Environmental Helicopter with Modular Sensor Concept: Example on Forestry Monitoring

by

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The tasks of an environmental helicopter (EHC) with high mobility fill the gap between ground-based measurement stations and satellites. In the last years ECD has made flight trials on a BK117 with a real-time, thermal imaging camera presenting colour-coded imagery which was used in trials to monitor AGRO-ECOsystems, forestry and waste deposits. The paper describes the results with two IR-cameras in the 3 - 5 µm and 8 - 12 µm band related especially to forestry monitoring. A comparison between satellite images from LANDSAT TM, ERS-1 and X-SAR on the one hand and helicopter borne IR scanner images on the other hand is given. In an own chapter the actions at Kalimantan concerning remote sensing by satellites in the tropical rain forest are documented. That shall give a motivation for ground truth actions with EUROCOPTER's Environmental Helicopter, which is described at the end of this paper.

1 INTRODUCTION

EUROCOPTER (EC) is a German-French helicopter company. EUROCOPTER France (ECF) is located in Marignane and Paris, while EUROCOPTER Deutschland GmbH (ECD) is located in Munich and in Donauwörth. IPTN in Bandung produces in licence the EC helicopters Puma, Super-Puma and BO105.

During summer 1992 ECD has made several flight campaigns with a BK117-helicopter. This helicopter was equipped with a real-time, colour-coded thermal imaging camera from AGEMA which was used in an experimental trial to monitor AGRO-ECOsystem FAM (Forschungsverbund Agrarökosysteme München) and a waste deposit (see chapter 3). The Thermovision 900 camera is a temperature measurement system with a spectral response in the ranges of 3-5 µm and 8-12 µm. The resolution is 12-bit for high image quality to get IR-signature from a.m. AGRO-ECO applications. The measured data of each image were digitally stored while live scenes were recorded on video tape.

With the remote sensing of rural surfaces it is possible to measure surface temperatures not only of single points on ground. These surface temperatures depend mainly on the content of soil moisture. Effects of solar radiation, wind, plant parameters incl. spectral emissivity/reflectivity and the angle of detection have to be taken into account during the evaluation/interpretation (see chapter 3.2). Additional measurements on a waste deposit showed strong chemical activity for some parts of the disposal which could not be seen in the visible spectrum (see chapter 3.3).

At present, there are ongoing experiments with an additional scanner (3-5 µm) mounted in parallel to the LOS of the first camera head (8-12 µm). In a ground measuring campaign different kind of trees were analysed (see chapter 4).

The monitoring of the tropical rain forest by LANDSAT TM, ERS-1 and X-SAR in Kalimantan is described in chapter 5. A general documentation about Kalimantan is included.

Changing environmental conditions and an increasing human pressure on endangered natural areas require enhanced efforts either to mitigate or to prevent severe threatening to human life or national economies. The environmental consequences of the tropical deforestation and its estimated impact on the world-wide ecosystem triggered intense scientific and political forces. Environmental research serves the communities to protect and to conserve the natural resources, to mitigate natural hazards, as well as to help optimising the land-use. Acquisition of meaningful data can be heavily improved and accelerated by using satellite imagery and aerial photographs taken by helicopters in order to understand the subsurface conditions and the land use dynamics. The improved understanding and the implementation of the resulting land-use proposals will influence to a large extent the well-fare of the population beyond the next generation.

The combination of an Environmental Helicopter (EHC) equipped with remote sensing systems including GPS for in-situ campaigns in conjunction with satellites is very useful for monitoring, inventorying, forecasting and supervising of forests, land-use, agricultural and coastal regions, for rapid assessment in response to environmental pollution and disasters. The global changes can be detected by multi-temporal monitoring.

In the future, field work with the aid of an EHC will take a part of verification methodology. The reflectivity of :

- closed canopy primary rain forest
- degraded rain forest where regional forest cover is less than 70%
- deforestation front or area identified using change detection indicators
- secondary forest
- seasonally gradient

can be monitored by an EHC very easy.

In the future the trials will be extended with an helicopter-mounted spectroradiometer (visible and near IR Range) to detect with high resolution the red-edge effect of chlorophyll. With this remote sensing techniques the crop type, the surface roughness, the growth of vegetation (biomass), evapotranspiration, vitality of plants, vegetation stress etc. can be monitored by spectral imaging systems mounted in helicopters (see chapter 6).

2 ADVANTAGES OF AN ENVIRONMENTAL HELICOPTER (EHC)

2.1 General Helicopter ADVANTAGES

The tasks resulting from the "Earth Environment" are just as versatile as complex and expending. They can only be solved by a co-ordinated action, by integrating modern technologies and by the use of existing institutions. The tasks are the investigation of the actual status of the environment for detecting the global change, a continuing surveillance and an early analysis of environment-relevant parameters of influence. These spectrum of tasks can be fulfilled only partially by stationary measurement facilities.

The helicopter is able to take over an essential part in the diagnosis and all kind of surveillance functions. The helicopter is capable of reaching a maximum number of measurement positions in a minimum of time unaffected by ground structure or obstacles. Other benefits/advantages of a helicopter are:

- **High mobility**
- **Hover, fly slowly and cross distances at high speed**
- **No runway necessary; Transportation of personnel and equipment**
- **Precise positions with global positioning system (GPS)**
- **Taking samples of the air, the water and from soil**
- **Detailed local environmental monitoring and ground truth actions**
- **Filling the gap between satellites (global) and ground based stations (local)**
- **Calibration of electro-optical- or radar-sensors on satellites**

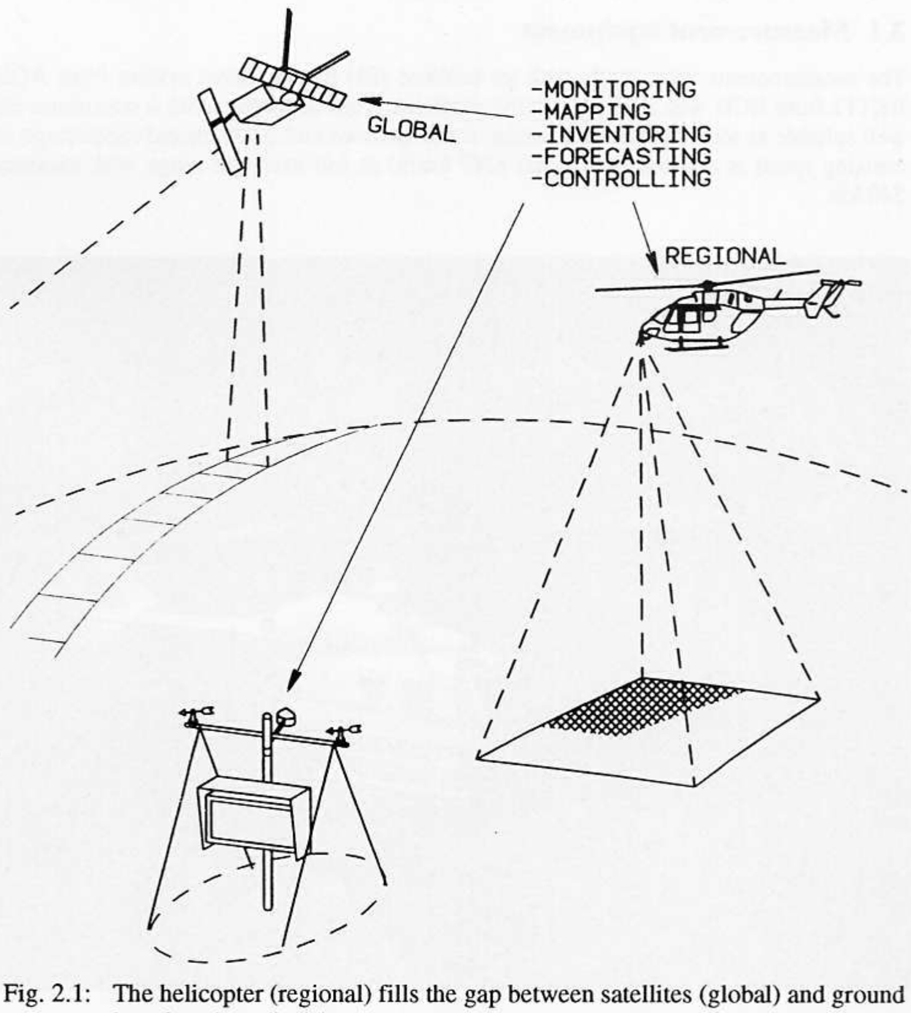


Fig. 2.1: The helicopter (regional) fills the gap between satellites (global) and ground based stations (local).

2.2 Typical mission of the EHC for forestry monitoring and research

Using satellite sensors is a well acknowledged method for forestry monitoring and research. The necessary ground truth assessments and measurements are mostly done by foot. The scientists need to inspect the respective areas. They take pictures, assess the vitality and stage of damage of the trees and make special measurements of the vegetation and the soil. Leafs, twigs and branches are taken as samples for examinations in the laboratory from the crown of the trees with the help of tree climbers. This kind of ground truth is time consuming and in the tropical rain forest sometimes impossible because of the bad infrastructure and the inaccessibility of primeval forest.

The Environmental Helicopter (EHC) is a very helpful mean to fulfil the requirements of forestry monitoring and research. There are three typical mission profiles for the EHC in this field:

- The easiest mission is the transport of staff and equipment from the basis station to the examination area.
- Sampling of leafs, twigs and branches out of tree crowns with the helicopter is often the only possibility to reach the crowns. There are two possible ways of sampling: a) Sitting in the H/C's open sliding door using special long branch shears and b) hanging in a climbing harness at the H/C 's winch.

The EHC is a very well suitable platform for airborne measurements with the requirement of high spatial resolution. The sensors are a multi spectral scanner in the optical and near IR band, two IR scanners (3-5 and 8-12 μm) and, for documentation, a TV camera. The basic equipment of the EHC includes GPS for localisation. For further description and other sensors please see chapter 6.
Beneath the pure research applications, the helicopter is used in the forests for several maintenance tasks:

- Logging in inaccessible mountain forests
- Liming of forests with acidic soil
- Fire detection and fire fighting; the water can be exactly dispensed onto the fire from a helicopter.

3 MEASUREMENTS AT EUROCOPTER WITH THE EHC

3.1 Measurement equipment

The measurements were made with an infrared (IR) measurement system from AGEMA. For all experiments a BK117 from ECD was used as a flying platform. This helicopter with a maximum take-off weight of 3.350 kg is well suitable as sensor platform because of the spacious and unobstructed cabin/cargo compartment. The maximum cruising speed at sea level is 133 kts (247 km/h) at full load, the range with maximum standard fuel capacity is 540 km.

Fig. 3.1: The BK117 helicopter from EUROCOPTER with a max. take-off weight of 3.350 kg in a hilly landscape

3.1.1 AGEMA infrared measurement equipment

The AGEMA "Thermovision 900 Series" infrared system is not only an imaging system like a Forward Looking Infrared (FLIR) but a surface temperature measurement system. It consists of two scanners with Stirling cooled detectors, one for the short-wave band (3-5 µm) the other for the long-wave band (8-12 µm). Both are equipped with lenses providing a 5 x 10 degrees field of view (FOV), a system controller, a special keyboard, mouse and VGA monitor. The scanners can be used real-time parallel in order to get bi-spectral images.

The pre-processed data from the scanners were send to the system controller and processed there digitally (12-bit = 4096 levels). The system controller software supports advanced image processing and analysis controlled by keyboard and mouse. The analysis capability includes statistics, emissivity equalisation, atmospheric modelling based on the LOWTRAN model in addition to basic functions like level and range adjustment and provides profiles, areas of interest, histograms and spotmeters. Images can be analysed either in real-time or after retrieval from storage. To ensure maximum accuracy, especially in long-distance measurement, all relevant object and measurement parameters such as emissivity, reflected ambient temperature, object distance, relative humidity and atmospheric temperature are taken into account.

3.1.2 Measurement set-up in the helicopter

The measurement trails described in chapter 3.2 and 3.3 were made as experimental tests. During the measurement flights the whole system was mounted in the helicopter behind the pilot's seat. The scanner was looking outside the open sliding door. For quicklook aspects a monitor showed the IR-image. The video signal of the IR-image generated in the AGEMA system-controller was recorded on a video tape during the whole flight tests. A small CCD black/white camera was mounted and adjusted in parallel to the scanner's LOS. This black/white signal was additionally recorded on a video tape recorder for the better documentation of the IR-images. The vibration attenuation was made with some pieces of foam. No problems were caused by HC generated vibrations. Even operating a standard mouse was possible.

