Reply | To All | Include text | Forward | Save | to reserve | Take | Delete | Undelete | [redacted]

Last of 38 messages (New)

Date: Wed, 4 Mar 2009 08:39:16 -0800
From: UW ILL Main <interlib@u.washington.edu>
To: englib@u.washington.edu
Subject: Pull and Scan from UW ILL Main - 458230

Article

Call Number: Canadian journal of remote sensing v.27
Branch Location: Engr Periodicals-Floor 2

Canadian Journal of Remote Sensing
v.27 no.6 p.679-685 2001

Author: Presutti et al.
Article: Supervised
classification of multisource spectral and texture data for agricultural crop mapping in Buenos Aires Province, Argentina

Need by: 01/01/2010

===

Ship via: Scan via ILLiad

Ship to: Ludmila Monika Moskal

Box 352100

Seattle, WA 98195

Email: lmmoskal@u.washington.edu
Fax/Ariel: Phone: 2062216391

User Name: lmmoskal
Status: Faculty - Forestry (all programs) / Seattle
Max Cost: Free / UW: ILL - UW

Ref No:
UW-ILL #: 458230

Interlibrary Loan
University of Washington Libraries
Box 352900
Seattle, WA 98195-2900

FAX: (206) 685-8049
Phone: (206) 543-1878
(800) 324-5351
OCLC=WAU

Email: interlib@u.washington.edu

Interlibrary Loan
Univ of Washington Libraries
Box 352900
Seattle, WA 98195-2900

(206) 543-1878 / (800) 324-5351
interlib@u.washington.edu
www.lib.washington.edu/ill
Fax: (206) 685-8049

CANADIAN JOURNAL OF REMOTE SENSING / JOURNAL CANADIEN DE TÉLÉDÉTECTION

CONTENTS / TABLE DES MATIÈRES

Publication of the Canadian Journal of Remote Sensing is made possible by a grant from **Geomatics Canada**.

❖

La publication du Journal canadien de télédétection est possible grâce à une subvention de **Géomatique Canada**.

CANADIAN JOURNAL OF REMOTE SENSING/JOURNAL CANADIEN DE TÉLÉDÉTECTION

Published six times per year, the *Canadian Journal of Remote Sensing* is the official journal of the Canadian Remote Sensing Society, a constituent society of the Canadian Aeronautics and Space Institute. The *Canadian Journal of Remote Sensing* is the official Science Journal of the Alliance for Marine Remote Sensing Association. The Editorial Board invites the submission of new and unpublished papers, research notes, and technical notes for publication in the Journal. Topics – including data acquisition, information processing methods, and applications development – may address technical topics of interest to the Canadian and international remote sensing communities. The Editorial Board examines all submitted papers before acceptance for publication.

Submission of Manuscripts
The initial manuscript submission may be made with paper copies or by electronic means, such as e-mail or password protected server download. The format should follow the style notes shown herein see Inside Back Cover, or our Website, at www.casi.ca/canadian . Detailed instructions on the preparation of manuscripts may be obtained upon request. Electronic submission is encouraged, particularly for Research Notes. We prefer Word, WordPerfect, or Portable Document Format (PDF) files. Figures should be embedded for the initial submission **only**. Please try to keep the document file as small as possible (< 1Mbytes, ideally) to facilitate straightforward distribution via e-mail. For paper submissions, four copies of the manuscript are required. Each copy should include figures of adequate quality for completion of the peer review process.

Page Charges
The organization sponsoring the work reported in any paper or article published will be asked to pay publication charges of $90 per page and $125 per colour separation. When page charges are covered by a purchase order or paid within 90 days of publication, 100 copies will be supplied free of charge.

Annual subscription $150.00 (NAFTA), $165.00 (elsewhere), single copies $30.00 (NAFTA), $35.00 (elsewhere). Price includes postage by surface mail. Special rates will be quoted when airmail is requested. The Society is not responsible for statements or opinions expressed in papers or discussions printed in its publication. All communications should be addressed to: General Manager, Canadian Aeronautics and Space Institute, 130 Slater Street, Suite 618, Ottawa, Ontario Canada KIP 6E2. Telephone (613) 234-0191; fax (613) 234-9039. E-mail: casi@casi.ca.

