LANDSLIDE RISK ZONING THROUGH REMOTE REMOTE SENSING AND GIS

By

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FINAL PROJECT REPORT

Submitted to the Civil Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

December 2008

ABSTRACT

The purpose of this study is to classify relevant information from satellite image to be used in landslide risk zoning. The information needed consists of the types of land use at the study area such as arable land, dense forest, rocky area, agriculture, mixed cultivated and grassland. All the relevant information that are contributing to the landslide was extracted from the satellite image using the MultiSpecW32 software. The study area took placed at a certain area of Cameron Highlands which was located in Pahang, Malaysia. The types of land use extracted from the satellite image using image processing software and the steepness of the slopes determined using Arcview GIS 3.3 software later on were grouped base on the possibility for landslide to occur. The outcome of this study is expected to be able to assist the users to identify the area which are prone to landslide just by looking at the satellite image and land use.

Keywords: Satellite Image, Landslide Risk Zoning, Remote Sensing, Landslide.

ACKNOWLEDGEMENTS

In The Name of God, The Most Gracious and The Most Merciful,

First and foremost, I would like to take this opportunity to express my appreciation to those who had assisted me in completing my Final Year (Civil) Project successfully in partial fulfilment of the requirement for the Bachelor of Engineering (Hons) (Civil Engineering).

Here, I would like to thank my parents, Encik Kamarudin Abu Hassan and Puan Sapiah Jaffar for their cheers and continuous moral supports throughout these years. I also would like to thank the university, University Teknologi PETRONAS (UTP) and my project's supervisor, Assoc. Prof. Dr. Abdul Nasir Matori for his willingness to take me in as his subordinate for this final year project course. I also would like to express my deepest gratitude towards my supervisor and Mr. Abdul Basith for all their guidance, concerns, advice, teaching and care while having me as subordinate under them.

I also would like to extend my appreciation to the whole UTP Civil Engineering Department's staffs for their acceptance, co-operation, guidance and hospitalities. I was indebted to many individuals who assisted in developing my skills, knowledge and experiences.

Thanks to all again.

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

Christophe Bonnard and Jordi Corominas (2005) had defined landslides as local phenomena occurring in different geomorphic contexts. They can be triggered by variety mechanisms, some of which are not well known yet. The phenomena affect a wide range of lithologies (earth materials) while displaying complex run-out behavior and subsequent damaging capability. In other words, landslide is a mass movement of earth materials that can be caused by various factors and its effect can be significant damages to the surrounding areas.

There are many controlling factors that cause landslide, among them are:

- Slope Gradient
- Curvature
- Land Use
- Soil Thickness
- Mean Annual Rainfall
- Water Content

Image Classification is a method used to identify certain characteristics or properties of an image. It has very important role in many applications such as biomedical and remote sensing image analysis, industrial visual inspection, video surveillance and many more. In remote sensing image analysis fields, image classification is one of the methods use in monitoring the landslide occurrences and to predict the chances for landslide to occur. In this study, the satellite image is use as the data and image processing software as the interpreter to identify the significant characteristics of the satellite image such as terrains, land use, soil moisture content, surface conditions and many more. Most of the above characteristics have a direct effect towards the slope stability therefore it is very important to identify them in this study to generate risk zoning.

1.2 Problem Statement

The conventional practices for monitoring the slopes stability such as land survey and aerial monitoring required extensive analysis and consumed a vast amount of time. Therefore, the need to have a better slope monitoring system which can produce a better accuracy within limited amount of time is high. Satellite image is one of the sources that can be acquired with minimum amount of time. With further modifications, the satellite image has a potential to become one of the method to monitoring the area which are prone for landslide to occur by classifying the area under landslide risk zoning.

1.3 Objectives

i. To classify and extract relevant information from satellite image to be used in landslide risk zoning.
ii. To generate the land use risk map to be used for producing the landslide risk zoning.
iii. To generate the slope risk map to be used for producing the landslide risk zoning.

1.4 Scope of Study

To extract information from the satellite image with respect to land use and determination of slope steepness.

CHAPTER 2: THEORITICAL STUDIES

2.1 Landslide Controlling Factor

The urges to monitor the slope failure and to prevent the landslide from occur has caused the Malaysian Government to spend more than 400 million Ringgit Malaysia (RM) for the past ten (10) years. Until now, the Government still is funding researches and projects that relate with the slope failure and landslide with the aim to prevent the landside from happening and minimize the adverse effect of landslide toward citizen. Figure 2.0 below shows the landslide incident occurred at one of the road inside the study area.

Figure 2.0: Landslide at km26 of Pos Slim road (photo by Basith)

Most of the landslides occurrences were said due to heavy rainfall and the effect of the earthquakes which is the movement of the earth crust; but in current context, other factors such as uncontrolled development or unregulated land-use practices are also some of the factors that may lead to landslide occurrences. The followings are some of the landslide controlling factors point out by Ladas I., Fountoulis I. and Mariolakos I. (2007):

i. Slope Gradient

The slope gradient has a direct effect toward the chances for landslide to occur. During and after the rainfall, the surface runoff will formed and flow from high gradient to low gradient. The surface runoff flow does not only contain the rainfall, but it also brings together the soil which was eroded from the slope's surface. Therefore, the steeper the slope gradient, the higher the chances for landslide to occur due to soil erosion.

ii. Curvature

Curvature is one of the factors that can lead to landslide due to its physical form. The concave slope can retain more water and hold it for a longer period compare to the convex slope which can not contain water. This will give effect to the hydrological conditions of the soil cover and loosen the strength of the soil. The loosen soil will have a tendency to segregate and cause landslide.

iii. Land Use

Land use is considered as one of the factor that affects landslide due to its effects toward the hydrological conditions and soil strength. The examples of the types of land use on the slope are arable land, dense forests, agriculture, rocky areas, mixed cultivated-shrub areas and many more. An area on the slope which is covered with dense vegetation has lower chances for landslide to occur compared with an area which has nothing planted on it. The reason is because of the plants' roots. The roots have increased the shear strength of the soil by binding themselves with each other and hold the soil from segregates. This situation prevents mass erosion of rainfall towards the slope surface.

iv. Soil Thickness

The landslide also being affected by the soil thickness. Because, the thicker the soil, the bigger the force of the soil mass that can trigger the landslide due to the contact between the bedrock and the soil which will cause sliding force.

v. Mean Annual Rainfall

Rainfall has a direct effect toward the water content of the soil. Depending on the soil type, if the soil type is a peat soil which has more pores and low soil strength, heavy rainfall may further reduce the soil strength by infiltrate into the soil and seep through the soil pores. This situation will favors the landside occurrences.

vi. Water Content

The slope stability also been affected by the water content. Water content has a direct effect onto the soil strength whereby the water content affects cohesion, friction and normal stress of the soil. Harry Williams (2007) explains that moist soil will have water film in between the soil particles. The water film will create a negative pore water pressure which produced a suction force and this force increases the cohesion by attracting the particles together. As for the saturated soil, the excessive water content inside the soil creates a positive water pressure. The pressure will push the particles apart and act against the normal stress thus caused the normal stress to reduce. As the particles become apart, the cohesion and the friction force among the particles is reduced and caused the soil to lose its strength.

2.2 Remote Sensing, RS

Online Journal of Space Communication defined Remote Sensing, RS as the "gathering of data about distant objects without coming in direct contact with them". This type of data gathering method mainly involved the pictures and images taken either from aircraft or satellite. Therefore, it certainly deals with devices which react with electromagnetic energy such as camera. The images taken by the satellite commonly known as Satellite Remote Sensing, as for the aircraft it is known as Remote Sensing Photograph.

Remote Sensing uses a system which the data can be used to regenerate the images and also can detect the atmosphere (clouds), ocean and land surface. The data resolution can be divided into four types which are:

a. Spatial Resolution

   The measure of the smallest distance (linear or angular separation) between objects that can be resolved by the sensor.

b. Spectral Resolution

   Refers to the dimensions (widths) and wavelength region of electromagnetic spectrum a specific censor is sensitive to.

c. Radiometric Resolution

   The sensitivity of a remote sensing detector to variations in the intensity of the emitted, reflected or scattered electromagnetic energy that is being detected.

d. Temporal Resolution

   How often a remote sensor has the ability to record data over the same area.

The common resolution that been taken into consideration are spatial resolution and spectral resolution. The spatial resolution has high accuracy in term of the physical terrain of an image. As an example a forest area and an urban area can be easily differentiate with high spatial resolution. As for the spectral resolution, it is needed to determine the non-physical properties of an image such as the soil moisture content and vegetation area.

2.2.1 Image Classification

Image classification is a technique used to extract required information or details from an image. This technique is widely used to process the Remote Sensing data, which is by treating the image as two-dimensional signal and applies standard signal processing technique to the image. The signal processing is the analysis, interpretation and manipulation of signals such as image. Processing of such signals include filtering, storage and reconstruction, separation of information from noise and compression. All of these features enabled the classification of an image

2.2.2 Satellite Image

Satellite image is an image taken by the satellite from the outer-space which has many applications in agriculture, regional planning, geology, forestry and many more. According to Malaysian Centre for Remote Sensing (MACRES), generally there are a few types of satellite image but the most commonly used are LANDSAT, SPOT, IKONOS, RADARSAT and QuickBird. Each of these images differ in-term of their spectral resolution range and spatial resolution range.

In this study, the type of satellite image that will be used is SPOT 5. SPOT is stand for 'Satellite Pour l'Observation de la Terre' and this type of image is belong to the France because it been captured using their satellite. The difference of SPOT 5 than the SPOT 1, 2, 3 and 4 is in term of its spatial resolution. SPOT 5 offer higher resolutions of 2.5 to 5 meters panchromatic mode (one range wavelength) and 10meters for multispectral mode (four different range of wavelength) compare to the other types of SPOT.

The SPOT 5 is chosen over the other types of satellite image because it provided the highest spatial resolution with considerable cost. The high spatial resolution is very useful in determine the land use due to its high accuracy in physical terrain resolution of the study area

2.3 Risk Analysis Approaches

International Union of Geological Sciences (IUGS) Working Group on Landslides, Committee on Risk Assessment during their Workshop on Landslide Risk Assessment in February 1997 had managed to come out with approaches to conduct the risk analysis for landslide study. The approaches are as follows.

2.3.1 Qualitative Analysis

Qualitative landslide risk analysis generally involves the process of acquiring information of the hazards, the factors or criteria at risk and their susceptibility, and at the same time expressing the information qualitatively by ranking. The risk can also be expressed verbally or ranked but it still results from consideration, or combination of the basic information of the hazard, susceptibility and factors at risk.

2.3.2 Quantitative Analysis

The quantitative risk analysis of slopes and landslide consists of the following activities:

- Hazard Identification and Analysis

  To determine the probability and characteristics of slopes and the potential landslides
- Elements at Risk

  To determine the probability distribution for the number and the nature and characteristics of the elements at risk which may be affected by landslide
- Analysis of Vulnerability

  To assess the degree of damage, or probability of loss of life of the affected area due to landslide
- Risk analysis.

  To determine the probability distribution for the consequences arising from the landslide occurrences

CHAPTER 3: LITERATURE REVIEW

3.1 Satellite Remote Sensing

The satellite image has been used for many applications especially in remote sensing field whereby, it allows the users to conduct extensive analysis of the colour composites to determine the land use, land use changes and also to study the landslide. Sauchyn and Trench (1978) have studied the satellite image by experimented it with the use of a true colour composite (TCC) for remote sensing purposes.

However, in some cases, false colour composite (FCC) images have proven to be useful to identify changes in the surface properties such as the removal of forest which expose bare soil and lead to landslide occurrences. For example, Greenbaum et al. (1995) have successfully examined the landslide in Papua New Guinea by using this technique. Furthermore, similar results were also achieved by Rothery (1987) to identify rock avalanche deposits. Other than surface changes, satellite image also useful in identify moisturise soil which is also one of the factors affecting slope stability. Kusaka et al. (1996) as example had managed to identify areas of perennially wet soil by using LANDSAT thermal bands. Generally, the satellite image is suitable and can be used for monitoring surface changes, but the limitation of using the satellite image is the spatial resolution and shadows which affecting the analysis results.

3.2 Risk Zoning

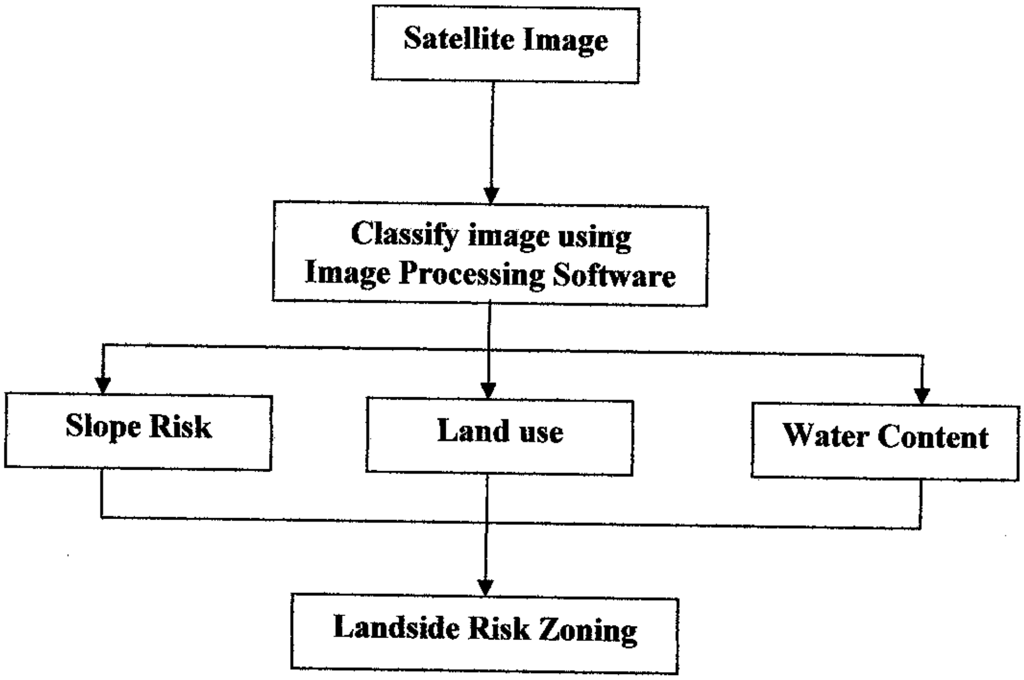
Zonation as defined by Varnes et al. (1984) and United Nations Educational, Scientific and Cultural Organization (UNESCO) is a term that applies in a general sense to division of the land surface into areas and the ranking of these according to degrees of actual or potential hazard for landslides or other mass movements on slopes. Meanwhile, risk can have various definitions and depending on the disciplines. As an example, in the insurance business, risk is often only the monetary component (Einstein HH, 1997) but in civil engineering disciplines, risk means "the uncertainty about the occurrences of an event" (Ioannou, 1984). Using the above definitions, risk zoning or mapping in this study can be defined as an area which been grouped and ranked by the potential for landslide to occurs.

There are a lots of technique been used to developed risk zoning and generally, each one of them are differ in term of method of analysis and the criteria being considered to produced the risk zoning. Carrara (1989) used the quantitative analysis to produce a landslide hazard mapping, where multivariate models were shown as the chances of actual and potential slope failures to occur in each of several zones studied in Italy. In his/her research, the author had listed three procedures for the site selection, which are, direct estimation by expert surveyors, 'index' thematic maps obtained by overlaying maps representing encoded slope instability factors that are rated and weighted, and statistical approach to actual/potential instability assessment using multivariate models to build hazard probability levels. The assumption made was 'the factors which caused and can cause the failures in the training areas are the same as those generating landslides' throughout the study area. Various factors were analysed and ranked into hazards levels and one of the factors is slope steepness.

Whereby for a study area in Swiss, Liener et al. (1996), have produced one type of hazard map, termed Simple Landslide Map or SLM through their proposed rule termed SLIDISP. SLIDISP is a procedure to locate landslide prone area through simplified safety factors obtained from geotechnical investigations such as slope topography, soil strength parameters, depths and shape of potential shear plane. The SLM, classify areas that are potentially hazard by comparing the slope angle, if the slope angle is steeper than the lowest critical slope angle, thus the probability for landslide to occur at that particular area is high. The research was done by estimating different slope angle through combination of landslide types and soil.

Another research to produce landslide susceptibility zonation was done by Clerici et al. (2002). The zonation was based on conditional probabilities using GIS and a scripting language for iterative processing. Five environmental factors that may contribute to landslide occurrences were considered and they are geology, land use, slope, rainfall, and bedding/topographic slope relationships. Five different maps were then generated from the above five factors and by overlying the five maps, the whole study area was divided into a number of 'unique-condition polygons'. The landslide susceptibility zones later on were generated through the overlying process.

CHAPTER 4: METHODOLOGY



4.1 Satellite Image

This research uses the Satellite Pour I'Observation de la Terre (SPOT) image as the medium to determine the characteristics of the study area. SPOT image is a high-resolution and optical imaging earth observation from the satellites. The image were acquired from the Malaysian Centre for Remote Sensing (MACRES). The location of the study area is Cameroon Highlands which located in Pahang state of Malaysia and the coordinate of the study area are as follows:

Top left point:		Bottom right point:	
Latitude	: 4° 42'	Latitude	: 4° 20'
Longitude	: 101° 17'	Longitude	: 101° 33'

Figure 3.0 on the next page shows the location of the study area and Figure 3.1 shows a portion of the satellite image of the study area.

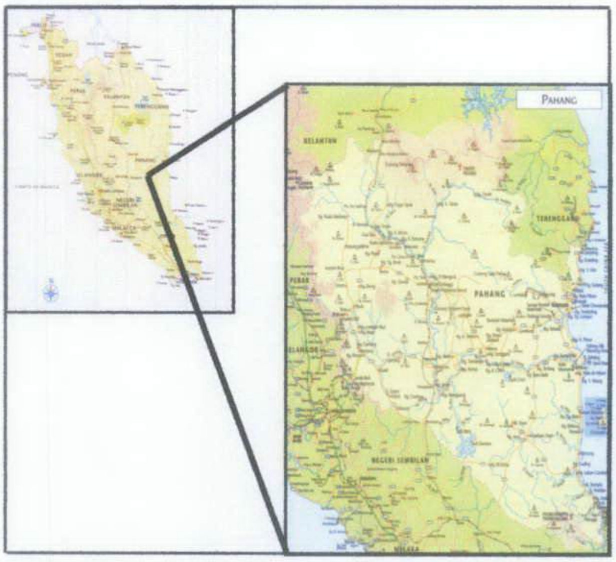


Figure 3.0: Location Plan of the study area

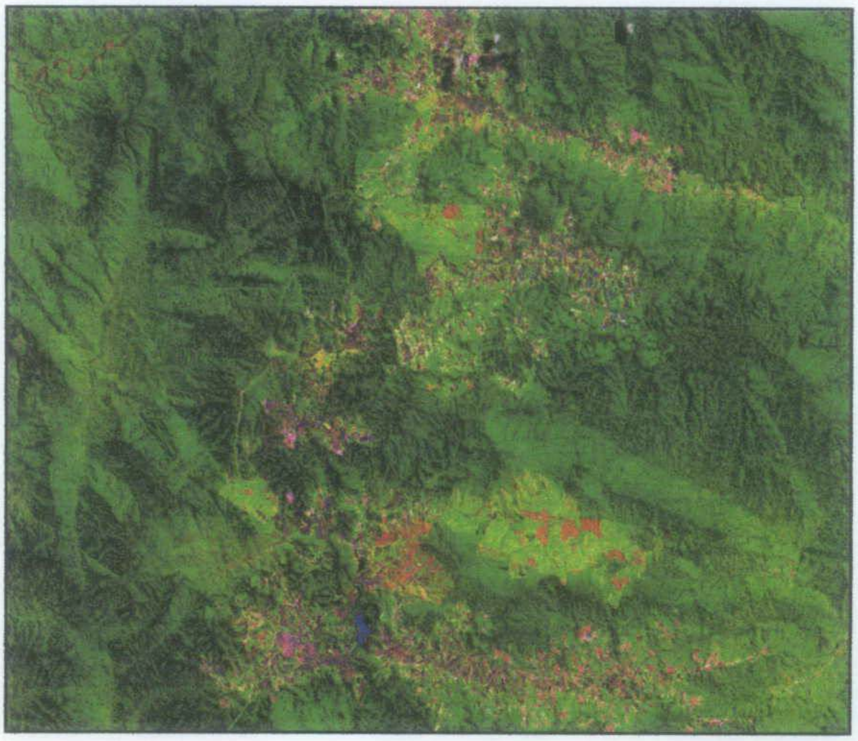


Figure 3.1: Some portion of satellite image (SPOT 5) of the study area

Figure 3.1 above is one of the examples of False Colour Composite (FCC) combination used by Greenbaum et al. (1995) in examined the landslide in Papua New Guinea.

4.2 Classify Image using Image Processing Software

After the SPOT image was acquired, the images been analyzed using the MultiSpec Application 3.1 software which is one of the image processing softwares available in the market. This software allows the author to classify and differentiate various types of landuse of the study area by manipulating the colour band width properties of the satellite image.

4.3 Water Content

The water content or moisture content of the soil within the study area will be determined through Short Wave Infrared (SWI). The reason is because the SWI is sensitive to soil and vegetation moisture content. The Colour Enhancement Wizards of ER Mapper 7.0 allow the user to manipulate the wavelength of the SPOT image properties such as the Red, Green and Blue (RGB) colour. The distinctive colour will be compare with the topography map and pictures taken at the study area to verify the accuracy of the generated image.

4.4 Land Use

The landuse of the study area will be determined by varying the properties of the colour which is wavelength. MultiSpec Application 3.1 software allows the users to convert the SPOT images colour properties to the natural colour images. This feature enables the users to identify the vegetation by comparing the satellite image with topography map and the nearby township to differentiate between buildings area and vegetated area.

4.5 Slope Risk

The slope risk is the step to determine the possibilities of the study area to experience landslide depending on the slope steepness of that particular area. The slope steepness was determined through the slope's angle generated using the ArcView GIS 3.3. Triangular Irregulated Network (TIN) image was generated from the contour image provided by the 'Jabatan Ukur dan Pemetaan Malaysia' (JUPEM).

4.6 Landslide Risk Zoning

The landslide risk zoning is the last step in this research. Whereby, all the slopes within the study area will be classified and grouped according to the possibility for landslide to occur. The land use and slopes will be grouped into three risk levels which are low risk, medium risk and high risk and each risk will have different colour to represent the possibility range for landslide to occur.

