Early results from crop studies using IRS-1C data

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The data acquired by WiFS and LISS-III cameras onboard IRS-1C during the first month of their operation have been investigated for various applications related to study of crops. WiFS data over Andhra Pradesh and Punjab have been used for state-level major crop inventory and estimating total cropped area in rabi season respectively. Multi-date WiFS data over West Bengal have been used to identify spectral changes associated with crop phenology. The LISS-III data over a wheat- and mustard-growing site in Pali district (Rajasthan) have indicated increase in crop separability with inclusion of middle infrared (MIR) channel.

THE applications of remote sensing data in the field of agriculture and crop studies in India from LISS-I and LISS-II onboard IRS-1A/1B/P2, MSS and TM on Landsat series and AVHRR on NOAA series in India cover as large canvas as the activities of agriculture[1]. Some of these are crop production forecasting[2] covering both crop inventory and crop yield forecast models, drought assessment[3], soil mapping and soil degradation[4], command area monitoring, flood damage assessment, etc.

The sensor package onboard IRS-1C includes enhancements over IRS-1A/1B/P2 specifically designed to improve agricultural application capabilities. The LISS-III camera has a higher spatial resolution of 23 m in comparison to 36 m of LISS-II. This is aimed at improving the detection, mapping and inventory of crops in regions having small fields and a mixed cropping pattern. An additional spectral channel in middle infrared region (MIR, band 5) has also been included for the first time in Indian earth observation sensors. Previous studies have indicated that inclusion of this channel improves crop discrimination in as diverse cases as wheat-mustard in Haryana[5], groundnut and other crops in Gujarat[6], rice and other vegetation in Orissa[7]. The 2-band WiFS sensor has 188 m spatial resolution, 5-day revisit capability and 800 km swath. This makes it ideally suited for high temporal resolution monitoring of crop spectral profiles, overcoming limitation of cloud cover in monsoon season for regional applications and in crop condition assessment. WiFS sensor is ideal for host of vegetation-related application which have been carried out by NOAA AVHRR derived NDVI.

Analysis of simulated data of LISS-III and WiFS

As part of pre-launch investigations of utility of LISS-III and WiFS, few studies using simulated data were carried out. LISS-III data were simulated by combining spectral information from SPOT XS for visible and NIR channels with MIR spectral band from Landsat TM over a previously investigated[8] site in North Gujarat. Separability amongst various crop/vegetation classes as estimated from Bhattacharya distance[9] increased when MIR band was also included in classification[10].

Multi-date IRS-LISS-I data over parts of West Bengal were used to simulate WiFS data of 18 dates covering both the kharif and rabi season. Analysis of these sets of data indicated the feasibility of deriving many useful cropping system information like cropping pattern, crop rotation, varietal differences in phenology spread, etc. It was possible to derive district-level crop rotation using only four date data acquired during different crop seasons[11]. Further, it was feasible to discriminate autumn and winter rice, irrigated and rainfed rice based on their profile characteristics (Figure 1). This analysis also indicated the optimum dates of data acquisition for taking an inventory of all the varieties of rice grown in an area[12].

Early results from analysis of WiFS data

Early assessment of rabi cropped area in Punjab

WiFS digital data of 28 January 1996 (path-row: 92–50) over Punjab were analysed for estimating total cropped area in rabi season. The analysis consisted of the following steps: (i) registration of data to UTM grid using

