Analysis of Forest Spatial Structure using Spatial Decision Rule

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ABSTRACT

The radar group at the Department of Environmental Sciences, Wageningen University, has several research activities to investigate radar tree mapping and data integration, and one of them is the study of "Analysis of Forest Spatial Structure using Spatial Decision Rule". The objective of this study is to investigate the tree grouping level using the spatial decision rule based on tree information derived from the interferometric SAR (InSAR) images. The results showed that tree objects could be quantitatively clumped in various degrees and different hierarchy levels using several parameters, e.g. distance to the closest neighbor tree(s), tree height, and canopy structure. The study also learned that trees can be grouped in a quantitatively way without loosing individual tree information to be integrated into the smaller scale geo-database, e.g. forest density cover type.

***Keywords and phrases*:** Forest Structure, Synthetic Aperture Radar (SAR), Interferometric, Spatial Decision Rule

1.0 INTRODUCTION

1.1. Background

The radar group at the Department of Environmental Sciences, Wageningen University, has several research activities to investigate radar tree mapping and data integration, and one of them is the study of "Analysis of Forest Spatial Structure using Spatial Decision Rule". The studies of the forest structure are usually based on the ground survey and these are related to the forest inventory activities. Conventional nomenclature for the forest structure has been summarised by Koop (1996). The common and simple nomenclature are **Gap, Building**, and **Mature** (Whitemore, 1990), but to arrive to these nomenclature of forest structure requires good ground forest inventory or survey activities. Obviously, this simple nomenclature could become input for the government to plan their action on forests, e.g. reforestation plan.

Forest survey measures parameters as complete as possible to describe the forest structure in plot sizes of 1 – 6ha (Oldeman, 1990, Koop, 1989, Prakoso and Suryokusumo, 2000). Prakoso and Suryokusumo (2000) established a 6 ha square plot of intact secondary forest to be used for DO-SAR image validation and this plot contained complete information, e.g. contour of the land, x,y,z coordinates of tree trunk, local-species-genus-family identification, tree height, diameter at breast height, height of first branch, height of periphery, canopy radii of 8 compass directions at periphery. Furthermore, the geo-database concept of tree could be directed as point features that have their own attributes and any aggregation process would not loose the individual tree attributes. This tree concept in geo-database is different from tree concept in an ecological concept (Oldeman, 1990; Koop, 1996, and Whitemore, 1990). Therefore, a good forest survey or forest plot could be used to simulate such a SAR image.

In East Kalimantan, Dipterocarpaceae is the dominant family and they tend to clump (Smits, 1994) and this clump symptom could be a nice indicator to judge the nomenclature of forests. This can be done because the tree trunk positions or 3D-coordinates including the form and height of tree canopy are measured (Prakoso and Suryokusumo, 2000). DO-SAR image after being processed in the algorithm developed by Dr. Hoekman could produce information on the volume of canopy, backscatter intensity of the tree canopy, and grouping trees using spatial decision rules, e.g. minimum 3D distance of trees and size of the canopy volume. Therefore, all information of various sources, e.g. SAR and forest survey could be used in a synergy way to develop a 'clumped' distribution of mature trees. The ‘natural’ mature tree-crown as well as their natural neighbourhood has a unique spatial structure. Deviations from the crown structure as well as the 'natural' distribution might indicate forest function loss, degradation or recovering stages in the forest development. Furthermore, Omon (2002) found that young *Shorea leprosula* of Dipterocarpaceae proves to be shade requiring, not shade-tolerant, because high light intensity damages it. Therefore, a good set of user requirements for 3D-tree grouping can fulfil a suitable microclimate for young trees to grow, which considers humidity, temperature (shade), and moisture content (Shugart, 1984).

1.2. Objective

The objective of this study is to investigate the tree grouping level using the spatial decision rule based on tree information derived from the interferometric SAR (InSAR) images.

1.3. Structure of the Paper

The structure of the paper consists of:
- Introduction
- Materials and Method
- Results and Discussions
- Conclusion and Recommendation

2.0. MATERIALS AND METHOD

2.1. Materials

This study uses data of Airborne DOSAR of August 1996 and the study area is located in Samboja, East Kalimantan, Indonesia (Figure 1). The latest fieldwork has been done in the study area in July 2002 along with Global Positioning Systems (GPS) measurement.