4.7 Hazard Analysis

This research involve thorough desk research which dealing with software and readings. Therefore, there are a few safety precautions that should be taken into consideration while doing the research. The Guidance for Employers and Employees on Health and Safety, suggest that the common injuries occurs while doing the desk job is Repetitive Strains Injuries (RSI) which commonly occurred at hand wrist and neck. This injury can be avoided by using the ergonomic keyboard and have a better view angle while using the computer. Frequent short break and working under sufficient light exposure are also recommended to avoid eye strain from occurring. It is important to sit with the right posture to avoid waist injury and help to maintain the concentration. Better work place can help in producing better quality of work.

CHAPTER 5: RESULTS AND DISCUSSION

The results and discussion for the study are divided into two sections. Section one will have the results and discussion for image classification of the satellite image (SPOT 5), and section two will be the discussions of results for the slope analysis in-term of the angle of steepness generate using the ArcView GIS 3.3 to produce the risk zoning.

5.1 Image Classification

The spectral wavelength of the satellite image has been manipulated in order to identify the land use of the study area. This process requires overlaying different spectral wavelength or band at one time under three colour that can be shown by display devices (monitor) which are red, green and blue. There are four multispectral bands and one panchromatic band for SPOT 5 image and the spectral range and spatial range of the band are as shown in Table 4.0 below:

No. of Spectral Bands / Spatial Resolution	Spectral Range (μm)	Spatial Resolution (m)
Panchromatic Band	0.48 – 0.71	5
Multispectral Band One (1)	0.50 – 0.59	10
Multispectral Band Two (2)	0.61 – 0.68	10
Multispectral Band Three (3)	0.78 – 0.89	10
Multispectral Band Four (4)	1.58 – 1.75	20

Table 5.0: SPOT 5 Band Properties

The analysis tasks has been divided into two parts, analysis for two channel colour and analysis for three channel colour. The two channel colour was analysed by combining two different multispectral bands under two channel colour. It means here, two multispectral bands out of the four bands were chosen and combined under two channel colour such as green – blue, green – red or red – blue to produce a false colour composite image. As an example, for two channel colour analysis under Red and Green colour, the results of combination between band two and four as shown in Figure 5.0.

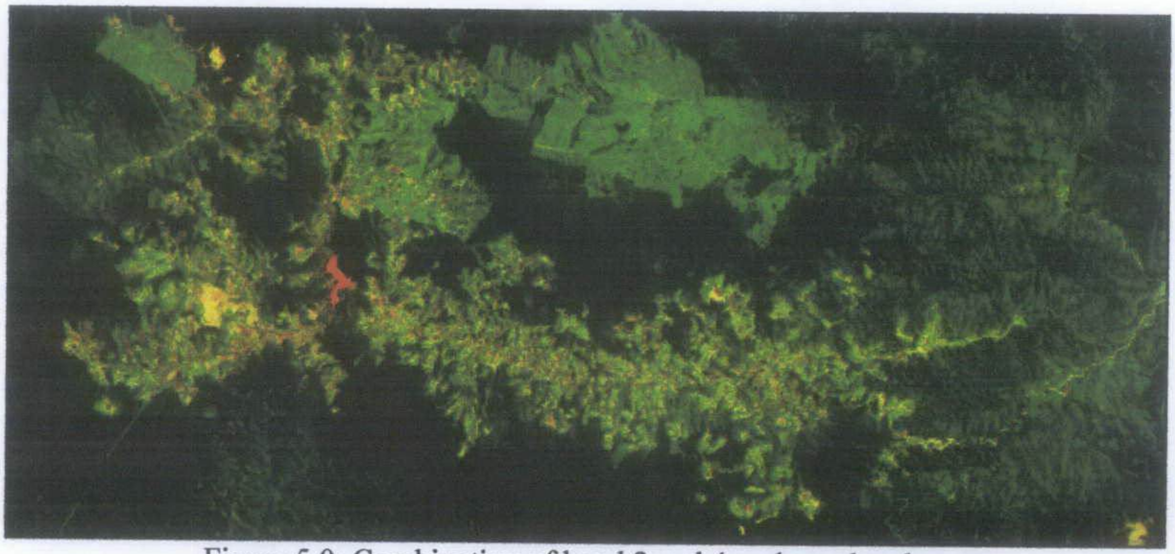


Figure 5.0: Combination of band 2 and 4 under red and green

The same method goes for rest of the two channel colour analysis and also the three channel colour analysis.

The following tables show the results of the analysis for combination options of two channels colour analysis and three channels colour analysis. The land use and physical terrain that had been decided to be determined are barren land, dense forest, agriculture, water body, buildings, topography, river and road. The reason is because most of the landuse mentioned are the common area that are expose to landslide hazards and affected by the landslide occurrences. All the mentioned criteria are being identified through their visibility. The band combination that can shows the most of the required criteria and the nearest to the true colour composite will be choose as the best and reliable combination to identify landuse and surface properties. These elements will be use for producing the risk zoning.

The overall analysis process is shown by the flow chart in Figure 5.1.

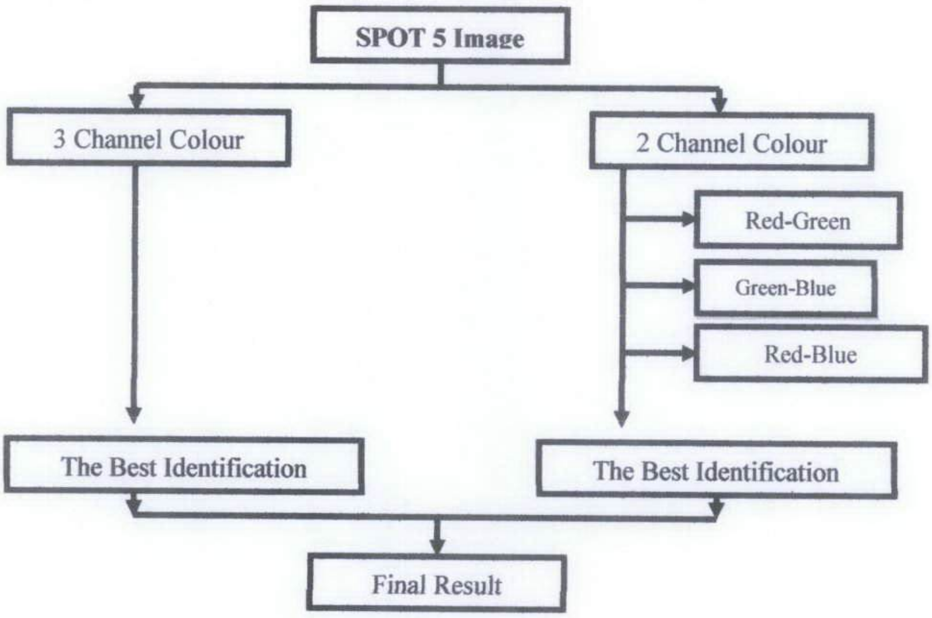


Figure 5.1 : Analysis Flow of Image Classification

Table 5.1 shows the results of two channel colour analysis under red – green colour and from the analysis done, combination that shows most of the required criteria is 3, 4 whereby most of the required criteria were identifiable except for barren land, buildings and road. Figure 5.2 below shows the identified land use extracted from the image.

RED	4	4	4	4	3	3	3	3	2	2	2	2	1	1	1	1	
GREEN	3	2	1	4	4	2	1	3	4	3	1	2	2	3	4	1	
BLUE																	
LANDUSE																	
Barren Land																	
Dense Forest	■	■	■	■	■	■	■	■	■	■				■	■		
Agriculture			■	■	■	■			■		■				■		
Water Body				■	■												
Buildings		■	■				■		■		■	■	■		■	■	
Topography	■		■		■	■	■	■		■				■			
River	■			■	■			■	■	■							
Road				■			■				■	■	■		■	■	

Table 5.1 : ***Two Channel Color (Red-Green)*** ■ Visible

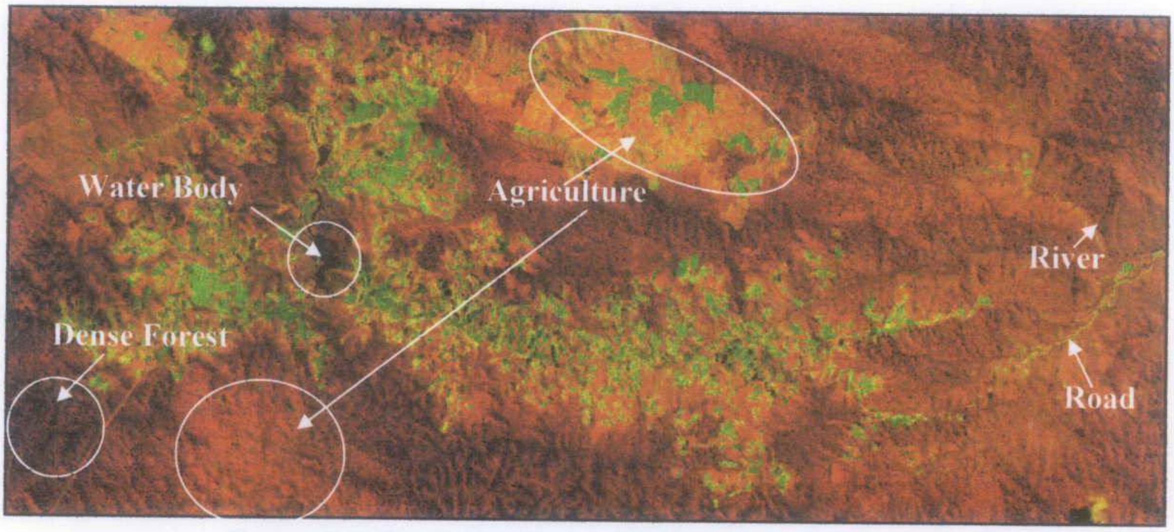


Figure 5.2: Combination of band 3 and 4 under red and green

Table 5.2 shows the results of two channel colour analysis under red – blue colour and from the analysis done, combination that shows most of the required criteria is 4, 2 whereby most of the required criteria were identifiable except for barren land, dense forest, topography and river. Figure 5.3 below shows the identified land use extracted from the image.

RED	4	4	4	4	3	3	3	3	2	2	2	2	1	1	1	1	
GREEN																	
BLUE	3	2	1	4	4	2	1	3	4	3	1	2	2	3	4	1	
LANDUSE																	
Barren Land																	
Dense Forest	■				■	■											
Agriculture		■	■	■	■				■								
Water Body		■	■						■	■				■	■		
Buildings	■	■	■				■				■	■	■		■	■	
Topography	■				■	■	■	■		■				■			
River	■		■	■	■	■	■										
Road		■	■			■			■		■	■	■	■	■	■	

Table 5.2: ***Two Channel Color (Red-Blue)*** ■ Visible

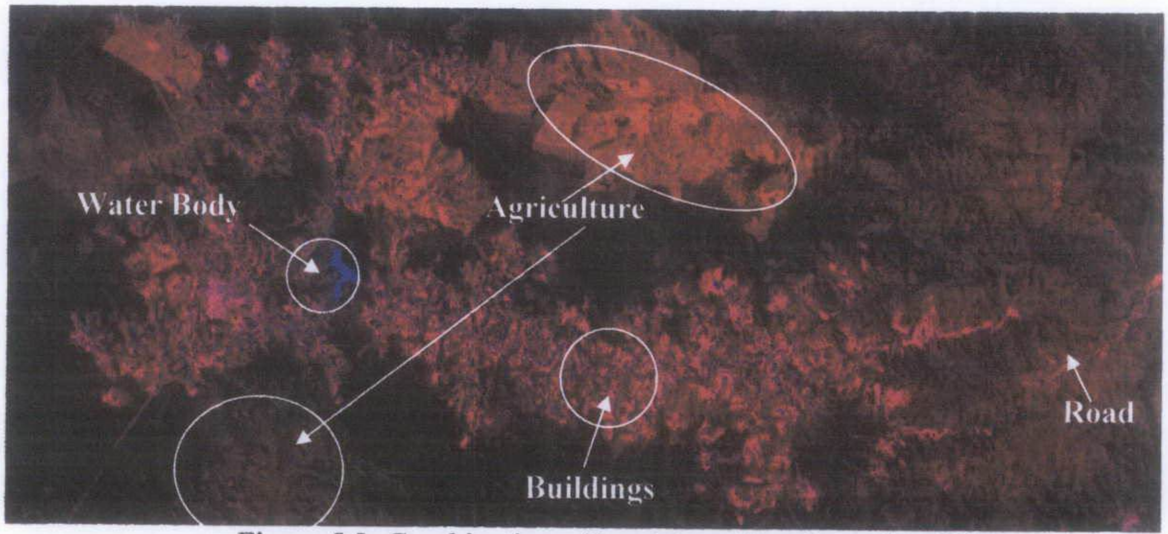


Figure 5.3: Combination of band 4 and 2 under red and blue

Table 5.3 shows the results of two channel colour analysis under green – blue colour and from the analysis done, combination that shows most of the required criteria is 4, 1 whereby most of the required criteria were identifiable except for topography and river. Figure 5.4 below shows the identified land use extracted from the image.

RED																
GREEN	4	4	4	4	3	3	3	3	2	2	2	2	1	1	1	1
BLUE	3	2	1	4	4	2	1	3	4	3	1	2	2	3	4	1
LANDUSE																
Barren Land																
Dense Forest	■	■	■	■	■	■	■		■	■				■	■	
Agriculture	■	■	■	■	■								■		■	
Water Body		■	■		■	■	■		■	■				■	■	
Buildings	■	■	■			■	■		■	■	■	■	■	■	■	■
Topography	■				■	■	■	■		■				■		
River					■	■	■		■							
Road	■	■	■	■					■		■	■	■	■	■	■

Table 5.3: ***Two Channel Color (Green-Blue)*** ■ Visible

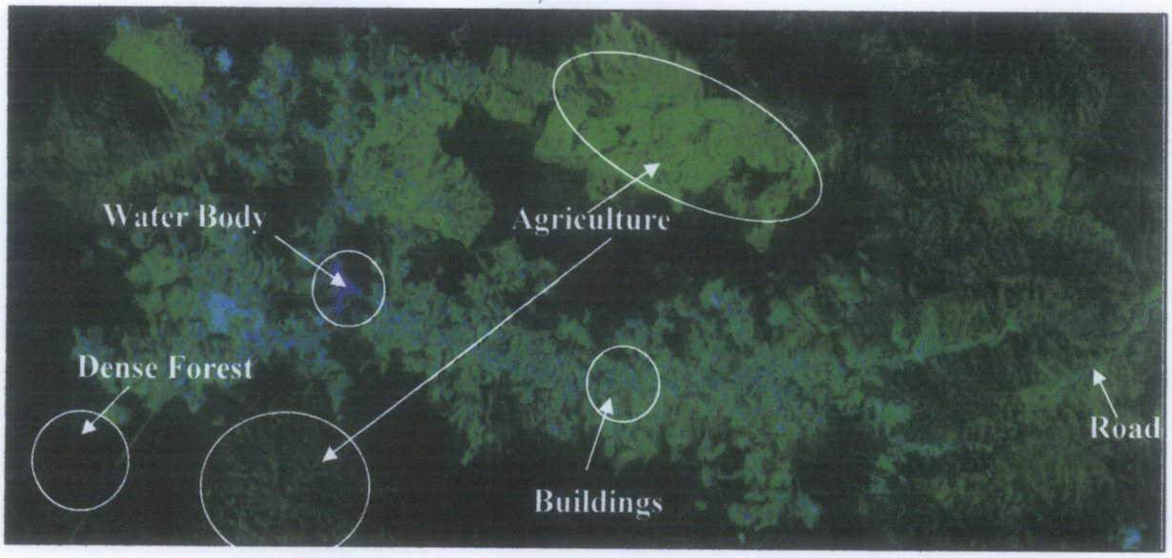


Figure 5.4: Combination of band 4 and 1 under green and blue

Table 5.4 shows the results of three channel colour analysis. From the analysis done, combination that shows most of the required criteria is 3, 4, 2 (three channel colour) whereby most of the required criteria were identifiable except for barren land. Figure 5.5 and Figure 5.6 below shows the identified land use extracted from 3, 4, 2 (three channel colour) combination.

RED	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	1	1	1	1	1	1
GREEN	4	3	1	3	1	4	4	2	1	2	1	4	3	2	1	2	1	3	2	3	3	4	2	4
BLUE	3	4	3	1	4	1	2	4	2	1	4	1	2	3	2	1	3	1	3	2	4	3	4	2
LANDUSE																								
Barren Land																								
Dense Forest	■	■	■	■			■	■	■	■	■	■	■		■	■	■		■	■	■	■	■	■
Agriculture	■	■	■		■	■	■				■	■			■	■		■			■	■	■	■
Water Body	■						■											■	■				■	
Buildings	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Topography	■			■		■	■	■	■	■	■	■	■	■			■			■		■		■
River							■								■	■		■	■				■	■
Road			■		■		■						■		■	■	■	■		■	■			

Table 5.4: ***Three Channel Colour***   ■ Visible

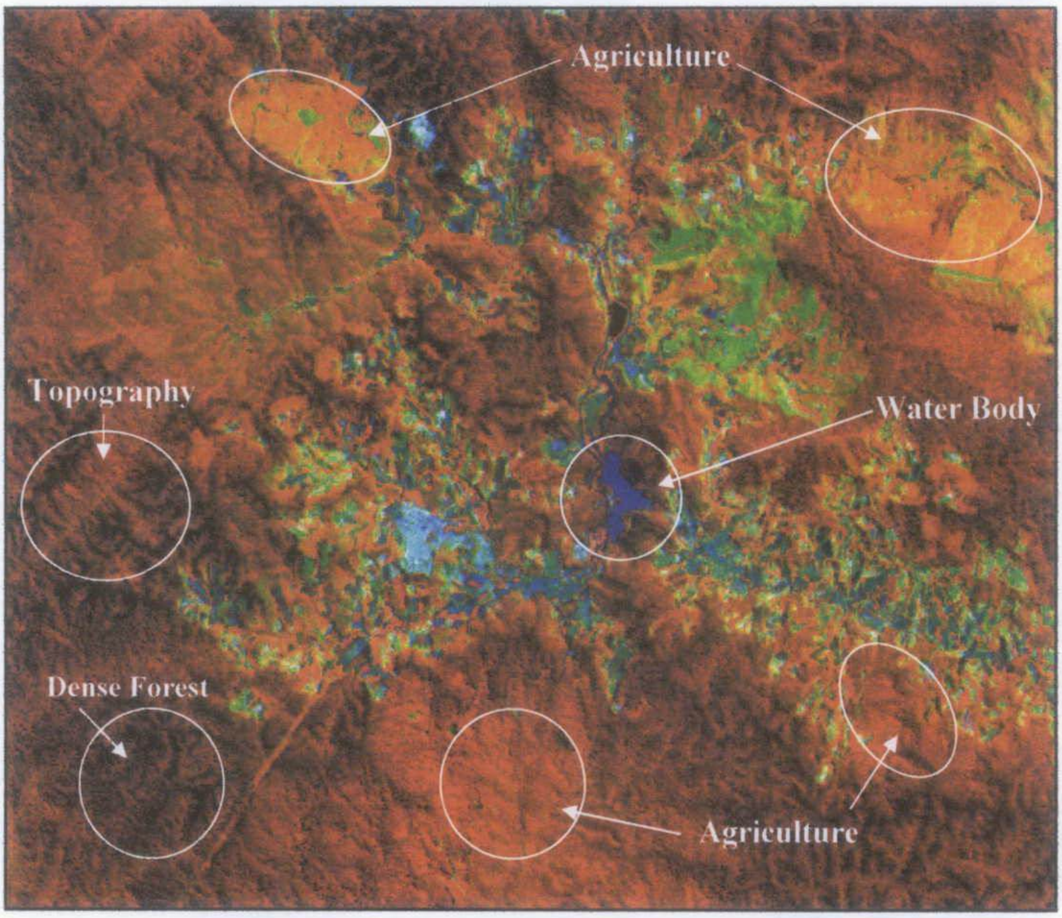


Figure 5.5 : Combination of band 3, 4 and 2

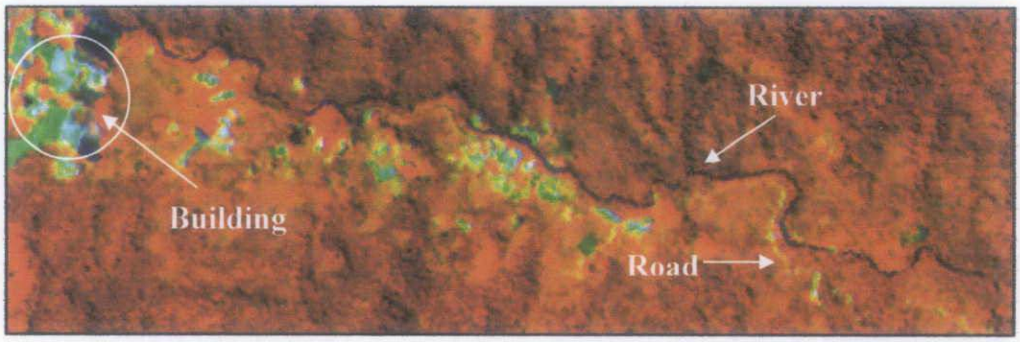


Figure 5.6 : Combination of band 3, 4 and 2

Throughout the image classification analysis, it is found out that some of the false colour composite combination can actually produce distinctive image that allows the user to identify certain criteria easily. Take combination of band 4 and 1 under green and blue colour as an example, this combination shows distinctive agriculture landuse and enable the users to identify the area easily (Figure 5.7).

Nevertheless, the combination of band 4 and 1 under green and blue colour is not chosen as the best combination under green and blue colour analysis although the combination shows most of the required criteria because the false colour composite generated is still far from the true colour composite image.

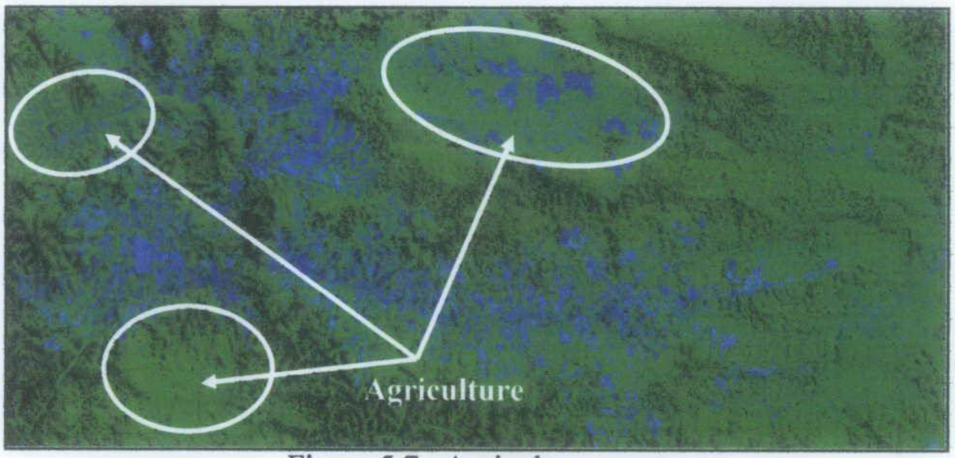


Figure 5.7 : Agriculture areas

The author also had faced some difficulties to identify and determine the river route, water body and barren land. The possible reason to the problem is because of the trees canopy. Cameroon Highland is well known for its nature beauty and preservation. Therefore, due to heavy forest that covered most part of the study area, the river route may has been covered too by the big trees that formed trees canopy, thus prevent the satellite from capturing the image of the river route. Due to this, the author only managed to identify the river route at certain location such as foothills and hillside. As for the water body, most of the identifiable water body appeared black in colour due to light reflected by the surface of the water body.