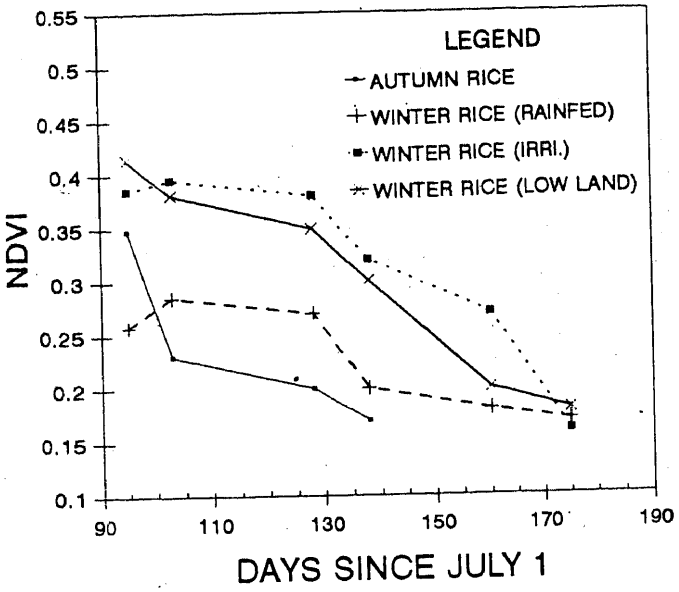

Figure 1. Spectral growth profiles of kharif rice in West Bengal generated from simulated WiFS data showing varietal discrimination due to differential temporal behaviour. (NDVI: Normalized difference vegetation index)

1 : 250,000 scale topographic sheets at pixel size of 188 m × 188 m, (ii) marking of training areas covering total variability of rabi crop signatures, and (iii) supervised classification using maximum likelihood procedure. The results gave an early pre-harvest estimate of 3.4715 Mha for 1995–96 rabi season. The fully revised estimates have been released by the Ministry of Agriculture for wheat, gram and mustard for crop seasons 1990–91 and 1991–92 add up to 3.406 and 3.398 Mha, respectively. Thus, WiFS data can be used for an early assessment of total cropped area in rabi, while for the acreage estimation of wheat using higher spatial resolution data acquisition of mid-February are generally used[13].

Major crop inventory in Andhra Pradesh

WiFS data of 25 January 1996 covering the state of Andhra Pradesh were used to identify and delineate major crops grown in various parts of the state. It was possible to visually identify paddy and pulses that are grown in Godavari and Krishna delta regions and cotton and other minor crops spread over in other districts on two-band false colour composite (FCC). On the basis of the information available on the crops being cultivated during the rabi season, training windows for paddy, pulses, cotton and other crops were delineated and the data were classified using maximum likelihood algorithm. The state and district masks were generated and overlaid on the image. Paddy and pulse crops in Godavari and Krishna deltas and the standing kharif cotton in Guntur, Khamam, Warangal and Kurnool districts were classified. The FCC generated by assigning red colour to NIR band (B4) and green and blue colours to red band (B3) with district boundaries and crop distribution from classified image overlaid on it is shown in Figure 2. The estimated acreage of paddy and pulses are 5.09 lakh ha and 2.69 lakh ha, respectively.

Observation of crop phenology by multi-date WiFS data

The temporal-spectral behaviour of crops is related to their phenology and agronomic practices and can be monitored for various applications like crop discrimination, crop assessment, identifying crop rotation and cropping pattern practices, etc. using the high repetivity WiFS data. Results from such an exercise which is in progress over Bardhman district and surrounding areas in West Bengal from the early analysis of 3 acquisitions between 22 and 31 January 1996 are reported here. Potato, mustard, wheat and vegetables crops are grown in this area during this period but are in different crop stages. Thus, this period corresponds to peak growth in potato, whereas mustard is in its rapid senescence phase and wheat in its early growing stage. The two-band FCC of WiFS for 22 and 26 January are shown in Figures 3 and 4 respectively. In the short difference of 4 days the decline in redness of mustard crop associated with senescence can be observed. The temporal-spectral behaviour of two WiFS bands for various crop and non-crop classes is shown in Figure 5. The various crops exhibit characteristic temporal-spectral behaviour in terms of direction and rate of spectral change. Thus, wheat and potato manifest increase in NIR and decrease in red associated with their growth while mustard moves in opposite direction due to senescence. This confirms the earlier observation made on simulated WiFS data that temporal signature will be helpful not only for crop type discrimination but also for varietal differentiation. As observed in Figure 5, the pseudo-invariant features (PIFs) like forest, urban and deep water areas show little or no change. These features can be used to normalize the atmospheric effects in temporal data set, which is essential for generating spectral growth profiles.