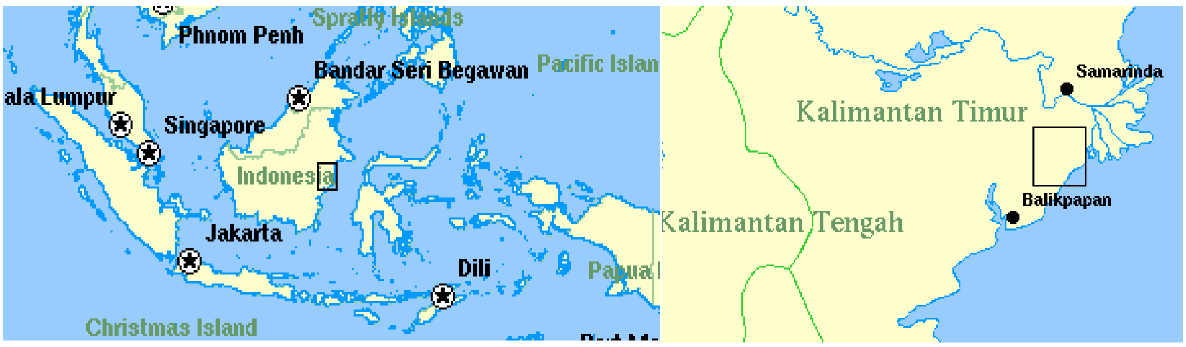


Figure 1. The location of study area

2.2. Method

In this paper or this study, the point of departure is an individual tree level up to a group of trees or groups of trees. This study also uses the 3D-tree-aggregation-mapping algorithm developed by Dr. Hoekman, Wageningen University. The simple ordinary least square (OLS) regression in SPPS software is used to find relationship between the proposed index and different forests or lands cover types.

