THE MERIT OF JERS-1 DATA IN ADDITION TO ERS-1 DATA FOR LAND COVER MONITORING

J.G.P.W. Clevers (1), H. Kramer (2), H.J.C. van Leeuwen (3) and D.H. Hoekman (4)

(1) Dept. of Landsurveying and Remote Sensing, Wageningen Agricultural University, P.O. Box 339, 6700 AH Wageningen, The Netherlands
(2) DLO - Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO), P.O. Box 125, 6700 AC Wageningen, The Netherlands
(3) Synoptics BV, P.O. Box 117, 6700 AC Wageningen, The Netherlands
(4) Dept. of Water Resources, Wageningen Agricultural University, Nieuwe Kanaal 11, 6709 PA Wageningen, The Netherlands

Commission VII, Working Group 1

KEY WORDS: SAR Imagery, Land_Use, Agriculture, Forestry, Monitoring

ABSTRACT

The applicability of the JERS-1 L-band SAR for land applications was evaluated in addition to the use of the ERS-1 (C-band). For operational applications, satellite data should be used for land cover classification, parameter estimation and the monitoring of vegetation and soils. The JERS-1 satellite is a new satellite, offering new features that must be tested in comparison to other satellite data. First of all, the JERS-1 combines an optical and a microwave sensor. Secondly, the microwave sensor is an L-band SAR having longer wavelengths than the C-band SAR of the ERS-1, thus offering interesting possibilities for parameter retrieval and monitoring of vegetation and soils.

In studying time series of radar backscatter from JERS-1 and ERS-1 for agricultural crops, it was found that the dynamic range of JERS-1 time series during the growing season was not as large as found before for L-band in airborne campaigns and it was less than the one of ERS-1 time series. The backscatter signatures of JERS-1 during the growing season were difficult to compare with those of ERS-1 during the growing season because of the very limited number of JERS-1 observation dates available.

Using three JERS-1 images, a multitemporal object-based classification of agricultural crops was performed. The classification results were compared with a composed digital reference map of the research area. When comparing the results of a multitemporal per field classification based on ERS-1 data with the results for JERS-1 data, varying results were obtained. Some crops were classified more accurately using JERS-1 data, other crops were classified worse in comparison to the use of ERS-1 data. For instance, grassland and potatoes were classified most accurately using ERS-1 data. On the contrary, sugar beet, maize and barley were classified more accurately using JERS-1 data.

In forestry, results showed that JERS-1 is better suited to discriminate forest species than ERS-1. A multi-temporal approach, i.e. at least one observation in winter and one in summer/spring, is recommended. A visual interpretation of images revealed that the broad discrimination between deciduous and coniferous species is well possible with a single L-band summer image.

1. INTRODUCTION

Using remotely sensed data for land cover mapping often implies the use of optical data. Several satellite sensors are available (e.g. Landsat TM, SPOT-XS) but due to weather conditions it is not always possible to get data for a specific area during a specific period of time. The availability of microwave data (e.g. ERS-1, JERS-1) is not restricted by weather conditions.

The application of ERS-1 SAR data (C-band) for mapping land cover was investigated by Nieuwenhuis & Van Rooij (1994). With images taken during the growing season of 1992 they showed the applicability of such images. The optimal classification results were obtained with 8 images well distributed in time. With a decrease of the number of images the discrimination between crops decreased.

The JERS-1 satellite is a new satellite, offering new features that must be tested in comparison to other satellite data. First of all, the JERS-1 combines an optical and a microwave sensor. Secondly, the microwave sensor is an L-band SAR having longer wavelengths than the C-band SAR of the ERS-1, thus offering interesting possibilities for monitoring and parameter retrieval of vegetation and soils. In this study, we tried to evaluate the applicability of the JERS-1 for land applications in comparison to the use of the ERS-1 (C-band).

For the JERS-1 application research (classification, parameter estimation, monitoring), actual field data (ground truth) was collected during the 1993 growing season (e.g. crop type, crop cover, crop reflectance, soil moisture). From November 1992 until November 1993, as many as possible microwave and optical scenes of the Flevoland and Veluwe region (The Netherlands) were recorded by the JERS-1 and made available by NASDA to this study. ESA-ESTEC made as many as possible ERS-1 scenes of Flevoland available to the study.