Observations on wheat-growing regions of India

As a part of ongoing project on Crop Acreage and Production Estimation (CAPE), a plan for national level wheat inventory and monitoring using WiFS data has been prepared. It envisages use of multi-date data for crop inventory, providing an early pre-harvest estimate of national wheat production, generation of crop vegeta-

tion index (VI) profiles for use in crop assessment and optimally combining[14] this early forecast with district-wise results from detailed analysis of LISS-I/II/III data to issue a second forecast with improved accuracy.

The WiFS data of second fortnight of January 1996, covering the major wheat-growing belt in the States of Uttar Pradesh, Punjab, Haryana, Bihar, Madhya Pradesh, Rajasthan, Himachal Pradesh, West Bengal and Gujarat were acquired and registered on respective UTM zone images with pixel size of 188 m × 188 m. The initial results on crop inventory are expected only after the registration of February acquisitions on these master images and their multi-date analysis. The observations on spectral characteristics of wheat and other rabi season crops observed in different regions are presented here.

In Jabalpur and surrounding region (Figure 6), site A represents predominantly irrigated wheat, while site B, lying in Narsimhpur district is a predominantly gram-growing area and exhibits markedly lower green canopy vigour in FCC. The site C represents the forest vegetation and the three sites can be discriminated easily. The scene over Karnal district (Haryana, Figure 7) and surroundings shows predominantly wheat-growing region in jointing stage (site A). To the east of Yamuna river,

