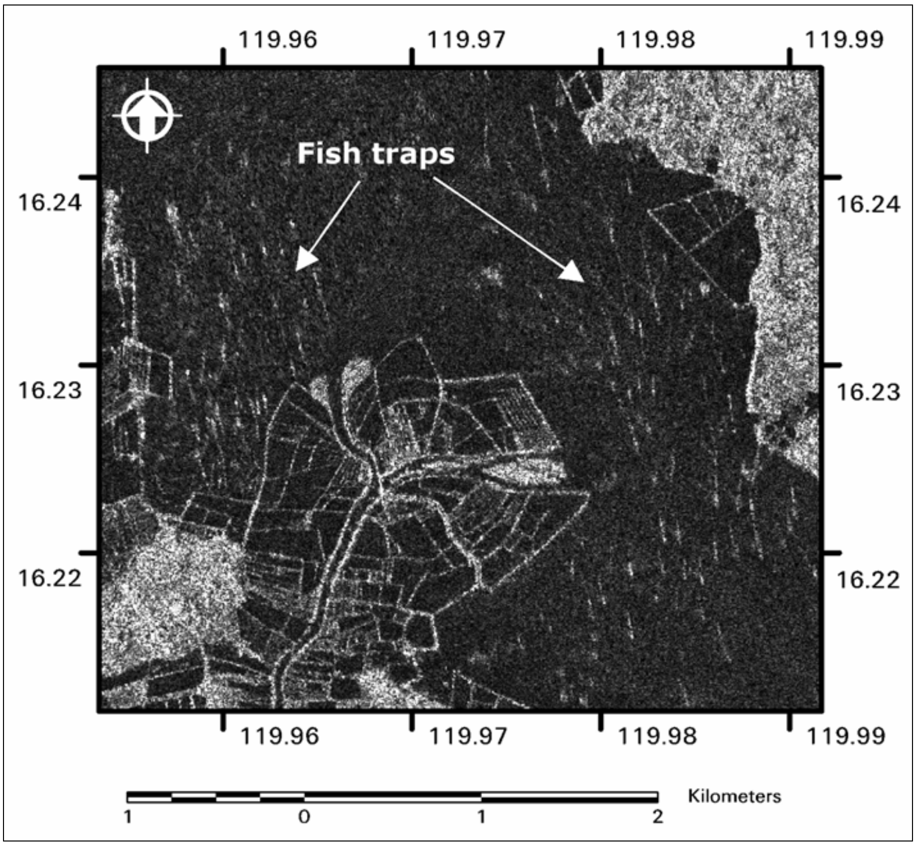

Figure 9: Appearance of offshore fish traps on the RADARSAT-1 SAR image.