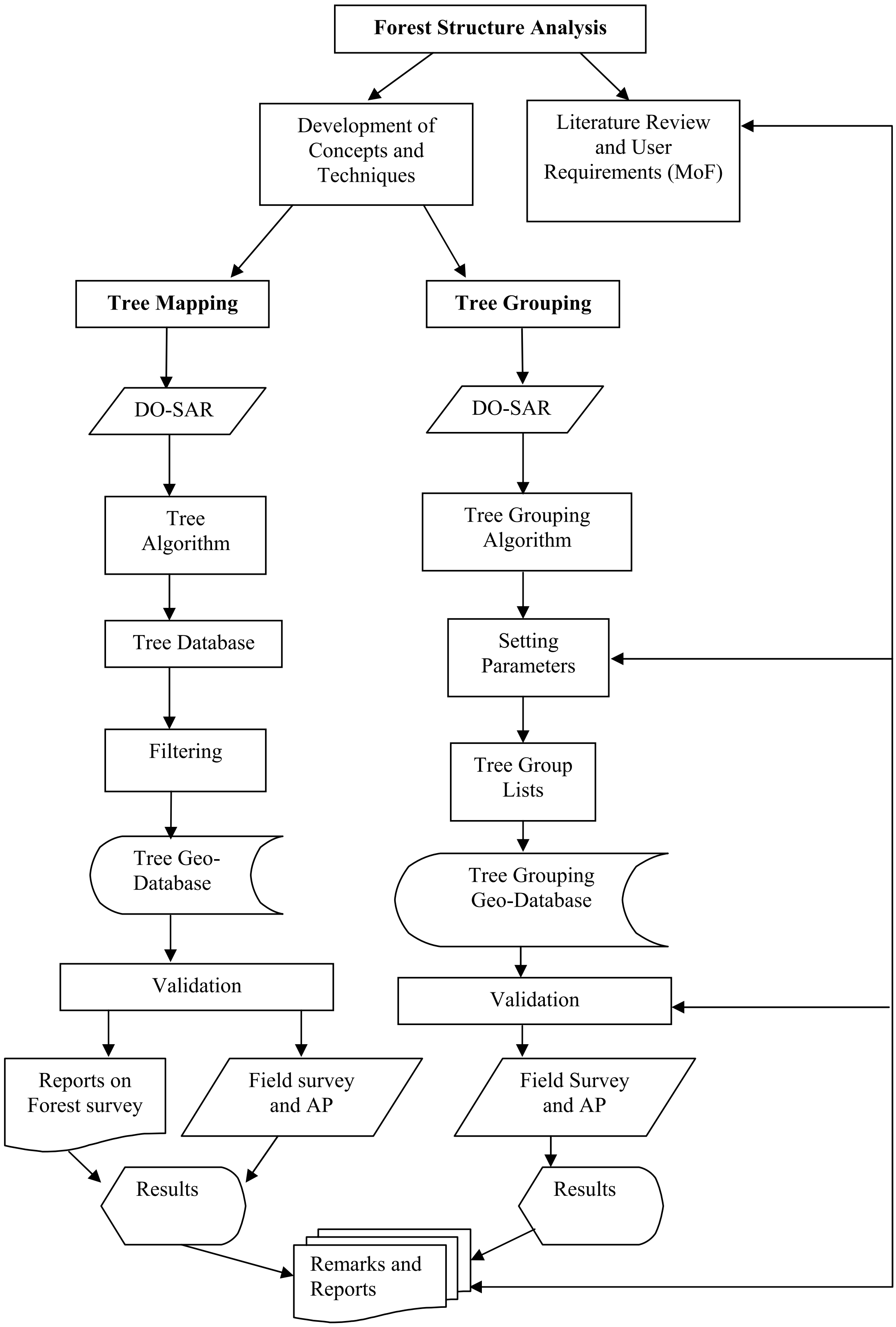


Figure 2. Flowchart of Forest Structure Analysis in DO-SAR images

3.0. RESULTS AND DISCUSSIONS

3.1. 3D Tree Mapping and Tree Grouping Concept

First, each tree can be defined as a tree when its canopy has a digitised 3D canopy and assuming such a centre gravity to obtain the z, y, z position of the individual tree (Figure 3). The anaglyph view of 1996 AP is looking up side down because it can give the right view of 3D-perspective.

