TWENTY FIRST EUROPEAN ROTORCRAFT FORUM

Paper No. V-1

ENVIRONMENTAL HELICOPTER WITH MODULAR SENSOR CONCEPT: EXAMPLE ON FORESTRY MONITORING

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SAINT-PETERSBURG, RUSSIA

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ABSTRACT

The tasks of an environmental helicopter (EHC) with high mobility fill the gap between ground-based measurement stations and satellites. The EHC can be equipped with several sensor packages depending on the mission. In the last years EUROCOPTER 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. With the remote sensing of rural surfaces it is possible to measure surface temperatures not only of single points on ground, but of whole areas. 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. The paper describes the results of experiments made 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 on the one hand and helicopter borne IR scanner images on the other hand is given. There is a further chapter, where 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. A clear and precise classification 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.

1 ADVANTAGES OF AN ENVIRONMENTAL HELICOPTER (EHC)

The problem today is the advancing destruction of the environment and, as a result, man's enormous land use. The consequences are not only the pollution of air, water and land, but also the extinction of species, climatic changes, diseases and many others.

The interrelations between the reasons, the symptoms and the consequences are not understood quite well in some areas, because they are very complex. It is necessary to measure a lot of parameters of the "environment patient". And this should not be done only at one location and one time. Whole areas have to be monitored over a long time period.

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) and data recording into a Geographical Information System (GIS)**
- **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**

Remark: The black and white images in this paper do not contain the full information of the coloured images in the original paper!

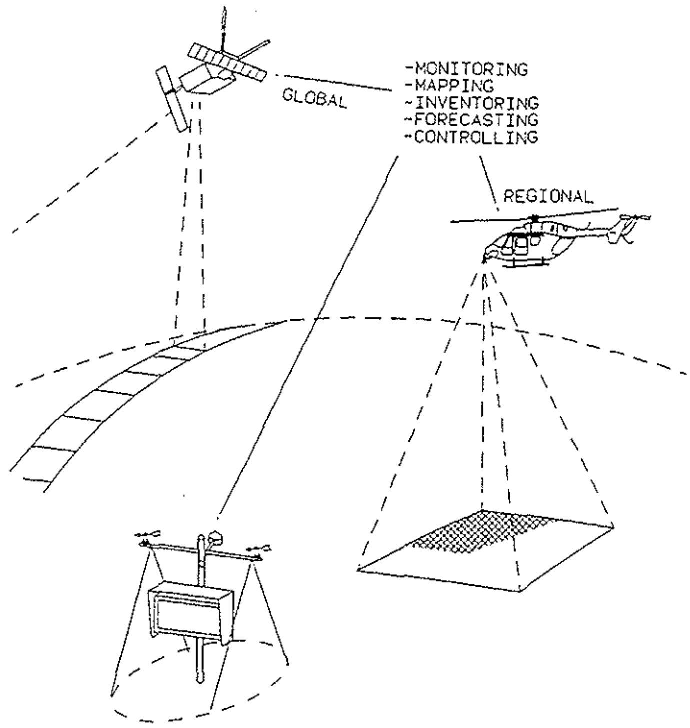


Fig. 1.1: The helicopter (regional) fills the gap between satellites (global) and ground based stations (local).

2 MODULAR SENSOR CONCEPT OF THE ENVIRONMENTAL HELICOPTER

At EUROCOPTER (EC) since several years studies and flight trials as described in this paper were made to define and develop an Environmental Helicopter (EHC) for measuring environmental parameters. Now EC plans to equip an Environmental Helicopter with a modular mission/sensor package, see Fig. 2.1. On the EHC there will be installed a basic equipment, which is part of each mission configuration. Additionally modular sensor packages can be easily mounted on the helicopter depending on the mission requirements. These sensor packages may be installed on several of the EC helicopters.

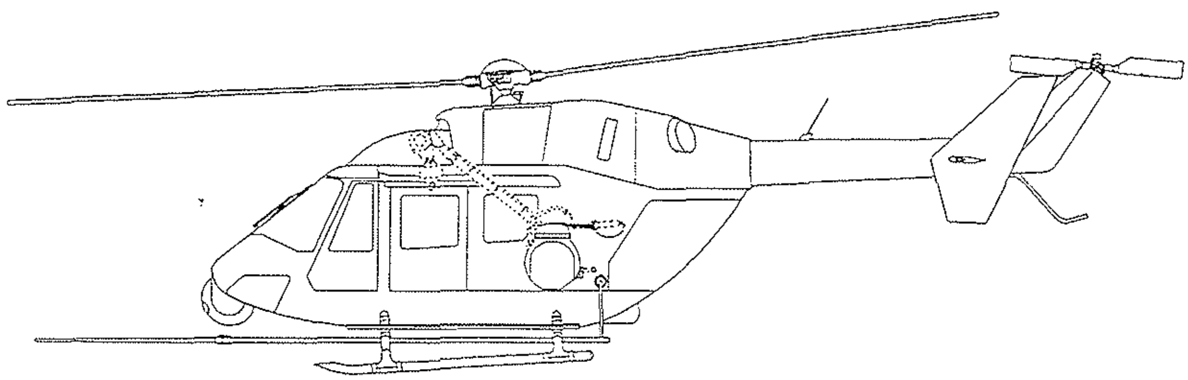


Fig. 2.1: The EHC equipped with all possible sensor modules as there are the Pitot tube for the GC/MS, a gimbal for the imaging spectrometer or alternative a winch and in the nose a gimbal for the IR scanners and the TV-camera. On the other side of the EHC a LIDAR system can be mounted.

The BK117 from EC 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.