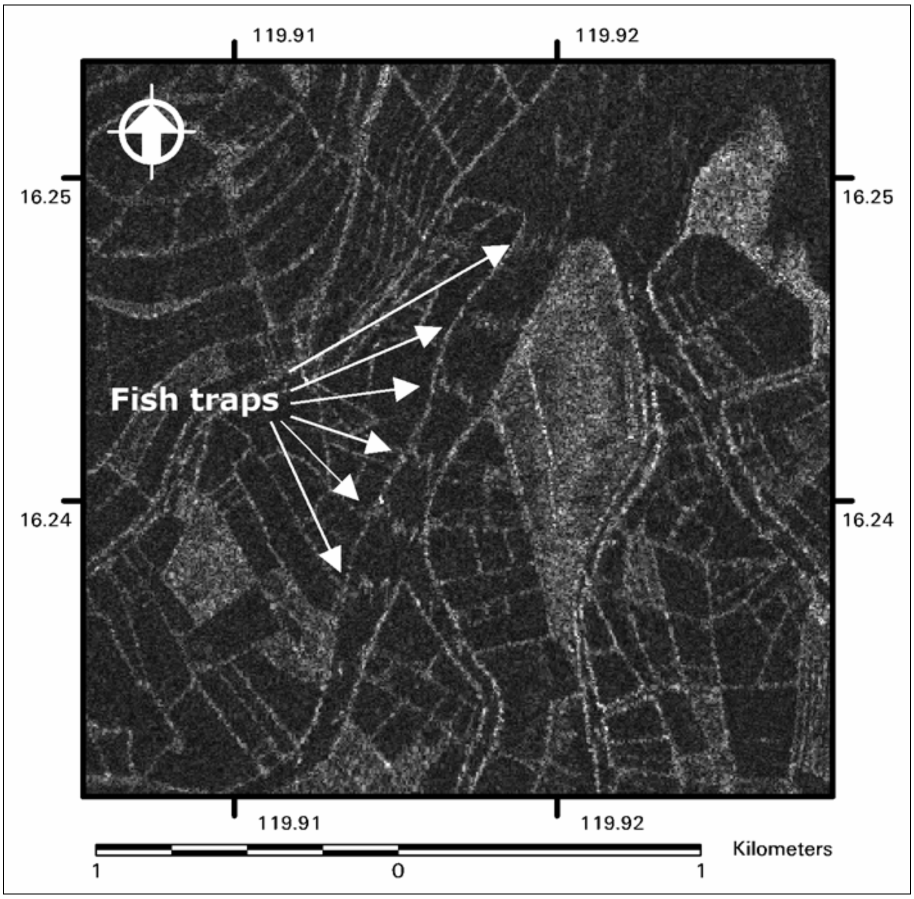

Figure 10: Appearance of fish traps inside rivers on the RADARSAT-1 SAR image.

Field verification exercise

A team of the Bureau of Fisheries and Aquatic Resources of the Philippines (BFAR) went in December 2003 to Lingayen Gulf to check the accuracy of the interpretation of SAR images. Before discussing the field validation results, the following aspects of the work should be considered:

1. Fish traps were recognized only on RADARSAT data which were acquired on February 2001, that is about two years before the field check. Some of them could have been removed or moved somewhere else in this timeframe;

2. Fish cages were easily mapped with both RADARSAT-1 and ERS-2 data. As the cages are floating, they can be moved to other places if there is a need. Actually, a group of cages located between Luzon Island, Santiago Island and Cabarruyan Island presents two distinct locations in RADARSAT-1 (February 2001) and in ERS-2 (December 2002), most probably as a consequence of a typhoon which affected the area. Thus the field checking of fish cages was limited to ascertaining the presence of fish cages in the vicinity of the place indicated in our SAR-derived maps, as in a one year interval the cages could have been moved somewhat. However, in the majority of the cases, the fish cages were still at the places mapped from radar data.

3. Fish pens and fishponds, being semi-permanent structures, were not influenced by the one year time interval and thus they were field checked at the exact coordinates reported in the radar-derived maps. In limited cases fishponds were converted to other uses in the most recent months, but interviews with local people confirmed their original nature.

The field work was thus aimed at mainly verifying the interpretation of fishponds and fish pens. The survey was conducted on 32 verification points, selected by means of a two-stage cluster sampling scheme. Two verification points were also located on the “fishponds, uncertain” class, as the results could have assisted in fine-tuning the interpretation keys. The ground verification included also six observation points located offshore and inside rivers, in order to confirm the presence of fish cages and traps in/or the proximity of the points in which they are located in the SAR images.

The analysis of the ground truth at the verification points shows that both the two points located on the class “fishponds, uncertain” are in fact other types of water-covered surfaces. This confirms the correctness of the main interpretation key, according to which the water-covered surfaces were assigned to the class fishponds only if the surrounding dykes were visible. Water-covered surfaces regular in shape but not surrounded by visible dykes were assigned to the class “fishponds, uncertain”; the results of the ground survey demonstrate that the class “fishponds, uncertain” should be removed from the final map. Of the other 30 verification points, 23 are located on areas interpreted as fishponds, four on fish pens and three on salt pans. The actual land use was different at one point only; it had been assigned to fishponds by the visual interpretation, but the corresponding area is a marshland bordering salt pans.

The user’s accuracy of the verified classes, e.g. the ratio between the total number of points truly belonging to a class and the total number of points assigned to the same class by the visual interpretation procedure, is thus 100 percent for salt pans and fish pens, and 95.7 percent for fishponds. These figures give the probability that a point on the interpretation map truly corresponds to the class to which it has been assigned. However, the actual accuracy of the “salt pans” class might be lower, due to the fact that they may appear very similar to fishponds when they are completely flooded.