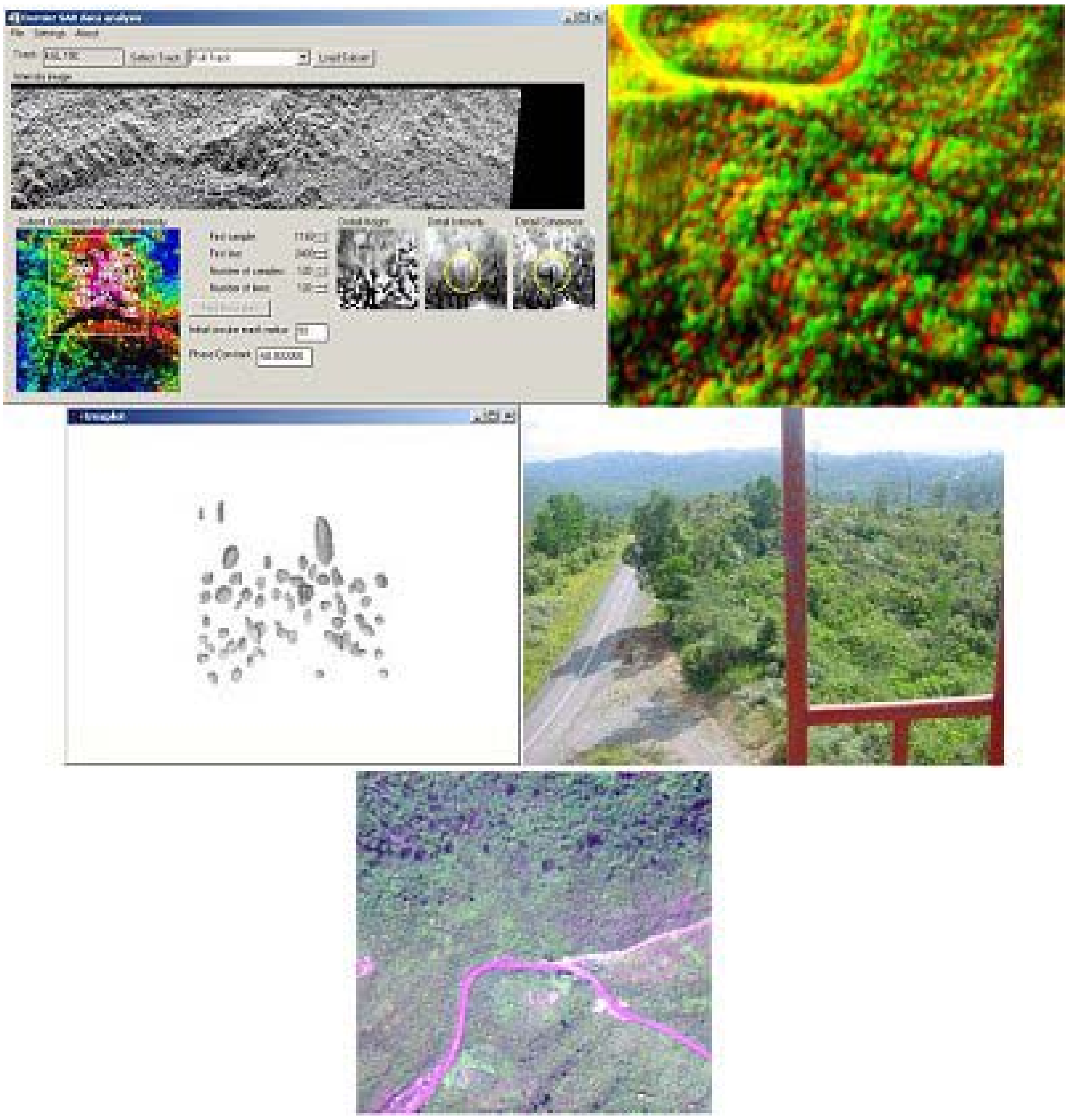


Figure 3. 3D- tree mapping outputs from DO-SAR interferometric, APof 1996 and recent situation

Traditionally in forest survey/inventory, the basic element is the tree stem along its attributes, e.g. position DBH, species, but currently these attributes could directly extract from remote sensing data/images. The stem is actually a point feature and this point feature is the basic input for assessing forest spatial structure (Pretzsch, 1999 in Olsthoorn *et al*., 1999). Difficulties are found because a certainty about the real tree-trunk or tree-stem position is being questioned. This uncertainty could be resolved at least to convince that the tree seen in DO-SAR was the tree found in the fieldwork and the use of GPS including compass and measuring tapes were very helpful. Certainly, there would be differences by time (1996 and 1999, 2002) and by the viewing, e.g. fieldworkers see from below and SAR sees from above. Prakoso and Suryokusumo (2000) has established a 6 ha square plot of intact secondary forest to be used for DO-SAR image validation and this plot contained complete information, e.g. contour of the land, x,y,z coordinates of tree trunk, local-species-genus- family identification, tree height, diameter at breast height, height of first branch, height of periphery, canopy radii of 8 compass directions at periphery that these data could be visualized in 3D look alike from any direction as well as from above views (Figure 4).

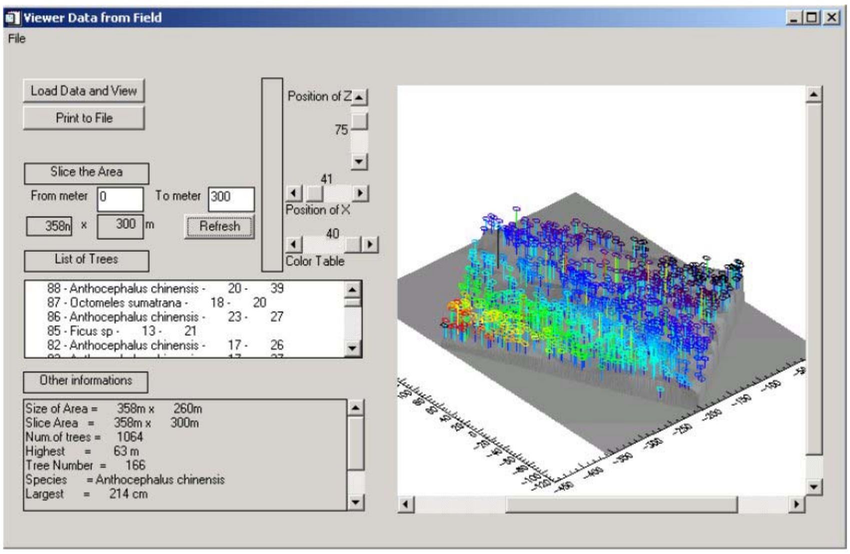


Figure 4. Example of Forest Survey Data Visualization

Second, a group of tree could be defined by users based on their requirements, e.g. capability of a tree group to provide opportunity for young trees to grow because they need shade or to define a tolerable gap between two groups of high trees (Figure 5).