2.1 The basic equipment of the EHC

In addition to the basic helicopter equipment as the communication (COM) and the navigation (NAV) system and a modern helicopter cockpit, the EHC will get a GPS and a flight management-system, including a digital map. An air data system consisting of climatic situation sensors for temperature, humidity and air pressure shall measure the climatic reference data. For both remote sensing and in-situ measurements it is important to know about the climatic circumstances, to make an exact interpretation of the sensor data.

The sensor and navigation data are brought together in the central data interface. There the sensor heads, the air data system and the navigation system are connected to. The central data interface is located inside of the fuselage. It contains sockets for all sensor plugs and sockets for the cabling to the central data management system, which is located in the operator console. This provides the possibility, to install/remove single sensor heads, depending on the planned mission, or the whole mission equipment including the operator console.

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 (central data interface), 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.

The central part of the whole equipment is the operator console. The console contains a large colour screen, a keyboard, a track-ball, the work station and, if necessary, control panels for special sensors. The work station performs the whole data management which means common data acquisition, processing and recording for all sensors. All sensor data can be displayed on one colour monitor at the operator console for quicklook and monitoring. Data recording is done digitally in a GIS and for the TV camera on a video recorder. A down-link to the ground station is possible by telemetry.

Advantages of the central data management:

- time referenced and localised (GPS+NAV+GIS) data set including all sensor data
- clear operation at one operator console
- flexibility and good compatibility for new sensors
- weight and power saving

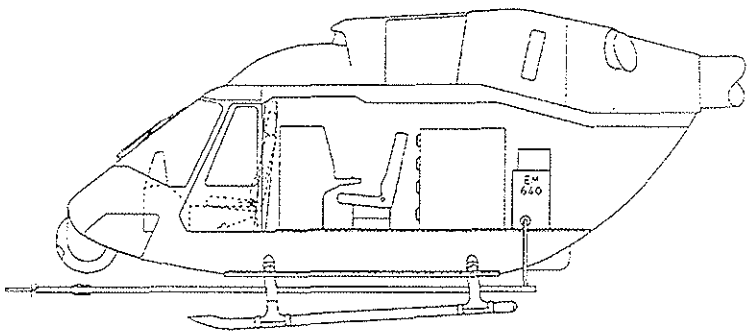


Fig. 2.2: The whole sensoric equipment can be controlled by the operator sitting at the operator console. This operator console provides a colour display, keyboard and track-ball. The central work-station is installed inside the operator console, while the electronic units of the sensors are mounted in 19"-racks in the cargo compartment.

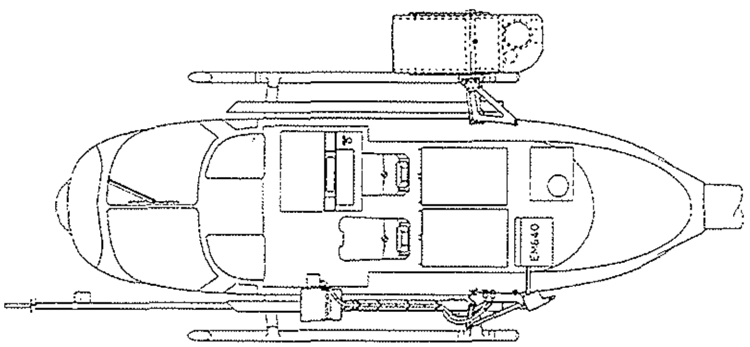


Fig. 2.3: The operator console and the racks with the electronic units are mounted on a plate, which can easily be pulled out of the helicopter through the back doors.

2.2 The modular sensor packages

A Modular Sensor Concept (MSC) for the environmental monitoring and disaster operation is under investigation for different applications. The main intention of the Modular Sensor Concept is the flexibility. Different sensor packages can be installed easily and in short time depending on the requirements of the planned mission.

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

2.2.1 Sensors for remote sensing

One of the most important sensors is the TV-camera, mounted in a gyro-stabilised gimbal in the nose of the helicopter. The video is used for the documentation of the measurements. The line of sight (LOS) of the TV-camera can be steered from the operator console.

Two IR-scanners are installed in the nose gimbal. They are sensitive in the 3-5 μm and 8-12 μm wavelength band and provide real surface temperature values (see chapter 4.1). Typical missions are surface temperature and IR-signature measurements for research applications, waste deposit monitoring (see chapter 4.3), fire detection, pipeline and power-line monitoring and detection of water pollution (oil spills and influences of chemicals in rivers or the sea).

The LIDAR-system mounted as a pod is an active remote sensing device. A laser beam is shot down from the helicopter to the (water)-surface and excites fluorescence of the materials to be analysed. The main use of the LIDAR is oil spill analysis. The fluorescence of the oil is detected by a telescope inside the LIDAR-system and is analysed spectrally and time resolved. So a differentiation even between different kinds of oil is possible.

Very interesting images will be provided by the pod mounted imaging spectrometer. This spectrometer covers the optical and the near IR bands. For example the red edge of chlorophyll (trees, plants) can be detected in supplement to the 3-5 μm and 8-12 μm channels. The sensor fusion technology can process the vitality of trees/plants and vegetation stress using the tree monitoring sensors. This sensor is also very useful for ground truth application of the LANDSAT TM satellite images.