The barren land is the result from the removal of forest in large area either by human or nature. The removal of forest or deforestation by human may due to land exploration for agriculture or development or also timbering process. As for the nature, it may because of earthquake, landslide or fire. However, through out the analysis, no single sign did of barren land is identified. This may because of there is no barren land area exists during the satellite image was taken or no landslide occurrences for a long period.

To identify the landuse of the study area, the best combination for each channel colour analysis were taken and compared. The best combination that enables the identification of most of the criterias is found to be the combination of band 3, 4 and 2 under three channel colour. The combination just not shows the most of the required criteria, but the false colour composite generated almost similar to the true colour composite. The criteria identified from the image generated then are used to produce the landslide risk zoning. All the images generated for Table 5.1 until Table 5.4 are shown in the Appendix 2 until Appendix 5.

5.2 Risk Zoning

The elements that had been chosen for producing the risk zoning are the slope steepness and the landuse of the study area. Figure 5.8 below shows the analysis flow done to produce the landslide risk zoning using both criteria aforementioned.

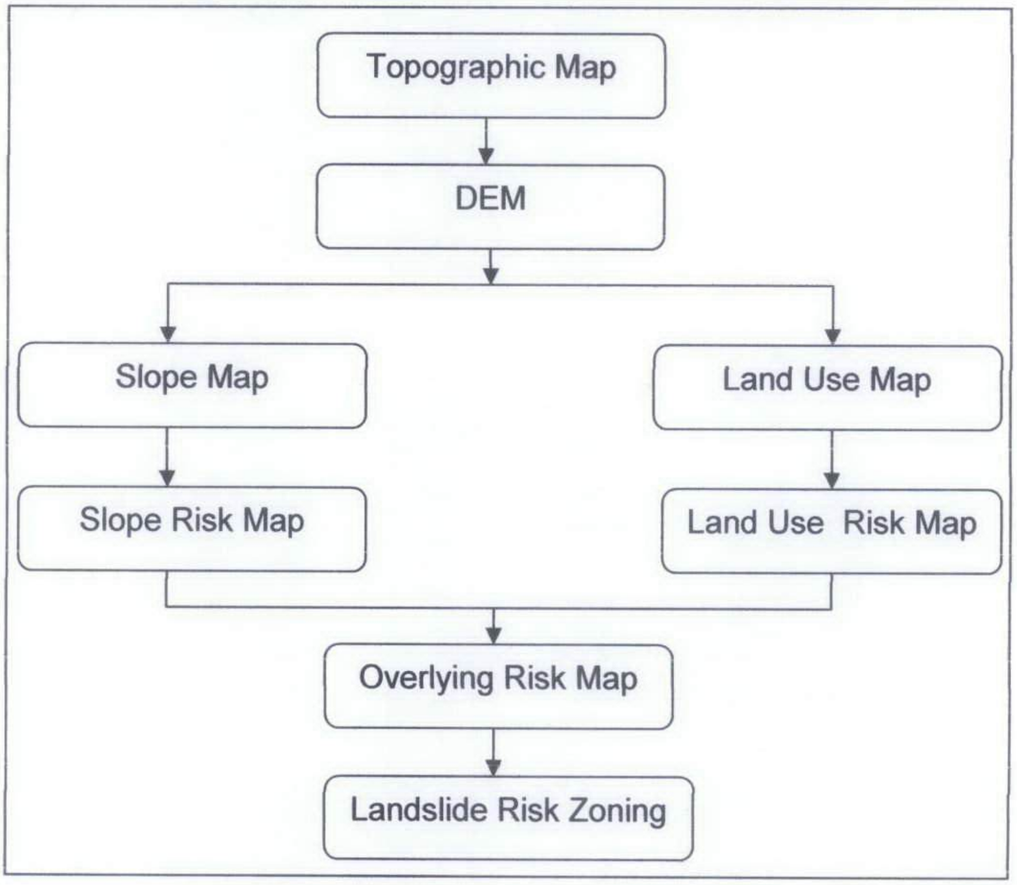


Figure 5.8 : Analysis flow of risk zoning

In this study, the landslide risk zoning map was generated by categorizing each of the two elements under three conditions which are, low risk, medium risk and high risk and the risk here, means the probability for land slide to occur.

5.2.1 Land Use Risk Map

The first step was to produce the land use risk map. Different landuse will have different possibility for landslide to occur due to their land usage. Therefore, in this study the landuse were categorized using the assumptions made by Sharifah et. al. (2004) and their assumptions were based on the relationship between landuse and soil erosion. In other words, the extent of soil erosion effects is varies according to the different types of landuse. Among of the assumptions made by them are:

i. Classified agriculture area, especially shifting cultivation by the Orang Asli, is identified to be an area highly exposed to erosion followed by forest and urban area.
ii. In forest areas, protection is better because of its rain forest trees. As for the urban areas, the pavement and bricks that cover help to give more protection to the soil underneath.
iii. It is assumed that areas of agriculture and shifting cultivation are identified to face landslide followed by forest, and finally urban or residential areas.

From the above assumptions, the risk contributed by each landuse at the study area was assigned as followed:

i. Urban is low risk
ii. Dense forest is medium risk
iii. Agriculture is high risk

In order to produce the land use risk map, the landuse identified through satellite image had been grouped into three conditions above. Using ArcView GIS 3.3 software, each of the landuse was zoned according to the risk they possess. Figure 5.9 until Figure 5.12 shows the zoning process of each landuse.

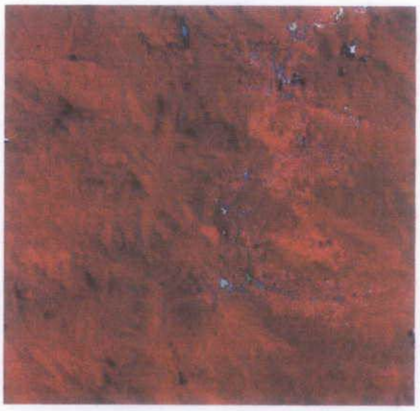


Figure 5.9 : Satellite image of the study area

The above satellite image shows the location of the study, under bandwidth three, four and two (red, green, and blue). All the landuse of the study area was identified using this image. The zoning for landuse was done by identifying each of landuse at the study area first. Then, using ArcView software, three different landuse layers which are urban layer, dense forest layer and agriculture layer were generated as significant of the risk each one of the landuse possess. The layer of the landuse was constructed using the GeoProcessing wizard tools. This tool allows the author to union the small portions of landuse and intersects the three landuse layers onto each other.

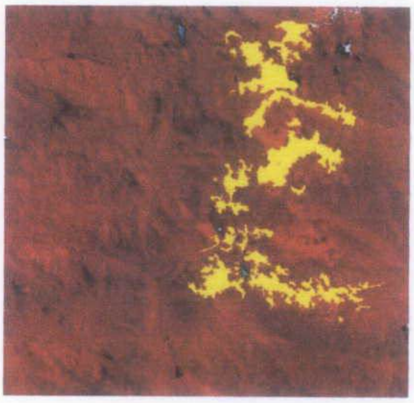


Figure 5.10 : Urban landuse zoning

The urban area was first identified through the satellite image and it consists of buildings and road. After the identification, the buildings and road have been zoned under one colour as shown by Figure 5.10. This stage involves the process of unite small portions of urban landuse and this particular layer also represents the low risk area. The same union process was applied to produce the others landuse layers.

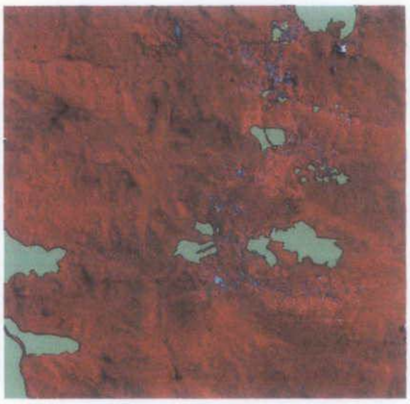


Figure 5.11 : Agriculture zoning

The agriculture zoning as shown by the coloured region in Figure 5.11 is the high risk area which consists of agriculture landuse. Among the agriculture activities that exist at the study area are tea plantation, palm oil plantation, vegetables plantation and many more. Most of the agriculture area was identified with the assistance of topography map.

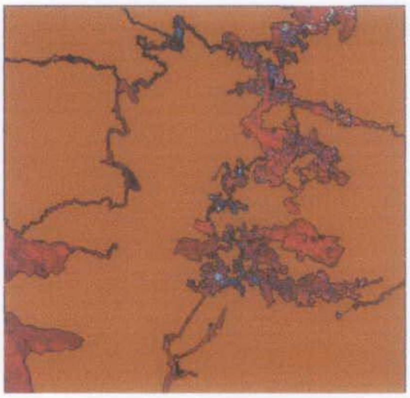


Figure 5.12 : Dense forest zoning

The dense forest zoning is shown by the coloured region in Figure 5.12 above and it is also represents the medium risk area. As can be seen in Figure 5.12, most part of the study area are made up of dense forest which has medium risk for landslide to occur.

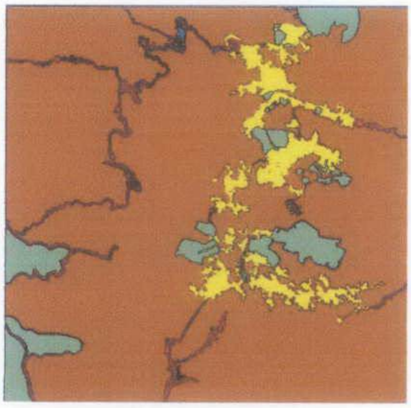


Figure 5.13 : Land use risk map

The land use risk map was produced by intersecting each of the landuse layer on each other. Figure 5.13 shows the land use risk map after intersected the three landuse layers. The risk of each colour possess are as follows:

i. Low risk
ii. Medium risk
iii. High risk

5.2.2 Slope Risk Map

Using the ArcView software, the Triangulated Irregular Network (TIN) image from the digital contour image purchased from 'Jabatan Ukur dan Pemetaan Malaysia' (JUPEM) had been generated. The TIN image later on was used to generate the slope angle's TIN image into three categories which are low risk, medium risk and high risk. The slope risk was categorised according to the slope angle specifications from risk rating methodology adopted in Slope Priority Ranking System (SPRS) by Ministry of Work (JKR). The ranges of the slopes angle are as the following:

i. Low risk, angle less than 45° (<45°)

ii. Medium risk, angle between 45° to 63 ° (45 ° - 63 °)

iii. High risk, angle more than 63 ° (>63 °)

The same GeoProcessing wizard tool was used to union and intersects the three different slopes angle risk layers. Figure 5.14 until Figure 5.16 show the slope risk map of each range.

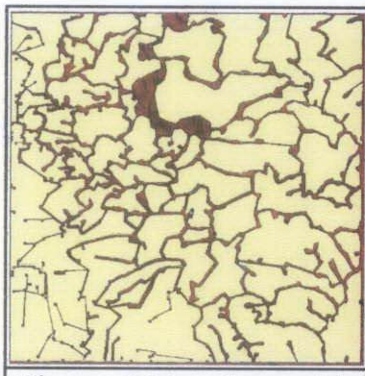


Figure 5.14 : Low risk slope zoning

Figure 5.15 : Medium risk slope zoning

Figure 5.16 : High risk slope zoning

Figure 5.17 : Slope Risk Map

The slope risk map (Figure 5.17) was produced by intersect the three above figures. The low risk area in Figure 5.17 is the transparent area and as for the rest as shown as follows:

i. Low risk
ii. Medium risk
iii. High risk

5.3 Landslide Risk Zoning

Risk's Possess	Slope's Angle	Land Use	Factors
Low	< 45°	Urban	0
Medium	45° - 63°	Dense Forest	1
High	>63°	Agriculture	2

Table 5.5: The zoning results

The overall results were summarised into Table 5.5. In order for author to produce the landslide risk zoning, the author had to overlay the slope risk map onto the landuse risk map to determine the resultant risk when both elements are combine. Each element has different degree of risk; therefore by combining each element with another, the author can determine the overall risk of the study area. Thus, the author had assigned each of the risk possesses by both elements a factor as shown in the above table. By combining these factors, the author had managed to determine and grouped the resultant risk as in Table 5.6.

Slope's Angle	Urban	Dense Forest	Agriculture
< 45°	0	1	2
45° - 63°	1	2	3
>63°	2	3	4

Table 5.6 : Resultant of factor by combining different elements

Table 5.6 shows the risks contribute if two elements are combine. As an example, when the agriculture was done on the slope which has angle more than sixty three degree, logically the risk contribute by this combination is more than urban area which are develop on a slope which has angle less than forty five degree. The higher the combine factors value, the higher the risk contribute by the combine elements. The combine factors were further subdivided into three general groups which are low risk, medium risk and high risk. The combine factors were grouped as follows:

i. Low risk, combine factor is zero (0)
ii. Medium risk, combine factor from one to two (1 - 2)
iii. High risk, combine factor from three to four (3 - 4)

Figure 5.18 until 5.20 show the combine risk zoning of the above factors.

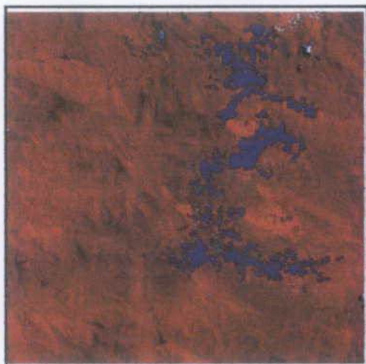


Figure 5.18 : Low risk zoning

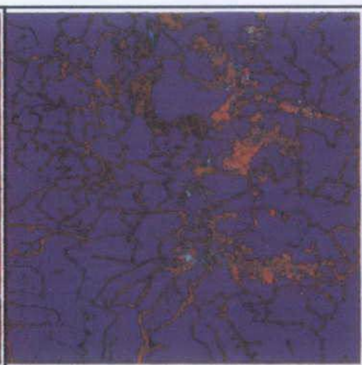


Figure 5.19 : Medium risk zoning

Figure 5.20 : High risk zoning

The landslide risk zoning map (Figure 5.21) on the page is the final product of this study. The landslide risk zoning was produced by overlay the three above figures onto each other. The risk of each colour possess are as follows:

i. Low risk
ii. Medium risk
iii. High risk

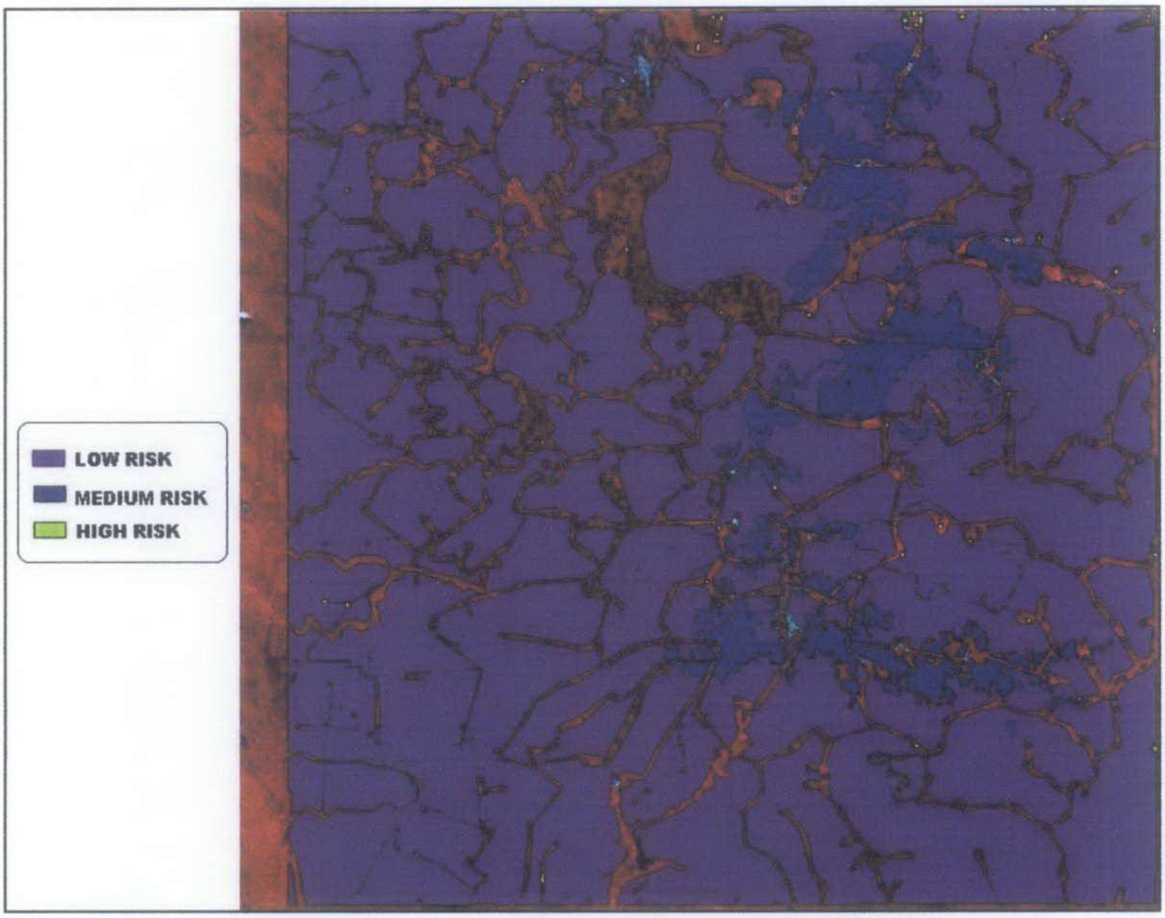


Figure 5.21 : Landslide risk zoning of the study area

The landslide risk zoning (Figure 5.21) generated can be used as general reference to identify the high risk area and as a starting point to develop a more comprehensive landslide risk zoning. Since this research using the qualitative analysis, therefore it is subject to error especially human error while zoning process was done. The error can be further reduced by field verification and comparison with other satellite image which has higher spatial resolution such as QuickBird.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

1. The SPOT 5 satellite image can be use to identify landuse and surface changes that may affected by the landslide.
2. The best combination to identify land use through SPOT 5 is the combination of band 3, 4 and 2 under three channel colour.
3. SPOT 5 image is not effective to identify and determine the river route and also water body.
4. The water content of soil at the study area cannot be determined because the SPOT 5 image does not have the short wave infrared (SWI) properties that required to determine the water content.
5. The information extracted from the satellite image can used to generate landslide risk zoning.
6. Objective of this research has been successfully achieved.

6.2 Recommendation

1. The use of satellite image to monitor development of an area.
2. Identification types of soil using satellite image such as LANDSAT.
3. Further classified the agriculture vegetation using satellite image.
4. Monitoring of forest preservation using remote sensing.
5. Using other criteria such as elevation and aspect in generating landslide risk zoning using satellite image.
6. Incorporate history of landslide occurrences at the study area in the research.