Typesetting and layout by James Fridrich.

Printed by Custom Printers, Pembroke, Ontario, Canada

Publications Mail Registration No. 173045

Perodicals postage paid at Champlain, N.Y. and additional mailing offices. Address changes should be sent to:
IMS of N.Y., 100 Walnut St. #2, P.O. Box 1518, Champlain N.Y. 12919-1518. For details call: IMS at 1(800) 428-3003.

Publié six fois par année, le Journal canadien de télédétection est la publication officielle de la Société canadienne de télédétection, société constituante de l'Institut aéronautique et spatial du Canada. Le Journal canadien de télédétection est aussi le journal officiel de l'Association pour l'Alliance de télédétection marine. Le Conseil éditorial sollicite des contributions nouvelles, non-publiées ailleurs, sous forme d'articles de recherche, de notes de recherche, et d'articles de synthèse techniques, pour le Journal. Les sujets doivent intéresser les communautés de télédétection canadienne et internationale, tel que l'acquisition des données, les méthodes de traitement des données, et le développement des applications. Toute soumission doit être acceptée par le Conseil éditorial avant de passer à la publication.

Soumission des manuscrits
La soumission initiale de manuscrit peut être en forme copie papier ou par des moyens électroniques, tels que le courriel ou le téléchargement de serveur protégé par mot de passe. Le format devrait suivre les indications dans ce journal - voir la couverture de dos intérieure, ou consultez notre site web, au www.casi.ca/canadian). Des instructions détaillées sur la préparation des manuscrits peuvent être obtenues sur demande. La soumission électronique est encouragée, en particulier pour les Notes de recherche. Nous préférons le format WORD, WordPerfect, ou les fichiers portatifs de documents (pdf). Les figures peuvent être incorporées au sein du texte pour une soumission initiale seulement. Autant que possible, veuillez assurer que le document est gérable (< 1Mbytes, idéalement) pour faciliter la distribution par l'intermédiaire par courriel. Pour les soumissions de papier, quatre copies du manuscrit sont exigées. Chaque copie devrait inclure des figures de qualité adéquate pour l'accomplissement du processus d'examen par les pairs.

Frais de publication
Des frais de publication de 90 $ par page et de 125 $ par séparation de couleurs seront demandés à l'organisme parrainant le travail décrit dans toute communication ou article publié. Lorsque les frais de publication sont couverts par un bon de commande ou sont payés dans les 90 jours suivant la publication, 100 copies seront fournies sans frais supplémentaires.

L'abonnement annuel est de 150 $ (NAFTA), 165 $ (partout ailleurs). Le prix d'un exemplaire est de 30 $ (NAFTA) et de 35 $ (partout ailleurs). Ces prix comprennent les frais postaux (courrier de surface). On peut obtenir sur demande les tarifs pour l'envoi par courrier aérien. La Société n'est pas responsable des déclarations ou des opinions exprimées dans les articles ou des discussions publiées dans le Journal. Toutes les communications doivent être adressées au Directeur général, Institut aéronautique et spatial du Canada, 130, rue Slater, local 618, Ottawa (Ontario) Canada K1P 6E2. Téléphone (613) 234-0191; télécopieur (613) 234-9039. Courrier électronique: casi@casi.ca.

Composition et mise en page par James Fridrich.

Imprimé par Custom Printers, Pembroke (Ontario) Canada

N° d'enregistrement postal : 173045

I.V., and de
AT-1 Images
Journal of

LANDSAT
da Província
University of

J.O., Santos,
977). Projeto
8.

Filtering on
note Sensing,

Geophysics:
rth Decennial
, pp. 13-30.