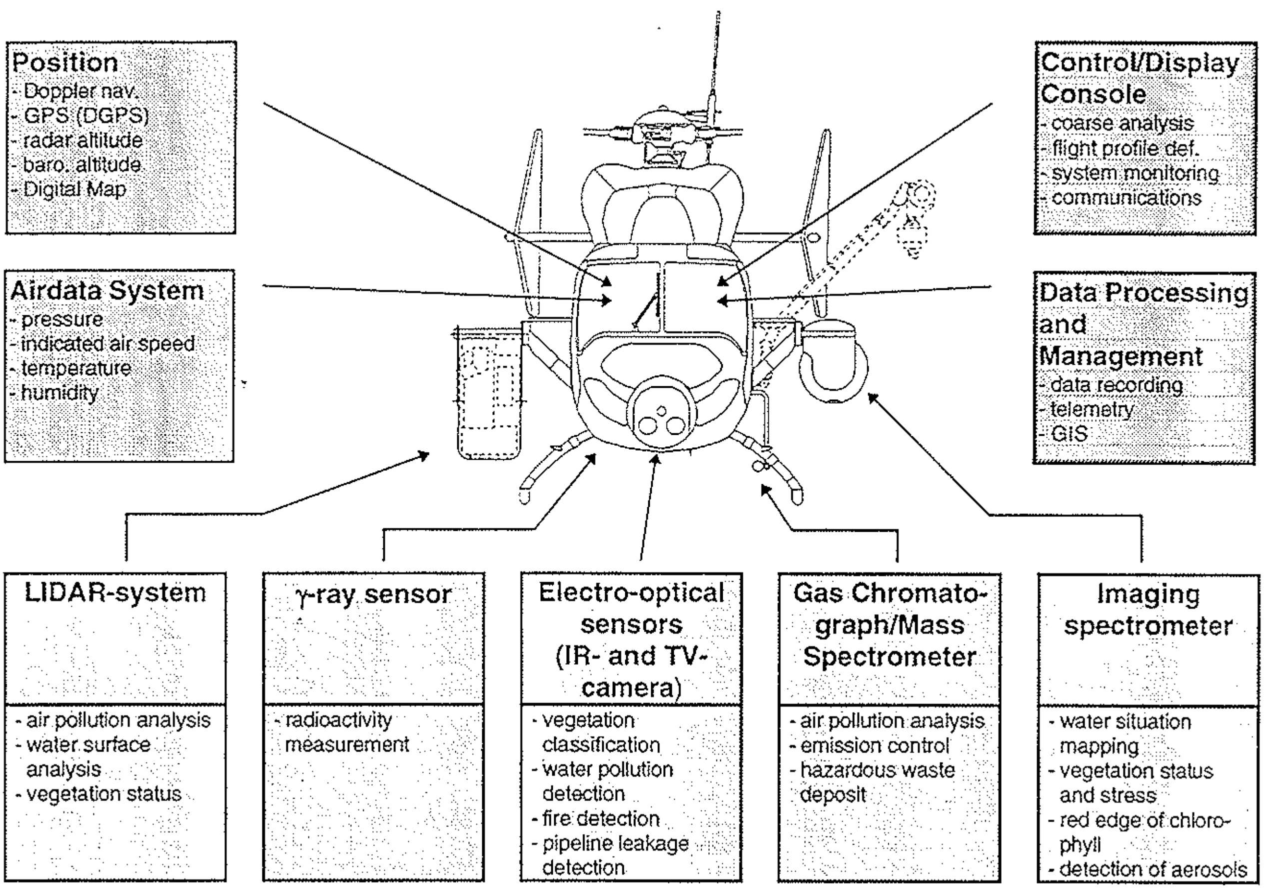


Fig. 2.4: Modular sensor packages for the Environmental Helicopter (EHC).

The γ-ray sensor measures the counts of radioactive decays producing γ-rays. The main task is monitoring around nuclear powerplants and operation in the case of a nuclear accident. For the monitoring it is necessary, to fly at exact altitude above ground. This is only possible by a helicopter.

On the external load hook a magnetical gradiometer can be hanged on as sling load. This kind of instrument measures the gradient and the absolute value of the magnetical field of the earth. Abnormalities in the magnetical field of the earth are indicators for mineral deposits or all kinds of magnetical materials above and under the surface. In this way gradiometers are used for exploration and buried dangerous metallic waste from the past.

2.2.2 Sensors for in-situ measurements

To analyse the composition of gases in the air the EHC provides a sensor package with a gas-chromatograph/mass spectrometer. For these measurements the helicopter requires a Pitot tube in front of the fuselage, to avoid false readings caused by turbine gas exhaust in the HC down wash. The tube is fixed at the bending tubes near the boarding step. To measure low concentrations of gas, the gas-chromatograph/mass spectrometer needs some minutes for accumulation. So two typical mission profiles are planned. First flying in a small area to get a mean value for the gas concentrations and second, to hover at one point and measure for example exhausts of a chimney.

Additionally rescue hoist can be mounted on the fixed provisions at the fuselage.

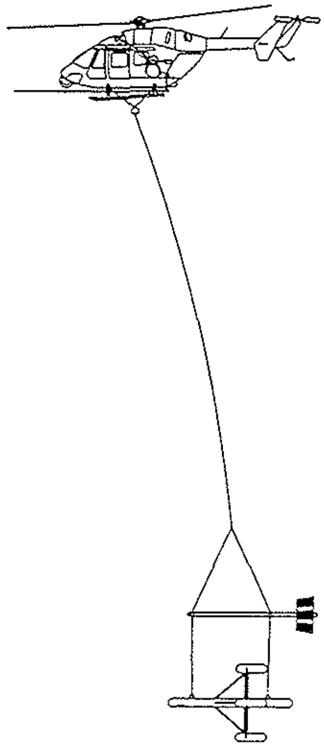


Fig. 2.5: The EHC carrying a towed-bird magnetic gradiometer system.

2.3 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 or car. 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 primary rain 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.

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
- Fire fighting; the water can be exactly dispensed onto the fire from a helicopter.

2.4 The EHC used for pipeline leakage detection and power-line monitoring

Oil and gas pipelines are mostly made of steel. Corrosion limits their life-time and causes leakage. An other reason for pipeline leakages can be movements of the earth and the forces of frozen earth. So the pipelines have to be monitored, to prevent damage of the nature and to lose oil or gas.