Type	**900 LW**	**900 SW**
Detector type	MCT Stirling cooler	2xInSb, parallel scanning, Stirling cooler
Spectral response	**8 - 12 µm**	**3-5 µm** (exactly 2 - 5.6 µm)
Frame frequency	15 and 30 Hz, selectable	15 and 30 Hz, selectable
Line frequency	2.5 kHz	2.5 kHz
Lines/frame	136	136
Spatial resolution at 50% modulation - elements per line - mrad (at 10° FOV)	 230 0.76	 200 0.87
Samples/line	272	272
Temperature range	-30 to +1500 °C	-20 to 500 °C
Sensitivity at 30°C	0.08 K	0.1 K
Dynamic range	12 bit (4096 levels)	12 bit (4096 levels)
Weight	3.5 kg	3.5 kg
Lenses	5° x 10°	5° x 10°

Table 3.1: The most important technical data of the two AGEMA IR-scanners

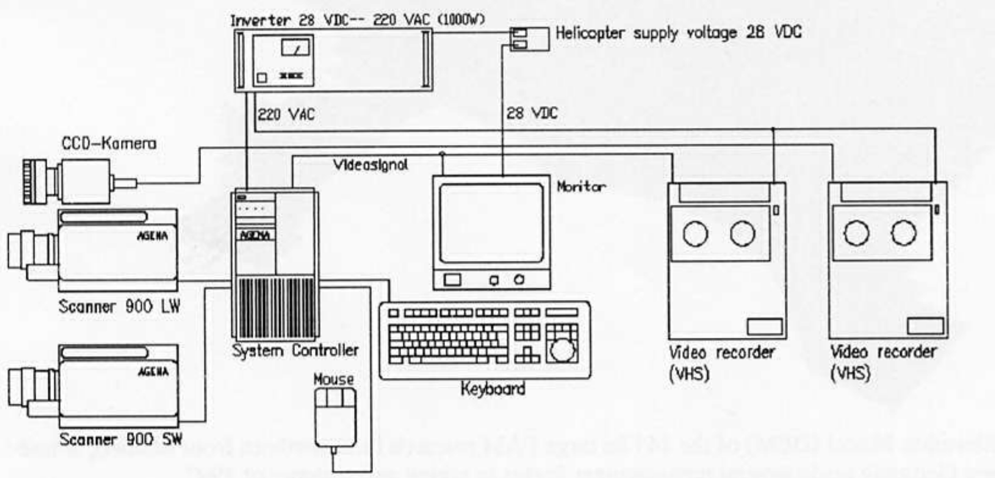


Fig. 3.2: Block diagram of the AGEMA measurement set-up used for the flight experiments.

Fig. 3.3: The AGEMA measurement equipment with the 3-5 µm and the 8-12 µm scanner mounted in an Aluminium-Rack is ready for helicopter flight trials.

3.2 AGRO-ECOsystem FAM-Project and results

3.2.1 The FAM project

The FAM (Forschungsverbund Agrarökosysteme München) project is a long-term research experimental program initiated and performed by a number of institutes of the Technical University of Munich and the GSF (Forschungszentrum für Umwelt und Gesundheit GmbH near Munich). The main purpose of the research network FAM is to evaluate changes in land usage of cultivation in agro-ecosystems.

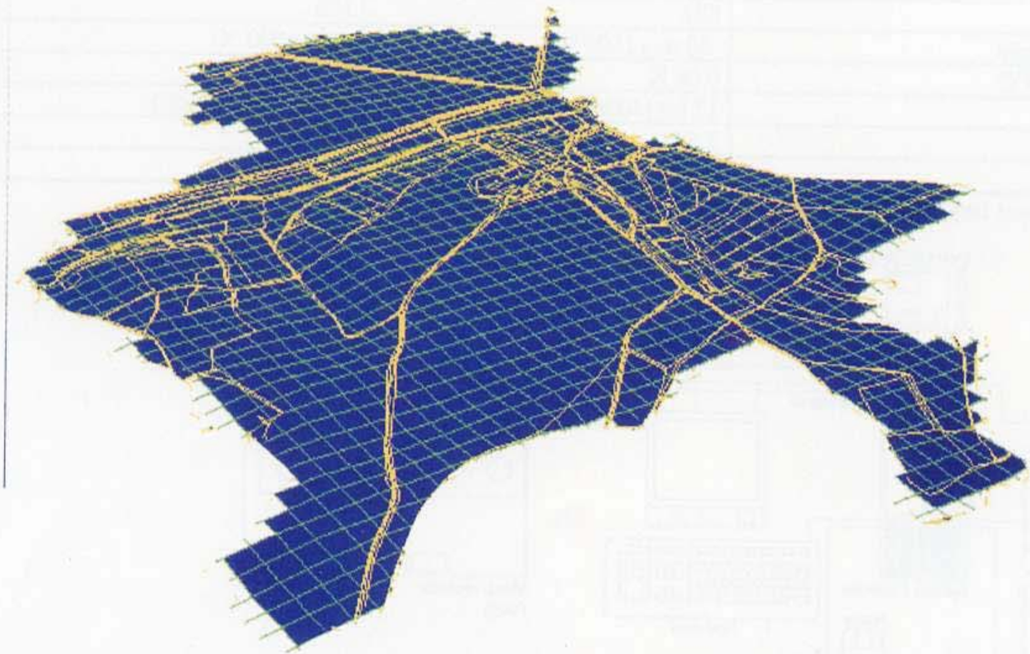


Fig. 3.4: Digital Elevation Model (DEM) of the 143 ha large FAM research farm northern from Munich, where Eurocopter Germany made several measurement flights in spring and summer of 1992.

At the research farm (143 ha) "Klostergut Scheyern" (FAM project) in the tertiary hills near Munich, three types of cultivation are situated - conventional agriculture, sustainable agriculture and landscape conservation. These types will be monitored in their influence on the ecological and economical cycles in the ecosystems especially on ground. Therefore a network of different kind of climatic and soil-ecological sensors was installed over the experimental area. Data were taken on ground. The measurement data of these in-situ sensors were recorded in the Geographical Information System (GIS) where they can be combined with additional sensing information.

Fig. 3.5: Aerial photo of the FAM research area. At the left side the farm and the fish ponds are located. Just at the right edge of the photo the two IR-images of figure 3.7 are located

3.2.2 Measurement flights and interpretation of results

In spring and summer of 1992 several measurement flights with the AGEMA colour-coded thermal imager (8-12 µm) were performed. The intention of these flights was to get first experience in the IR-signature of a landscape and to learn about the problems arising from physical constraints as well as from technical aspects.

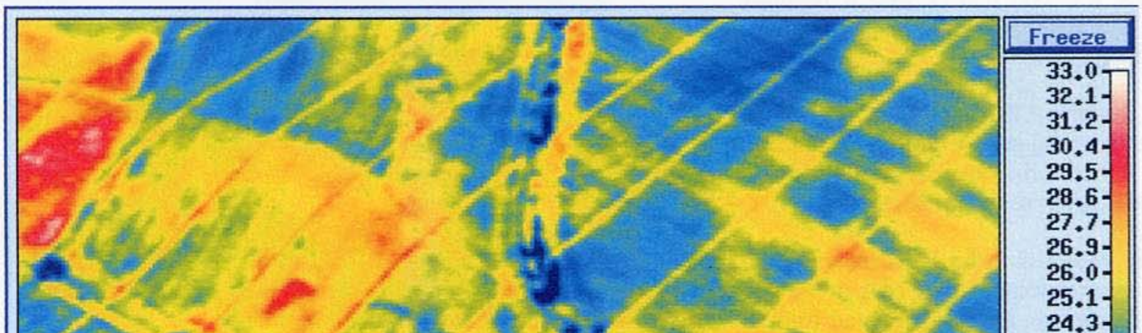


Fig. 3.6: IR-image in the 8-12 µm band of the FAM research area. Notice the dark trees and the 50 m stripes.

At the flight campaign on 13.07.92 the FAM area was scanned three times (morning, afternoon, evening) by flying 16 stripes side by side in an altitude of 600 meters to learn about the effects caused by the daily course. The daily course is mainly influenced by the position of the sun. First the landscape's surface is heated up by the sun during the day and second the angle of incidence of the sun rays turns from east in the morning to west in the evening.
After the geometrical correction (warping) of three corresponding scenes in the daily course an overlay was made. The IR grey-scale values of the three images were transformed separately to the red, green and blue colour channel and together presented in a true colour image. The produced colours of this image are related to the heat capacity. Areas with the same colour have the same heat capacity.

In an other flight campaign, the correlation between the surface temperature and the soil moisture on the FAM area was examined together with scientists from the GSF. Most of the measurement area was covered with wheat. For ground truth a grid (50 m x 50 m) of measurement points was available. In order to ease the geometrical correction of remote sensing images a set of one meter wide stripes in a distance of 50 meters was milled through the fields (see fig. 3.5 and 3.6). The direction of these stripes was east to west.
The test flights were made in heights of 150, 300 and 600 meters. Additionally, a height profile from 100 up to 1000 meters was flown. The investigations show a correlation between the soil moisture and the surface temperature which is in accordance with the calculation models. In a special case, a lens of clay was found on a slope, which stops the water flow in the slope. The area beneath this lens of clay was that dry, that the surface temperature was about 7 degrees warmer than in the wet area above.

In a further experiment the water temperature of a little fish pond was measured with the IR scanner. The surface of water can reflect the sky in the 8-12 μm band. But in this case, the IR-images show directly the water surface temperature. A inflow of fresh water in the fish pond was clearly recognisable. The areas where different kinds of sea weeds were swimming showed a water surface temperature of six degrees higher than the fresh water influx.

3.2.3 Comparison between the LANDSAT and the helicopter data

At the 29.06.92 a LANDSAT image containing the FAM research area was made. About two weeks later at the 13.07.92 a helicopter campaign was performed by Eurocopter with the 8-12 μm IR scanner and a black/white CCD camera with a line of sight in parallel. The flight altitude was 600 meters with a resulting pixel resolution of 0.77 x 0.92 meters results.

The LANDSAT data have a spatial resolution of 30 meters for the channels 1-5 and 7 while the thermal IR channel 6 provides a resolution of 120 meters.

So the EHC using the IR scanners and a multispectral camera (see chapter 6) will provide very good data for ground truth of the LANDSAT TM data. In fact a comparison of the LANDSAT TM channel 4 of the FAM research area with two IR images in the 8-12 μm band out of the flight path shows an evident difference in spatial resolution (see fig. 3.7).

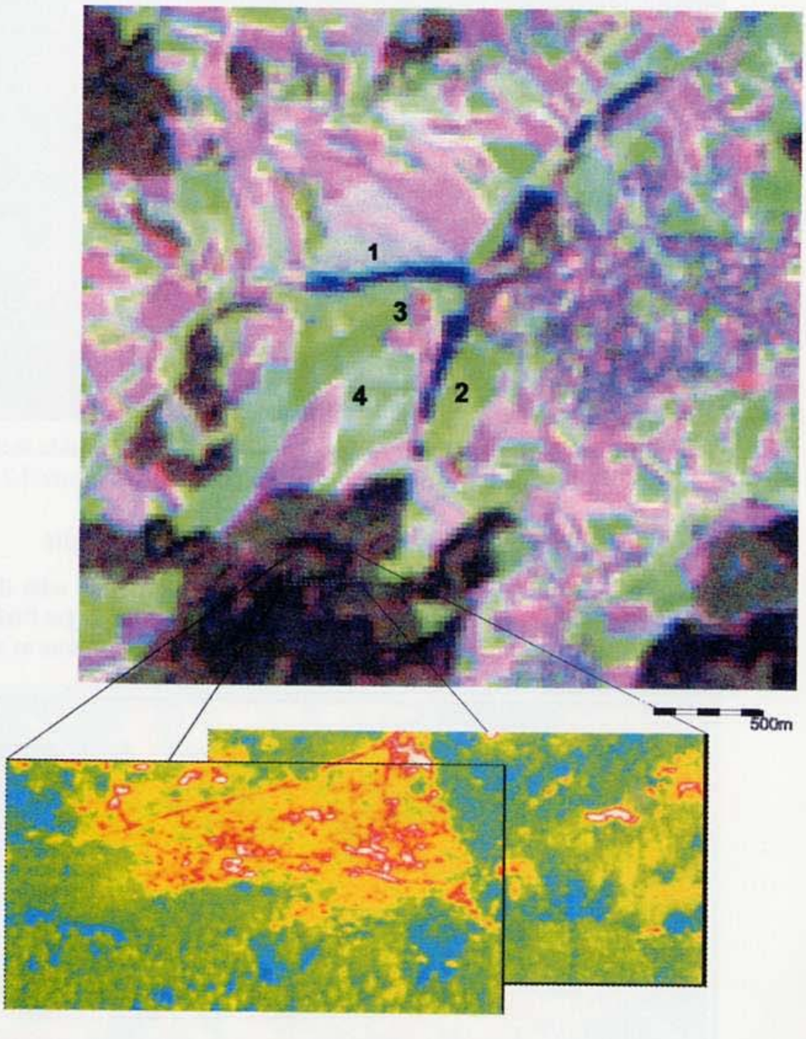


Fig. 3.7: Part of a LANDSAT TM image channels 5, 4 and 3 with the FAM research area compared with the two IR images taken from the EUROCOPTER's helicopter. For the numbers see text.