, V. (1994).
Deformation
R", Canadian

zil", Mission
evelopment in

the Selection
ns", Canadian

K. (1989). "A
on: Tectonic

Research Note • Note de recherche

Supervised Classification of Multisource Satellite Image Spectral and Texture Data for Agricultural Crop Mapping in Buenos Aires Province, Argentina

by M.E. Presutti • S.E. Franklin • L.M. Moskal • E.E. Dickson

RÉSUMÉ

Nous avons développé et testé une méthodologie opérationnelle pour la cartographie des cultures à partir de la classification des données spectrales et texturales RADARSAT et Landsat TM dans le sud-est de la province de Buenos Aires, en Argentine. Les principales cultures visées étaient le blé (en hiver) et le maïs, le tournesol et les pommes de terre (en été). Ces cultures sont en rotation avec les pâturages pour le bétail tous les 4-5 ans, créant ainsi une importante hétérogénéité spatiale dans les caractéristiques d'utilisation du sol et du couvert. Nous avons utilisé des données RADARSAT (SGF W2 ascendantes, 10 juillet et 7 novembre 1997) et des valeurs texturales dérivées obtenues des matrices de co-occurrence en combinaison avec des données optiques satellitales (Landsat TM - bandes 3, 4 et 5, 27 novembre 1997). Des méthodes standard de géorectification ont été utilisées pour le calcul de la rétrodiffusion et de la texture. Les sites d'entraînement et les sites tests ont été sélectionnés à partir des relevés de terrain et une classification dirigée a été réalisée à l'aide d'une règle de décision basée sur le maximum de vraisemblance. Les résultats de la cartographie indiquent que les données de teinte et de texture de RADARSAT donnent des résultats de classification supérieurs (amélioration d'environ 10%) comparativement à l'utilisation seule des données TM dans la règle de décision. La précision globale de classification était environ 62% correcte (à un intervalle de confiance de 95% = 57.8% - 66.5%). La classe "blé" était la plus intéressante car elle s'est avérée approximativement 81% correcte.

SUMMARY

We developed and tested an operational methodology to map agricultural crops from the classification of RADARSAT and Landsat TM spectral and texture data in southeast Buenos Aires Province, Argentina. The main crops of interest were wheat (in winter) and corn, sunflower and potato (in summer). The crops rotate with pasture for livestock every 4-5 years, creating a high spatial heterogeneity in the land use and land cover characteristics. We used RADARSAT data (SGF W2 Ascending, 10 July and 7 November 1997) and textural derivatives obtained from co-occurrence matrices in combination with optical satellite data (Landsat TM - bands 3, 4 and 5, 27 November 1997). Standard methods for georectification, backscatter calculation and texture calculation were employed. Training and test areas were selected based on field surveys, and a supervised classification was performed using the maximum likelihood decision rule. The mapping results indicate that RADARSAT tone and texture data provide a superior classification result (approximately 10% better) when compared to the use of Landsat TM data alone in the decision rule. The overall classification accuracy was approximately 62% correct (95% Confidence Interval = 57.8% - 66.5%). Of principal interest was the wheat class, which was determined to be approximately 81% correct.

INTRODUCTION

Crop identification and crop acreage estimation as early as possible during the agricultural season is an important component of satellite remote sensing programs supporting agricultural policies. Several studies have investigated the interaction of microwave and optical electromagnetic energy to extract crop and forest assessment information (Brown *et al.*, 1993; Lozano-Garcia and Hoffer, 1993; Hochheim and Barber, 1998; Wang and Shang, 1998). Some general conclusions have been reached that have implications for operational vegetation mapping applications based on, or which require information from, satellite SAR imagery such as that available from Canada's RADARSAT system:

1) SAR data when combined with other data provide higher classification accuracies (Shimabukro *et al.*, 1997);
2) Texture data extracted from the SAR image can be used to improve classification accuracy (Wilson, 1996); and
3) Multitemporal SAR imagery is more powerful in discrimination of certain vegetation classes than single date imagery (Kasischke *et al.*, 1995; McNairn *et al.*, 1998).

Also, generally, it has been suggested that the smaller incidence angles are preferred for vegetation mapping applications, as the contribution to the total measured radar backscatter from vegetation and soil roughness is less at these angles (Brown *et al.*, 1993). This implies that Standard Mode beams 1 and 2 are the preferred RADARSAT configuration for agricultural classification, although the Wide Mode may be used for regional mapping applications.

Manuscript received: July 17, 2000 / Revised: June 4, 2001.

• M.E. Presutti is with the Universidad Nacional de La Plata - Ministerio de Agricultura, Ganadería y Alimentación, 60 y 118 (1900) La Plata, Argentina.