To compare the applicability of JERS-1 L-band SAR with ERS-1 C-band SAR the following activities were performed:
(1) Comparison of time series of JERS-1 and ERS-1 radar data: for agricultural areas, radar backscatter data were extracted from the available images for selected polygons. The obtained time series for L- and C-band data were compared with each other.
(2) Agricultural classification experiment: for the growing season of 1993, 3 JERS-1 L-band images were used in a multitemporal object-based classification. The classification results were compared with a composed digital reference map of the research area. Finally, the obtained classification accuracies for the different land cover types were evaluated in comparison with results based on 3 ERS-1 images.
(3) Forest classification experiment: because of the larger wavelength and larger tree crown penetration, the JERS-1 L-band was expected to yield other information about forests than C-band ERS-1. Therefore, the utility of JERS-1 and ERS-1 SAR data for forest inventory was compared.

The current paper presents detailed results of the above studies.

2. MATERIAL AND METHODS

2.1 Test Sites

The test sites selected for the ERS-1 and JERS-1 campaign were the Flevoland agricultural test site, the Horsterwold site (forested) and the Speulderbos site (forested) in the Netherlands.
The Flevoland site is situated in Southern Flevoland, a polder reclaimed in 1966 from lake IJssel, and it is in cultivation by individual farmers and a state owned farm. The fields of the state farm are relatively large (approximately 1500 x 500 m) compared to the fields cultivated by private farmers (approximately 500 x 200 m). The general altitude is 3 metres below sea level.

The Horsterwold site is also located in Southern Flevoland. The forest is managed by the "Directie Flevoland". Planting started in 1973. When completed the forest will be 4000 ha large and, herewith, will be the largest deciduous forest in the country. The site comprises large numbers of poplar stands and stands of other deciduous species like: willow, elm, beech, oak, alder, maple and ash.
The Speulderbos site, located at the Veluwe which is a part of the province of Gelderland and features the largest forested region in the Netherlands, is managed by the State Forest Service. The area measures 2390 ha and contains many species in many age classes. Scots pine, Douglas fir, Japanese larch, beech and oak stands prevail. Corsican pine, European larch, Norway spruce and grand fir stands occur less frequently.
These two forest test sites comprise a fair range of species, age classes, soils and other environmental conditions. Stand areas typically range from one to several hectares, which is quite small but normal for large parts of Europe.

For ERS-1 and JERS-1 application research (classification, parameter estimation, monitoring), actual field data (ground truth) had to be collected during ERS-1 and JERS-1 overflights. From November 1992 until November 1993, microwave and optical scenes of the Flevoland test site were obtained from the ERS-1 and JERS-1 on a regular basis. As a result, ground truth data also were acquired on a regular basis for that period. A complete overview of the ground truth can be found in Vissers (1994).

2.2 Satellite Data

The following ERS-1 SAR images covering Flevoland in 1993 were available for this project: 12/01, 16/02, 23/03, 11/04, 18/04, 27/04, 16/05, 23/05, 01/06, 20/06, 27/06, 06/07, 25/07, 01/08, 10/08, 29/08, 05/09, 03/10, 10/10, 19/10.

The following JERS-1 SAR images were available for 1993: 12/02, 28/03, 12/05, 07/08, 20/09.

For comparison of JERS-1 and ERS-1 classification results ERS-1 images close to the acquisition dates of the JERS-1 images were selected. This results into the images given in table 1.

Table 1. Selected SAR images from the total set for classification purposes.

JERS-1	ERS-1
12-02-1993[(1)]	16-02-1993[(1)]
28-03-1993[(1)]	23-03-1993[(1)]
12-05-1993	16-05-1993
07-08-1993	10-08-1993
20-09-1993[(2)]	05-09-1993[(2)]

[(1)] not used for classification of agricultural crops
[(2)] not used for forest classification

2.3 Reference Data

A SPOT-1 optical image of the 2nd July of 1993 was used to identify 530 agricultural fields of 24 different crops which were indicated on the "Vegetation inventory map Zuidelijk Flevoland (NL) 1993" (Vissers, 1994). By digitizing the lot boundaries on the screen of the image processing system a vector map was constructed. The vegetation map thus obtained is the basis for the classification in section 4.

For the forest classification study, data for 196 forest stands in the two test sites were collected from previous ERS-1 studies (van der Linden, 1995). These include descriptions of (main) species, height, density, age and area. In this study a part of these stands could not be used because of the incomplete overlap of the JERS-1 images (differing somewhat between dates) with the ERS-1 images. A database was created for all stands present in these images. The database includes data on stand averaged σ^{0} and the within stand standard deviation of σ^{0}.