The gas in the pipelines stand under high pressure up to 150 bar. The gas and also oil in the pipelines is relatively warm compared to the earth. If there is a leakage where the gas or the oil escapes from the pipeline, an abnormality in temperature of the earth is caused. This can be shown by the IR-scanners. It is not possible, to determine the concentration of the gas only with IR-scanners. Using a special LIDAR system the EHC-operator is able, to measure also gas concentrations and to analyse the gas. The principle is based on the specific absorption of each gas. Each gas has its own "fingerprint". In correlation with the surface temperature data from the IR-scanners, done by the computer, the EHC can detect pipeline leakage.

Power-line monitoring is usually done by helicopter, flying along the power-line. The operator looks at the lines with his unaided eyes, searching for abnormalities. Additionally the EHC can detect with the IR-scanner hairline cracks in powered cables and isolators with the IR-scanner package. Hairline cracks in powered cables increase the resistance. This leads to an increased power dissipation at this location, what can be made visible by the IR-scanners.

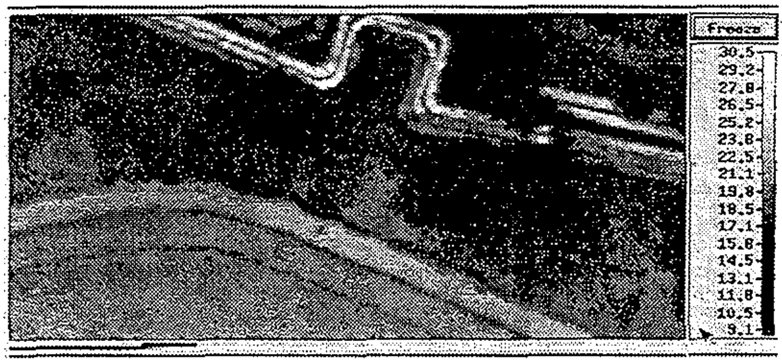


Fig. 2.6: IR-image from a district heating pipeline. Hot spots on the pipe indicate locations with bad isolation.

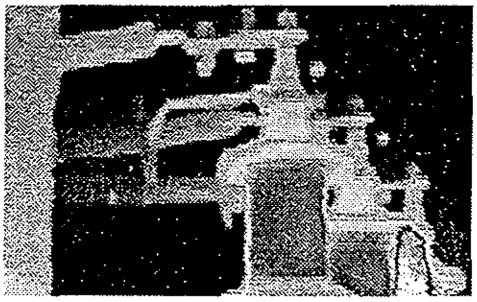


Fig. 2.7: IR-image of isolators in an electric power plant.

3 MEASUREMENTS AT EUROCOPTER WITH THE EHC

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

3.1 AGRO-ECOsystem FAM-Project and results

3.1.1 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 AGEMA "Thermovision 900 Series" infrared system is not only an imaging device like a Forward Looking Infrared (FLIR) system, but a surface temperature measurement system. The intention of these flights was to get first experience in the IR-signature of an agricultural landscape and to learn about the problems arising from physical constraints as well as from technical aspects. The measurements showed, that effects of solar radiation (day/night, daily course), wind, plant parameters incl. spectral emissivity/reflectivity and the angle of detection have to be taken into account during the evaluation/interpretation, because they have a not negligible influence on the IR signature.

The flights were made over the research farm "Klostergut Scheyern" (FAM project). 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. 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 dry. Thus 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.

3.1.2 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

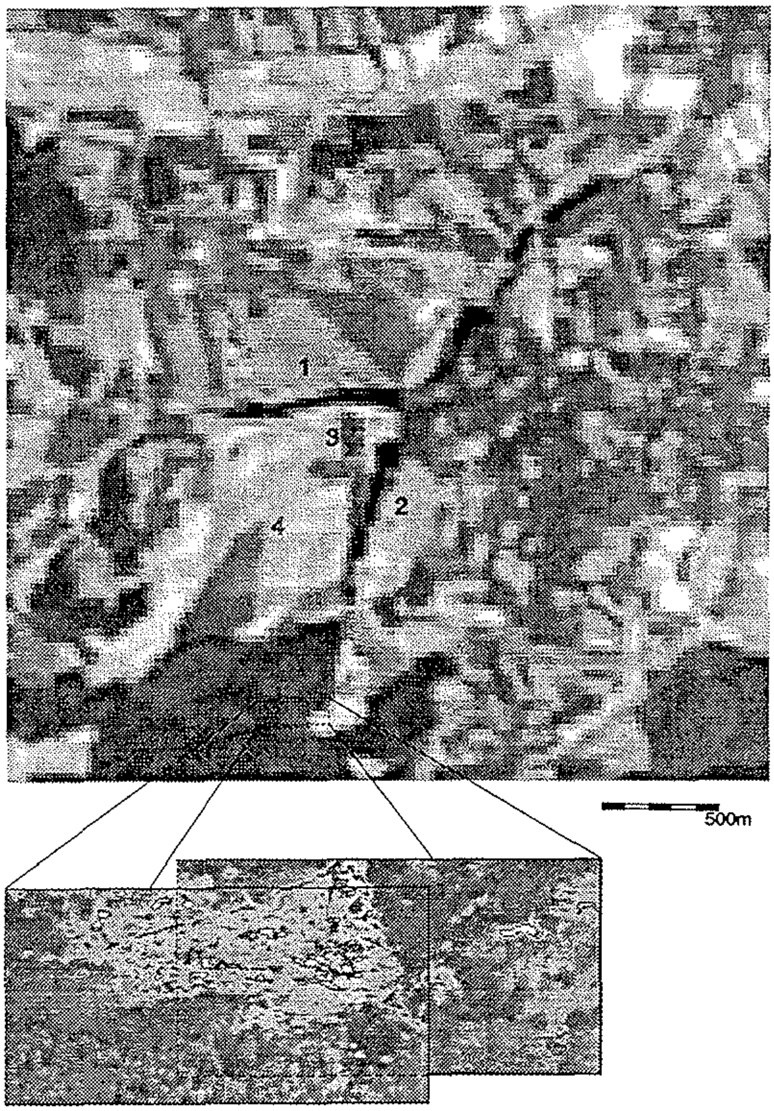


Fig. 3.2: Part of a LANDSAT TM image channels 5, 4 and 3 with the FAM research area compared with the two IR images taken from the EUROCOPTER's helicopter. For the numbers see text. Remark: images in this paper only black and white.

a resulting pixel resolution of 0.77 x 0.92 meters. 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 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. 3.2). Figure 3.2 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.