• S.E. Franklin and E.E. Dickson are with the University of Calgary, 2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4, E-mail: franklin@ucalgary.ca.

• L.M. Moskal is with the University of Kansas, Kansas Applied Remote Sensing Program (KARS), Nichols Hall, 2335 Irving Hill Rd., Lawrence, KS, USA, 66045-7612.

Presutti *et al.* (2000) provided a test of some of these ideas in training areas using discriminant analysis in a study area in Argentina. For example, the discrimination of 19 landcover classes using single-date RADARSAT imagery improved marginally when augmented with Landsat TM imagery, and improved still further when multidate RADARSAT imagery and texture derivatives were added to the discriminant function. The best discrimination achieved was 90% based on several hundred pixels in a few well-surveyed training areas. The best discriminant function was built with multi-date RADARSAT, TM and texture variables. The 10% misclassified pixels were easily explained by considering spectral overlap in the 19-class scheme. Forest classes were confused with other forest classes; agricultural classes were confused with other agricultural classes; urban classes were confused with other urban classes. Texture improved forest classes by 25%, urban classes by 12%, and agricultural classes by 7%. Row crops, such as potatoes and corn, increased in accuracy by 25%. On average, texture increased discrimination by 10% over that which could be obtained using spectral data alone.

These discriminant results provided some encouragement that an operational classification procedure that includes RADARSAT imagery, TM imagery, and texture derivatives could be developed in this Argentine agricultural application. However, good discrimination in selected training areas does not automatically suggest that high levels of classification and mapping accuracy can be achieved in broader, spatially-heterogeneous areas. Instead, mapping procedures must be tested that include analysis of independent test sites. This is the focus of the present study: *to operationalize the discriminant results of Presutti et al. (2000) in a supervised classification of agricultural, urban, and forest landcover classes using RADARSAT and Landsat TM data in a large study area in the pampas region of Argentina.* In this paper, the focus is on the general quality of the map and the improvements in the overall classification accuracy, and specific improvements in classification accuracy in the agricultural wheat class, when the RADARSAT tone, texture and Landsat TM data were used together.

Study Area and Data Description

The location of the study (38° 06′ to 38° 54′ LS and 58° 30′ to 59° 20′ LW) was in the southeastern area of Buenos Aires province, Argentina, north of, and including, the coastal city of Necochea (**Figure 1**). The Buenos Aires province comprises a wide, flat plain broken only by the presence of two hilly ridges in the centre and south-centre of the province. The Quequen River flows through the study region into the Atlantic Ocean near the towns of Necochea and Quequen. A moderate temperature predominates with an annual rainfall of aproximately 1000 mm. Traditionally, the major economic activities in the region include the production of livestock, grain and other agricultural products. The main crops are sunflower, corn and potato in summer, and wheat in winter. In this area, there are three dates for seeding wheat: March/April for the "long cycle", June/July for "intermediate cycle" and August for the "short cycle". The largest area is seeded with the intermediate cycle, approximately 180-150 days from seed to harvest. The harvest takes place in December for all three crops. For summer crops, the soil preparation for seeding is in October, and the harvest is in February/March. More recently, tree plantations have been established that have proven to be profitable. The major species introduced include *Eucalyptus globulus* and *Pinus radiata*, planted for the production of fiber and wood respectively.

Figure 1.
Location of the study area in southeast Buenos Aires Province, Argentina.

RADARSAT data (SGF W2 Ascending, 10 July and 7 November 1997) and optical data (Landsat TM - Bands 3, 4 and 5, 27 November 1997 shown in **Figure 2**) were acquired. Ground data were collected for agricultural fields; these data included observations and ground photographs of crop species, row direction, percentage cover, plant condition, soil roughness, for both dates in July and November. Since the radar images were collected on 10 July (winter) and 7 November 97 (spring), we expected to predict seeding for winter crops. With the second image, we expected to calculate the real area planted with this crop, and the intention of seeding for summer crops.

es Province,

seeded with
days from
mber for all
paration for
uary/March.
blished that
introduced
planted for

July and 7
ands 3, 4 and
re acquired.
; these data
crop species,
il roughness,
radar images
97 (spring),
th the second
ted with this
s.