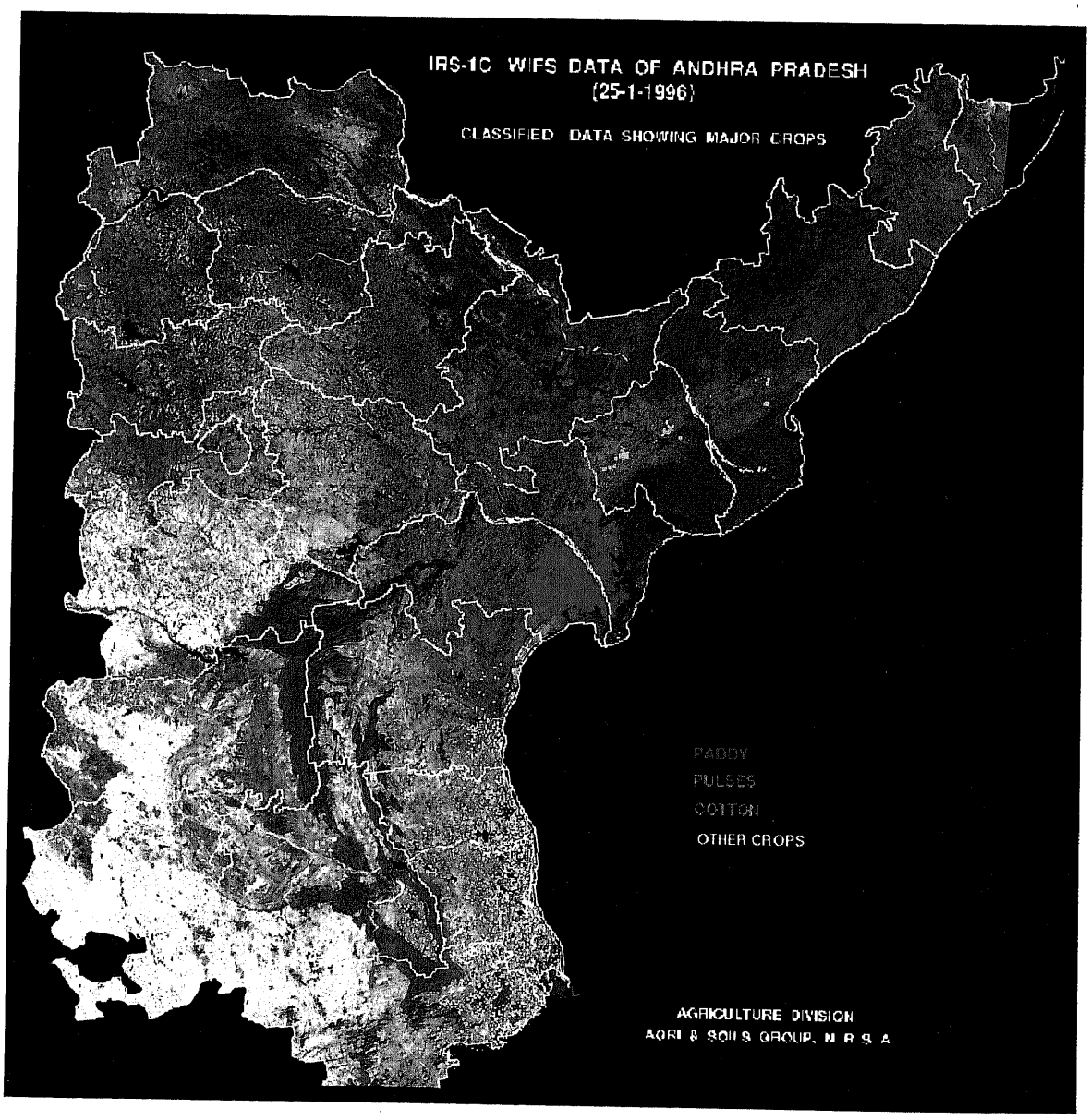

Figure 2. Two-band false colour composite (FCC, colour assignments are red: NIR band-B4, green & blue: red band-B3) of WiFS scene (25 January 1996) overlaid with district boundaries and distribution of major crops (paddy, pulses, cotton and other crops) in Andhra Pradesh.

Figure 3. Two-band FCC of WiFS (22 January 1996) over Bardhman (W. Bengal) and surrounding areas.

Figure 4. Two-band FCC of WiFS (26 January 1996) over Bardhman (W. Bengal) and surrounding areas.

in Bulandshahr and Ghaziabad districts (Uttar Pradesh), the mixed distribution of sugarcane and wheat fields, suppresses the bright red tone associated with green vegetation (site C), while the predominantly sugarcane-growing site where sugarcane is being harvested/in maturity stage shows up in dark tone. Because of the small size of individual fields of wheat and sugarcane and interspersed spatial distribution in western UP, crop-specific inventory without use of mixture modelling of

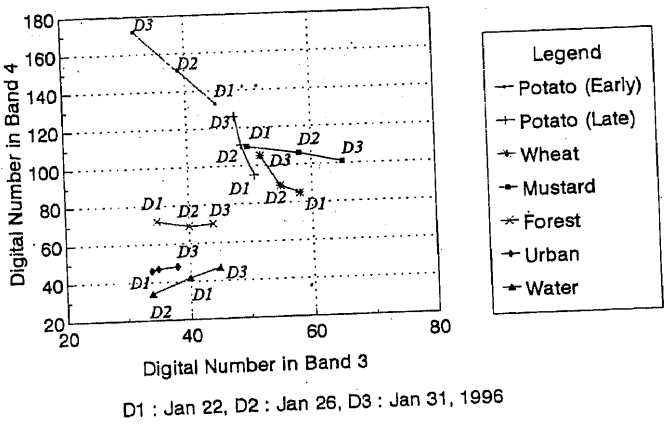

Figure 5. Temporal-spectral plot of 2-band WiFS data between 22 January and 31 January 1996 over various crop and non-crop sites over Bardhman (W. Bengal) and surrounding areas.

signatures will be difficult. In the scene covering Ludhiana (Figure 8) and surrounding districts of Punjab, wheat is the dominant crop. Here, amongst wheat, 3 vigour/crop density classes can be observed. In the area south of Sutlej river, a high density crop is seen in old floodplain of the river, a medium density crop is seen south of Ludhiana city while north of Sutlej relatively poor density class is seen. Although minor crops make up 10% of total rabi crops, these are not seen in WiFS data as they are sown in individual fields widely scattered in the predominantly wheat growing region.

