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LAND-COVER MAPPING: A REMOTE SENSING APPROACH

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Abstract

SPOT (Systeme Pour l'Observation de la Terre) XS (multi-spectral) satellite sensor data were evaluated for mapping different land-covers/uses in the suburb of Rawalpindi to assess the impact of urbanization on the scrub forest dominated by *Acacia modesta*. Various data layers were generated and co-registered with the land-cover map. Field data collected using GPS were employed to evaluate the land-cover map. The results showed that several land-cover types can easily be identified and mapped while some land-covers were difficult to identify, as they could be confused with each other due to their similar spectral reflectance. Thirteen land-covers were mapped using fuzzy supervised likelihood classifier. The statistical evaluation of the classified image indicated an overall accuracy of 72.86% with a kappa statistics of 0.70. The results suggest that extensive and massive clearance of reserve forest occurred in most of the forest stands. The existing scrub forest is becoming smaller and fragmented; only patches of mature forest are left in forest stand 6, 7 and 8, which are under threat from urban encroachment evincing that soon the remaining forest will be engulfed by concrete jungle if Rawalpindi Authority and the Forest Department of Rawalpindi District does not take immediate auction as a priority to save this national heritage. Cover types map derived could be used as a valuable base for the monitoring changes in land-cover pattern and deforestation assessment of the scrub forest of the study site.

Introduction

The Lohibehr reserve, some 15 km on the west of Rawalpindi district was declared as Lohibehr Wildlife Park in 1987 (Lohibehr History Files, 1989-90) and was selected because it is very vulnerable to commercial exploitation and urban development due to its location in the immediate vicinity of the heavily populated city Rawalpindi with increasing commercial and urban development, farming activities along with crops, high grazing pressure and fuel wood consumption from nearby villages. The Park is recognised as part of a scrub forest series raised artificially in Pakistan (Lohibehr History Files, 1989-90; Khan, 1994) and has been used as a grazing site for the last twenty years. The land area where the reserve forest is located, especially the south-eastern and northern sides, has undergone steady urban development for over ten years and exhibits a diversity of residential and commercial areas. The Lohibehr site was chosen in order to assess the impact of urbanisation on the reserve forest which is suffering deterioration as almost half of the forested area had been deforested and soon it would be unproductive, if proper management are not undertaken (Amin *et al*., 1984). Unfortunately the latest land-cover map of the study area is not available and it is of prime importance that the flora of the area is surveyed and recorded before the whole site is totally urbanised. The study site is also an appropriate location to apply remote-sensing techniques to prepare and update land-cover map, and its periodic monitoring without disturbing the ecosystem balance. Mapping different land-covers in the field is a complex and difficult exercise. Malik *et* *al.*, (1999, 2000) San Miguel-Ayanz & Biging (1997) argued that as there is no reasonable means of providing timely and accurate data for land-cover mapping using traditional methods there may be a need to map many cover-types. Remotely sensed data from airborne or space-borne sensors which provides a spatially extensive means to produce maps of the surface cover types and are capable of providing accurate and cost-effective information about any given area on the earth's surface at short intervals and on continuous basis (Verbyla & Richardson, 1996).

Although satellite imagery in the form of aerial photographs and images have been demonstrated to be cost effective method for land-cover mapping throughout the world (Trisurat *et al.*, 2000), it has not been extensively used in Pakistan (Siddiqui, 1991; Malik *et al.*, 2000). SPOT data with the spatial resolution of 10m for the panchromatic band and 20m for the multispectral (XS) bands are commonly used for the land-cover mapping e.g., Gao & Skillcorn (1998) produced land-cover map of the rural-urban periphery using summer and winter SPOT XS data with the mapping accuracy was 76.2% and 81.4% for the winter and summer data. Similarly, Treitz *et al*., (1992) took an advantage of 10m resolution of the panchromatic band by registering it with the multi spectral bands and an accuracy of 78% was achieved in a classification of eight land-covers at the urban-rural fringe of Toronto, Canada. Harvey & Hill (2001) evaluated SPOT data (XS and panchromatic) along with Landsat TM data for mapping different vegetation types of a tropical fresh-water in Australia. Multitemporal SPOT XS data was classified using supervised, unsupervised and an alternative classification scheme which utilized a series of steps (unsupervised classification, stratification and supervised classification) for mapping rice fields on a West African floodplain (Turner & Congalton, 1998). Gastellu-Etchegorry (1990) tested the potential of SPOT XS images for automatically outlining agricultural near-urban interfaces for an area around Yogyakarta, Central Java. It was found that the results digitally classified from the satellite data are comparable to those obtained from visual interpretation of 100, 000 near-infrared aerial photographs.

