POTENTIAL FOR IDENTIFYING CHANGES IN LAND COVER IN NEPAL USING SATELLITE IMAGERY

By

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I. INTRODUCTION

Nepal is a mountainous country, geologically fragile, and economically backward with an area of 14.75 million hectares in which 20.1 % is cultivated, 18.5 % is ice, snow, rock, urban etc., and 61.4 % (8.85 million hectares) is grassland, shrubland, or forested land. The forested lands have deteriorated, depleted, and converted to other uses such as cultivation and urbanization. As a result, the forest land is shrinking and the agricultural land is eroding at an alarming rate. The fundamental problem is the pressure of human population on the land. There is an impact of farmers and their common practices on the forests. The farmer gets fertilizer for the agricultural land, fuelwood for household cooking and warming, and fodder leaves for the cattle from the forests.

Clearly, there is a need to monitor these changes in land cover. The remoteness and ruggedness of the country, and its limited resources require that the monitoring efforts be inexpensive. In the past, a method which employed photointerpretation of large scale black and white aerial photography was used to determine land cover change.

For two decades, a large volume of literature concerning the use of remotely sensed satellite imagery for detecting or identifying changes in land cover has been published. This developing technology offers an efficient method for mapping basic land cover and land use types over large areas. Moreover, the satellite provides a synoptic view, and the ability to spectrally manipulate the imagery relatively inexpensively. However, its main drawback has been its poor spatial resolution.

Recent advances and refinements in satellite sensors (Table 1 & 2) are producing higher resolution images with more spectral bands for thematic mapping. Thus, satellite remote sensing may be useful for identifying land cover types in Nepal, and over a period of years, changes in land cover.

The objective of the study is to explore the feasibility of identifying changes in land cover in the Terai region of Nepal using satellite imagery.

Table 1: Range of the Multispectral Scanner (MSS) Spectral Bands

Bands Landsat 1,2,3	Bands Landsat 4,5	Spectral range (Micrometers)
4	1	0.5-0.6 (blue)
5	2	0.6-0.7 (green)
6	3	0.7-0.8 (red)
7	4	0.8-1.1 (Infra-red)

Table 2: Thematic Mapper (TM) Spectral Bands

Band	Wavelength (mm)	Nominal spectral location	Main Application
1	0.45-0.52	Blue	Plant stress discrimination & mapping of soil and vegetation types.
2	0.52-0.60	Green	Measurement of green reflectance.
3	0.63-0.69	Red	Peak of vegetation and vigor assessment.
4	0.76-1.75	Near-IR	Maximum sensitivity to plant vigor.
5	1.55-1.75	Mid-IR	Differentiating between snow
7	2.08-2.35	Mid-IR	and cloud covered areas, and sensitivity to plant stress water.
6	10.4-12.5	Thermal-IR	A range of thermal mapping.

Source: Lillesand, T.M. and Kiefer, R.: 2nd ed. Remote Sensing and Image Interpretation (1987).

II. IMAGE AVAILABILITY

The project area chosen was the Chitwan National Park from Chitwan District situated in the Terai physiographic region. The selection of the area was based on the following criteria:

- this area belongs to the inner Terai or Dun valley grouped together into a single physiographic region known as the Terai i.e., a low land, plain area with a sub-tropical climate.
- this area comprises a forest composition typical of the whole Terai belt, i.e., Sal Type, Tropical Mixed Hardwoods, and Khair-Sissoo.
- problems such as degradation, forest depletion, and erosion are widespread in the park.
- this park possess various categories of land cover.
- this area has unique habitat for certain important wildlife species.

The process of data acquisition involved the following steps:

1. A request for information on Landsat imagery was made to the Customer Service, Earth Resources Observation System (EROS) Data Center, Sioux Falls.
2. EROS sent a list of all Landsat scenes available for the selected project area.
3. The methods for the Landsat search are Point Search, Area Rectangle, or Path/Row Inquiry. Generally, the most preferred search method is an identification of Worldwide Reference System (WRS) Path and Row Centers. The WRS is divided

into two types, WRS1 for the Landsat 1,2, & 3 and WRS2 for the Landsat 4 & 5. However, if the WRS information is unavailable, a geographic reference using Latitude and Longitude (Point Search/Area Rectangle option) will suffice.

4. The final selection of imagery was made based on three criteria: minimum data quality, maximum cloud coverage, and preferred date of acquisition.
5. A total of 146 scenes representing a range of years and dates of acquisition of the study area were identified.
6. At the same time, a second request was made to Catalog Search Results, SPOT (Systeme Probatoire d'Observation de la Terre) Image Corporation. The same type of available imagery list was received, totalling 114 scenes.
7. On a SPOT search, two methods are used, KJ box point and Latitude/Longitude Polygon.

Clearly, a sufficient number of satellite images are available of the region, making its use for identifying changes in land cover possible.

III. Literature Review

Land Cover

For natural resource inventory and monitoring, accurate and current information on land cover is needed. In the context of the rapid change occuring in land cover due to increased human population pressure, and continued exploitation of natural resources, the resource managers and planners are looking for efficient and cost effective techniques.

Aerial photography has proved itself to be a useful tool for mapping over many decades because it possesses high spatial resolution, and can be utilized with simple methods of visual interpretation. However, space remote sensing with satellites created an alternative form of data acquisition for mapping.

Many published articles have cited Landsat data as a logical and supplementary source of data to the conventional method of aerial photography for type and change detection in land cover and land use. Many authors applied Landsat data successfully in operational programs of digital map production. Moreover, it helped in the identification and reduced the time required for the detection of land use features when incorporated with tone and pattern. In addition, a relationship between reflectance, slope and slope orientation improved accuracy in the classification of land cover and land use (Prout, 1980, Soloman et al., 1977, Pala et al., 1981).

Landsat MSS and TM data and imagery have been used in different ways and forms by developing techniques such as visual interpretation and computer --assisted classification with statistical procedures. It has been shown to be applicable for the assessment, evaluation and estimation of land use and land cover, and the extent of forest types. It provided a better result for land use and land cover identification when incorporating topographic influences. A description of techniques for land cover mapping is available in the literature (Pala et al., 1981).

Many statistical procedures used in the digital analysis of Landsat MSS have been described. The two main types of classification are often called supervised and unsupervised classification. In the supervised classification, the maximum likelihood classifier is most often applied to get a higher accuracy in the land cover classification (Adeniyi, 1985).

Landsat imagery can be compared with AVHRR (Advanced Very High Resolution Radiometer) on the basis of their accuracy performance and their cost-effectiveness. For land cover and land mapping, MSS gave higher accuracy (76.8%) than AVHRR (71.9%). On the other hand, the AVHRR result was better than MSS in classifying large homogeneous areas. AVHRR also provided a map with lower processing cost and its coverage is available more frequently all over the world (Gervin et al., 1985).

The SPOT satellite system has been evaluated for its utility, capability and applicability for discriminating land cover classes. A layered textural / contextual classifier approach is the preferred method because it requires much less input from operators. Moreover, the average accuracy obtained in land cover mapping determined by a field check was 90 per cent (Gastellu and Gambart, 1991). Another report mentioned that the Kappa coefficients also improved. Four feature groups, two training strategies, three classifiers and three accuracy assessment methods have been analyzed. Researchers found that single pixel training gave the largest contribution to improving classification accuracies. They also decided that the maximum likelihood classifier is better than the minimum euclidean distance classifier (Gong and Howarth, 1990).