Early results from analysis of LISS-III data

LISS-III data of path 93 row 54 acquired on 7 February 1996 were analysed for various characteristics including crop separability (Table 1) over a 20×20 km predominantly agricultural site in Bali Tahsil of Pali district (Rajasthan). The main crops grown in rabi season in this area are wheat and mustard. The FCC generated from MIR(B5), NIR(B4) and red(B3) channels is shown in Figure 9, the wheat is in light green colour and mustard in dark green colour. The MIR channel (B5) displays the highest digital counts as well as standard deviation amongst 4 bands (Table 1). The inter-band correlation shows high positive correlations between B2 & B3, B2 & B5 and B3 & B5. The principal component analysis indicates the data over this scene lies in two major axes which explain 97.6% of variance. The first component has contributions from B2, B3 and B5 which together explain 91.9% of the scene variance, while second component has contribution from NIR channel (B4). The study of crop separability over ground truth sites representing vigour/phenology classes of wheat and mustard indicates improvement in crop type and conditio

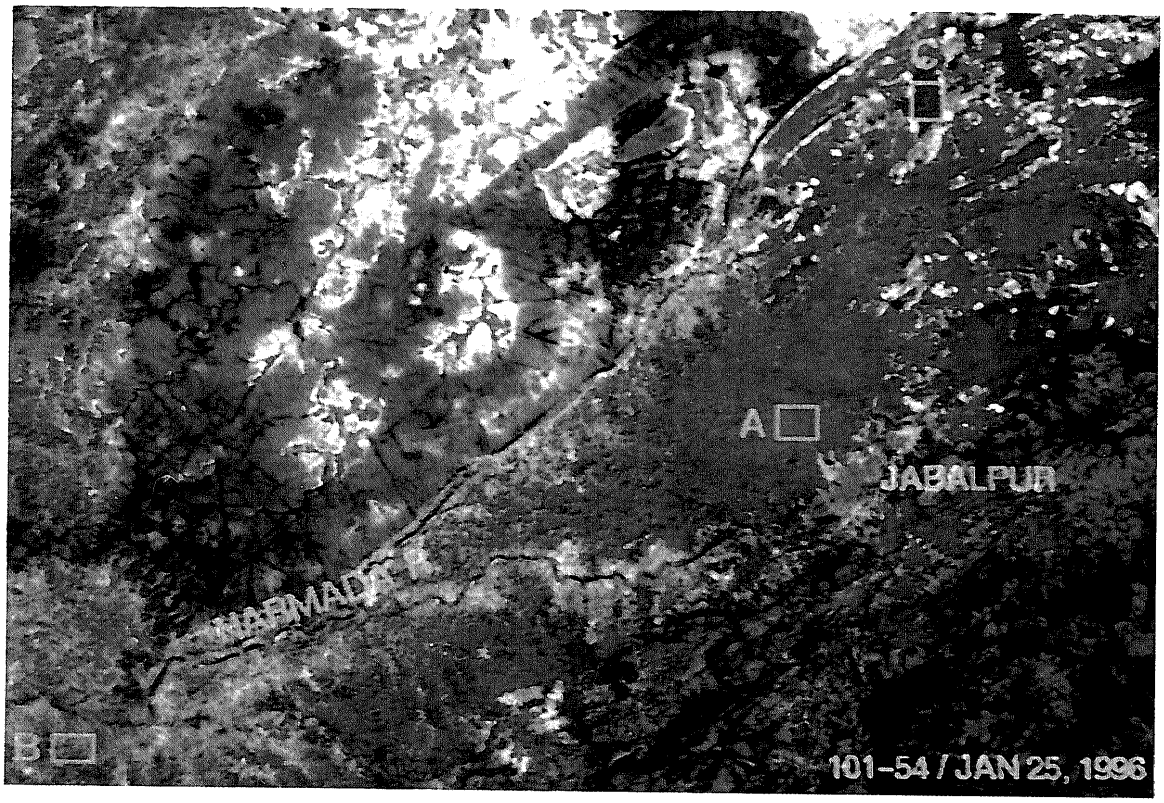

Figure 6. Two-band FCC of WiFS (path-row: 101-54, 25 January 1996) over Jabalpur and surrounding regions showing irrigated wheat (site A), predominantly gram (site B) and forest (site C).