Figure 3.7 shows the LANDSAT image where the FAM research area is situated in the lower left quarter of the image. The dark elongated areas 1 and 2 are two chains of fish ponds belonging to the FAM area. Number 3 indicates the farm buildings and the whole bright area indicated by number 4 is the field of wheat. The dark area in the lower left corner is the signature of forest. The squares show the localisation of the two IR example images taken from the helicopter. The IR scene shows a glade in the forest. Single crowns of trees are recognisable in the bottom area. The colour presentation (false colour) of the IR images shows much more contrast as a black and white presentation.

3.3 Monitoring of a waste deposit

In a waste deposit, especially in a deposit for domestic waste, chemical and biological reactions occur. The exothermic reactions cause a heating of the surrounding area up to the soil surface. The so-called hot spots can be detected by an infrared temperature measurement system such as the one used in this experiment.

Fig. 3.8 shows the embankment at the south-west part of the Munich waste deposit. The grey "S"-shaped band in the upper part of the image is a street leading up the hill. The most striking part of the image is the dark spot at the bottom to the left. The inner dark area indicates that the sensor is saturated in the actual temperature set-up, which allows temperature measurements in a range of -30° up to 80°C. It is also possible to select other temperature ranges between -30° and +1500°C, but for environmental measurements the applied one is the best choice. A comparison of the video tape and the photos show that the source of this hot emission is the flame over a gas nozzle, where the methane gas emitted by the deposit is burned. The flame itself is not visible at daylight.

The embankment shows a surface temperature range from 19°C up to over 42°C. A comparison between visual images and the IR-image shows, that with increasing plant height the temperature decreases (dark). There are two reasons for this fact. First the higher the tree is, the better the wind can reach the treetop and decrease the temperature by evapotranspiration cooling. Second, the denser the plants, the lesser soil is visible and soil will be heated by sun radiation.

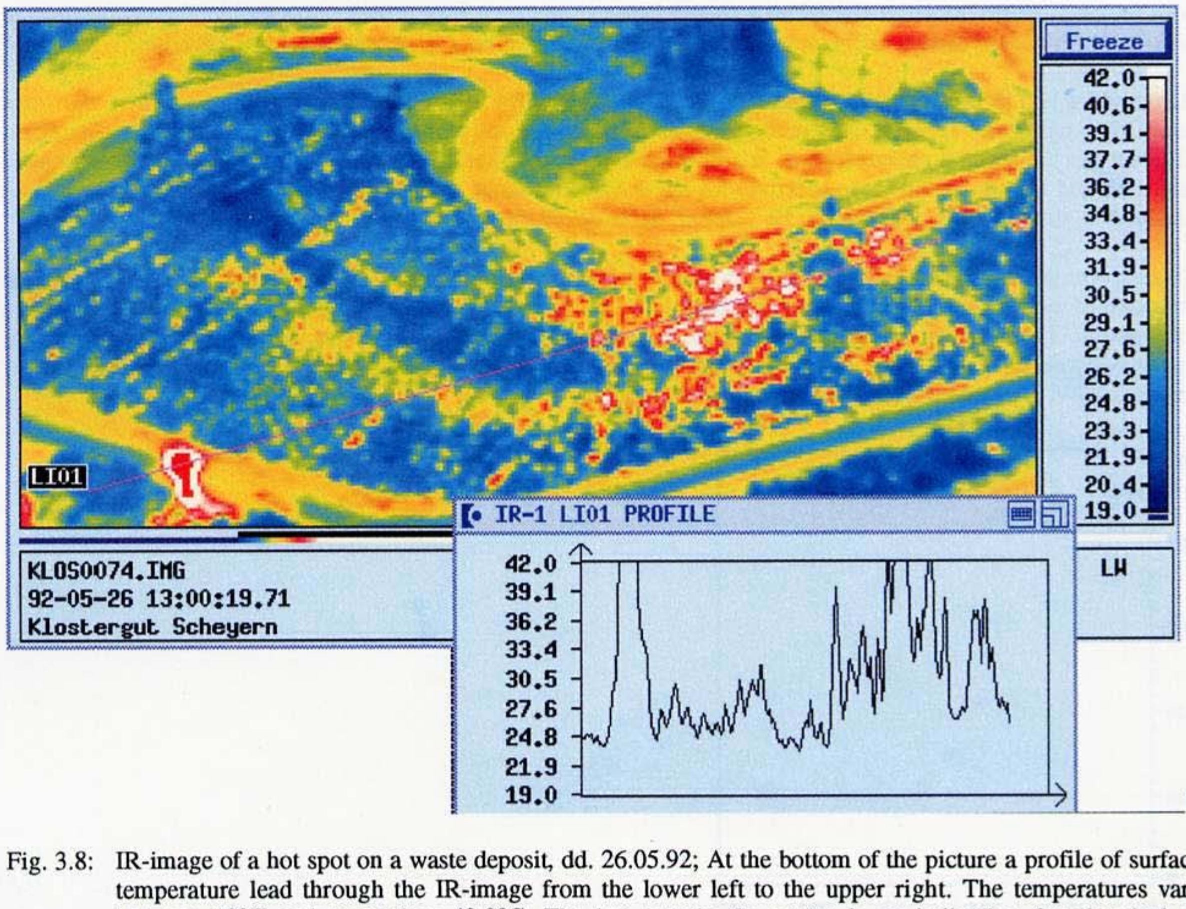


Fig. 3.8: IR-image of a hot spot on a waste deposit, dd. 26.05.92; At the bottom of the picture a profile of surface temperature lead through the IR-image from the lower left to the upper right. The temperatures vary between 19°C and more than 42.0°C. The hot spot in the centre is an indication for chemical or biological reactions taking place under the surface.

The most interesting area in Fig. 3.8 is the hot spot in the centre. The colour code assigns a temperature of more than 42°C to this area. This is an indication for chemical or biological reactions taking place under the surface. Now further investigations of this area should be made by taking soil and air samples and analysing them in the lab. This is a good example to show the advantages of an helicopter in remote sensing of large areas and detecting conspicuous hot spots within a short time.

4 COMPARISON OF MEASUREMENTS IN THE 3-5 μm, 8-12 μm AND VISIBLE BANDS

The spruce tree are conifers, which are frequently found in European woods. Especially this type of tree has severe forestry damage. Specific symptoms are for example loss of needles, mainly in the crown, and a change of colour of the needles to yellow.

In the past several investigations on reflectivity of conifers were established by some german research centres. The results and experiences of these investigations can be used to detect significant differences between the long and short infrared wave spectrum. In our experiments we use both infrared and visible channels to extract information about states of vegetation. Classification of state of vitality can be, for example, derived from sources of evidence as shown in the figure below. Any bands can be correlated with another to look for different results.

The loss of needles causes a shift of the spectral reflectivity. Branches and trunks become more exposed. In addition to its different specific reflectivity, the branches and trunks are heated up by the sun on daytime. This measurable significance shows the condition of trees.

During measurements it is necessary to monitor environmental influences like wind (cooling effect), intensity of sunshine etc. as well as flight parameters.

Before classification of tree vitality, it is necessary to accomplish different image processings. Then, for instance both infrared channels can be plotted as a classification chart, each axes representing the grey scale ranges and histograms. By correlation of different grey scale values, classification, e.g. of tree types, is achievable.

Between the two infrared images differences are evident. The two temperature scales to the right have the same range. The difference between each corresponding picture element pair of the images is based on a significant difference in the spectral characteristics. It will be examined, whether it is possible to distinguish between healthy and damaged trees by using these spectral characteristics. The short wave band is more sensitive to atmospheric attenuation, therefore the sky seems to be 'warmer' in the upper infrared image.

To get corresponding pixel pairs, warping of one IR image above the other has to be made, using transformation matrices. If using image processing, it is sensible to use the red, green and blue colour channel to visualise information. The short wave image, for example, covers the red, the long wave scan the green and the difference image between short and long wave images or the video image the blue channel. The result is a false colour representation (like satellite images attached to this report).

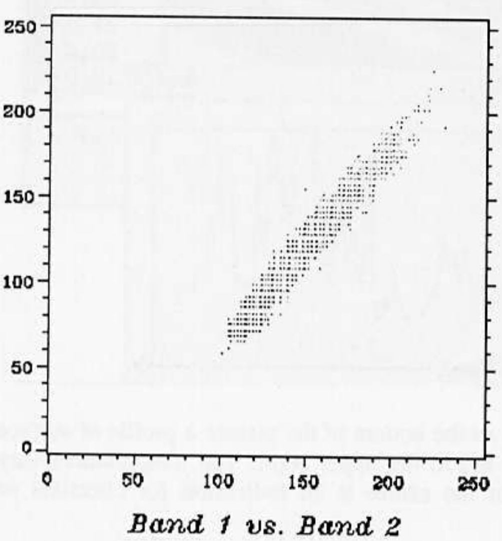
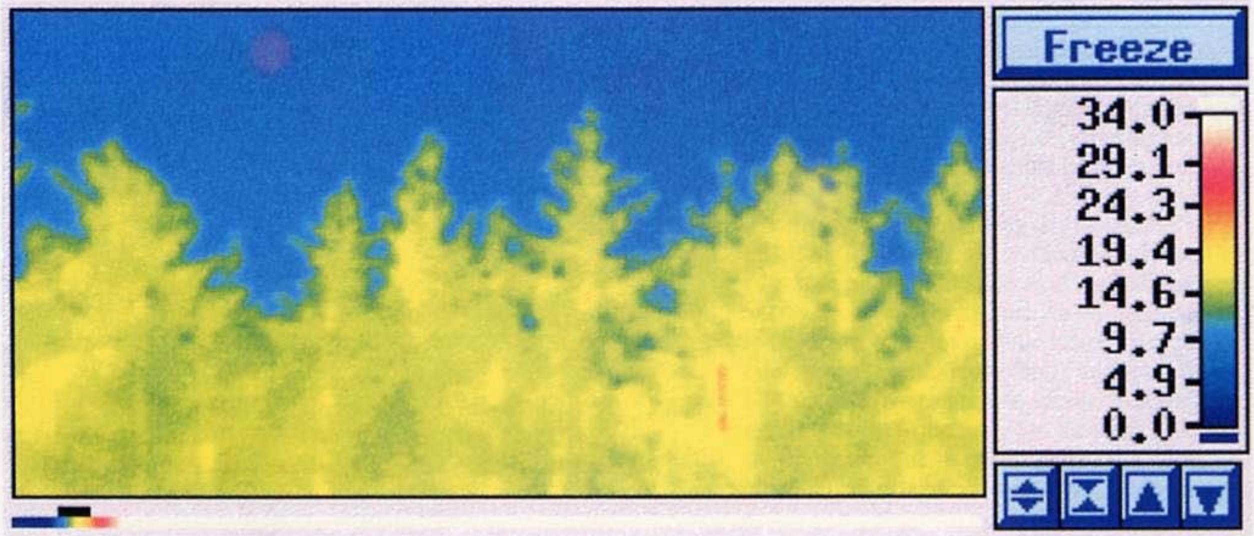
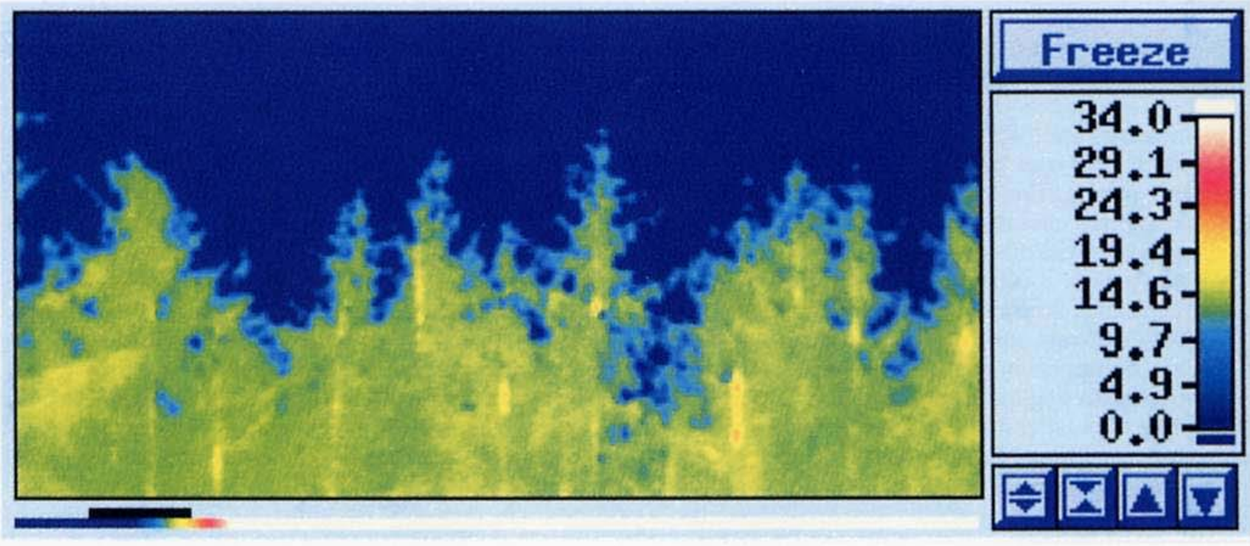


Fig. 4.1: Example for a sources of evidence. The cloud of points indicates correlated grey scale values.