A test was done to evaluate the monitoring capability of SPOT for land cover change that could be useful in land fill investigation. An enhancement of the digital image was carried out to obtain an accuracy of 95 % on the image interpretation. This imagery could be a cost effective tool for a county or regional monitoring program (Philipson et al., 1988).

Finally, in comparison to MSS, the SPOT XS (multispectral) data did not give any accuracy improvement on land cover, even when reducing the classification to fewer groups (three main groups). This result indicated that SPOT did not give more classification accuracy than Landsat MSS data. Another paper (Gong & Howarth, 1990) suggested that structural information generated from a SPOT HRV (High Resolution Visible) sensor, high resolution spectral image provided improved land cover classification when using the maximum likelihood classification. In this case, the overall accuracy was 86.1 per cent in discriminating twelve land cover types. (Baker et al., 1991, Gastellu & Gambart, 1991, Martin et al., 1988, Philipson et al., 1988, and Treitz et al., 1992).

A third sensor, Landsat TM is an improved and refined device having seven narrow bands especially designed for increasing discriminating capability for vegetative crops and land cover classification. A Landsat TM image was evaluated for nine categories of land use and land cover types. They concluded that TM was a very useful tool for identifying Level I (Anderson, 1976) land cover categories. Another report indicated that digital enhancement of TM under typical tropical environmental conditions gave improved accuracy for land cover maps. This improved accuracy may help in stratifying two density classes in each cover type based on texture information, greenness or wetness and near IR bands data (Khorram and Brockhaus, 1991, Marczyk et al., 1984, Roy et al., 1991).

SPOT Satellite

Work on simulated SPOT imagery was carried out to determine its usefulness for forestry applications such as species and growth potential. The resultant data was examined critically in order to find the level for mapping in terms of scale and classification accuracy. For that, various techniques such as different contrast stretches, band ratios, and filters were used to obtain an optimum classification. To further improve classification accuracy, an attempt was made to utilize texture analysis and terrain modelling (Dury, 1985).

In relation to the quality of imagery, SPOT and TM have better resolution than AVHRR. This was reported (Aridre, 1989) for identifying geological and topographic features. A provision for radiometric and geometric corrections creates ample opportunities to obtain a qualitative product (Begni, 1988). In addition, SPOT has eight gain settings with dark and bright albedos for collecting data, whereas other satellites have only two settings (Chavez & Pat, 1989). In relation to its spatial resolution, synoptic view, and higher resolution, SPOT imagery can be used to investigate river transportation systems (Lathrop and Lillesand, 1989).

The technique of Intensity-Hue-Saturation (IHS) was used to merge 10 meter panchromatic and 20 meter XS to enhance visual interpretability (Carper et al.,1990, Clinche et al.,1985). Due to the complementary nature of TM and SPOT, a procedure for merging 10 meter single band SPOT-panchromatic into the six band Landsat TM has been successfully applied (Chavez et al., 1991). In addition, the integration of SPOT and TM with GIS can provide data for routine up-dates for monitoring and inventorying forests (Goodenough, 1988).

Many authors have applied SPOT imagery in different ways to achieve their goals in terms of cartography, photogrammetry, and topographic mapping under a variety conditions and constraints (Ahearn and Wee,1991, Connars et al.,1987, Eyton, 1990,and Krattky, 1989). The most interesting approach among them was reflectance factor mapping for SPOT HRV (Martin & Howarth, 1989, Su, 1990, Theodossiou et al., 1990, Ungar et al., 1988, Westin, 1990, and Yang & Vidal, 1990).

Major areas chosen for the test of SPOT data were woodland and agricultural land. These two categories have great potential for primary application in several ways, such as detection of cover type change, discrimination of mine fields, extraction of map detail, delineation of fluvial networks for hydrological modelling, differentiation of levels for suspended sediments and development for elevation extraction (Buchhiem et al., 1985, Borengausser et al., 1985, Ciesla et al., 1989, Chamignon et al., 1990, Cugan & Dowman, 1985, De Gloria & Benson, 1987, Wulf et al., 1990, Ehlers et al., 1990, Eckhardt & Verdin, 1990, Guebert & Gardner, 1989, Gardner et al., 1989, Jones et al., 1988, Jewell, 1989, Merry et al., 1988,and Welch 1985).

Monotemporal SPOT HRV panchromatic and XS imagery have been used for the identification and classification of forest tree species using methods of digital classification and visual interpretation of digitally enhanced imagery . A study was undertaken on the relationship between sizes of land parcel units and pixel sizes of SPOT imagery. The study also assessed the geometric accuracy of SPOT XS (Borry & Rover, 1990, Gastellu, 1980, and 1990, and Konecny et al., 1987, Rodriguez et al., 1988). Many authors have investigated the utility of SPOT for mapping, estimating forest stand characteristics, monitoring forest cover change, discriminating multiple agriculture crop types, developing vegetation indices, and revising road networks (Aungenstein et al., 1991, Danson, 1987, Colwell & Poulton, 1985, De Gloria, 1985, Gallo & Daughtry, 1987, Jaskolla & Henkel 1988, Maillard & Cavayas, 1989, and Skidmore & Turner, 1988).

In comparison with other sensors such as TM, MSS, and AVHRR, SPOT was found to be better for the delineation of water masses based on gray levels because of its greater range (Ackleson et al., 1985). Landsat TM bands 1,3, 4, and 5 contain more spectral information for agricultural and geological applications than other sensors. Another author suggested that geo-corrected imagery was found to be useful for planimetric mapping except in hilly regions where a digital elevation model was required. Moreover, high resolution SPOT data was used to discriminate different species of vegetation, age classes, and cover densities (Agbu & Nizeyimana, 1991, Buttnerie & Csillag, 1982, Chavez & Bowell, 1988, Hill & Aifadopoulou, 1990, Park et al., 1987,and Quarmby & Cushnie, 1989).

IV. Study Area Description and Selected Images

The area chosen for study was the Chitwan National Park of the Chitwan District, which falls in the Dun valley within the Inner Terai physiographic region. This area has several problems, primarily deforestation and resulting soil erosion. This Park is composed of a variety of landforms with valuable and commercially important tree species. Predominant land cover categories are agriculture, water, grassland, and natural forest. The natural forest can be categorized into three broad types which are known as Sal, Tropical Mixed Hardwoods, and Khair-Sissoo.

An important consideration in any remote sensing mapping project is the system of categories to be identified. Categories should reflect user needs, and the biological conditions of the study area. A brief description of the major land cover types is given:

Agricultural Land

Agricultural lands are mainly used for the production of cereal crops. Parcels vary in shape and size.

Water Bodies

Water bodies refer mainly to perennial rivers, streams, lakes and ponds, as well as dry streams and rivulets.

Grassland

Grasslands are lands where the natural plants are dominated by grasses, forage and shrubs.

Forest land

The forest land is generally considered to be an area comprised of tree species with at least 10 % tree crown cover. It can be broadly classified into three types, called Sal, Tropical mixed hardwoods, and Khair-Sissoo.

Sal Type: This forest type consists of mainly Shorea robusta (Sal), Terminalia myriocarpa and Terminalia species, Schleicherea trijuga, Dillenia pentagyna, Anogeissus latifolia, Adina cardifolia, and others. Among these species, the type identification in the visual interpretation would be done mainly based on dominant species as Sal.