For the extraction and calibration of the JERS-1 backscatter, parameters and algorithms were used described by Kleijweg & Groot (1995). The ERS-1 images were calibrated according to a procedure described by Laur (1992).

3. TEMPORAL RADAR BACKSCATTER SIGNATURES

3.1 Introduction

The ERS-1 and JERS-1 recordings of the growing season of 1993 provided a large number of microwave measurements in time. In the 1993 growing season 20 ERS-1 recordings with an interval of about 10 to 16 days are available. For the JERS-1 only four recordings during the growing season with an interval of 30 to 70 days are available. It is therefore important to consider the measurement frequency in relation to the shape of the time series curves for each crop with ERS-1 first. Subsequently, the performance of JERS-1 can be studied with the conclusions of the ERS-1 in mind. Of course a different backscatter behaviour can be expected from the various agricultural crops with L-band HH of JERS-1 compared to C-band VV of ERS-1.

The main crops at the Flevoland site have been selected and ordered into 4 groups:
1. crops with abundant leaves and biomass, like sugar beet and potato;
2. crops with less biomass like grass, lucerne and rapeseed;
3. vertically oriented crops like wheat, barley and maize;
4. miscellaneous crops like bush and fruit trees.

Results for group I and III only will be presented since these are the most important crops in the region.

3.2 Average backscatter ERS-1

The average curves in group I show a similar backscatter behaviour (e.g. figure 1 for sugar beet). The peak at day 108 can be noticed for potato as well as for sugar beet. On that day, it was raining probably during the ERS-1 observation. After the peak and subsequent dip, a clear increase in backscatter can be noticed. This increase is most likely due to a combined effect of soil moisture and biomass, until complete cover has been reached. Then the backscatter signal saturates and remains on a more or less stable level.

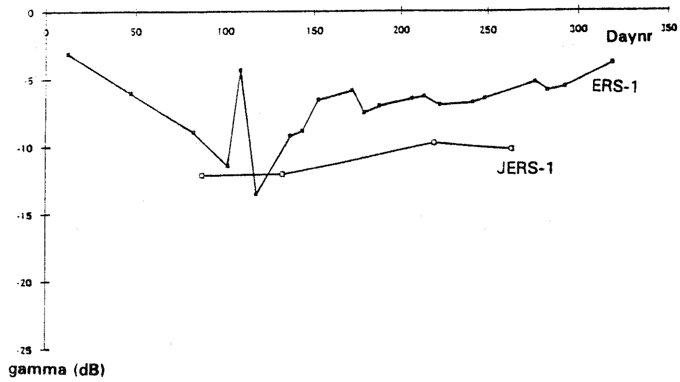

Figure 1. ERS-1 and JERS-1 backscatter signatures of sugar beet for the 1993 growing season.

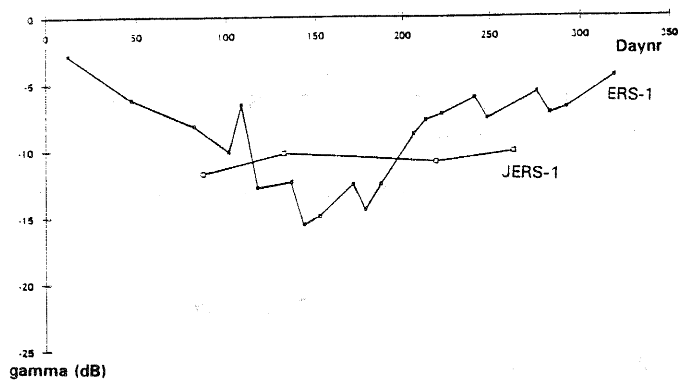

Figure 2. ERS-1 and JERS-1 backscatter signatures of winter wheat for the 1993 growing season.

The crops in the third group show a similar behaviour as well. The vertically oriented crops like winter wheat (figure 2) and barley have a clear dip in backscatter in their curves when the stems are elongating (downwards) and the ears are growing and filling (upwards). It seems that the growth started at the same time (when average temperature is rising) for the three crops, because in the beginning of the growing season the curves look rather similar. The wheat is sown before the winter in 1992 and the small amount of biomass is apparently not affecting the curve compared to the bare soil of the other two crops. A shift between the crops can be noticed during the upward move of backscatter when the crop is maturing, which offers quite good distinction between the crops. From day 130 till 200 about 2-3 dB difference can be noticed between the crops in this group.