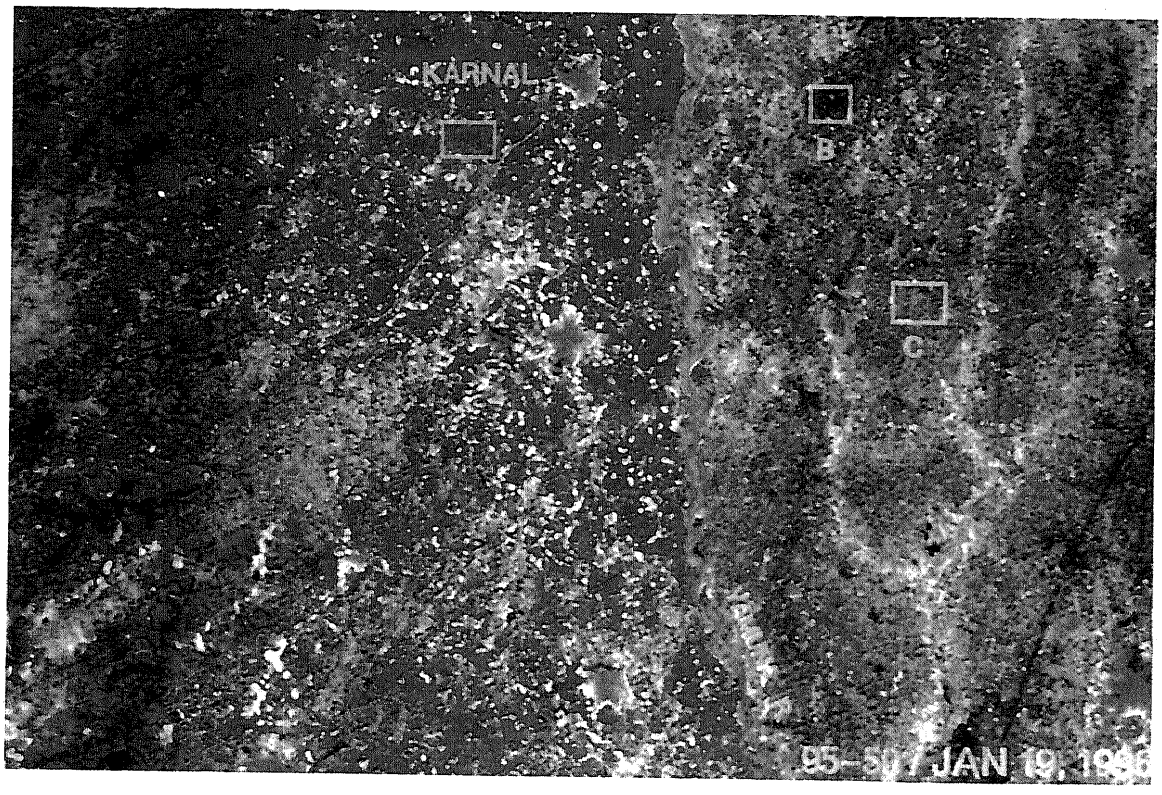

Figure 7. Two-band FCC of WiFS (path-row: 95-50, 19 January 1996) covering parts of Haryana and western Uttar Pradesh.