The aim of this study was to evaluate the SPOT XS (HRV 2) sensor data as a mechanism of providing the information regarding the land-cover type classification and mapping to assess the impact of urbanization on scrub forest.

Materials and Methods

Study area: The study site, Lohibehr is located between 33^0 34′ and 33^0 36′ north and 73^0 05′ and 73^0 06′ east at an altitude of 500 metres at a distance of 16 kilometres from Islamabad on right side of Islamabad-Lahore Highway (Fig. 1). The site is bounded in the north by Chaklala airport, in the west by Lohibehr village and Soan River runs along the eastern and southern sides. The physical features of the site exhibit a variety of plateaus, hillocks, valleys, ravines, streams, plains and other forms of topography. The rock formation is composed of tertiary sandstone and alluvial deposits. The western and northern portion is a plain with clayey loam soil and the hillocks are made of alluvial material with a large number of stones cemented together (Leh conglomerate). The sandstone apparently belongs to the Sirmur and Siwalik series of the Sub-Himalayan system. The pebble ridges describe as alluvial deposits are a peculiar feature of the Rawalpindi district and most of the forests in the district are on the pebble ridges. Large isolated boulders in many places seem to point to a glacial epoch in the Pothowar plains.

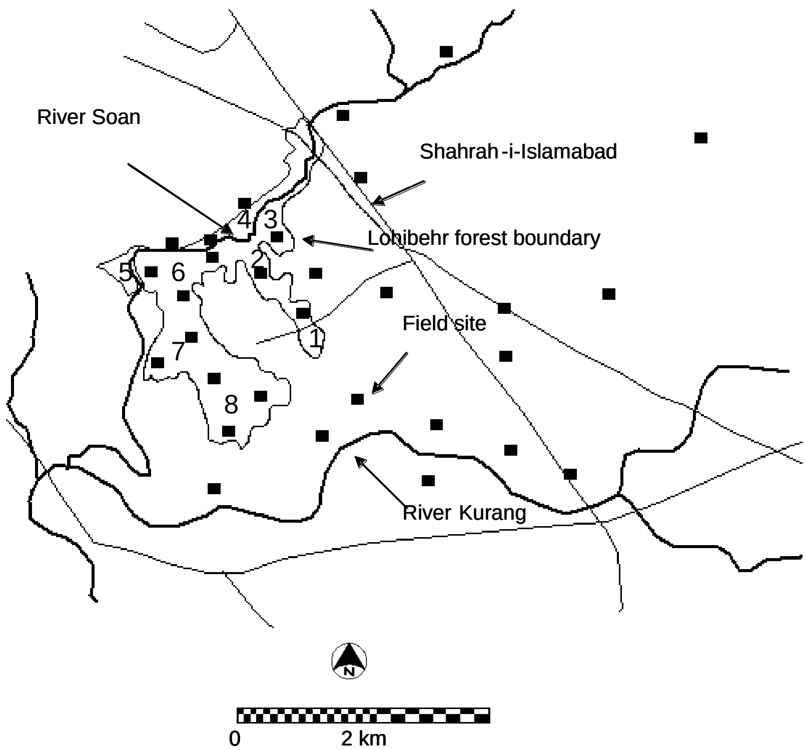

Fig. 1. location of the study area and also shows the road and drainage networks. Numbers inside the Lohibehr forest indicate different compartments.

Soils belong to the Rawalpindi series which have been derived from loess material (Ali, 1967). The climate of the area is sub-tropical continental low lands, sub-humid Pothowar plateaus with a mean annual precipitation of 970 mm, most of which falls in monsoon during the months of July and August. The wind generally blows from northwest but during the monsoon season, its general direction is southeast. The main drainage systems are river Korang and Soan. A large number of seasonal nallahas flow though the site beside Korang River, a part of which passes through the area. The whole area encloses reasonable large chunk of private lands on three sides and eight villages are located around the area. Most of the animals as well as some migratory herds also graze in the area.