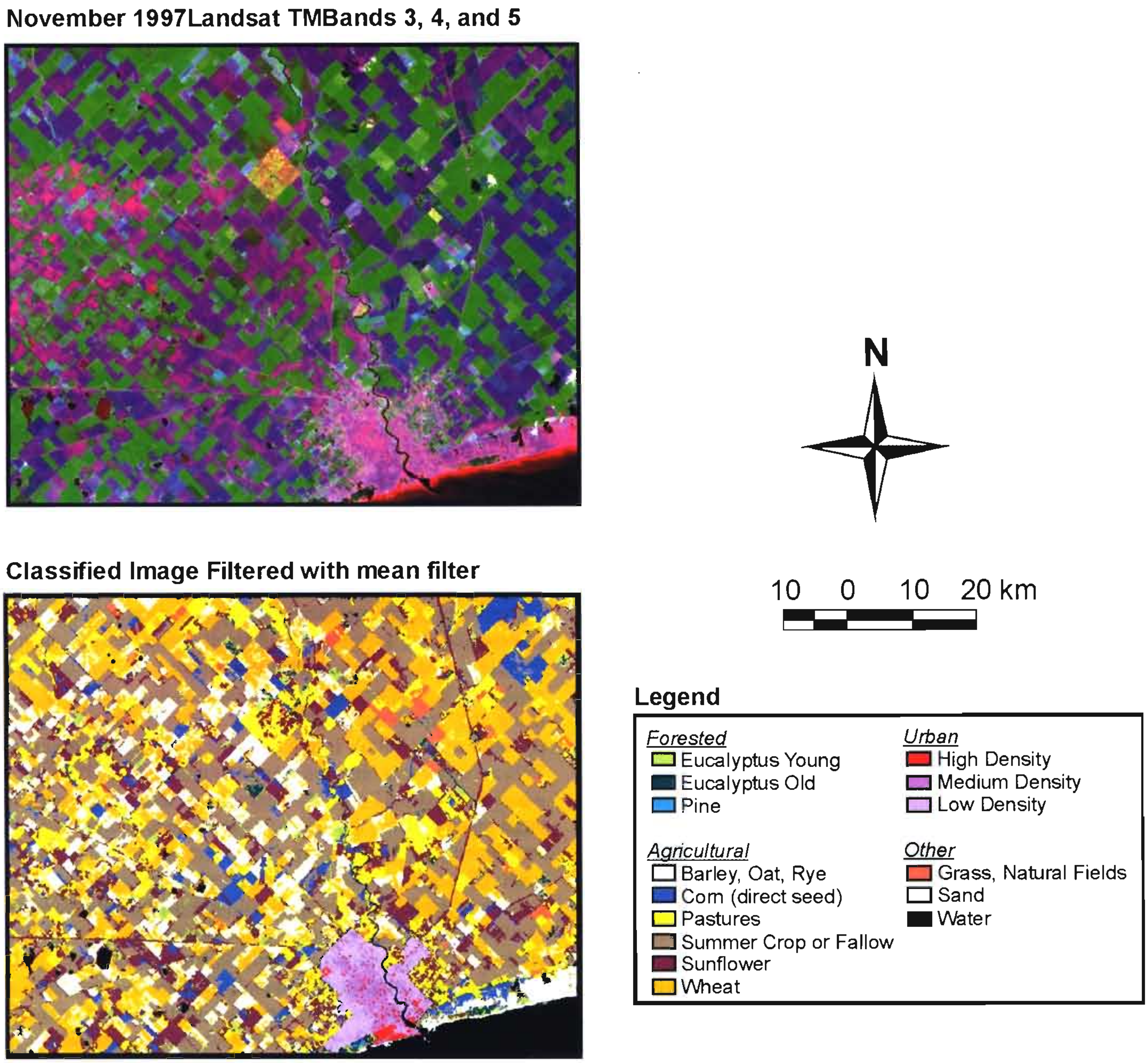

Figure 2.
The final classification map showing the distribution of 15 classes as indicated in the map legend (three forest classes, six agricultural classes, three urban classes, and three other classes); mapping variables included Landsat TM (shown above), two RADARSAT image dates, and RADARSAT texture variables. Final map accuracy was determined to be approximately 62% correct overall (kappa coefficient = 0.56).