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APPENDIX 1

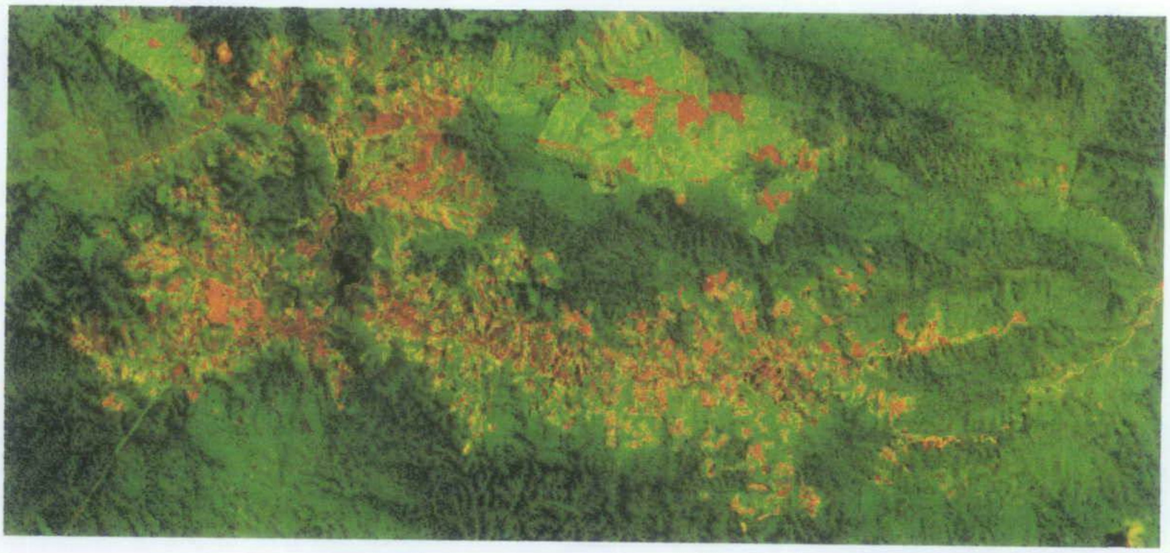
No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
	Semester 1															
1	Selection of Project Topic															
2	Preliminary Research Work															
3	Submission of Preliminary Report				¤											
4	Project Work															
5	Submission of Progress Report									¤						
6	Project work continues															
7	Submission of Interim Report Final Draft														¤	
8	Oral Presentation															¤
	Semester 2															
11	Project Work Starts															
12	Submission of Progress Report 1				¤											
13	Submission of Progress Report 2									¤						
14	Seminar (compulsory)															
15	Poster Exhibition											¤				
16	Submission of Dissertation (soft bound)													¤		
17	Oral Presentation														¤	
18	Submission of Project Dissertation (Hard Bound)															¤
	Period															
	Milestone	¤														

Appendix 1.0: Gantt Chart for Final Year Project

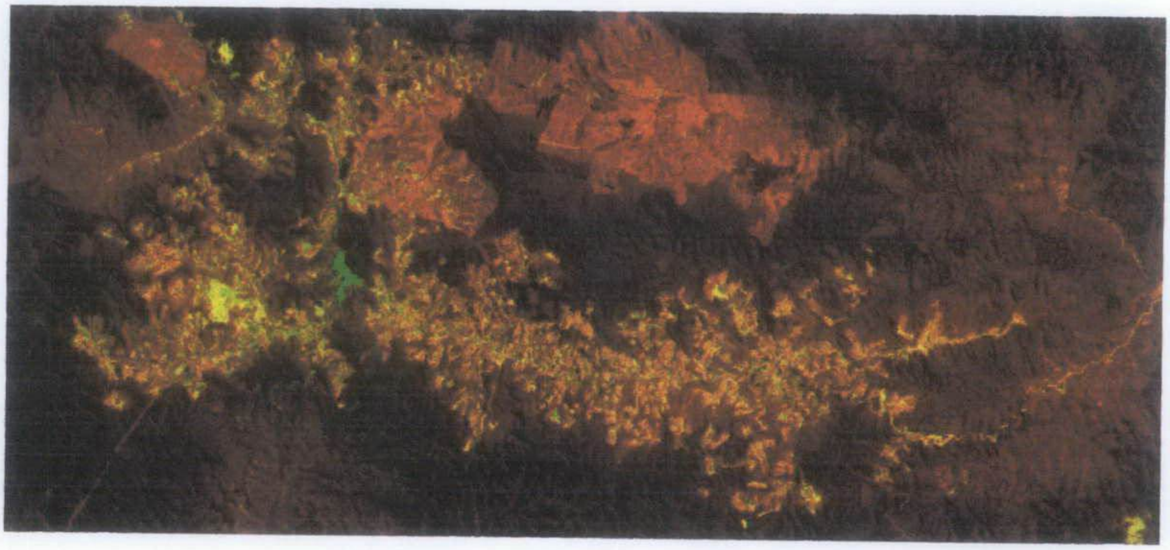
APPENDIX 2

Two Channel Colour (Red-Green)

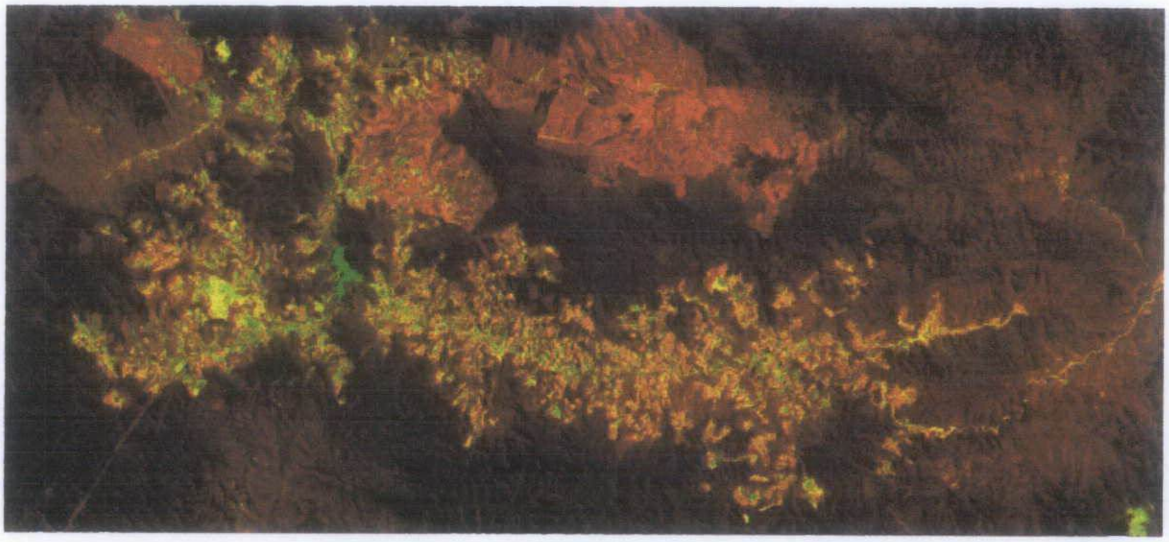
Combination of band 4 and 3



Combination of band 4 and 2



Combination of band 4 and 1



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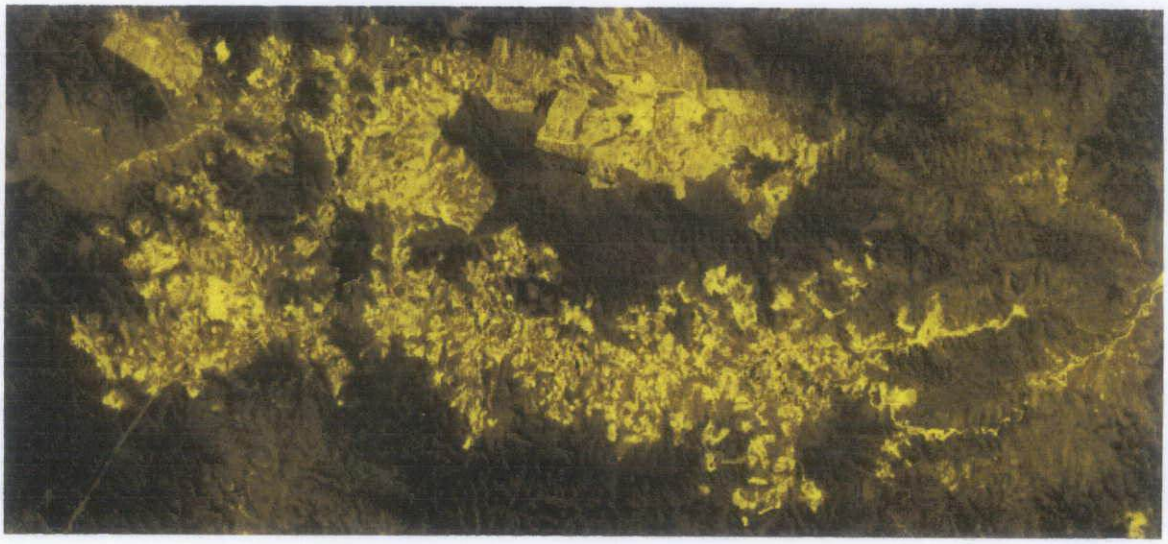

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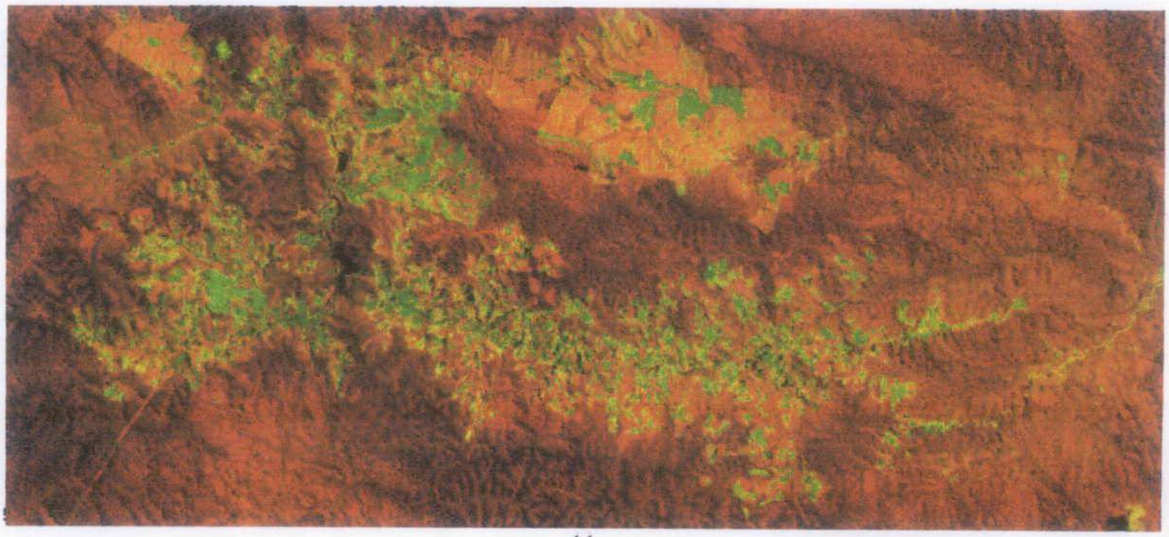
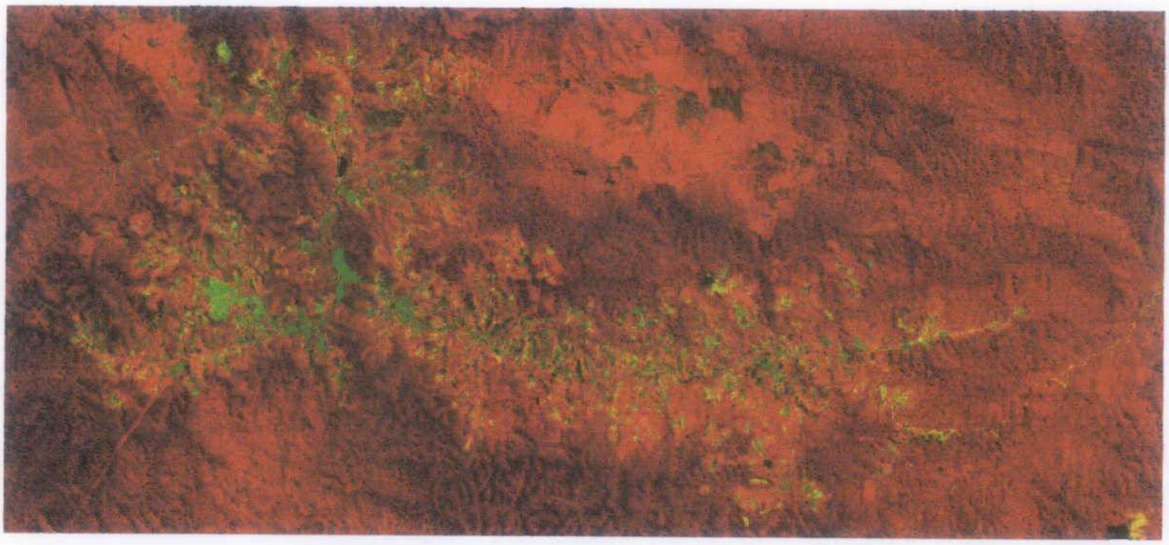
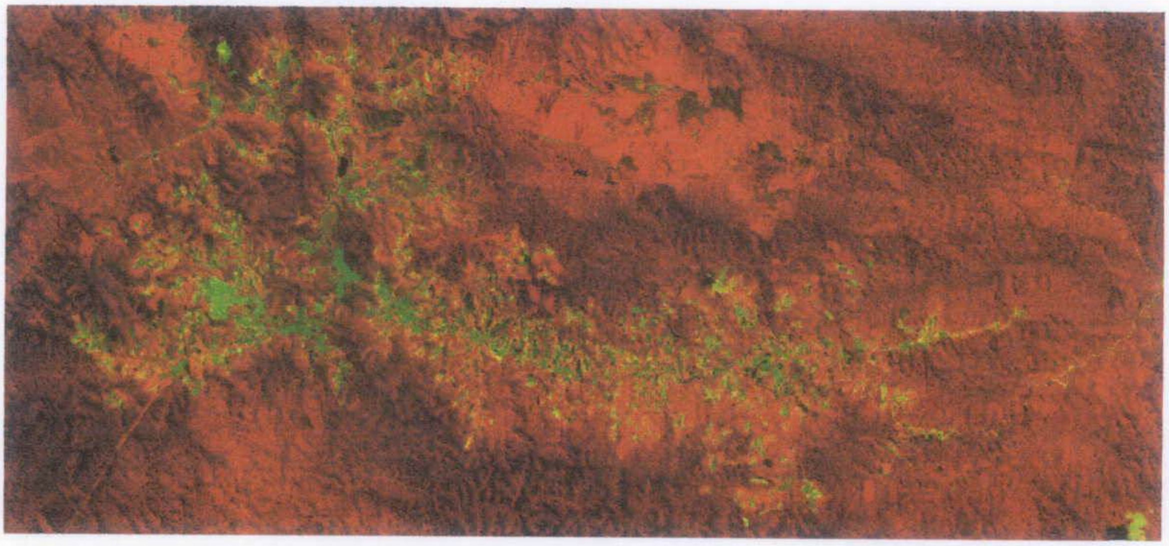


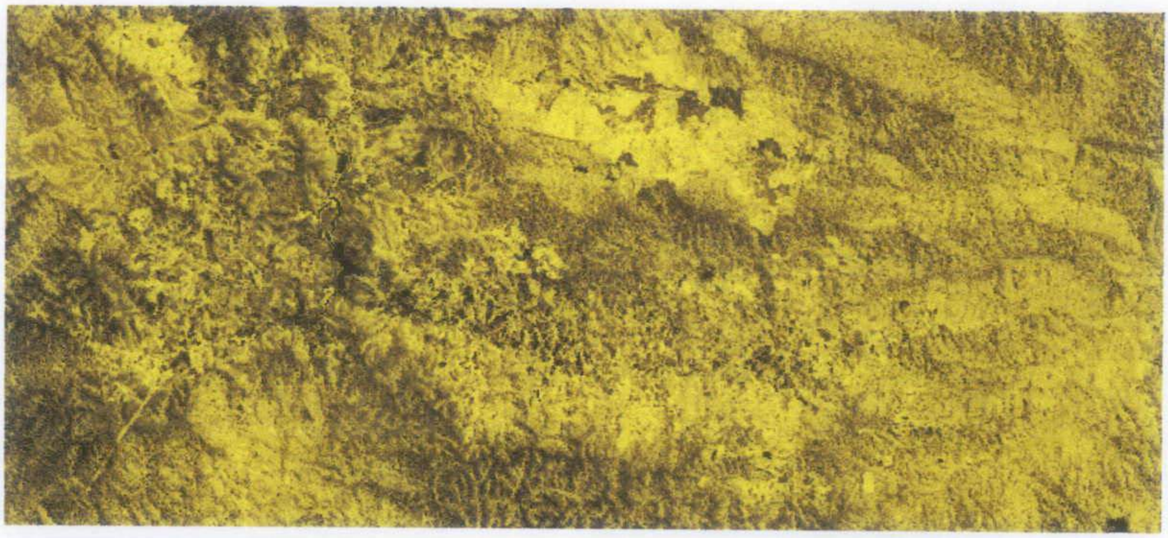
Combination of band 3 and 2



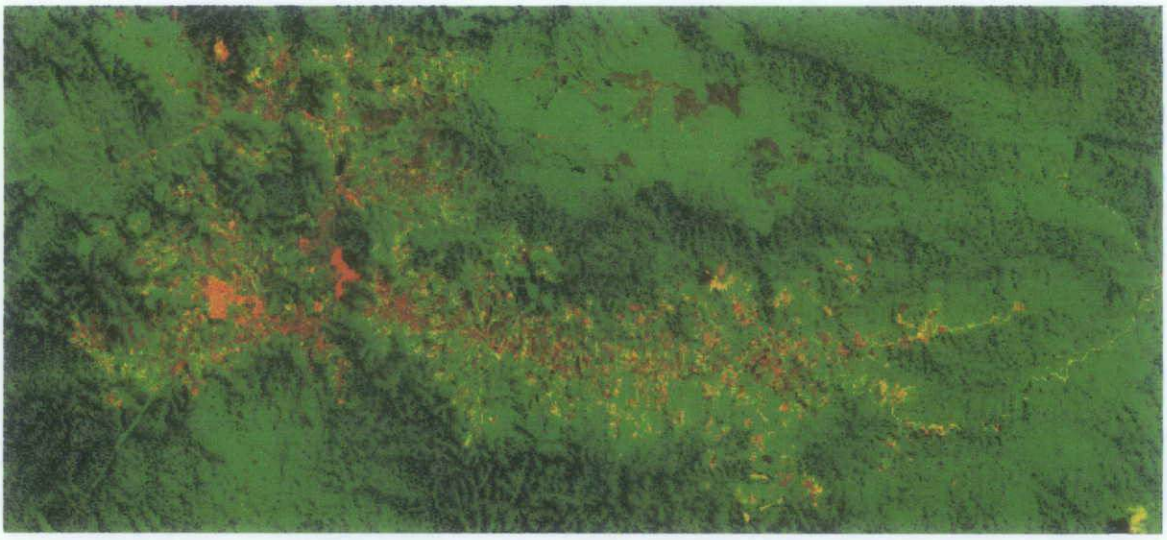
Combination of band 3 and 1



Combination of band 3 and 3



Combination of band 2 and 3



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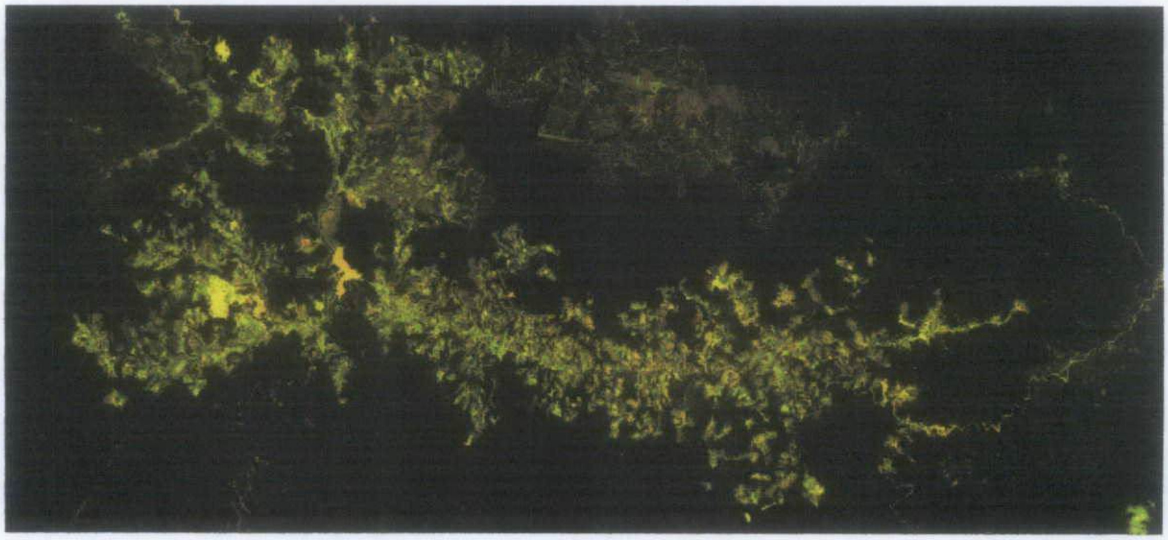
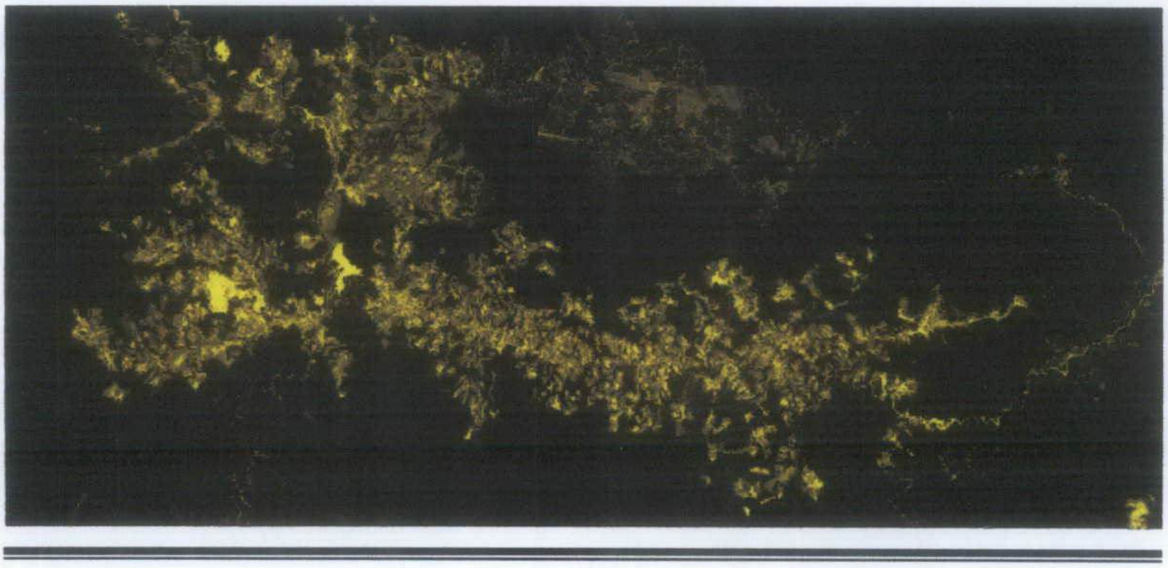
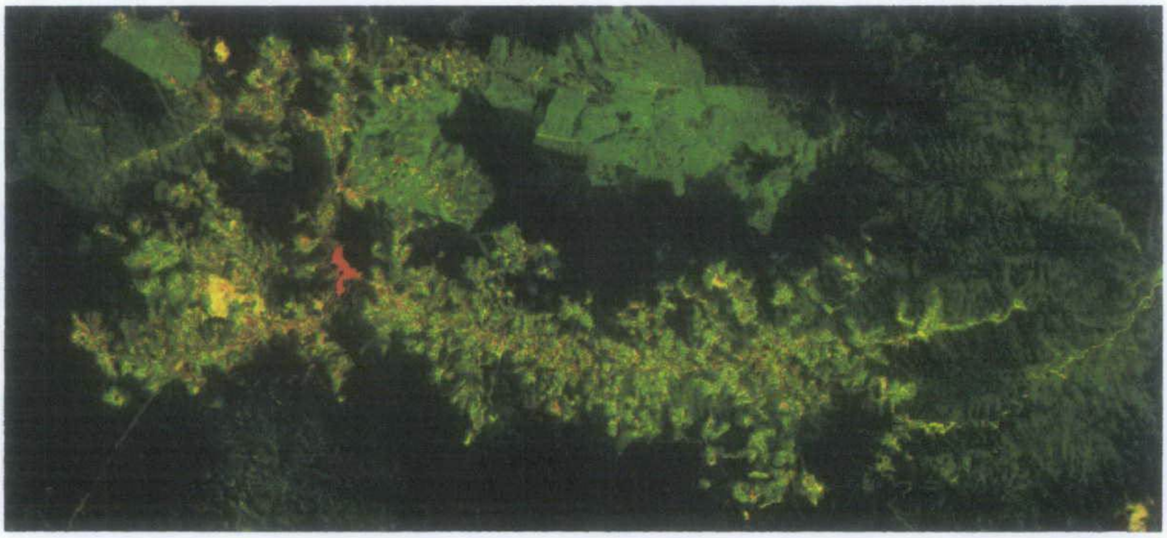