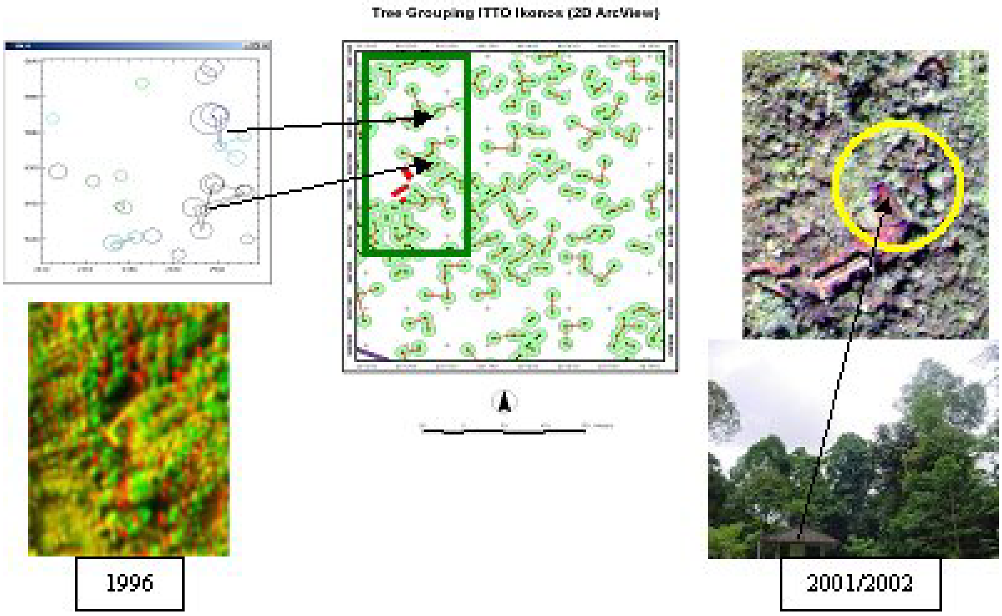


Figure 5. 3D tree grouping that based on user requirements on distance and difference tree height

This definition of 3D-tree grouping tries to accommodate a real world situation when within a group would consist of big trees and several small trees in between. The concept of network limits one tree not to have more than one link to other trees. The transect of many tree plots could show that groups of tree related to a type of forest type, e.g. a clump of big trees could be defined as a biostatic ecological unit according to Oldeman (1990) or a mature class in Whitemore (1990). The expectation from this 3D-tree grouping is to link such a proposed index with various forests or land cover features used by the Indonesian MoF concerning also the nomenclature of gap, building, and mature (Whitemore, 1990). Qualitatively, this 3D-tree grouping approach on an intact secondary forest showed a slight difference result with the 2D-tree grouping approach that based on a fixed buffering, e.g. a canopy radius is assumed 6 meter (Figure 5).

3.2. Radar Plot and Tree Grouping

Radar plot is one of the most complete plots for DO-SAR 3D tree mapping validation. The validations of DO-SAR and AirSAR images are still ongoing. Prakoso and Suryokusumo (2000) have reported first validation in 1999 for DO-SAR 3D tree mapping in their M.Sc thesis. The 3D tree mapping results did not really agree with the radar plot from forest survey. Therefore, the improvement of 3D tree mapping algorithm would be necessary. Meanwhile the exploration of data in radar plot showed positive results in allometric equation (Nugroho *et al.*, 2001) and tree grouping aspects (Figure 6).