3.3 Average backscatter JERS-1

In figures 1 and 2 also the JERS-1 average signatures for sugar beet and winter wheat are shown. It is clear that the dynamic range is in general rather low: much lower as was expected for the L-band in agricultural applications. In the MAC Europe 1991 campaign the dynamic range was about 5 to 10 dB for L-band (van Leeuwen, 1996). These time series have a range of not more than 5 dB. Even the soil backscatter is a bit higher than expected. The backscatter is most likely very close to the noise level of the JERS-1 radar system (about -15 dB). Opposite to the airborne campaigns, the JERS-1 does not show clear backscatter signatures. The contrast in the images is nevertheless rather high, which is important for classification.

In group I, the increase in biomass (and soil moisture) in figure 1 of leafy crops results apparently in an increase in backscatter. This occurred also in the signatures of ERS-1 at the same period (day 130 - day 180) until the signal saturates. For ERS-1, the signal seems to saturate somewhat earlier than for the L-band signature of JERS-1. The increase in backscatter for L-band coincides with the increase of biomass, especially for potato. This is less pronounced for sugar beet.

In group III, the cereals exhibit rather stable signals, around -10 dB. However, maize is rather different from wheat and barley and shows a clear increase of backscatter probably due to the increase of biomass (the voluminous leaves and the elongation of the stems during day 130-180). This increase in backscatter during the same period in the growing season can be noticed for the ERS-1 signature of maize as well.

4. CLASSIFICATION AGRICULTURAL CROPS

4.1 Introduction

For the growing season of 1993 a restricted number of JERS-1 images were available, especially in the beginning and at the end of the growing season. Unfortunately images taken in the middle of the growing season were missing. To investigate the applicability of JERS-1 SAR-images in relation to ERS-1, ERS-1 SAR-images were selected close to the acquisition dates of the available JERS-1 images (table 1).
The JERS-1 image of 28-03-1993 was not used for this experiment. Part of the image shows a clear distortion in radar backscatter making automatic classification methods nearly impossible.

In total 24 different crop types are present in the test site. Several crops are combined to one class. These crops are diverse (horticulture, other) and consist of many small parcels. Crop types used for classification are: potato, sugar beet, winter wheat, grass, maize, rapeseed, barley, fruit, horticulture (mixed), other (mixed), lucerne and bush.

4.2 Classification Method

All image sets were classified with a field-based classification approach (Janssen, 1994). For the JERS-1 data, an average backscatter per field was calculated. A maximum likelihood classification was performed using the average values per field as input. So the classification result contains one class for each field. The ERS-1 data set was classified using the same field-based classification method. Results are compared with the classification results obtained from JERS-1 to investigate the applicability of ERS-1 and JERS-1 data.
Schotten et al. (1995) showed that minimally 25 training fields are needed applying a field-based classification method. As we had only a restricted number of reference fields the whole reference data set was used as training data for 1993. Consequently the validation deals with the available training data. So, a validation with an independent data set could not be performed.

4.3 Classification Results

The classification results as obtained with JERS-1 data are shown in table 2. An overall classification accuracy of 58% (in terms of hectares) is obtained.

Table 2. Field-based classification results (hectares) as obtained with three JERS-1 SAR images or three ERS-1 SAR images during the growing season of 1993.

Crop type	JERS-1		ERS-1	
	acc-%	rel-%	acc-%	rel-%
potato	47	65	82	71
sugar beet	82	85	40	52
winter wheat	58	78	47	67
grassland	15	42	65	82
maize	88	22	65	39
rapeseed	93	99	98	74
barley	80	40	42	37
fruit trees	86	76	51	58
lucerne	91	58	85	77
total	58		60	

acc-% = percentage classification accuracy
rel-% = percentage classification reliability

Classification results for sugar beet, maize, rapeseed, barley, fruit and lucerne are all above 80 % accuracy (area %). Sugar beet and rapeseed also have a reliability above 80 %.
The classification result for grass is very poor. Visual interpretation of the JERS-1 images already indicated the problems with the unambiguous interpretation of grassland.