Methodology and data analyses: Satellite sensor data of SPOT XS of 410 x 490 pixels acquired on 8 June 1998 were subset and georeferenced to 1: 50, 000 topographic map in the ERDAS imagine (version 8.2) and ILWIS (version 2.1) digital processing systems. Ground control points (GCPs) were selected at locations distinct on both the imagery and topographic map. Care was taken while establishing the GCPs that they should be as small as a single pixel, contrasting strongly with their background and should not be too large to preclude accurate determination of their location (Campbell, 1996). Features subject to seasonal or annual variations were avoided. These reference points (GCPs) were then used to derive polynomial transformations of the first order (affine transformation) which is given below:

$$x= a_0+a_1r_n+a_2c_n \quad \text{Eq1}$$
$$y=b_0+b_1r_n+b_2c_n \quad \text{Eq2}$$

where:
r_n is a row number, c_n is a column number, x and y are the map coordinates and (a_0, a_1, and a_2), (b_0, b_1, and b_2) are the coefficient of the polynomial.

Twenty-five GCPs were used for the affine transformation and a RMSE (the average of the errors in the reference points: also called the root mean square error or sigma) of 0.19 metres was achieved. To create a distortion-free image, the image was resampled by applying an interpolation method of nearest neighbourhood to retain radiometric integrity (Jensen, 1996; Michener & Houhoulis, 1997). This method computed the radiometric values of the nearest pixel in the new image based on the DN values in the original image (Campbell, 1996). Various enhancement models were tested on the image to increase the overall contrast between all cover-types.

The fuzzy supervised classification using maximum likelihood algorithm was used. Polygons representing homogenous sites for each land-cover type were identified and marked onto the satellite sensor data. More than five to eight training samples (containing at least 5-8 pure training pixels) were selected for each land-cover type. Statistical parameters such as maximum, minimum, average and standard deviation of the digital number were calculated for each land-cover type for the purpose of developing a representative set of the spectral signature for the land-cover classes. Spectral signatures were created and their histograms and spectral plot were evaluated for their spectral separability. The classified image was smoothed using neighbourhood model analysis through a majority 3x3 filter.

Classified image was assessed for the classification accuracy using 70 reference pixels for each class by equalized random sampling method (Gao & Skillcorn, 1998). Accuracy of each class was expressed as a matrix showing errors of commission and omission. Overall classification accuracy and accuracy of individual classes, overall kappa statistics and kappa statistic of each class was computed.

Overall map accuracy was computed by dividing the total number of correctly classified pixels by the total number of reference pixels in the error matrix (Mather, 1999). Overall accuracy uses only the main diagonal elements of the error matrix. The accuracy of individual categories is computed by dividing the corresponding row or the corresponding column (Congalton, 1991). When the number of correct pixels in a category is divided by the total number pixels in the corresponding row (i.e. the total number pixels that were classified in that category), the result is an accuracy measure called "user's accuracy" and is a measure of commission error. "User's accuracy", or reliability, is indicative of the probability that a pixel classified on the map actually represent that category on the ground. On the other hand, when the correct number of pixels in a category is divided by the total number of pixels in the corresponding column (i.e. the total number of pixels for that category in the reference data) the result is called "procedure's accuracy". Procedure's accuracy indicates the probability of reference pixels being correctly classified and is really a measure of omission error (Lillesand & Kiefer, 1994).

Table 1. Mean pixel values and standard deviation of land-cover types.

Land-cover classes	SPOT XS bands		
	Band 1	Band 2	Band 3
Ziziphus malcolmia	57.6±1.3	40.4±2.1	92.0±2.3
Capparis eleusine	67.5±1.7	56.5±2.6	85.7±4.4
Prosopis chrysopogon	67.4±1.6	55.8±2.8	90.5±3.5
Degraded land	81.2±2.6	84.0±2.8	81.1±4.7
Cultivated land	68.4±0.7	63.9±0.8	69.2±2.6
Salix saccharum plant community types	64.2±2.6	53.6±3.7	76.7±2.7
Water bodies	71.5±1.9	67.6±2.5	38.2±7.5
Settlements and barren land	100.6±4.3	93.8±4.1	95.7±3.0

E.O: error of omission,
E.C: error of commission.