The figures 4.2 - 4.4 are taken from spruce woods. The upper one represents the view of a S-VHS video camera, in the middle a 3 µm to 5 µm band (short wave-length) infrared image is shown und below there is a scan with a spectral sensitivity from 8 µm to 12 µm (long wave-length). An investigation is in preparation, to assess the correlation between vitality of vegetation and spectral signatures in both IR channels and the S-VHS RGB-channels.

left	Fig. 4.2	S-VHS (RGB)
middle	Fig. 4.3	3-5 µm (false colour)
bottom	Fig. 4.4	8-12 µm (false colour)





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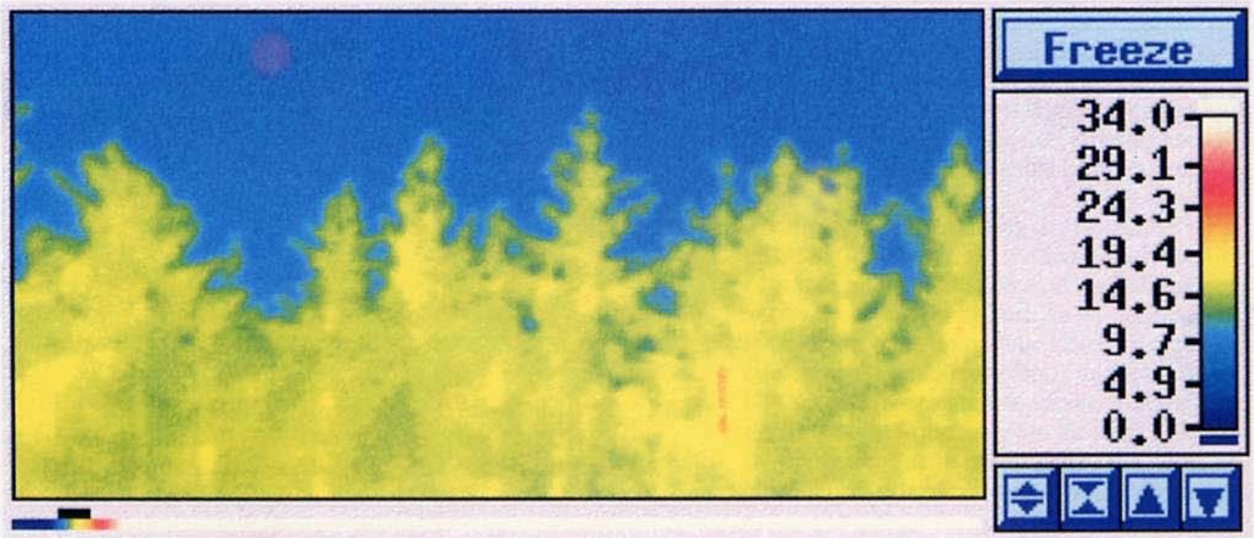
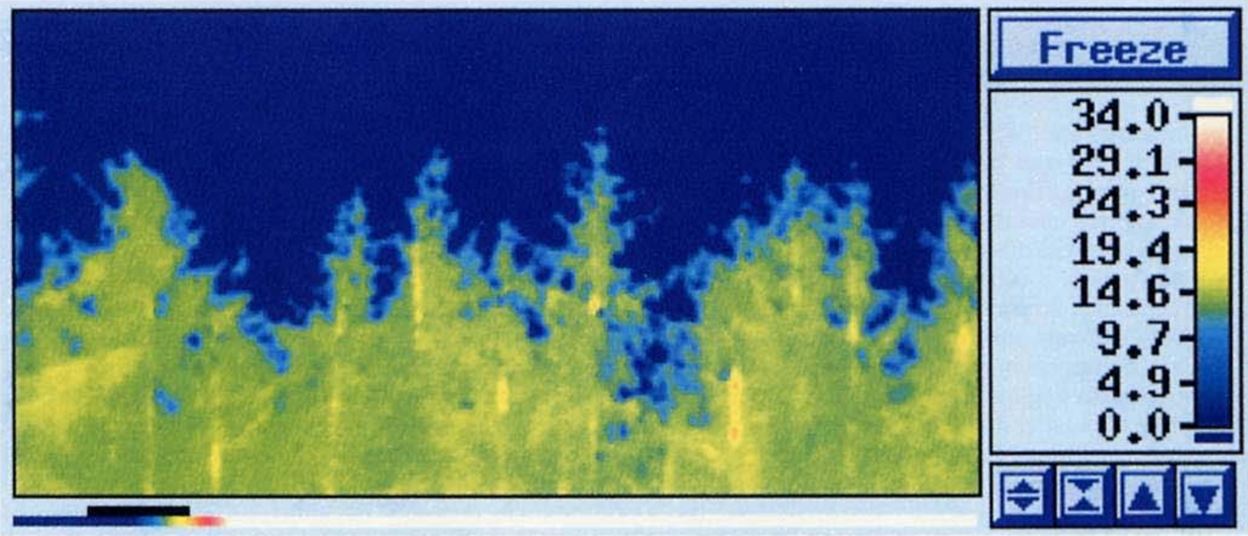




5 LANDSAT TM, ERS-1 SAR AND X-SAR IMAGES FROM KALIMANTAN

ECD has a project in the tropical rain forest of Kalimantan in the frame of a study work. The tropical rain forest in Kalimantan is also one test area of the European TREES (TRopical Ecosystem Environment observations by Satellites)-Project supported by ESA, JRC and DARA. The access to Kalimantan on ground is only possible by rivers, existing streets or logging roads. Satellites, aeroplanes and helicopters can monitor the landscape very easily. Ground truth campaigns with a helicopter equipped with sensors incl. a GPS are possible to verify the classification results of satellite images and to simplify the field work. A helicopter can transport equipment and personnel. The helicopter needs no runway, but only a helipad and it is able to hover.

5.1 Kalimantan (Borneo)

Borneo is behind Greenland and New Guinea the third largest island in the world. Beside New Guinea it has the greatest closed tropical rain forest in South-East Asia.

The location of Borneo is situated north and south of the equator. Over 80 % (est. 1981) of Kalimantan is jungle; the coastal areas, low-lying and large swampland, rise up slowly to high central mountains higher than 2 000 m, drained by eleven main rivers. Unlike the volcanic nature of the surrounding islands, Kalimantan is of alpine nature, having been thrust from the sea and originally joined with the Asian mainland. Rock structures are primarily of sedimentary origin. Human influence is concentrated along the coasts and rivers.

Kalimantan is extremely rich in proven natural resources. The island is a major supplier of the worlds timber and rattan. A number of oil and gas fields exist at the Eastern coast and a refinery operates at Balikpapan. Coal, gold, silver, copper and precious stones mining is developing and over fourteen other metals or minerals from mercury, zinc, bauxite and platinum to uranium have been defined in exploitable quantities.

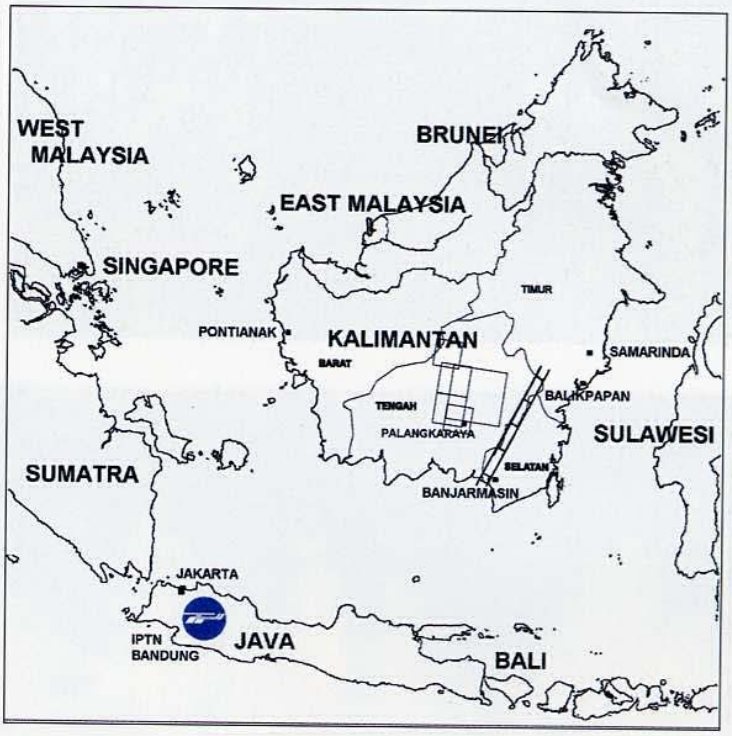


Fig. 5.1: The map shows the location of the ERS-1, X-SAR and LANDSAT images which were used. In Bandung near Jakarta Eurocopter helicopters are manufactured at IPTN.

In East Kalimantan the German GTZ (Gesellschaft für Technische Zusammenarbeit, Eschborn) is engaged in several projects since many years. The LUPAM (Land Use Planning and Mapping)-Project trains several employees of the BPN (National Land Agency, Badan Pertanahan Nasional in Jakarta and Samarinda) in visual and digital satellite image interpretation.

Indonesia has the second largest area of tropical rain forest. A healthy primary forest is a complex biotic system which comprises trees of different sizes and of numerous species. On 1 ha more than 180 different types of trees are growing. The tropical forest is rich in species, beauty and genetic resources. In Primary Rain Forests large dipterocarp trees reaches a size of 60 m. If the crowns are closed the sensitive tropical rain forest can preserve the symbiosis with other plants.
Indonesia is a country with a fast growing population. Since the end of 70th an Indonesian Transmigration-Programme is underway to settle people from Java in Kalimantan, Sumatra, Sulawesi and Irian Jaya. This people find a different sensitive soil than in fertile volcanic island of e.g. Java. The population in Kalimantan is growing fast. Deforestation to get timber products, shifting cultivation, land use for agricultur and natural fire burning reduces the tropical forest. This changes the vegetation cover, which is one parameter in the global climate models. Since the mid of the 80-ies the Indonesian government preserves the rain forests by creating of reservations and establishes laws to use e.g. circular logging methods and sustainable use. Remote sensing by satellites is a good tool for monitoring, mapping, inventory, forecasting and controlling.

Statistics of Indonesian Kalimantan (1981):

Area	Kalimantan	539 489 km²
	Central Kalimantan	153 000 km²
Population		6 800 000 est.1981
	Indonesian races	2 500 000 mainly of Malay ethnic origin
	Banjarese	2 500 000 a developed "mixed" race around Banjarmasin
	Local tribes	1 000 000
	Other	800 000
Climate tropical		
	Average rainfall	3 500 mm per year
	Average temperature	27°C relatively constant throughout the year

5.2 Kalimantan Tengah

The monitoring project of ECD was chosen in the frame of a study work in Kalimantan Tengah. This is one of the 27 Provinces of the Republic of Indonesia. A Provincial Parliament and a Governor are situated at the capital city of the Province, Palangkaraya. 82% of the Province are jungle; 12% swampland, 3% natural reservations (1981). Timber production reached over 3 million cubic meters per year, mostly for export. Other major export goods are rubber (23 850 t) and rattan, coconut and cloves.
Palangkaraya (pop. 125 000; 1994) is located 200 km up the Kahayan River, shipable by small freighters. The city is connected to Banjarmasin (see fig. 5.4) by river transport through a channel system linking the rivers (compare X-SAR image) and by air to the main centres of Indonesia. There is also a direct flight to Jakarta.
The main port of Central Kalimantan is Sampit, which handles ocean-going freighters, mainly log-carriers. Access to this port from Palangkaraya is difficult. The Province contains 849 km of roads, mostly of compressed earth. A major road improvement programme is underway.
The indigenous Punan and Dajaks are living mainly by shifting cultivation. They grow rice or maize in this area.

5.3 Satellite Images from Kalimantan Tengah

Deforestation figures and change detection images by multitemporal techniques are necessary to know for the province Kalimantan Tengah. Problems arises with the cloud situation in the tropical area for electro-optical systems. Radar systems are independent from cloud effects, day, night and adverse weather conditions.

In the northern area of Palangkaraya two ERS-1 SAR images (an ESA product) were available in time for this paper with

- ERS-1 Orbit 9438 from 6th of May 1993 frame 3627 and 3645 (5.3 GHz, C-Band)
  of a 12.5 m x 12.5 m resolution; central co-ordinates (each 100 km x 100 km)
  113.39° East, -1.913° South (northern area of Palangkaraya, fig. 5.5)
  113.58° East, -1.018° South (eastern area of Schwaner Mountain, fig. 5.3)

During the Space Shuttle mission in April 1994 one strip of Kalimantan was monitored, compare fig. 5.1.