3.2 Monitoring of a waste deposit

In 1992 Eurocopter has also made flights over 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. 3.3 shows the embankment at the south-west part of the Munich waste deposit. 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 room temperature range 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 treetops of higher trees can better be reached by the wind, which decreases the temperature by evapotranspiration cooling. Second dense plants are covering the soil. The soil is not more visible and will not be heated by sun radiation.

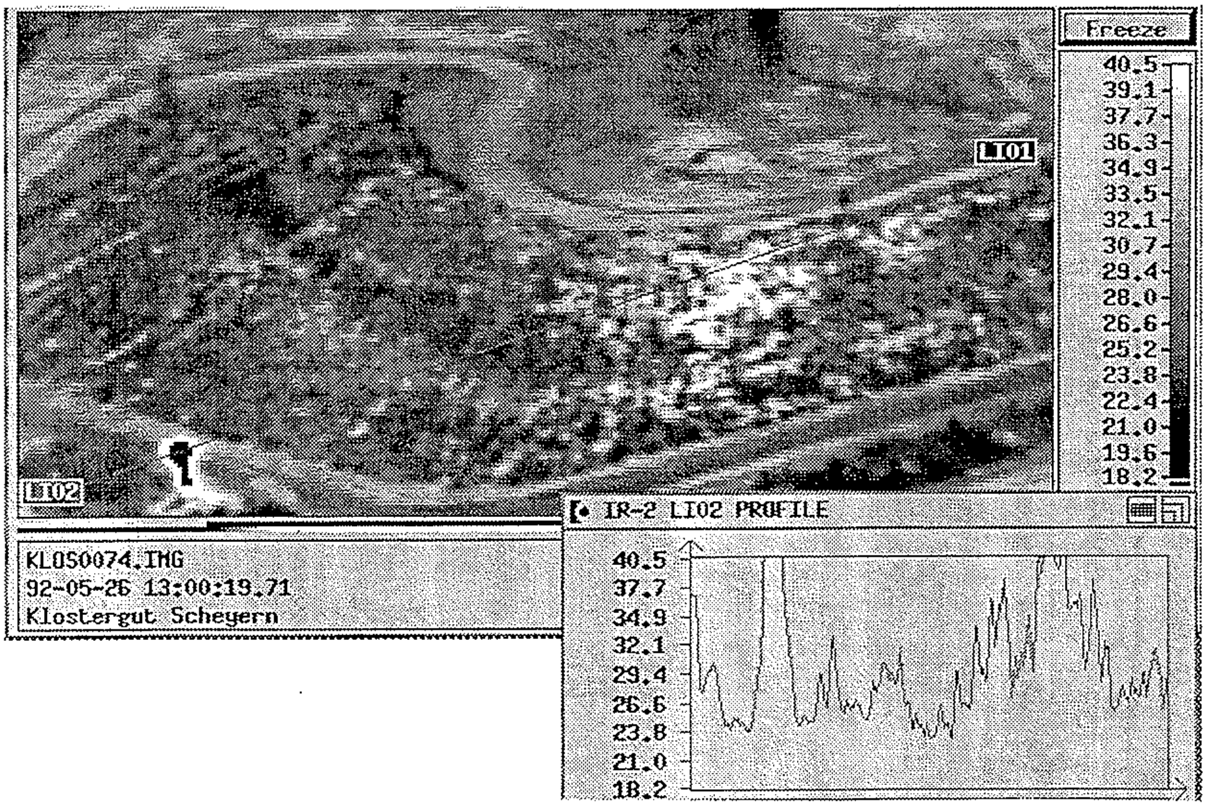


Fig. 3.3: IR-image of a hot spot on a waste deposit, dd. 26.05.92; At the bottom of the picture a profile of surface temperature lead through the IR-image from the lower left to the upper right. The temperatures vary between 19°C and more than 42.0°C. The hot spot in the centre is an indication for chemical or biological reactions taking place under the surface.

The most interesting area in Fig. 3.3 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.

3.3 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 the state of vegetation. Classification of state of vitality can be, for example, derived from sources of evidence as shown in the figure below. Any band with reflectivity and emissitivity information 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 (see fig. 3.5-6) 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 (3-5 μm) , for example, covers the red, the long wave image (8-12 μm) 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).

Classification by use of a sources of evidence chart:
A source of evidence indicates, which greyscale value pairs of the same pixel location in different wavelength bands are existing. So the histogramm charts of two wavelength bands are combined in one presentation. By matching some of these values characteristics in the image can be found. In the figure 3.4 there is a little area marked by a pointer, in which the branches and needles have become brown due to drying up. These pixel greyscale value pairs in the red and green colour channel appear in the according source of evidence as a white cloud of points. By the use of this cloud on the whole image, not only the marked area, all pixel with the same value pairs will be found. These locations can be interpreted as parts of the tree, which are going to dry up.