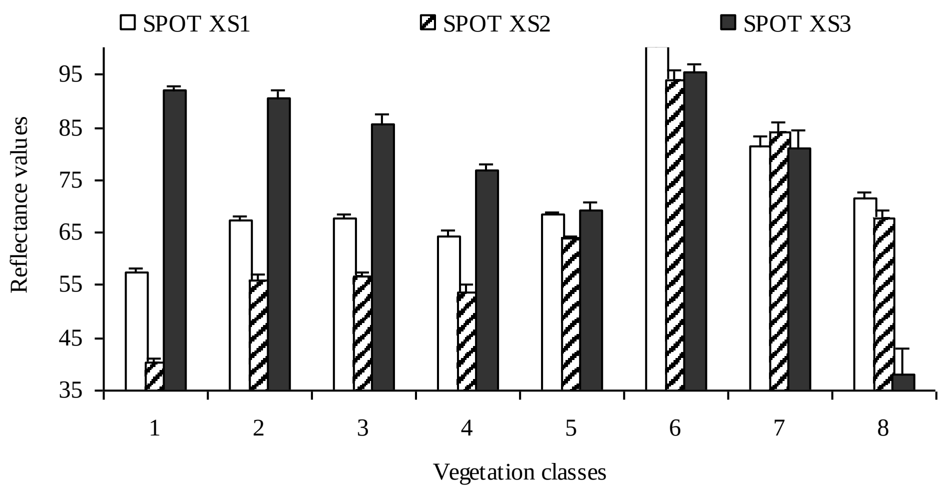

Fig. 2. Mean reflectance values of land-cover classes showing level of significance in the Lohibehr site where (1) *Ziziphus-Malcolmia* (2) *Prosopis-Chrysopogon* (3) *Capparis-Eleusine* (4) *Salix-Saccharum* community types (5) cultivated land (6) settlements and barren land (7) degraded land and (8) water bodies. Y-bars represent LSD values.

The kappa coefficient of agreement (K) was developed which is a measure of the actual agreement (indicated by the diagonal element of the matrix) minus chance agreement (indicated by the product of row and column marginal). A Kappa value is computed for each error matrix. It measures how the classification performs as compared to the reference data (Lillesand & Kiefer, 1994).

Results

The mean spectral values of land-cover types identified along with their standard deviations is given in Table 1 whereas Fig. 2 show the spectral variability of vegetated and non-vegetated types in three SPOT XS bands. The results obtained from separability analysis using Transformed divergence of three different band combinations are given in Table 2 shows that the vegetation types are clearly distinct from non-vegetation types. Water bodies, settlements and barren land, degraded land, and cultivated land categories remained separable from each other and also from vegetated types in either of the band combinations also show high transformed divergence values. Similarly significant differences were found (*P*=0.05) between them and the vegetation types.

The settlements and barren land category comprises towns, villages, construction sites, industrial/commercial areas that include man-made features, and bare land that normally appeared dirty white in the image. Settlements generally appeared grey on the NIR image and light grey (near infra-red) in visible bands and show a typically chequered pattern due to the house clustering separated by paths and roads. Examination of satellite imagery demonstrated that settlements and transport network features are more prominent in visible bands compared to the NIR band. The results also revealed significant differences (*P*=0.05) based on their spectral separation from other categories and also transformed divergence analysis indicates the highest values of this category from other classes.

The cultivated land category that appeared in varying tones of greyish green in the satellite imagery showed lower reflectance values in all spectral bands from other non-vegetation classes. Degraded land is mostly located on the east side of the study area very close to Shahrah-i-Islamabad (road that leads to Islamabad) and was made up of earth quarries and land which has been flattened for the construction of new roads after forest vegetation had been cut down. Large parts of this land-cover type are used for brick factories which mushroomed rapidly particularly along the eastern part of Shahrah-i-Islamabad. This land-cover type gives very distinct colour on the image and is clearly distinct from settlements & barren land and other categories showing high transformed divergence values (Table 2).