Tropical Mixed Hardwood Type: This type is identified when the forest contains less than fifty per cent Sal species other than associated miscellaneous species listed above. These species are Terminalia myriocarpa, Terminalia tomentosa and Terminalia belerica, accompanied by some Eugenia jambolana, Lagerstroemia parviflora, Dillenia pentagyna, Adina cardifolia (Haldu). The latter species is distinct in the type due to its large crown. Likewise, the dry type contains Terminalia sp., especially Terminalia tomentosa with scattered isolated Eugenia jambolana (Semal/Cotton tree).

Khair and Sissoo Type. This is a riverain type of forest. It is mainly composed of Acacia catechu (Khair) and Dalbergia sissoo (Sissoo) along with some shrubby types of undergrowth. These species mostly grow on new alluvium along streams and rivers in the Bhabar and Dun valleys. Both predominating species are deciduous in nature.

Characteristics of dominant tree species of the forest types

These descriptions were adopted from Dietrich Brandis,reprinted ed.,1972, The Forest Flora of North-west and Central India.

Sal Type

Sal -- This Sal species belongs to a family of Dipterocarpaceae. Its height is generally 80-150 feet. It is never quite leafless, and the young foliage issues in March. Leaves are glaborate, shinning when full grown 4-8", long petiole, broad-ovate, from a rounded or cordate base, entire more or less acuminate.

Terminalias (T. myriocarpa, T. chebula, T. tomentosa, & T. belerica) -- These species belong to a family Combretaceae. They are large trees. Their leaves are broad elliptic, or ovate-elliptic to oblong-ovate, 3 to 8 - 5 to 9 in. (bigger leaves in T. tomentosa). T. belerica and T. chebula shed their leaves in February and March; the new leaves emerge in April. T. tomentosa does not generally lose its leaves until February, March or April, but it is one of the latest trees in the dry forest to come out in fresh leaf with drooping branchlet. It is an evergreen tree.

Tropical Mixed Hardwoods Type

This forest type is identified as a class when the forest composition contains less than fifty per cent Sal. Generally, species are almost the same as in Sal type, as T. myriocarpa predominates with T. tomentosa and T. belerica accompanied by some E. jambolana, Lagerstroemia parviflora, Dillenia pentagyna, Adina cardifolia and Cedrela toona.

Eugenia jambolana or Bombax malabaricum or Salmalia malabaricum.

This is a large deciduous tree that covered with stout hard conical prickles; branches spreading. Leaflets 6-12 in., glabrous. Ascending to 3500 feet in the north-west Himalayan, and cultivated as high as 6000 feet. Leafless from Nov., Dec. until April. It is covered with the large scarlet flowers in Feb., March, and the fruit ripens in April and May. The trunk is straight, the upper part cylindrical, at the base generally with large buttresses, running up the trunk to some distance, and often 5 to 6 ft. deep near the ground.

Adina cardifolia (Haldu)

This is a large tree, branchlet, leaves, petioles pubescent. Leaves are cordate, short-acuminate, 4-9 in. long, nearly as broad as long. A common tree that is found throughout the moisture region of Nepal, and ascending to 3000 feet. Not gregarious. The old leaves shed April-May. The tree is then leafless for a short time, until the new foliage comes out in May and June. It flowers in June, July, and seeds ripen Dec. -- March.

Khair-Sissoo Type

This forest type is generally found near river banks where forest alluvial soil is deposited and classified as a riverain type forest. It is comprised predominantly of Khair and Sissoo.

Acacia catechu (Khair)

This tree comes under the family of Leguminoceae. A moderately sized tree with thorny branches and dark-colored bark. It ascends to 3000 feet in the valleys, generally gregarious in the sub-himalayan tract and the banks of rivers near their entrance into the plains. Flowers come out May-July; the new foliage appears March-April.

Dalbergia sissoo (Sissoo)

This is a large tree with brown heartwood. It is indigenous in the sub-himalayan tract, ascending to 3000 feet. Generally gregarious, mostly on sand or gravel all along the banks of river. The old leaves turn reddish brown, and begin to fall in Dec., but continue to be shed up to Feb. when the young foliage comes out, continuing until April. The full-grown foliage is of a fine clear green color. Young trees are occasionally leafless for a few week; old trees are hardly ever without leaves. Flowers comes out from March -- June; the seed ripens from Nov. -- Feb.; and generally remains long on the tree.

Selected Satellite Images

The following satellite images were selected upon consideration of biological phenomena and human activities. The imagery should be timed to capture the maximum spectral difference between the desired categories. The tree leaves shed for only a short period, and flowering and fruiting normally occur in the months of March and April. Change detection and identification of land cover will be appropriate when there will be less human activity and biological change. Forestry activities such as cutting and cultural operations are performed normally during the late winter and the spring. Also, activities on agricultural land such as harvesting, ploughing, and planting are done in the winter and rainy season. Therefore, the selection of an autumn image will likely be better because there will be less deviations in the reflectance value.

a) Landsat MSS imagery scene of path 152 and row 41 covers the area of interest, the Chitwan Valley in the latitude of 27^0 30' East and longitude of 84^0 20' East. The images selected were LM 8109104231500 dated 10/22/72 and LM 8264504011500 dated 10/28/76.

b) SPOT: A scene (J row - 295 , K column - 223 and 224) is available on date of 11/07/86.

V. <u>An Example Classification Project</u>

Introduction

Budget and time constraints prevent us from performing a classification project on the selected images of Nepal. Thus, an example land cover classification project was carried on using an image of the Blacksburg, Virginia. The intent was to actually perform a complete classification as part of this M.F. project. The area chosen for the project was centered near the town of Mc Coy, in northwestern portion of Montgomery County, Virginia.

Objective

The objective of this classification project was to develop two maps of Land Use / Land Cover of the study area from satellite imagery. One map was developed using supervised classification techniques, and one using unsupervised techniques.

Data

A subset of a SPOT multispectral image with 512 rows by 512 columns scene of the study area was provided for the digital analysis. The 3-band, XS scene was acquired during the early spring season and has 20 meter resolution.

Procedure

Land Use / Land Cover types to be mapped

Five categories of Land Use / Land Cover were of interest in the study: Water, Developed Land, Agricultural Land, Deciduous Forest, and Coniferous Forest. Each category was defined as follows:

a) Water: This category included open water, lakes, streams, ponds, and rivers.

b) Developed Land: Under this category, there were residential areas, commercial land, and industrial land that includes roads and railroad.

c) Agricultural Land: This covered those areas which are dedicated to row crops, pastures, and orchards. It should be mentioned that less than 15 % forest cover is allowed to be classified as agricultural land.

d) Deciduous Forest: This classification requires more than 15 % forest cover having more than 50 % deciduous species.

e) Coniferous Forest: This class requires more than 15 % forest cover having more than 50 % coniferous species.

Unsupervised classification

Unsupervised classification is used for discriminating spectral classes in a digital image. It is defined as a means by which pixels in an image are assigned to spectral clusters without a priori knowledge of desired categories. The unsupervised classification was performed using clustering methods in VGA ERDAS version 7.5. The analyst then matched final spectral clusters to actual desired categories using maps, aerial photos or ground information.

The following ERDAS commands were used in the unsupervised classification:

CLUSTR (Sequential Clustering): This command in ERDAS is used for clustering data from the input image file.