When comparing the results of a multitemporal (three dates) per field classification based on ERS-1 data with the results for JERS-1 data, varying results were obtained (cf. table 2). Some crops were classified more accurately using JERS-1 data, other crops were classified worse in comparison to the use of ERS-1 data. For instance, grassland and potatoes were classified most accurately using ERS-1 data. On the contrary, sugar beet, maize and barley, for instance, were classified more accurately using JERS-1 data. The difference in overall accuracy between JERS-1 and ERS-1 was only minor. Due to the restricted data set the overall accuracies are low in relation to the results with an optimal data set (about 80% overall classification accuracy).

5. FOREST CLASSIFICATION

5.1 Introduction

For the classification experiment a selection of species from the two forest test sites was made. All species and species varieties listed in table 3 occur at least 5 times, excluding stands with extreme values, i.e. stands for which the stand averaged σ^0 deviated from the species averaged σ^0 more then 2 times the standard deviation of the stand averaged values.

Table 3. Selected classes for classification experiment.

1	*Populus* 'Dorschkamp'
2	*Populus* 'Flevo'
3	*Populus* 'Robusta'
4	*Populus* 'Zeeland'
5	*Populus* 'Oxford'
6	*Acer pseudoplatanus*
7	*Fraxinus excelsior*
8	*Quercus robur*
9	*Pinus sylvestris*

5.2 Classification Method

To assess classification possibilities, temporal signatures were visualized to get an impression of class separability. Subsequently, a maximum likelihood classification was made using Bayes criterion. Both approaches were applied on the ERS-1 and the JERS-1 data sets separately.

5.3 Classification Results

The temporal signatures of the selected classes are shown in figure 3 for the ERS-1 images. In February all poplar classes are clearly differentiated from the other tree species. This may be a result of the relatively large trunk size, the relatively high soil moisture content at that date and the absence of leaves and undergrowth. In March the soil is drier and the contrasts are lower. In April leaves start to develop and contrasts start to change. Especially in May the contrast between classes is large and three groups of classes can be differentiated. In August the contrasts decrease again. It appears to be impossible to properly differentiate coniferous (*Pinus sylvestris*) from the deciduous species.

A maximum likelihood classification using four ERS-1 images resulted into an overall classification accuracy of 65%.

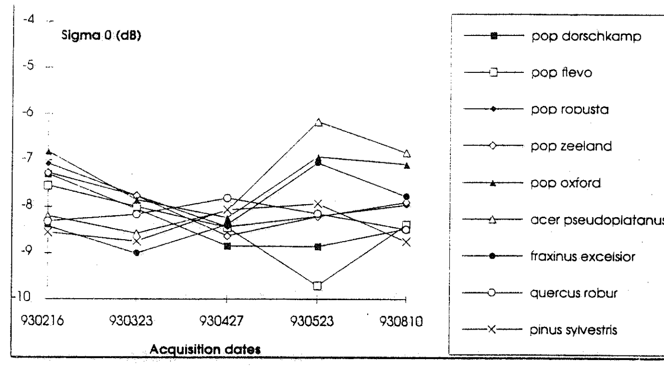

Figure 3. Class averaged backscatter as a function of time for ERS-1.

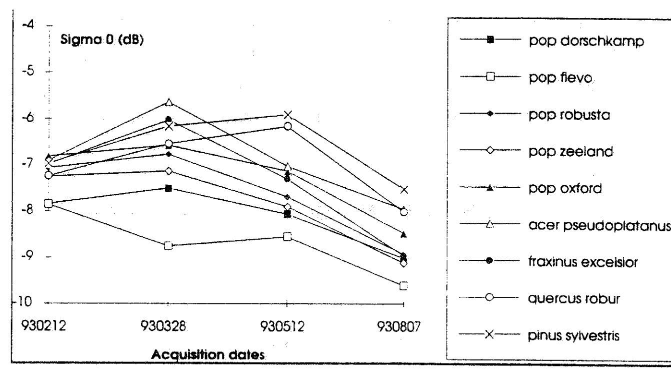

Figure 4. Class averaged backscatter as a function of time for JERS-1.