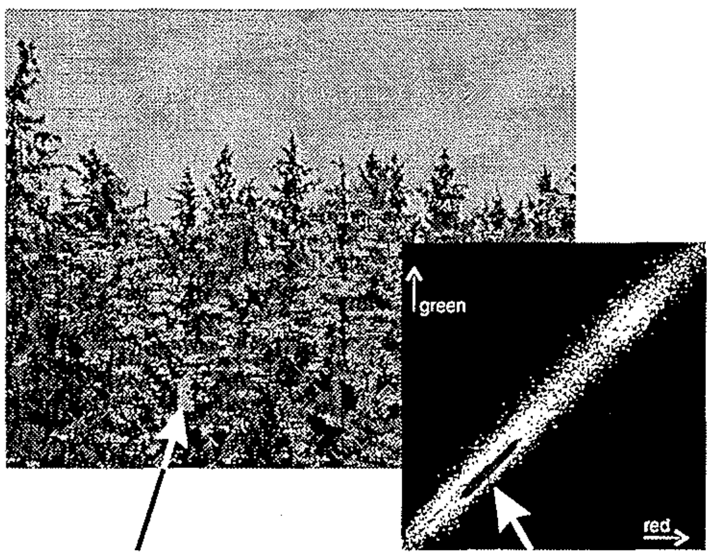
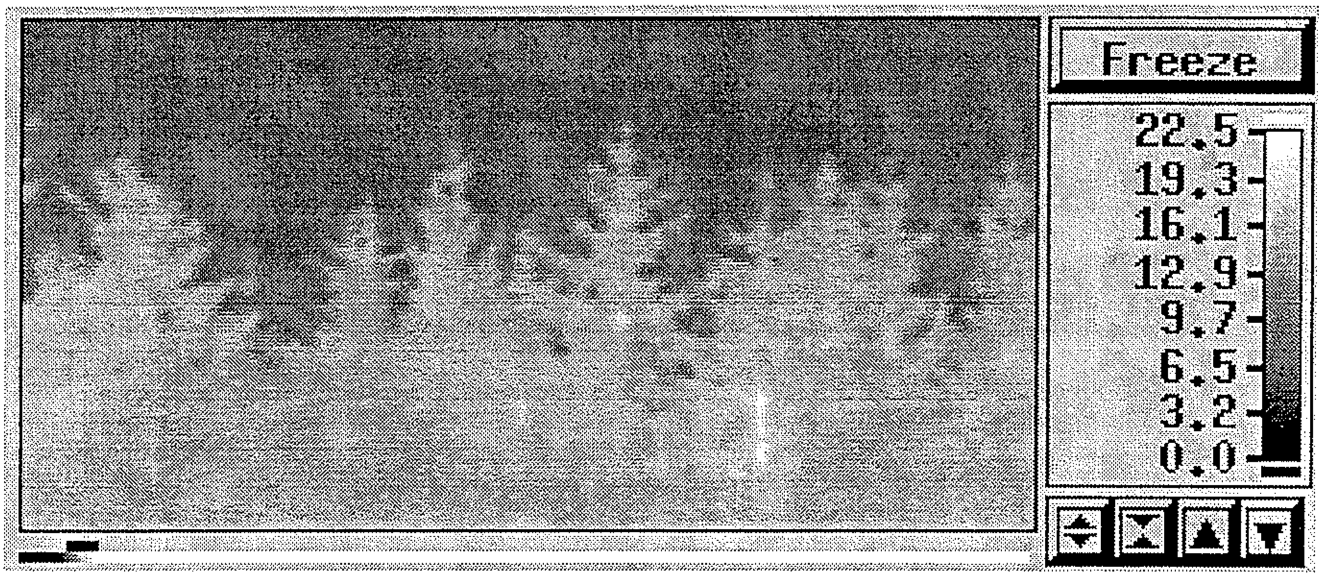


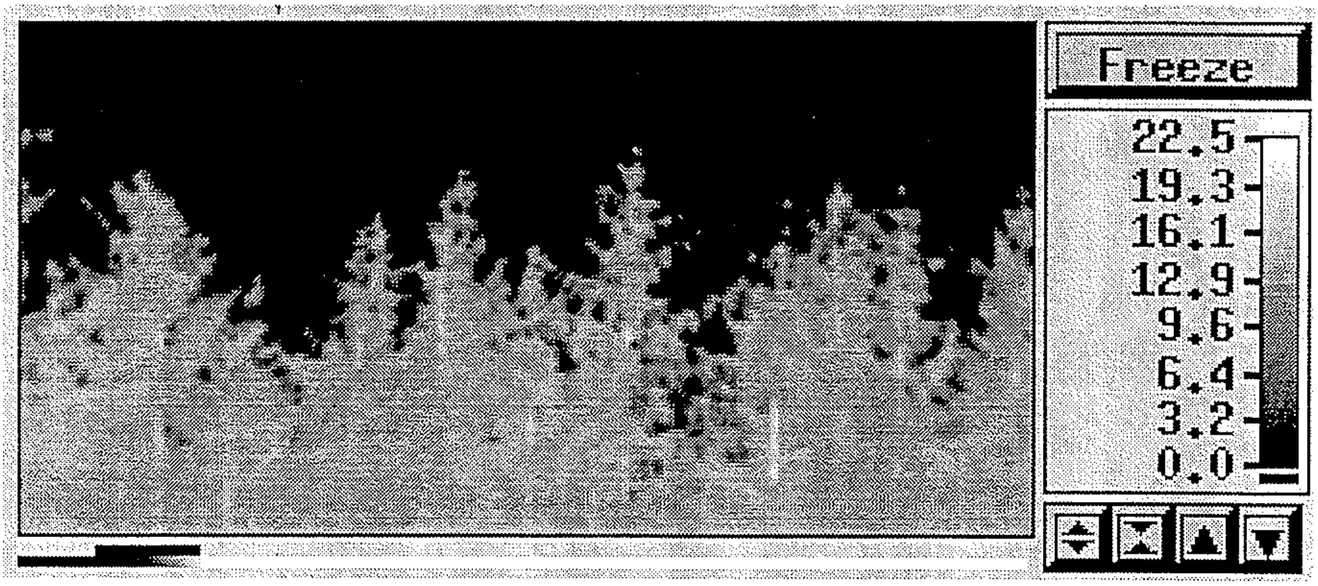
Fig. 3.4: Assessment of state of vegetation using a source of evidence chart.