- X-SAR from 17th of April 1994 17:15:49 (9.6 GHz, X-Band)
  of a 25 m x 25 m resolution; central co-ordinates (approx. 25 km x 100 km)
  114.494° East, -3.259° South (at Banjarmasin, fig. 5.4)

Different LANDSAT 5 Thematic Mapper images of the same season from end of June 1991 and July 1994 were selected and ordered. Three images

- LS TM 118-061 from 30th of June 1991
  of a 30 m x 30 m resolution; central co-ordinates (180 km x 180 km)
  114.26° East, -1.458° South (northern area of Palangkaraya, fig. 5.2)
- LS TM 118-062 quarter image No. 5 from 8th of July 1994
- LS TM 119-060 quarter image No. 4 from 18th of October 1988

was received from the ground station Bangkok, Thailand. Agricultural approaches were done. In the future classification of different types of forests will be done by field campaign.

In the satellite images different forest types are visible. People who live near the rivers are converting forests for agricultural, urban and industrial use. Intense human impacts on nature by shifting cultivation, forest clear felling, selective timber logging, natural burning, plantations and reforestation can be monitored in the high-resolution coloured satellite images. The test side in the north of Palangkaraya is a low land area with several rivers while the northern area is a hilly region. The TM channels 2, 4 and 5 (approx. 0.56, 0.83 and 1.65 µm) detects many sand banks on the inside of the meandering river, see Fig. 5.2.
In the annex you will find additional Landsat images.

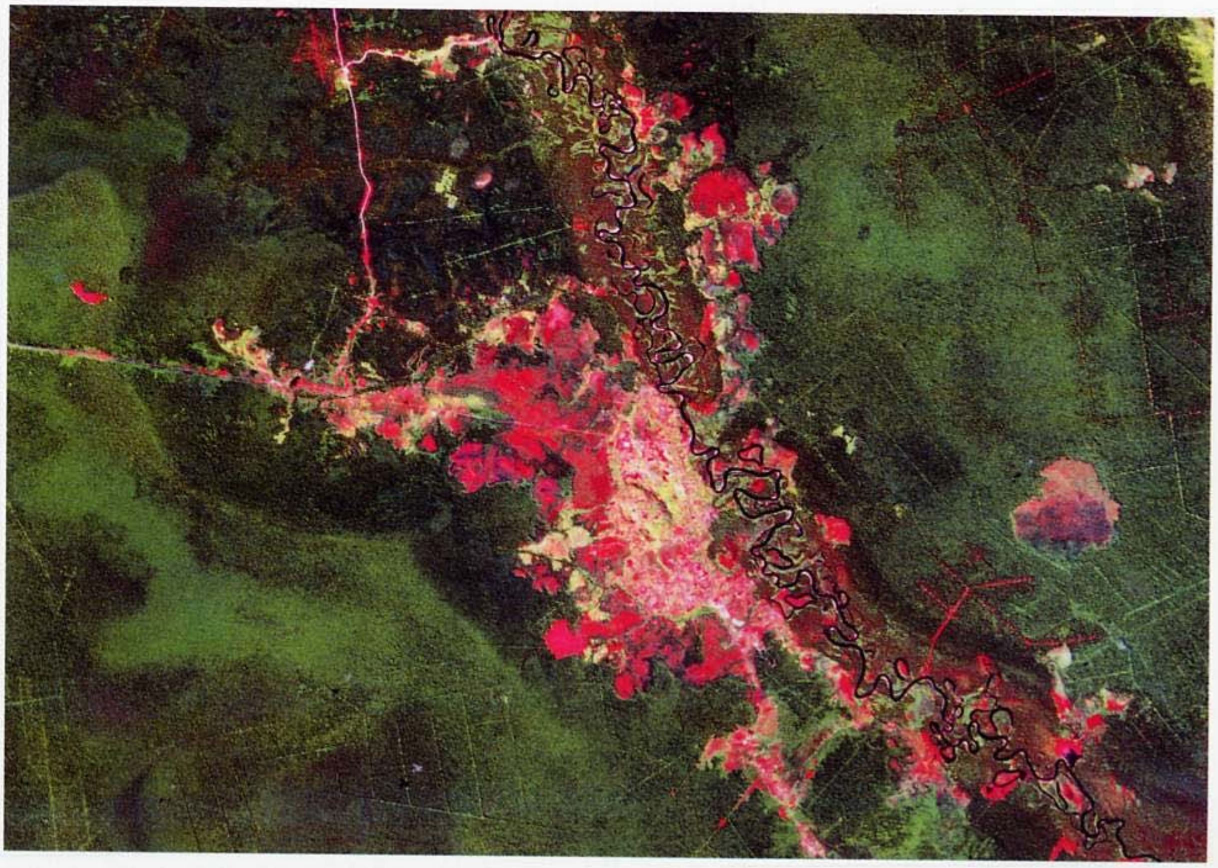


Fig. 5.2: A section of LANDSAT TM image from 30. 6. 1991 showing the Rungan river at Tengkiling in the north of Palangkaraya. Red-Green-Blue = Channel 5, 4 and 2 (approx. 35 km x 20 km). Some of the thin straight lines are probably a railway for selective logging in swampy regions, others represents logging roads.

Résumé:

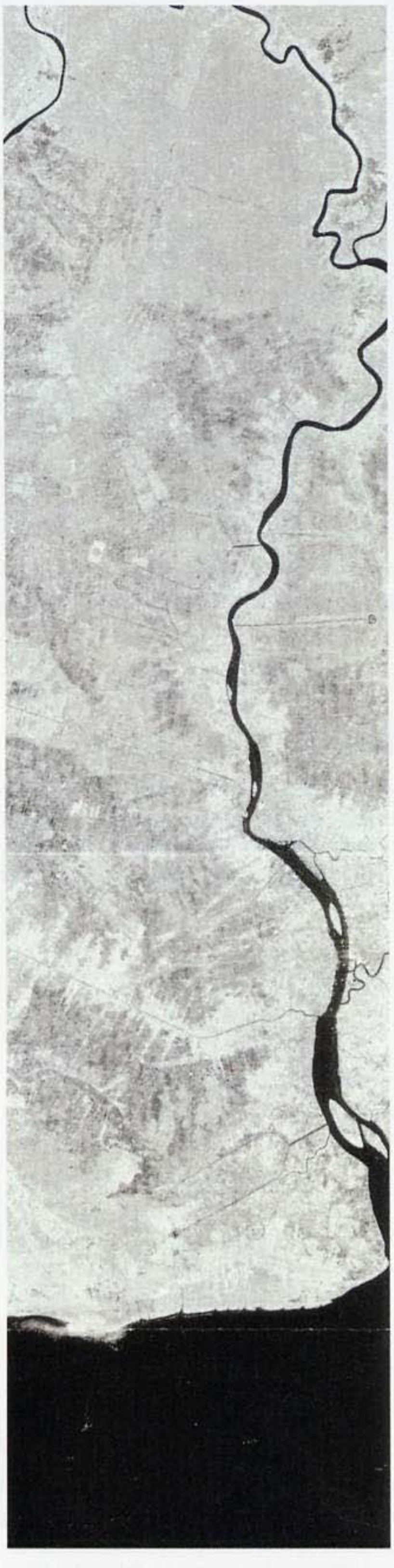
A clear and precise classification (interpretation) of satellite images of an unknown area is sometimes not possible. Field campaigns with a helicopter can help to analyse and specify the detected information.

Remote Sensing from satellite with image calibration and ground truth verification by helicopter sensory survey is a helpful mean for:

- monitoring
- mapping
- inventorying
- planning
- change detection (multitemporal)
- controlling

in the areas of:

- establishing topographical maps with e.g. a scale of 1:50 000
- forestry
- agriculture
- land use
- soil erosion and soil degradation
- hydrography, water in coastal regions
- geology, exploration and mining



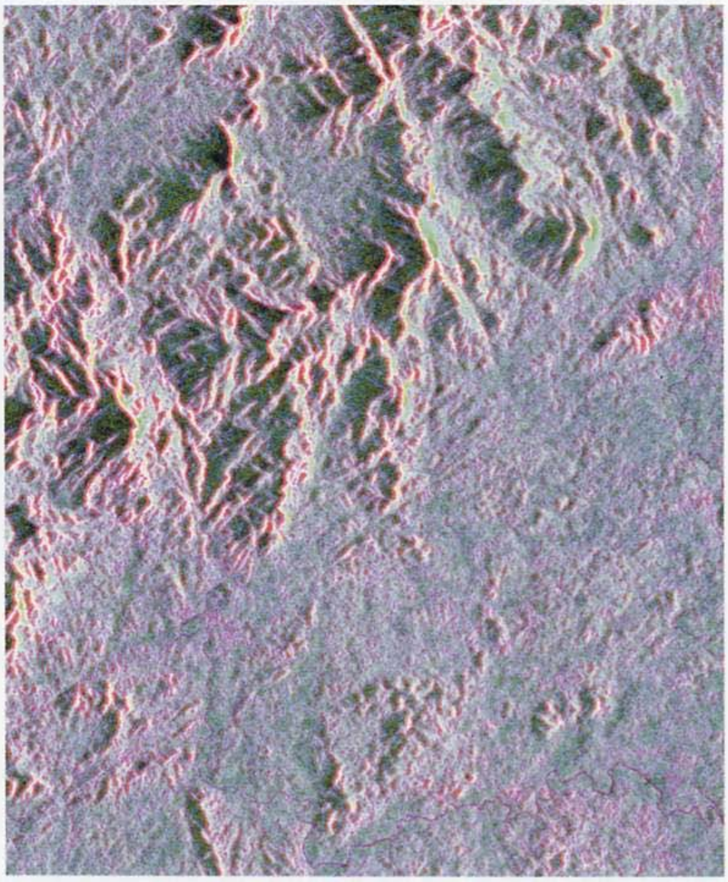


Fig. 5.3: A section of ERS-1 image from 6. 5. 1993 showing the mountains area in Kalimantan Tengah in the eastern part of Schwaner Mountain (approx. 40 km x 70 km); processed by W. Bergbauer (Red = 15x15 convolution matrix, green = σ 7 speckle filter, blue = 31x31 convolution matrix)

Fig. 5.4: A section of X-SAR image from 17. 4. 1994 showing Banjarmasin in Kalimantan Selatan (approx. 25 km x 100 km). In the river Barito ships can be resolved easily.

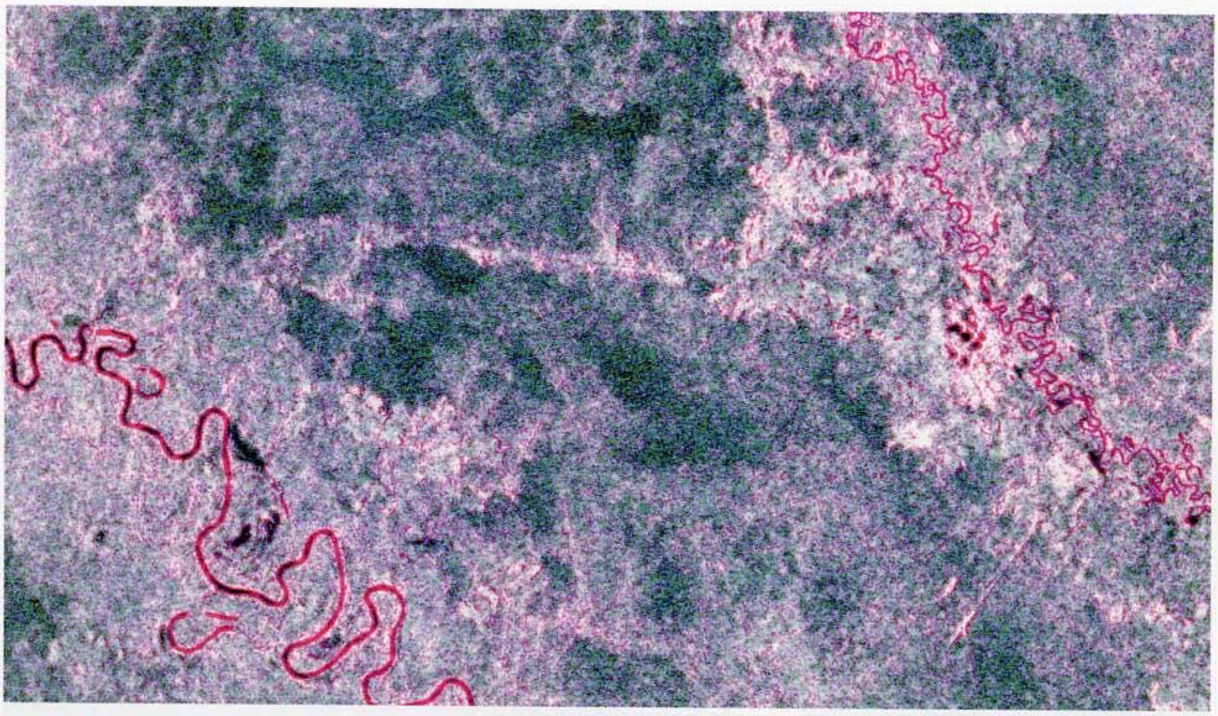


Fig. 5.5: A section of ERS-1 image from 6. 5. 1993 showing the Rungan river at Tengkiling in the north of Palangkaraya. (approx. 45 km x 20 km); processed by W. Bergbauer (Red = 15x15 convolution matrix, green = σ 7 speckle filter, blue = 31x31 convolution matrix)

6 MODULAR SENSOR CONCEPT OF THE ENVIRONMENTAL HELICOPTER

At ECD since several years studies and first flight trials as described in this paper were made to define and develop an Environmental Helicopter (EHC). Now ECD plans to equip an Environmental Helicopter with a modular mission/sensor package, see Fig. 6.1. GPS and flight management-system, central data management, telemetry, climatic situation sensors and an operator seat including a console will be the basic equipment of the Environmental Helicopter.