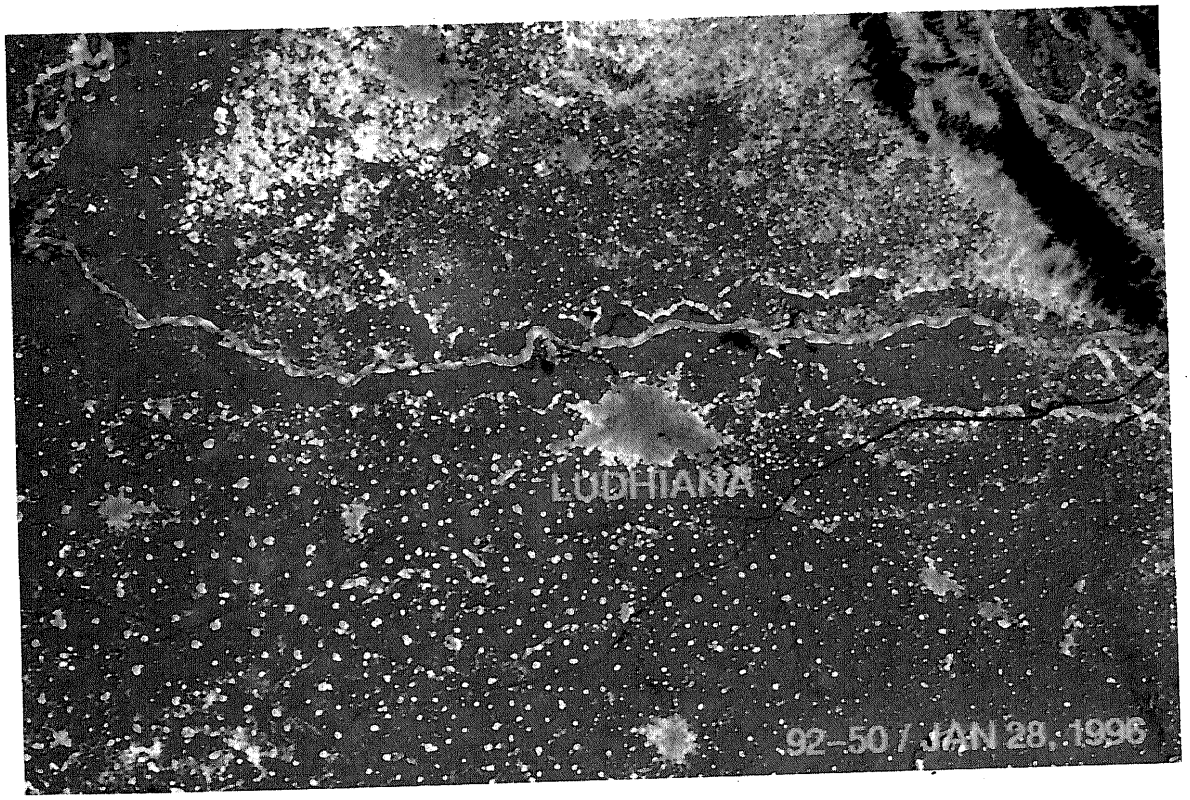

Figure 8. Two-band FCC of WiFS (path-row: 92-50, 26 January 1996) covering Ludhiana and surrounding districts of Patiala, Jallandhar, Kapurthala.

Table 1. Analysis of LISS-III data over an agricultural site in Pali district (Rajasthan)

Scene spectral characteristics

Band	Mean	Std. dev.
B2	84.80	10.76
B3	52.88	14.34
B4	84.73	11.30
B5	121.09	40.41

Inter-band correlation

	B2	B3	B4
B2	1.000		
B3	0.943	1.000	
B4	–0.179	–0.322	1.000
B5	0.868	0.922	–0.297

Principal component analysis (PCA)

		Eigenvectors			
PC	% Variance explained	B2	B3	B4	B5
1	91.93	–0.219	–0.311	0.082	–0.921
2	5.62	0.121	–0.029	0.989	0.069
3	2.15	0.644	0.663	–0.033	–0.380

Crop separability

	B234	B2345
Bhattacharya distance	1.058	1.322
Minimum distance	1.650	1.706
Average distance		

Figure 9. FCC generated from red (B3), NIR (B4) and MIR (B5) channels (colour assignments: B5-red, B4-green, B3-blue) of LISS-III (path-row: 93-54, 7 February 1996) data over a wheat and mustard growing site in Pali district (Rajasthan).

discrimination by inclusion of MIR channel, whether measured by minimum Bhattacharya distance (BD) or average BD.

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