METHODS

The methods in this study included:

1) preprocessing of the imagery,
2) extraction of mapping variables (such as texture) from the data, and
3) the generation of a map using a supervised classification approach.

Image Preprocessing

The calculation of SAR backscatter was performed using the PCI EASI/PACE Program and standard coefficients supplied with the RADARSAT imagery. This calibrated SAR image, in 32-bits, was geometrically corrected to the Universal Transverse Mercator, Gauss Krugger Projection, with a 15-metre pixel resolution using a second-order polynomial and nearest-neighbour resampling. Less than one pixel RMS error was obtained in the geometrical transformation. The second RADARSAT SAR image and the available Landsat TM image were co-registered to the first radar image, again with less than one pixel RMS error. We retained the pixel size of the first radar image in these resampling procedures. The resampled RADARSAT data were linear scaled to 8 bits from 32 bits and a median filter (5x5) was applied to reduce speckle. No atmospheric or radiometric processing of the TM image was conducted; after inspection of the high quality of the imagery and the large dark object in the scene (the Atlantic Ocean), it was thought that such corrections were unnecessary.

Texture Analysis

Texture variables were calculated for the two RADARSAT images using spatial co-occurrence (Haralick *et al.*, 1973; Franklin and Peddle, 1987) with three windows sizes: 3x3, 5x5 and 9x9. We used an invariant direction for the texture algorithm provided within PCI EASI/PACE software package, and extracted a number of texture variables (*e.g.*, homogeneity, contrast, dissimilarity, entropy, angular second moment). We used an *ad hoc* 'band-selection' procedure based on inter-texture correlations to select the ten best texture variables because of a restriction in PCI to generate signatures using no more than 16 bands. The texture bands were retained in 32-bit format even though Ban *et al.* (1995) have suggested that reasonable classification accuracy results can be obtained using 8-bit and 16-bit SAR texture data for crop discrimination.

Supervised Classification

Training data were developed following extensive field visits in the previous four years by Argentine soil scientists and agronomists. These training areas were augmented with image patterns that could be interpreted on the image displays and understood relative to aerial photos, existing maps, and field photographs available during the image analysis work. In order to compare the improvement in classification accuracy possible with the various data combinations, several classification runs were executed with different combinations of mapping variables. The combination with the highest classification accuracy in the training data set was selected for further work to produce the final map. Accuracy assessment of this final map was performed using 500 pixels for which collected and verified field data were available but not used in training. Small classification polygons were removed from the classification map with the aid of a modal filter. This filter merged image polygons smaller than a user-specified threshold with the largest neighbouring polygon. A polygon of 60-pixels size was used based on the approximate mean sizes of the agricultural fields of interest in the study.

Results

The overall classification accuracy in independent test areas using different mapping variable combinations confirmed the trends in the earlier discriminant tests (Presutti *et al.*, 2000) and are not repeated in detail here; in essence, the use of TM data alone provided a superior classification accuracy compared to the use of RADARSAT data alone (either single-date or multidate); the use of texture improved the RADARSAT classification marginally; and the addition of RADARSAT data and texture to the Landsat TM data improved the overall classification accuracy considerably (up to 10% over all the classes). Based on these findings with independent test pixels and the earlier training data tests, a supervised classification approach using the two RADARSAT images, the Landsat TM data, and texture variables was clearly the optimal combination to produce a map of the study area.

The final map generated in this study is reproduced in **Figure 2**. Overall classification accuracy obtained when the 500 pixels were tested against the field observations was 62.2% (kappa coefficient = 0.56) (95% Confidence Interval = 57.8% - 66.5%). The spatial arrangement and distribution of classes appeared very realistic in this map, based on the expert knowledge of the study area and the predicted occurrence of different crop types based on seeding and rotation patterns known to have taken place in 1997. In essence, the map appeared to be a reasonable and realistic generalization of the agricultural, forest and other classes in the area.