The figures 3.5 - 3.7 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 and 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. 3.5	S-VHS (RGB)
middle	Fig. 3.6	3-5 µm (false colour)
bottom	Fig. 3.7	8-12 µm (false colour)

Remark: Coloured only in the original paper





3.4 Calibration of satellite images with the EHC on the example of Kalimantan

Satellite sensors are the suitable means for global monitoring of the wide areas of Russia as Siberia. But they do not provide in all cases high spatial resolution. In addition the satellite image data are attenuated by the atmosphere. Therefore the satellite images need to be calibrated and a classification methology have to be found. Because of the bad accessibility of these areas by car the helicopter is here the preferable mean. The same facts are valid for the tropical rain forests.

EC 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.

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. 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. 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.

Fig. 3.8: 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.

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. 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.

Different LANDSAT 5 Thematic Mapper images of the same season from end of June 1991 and July 1994 were selected and ordered. It was difficult, to find images with only few clouds. 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)
- LS TM 118-062 quarter image No. 5 from 8th of July 1994, partly TM 118-061 quarter 3
- 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.

Fig. 3.9: Section from Landsat TM 118-61, **30.06.91**; channel 5-4-3 (R-G-B).
In the center there is Tengkiling, located at the Rungan River. 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.

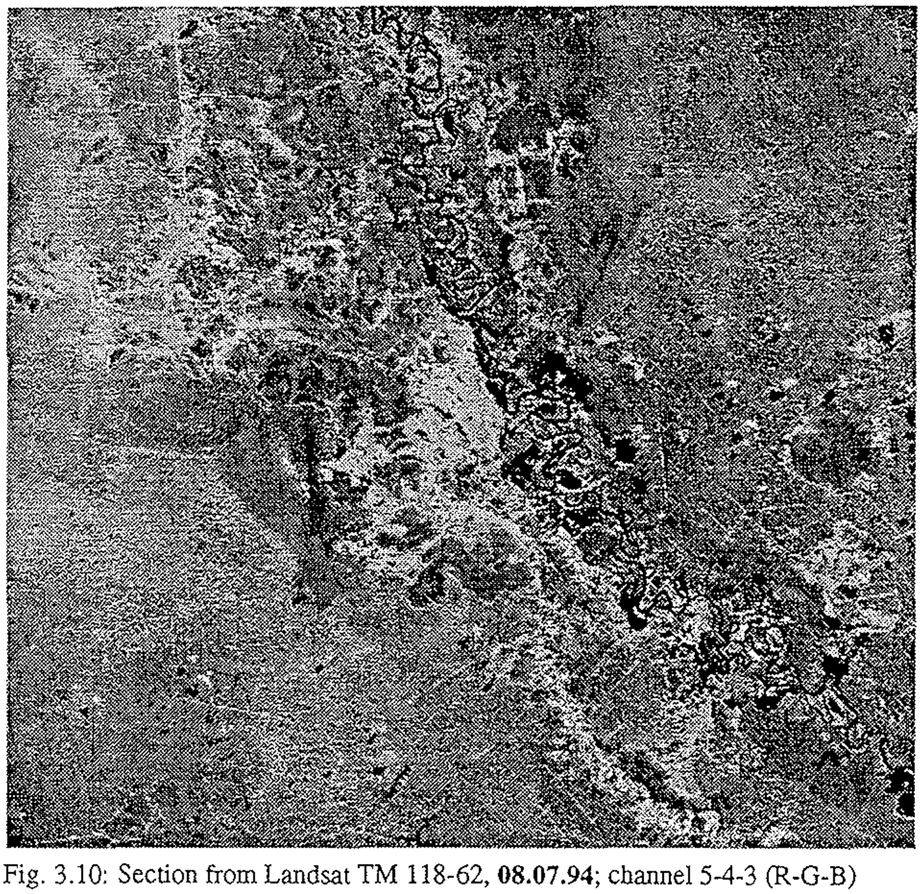


Fig. 3.10: Section from Landsat TM 118-62, **08.07.94**; channel 5-4-3 (R-G-B)
The bright areas in the center of the image means the town of Tengkiling at the riverside of Rungan River. As mentioned before a helicopter operation can help to survey the area of interest.

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 cutting, 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.

Changes occurring over a period of time can be detected by comparing of two or more data sets, monitored at different times. Therefore it is called "multitemporal monitoring". ECD, for example, has got two Landsat Thematic Mapper (abbreviated: TM) satellite scenes of the region Tengkiling / Kalimantan from the years 1991 and 1994. The difference image, to be seen below as figure 3.11, was calculated as follows: difference = [0 < (dataset1994 - dataset1991)]. Calculated values less than zero are set to zero. Important is, that the data is received from TM channel 5, i.e. the band 1.55 - 1.75 µm, near infrared, which is sensitive to clear cuttings, shifting cultivation and other human influenced occurrences.