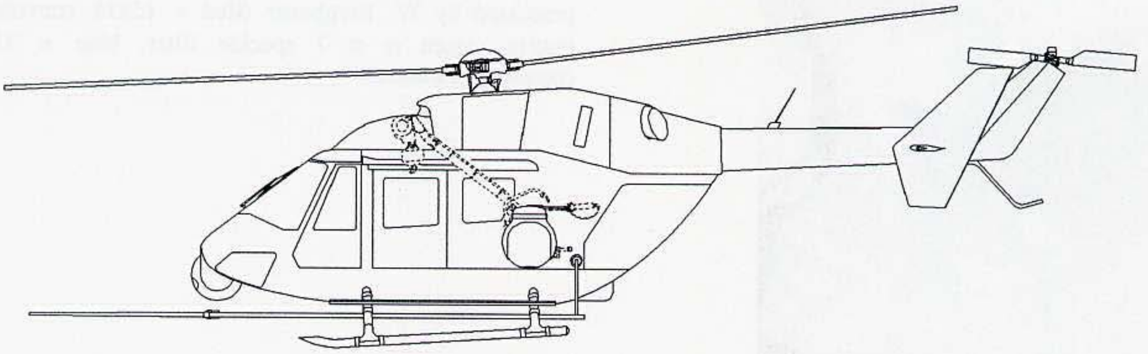


Fig. 6.1: The EHC equipped with all possible sensor modules as there are the Pitot tube for the GC/MS, a gimbal for the imaging spectrometer or alternative a winch and in the nose a gimbal for the IR scanners and the TV-camera. On the other side of the H/C the LIDAR system can be mounted. Remark: The BO 105 can also be equipped as EHC.

The sensor tasks are divided mainly into two domains: remote sensing and in-situ measurements of gases.

LIDAR-systems, electro-optical sensors, Radar sensors incl. a SAR, γ-ray sensors and image spectrometers belong to the active and passive remote sensing devices while a gas-chromatograph/mass spectrometer is suitable for in-situ measurements. For these in-situ measurements the helicopter requires a Pitot tube to avoid false readings caused by turbine gas exhaust in the HC down wash. The calibration of the sensors is a special task for all applications.

With the imaging spectrometer (e.g. ROSIS) the red edge of chlorophyll (trees, plants) can be detected in supplement to the 3-5 µm and 8-12 µm channels. Sensor fusion can process the vitality of trees/plants and vegetation stress using this tree monitoring sensors. A day-light-TV-camera will be always used for quick-look aspects.

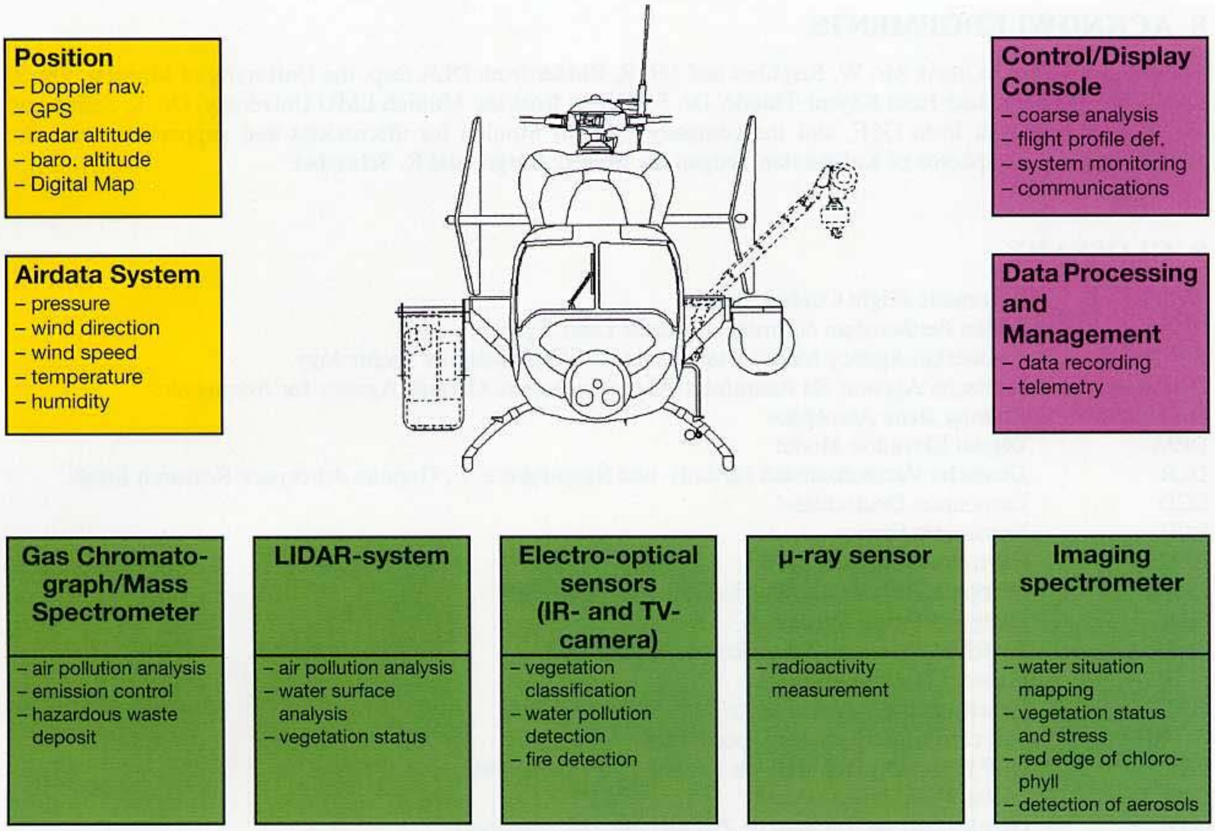


Fig. 6.1: Modular sensor packages for the Environmental Helicopter (EHC).

A Modular Sensor Concept (MSC) for the environmental monitoring and disaster operations is under investigation for different applications. The EHC is equipped with basic and specific avionics and an operator console where the crew controls and monitors the function of the sensors. Different sensors can be installed depending on the requirements of the planned mission.
The basic avionics provide a modern cockpit with an AFCS and Flight Guidance system, a NAV-system incl. GPS and an Air Data System.
The mission avionics includes a common data acquisition, processing and recording system for all sensors. All sensor data can be displayed on a colour monitor at the operator console for quicklook and monitoring.

The operator console and the racks for the mission avionics are together mounted on a plate. After removing the cable connections to the fixed provisions of the helicopter, this plate with the console and the racks can easily be pulled out of the helicopter through the back doors. Then the helicopter can be used for transportation of persons and equipment.

7 SUMMARY

Forests are one of the few renewable natural resources. With careful planning and good reforestation programmes we can harvest timber for long periods. The forest land-use should be planned in conjunction with the land-use plan. The deterioration of the constitutions of forests is due to the population increase and political, economical and social pressure. All of these pressures make the forest constitution in Kalimantan getting very worse and cause a lot of problems to be solved.

It is necessary to expand the forest plantation area by establishing forest plantation programmes. Additionally, the forest resources must be regularly monitored by using remote sensing as a tool in forestry in order to know exactly the existing forest area as an input to the optimum forest land use planning.

A proposal is under way for a common test trail in Kalimantan Timur (TRULI-Project on river Mahakam and Bukit Suharto). This will be done in the frame of TREES by using a helicopter for the ground truth measurements with a GPS.

8 ACKNOWLEDGEMENTS

The authors wishes to thank Mr. W. Kirchhof and Mr. R. Ridder from DLR resp. the University of Munich, Dr. S. Kuntz and W. Bergbauer from Kayser-Threde, Dr. F. Siegert from the Munich LMU University, Dr. T. Selige and Mr. J. Raubenstrauch from GSF, and the company GAF in Munich for discussions and support to order the satellite images. The photos of Kalimantan Tengah are from L. Berger and R. Schreiber.

9 GLOSSARY

AFCS	Automatic Flight Control System
BPN	Badan Perthanahan Nasional, National Land Agency
BTTP	Indonesian Agency for the Assessment and Application of Technology
DARA	Deutsche Agentur für Raumfahrt-Angelegenheiten, German Agency for Aeronautic
DASA	Daimler Benz Aerospace
DEM	Digital Elevation Model
DLR	Deutsche Versuchsanstalt für Luft- und Raumfahrt e.V., German Aerospace Research Estab.
ECD	Eurocopter Deutschland
ECF	Eurocopter France
EHC	Environmental Helicopter
ERS-1	European Remote Sensing Satellite first generation
ESA	European Space Agency
FAM	Forschungsverbund Agrarökosysteme München
FLIR	Forward Looking Infra Red
GAF	Gesellschaft für Angewandte Fernerkundung mbH
GC/MS	Gas chromatograph/mass spectrometer
GSF	GSF Forschungszentrum für Umwelt und Gesundheit, Neuherberg
GPS	Global Positioning System
GTZ	Gesellschaft für Technische Zusammenarbeit, Eschborn
H/C	Helicopter
IPTN	Nusantara Aircraft Industries Ltd., Bandung
IR	Infra Red
JRC	Joint Research Center of the Commissions of the European Union, Ispra
KT	Kayser Threde, München
LS TM	LANDSAT Thematic Mapper
LIDAR	Light Detection and Ranging
LMU	Ludwigs-Maximilians Universität, München
LUPAM	Land Use Planning and Mapping, Project of GTZ
MSC	Modular Sensor Concept
NAV	Navigation
RADAR	RAdio Detection and Ranging
SAR	Synthetic Aperture Radar
S/W	Software
TREES	TRopical Ecosystem Environment observations by Satellites
TRULI	Tropical Rain forest and Use of Land Investigation, project by KT and LMU

Landsat TM bands:

1 (blue)	0.45 - 0.52 µm
2 (green)	0.52 - 0.60 µm
3 (red)	0.63 - 0.69 µm
4 (near IR)	0.76 - 0.90 µm
5 (mid-IR)	1.55 - 1.75 µm
6 (thermal IR)	10.40 - 12.50 µm
7 (mid-IR)	2.08 - 2.35 µm

RADAR bands:

ERS-1	C-band	5.3 GHz
X-SAR	X-band	9.6 GHz (sensor borne on Space Shuttle)

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Helicopter approach to the test site in the north of Tengah.

View onto a typical rain forest in the north of Tengah from 150 m height

With the helicopter it is possible, to examine the trees from close up.

Look at the provisional landing area out of the cockpit.

The image shows a typical logging road.

The tropical wood is desirable due to its high quality and trunk length.

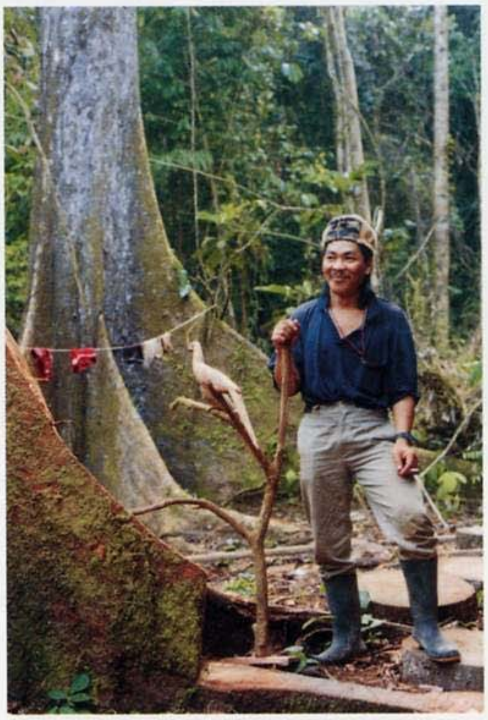
This fire clearing area shows first signs of erosion

Bridge built with tropical wood.