The CLUSTR command performs two functions, clustering and classifying. It processes the image data in two passes. In the first pass, the program reads the entire data set, and builds clusters sequentially based on spectral values and certain specified parameters (for instance,the desired number of clusters). It then computes the spectral mean vector for each cluster. In the second pass, it calculates the spectral distance from each candidate pixel to the mean value of each cluster. The candidate pixel is assigned to the cluster with the minimum spectral distance.

COLORMOD: This command executes a multipurpose color selection, modification, and management program. It provides a variety of options to control the colors displayed in the clustered image. Each pixel has an R G B look up table of intensities for each colorgun. An image memory value to be displayed is mapped through its corresponding

RGB values in the look up table to produce the color on the display. COLORMOD has a variety of options to create, modify, save, retrieve, and display individual colors and color schemes in both the image and overlay planes.

Supervised classification

Supervised classification is a technique commonly used for quantitative analysis of remote sensing image data. This method uses an algorithm to label the pixels in an image using pixels that the operator identifies as being in a particular land cover category. For performing the supervised classification, the essential steps were as follows:

1) Using a color aerial photograph, representative areas were selected to serve as training sites. The same image data (3 bands multispectral SPOT) as in the unsupervised classification was used.

2) Several training sites were chosen for each land cover class based on personal knowledge, a site visit of the area, and photo- interpretation.

3) Spectral signatures were generated from the training area data and employed in the maximum likelihood classifier to allow all pixels to be placed into one of the land cover/land use classes. A maximum likelihood algorithm selected over the

parallelepiped classification algorithm in order to avoid overlapping pixels, as well as the occurrence of unclassified pixels. Keeping in mind all the above steps, the supervised classification was undertaken using the ERDAS software package. It was implemented for the five categories of land use/ land cover defined.

For classifying spectral signatures by supervised classification using the ERDAS program, the following commands were used:

a) **SEED** (SEED selection of training samples):

This program had the capability to identify groups of adjoining homogeneous pixels based on spatial and/or spectral parameters. It began with an operator selecting a model pixel for each category and the adjoining pixels were compared. Subsequently, mean and variance of the sample pixels were calculated. This process repeated either until all adjoining pixels satisfied the spectral parameters, or the sample reached the limit set by the spatial parameters. Another function of SEED was to create or add to a signature file (SBD extension) that contained the statistics of each sample. Moreover, it was used as input to SIGMAN, a command for signature manipulation.

b) **SIGMAN**:

This command was used to view and manipulate signatures. The main functions of this command were:

- decision rule for the parallelepiped or minimum (spectral) distance.
- view and print reports of statistics and histograms.
- merge, delete, and rename signatures, and specify the order and number of signature to use for SBD file.

c) **MAXCLAS** (Classification)

This command performs a classification on an input LAN file using a Bayesian maximum likelihood decision rule. It first provides the option of narrowing down the number of possible classes for each pixel by using a parallelepiped decision rule.

In relation to signatures and classes, MAXCLAS received information from the signature file (SBD) as input for each land cover/land use class. That signature file was created during the process of training. The output GIS class names would be the same as the input signature names.

Results and Discussion

Table 3 presents the clustering statistics for the unsupervised classification. The 27 clusters were grouped by category. The major three cover classes (developed land, agricultural land, and forest) occupied almost 89 % of the total land area. Other minor classes occupy 5.2 % of the area. This method classified only 94.2 % of the total land area. The remaining percentage in the total number of pixels were unclassified, an inherent limitation of the classification.

Table 4 presents the results of the supervised classification after performing the MAXCLAS routine. It gave seven spectral classes which represented different land cover/land use groups as described in previous section. Out of the seven classes, Agricultural Land, Developed Land and Deciduous Forest occupied 91.7 % of the scene. Almost all pixels were classified. Some differences in the classification are apparent. Agriculture, Shadow, and Cloud are similar in the two maps. However, there was far less Developed land identified in the supervised map, and far more Deciduous Forest. Either the signature identified in the supervised method were unrepresentative or in error , or cluster(s) were incorrectly matched to categories during the unsupervised procedure. This kind of difference in result is not expected.

Table 3: Classification results for unsupervised classification method

Category	Clusters	Percent of total area
Developed land	1,5,9,21,	
	10,11,12	33.8
Agriculture	2,7,14	24.6
Water	19	1.3
Deciduous forest	3,4	21.8
Coniferous forest	6,16	9.1
Cloud	18	1.7
Shadow	15,27	2.2
	Total	94.5

Table 4 : Classification results for the supervised method

Class	No. of points	Per cent of total	Cover type
1	65116	24.8	Agriculture
2	14789	5.6	Conifer forest
3	0	0.0	Water
4	3533	1.3	Cloud
5	3342	1.3	Shadow
6	32666	12.5	Developed land
7	142698	54.4	Deciduous forest
Total	262144	99.9	

The two classification methods are also different in their ease of use. The unsupervised classification was less complicated to use because it relied on only a few commands, whereas the supervised had several steps and was tedious. The most tedious aspect in the supervised procedure was the need for a priori knowledge of categories in order to establish the training samples, which was difficult and time consuming.

5. Conclusion and opinion

Large differences, especially in Deciduous Forest / Developed land were apparent, but no accuracy assessement was performed to determine which classification was better. In real situations, an accuracy assessment is required to evaluate the quality of the classification.

The techniques of supervised and unsupervised classifications are equally useful, each in their own way. Supervised methods are lengthy and complicated, and can be used where some information on cover types is available. On the other hand, the unsupervised technique is good for determining spectral class composition when less is known about the area, or if the area is ecologically diverse.

VI. ANNOTATED BIBLIOGRAPHY

For this study, various articles were collected from different international journals, symposia, and proceedings. Our main goal was to locate published papers relevant to the problem of using satellite remote sensing to identify land cover changes in Nepal. The collected articles were principally from the International Journal of Remote Sensing (Int. J. Remote Sensing), Photogrammetry Engineering and Remote Sensing (PE & RS), Remote Sensing of Environment (R. S. Environ), Canadian Journal of Remote Sensing and Proceedings of the Canadian Symposium on Remote Sensing.

Land Cover

1. **Adeniyi, P. O.,** 1985, Digital Analysis of Multitemporal Landsat for Land-Use / Land Cover Classification in a Semi-Arid Area of Nigeria, PE & RS, Vol.51, No.11. 1761 - 1774.

A specific goal of the paper was to determine if a classification of land use and land cover for a semi-arid area of Nigeria using a multispectral Landsat MSS classification could provide basic, up-to-date, location specific as well as a quantitative data on broad categories of land use and land cover. The designated land use and land cover classes were separable and were statistically accurate.

2. **Baker, J. R., Briggs, S. A., Gordon, V., Jones, A. R., Settle, J. J., Townshend, J. R. G., and Wyatt, B. K.,** 1991, Advances in Classification for Land Cover Mapping Using SPOT HRV Imagery, Int. J. Remote Sensing, Vol.12, No.5, 1071 - 1086.

The authors attempted to use SPOT HRV for mapping semi-natural and agriculture land cover. They found that a classification of land cover types by using training data from spectral feature space was not adequate for improving classification. Digital terrain information could be useful for reducing the effect of topography on the spectral information.

3. **Dwivedi, R. S. and Shanker, T. Ravi.,** 1991, Monitoring Shifting Cultivation Using Space-borne Multispectral and Multitemporal Data, Int. J. Remote Sensing, Vol.12, No.3, 427 - 434.