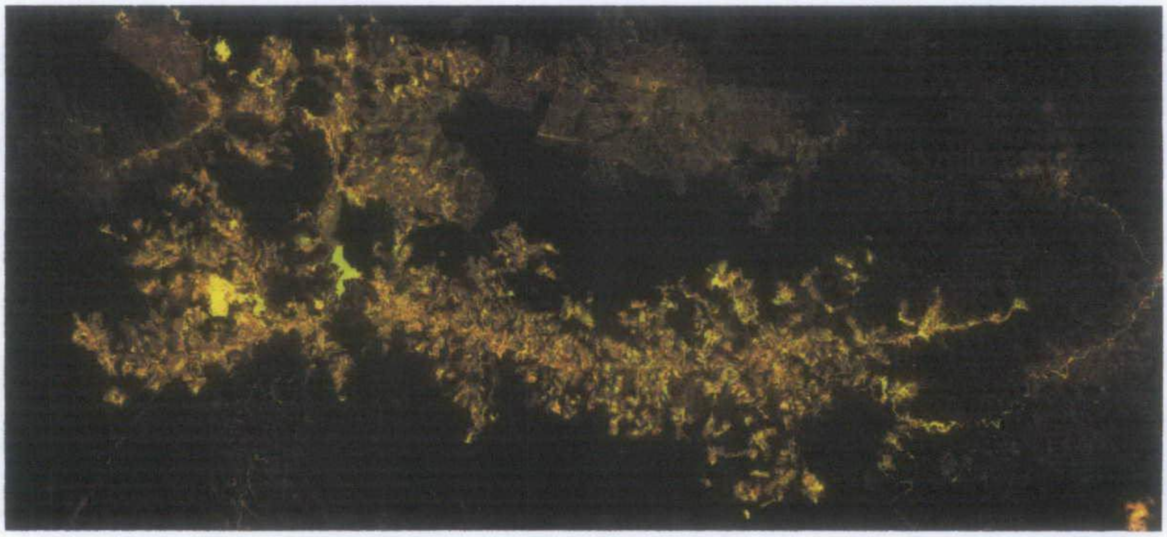
Combination of band 2 and 2



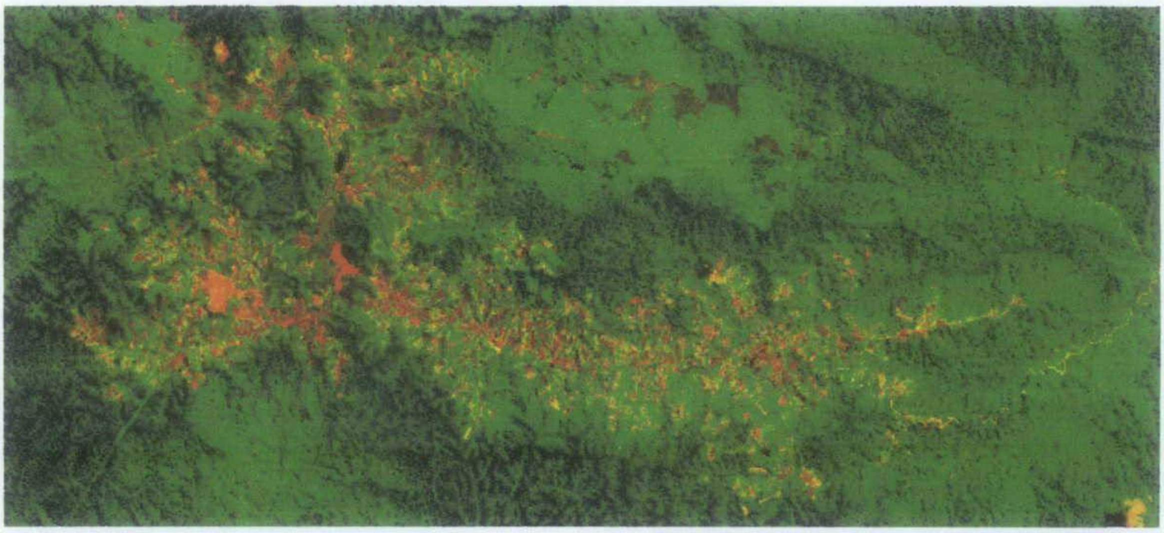
Combination of band 2 and 4



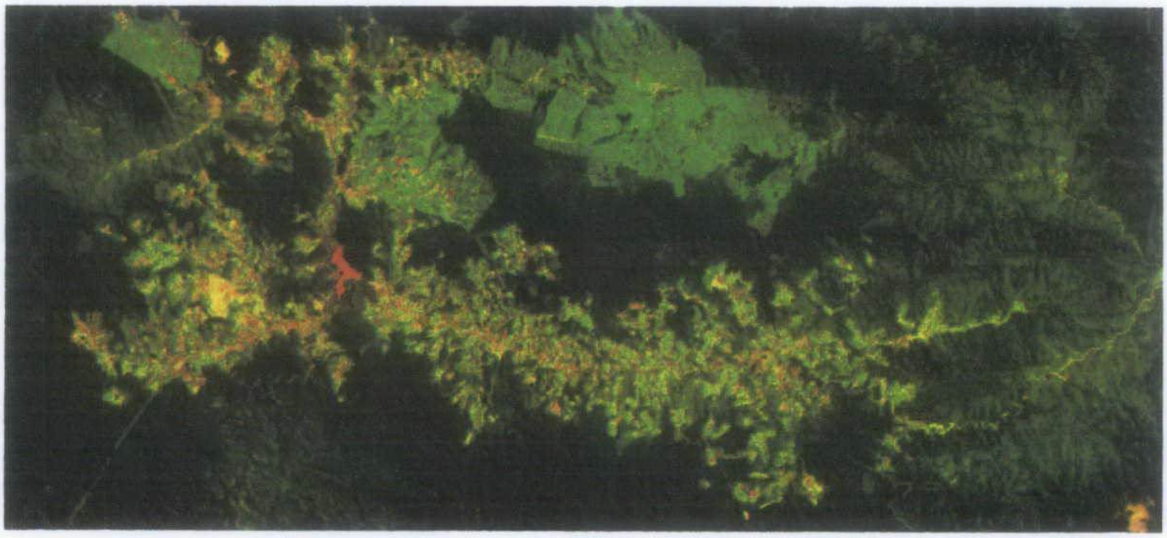
Combination of band 1 and 2



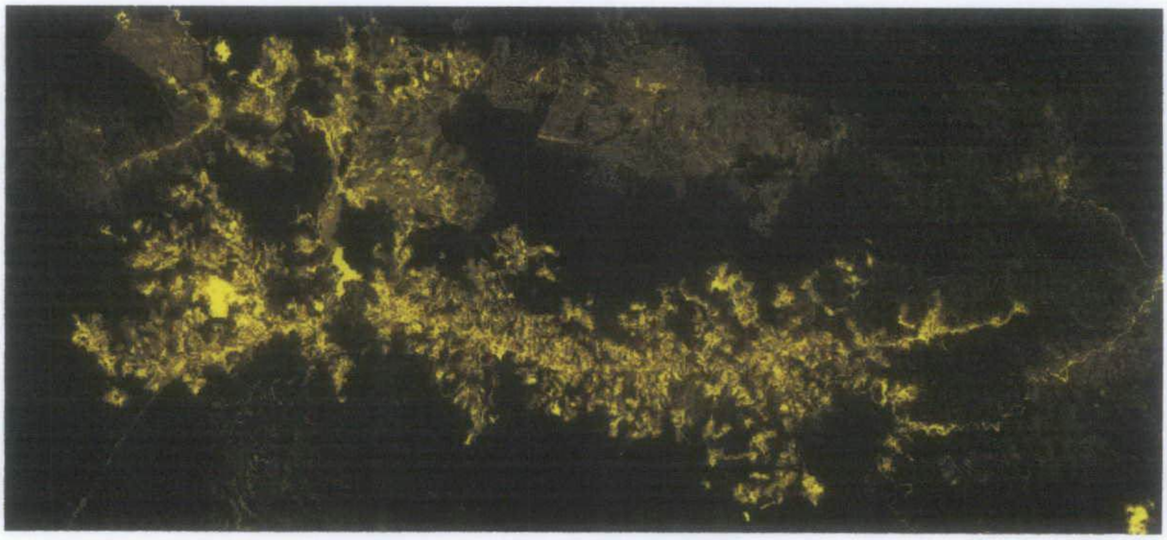
Combination of band 1 and 3



Combination of band 1 and 4



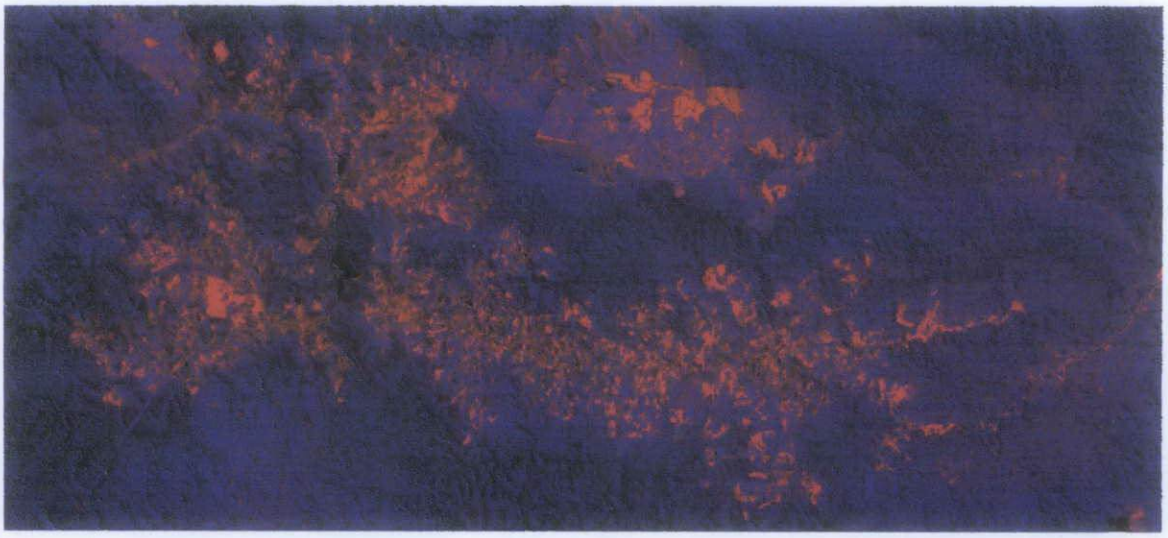
Combination of band 1 and 1



APPENDIX 3

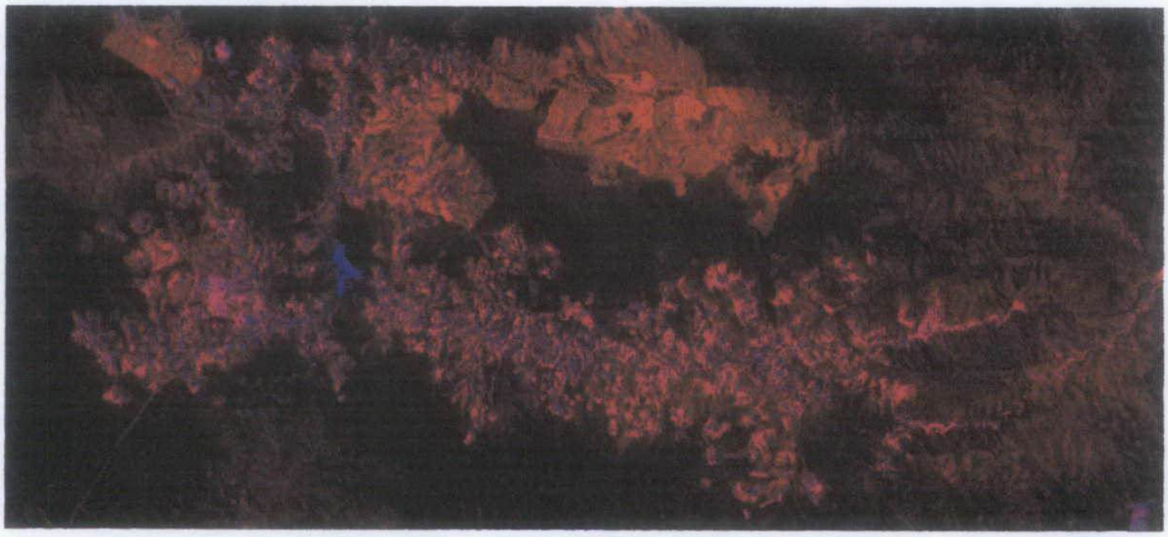
Two Channel Colour (Red-Blue)