The tropical rain forest shows a great variety.

The climax trees grow up to 60 m, pioneers 5-8 m.

Picturesque untouched nature in the rain forest



The rain forest is the basis of life - locally and globally

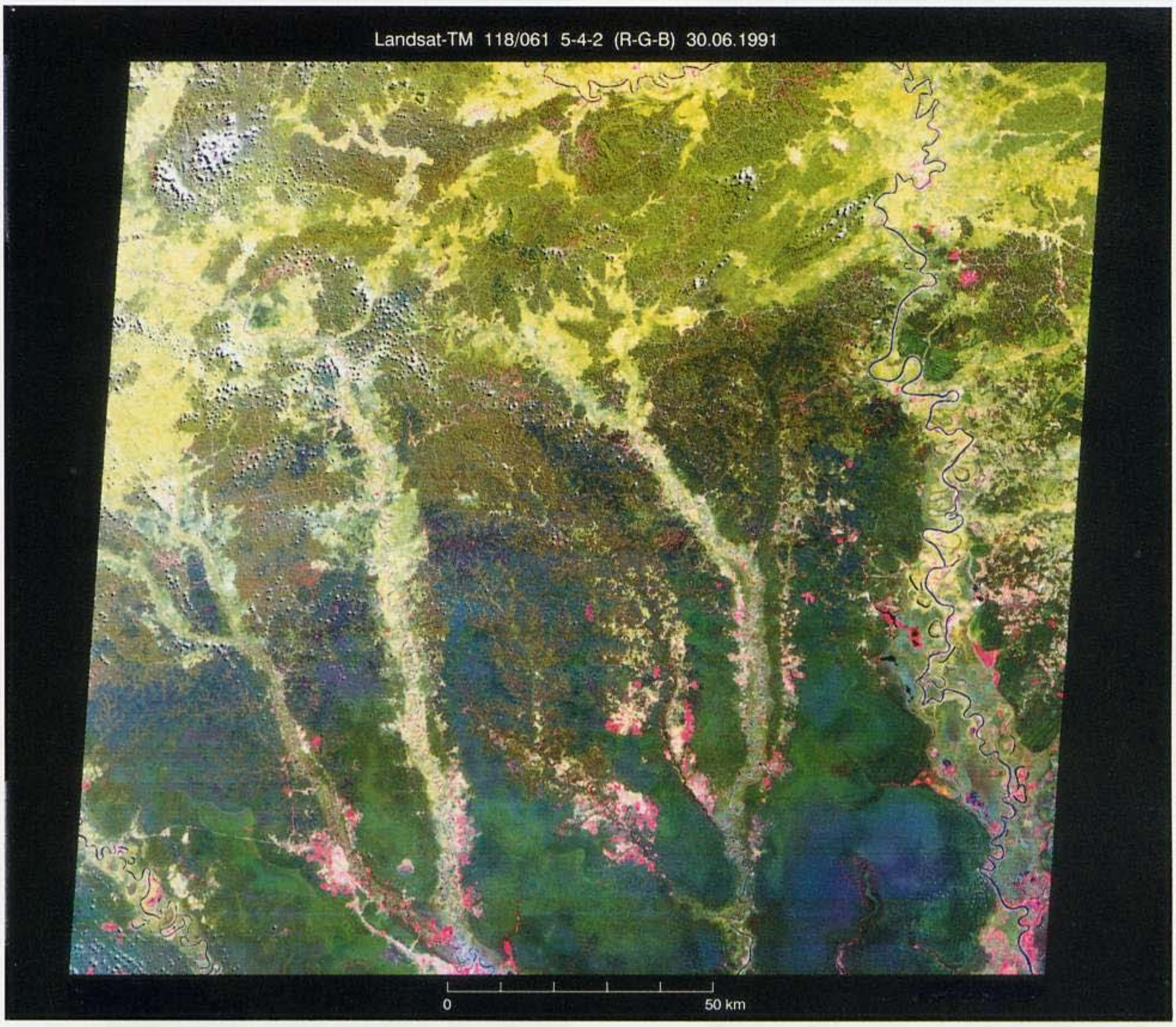


Fig. Annex 1: Quick look from Landsat TM 118-61, **30.06.91**; full image, channel 5-4-2.
The big river on the right side is the Barito River. At the bottom left to the mid there is Palangkaraya, located at the Kahayan River, 25 km in the north-west direction along the Rungan River lies Tinkling (compare Fig. 5.2). The thin white lines are mostly big logging roads. It is possible to distinguish between untouched forest, selective logging areas and shifting cultivation by interpreting the different hues. The satellite data interpretation fits on the reality with an accuracy of 50% up to 90%. For exact ground truth monitoring a helicopter operation is useful.

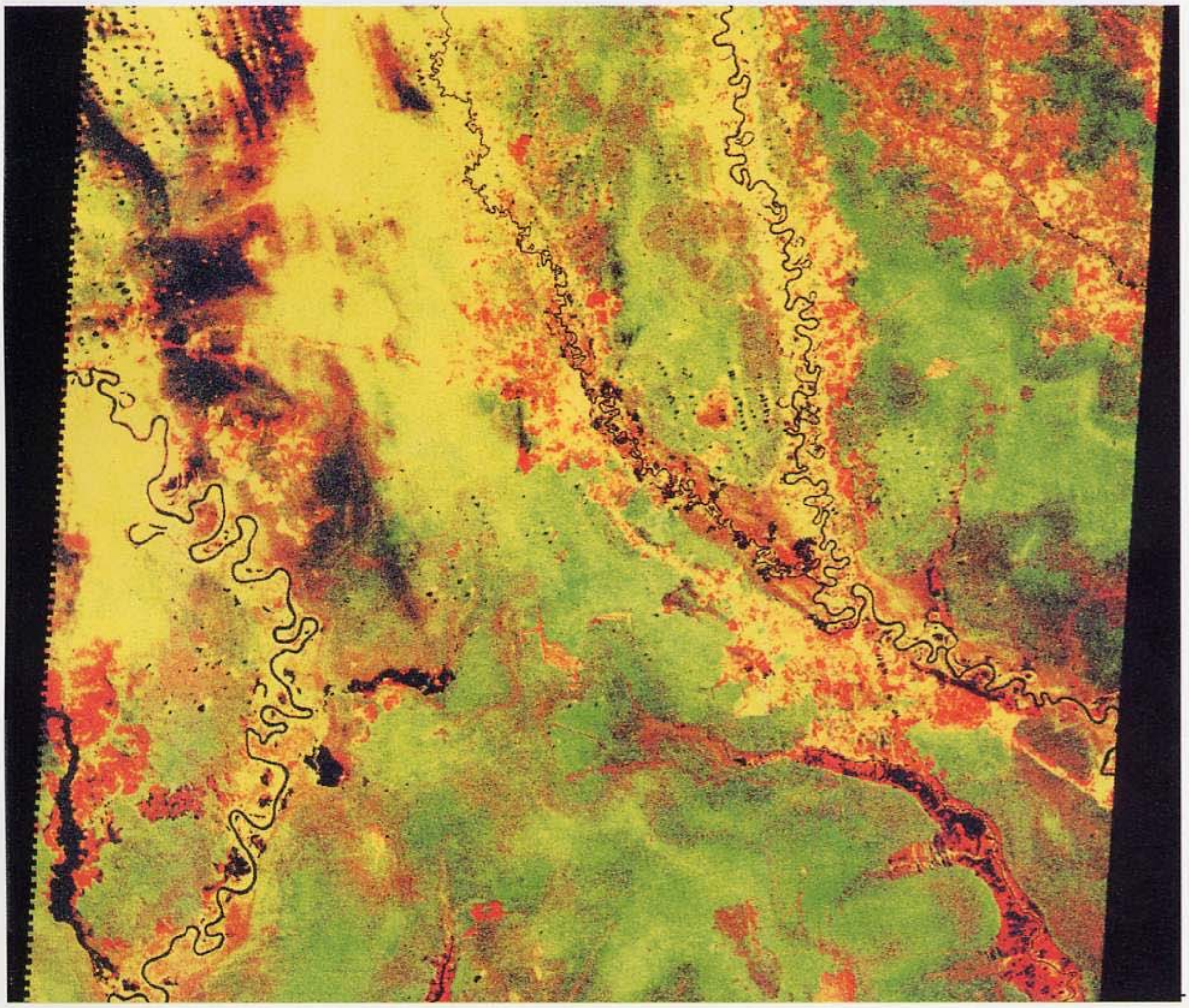


Fig. Annex 2: Quick look from Landsat TM 118-62, **08.07.94**; quarter image No. 5, channel 5-4-7.
The river on the left side is called Mendawai River. In the middle and right part of the image there is the Rungan River flowing into the Kahayan River at Palangkaraya. In the left upper corner the land is covered with thin clouds. A net of logging roads and rails are visible in the green areas.

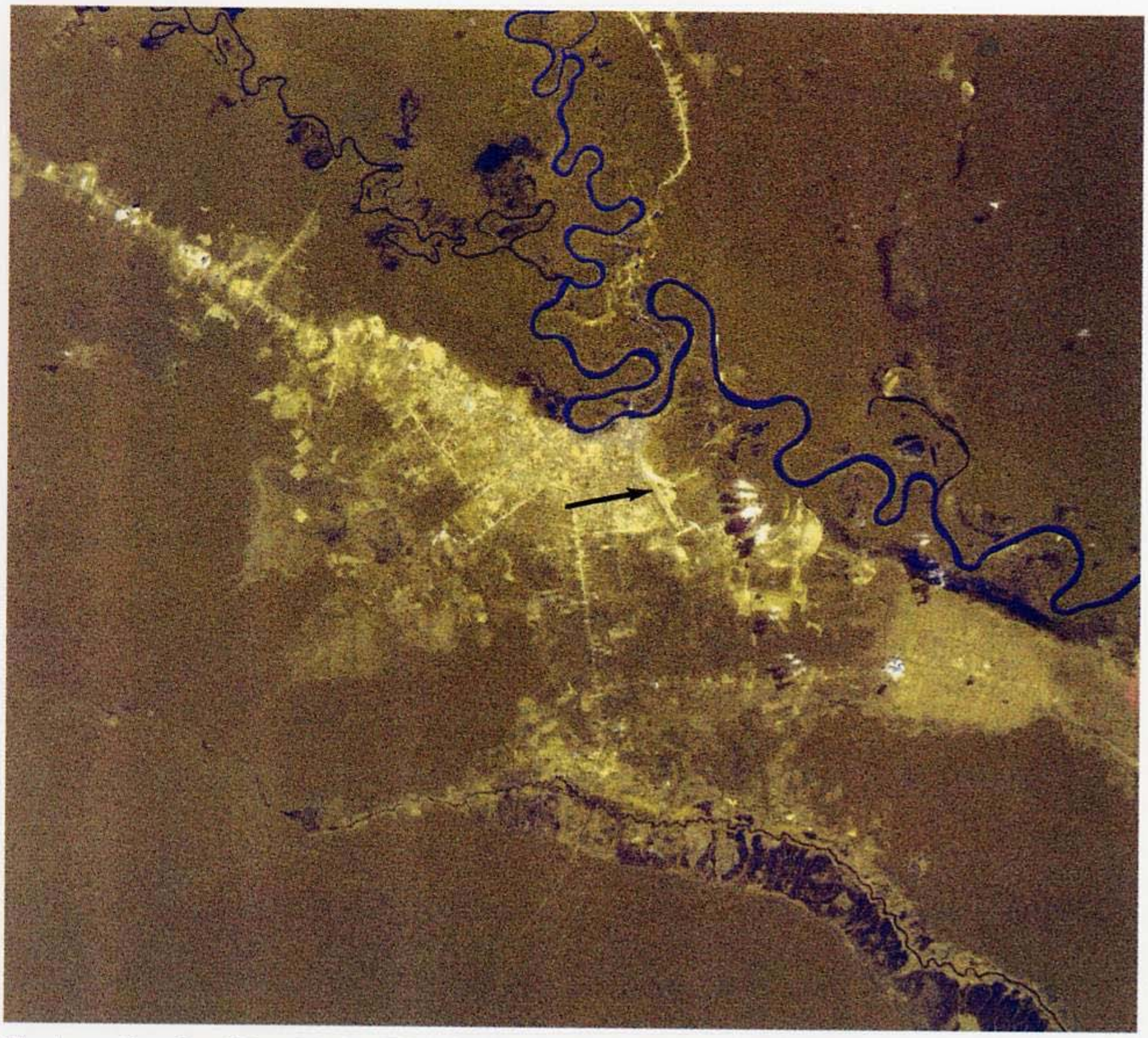


Fig. Annex 3: Detail from Landsat TM 118-62, **08.07.94**; channel 5-5-3; remark: one channel on two colours. In the center lies Palangkaraya. In this composition of the channels it is possible to recognise a lot of details in the urban area of Palangkaraya. The airport with the two runways is marked by a pointer.