By examining two different dates, Landsat MSS data for 1978 and 1984, shifting cultivation was detected successfully using monoscopic interpretation.

4. **Gervin, J. C., Kerber, A. G., Witt, R. G., Lu, Y. C., and Sekhon, R.,** 1985, Comparison of Level I Land Cover Classification Accuracy for MSS and AVHRR data, Int. J. Remote Sensing, Vol.6, No.1, 47 - 57.

The authors claimed that AVHRR data gave better results than MSS, especially when classifying large homogeneous areas. In this study, AVHRR had a classification accuracy of 71.9 % while MSS had 76.8 %. However, considering worldwide availability and lower processing cost, AVHRR seems more promising for the regional land cover mapping.

5. **Gautam, N. C. and Chennaiah, G. H.,** 1985, Land-Use and Land-Cover Mapping and Change Detection in Tripura Using Satellite Landsat Data, Int. J. Remote Sensing, Vol.6, No.3 & 4, 517 - 528.

When using Landsat digital data, the accuracy of a land cover map was 91 %.

6. **Gastellu-Etchegory and Gambart, D. Ducros,** 1991, Computer- Assisted Land Cover Mapping with SPOT in Indonesia, Int.J.Remote Sensing, Vol.12, No.7, 1493 - 1508.

According to the study, using SPOT HRV for the investigation of spectral characteristics validity for classifying large areas. The conclusion was that both an interactive box classifier with visual interpretation and a layered textural/ contextual classifier gave similar results. However, the layered textural/contextual approach was preferred because it required less input from operators. In addition, a large number of land cover classes was retained, and it produced Level II land cover maps (Anderson, 1976). By checking results in the field, the accuracy was found to be 90 %.

7. **Gong, P. and Howarth, P. J.,** 1990, The Use of Structural Information for Improving Land-Cover Classification Accuracies at the Rural-Urban Fringe, PE & RS, Vol.56, No.1, 67 - 74.

These authors suggested that structural information generated from the high resolution spectral image of SPOT XS band 1 data could improve a land cover classification. An algorithm for edge extraction was used, and it produced an edge density image. The authors concluded that structural information generated from the high spatial resolution data of SPOT XS could readily combine with spectral data for image classification. The edge density image could help the distinguish between rural and urban areas. Classification accuracies increased from 76.6 % to 86.1 % in overall.

8. **Gong, P. and Howarth, P. J.,** 1990, An Assessment of Some Factors Influencing Multispectral Land-Cover Classification, PE & RS, Vol.56, No.5, 597 - 604.

The main goal of this research was to evaluate the accuracies at different stages of land cover classification. The analysis was conducted on four feature groups, two training strategies, three classifiers, and three accuracy assessment methods. The four features were derived from SPOT HRV data. For calculation of the training statistics, single pixel training and block training methods were applied in each image (3 original SPOT HRV and one-edge density image). The results of the classification were assessed in terms of Kappa coefficient. It was noted that the single pixel training gave more accurate results than the block training. The maximum likelihood classifier produced the highest percentage of accuracy.

9. **Hudson, W. P.**, 1987, Evaluating Landsat Classification Accuracy from Forest Cover Type maps, Canadian J. Remote Sensing, Vol.13, NO. 1, 39 - 42.

The primary goal was to evaluate the validity and effectiveness of using forest cover type maps for determining Landsat classification accuracies. The finding was that discrepancies between minimum-type-size and crown closure estimates of forest were determined to be primarily caused by the classification.

10. **Hudson, W. D.**, 1987, Evaluation of Several Classification Schemes for Mapping Forest Cover Types of Michigan, Int. J. Remote Sensing, Vol.8, No.12, 1785 - 1796.

In relation to its effect on overall classification accuracy, the author examined seasonal variation, interpreting procedures, and vegetative composition and distribution. He found that the visual interpretation was ranked the best, but was least accurate depending on the distribution of spatial characteristics and composition of the forest cover.

11. **Khorram, S., Brockhaus, J. A., and Geraci, A.,** 1991, A Regional Assessment of Land Use/Land Cover Types in Sicily with TM Data, Int. J. Remote Sensing, Vol.12, No.1, 69 - 78.

A study was conducted to evaluate Landsat TM data for obtaining information on land use / land cover types. Here, the Landsat TM, along with accurately collected ground truth data, produced a better result for mapping of Anderson Level I and selected Level II categories in terms of time consumption and cost-effectiveness.

12. **Lo, C. P.,** 1981, Land Use Mapping of Hong Kong from Landsat Images - An Evaluation, Int. J. Remote Sensing, Vol.2, No.3, 231- 252.

It was confirmed that an analytical method based on a computer would give more detailed information on urban land-use, but the final accuracy achievement was poor i.e., only 69 %.

13. **Marczyk, J. S., Karpuk, E. W., & Rayner, M. R.,** 1984, Digital Landsat Data for Land Cover and Land Use Classifications for Use in Integrated Resource Planning: A Feasibility Study, Canadian J. Remote Sensing, Vol.10, No.2, 177 - 189.

The goal was to determine whether digital Landsat data could be used to map land use and land cover both accurately and inexpensively as a complementary source of data. The paper illustrated that the use of digital Landsat data had been proved technically feasible for producing land cover and land use map.

14. **Martin, L. R. G., Howarth, P. J., & Holder, G. H.,** 1988, Multispectral Classification of Land Use at the Rural - Urban Fringe using SPOT Data, Canadian J. Remote Sensing, Vol.14, No.2, 72 - 79.

An aim was to show the extent to which supervised and unsupervised classification of SPOT XS data can be used to identify land cover and land use at the rural-urban fringe. The paper concluded that the SPOT XS data provided more detailed land cover and land use than Landsat, primarily because it had a higher spatial resolution and could detect a smaller parcel of land with the greater precision.

15. **Nelson, R. F.**, 1981, A Comparison of Two Methods for Classifying Forest Land, Int. J. Remote Sensing, Vol.2, No.1, 49 - 60.

The author reported on two methods developed for use with Landsat MSS. On the first method, called as P-1, a semi-automated approach was used to develop training statistics for land cover types. The second method was called multicluster block, and depends on analyst interaction in order to produce training statistics used by the classifier. The results of the P-1 approach indicated that the resource managers could use it to detect major changes such as burns, blowdown, major disease or insect infestation, or unrecorded cutting.

16. **Nelson, R., Case, D., and Horning, N., Anderson, V., and Pillai, S.**, 1987, Continental Land Cover Assessment Using Landsat MSS Data, Remote Sens. Environ., Vol.21, 61 - 81.

An objective of this investigation was to describe a rigorous sampling procedure which incorporated Landsat MSS digital data in order to derive level II information on a subcontinental area. The results showed that a two-stage cluster sample within a stratified random sampling procedure could be appropriately used to estimate the extent of conifer/hardwood cover types.

17. **Prout, N. A.**,1980, Land-Use / Cover Mapping for Halifax County: Remote Sensing Alternatives, Proceedings of the Sixth Canadian Symposium on Remote Sensing, 307 - 320.

The author illustrated a simple method of land use/land cover mapping using Landsat remote sensing as an alternative to smaller scale B/W photography and color infrared photography. According to him, the remote sensing technique was widely used, and relatively inexpensive.

18. **Philipson, Warren R., Barnaba, Eugenia M., Ingram, A., and Williams, V. L.**, 1988, Land Covering Monitoring with SPOT for Landfill Investigations, PE & RS, Vol.54, No.2, 223 - 228.