Combination of band 4 and 3

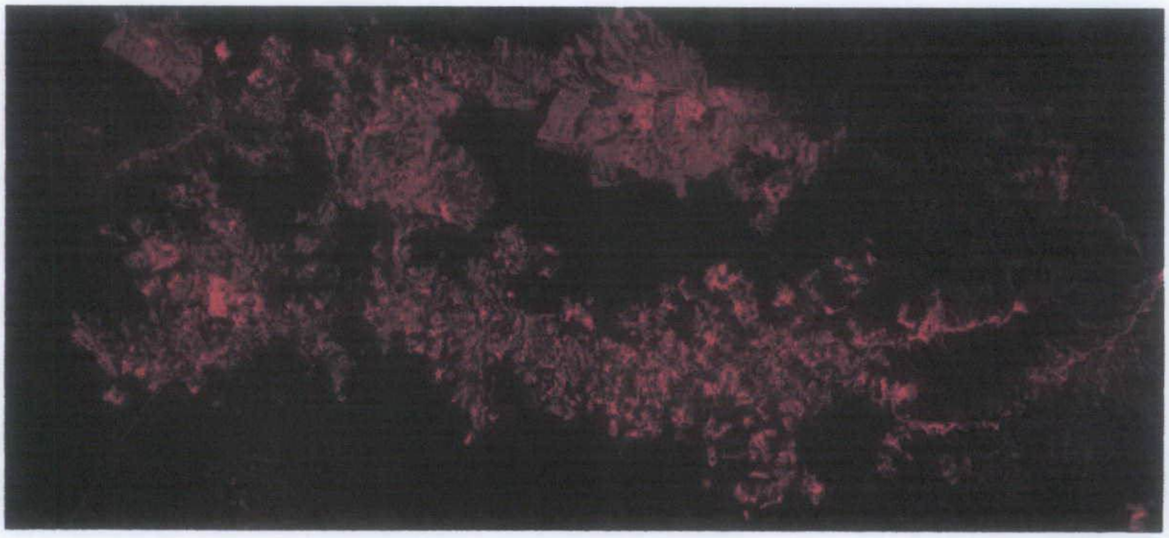


Combination of band 4 and 2

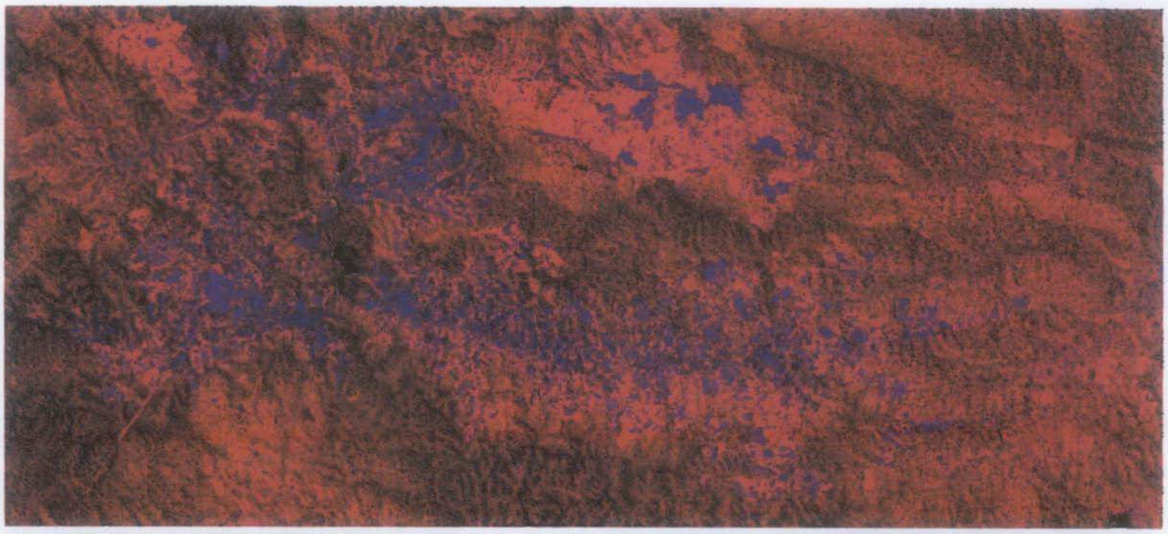
Combination of band 4 and 1



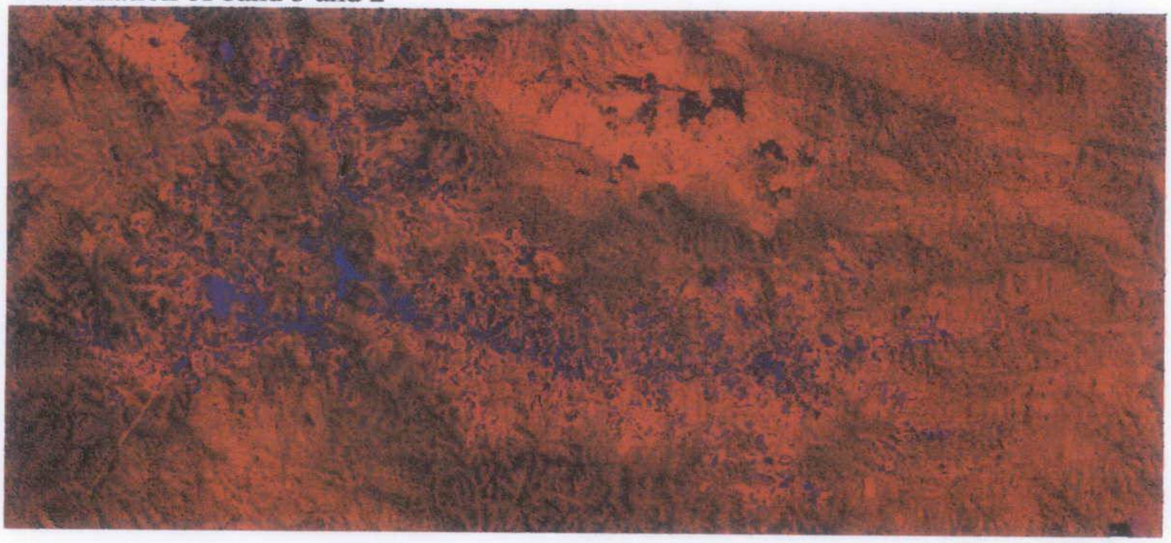
Combination of band 4 and 4



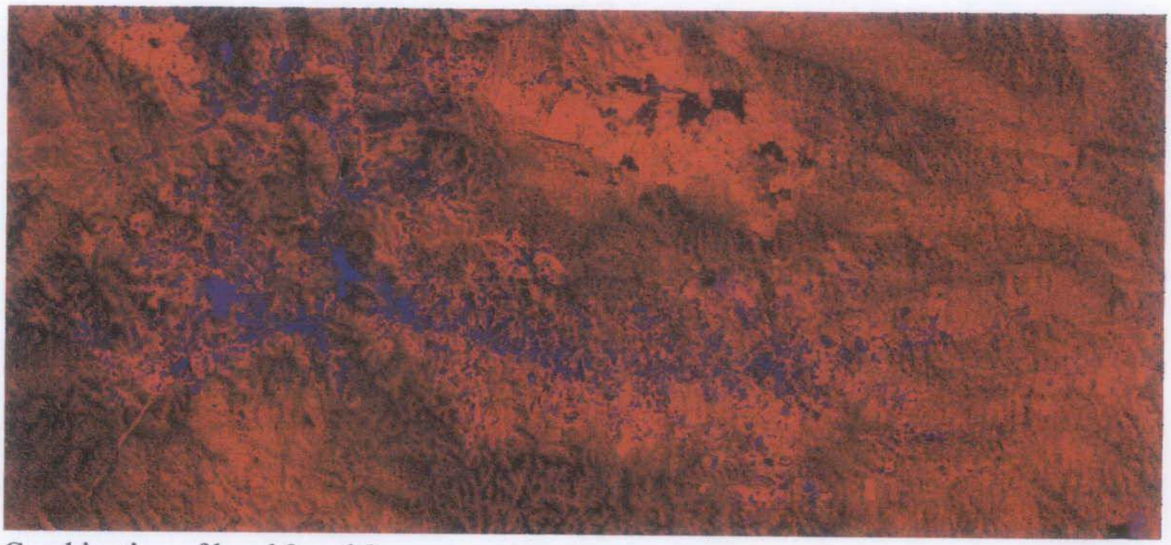
Combination of band 3 and 4



Combination of band 3 and 2



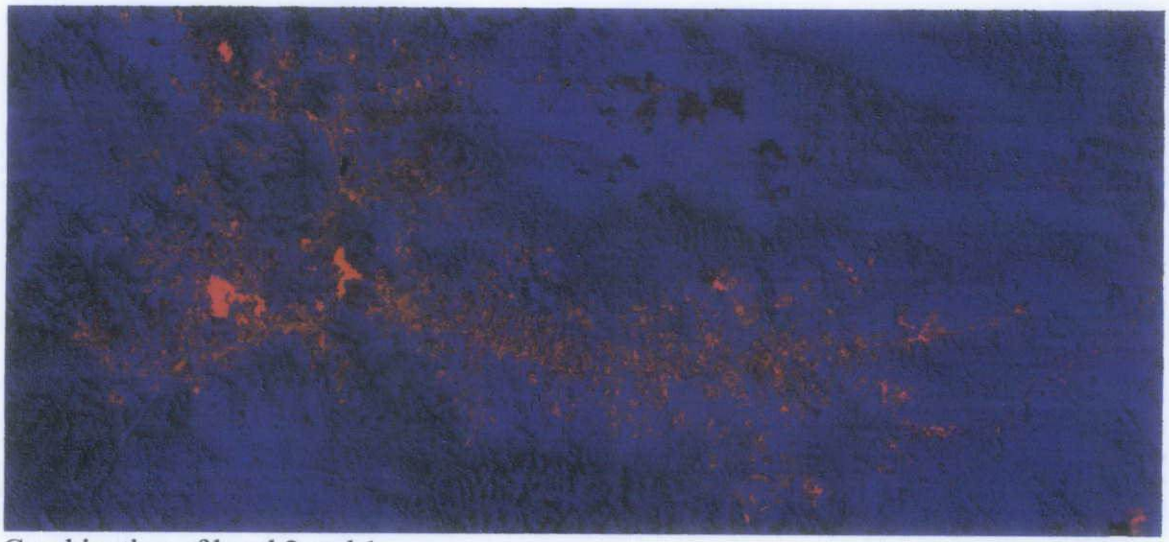
Combination of band 3 and 1



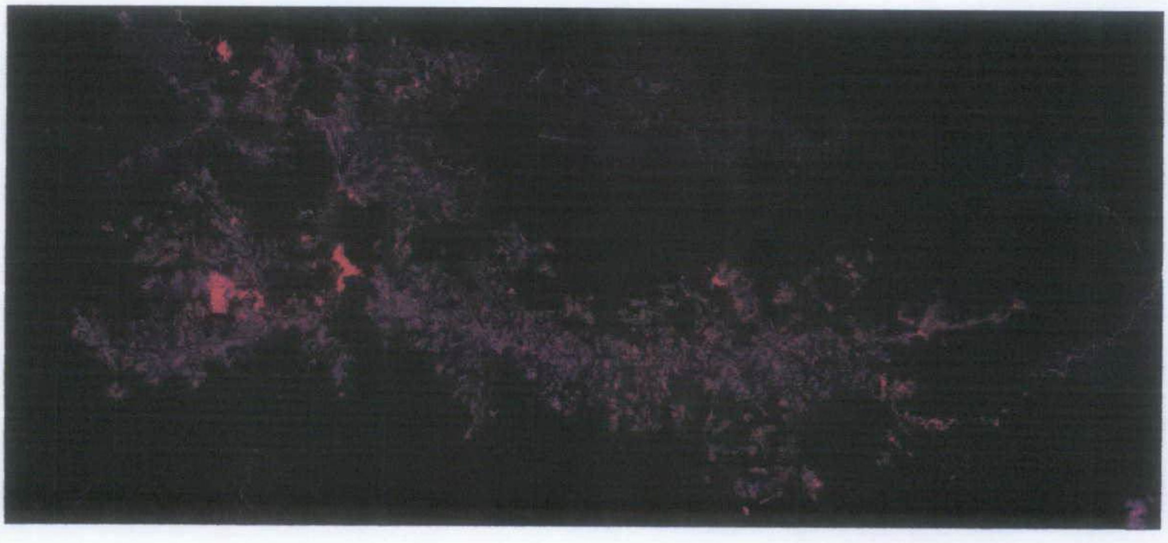
Combination of band 3 and 3

Combination of band 2 and 4

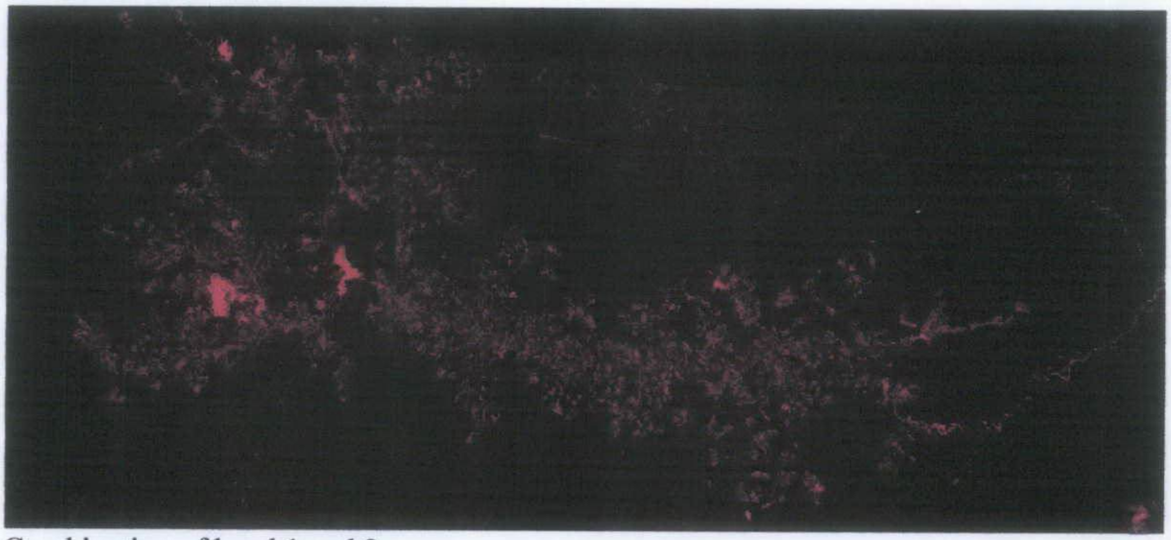
Combination of band 2 and 3



Combination of band 2 and 1

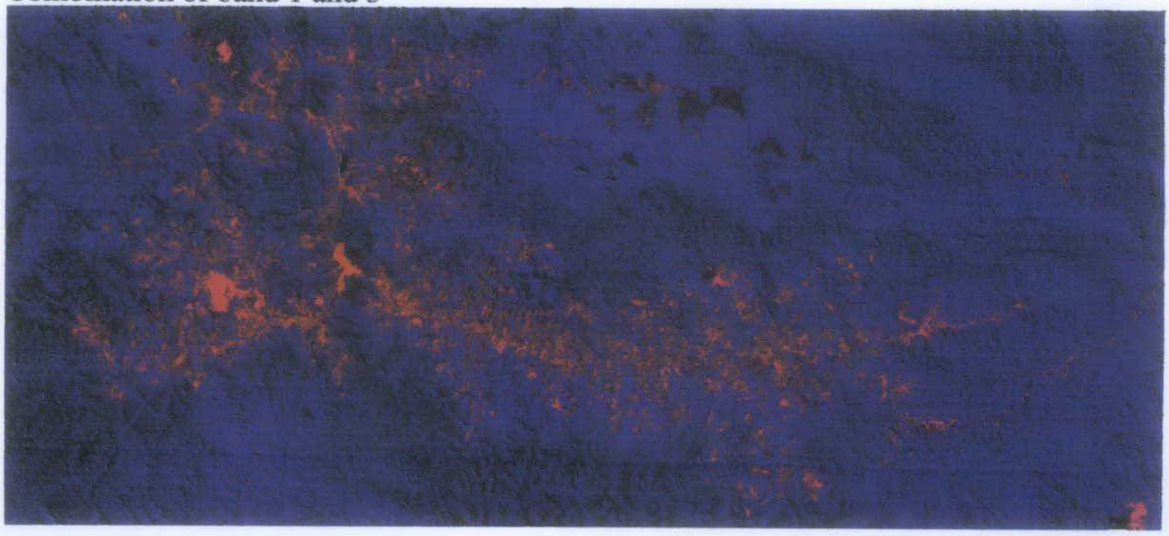


Combination of band 2 and 2



Combination of band 1 and 2

Combination of band 1 and 3



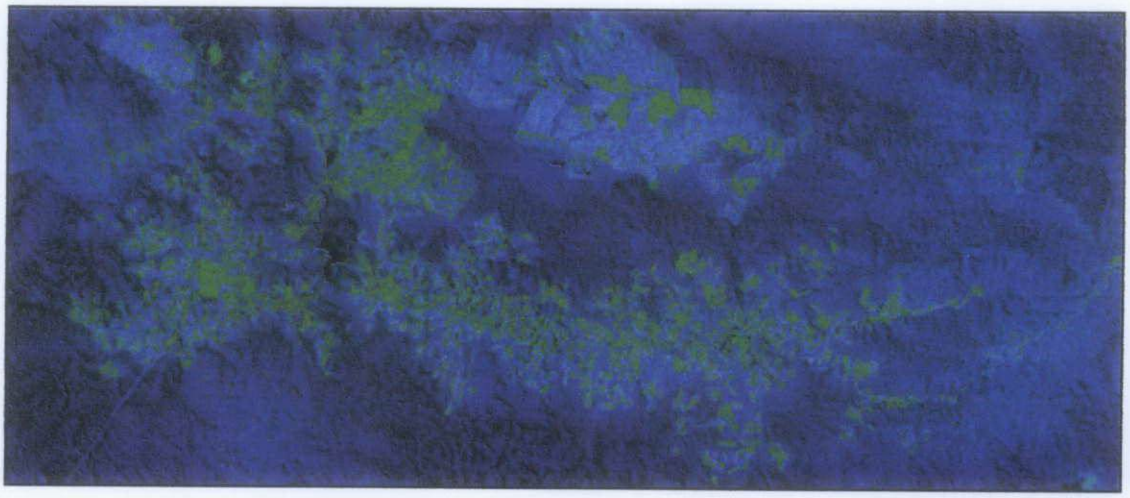
Combination of band 1 and 4

Combination of band 1 and 1

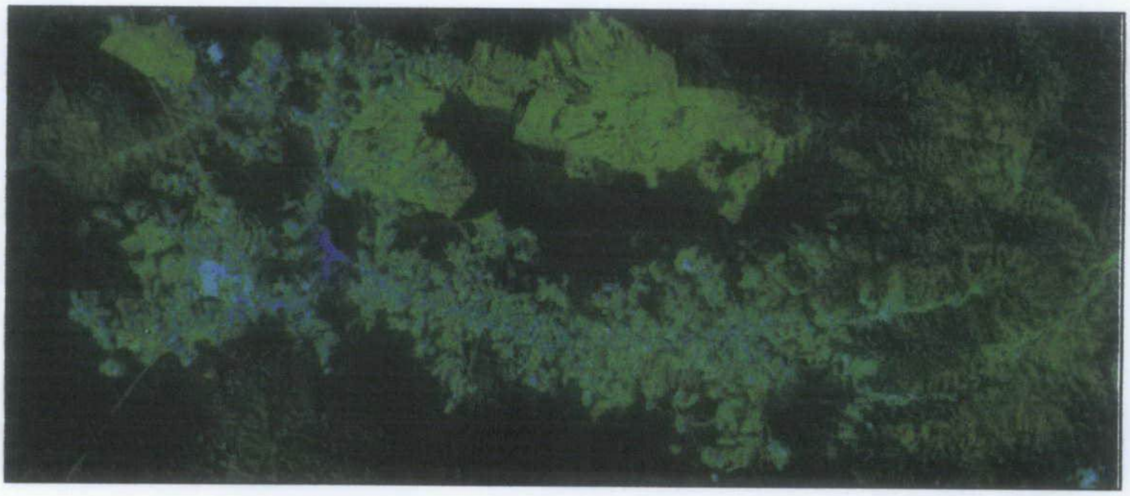
APPENDIX 4

Two Channel Colour (Green-Blue)