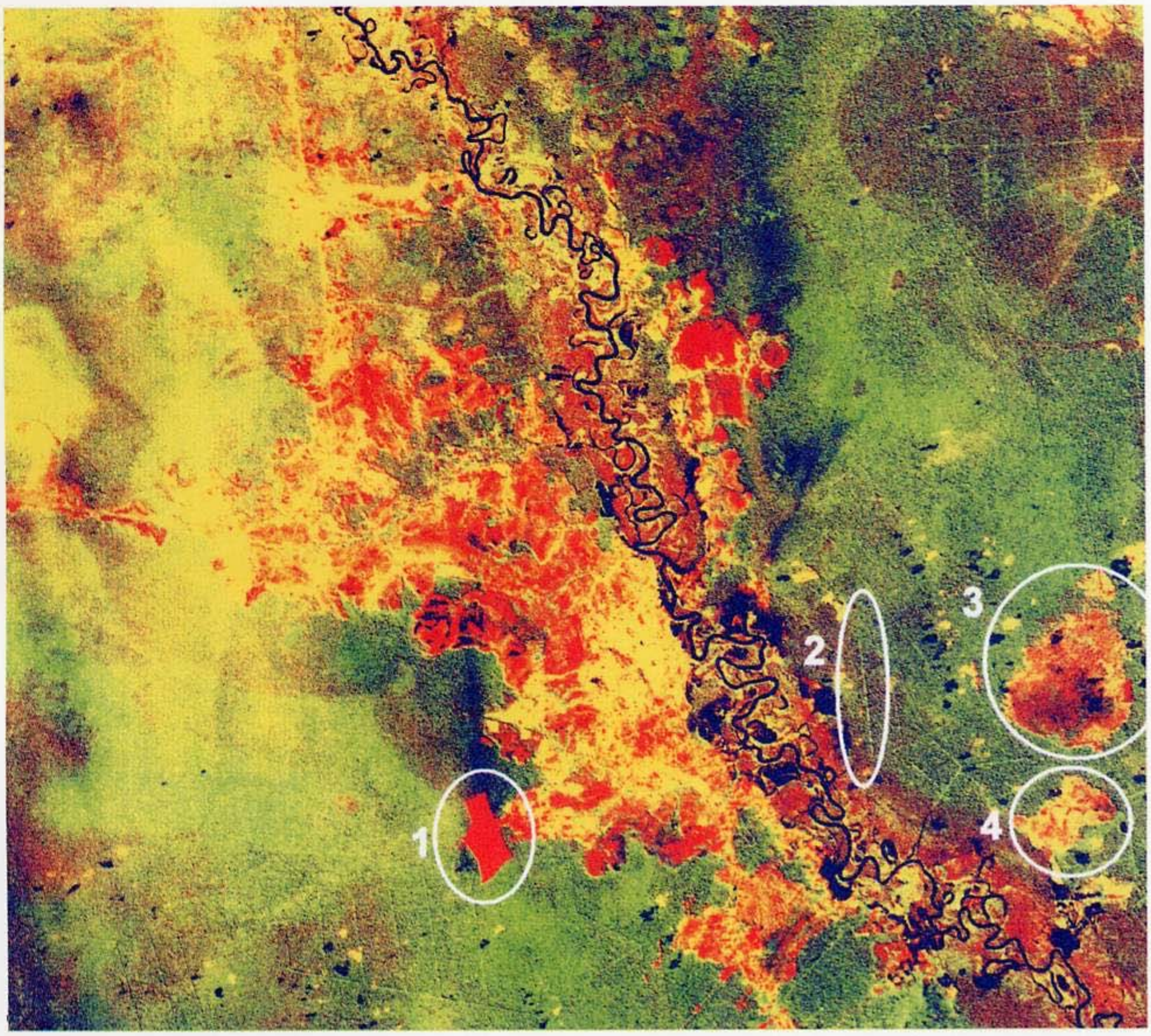


Fig. Annex 4: Detail from Landsat TM 118-62, **08.07.94**; channel 5-4-7
The red and yellow areas in the center of the image means the town of Tengkiling at the riverside of Rungan River. Please compare this image to figure 5.2. The white marked areas indicate some changes from 1991 to 1994. There was made clear cuttings of the rain forest (1,3,4). A new logging road was built (2). This road can easily be recognised in the ERS-1 image from 1993 in fig. 5.5, while the clear cuttings are mostly visible for the expert only. There are further changes, e.g. in the north of Tengkiling, which are not marked. Compare also to fig. Annex 1 and Annex 2. As mentioned before a helicopter operation can help to survey the area of interest.

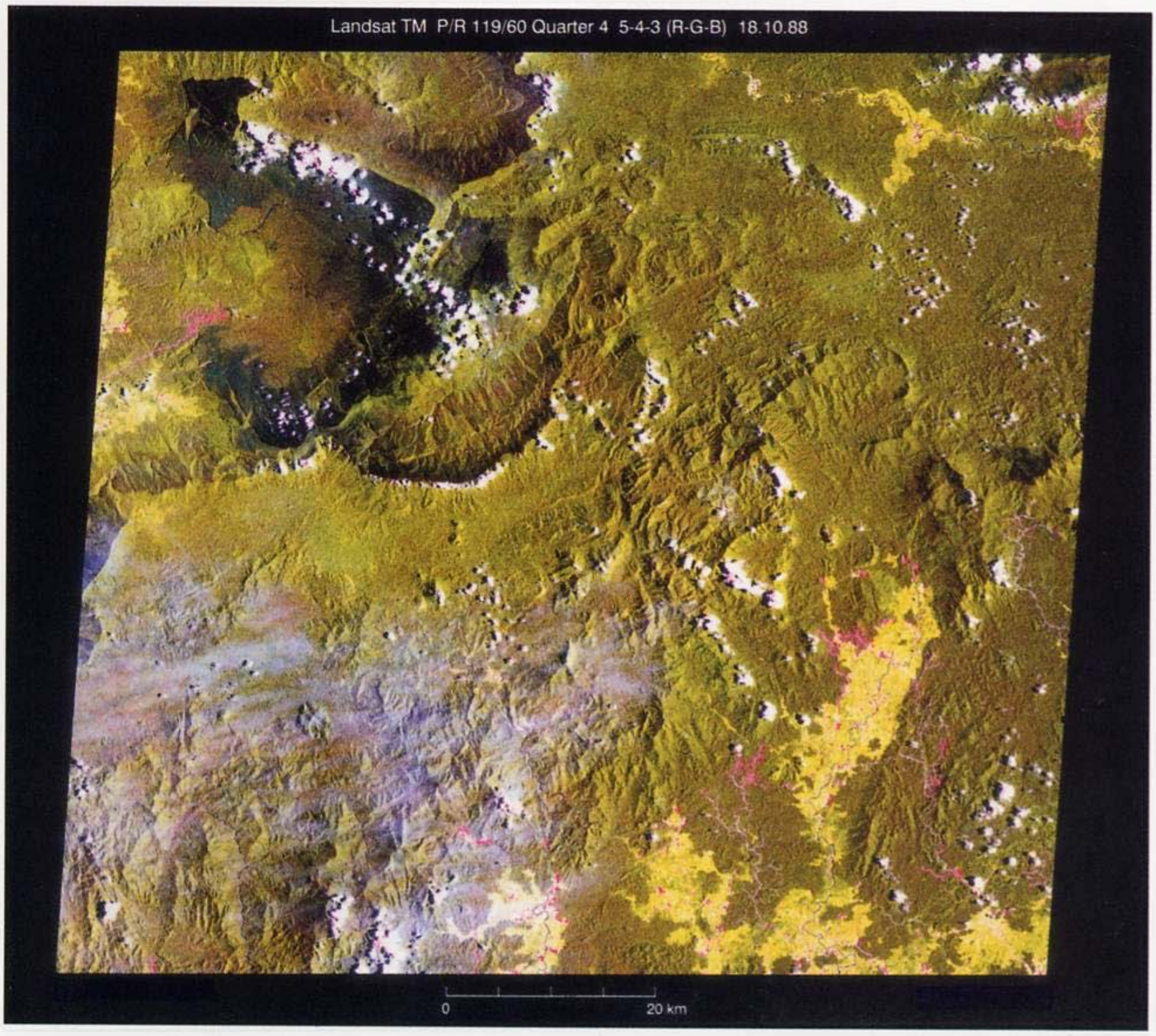


Fig. Annex 5: Quick look from Landsat TM 119-60, **18.10.88**; quarter image No. 4, channel 5-4-3.
In the upper left corner you see the high Schwaner Mountains, lower left there is a lightly clouded hilly area and bottom right you see the Kahayan River with tributaries. Most parts of the scene are covered with primary rain forest. The purple areas near logging roads are caused by recent selective logging. Bright green areas beside rivers show agricultural regions.

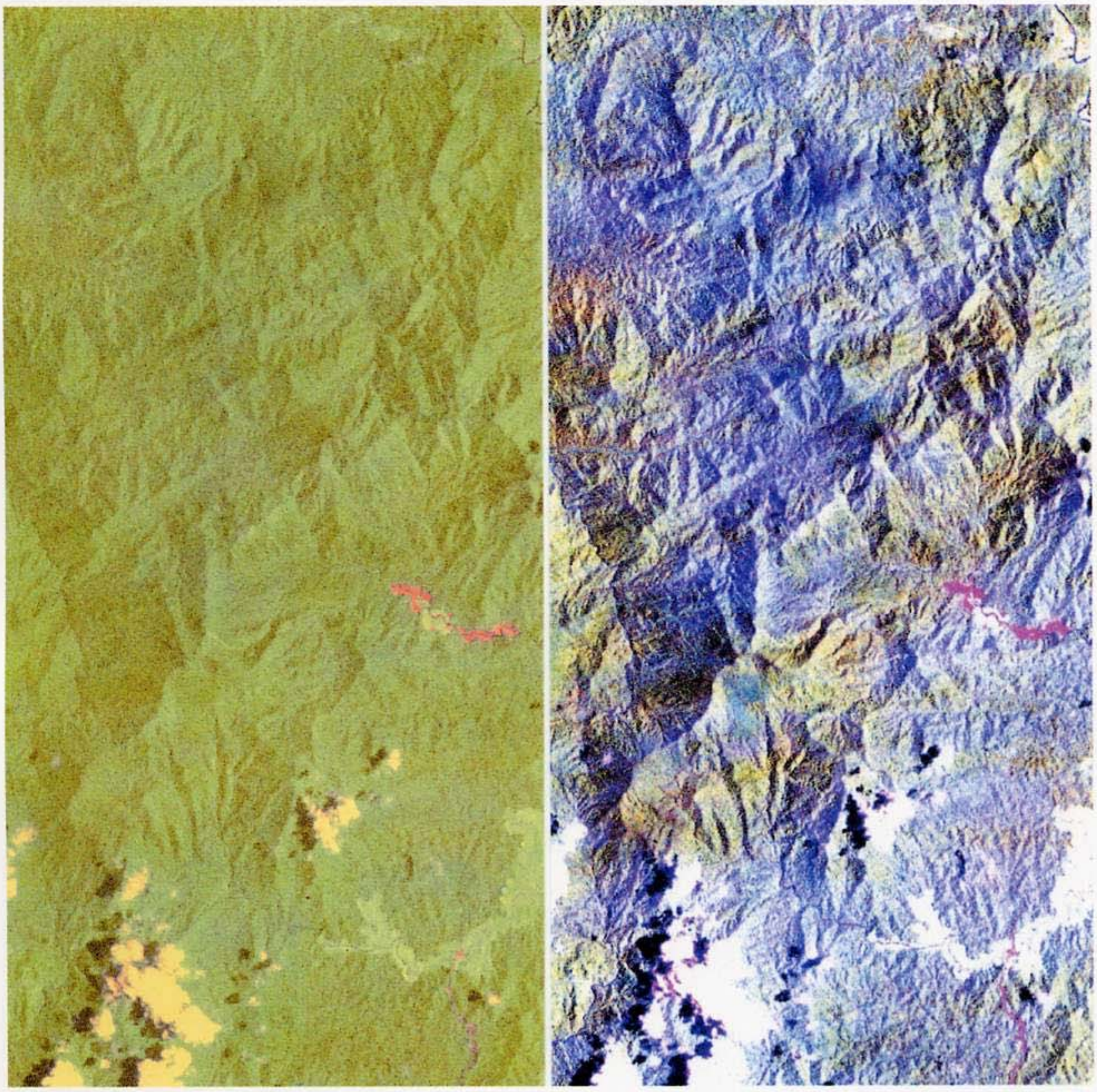


Fig. Annex 6: Detail from Landsat TM 119-60, **18.10.88**; channel 5-4-7/5-4-2.
Both images are magnifications of a section from the bottom left corner of fig. annex 5. The right colour image (RGB = 5-4-2) shows the sensitivity of the blue band (2) on atmospheric attenuation. In contrast to the right image the left one, composed of IR-channels only, shows less sensitivity on clouds.

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