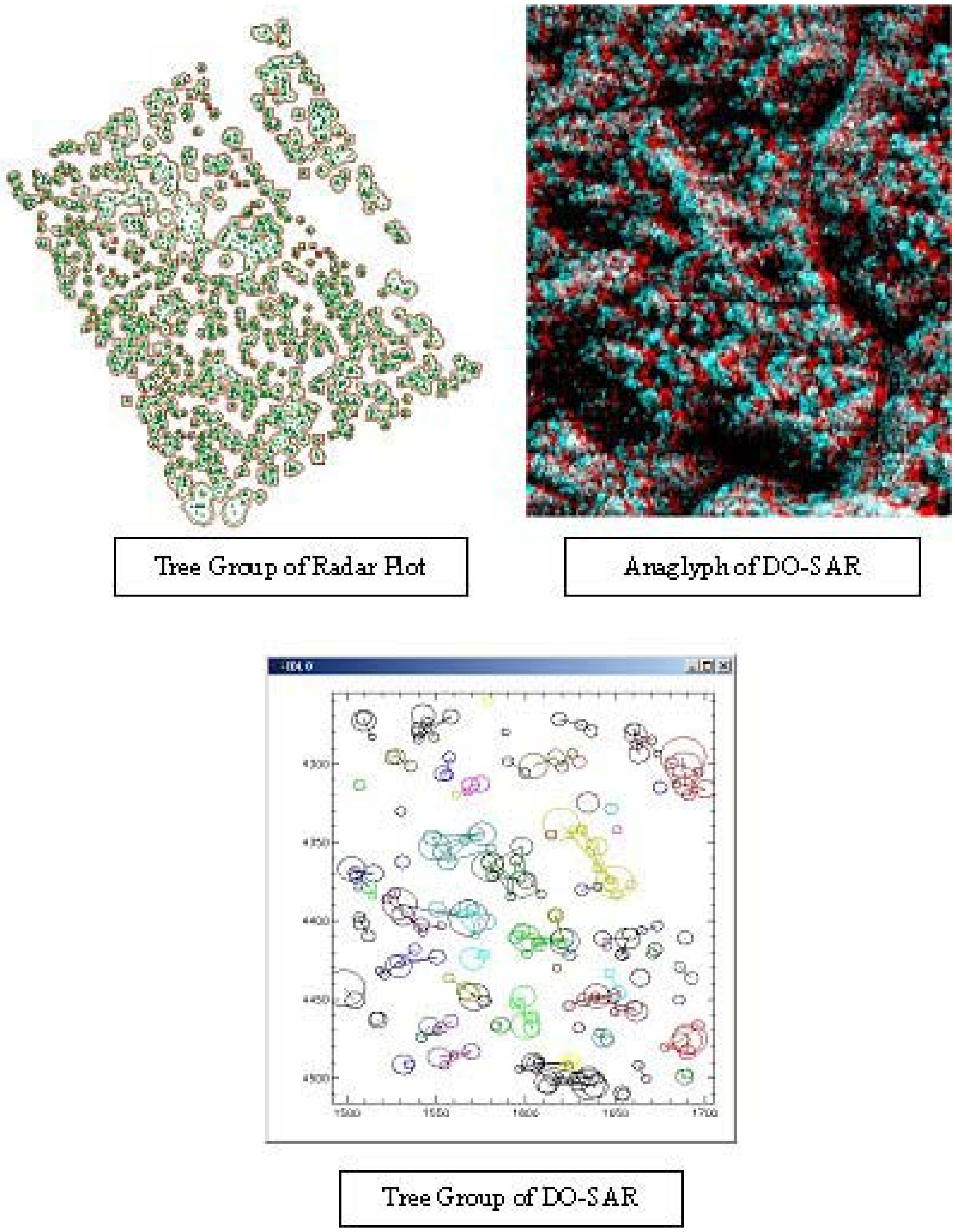


Figure 6. The 3D- tree group and tree group using buffering technique with tree height as a weighting factor

This result could produce tree group polygons without loosing tree point feature and its attributes. The need of tree grouping is an effort to quantify the conventional approach of forest nomenclature, e.g. gap, building, and mature (Whitemore, 1990). The benefit of grouping a tree on different forest nomenclature or classes, e.g. primary forest, secondary forest, degraded secondary forest, burnt secondary forest, and damaged forest/alang-alang is to provide user with information about existing condition that can show level of forest micro-climate of tree groups. For example, three Dipterocarpaceae tree groups with average tree height of 30m separate only 10 m away among others can give high chance for natural regeneration because its shade effect protects the new growth.