A specific objective for this study was to determine the capacity for monitoring land cover changes that could be significant in the investigation of landfills. The results obtained showed that SPOT imagery (10 meter resolution of Panchromatic and 20 meter resolution of 3-band multispectral) could do well enough for detail change in land cover for landfill investigation. For an areas like a county or state, the imagery product will be cost-effective tool.

19. **Pala, S., Ellis, T. J., & White, D. B.**,1981, Operational Land Cover Type Mapping in Ontario by Landsat-Based Digital Analysis and Map Production, Proceedings of the 7th Canadian Symposium on Remote Sensing, 42 - 50.

An intention of the paper was to describe an operational program of land cover mapping based on the digital analysis of Landsat data and digital map production for the province of Ontario, Canada. They found that digital analysis of Landsat data in hard-copy format served as a new generation map of land cover and land use.

20. **Roy, P. S., Ranganathan, B. K., Diwaker, P. G., Vohra, T. P. S., Bhon, S. K., Sing, I. J., and Pandian, V. C., 1991,** Tropical Forest Type Mapping and Monitoring Using Remote Sensing, Int. J. Remote Sensing, Vol.12, No.11, 2205 - 2226.

The authors suggested that digital enhancement technique under typical conditions using Landsat TM gave useful results. It increased the confidence level of visual mapping because the spectral band combination of 3, 4 and 5 for vegetation type stratification was suitable for discriminating tropical forest types. In addition, it indicated a further possibility for stratifying two density classes in each type with a combination of texture information, greenness or wetness and near IR band data.

21. **Solomon, S. I., Aggarawal, A. S., Nazar, T., & Chadwick, T.**, 1977, Use of Topographic Data for Land Use / Cover Identification by Landsat Imagery, Proceedings of 4th Canadian Symposium on Remote Sensing, 158 - 162.

A study was undertaken to determine the incoming and reflected radiation from an area detected by Landsat. It was found that developing a relationship between reflectance, slope, and slope orientation could improve the accuracy of the land cover and land use classification derived from Landsat data.

22. **Treitz, P. M., Howarth, P. J., and Gong, P.**, 1992, Application of Satellite and GIS Technologies for Land Cover and Land Use Mapping at the Rural Urban Fringe, PE & RS, Vol.58, No.4, 439 - 448.

In this study, the main purpose was to produce a updated land cover map using SPOT HRV imagery, GPS data, and zoning information. The SPOT HRV data was found to be satisfactory. However, the SPOT HRV XS and P data could be jointly used to provide sufficient detail in perpetuity to routinely update map information. Through integration of zoning and land cover and land use information extracted from the digital classification of SPOT HRV data, an intermediate map could be prepared for monitoring the landscape change. This technique was highly applicable where rapid change occurred, especially in rural-urban fringe areas.

23. **Wilson, J. D.**,1992, A Comparison of Procedures for Classifying Remotely-Sensed Data Using Simulated Data Sets, Int. J. Remote Sensing, Vol.13, No.2, 365 - 386.

The main aim of this paper was to study a number of different land cover classification procedures systematically. Here, three algorithms such as a minimum distance classifier (MD), a maximum likelihood classifier (ML), and a penalized maximum likelihood classifier (PL) were comparatively tested on different land cover-maps. Results obtained indicated that MD classification gave poor classifications with an accuracy of 70% for pure pixels. On the other hand, the ML gave accuracy of over 90%. This improvement was achieved due to the introduction of contextual information which helped to correct misclassification. PL produced marginal improvements with some computational cost.

<u>On SPOT satellite</u>

1. **Ackleson, S. G., Klemas, V., Mckim, H. L., & Merry, C. J.,** <u>A comparison of SPOT simulator data with Landsat MSS imagery for delineating water masses in Delaware Bay, Broadkell River and adjacent wetlands</u> ,PE & RS 8 : 1985 : 1123.

   The paper focused on comparing SPOT simulator data with Landsat MSS data with respect to the range of gray level values for all water areas. Good results can be achieved by the SPOT simulator data because of its greater range of gray values.

2. **Aridre, C. G.,** <u>Evidence for Phanerozoic reactivation of the Najd Fault system in AVHRR, TM, and SPOT images of central Arbia</u>, PE & RS 8 : 1989: 1129 - 1136.

   This is a geological and topographical study conducted with the help of TM and SPOT imagery and AVHRR. It gives a low resolution. Therefore, some objects may not be identified very clearly.

3. **Ahearn, S. C., & Wee, C.,** <u>Data space volumes and classification optimization of SPOT and Landsat TM data</u>, PE & RS 1: 1991: 61 - 65.

The main intention of the paper is to highlight data space volumes of several band combinations of Landsat TM with SPOT XS for three data sets.

4. **Agbu, Patrick A., & Nizeyimana, E.**, Comparison between spectral mapping units derived from SPOT image texture and field soil map units, PE & RS 4 : 1991 : 397 - 405.

   This paper describes a technique for estimating overall accuracy of soil spectral classes of SPOT data which are improved after merging digital elevation model data with imagery data.

5. **Aungenstein, Eric W., Stow, Douglas A., & Hope, Allen S.**, Evaluation of SPOT-XS HRV data for Kelp resource inventories, PE & RS 5 : 1991 : 501 - 510.

   The main purpose of the article is to evaluate the utility of digital multispectral radiance data acquired from the SPOT HRV for mapping the distribution and abundance of Kelp resources.

6. **Buchhiem, M. P., Maclean, A. L., & Lillesand, T. M.**, Forest cover type mapping and spruce budworm defoliation detection using simulated SPOT imagery, PE & RS 8 : 1985 : 1115.

The main intention of this paper is to examine the future potential of SPOT satellite data for forestry applications: forest cover type mapping and spruce budworm defoliation detection (applied techniques are visual interpretation and traditional supervised classification).

7. **Borengausser, M. X., & Taranik, J. V.,** Evaluation of SPOT simulator data for the detection of alteration goldfield/cuprite,Nevada, PE & RS 8: 1985 : 1109.

The SPOT simulator data could be used for mining application such as gold and silver detection in south central Nevada, mainly because of the high spatial resolution(10 m or 20 m) and sensitivity to iron oxides.

8. **Borry, F. C., & De Rover, B. P.,** Assessing the value of monotemporal SPOT-1 imagery for forestry applications under Flemish conditions, PE & RS 8: 1990 : 1147 - 1153.

The characteristics of monotemporal SPOT-imagery are a great help in forest tree species and forest tree classification. Furthermore,the study distinguishes between the performance of conventional digital classification techniques and visual interpretation of digitally enhanced monotemporal SPOT imageries.

9. **Begni, G.,** SPOT image quality, Int. J. Remote Sensing, 1988, Vol.9, No.9, 1409 - 1414.

The geometric and radiometric image quality parameters of SPOT are discussed in the paper.

10. **Buttnerie, G., & Csillag, F.,** Comparative study of crop and soil mapping using multitemporal and multispectral SPOT and landsat TM data, R.S.Envion., Vol.29, No.3, 1982, 241 - 249.

The paper describes the capability of SPOT and other images, such as Landsat TM and aerial photographs for separability assessment, classification of main crops, data quality and information content in the imagery.

11. **Chevrel, M., Courtois, M., & Weil, G.,** The SPOT satellite remote sensing system, PE & RS 8 : 1981: 1163.

This article presents a general idea about SPOT mission objectives and satellite characteristics.