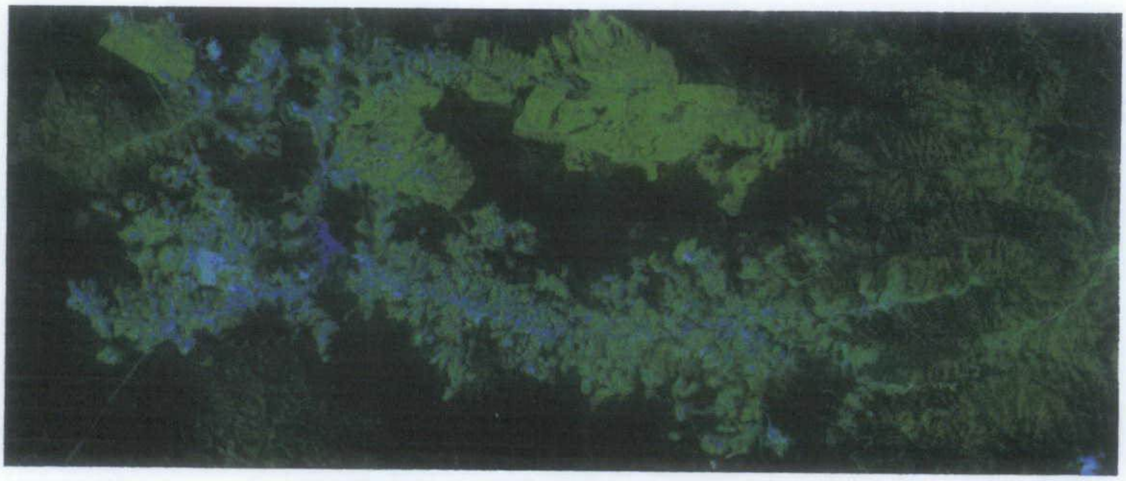
Combination of band 4 and 3



Combination of band 4 and 2

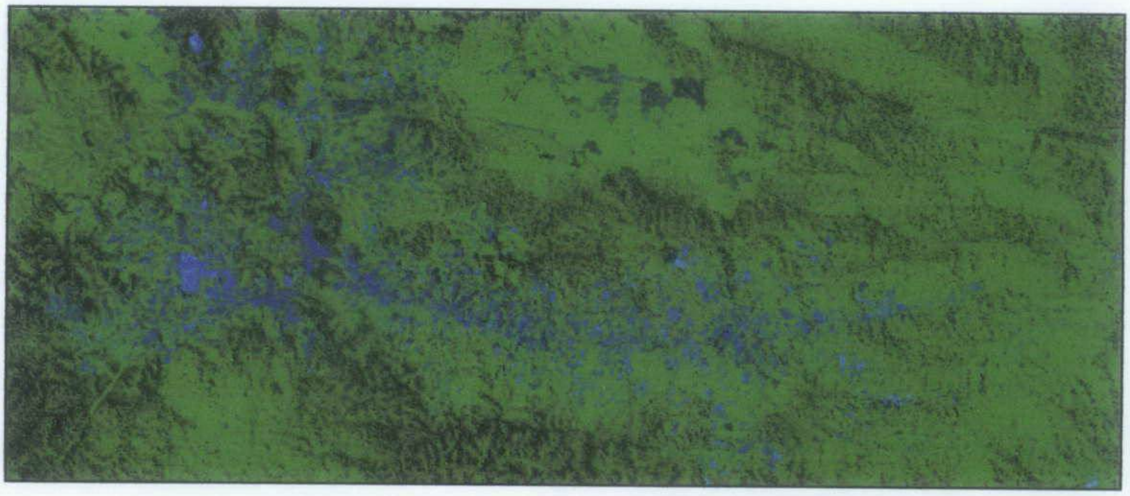


Combination of band 4 and 1

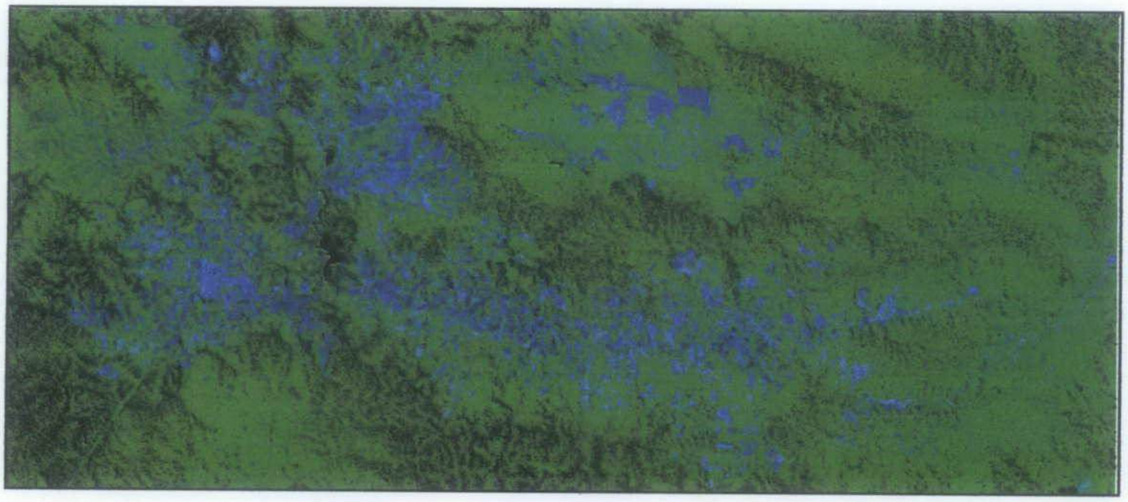


Combination of band 4 and 4

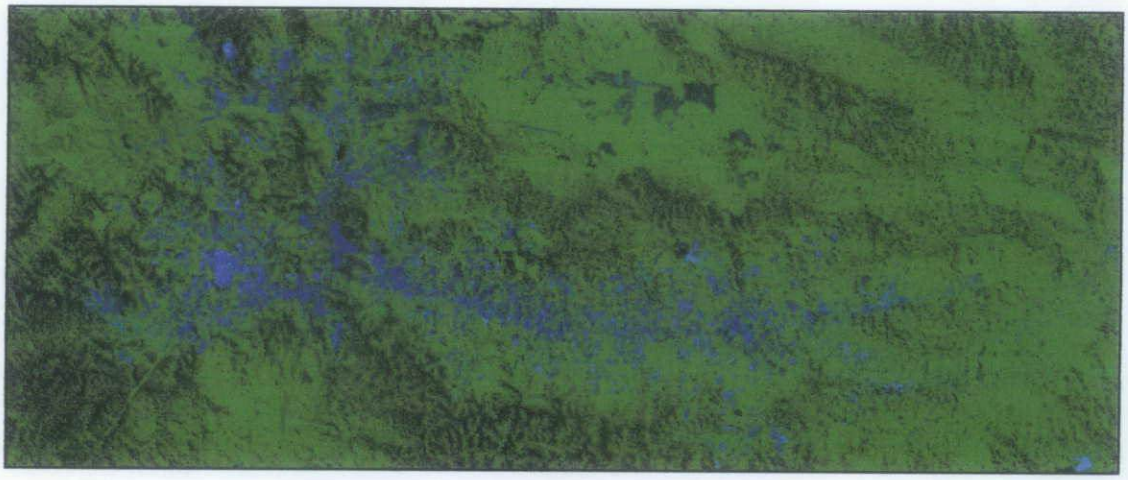
Combination of band 3 and 4



Combination of band 3 and 2

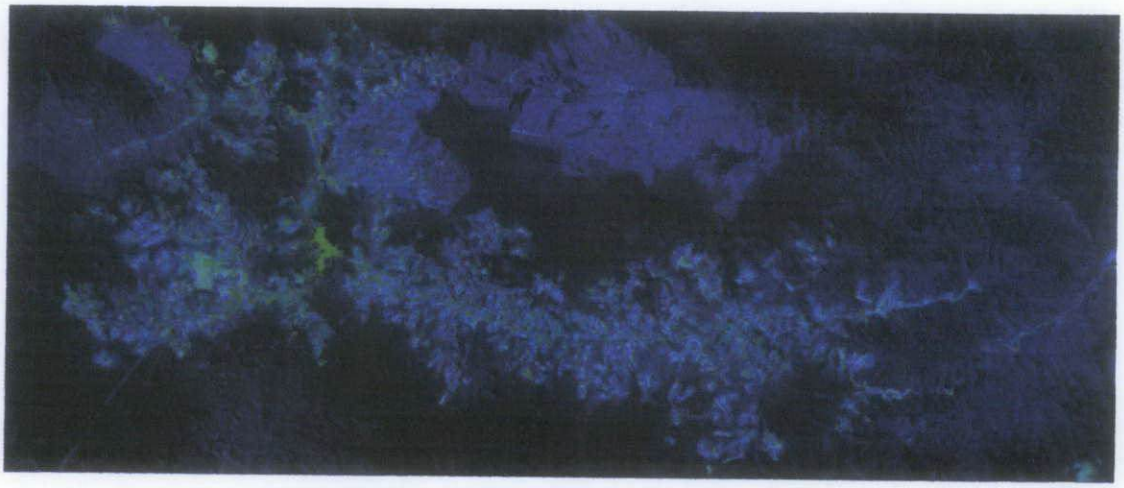


Combination of band 3 and 1

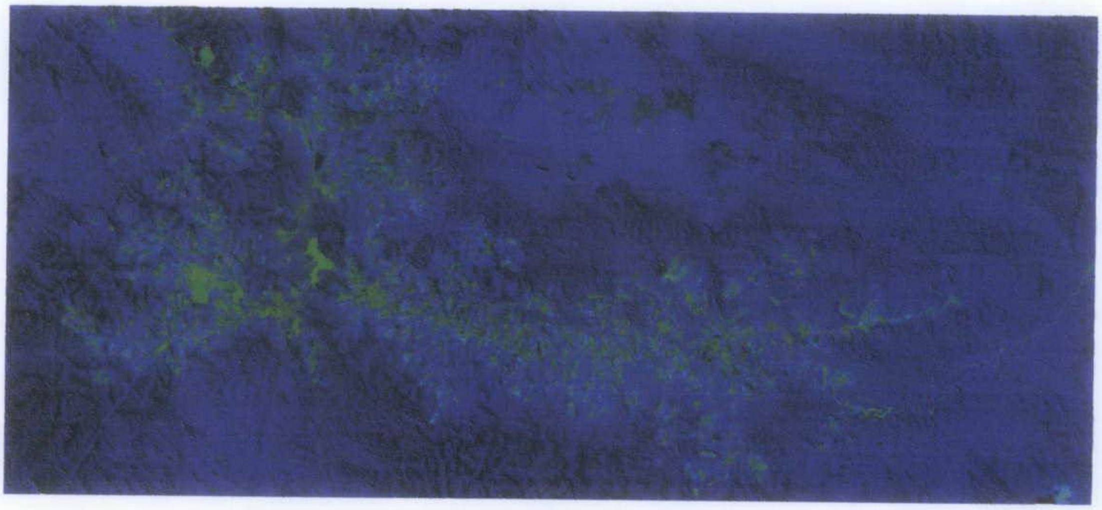


Combination of band 3 and 3

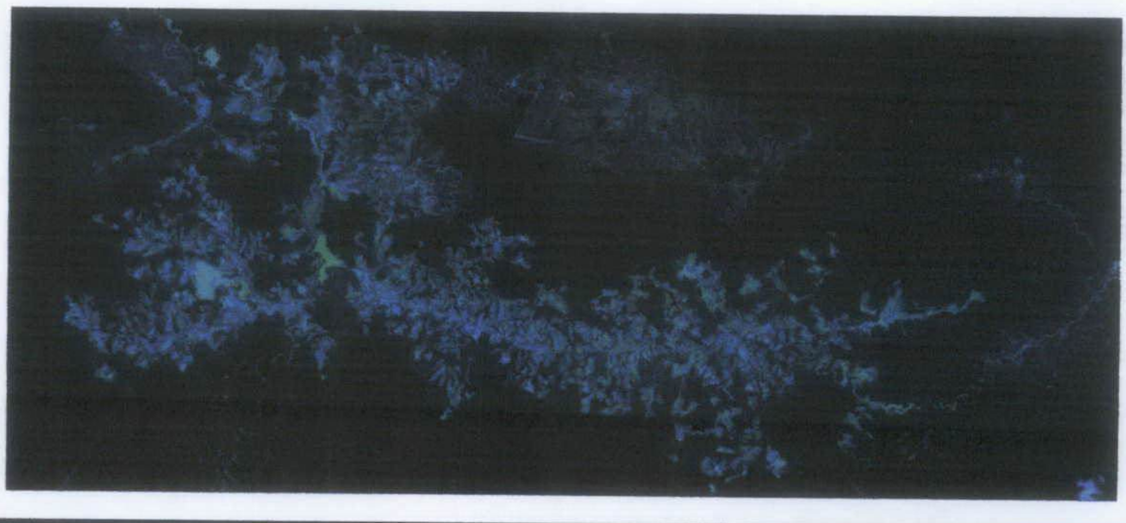
Combination of band 2 and 4



Combination of band 2 and 3



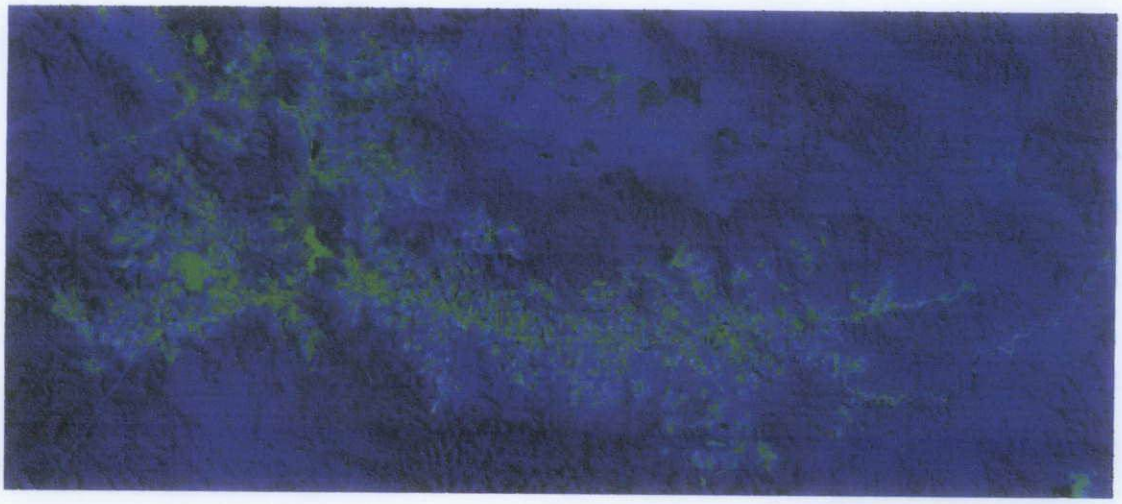
Combination of band 2 and 1



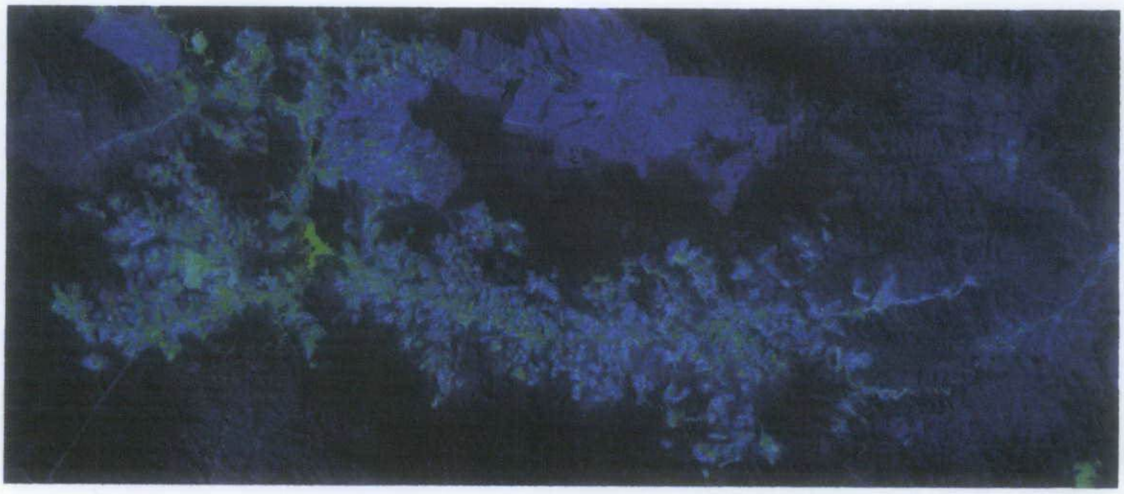
Combination of band 2 and 2

Combination of band 1and 2

Combination of band 1and 3



Combination of band 1and 4

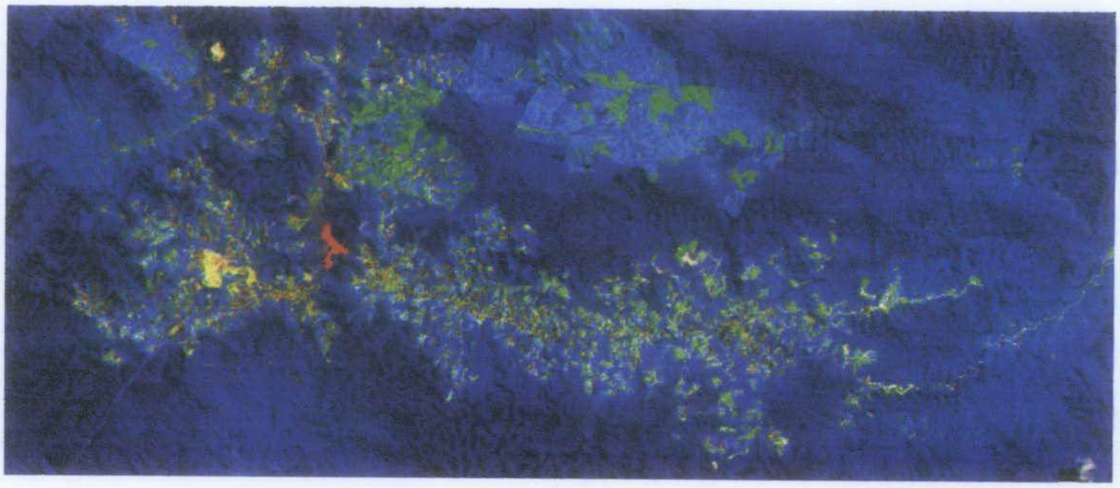


Combination of band 1 and 1

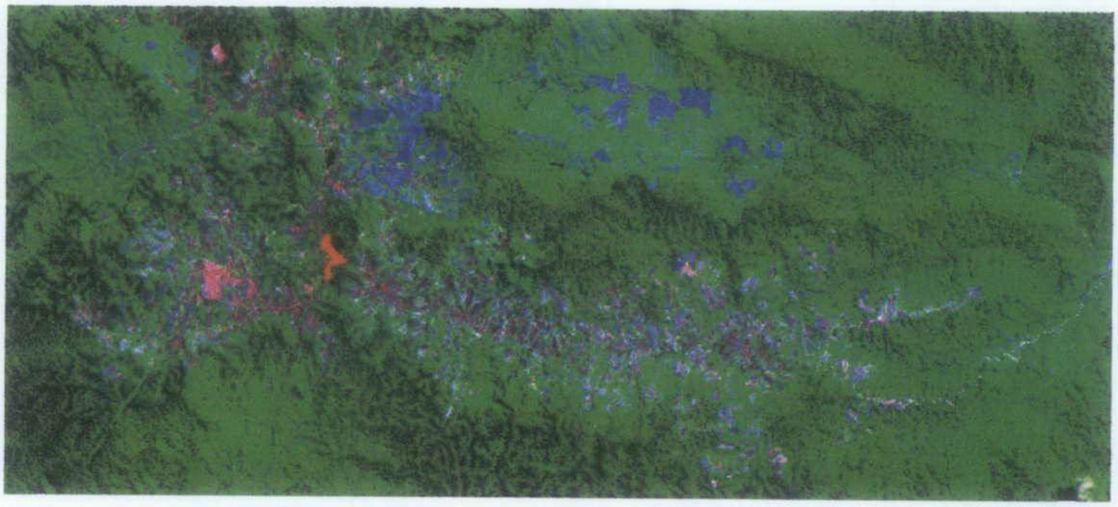
APPENDIX 5

Three Channel Colour

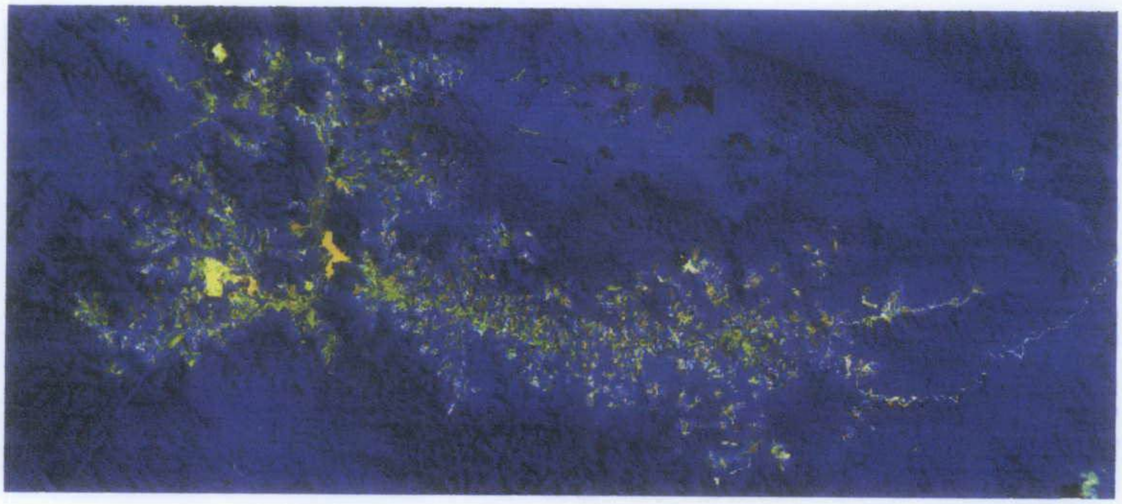
Combination of band 2, 4 and 3



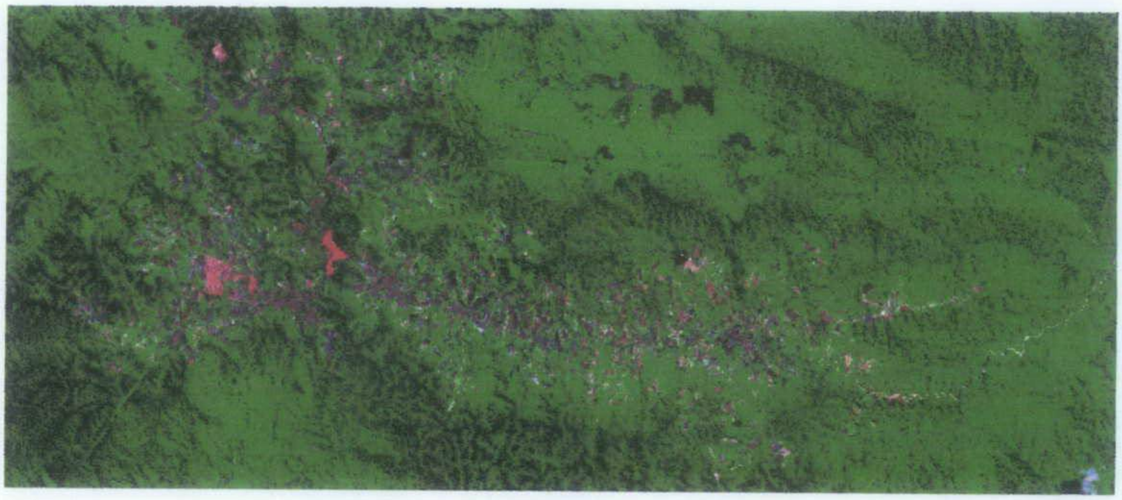
Combination of band 2, 3 and 4



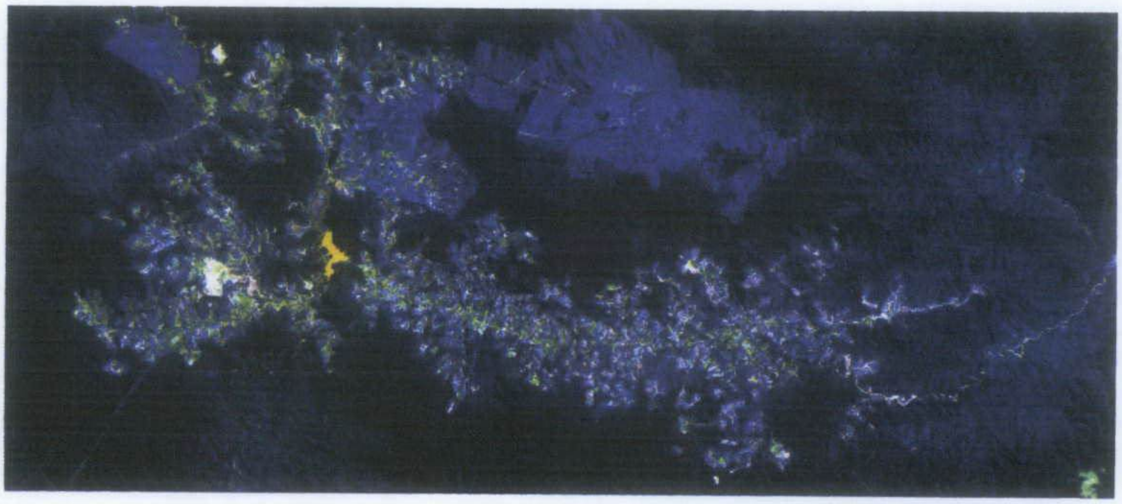
Combination of band 2, 1 and 3



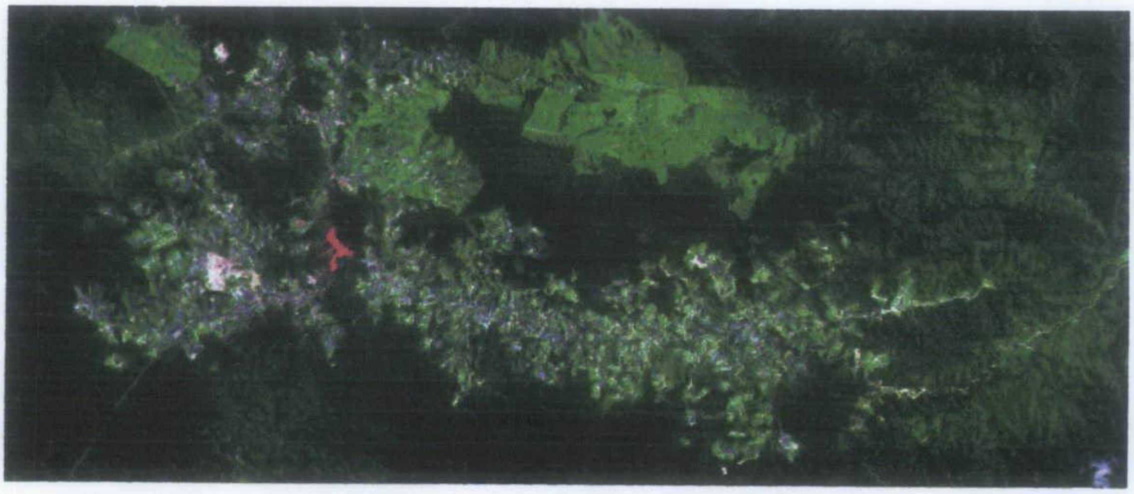
Combination of band 2, 3 and 1



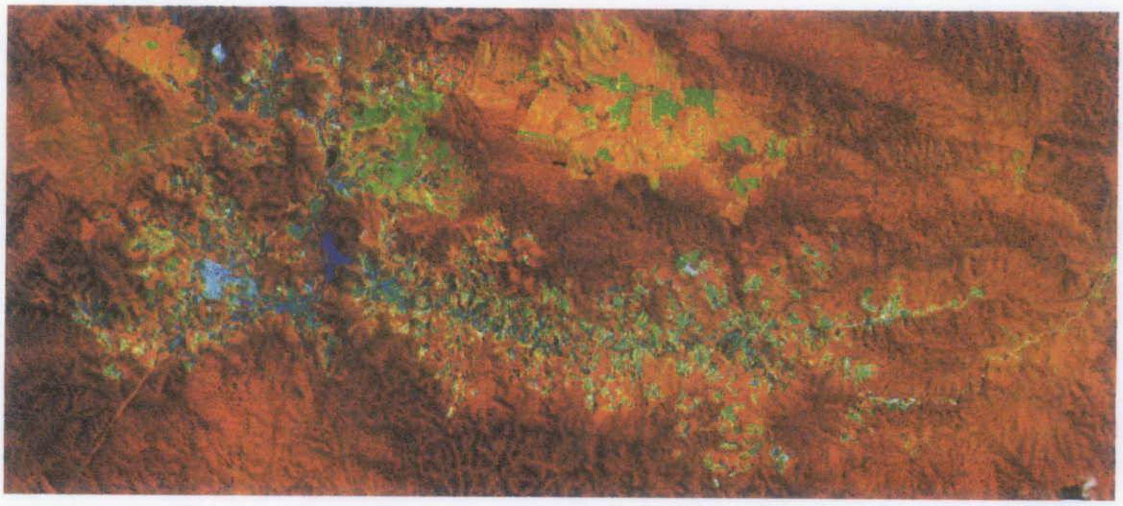