Water bodies represented by streams and rivers (such as the Soan and Kurang) in the Lohibehr site were separated and distinct in their reflectance behaviour from other land-cover types. This could be due to their high reflection in visible bands compared to the near infrared band, where reflection is low due to absorption by water bodies and because of this effect, water usually appears dark black. It is also characterized by high reflectance in SPOT XS1 and XS2 bands and low reflectance in SPOT XS3. The results of transformed divergence analysis also revealed a very high transformed divergence value, greater than 1999, indicating its spectral separation from other land-cover types.

Acacia modesta scrub appears relatively bright in the SPOT XS1 image, due to a small reflection peak, very dark in SPOT XS2 image due to absorption by chlorophyll present in the green leaves and very bright in SPOT XS3 where the brightness is governed by the internal structure of the leaf. In the SPOT XS false colour composite image, *Acacia modesta*-dominated scrub appeared in shades of red and brown and in patches of varying spatial extent while in some parts the boundaries were quite sharp, while in other places they were irregular. It was significantly different from *Salix-Saccharum* and *Capparis-Eleusine* vegetation types, whereas it showed insignificant differences in spectral reflectance from *Prosopis-Chrysopogon* in SPOT XS3.

Insignificant differences were observed in the spectral reflectance vegetation types such as *Prosopis-Chrysopogon* and *Capparis-Eleusine* in SPOT XS1 and XS2 (*P*=0.05). However they could be differentiated in SPOT XS3. Similarly theses vegetation type remained inseparable based on transformed divergence values (Table 2). The *Salix-Saccharum* community types remained distinct and significantly different (*P*=0.05) from vegetation and non-vegetation types. Transformed divergence also confirmed these results.

Table 2. Transformed divergence of land-cover classes. For land-cover classes key see Table 1. (a) Band 1; (b) Bands 2, 3; and (c) Bands 1, 2, 3. Best average statistical separability using: Band 1=1940, Bands 2, 3 = 1971, and Bands 1,2,3 = 1948

	Class names	Ziz	Cap	Pros	Deg	Cul	Sac	W	Sett
(a)	Ziz	0							
	Cap	2000	0						
	Pros	2000	1263	0					
	Deg	2000	2000	2000	0				
	Cul	2000	1639	1990	2000	0			
	Sac	2000	1999	1925	2000	2000	0		
	W	2000	1999	2000	2000	1583	2000	0	
	Sett	2000	2000	2000	1937	2000	2000	2000	0
(b)	Ziz	0							
	Cap	2000	0						
	Pros	2000	1613	0					
	Deg	2000	2000	2000	0				
	Cul	2000	1596	1993	1999	0			
	Sac	1990	1999	1993	2000	2000	0		
	W	2000	2000	2000	2000	1999	2000	0	
	Sett	2000	2000	2000	2000	2000	2000	2000	0
(c)	Ziz	0							
	Cap	2000	0						
	Pros	1995	1174	0					
	Deg	2000	1999	1999	0				
	Cul	2000	1649	1981	1999	0			
	Sac	1997	1932	1842	2000	1996	0		
	W	2000	2000	2000	2000	1999	2000	0	
	Sett	2000	2000	1999	1999	2000	2000	2000	0

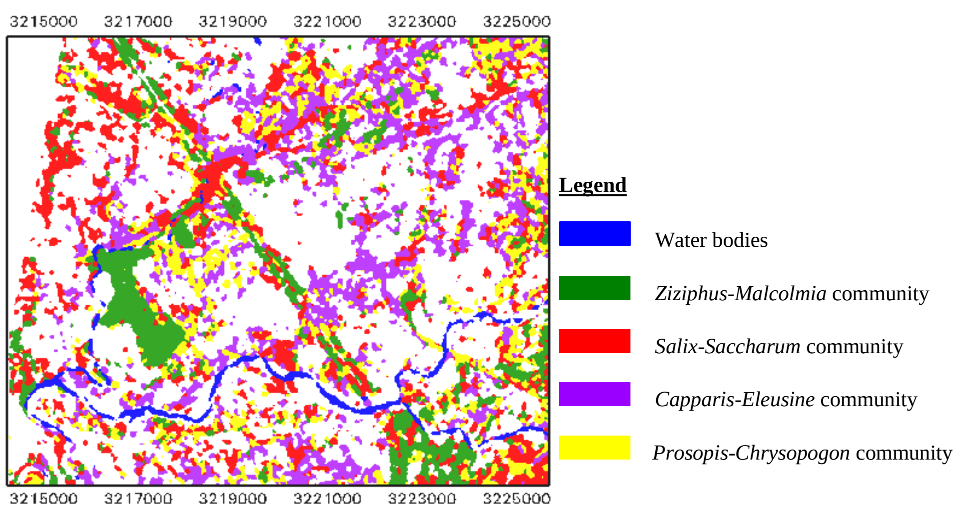

Fig. 3. Land cover maps showing the spatial distribution of vegetation classes.

