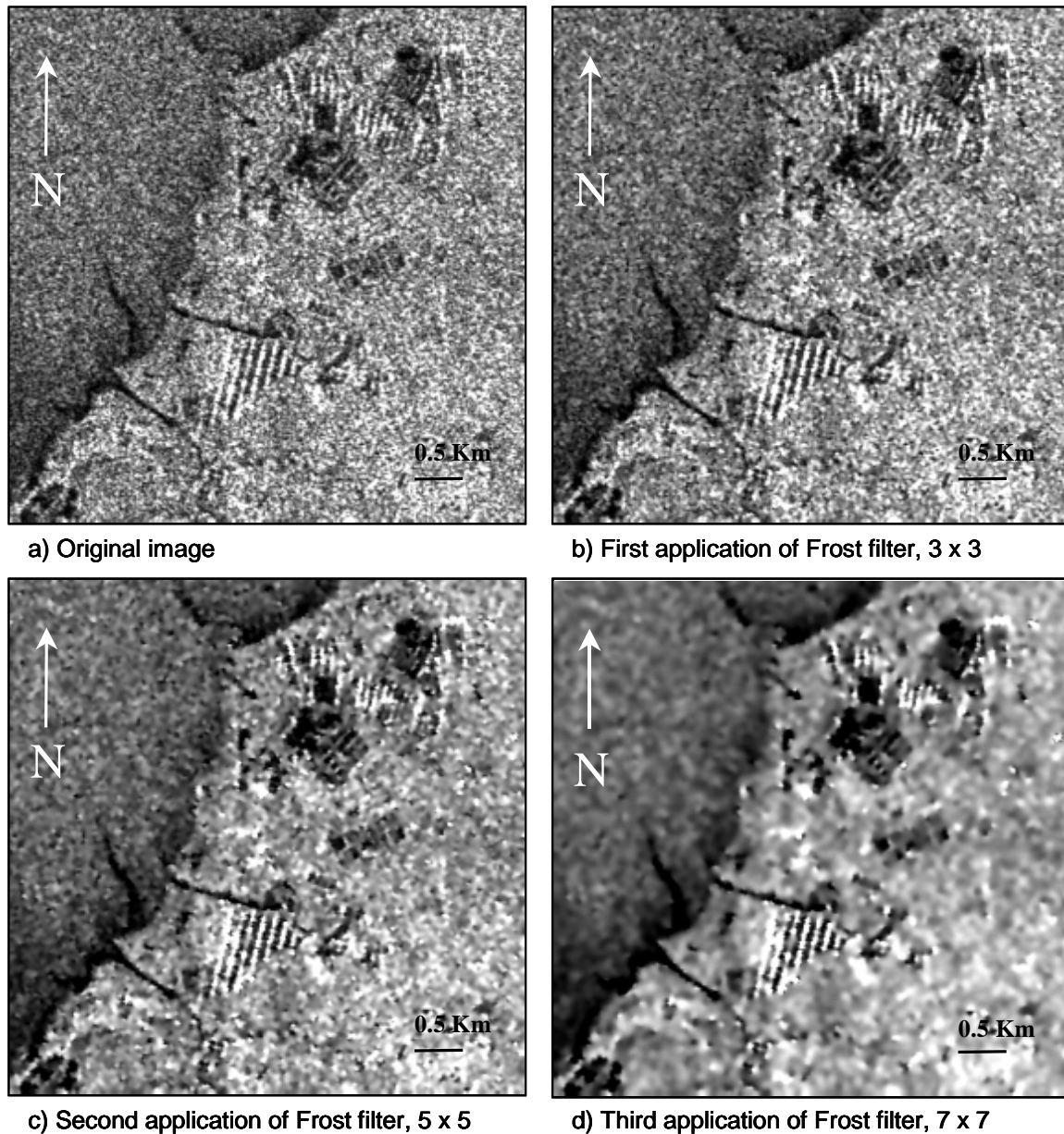


Figure 17 Sequential application of Frost filter to the image of Seguwantiyu test site

Classification

The purpose of this part of the analysis procedure is to identify water bodies, and possibly dykes, in the ERS SAR images. The identification of other types of land cover is not required. Thus, the images can be analyzed only by means of unsupervised classification procedures or by histogram thresholding.

As described in the preceding paragraph, water bodies are characterized by typically low values in SAR images. Conversely, the values of dykes surrounding shrimp ponds vary in SAR images according to their position relative to the satellite cross-track direction. Thus, dykes perpendicular