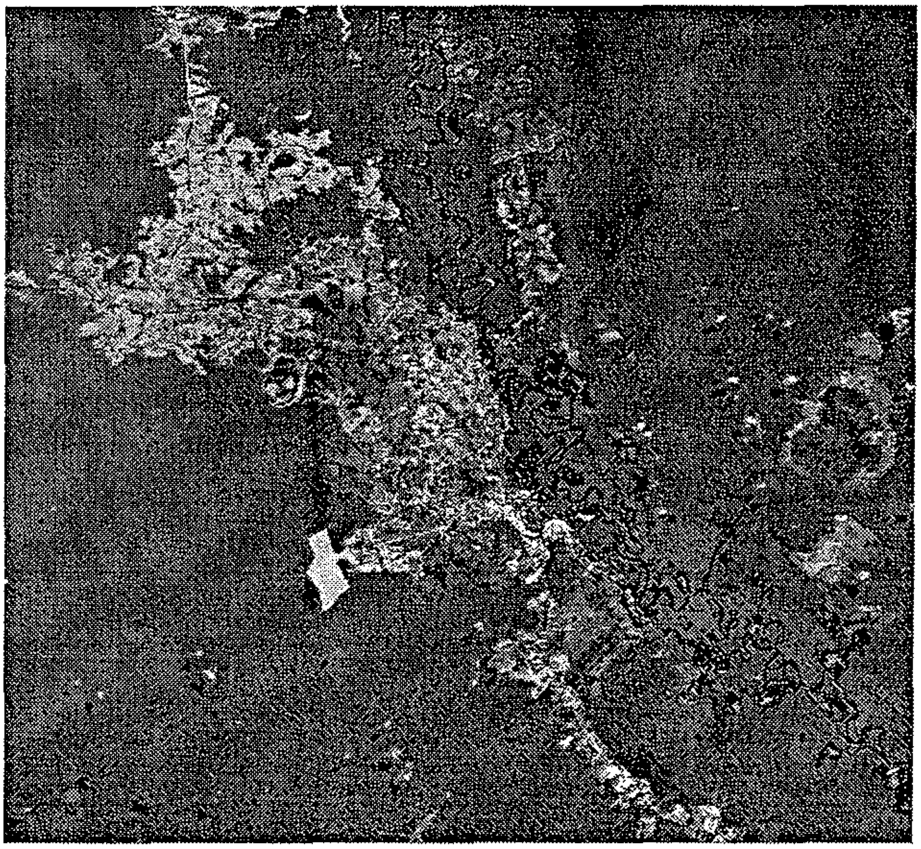


Fig. 3.11: **Multitemporal** difference image from Landsat TM 118-61 (**30.06.91**) and 118-61/62 (**08.07.94**)
The bright zones mean an increase of reflection from 1991 to 1994, which is an indication for anthropological changes. Black zones stand for no change or reflection. Pairs of white and black dots are caused by little clouds and their shadows in 1994.

Interpretation of the image: The bright zones indicate that in 1994 an increase in reflection of the near infrared radiation compared to 1991 happened (Ch. 5). That is a trustworthy indication for anthropological changes, as mentioned above. But not all changes are anthropological: In the upper left corner there is a diffuse light area. This is mist and clouds, which occur in 1994, and therefore no human influenced changes. In nearly black zones there are on the one hand nearly no changes (e.g. the middle of the river), on the other hand reflections, which were stronger in 1991 than in 1994, especially around the river: The region was more dry in 1991, less area were covered by water (water hardly reflects the mentioned infrared radiation, e.g. the river). Clouds, visible in 1994, appears very light, the shadows very dark and vice versa for 1991. The dark grey areas, which occupies most parts of the image, have to be interpreted as noise, caused by natural changes of vegetation. In the scene you can see huge areas of shifting cultivation and clear cuttings to be added in a period of three years.

The satellite data are a good indicator for alarming developments, but there is no real exact classification possible, because the TM resolution of 30m x 30m is not good enough. After interpretation of endangered areas exact monitoring of this areas with a helicopter is very useful. A survey with a helicopter can bring necessary information for land use.

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.

4 SUMMARY

Environmental Helicopter (EHC) and Modular Sensor Concept (MSC)

The combination of an EHC equipped with modular 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 destruction, pollution and disasters as forest fires.

The MSC enables the operator of an EHC, to react with a specific combination of sensor packages on the requirements of the mission. It is also possible to remove all sensor packages and the operator console with the electrical units and to use the helicopter for transportation. The main sensor packages are for instance:
- nose gimbal with two IR scanners and a TV camera
- LIDAR
- Gas-chromatograph/Mass spectrometer (GC/MS)
- Magnetometer
- γ-ray sensor
- Imaging spectrometer

Different applications of the EHC:
- Monitoring of gas and oil pipeline conditions (leakage detection)
- Monitoring of agricultural and forestry areas (vegetation status, biomass, humidity, soil erosion, etc.)
- Exploration
- Monitoring of hazardous waste deposits
- Planing of roads and rails
- Land use planning
- Coastal applications (oil spill detection, situation mapping, etc.)
- Disaster management (forest fires, chemical and nuclear accidents, etc.)
- Radioactivity measurements
- Calibration of satellite data

Forestry application of EHC

Forests are one of the few renewable natural resources. With careful planning, forest management 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 the tropical rain forests 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 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

5 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.

6 GLOSSARY

CCD	Charged Coupled Design
DARA	Deutsche Agentur für Raumfahrt-Angelegenheiten, German Agency for Aeronautic
DLR	Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V., German Aerospace Research Estab.
EC	Eurocopter
ECD	Eurocopter Deutschland
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
GIS	Geographic Information System
GPS	Global Positioning System
GSF	GSF, Forschungszentrum für Umwelt und Gesundheit, Neuherberg
H/C	Helicopter
IPTN	Nusantara Aircraft Industries Ltd., Bandung
IR	Infra Red
JRC	Joint Research Center of the Commissions of the European Union, Ispra
LS TM	LANDSAT Thematic Mapper
LIDAR	Light Detection and Ranging
LMU	Ludwigs-Maximilians Universität, München
MSC	Modular Sensor Concept
NAV	Navigation
RADAR	RAdio Detection and Ranging
RGB	Red-Green-Blue
SAR	Synthetic Aperture Radar
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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