Tables 3 and 4 represent the error matrices of the fuzzy supervised classifications and the accuracy totals of the classified land-cover types. The land-cover maps produced after fuzzy supervised classification are given in Fig. 3 and 4.

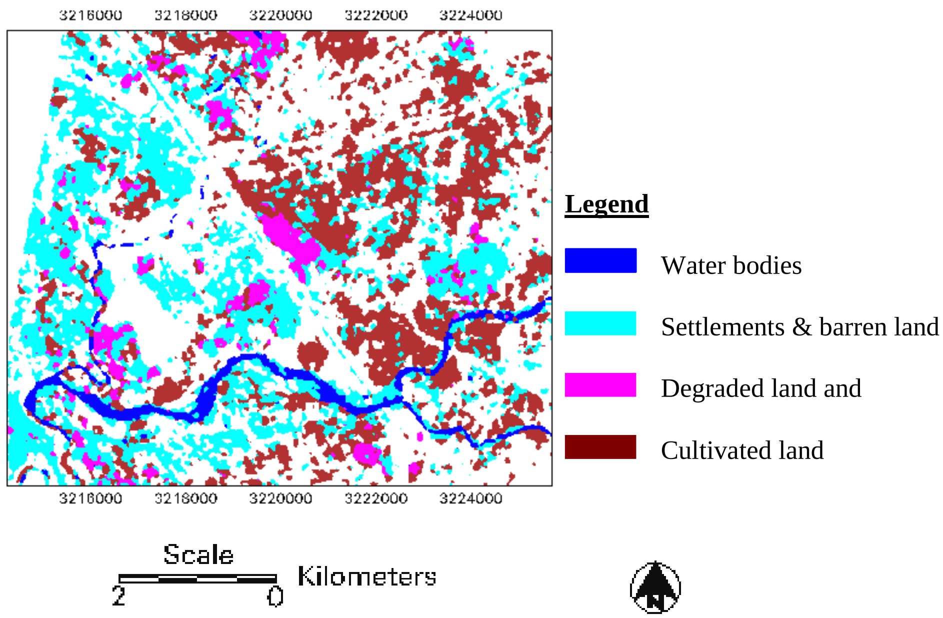

Fig. 4. Land cover maps showing the spatial distribution of non-vegetation classes.

Table 3. Error matrix of fuzzy supervised classified map. For land-cover types abbreviation see Table 1.

Class Name	Aca	Cap	Pros	Deg	Cul	Sac	W	Sett	Totals
Ziz	8	0	2	0	0	0	0	0	10
Cap	1	4	0	0	1	1	0	0	7
Pros	1	0	5	0	0	0	0	0	6
Deg	0	0	0	8	0	0	0	2	10
Cul	0	1	0	0	7	1	1	0	10
Sac	0	2	0	0	1	4	0	0	7
W	0	0	0	0	0	0	8	1	9
Sett	0	0	0	2	1	0	1	7	11
Totals	10	7	7	10	10	6	10	10	51

A total of 70 pixels were used for the calculation of the error matrix. Out of total pixels evaluated, 51 were correctly classified into the various land-cover types. The overall classification accuracy achieved for all land-cover classes was 72.68% and the overall kappa statistic was 0.70. The Kappa statistic ranged from 0.55.14 for *Capparis-Eleusine* and 0.87 for water bodies and the procedure's and user's accuracies ranged from 57.14% to 80.00% and 57.14% to 88.89% respectively.

The data in Tables 3 and 4 also indicate that non-vegetation classes were more accurately classified as compared to vegetation classes which are due to fact that boundaries between these classes are clearly defined and these classes are more uniform in their detail compared to vegetation classes.