Combination of band 2, 1 and 4



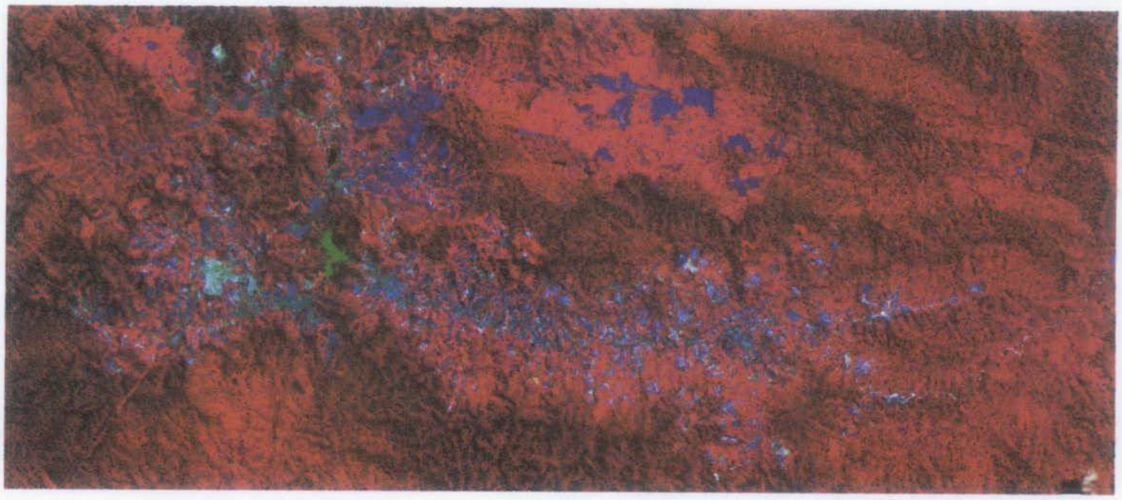
Combination of band 2, 4 and 1



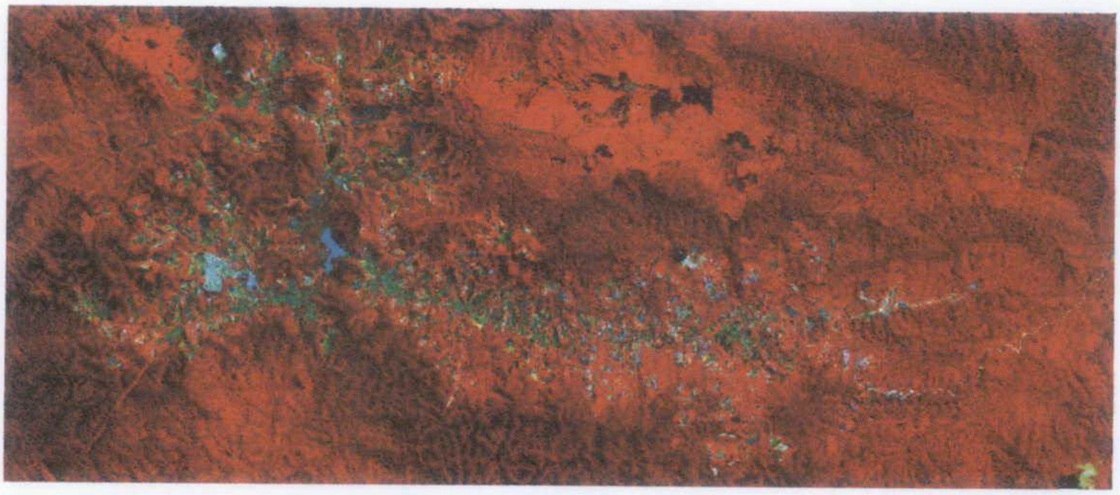
Combination of band 3, 4 and 2



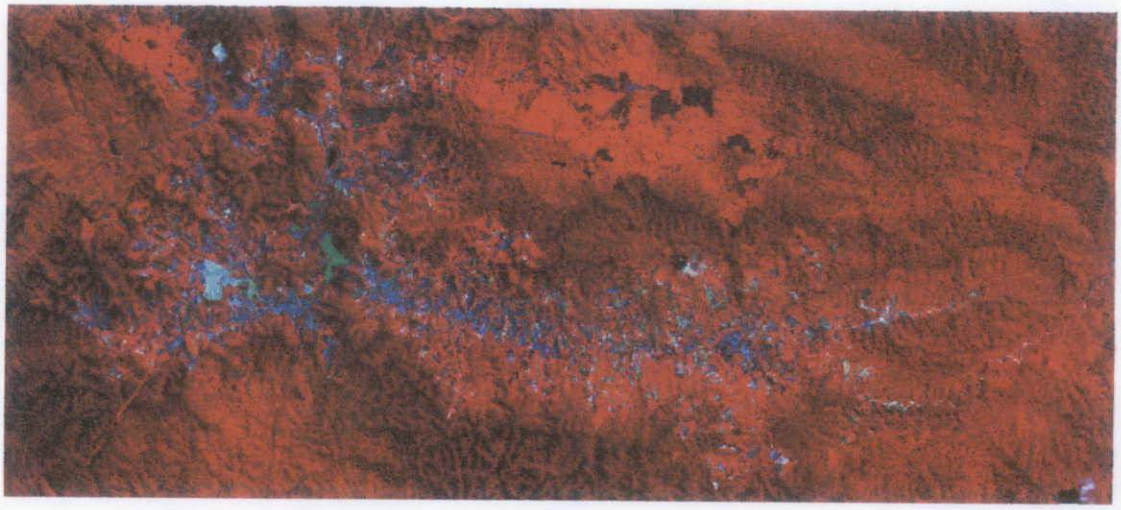
Combination of band 3, 2 and 4



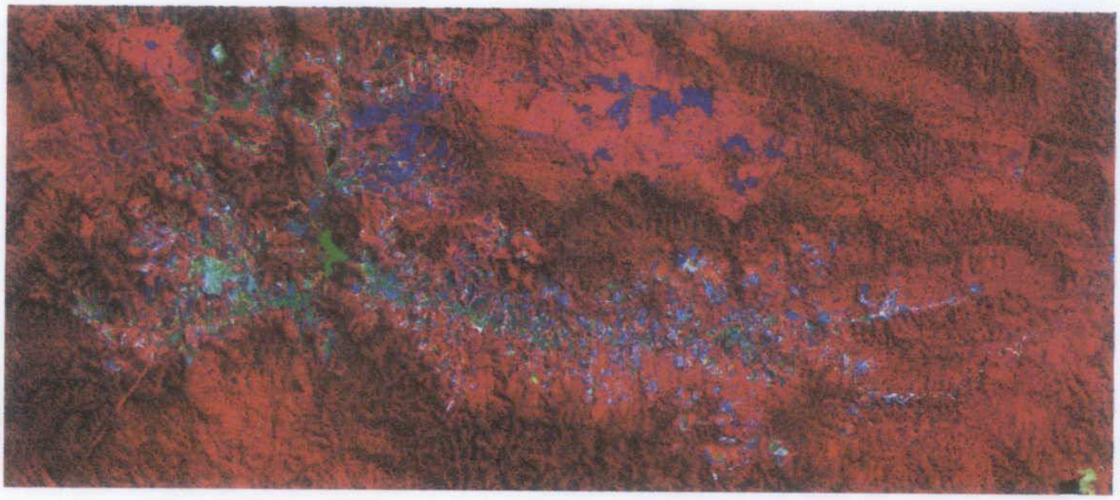
Combination of band 3, 1 and 2



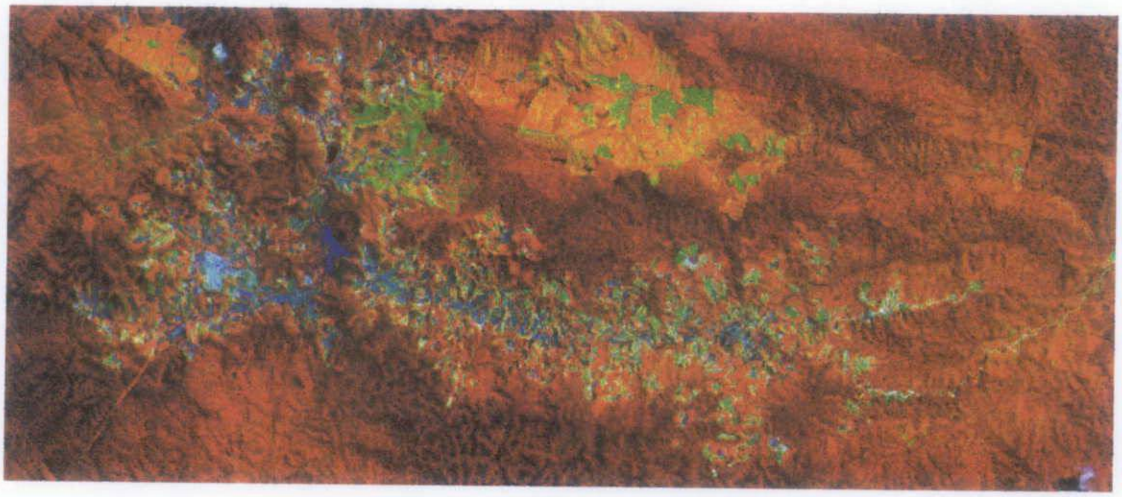
Combination of band 3, 2 and 1



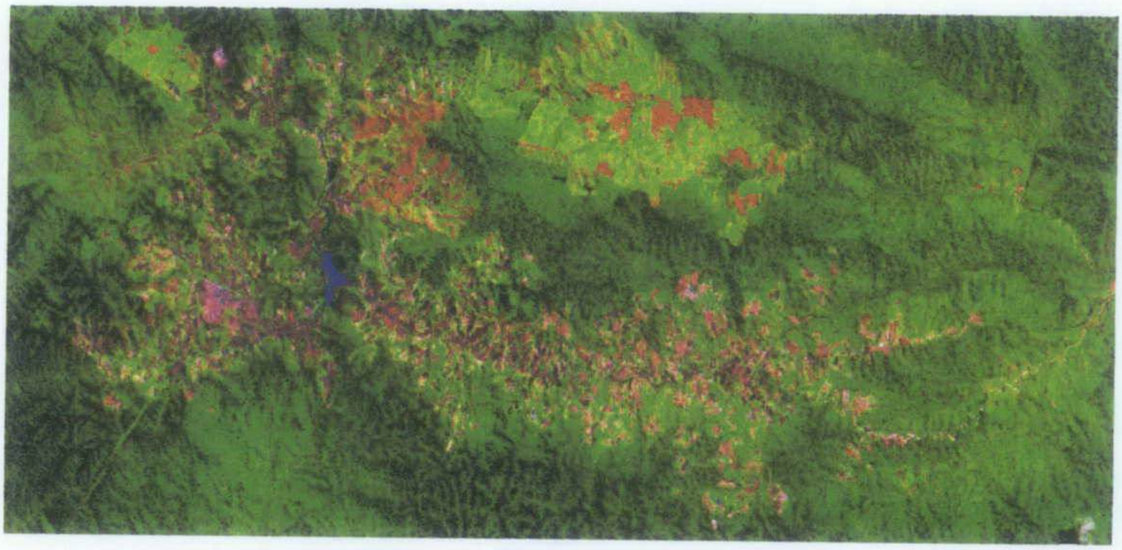
Combination of band 3, 1 and 4



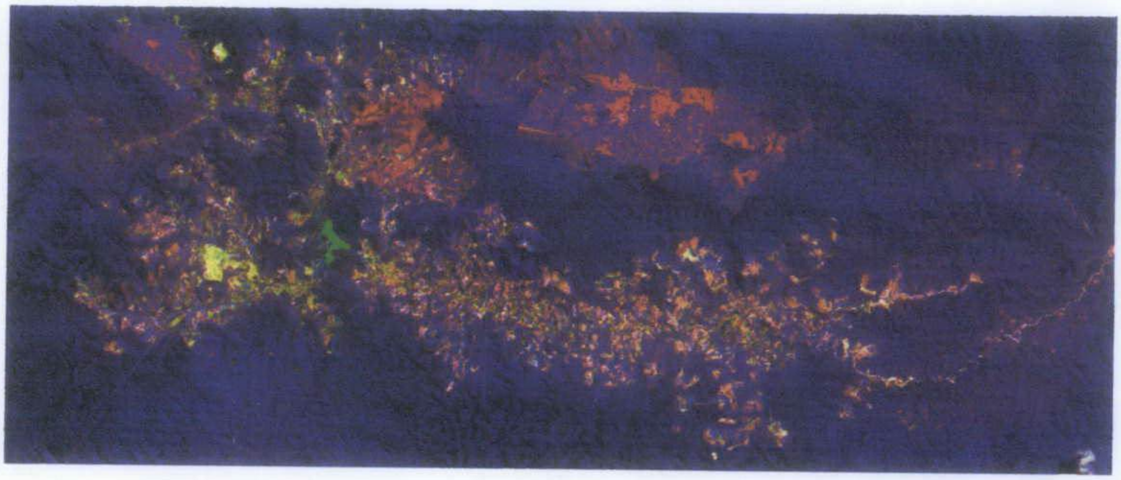
Combination of band 3, 4 and 1



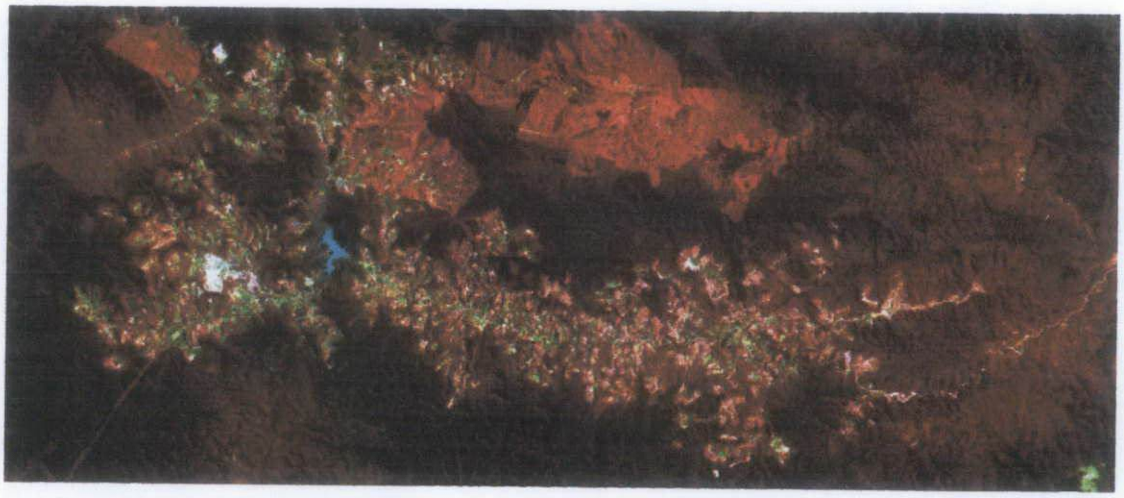
Combination of band 4, 3 and 2



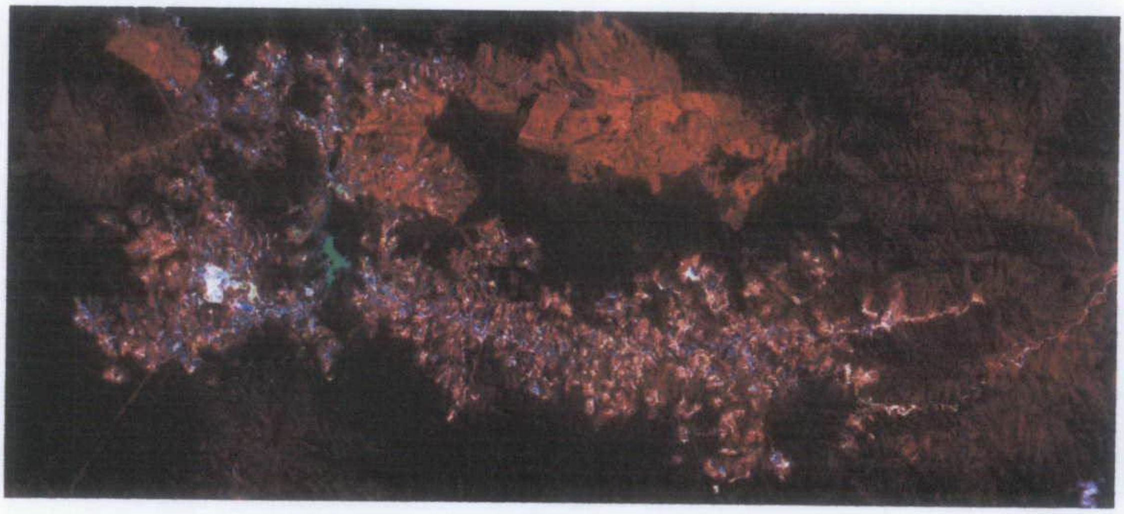
Combination of band 4, 2 and 3



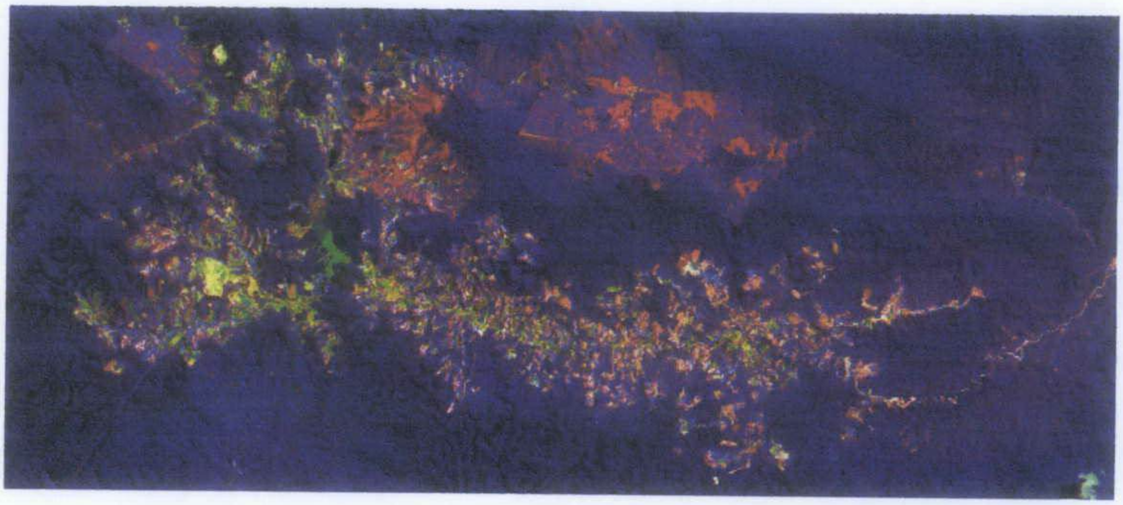
Combination of band 4, 1 and 2



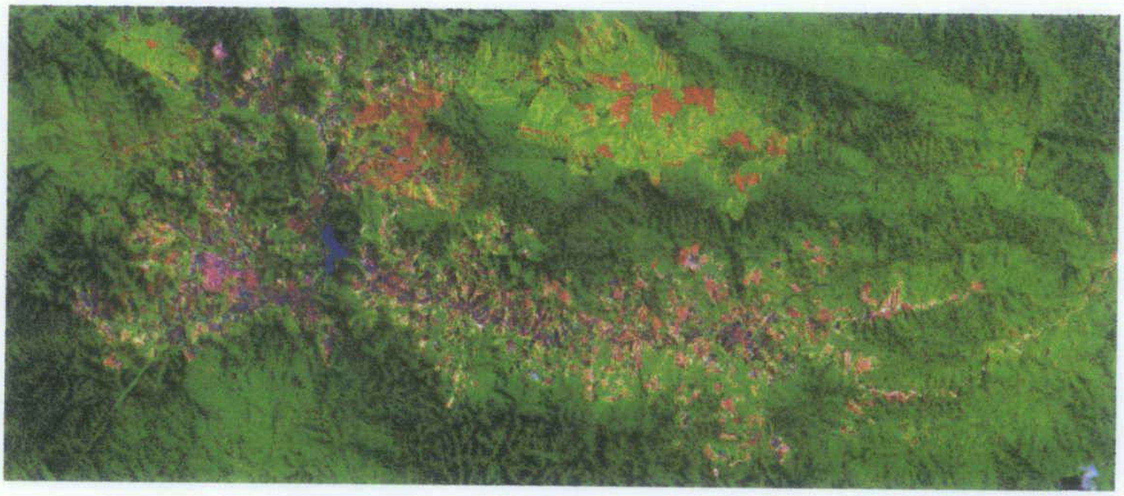
Combination of band 4, 2 and 1



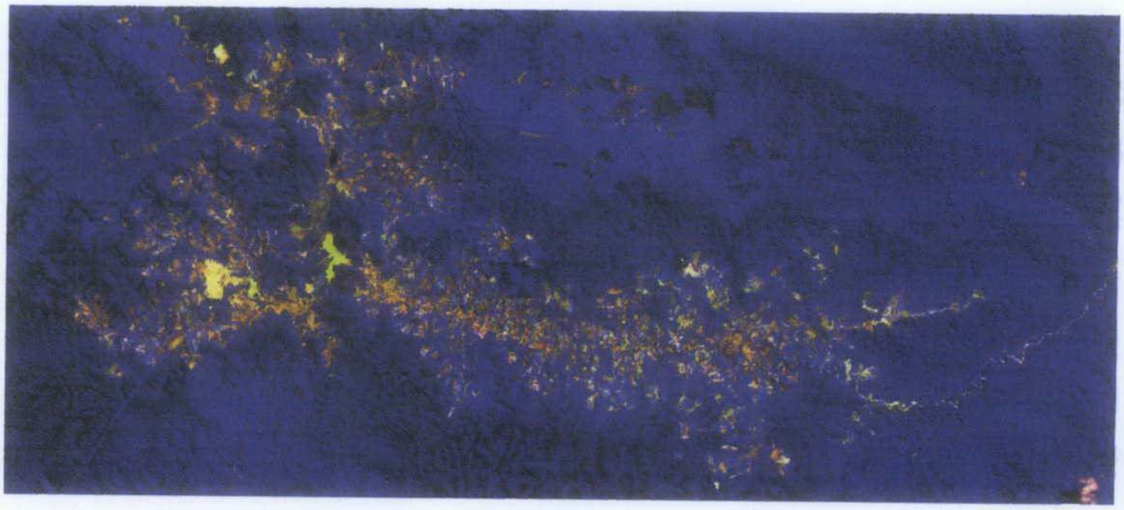
Combination of band 4, 1 and 3



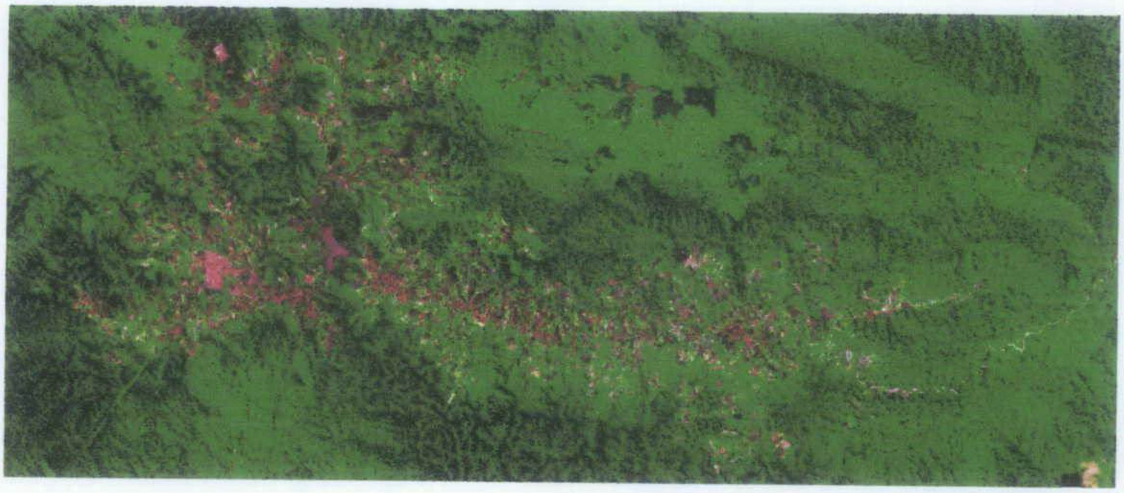
Combination of band 4, 3 and 1



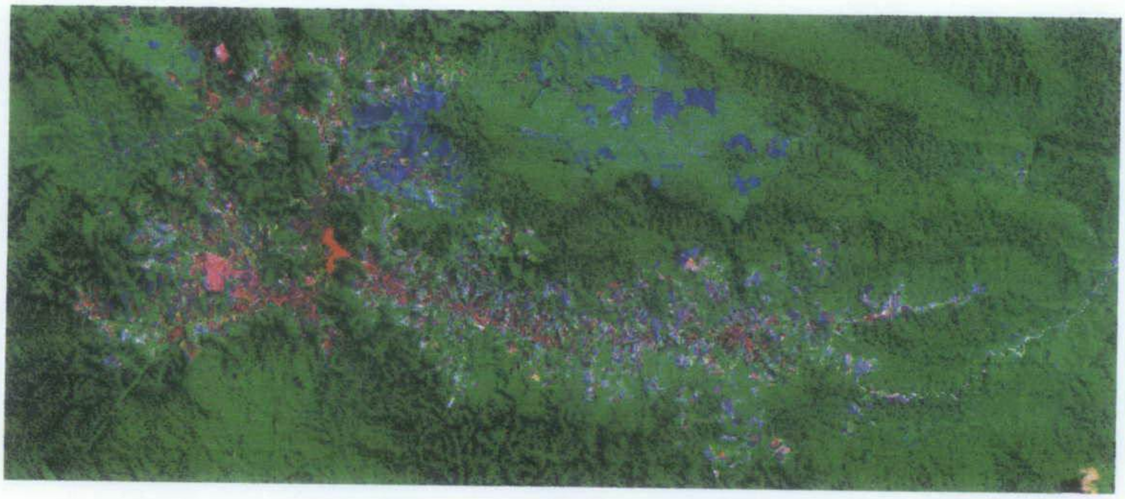
Combination of band 1, 2 and 3



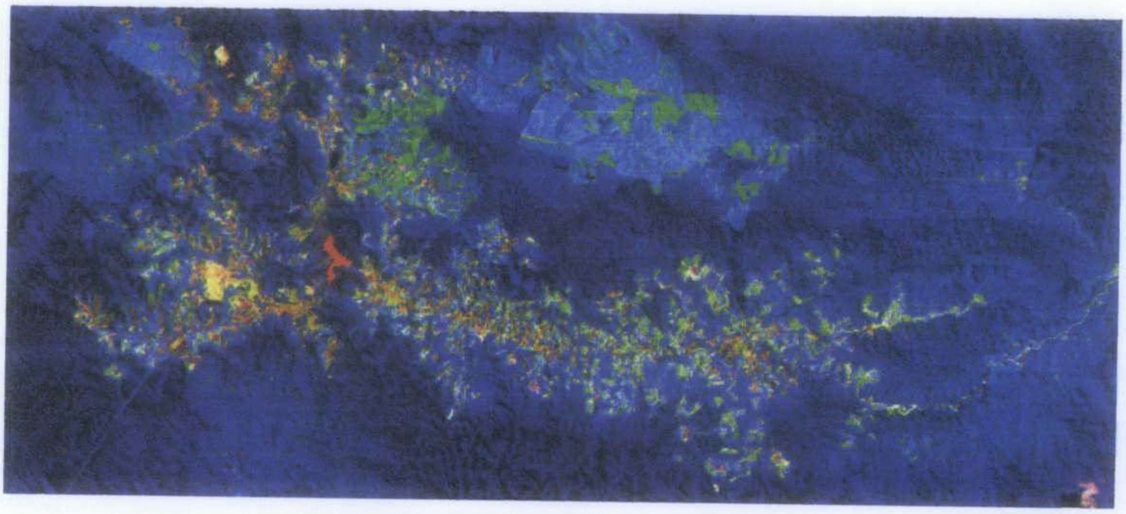
Combination of band 1, 3 and 2



Combination of band 1, 3 and 4



Combination of band 1, 4 and 3



Combination of band 1, 2 and 4

Combination of band 1, 4 and 2