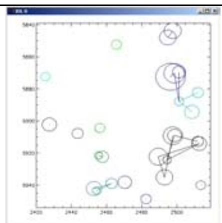
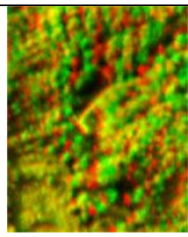
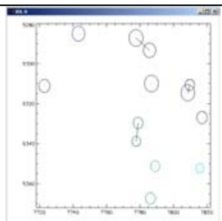
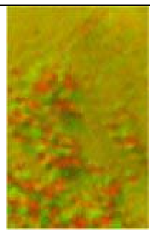
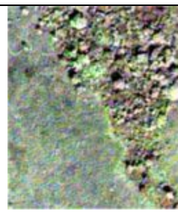
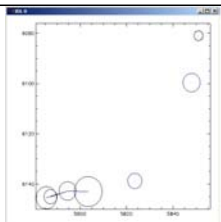
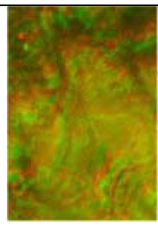
Currently, there are about 18 plots are being investigated to be used for SAR image validation, e.g. AirSAR. Fieldwork has been also done in July 2002 to improve the quality of the plots. For further research, our radar group would like to investigate the use different aggregation indexes (Pretszch, 1999 in Olsthoorn *et al.*, 1999).

3.3. Dornier SAR

The Dornier SAR (DO-SAR) image is an interferometric airborne SAR and this means that a digital elevation model can be derived. This paper is trying to continue discussion of 3D tree mapping, but it will focus on the tree grouping aspect. Aforementioned a special user-friendly program of 3D tree grouping is based on IDL program in order to further process of 3D tree mapping data and the to be validated in the real world situation.

Qualitatively, the results show a slight difference between radar plot buffering and 3D-tree aggregation result (Figure 6). It is obvious that they can be differences because both techniques have different starting points respectively. First technique is available in ILWIS 3.0 software and its algorithm is based on distance calculation with 3 x 3 matrixes and with adding a weight factor, it will be multiplied by the weight value/map, e.g. tree height map. Second technique is based on aforementioned 3D parameters and the grouping use a networking of one to one relationship. Furthermore, 3D-tree grouping were applied on different forest features, e.g. intact secondary forest, degraded secondary forest, and an open area/paddy field. Results showed that an applied set of tree grouping requirements indicated ratio between number of groups and number of trees were increased when forests were degraded (Table 1). Therefore, the result initiates to propose such an indicator for tree grouping related to the forest features and other attributes e.g. canopy volume in the further research. Further criteria or such an index may explain different nomenclature e.g. whether the burnt secondary forest of MoF can be related to a gap nomenclature of Whitemore (1990). There are also many useful matters that can be developed for further research work especially when users, e.g. MoF needs a special index or indicator to assess their forests and the investigation of tree grouping or clump can be further go on the higher level of relationship among tree grouping. In addition, this new 3D-tree aggregation algorithm provides information on the volume of canopy and this can be linked to a biomass aspect.

Table 1. Different forest features and their attribute information respectively on 3D-tree grouping

Forest Feature	**3D-TreeGroup 1996**	**Aerial Photographs 1996**	**Ikonos 2001**
1. Intact Secondary Forest Number of Tree=28 Number of Group=14 Ratio #Tree/#Group=0.50 Total Canopy Volume=10,060.0 m^3			
2. Degraded Secondary Forest Number of Tree=13 Number of Group=10 Ratio #Tree/#Group=0.77 Total Canopy Volume=2,641.5 m^3			
3. Open Area/Paddy Field Number of Tree=7 Number of Group=5 Ratio #Tree/#Group=0.71 Total Canopy Volume=1,740.9 m^3			

4.0. CONCLUSION AND RECOMMENDATIONS

The objective of this study is to investigate the tree grouping level using the spatial decision rule based on tree information derived from the interferometric SAR (InSAR) images. The results showed that tree objects could be quantitatively clumped in various degrees and different hierarchy levels using several parameters, e.g. distance to the closest neighbor tree(s), tree height, and canopy structure. The study learned that trees can be grouped in a quantitatively way without loosing individual tree information to be integrated into the smaller scale geo-database, e.g. forest density cover type. The tree geo-database requires consistency and up-to-date ness.

Further investigations on developing tree grouping indexes and species or genus identification by SAR images would be important for future forest planning at various levels. The exploration and data mining for many plots should be improved in order to achieve the best validation result of 3D-tree grouping.

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