The accuracy cannot be calculated for fish cages and traps, as they may have been moved or removed in the time interval between the image acquisition and the field verification, as a consequence of severe weather conditions. In fact, differences in their positions are visible on the 2001 and 2002 images, as explained above. Thus, mapping accuracy for fish cages was estimated at 90 percent and for fish traps at 70 percent. The results of the ground survey show that offshore fish traps are still approximately located in the same areas in which they were when the images were acquired, while the traps detected inside rivers were not observed in the two surveyed points. The fish cages at the southern border of Santiago Island, clearly visible in all SAR images, are still located there, while the fish cages identified offshore Barangay Dori (Bolinao) are now replaced by fish pens built seaward from the rocky coastline.

Discussion

RADARSAT fine beam

RADARSAT fine beam data, thanks to their ground resolution of 6.25 m, provide excellent images of all aquaculture and fisheries structures considered in this study and, therefore, allow for their inventory and monitoring with great accuracy. Actually, fish pens were detected and easily mapped only with RADARSAT data. Similarly, fish traps were visible only on the RADARSAT image, but their mapping was not immediate due to the inherent characteristics of the traps themselves.

Having considered these evident advantages, some other aspects of RADARSAT data should be evaluated: a RADARSAT fine beam frame covers only 50 x 50 km at a cost of US$ 3000 if the image has been already acquired and is available (archive data). Satellite programming cost is US$ 100 but goes up to US$ 500 if an acquisition date is booked in advance.

ERS SAR

ERS SAR data in their GEC format have a ground resolution of 12.5 m and cover a 100 x 100 km area. Fishponds and fish cages were easily mapped through ERS SAR data during this study with accuracy comparable to that of RADARSAT. An ERS SAR frame costs US$ 1400 for both archived and programmed data.

In the present study we had the possibility of having ERS SAR data both in ascending and descending orbit. As discussed, this is a distinct advantage as it greatly increases detection and, thus, accuracy in fishponds mapping. For mapping fishponds and fish cages we recommend using ERS SAR with data from ascending and descending orbits acquired with a limited time interval between dates of recording.

Final considerations

Mapping and monitoring coastal aquaculture and fisheries structures is extremely important for governments as this generates baseline information for decision-making for a proper development of aquaculture and fisheries, including regulatory laws, environmental protection and revenue collection.

This can be achieved with good accuracy and at regular intervals by satellite remote sensing, which allows observation of vast areas, often of difficult accessibility, at a fraction of the cost of traditional surveys. In several cases the information obtained through satellite remote sensing is unique, as it cannot be generated by any other means.

The mapping accuracy obtained with SAR data is very high: 100 percent for fish pens and 95 percent for fishponds. It has been difficult to field check the mapping accuracy for fish cages, as they are floating and thus movable if need arises. However, their clear appearance on the SAR data, including information on their metallic/non metallic structure and the fact that they cannot be mistaken for any other object, permit a 90 percent estimated mapping accuracy.

Fish traps are detectable only on RADARSAT fine beam data, both offshore and inside river estuaries. Often their length can be measured. Being thin elongated structures almost completely under the water, their backscatter on SAR data should be maximum at low tide. Unfortunately, as indicated in section 4.1, tide information for the Lingayen Gulf was not available for the selection of the relevant data. Thus for fish traps it can be said that detectability on RADARSAT fine beam data is high and mapping accuracy can be estimated at 70 percent.

An extremely important aspect of aquaculture and fisheries structures mapping by satellite imaging radar (SAR) is that the resulting maps are geocoded and available in a Geographic Information System (GIS) as information layers. By adding other GIS layers such as land cover, urban development, tourist sites, areas subjected to conservation measures, potential/existing pollutants, water quality and other information layers of interest, the resulting database becomes a powerful tool for a proper management and development of the local resources, including environmental protection.

Another important aspect which should be considered is that the database facilitates identifying land cover changes which occurred during the development of the structures, mainly fishponds, and/or selection of the best places for their expansion, taking into account other potential and often conflicting uses of the area.

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