The agricultural class "wheat" was of principal interest in this study since this crop covered the largest area of the study region and also because the different planting times and rotations represented one of the more difficult classes in the mapping exercise. The earlier discrimination results for this class suggested a significantly higher classification accuracy when using the combined RADARSAT and TM optical data set (Presutti *et al.*, 2000). In the mapping exercise, approximately 77% accuracy was obtained when using Landsat TM data alone; when RADARSAT and the texture variables were added to these optical data, the accuracy increased to 80.6% (kappa coefficient = 0.75). These results are very good; a map with this level of accuracy for this important crop type would be extremely useful in an operational crop identification program in which the goal is to estimate the area cultivated with different crops. However, the approximately 4% increase in classification accuracy attributable to the use of RADARSAT data may not represent a significant difference such that the additional effort required to incorporate these data is completely justified.

We originally based the list of classes on the different types of vegetation present in the study area during spring (November). In the case of wheat, this means that in November, wheat was growing to about one metre in height (ear state), but in July the same plots were recently seeded or presented only bare soil. This is thought to be the main reason for continued misclassification when the two RADARSAT images were used. The major confusion appeared to exist between the classes "Fallow" and "Wheat". When only Landsat optical data were used, the major confusion was between the classes "Pasture" and "Wheat" because these crops were at a similar growing stage in spring. In general, the pasture class was mostly comprised of cereals such as oats, barley or rye; very similar to wheat in aspect.

Table 1.
Map accuracy assessment of the agricultural classes of interest using a sample of independent pixel test areas (overall accuracy = 62.2%, 95% Confidence interval = 57.8% - 66.5%), overall Kappa statistic = 0.56%).

Class name	Producer's accuracy	95% Confidence interval	User's accuracy	95% Confidence interval	Kappa statistic
Wheat	68.1%	(59.1% 77.0%)	80.6%	(72.2% 88.9%)	0.74
Plowed	70.5%	(61.9% 79.1%)	87.5%	(80.3% 94.6%)	0.83
Corn	68.7%	(54.5% 82.9%)	71.7%	(57.6% 85.8%)	0.68
Pasture	65.8%	(54.7% 76.9%)	53.6%	(43.1% 64.0%)	0.44
Sunflower	55.5%	(29.8% 81.2%)	50.0%	(25.5% 74.4%)	0.48

In this study, phenology and soil conditions may account for differences in the ability of the RADARSAT data acquired in winter and summer to separate certain crop classes. During November when the plants were recently seeded and young vegetation was actively growing, pixels of corn and potato could not be distinguished from the pixels of exposed soil and fallow fields. Recently seeded plants were small, surrounded by soil on all sides. During July, most of the agricultural crop fields in the study region were fallow. Therefore, it seems reasonable to suggest that the variations in soil characteristics (moisture content, mineral content, texture), rather than the variations in crop type, were detectable by RADARSAT data in the July agricultural fields. In July, potato fields were confused with corn (conventional), open soil, and fallow field classes because potato plants were not growing at this time.

Conclusions

An earlier study of training area classification accuracy in a large heterogeneous area of the Pampas region of Argentina (Presutti *et al.*, 2000) suggested the potential utility of combining Landsat and RADARSAT spectral and texture data in landcover classification in a mapping exercise. In this follow-on study, we created the classification map using the best available combination of mapping variables. A supervised classification method using two RADARSAT images, texture derivatives in small but variable windows, and a Landsat TM image, provided a classification accuracy of approximately 62% (kappa coefficient = 0.56, 95% Confidence Interval = 57.8% - 66.5%) in 15 classes that were of interest for operational mapping of crop types and other landcover categories.

The mapping results indicated that RADARSAT tone and texture data in combination with Landsat TM data provided a superior classification result (approximately 10% better) when compared to the use of Landsat TM data alone in the decision rule. Specific classes of interest, such as wheat, were mapped more accurately than others, such as sunflowers and corn; area estimates of crops could be produced operationally based on this map. The overall classification accuracy for the wheat class reached 80.6% (kappa coefficient = 0.75); this represented an approximately 4% increase over the mapping results available from a Landsat TM image alone. The optical image used did not appear to have significant atmospheric or radiometric problems, but usually this region of Argentina is cloudy in spring and early summer when early assessment of crop area is required. The user must take into account that this operational mapping procedure using RADARSAT and Landsat data implies a higher cost, since it was obtained using more images. Perhaps the best use for RADARSAT data in this region is restricted to those occasions when it is impossible to acquire an ideal, cloud-free optical satellite image.

