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ABSTRACT

Knowledge of the environment has grown to such an extent that information technology (IT) is essential to make sense of the available data. An example of this is remote sensing by satellite. In recent years this field has grown in importance and remote sensing is used for a range of uses including the automatic survey of wheat yields in North America, the examination of the rain forests in South America, the observance of extension measures in Europe, and the examination of land use in Germany. This paper describes different aspects of remote sensing by satellite using relevant examples. Methods of using remote sensing in environmental education at the upper secondary level and the university level are outlined. Key principles, methods of using satellite data in class, modular structure, and future developments are discussed. Contains 11 references. (JRH)

Remote Sensing by Satellite for Environmental Education: A Survey and a Proposal for Teaching at Upper Secondary and University Level

by

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Introduction

Our knowledge of the environmental has grown to such an extent that information technology (IT) is essential to make sense of the available data. An example of this is remote sensing by satellite. In recent years this field has grown in importance and remote sensing is used for a range of uses including the automatic survey of wheat yields in North America, the examination of the Rain Forest in South America, the observance of extension measures in Europe and the examination of land use in Germany.

1. Remote sensing by satellite

Fundamentally, remote sensing can be carried out either from an aeroplane or a satellite. For several years, data concerning the earth's surface has been gathered regularly (weather satellite stations such as METEOSAT or NOAA have become known to the general public through weather forecasts).

An important aspect of remote sensing is that measurements are usually carried out *automatically*.
Photographs are not taken by camera (the Soviets did this for many years), but instead data is recorded in *digital form*; that makes subsequent evaluation possible. The majority of satellites - not including radar satellites - do not *transmit* any radiation but *measure* radiation which is *reflected or emitted* from a certain area or at a certain time from the earth ("passive systems"). The American Landsat TM and the French SPOT satellite (launched in 1982 and 1986 respectively) are particularly important. However, one disadvantage of the passive system is that it is impossible to carry out measurements through clouds. This limits the use of remote sensing of several countries.

The quality of the recording system is decisive for the subsequent evaluation of satellite data. An important feature of satellite measuring equipment is the radiometric (spectral) dissolution that enables the recording of different ranges of radiation. A satellite's sensors can perceive different spectral ranges individually which means that they can measure in several *recording bands*. This is particularly the case with the Thematic Mapper (TM) of Landsat satellites 4 and 5.

Our eyes can perceive reflected light in the narrow visible range of the electro-magnetic spectrum (0,4 - 0,7 µm). However natural objects also reflect in non-visible ranges (for example, in the infra-red range). A satellite is able to perceive radiation within non-visible ranges. For example, Landsat TM bands 1 to 3 measure in the *visible* area and bands 4 to 7 measure *the near and middle infra-red* electromagnetic radiation[1].

A further important quality of the recording system is its geometrical dissolution. This describes the smallest area possible (pixel) for which the sensors can measure radiation. For Landsat 4-5, the *pixel size* is 30m * 30 m (by SPOT multi-spectral 20 m * 20 m) which means that any large building can be identified. In every band, and for every pixel, a value of the reflected radiation is measured; so that quite different variations (such as coniferous forest, deciduous forest) can be made. Landsat TM registers 256 *stages of radiation intensity*.

Table 1 gives an overview of the Landsat TM bands.

Band No.	*Wave length*	*Area*
1, 2 ,3	0,45 - 0,52; 0,52 - 0,60; 0,63 - 0,69 µm	visible blue, green, red
4, 5 ,7	0,76 - 0,90; 1,55 - 1,73; 2,08 - 2,35 µm	near and middle infra-red
6	10,4 - 12,5 µm	thermal infra-red

Table 1: Bands and wave lengths of the Landsat TM 4-5 satellites. It must be said additionally that these satellites have been in circulation since 1982 at an altitude of 705 km. The full circulation lasts 16 days, the image format is 185 km * 185 km and the pixel size 30 m * 30 m.

It is important to realise that objects do not reflect to the same degree in different ranges. If one wishes to interpret the reflection values which are received from the satellites, it is important to know in which bands certain objects reflect very strongly or weakly.

As an example, consider the question: "Which Landsat band is most appropriate for observing vegetation?" In figure 1, the *spectral curves* of water, ground and vegetation are depicted. It can be seen that for vegetation a large peak of anything between 0,8 µm and 1,4 µm is available. Weaker, but at the same time clear peaks can be found between 1,6 µm and 2,2 µm. The weakest peak lies at about 0,5 µm. As table 1 shows, the first peak is in band 4, the second in band 5 and the third in band 7. The weakest peak is in band 2 ("visible green"). For the examination of vegetation, the visible bands are not as suitable as bands 4 and 5 with their clear peaks.

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1 The SPOT satellite with the HRV recording techniques measures multi-spectrally in the wave areas (1) 0,5 - 0,59 µm, (2) 0,61 - 0,69 µm and (3) 0,79 - 0.89 µm. Even though the dissolution is better with 20 m * 20 m than with Landsat TM, the smaller number of infra-red bands means that SPOT data is less suitable for the examination of vegetation. Especially the important area of 1,55 - 1,73 µm, band 5 by Landsat TM (c.i.f. also table 2) is missing.