The temporal signatures for JERS-1 are shown in figure 4. Though the wavelength is longer the backscatter level is comparable or even slightly higher. This behaviour may be caused by the fact that the longer wavelength radiation penetrates deeper into the canopy and is reflected by larger canopy components, i.e. by large branches and through the trunk-ground interaction, rather than by leaves and twigs as may be the case for the C-band. In the winter observations *Populus* 'Flevo' and *Populus* 'Dorschkamp' show a relatively low backscatter level. These may be caused by the low trunk density of these stands and/or the non-vertical orientation of the trunks. The latter is caused by dominant wind and theoretically results in a lower

contribution from the trunk-ground interaction. In contrast to ERS-1, backscatter levels, in general, increase between February and March and show a gradual decrease when leaves develop. The latter may indicate that contributions from bigger branches are attenuated by the leaf layer, while the leaves themselves give a relatively low return. The patterns for *Pinus sylvestris* and *Quercus robur* are different, which, following the same line of reasoning, is logical because *Pinus* keeps its needles during winter and *Quercus* starts developing leaves after the May observation, in contrast to the other deciduous species present here. The drop in the signature of Pinus in August may be explained by the increase of undergrowth, and, consequently, reduced trunk-ground interaction. In summer it may be well possible to distinguish between coniferous and deciduous tree species in L-band.
A maximum likelihood classification using four JERS-1 SAR images resulted into an overall classification accuracy of 72%.

6. CONCLUSIONS

As the contrast of the JERS-1 images appeared to be rather well when compared with the ERS-1 images visually, classification for agricultural crops was expected to give good results. However, the dynamic range of the JERS-1 time series during the growing season was not as large as found before for L-band in other campaigns. The backscatter signatures of JERS-1 during the growing season were difficult to compare with those of ERS-1 during the growing season. For the leafy crops such as potato or sugar beet, there were some similarities in backscatter behaviour.

When comparing the results of a multitemporal (three dates) per field classification based on ERS-1 data with the results for JERS-1 data, varying results were obtained. For instance, grassland and potatoes were classified most accurately using ERS-1 data. On the contrary, sugar beet, maize and barley, for instance, were classified more accurately using JERS-1 data. With an optimal multi-temporal data set agricultural crops can be classified with an overall accuracy of 80% using ERS-1 SAR data. Although in this experiment we had only a restricted number of JERS-1 and ERS-1 images for the growing season of 1993, several crops could be classified with an accuracy of more than 80%.

Results showed that JERS-1 is better suited to discriminate forest species than ERS-1. A multi-temporal approach, i.e. at least one observation in winter and one in summer/spring, is recommended. A visual interpretation of images revealed that the discrimination between deciduous and coniferous species is well possible with a single L-band summer image. In winter this is not possible and in C-band it is not possible at all. These results are in agreement with results of previous studies for this test area.

ACKNOWLEDGEMENTS

This report describes a study that was carried out in the framework of the NRSP-2 under responsibility of the Netherlands Remote Sensing Board (BCRS). NASDA is acknowledged for providing JERS-1 SAR images and ESA is acknowledged for providing ERS-1 SAR images and for financing the ground truth collection. Martin Vissers is acknowledged for doing the field work and the preprocessing of all the radar images.
This study was performed partly in parallel to ESA-ESTEC study contract no.1154/94/NL/NB(SC), which was managed by Synoptics.

REFERENCES

Janssen L.L.F. 1994. Methodology for updating terrain object data from remote sensing data. PhD thesis, Wageningen Agricultural University, the Netherlands, 173 pp.

Kleijweg, J.C.M & J.S. Groot, 1995. JERS-1 Calibration. Physics and Electronics Laboratory TNO-FEL, The Hague.

Laur, H., 1992. ERS-1 SAR calibration; derivation of backscattering coefficient σ^0 in ERS-1 SAR PRI products. ESA, ESRIN, 16 pp.

Leeuwen, H.J.C. van, 1996. Methodology for combining optical and microwave remote sensing in agricultural crop monitoring. PhD thesis, Wageningen Agricultural University, the Netherlands, 233 pp.

Linden, M. van der, 1995. Monitoring van bossen met ERS-1 en de JPL/AIRSAR. MSc Thesis, Wageningen Agricultural University, Dept. of Water Resources.

Nieuwenhuis, G.J.A. & W.W.L. van Rooij (eds), 1994. Application of ERS-1 SAR data in agriculture and forestry. Report 101, SC-DLO, Wageningen, the Netherlands, 182 pp.

Schotten, C.G.J., W.W.L. van Rooij & L.L.F. Janssen, 1995. Assessment of the capabilities of multi-temporal ERS-1 SAR data to discriminate between agricultural crops. Int. J. Remote Sensing, vol. 16, no. 14, 2619-2637.

Vissers, M.A.M., 1994. ERS-1 / JERS-1 Ground truth data collection in Flevoland (NL) 1993. Wageningen Radar Surveys, Wageningen, The Netherlands, 44 pages & 3 appendices.