Acknowledgements

Financial support for this study was provided by the GlobeSAR-2 Project funded by CIDA and CCRS through the University Exchange Program (University of Calgary and Universidad Nacional de La Plata). We also thank CONAE (Comisión Nacional de Actividades Espaciales, Argentina) for providing the Landsat TM image; and to the Ministerio de Agricultura, Ganadería y Alimentación, Buenos Aires Province, for permission to use the image processing system. We thank Ing. Adriana Lombardo, Ing. Jose Garces and Mr. Rafael for their help in the field.

References

Ban, Y., Treitz, P.M., Howarth, P.J., Brisco, B., and Brown, R.J. (1995). "Improving the Accuracy of Synthetic Aperture Radar Analysis for Agricultural Crop Classification", *Canadian Journal of Remote Sensing,* Vol. 21, No. 2, pp. 158-164.

Brown R.J., Brisco B., Leconte R., Major D.J., Fischer J.A, Reinchert G., Korporal K.D, Bullock P.R., Pokrant H., Culley J. (1993). "Potential Applications of RADARSAT Data to Agriculture and Hydrology", *Canadian Journal of Remote Sensing*, Vol. 19, No. 4, pp. 317- 327.

Franklin, S.E., and Peddle, D. (1987). "Texture Analysis of Digital Image Data Using Spatial Co-Occurrence", *Computers & Geosciences* , Vol. 13, No. 3. pp. 293-311.

Haralick, R.M., Shanmugam, K., and Dinstein, I. (1973). "Texture Features for Image Classification", *IEEE Transactions on Systems. Man, and Cybernetics,* Vol. 3, pp. 610-621.

Hochheim, K., and Barber, D. (1998). "Integration of SAR and Optical Wavelength Data for Crop Yield Estimation", *ADRO Technical Volume: Agricultural Application.* CD-ROM.

Jensen, J.R. (1996). *Introductory Digital Image Processing. A Remote Sensing Perspective,* Second Edition, Prentice-Hall, New Jersey.

Kasischke, E.S., Morrissey, L., Way, J., French, N.H.F., Bourgeau-Chavez, L.L., Rignot, E., Stearn, J.A., Livingston, G.P. (1995). "Monitoring Seasonal Variations in Boreal Ecosystems Using Multi-Temporal Spaceborne SAR Data", *Canadian Journal of Remote Sensing*, Vol. 21, No. 2, pp. 96-109.

Lozano-Garcia D.F., and Hoffer, R.M. (1993). "Synergistic Effects of Combined Landsat TM and SIR-B Data for Forest Resources Assessment", *International Journal of Remote Sensing,* Vol, 14, No. 14, pp. 2677-2694.

McNairn, H., Wood, D., Gwyn, Q.H.J., Brown, R.J., and Charbonneau, F. (1998). "Mapping Tillage and Crop Residue Management Practices with RADARSAT", *Canadian Journal of Remote Sensing*, Vol. 24, No. 1, pp. 28-35.

Presutti, M.E., Moskal, L.M., Dickson, E.E., and Franklin, S.E. (2000). "Forestry and Agricultural Land Cover Classification Using RADARSAT and Landsat TM in SE Buenos Aires Province, Argentina", *Proceedings, 22nd Canadian Symposium on Remote Sensing.* Victoria, BC, pp. 715-726.

Shimabukro, Y.E., Amaral, S., Ahern, F.J., and Pietsch, R.W. (1997). "Classification and Monitoring the Tapajos National Forest Region Using SAR (RADARSAT – Standard Mode and SAREX – Wide Swath Mode) and Landsat Thematic Mapper Data", *Proceedings, GER'97 Conference,* Ottawa, Ontario, pp. 103-115.

Wang J., and Shang, J. (1998). "Evaluation of Multidate ERS-1 and Multispectral Landsat Imagery for Wetland Detection in Southern Ontario", *Canadian Journal of Remote Sensing*, Vol. 24, No. 1, pp. 60-68.

Wilson, B.A. (1996). "Estimating Coniferous Forest Structure Using SAR Texture and Tone", *Canadian Journal of Remote Sensing*, Vol. 22, No. 4, pp. 382-389.