12. **Ciesla, W. M., Dull, C. L., & Acciavatti, R. E.**, Interpretation of SPOT color composites for mapping defoliation of hardwood forests by Gypsy Moth, PE & RS 10 : 1989 : 1465 - 1470.

The paper mainly dealt with visual interpretation of SPOT-1 color composite transparencies for mapping of Gypsy-Moth defoliation. The accuracy is relatively higher in SPOT-1 imagery than in CIR panoramic aerial photos.

13. **Colwell, R. N. & Poulton, C. E.**, SPOT simulator imagery for urban monitoring: a comparison of Landsat TM and MSS imagery with high altitude color infrared photography, PE & RS 8 : 1985 : 1093

Simulated SPOT data is useful for assessing multiple crop types and agronomic conditions.

14. **Chavez Jr., P. S. & Bowell, J. A.**, Comparison of the spectral information content of Landsat TM and SPOT for three different sites in the Phoenix, Arizona region, PE & RS 12 : 1988 : 1699 - 1708.

The main conclusion of the study is that Landsat TM bands 1, 3, 4, and 5 contain more spectral information than SPOT XS, especially for agriculture and geologic sites.

15. **Chavez Jr., Pat S.,** Base of the Variable Gain Settings SPOT, PE & RS 2: 1989 : 195 - 201.

Normally the satellites are provided with two gain settings, low and high, whose functions are to increase and decrease brightness or reflectance resolution affecting the DN range in the image. The SPOT has eight settings for collecting data of area with dark and bright albedos.

16. **Carper, W. J., Lillesand, T. M., & Kiefer, R. W.,** The use of Intensity - Hue - Saturation transformation for merging SPOT-panchromatic and multispectral age data, PE & RS 4 : 1990 : 459-467.

This article illustrates the use of the hue technique for merging SPOT - 10 m resolution panchromatic data with 20 m resolution multispectral data in order to create a composite image of enhanced interpretability.

17. **Clinche, G., Bonn, F., & Teillet, P.,** Integration of the SPOT Panchromatic channel into its multispectral mode for image sharpness enhancements, PE & RS 3 : 1985 : 311.

SPOT can produce a high resolution image for photo interpretation by integrating 10 m panchromatic channel into its 20 m multispectral data.

18. **Chavez Jr., P. S., Sides, S. C., & Anderson, J. A.,** Comparison of three different methods to merge multi-resolution and multi-spectral data: Landsat TM and SPOT panchromatic, PE & RS 3 : 1991 : 295-303.

The study describes a procedure for merging data from 10 m single band SPOT panchromatic and the six reflective bands of Landsat TM because of their complementary nature.

19. **Chamignon, C., & Maniere, R.,** Forest cover type mapping and damage assessment of Zeiraphira diniana by SPOT - 1 HRV data in the Mercantour National Park, Int.J.Remote Sensing, 1990, Vol.11, no.8, 1439 - 1450.

The study investigates the usefulness of high resolution satellite imagery such as SPOT HRV and Landsat TM for land-use monitoring.

20. **Connors. F., Gardner, T. W., & Peterson, G. W.,** Classification of geomorphic features and landscape stability in Northwestern New Mexico using simulated SPOT imagery, R.S.Environ., Vol.29, No.2, 1987, 187 - 207.

The paper justifies the use of simulated SPOT data for identification and classification of landscape stability in semiarid environment.

21. **Cugan, D. J. & Dowman, I. J.,** Topographic mapping from SPOT imagery, PE & RS 10 : 1985 : 1409 - 1414.

The objective here is to extract map detail from SPOT somewhere between that of small scale aerial photography and Landsat TM -imagery.

22. **Danson, F. M.,** Preliminary evaluation of the relationships between SPOT-1 HRV data and forest stand parameters, Int.J. Remote Sensing, 1987, Vol.8, No.10, 1571 - 1575.

SPOT imagery data could provide a high potential tool for the estimation characteristics of forest stands and monitoring changes.

23. **De Gloria, S. D.**, Evaluation of simulated SPOT imagery for the interpretation of agricultural resources in California, PE & RS 8 : 1985 : 1103.

An idea is proposed to use SPOT imagery for discriminating multiple agricultural crop types.

24. **De Gloria, S. D., & Benson, A. S.**, Interpretability of advanced SPOT film products for forest and agricultural survey, PE & RS 1: 1987 : 37 - 44.

To study the interpretability of current and proposed SPOT imagery for forestry and agricultural applications in order to determine the capability of SPOT film products for discriminating forestry and agricultural resource categories.

25. **De Wulf, R. R., Goosens, R. E., De Rover, B. P., & Borry, F. C.**, Extraction of forest stand parameters from panchromatic and multispectral SPOT-1 data, Int. J. Remote Sensing, 1990, Vol.11, No.9, 1571 - 1588.

The study has analyzed the usefulness of SPOT data for discriminating among forest types.

26. **Ehlers, M., Jadkowski, M. A., Howard, R., Richard, B., & David, E. ,** Application of SPOT data for regional growth analysis and local planning, PE & RS 2 : 1990 : 175 - 180.

This paper describes SPOT imagery as a useful tool for timely and accurate analysis of regional urban and sub-urban development planning after combining image processing and GIS.

27. **Eyton J.R.,** SPOT PLA photographic image processing, PE & RS 8 : 1990 : 1129 - 1134.

Enhancement of SPOT panchromatic linear array (PLA) could be possible to obtain by adopting a method of effective photographic processing techniques.

28. **Eckhardt, D. W., & Verdin, J. P.,** Automated update of irrigated lands GIS using SPOT HRV imagery, PE & RS 11 : 1990 : 1515 - 22.

This paper discusses how spaceborne acquired imagery could be merged with accurate spatial information contained within a GIS to produce useful information for irrigated land management.

29. **Goodenough, D. G.**, TM and SPOT integration with a geographic information system, PE & RS 2 : 1988 : 167 - 176.

A mixture of automated and manual procedures is possible for providing routine updates to a GIS for monitoring and inventorying of forests.

30. **Guebert, M. D. & Gardner, T. W.**, Unsupervised SPOT classification and infiltration rates on surface mined watersheds, Central Pennsylvania, PE & RS 10 : 1989 : 1479 - 1486.

This study describes how SPOT data was used with unsupervised minimum distance classification to produce seven prominent spectral classes on four reclaimed mines and non - mined lands.

31. **Gastellu- Etchegory, J. P.**, An assessment of SPOT capability for cartographic applications Indonesia, Int. J. Remote Sensing, 1989, Vol.10, No.11, 1763 - 1774.

In this study, two different ideas can be extracted: 1) evaluation of the relationship between sizes of units and SPOT pixels, and 2) assessment of geometric accuracy of SPOT.

32. **Gardner, T. W., Connors, K. F., & Hu, H.**, Extraction of fluvial networks from panchromatic data in a low relief arid basin, Int. J. Remote Sensing, 1989, Vol.10, No.11, 1789 - 1801.

SPOT panchromatic data is useful for delineating fluvial networks for hydrological modelling in similar areas without topographic maps, or to update existing topographic maps.

33. **Gastellu-Etchegorry, J . P.**, An assessment of SPOT XS and landsat MSS data for digital classification of near-urban land cover, Int. J. Remote Sensing, 1990, Vol.11, No.2, 225 - 235.

This report describes the mapping ability and reliability of SPOT XS. Alternatively, Landsat was found to be good for overall information.