Table 4. Accuracy total of fuzzy supervised classified map. For land-cover types abbreviation see Table 1. Overall Classification Accuracy = 72.86%, Overall Kappa Coefficient = 0.70

Class Name	Reference Totals	Classified Total	Number Correct	Procedure's Accuracy (%)	User's Accuracy (%)	E.O (%)	E.C (%)	Kappa coefficient
Ziz	10	10	8	80.00	80.00	20.00	20.00	0.77
Cap	7	7	4	57.14	57.14	42.86	42.86	0.55
Pros	7	6	5	71.43	83.33	28.57	16.67	0.82
Deg	10	10	8	80.00	80.00	20.00	20.00	0.77
Cul	10	10	7	70.00	70.00	30.00	30.00	0.67
Sac	6	7	4	66.67	57.14	33.33	42.86	0.55
W	10	9	8	80.00	88.89	20.00	11.11	0.87
Sett	10	11	7	70.00	63.64	30.00	36.36	0.60
Totals	70	70	51					

Discussion

Visual analysis of the FCC 321 of SPOT XS allowed the identification of the main land cover classes within the study area. The results revealed that higher classification accuracies were obtained. These accuracy levels are very close to those reported by Verbyla & Richardson (1996). Their mean overall accuracy exceeded 72% and possibly due to the analyst's increased control in defining signatures for the classification decision rule (Trisurat *et al.,* 2000), however lower accuracies were observed for the classes where settlements and sparse vegetation make an important component. This indicates the poor performance of SPOT XS data with high spatial resolution for mapping heterogeneous land-cover types which forms many mixed pixels. The high spatial resolution restricts the integration of the radiometric energy reflected back from various cover components of the heterogeneous land-cover categories. Consequently, the reflectance intensity from individual component remains remarkably close to that of similar but separate cover categories (Gao & Skillcorn, 1998). The limited integration problem is exacerbated by the coarse spectral resolution of SPOT XS bands which undermines the superior spatial resolution of the SPOT data, which in turn directly affects the accuracy of mapping spectrally heterogeneous land-cover types.

The classification analyses resulted in the development of a land-cover map showed that the reserve forest was dominated by thick *Acacia modesta* scrub occupying the western slopes and is the only remnant of the original scrub forest facing pressures such as encroachment by urbanization, clearing of vegetation for road construction inside the reserve forest. Under-canopy of the reserve forest was not thick, had open patches, and covered by grasses like *Desmostachya bipinnata*, *Chrysopogon montanus* and *Heteropogon contortus*. Regeneration of *Acacia modesta* was insignificant. *Dodonea viscosa,* a native of the site and an essential member of the scrub forest, reported in the earlier studies (Amin *et al.,* 1984) had been completely destroyed from the site as no single plant was observed within the vicinity of 3km during field visits. *Olea cuspidata,* another important member of the scrub forest has been under threat, and few medium size trees were observed at protected sites. No regeneration of *Olea cuspidata* was found during field visits. *Olea cuspidata* wood is considered very strong, hard and heavy and villagers use it for various purposes especially for fuel wood (Shinwari & Khan, 1998). If cutting pressure from the villagers continues, it is very likely that this species will be completely eliminated from the site. *Broussonetia papyrefera* was observed in compartments 3 and 4 of the reserve forest where it borders with river Korang and it could spread quickly as maximum moisture is available for its growth. According to Lohibehr History Reports (1989-90), the Lohibehr reserve forest is divided into eight compartments for management and planning purposes and thick vegetation cover that is the only remnant of the original forest is present in compartment 6, 7 and 8, where *Prosopis juliflora* was found sparsely spreading in small patches. Compartment 5 is engulfed by the Behria town and presents a picture of sparse vegetation as in Compartments 3 and 4. The south facing slopes, where the reserve forest is located especially in Compartments 3 and 4, which are covered with sparse vegetation represented by bushes of *Capparis decidua, Periploca aphylla, Otostegia limbata, Ziziphus nummularia, Gymnosporia royleana, Adathoda vesica and grasses like Desmostachya bipinnata, Chrysopogon montanus, Heteropogon contortus, Cymbopogon schoenanthus* and *Dicanthium annulatum.* This vegetation is under heavy grazing pressure from local villagers who regards the forest as their own property and also from urban pressure as the area is easily accessible and is in the close vicinity of newly developed towns and over populated Rawalpindi. Non-palatable species like *Capparis decidua* and *Cymbopogon schoenanthus* indicate heavy grazing pressure in the past confirming the finding of Amin *et al.* (1984). The upper ridges of hill slopes were highly degraded and devoid of any tree species, whereas remnant scrub forest was still present at the lower edges, especially along the river Korang. This is due to the steepness of the slopes, which results in inaccessibility to this part of the vegetation. Amin *et al.,* (1984) while, working on a range ecological survey of Lohibehr during 1981 and 1982, found a plant community represented by the same plants and grasses on eroded hill slopes and tops.