34. **Gallo, K. P., & Daughtry, C. S. T.**, Differences in Vegetation Indices for simulated Landsat-5 MSS and TM, NOAA-9 AVHRR and SPOT-1 sensor system, R. S. Environ., Vol.23, No.3, 1987, 439 - 452.

The aim of the paper is to evaluate the effects of different wavelength bands of Landsat - 5 MSS, NOAA - AVHRR, and SPOT - 1 sensors on two vegetation indices.

35. **Hill, J., & Aifadopoulou, D.**, Comparative analysis of Landsat- 5 TM and SPOT-1 HRV data for use in multiple sensor approaches, R. S. Environ., Vol.34, No.1, 1990, 55 - 70.

With reference to multiple sensor approaches in remote sensing, an analysis was conducted of geometric and radiometric accuracies of SPOT HRV and Landsat TM imageries. As a result, the acquired data were found to be quite acceptable for use in map production, except in the mountainous region where a digital elevation model is required to compensate for relief induced distortions.

36. **Jones, A. R., Settle, J. J., & Wyatt, B.**, Use of digital terrain data in the interpretation of SPOT - 1 HRV multi - spectral imagery, Int. J. Remote Sensing, 1988, Vol.9, no.4, 669 - 682.

The paper tries to explain the complementary use of digital terrain information and SPOT-1 HRV for the study and mapping of semi-natural upland vegetation. Moreover, digital terrain data was used to generate slope and aspect images.

37. **Jaskolla, F., & Henkel, J.**, Evaluation and digital processing of multispectral SPOT data, Int. J. Remote Sensing, 1988, Vol.9, Nos.10 & 11, 1629 - 1637.

As pointed out in the paper, the map guided approach could be used to revise the road network on a 1:50,000 scale topographic map, and is also applied to other features.

38. **Jewell,N.**, An evaluation of multi-date SPOT data for agriculture and land use mapping in the United Kingdom, Int. J. Remote Sensing, 1989, Vol.10, No.6, 939 - 951.

The main idea here is to determine major arable land cover types on SPOT data using methods of discrimination based on the analysis of the multi - date imagery.

39. **Konecny, G., Lohmann, P., Engel, H., & Kruck, E.**, Evaluation of SPOT imagery on analytical photogrammetry instruments, PE & RS 9: 1987: 1223 - 30.

This paper gives ideas concerning geometric correction of SPOT imagery with the help of photo co-ordinates.

40. **Krattky, V.**, On-line aspects of stereophotogrammetric processing of SPOT images, PE & RS 3 : 1989 : 311 - 316.

SPOT possesses a great potential in the context of cartography, photogrammetry and topographic mapping. The study highlights the principles of real time positioning.

41. **Lathrop Jr., R. G. & Lillesand, T. M.,** Monitoring water quality and river plume transport in Green Bay, Lake Michigan with SPOT - 1 imagery, PE & RS 3: 1989, 349 - 354.

The synoptic view of SPOT imagery can produce a high spatial resolution data base for investigating river plume transport.

42. **Merry, C. J., Mckim, H. L., Potim, N. La, & Adams, J. R.,** Use of SPOT HRV data in the corps of engineers dredging program, PE & RS 9: 1988, 1295 - 1299.

The study gives a clear indication about the usefulness of multispectral data for differentiating between relative suspended sediment levels at dredged disposal areas.

43. **Maillard, P., & Cavayas, F.,** Automatic map - guided extraction of roads from SPOT imagery for cartographic database updating, Int. J. Remote Sensing, 1989, Vol.10, No.11, 1775 - 1787.

After evaluation of SPOT simulation data, the SPOT data have indicated a high correlation between S1 and S2 spectral bands, and thus the SPOT can be considered a two - dimensional system from the spectral point of view.

44. **Martin, L. R. G., & Howarth, P. J.,** Change detection accuracy assessment using SPOT multispectral imagery of the rural - urban fringe, R. S. Envion., Vol.30., No.1, 1989, 55 - 66.

In this paper, studies are conducted to determine the capability of SPOT for providing information about the conversion of rural to urban land.

45. **Park, N. F., Peterson, G. W., & Baumer, G. M.,** High resolution remote sensing of spatially and spectrally complex coal surface mines of central Pennsylvania: A comparison between simulated SPOT MSS and Landsat - 5 TM, PE & RS 4 : 1987: 415 - 420.

The study attempted to create a new database from the high resolution data imagery in order to discriminate the different vegetation species, age classes and cover densities.

46. **Quarmby, N. A., & Cushnie, J. L.**, Monitoring urban land cover changes at the urban fringe from SPOT-1 HRV imagery in south-east England, Int. J. Remote Sensing, 1989, Vol.10, No.6, 953 - 963.

This research was undertaken to evaluate the use of SPOT HRV data in combination with digital terrain data and line information for land-use planning. It described change detection techniques which delineate areas of change in land use from rural to urban development, and for monitoring gravel extraction and land reclamation.

47. **Rodriguez, V., Gigord, P., De Gaujac, A. C., Munier, P., & Begni, G.**, Evaluation of the stereoscopic accuracy of the SPOT satellite, PE & RS 2 : 1988: 217 - 221.

The paper describes the method used for assessment, the sequence of operation and all the results obtained from the stereoscopic imagery of SPOT.

48. **Skidmore, A. K., & Turner, B. J.**, Forest mapping accuracies are improved using a supervised non - parametric classifier with SPOT data, PE & RS 10 : 1988: 1415 - 1421.

The main purpose of the study is to improve the accuracy of forest maps developed from remotely sensed data where supervised and unsupervised techniques have been adopted together.

49. **Su, Haiping**, Separability of soils in a Tallgrass Prairie using SPOT and DEM data, R. S. Envion., Vol.33, No.3, 1990, 157 - 163.

The main aim of the paper is to investigate the separability of soil spectral classes by using a canonical transformation technique. The authors extracted important soil features from SPOT imagery and DEM data, especially in the grassland.

50. **Theodossiou, E. I., & Dowman, I. J.**, Heightening accuracy of SPOT, PE & RS 12 : 1990 : 1643 - 49.

This paper attempts to assess the feasibility of using SPOT stereo data as a source of height information. This information is useful for topographic mapping.

51. **Ungar, S. G., Merry, C. J., Irish, R., Mckim, H. L., & Miller, M. S.**, Extraction of topography from side-looking system case study with SPOT simulation data, R. S. Envion., Vol. 26, No.1, 1988, 51 -73.

The main target of the study is to construct data sets of SPOT HRV in order to test techniques for the development of elevation extraction.

52. **Welch,R.**, Cartographic potential of SPOT image data, PE & RS 8: 1985 : 1085.

SPOT satellite imagery has unique capabilities for stereo-viewing, high spatial resolution(10 m and 20 m) and can produce good quality cartographic information.

53. **Westin, T.**, Precision rectification of SPOT imagery, PE & RS 2: 1990 : 247 - 253.

An aim of the paper is to produce accurate SPOT imagery by applying a method based on analytical photogrammetric instruments.

54. **Yang, C., & Vidal, A.**, Combination of digital elevation models with SPOT-1 HRV multispectral imagery for reflectance factor mapping, R. S. Envion., Vol. 32, No. 1, 1990, 35 - 45.

In this paper, an approach to reflectance factor mapping and SPOT HRV multispectral imagery is discussed as a fundamental problem of the remote sensing.

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