The depletion of vegetation is quite severe along the southern and eastern parts of the reserve forest as Compartments 1 and 2 were allotted to the Rawalpindi Development Authority (RDA) for the construction of new housing colonies. The vegetation cover was bulldozed in these compartments. Fig. 2 shows that forest cover has been completely. The vegetation at these places was dominated by *Prosopis juliflora* and *Desmostachya bipinnata.* Along the floodplains of the river Soan, especially along the area adjoining the Kak bridge on either side of the Shahrah-i-Islamabad road, the *Salix - Saccharum* plant community was observed growing. During the field surveys, it was observed that this plant community is under heavy grazing pressure and is dominated by *Saccharum spontaneum*, which was found in small clumps dispersed uniformly. *S. bengalense* was found only along the road edges possessing thicker deposits of sands (Amin *et al.,* 1984). *S. spontaneum* can withstand drought and has significantly checked erosion. *S. spontaneum* and *S. bengalense* were found to be the pioneer species in the floodplains of river Indus near Attock Khurd (Chughtai *et al.,* 1987). It was also considered an early colonizer in the floodplains of Indus at Dera Ismail Khan (Alizai & Naqvi, 1976). *Typha augustifolia* appears during monsoon rain (June-July), covering the whole area and becoming an important member of the community. Besides annuals, the only woody perennial found growing was *Salix tetrasperma* as sub-dominat speicies however some other woody species such as *Ricinus communis* and *Dalbergia sissoo* were also found growing along the edges but were very rare. *Populus* sp. an early colonizer of the floodplains of the Indus (Alizai & Naqvi, 1976), was absent either due to severe competition from *S. spontaneum* or lack of a seed source in the vicinity. This study results also confirmed the finding of Chughtai *et al.* (1987). They argued that the vegetation of the floodplains is much influenced by the frequent change between erosion and deposition of sand due to flooding and the changing course of the river, and tolerance to floods and moisture conditions are the primary sorting factors controlling the species distribution in a floodplain. No young seedlings of *Salix tetrasperma* were observed during the field visits and it seems that establishment of tree species has become difficult because of trampling by grazing animals like buffalo, cows and goats. Surveys conducted in June-August 2000 indicated that a new dual carriage-way is under construction along Shahrah-i-Islamabad and the vegetation has been heavily degraded by vehicles and gravel excavation from the river for road construction. Along the riverbank, the vegetation is dominated by *Polygonum plebejum* and the supporting vegetation largely comprises annuals (i.e. *Ranunculus arvensis, Nasturtium officinale, Bacopa monnieri, Juncus sp., Angallis sp., and Psammogeton sp.*). Hundreds of small seedlings of *Salix tetrasperma* were found growing over a large area along the river courses and in future; if the area remains protected from grazing and other disturbances, Salix scrub will establish over a large area. Along the edges, large numbers of *Saccharum bengalensis* were found growing in the sandy soils. This plant community was not identified on either of the image; however it was observed along the banks of rivers Kurang and Soan.

Study conducted by Malik *et al.* (1999; 2000) showed that the proportion of dense forest had been diminished drastically between 1990 and 1998 indicating trend towards urbanisation as large number of new settlements, especially along the western site of the Shahrah-i-Islamabad road, were established, where most of the reserve forest is located. One other factor contributing to deforestation is that the west side of the road borders the heavily populated city, Rawalpindi, and is more prone to encroachments than the eastern part. It is possible that, in the next 5-10 years, when more land will be acquired by the developers, the reserve forest will be completely urbanised.

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