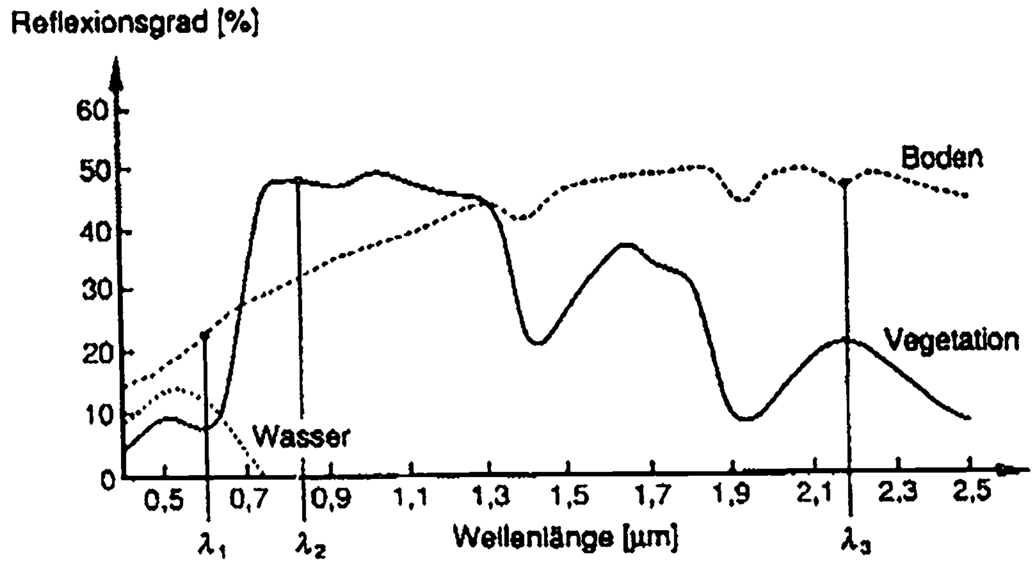

Figure 1: the relative reflectance of water, ground and vegetation according to Albertz, 1992, p. 141. Slightly different reflectance values for ground, water and vegetation are available in the visible area, cif. e.g. the position λ_1 in band 2 (0,52 - 0,6 µm). Clean water does not reflect in near and middle infra-red.
In position λ_2 in band 4 (0,76 - 0,9 µm), the reflectance value is higher for vegetation than for the ground.
In position λ_3 in band 7 (2,08 - 2,35 µm), the reflectance value for ground is higher than that for vegetation.

With vegetation, the nature of the reflection is strongly dependent on the surface of the leaves and on their construction. It has been demonstrated that through dissemination, refraction and reflection, the light in the leaf covers much of the direct distance through the tissue. The probability for an absorption is greatly increased also in the spectral areas with less absorption (green light).
Further explanations cannot be dealt with in detail here. More information on the subject can be found in, for example, the paper by Buschmann, 1993 and the literature mentioned in the bibliography.

In table 2 the reflectances of the most important physical and physiological features of the plants are shortly mentioned.

Cause	*Wave length*	*Band*
leaf pigments	about 0,4 to 0,7 µm	visible area, mostly in band 2
cell structure	about 0,7 to 1,2 µm	near infra-red, band 4
water content	about 1,2 to 2,4 µm	middle infra-red, band 5

Table 2: the most important physical and physiological features of plants and their reflectance in the different bands (according to Landauer and Voss, 1989, p.26); cf. also Colwell, 1963 and Gates, 1970.

Each of the seven bands available from Landsat TM has different characteristics which are summarised in table 3.

Band No.	*Wave length*	*Abridged characteristics*
1	0,45 - 0,52 µm	differentiation of ground and vegetation, using coastal water, does something enter the water
2	0,52 - 0,60 µm	in the first maximum of the green reflection, for vegetation, for vitality examinations
3	0,63 - 0,69 µm	in a minimum of green reflection, to differentiate from other vegetation
4	0,76 - 0,90 µm	in a maximum of chlorophyll reflection, for vitality examinations
5	1,55 - 1,73 µm	dampness indicator for ground and vegetation
7	2,08 - 2,35 µm	for the differentiation of stones, geological applications
6	10,4 - 12,5 µm	thermal radiation with a reduced geometrical dissolution of 120 * 120 m

Table 3: the bands from Landsat TM and their abridged characteristics (according to Bähr, 1985)

2. Working with remote sensing at upper secondary level and university

Although the professional use of computer technology has been a matter of course for years now in many areas of environmental protection (cf. Bosler, 1995) it has however made little impact on environmental education. This is certainly directly related to the fact that the important goals of environmental education include first-hand experience of nature as a means of getting to known one's own environment. From this perspective, the use of IT to get to know one's local environment offers few advantages. On the contrary, the new computer vocabulary and the required user's knowledge can act as deterrents.

The situation is somewhat different when *environmental conditions need to be considered over a larger region.* The question, for example, can then be posed: is the condition of a particular lake or a coniferous forest typical of a region where a survey has been carried out on-the-spot? A substantial number of local surveys are usually impossible. For this, the data gained from satellites can be of great help to answer such questions. The data is available in digital form and enables a data review regarding certain issues (e.g. the proportion of damaged areas of a coniferous forest) to be carried out independently.

Another example is the examination of *land use.* Data supplied from a satellite enables an easy evaluation of the area of the sand strand of an island. If a comparative image is available, one can then work out how much land has been lost during a storm. Further examples for land use include determining the proportions of streets, vegetation, forest and moors.

The examination of the ecological effect of *alternative transport routes* is an additional example of interest. It is possible to draw planned transport routes onto a satellite image and to examine the pollution from different forms of land use. The user can give the different forms of land use evaluation coefficients, and as a result of this can carry out an intensive study in the form of a simulation or a game.

A recent innovation is software which has been developed for utilising satellite data in class. The *educational software* Windows-Probe (cf. Orfeus, 1995) enables students to work with satellite data in a simple form. The sophisticated software Idrisi for Windows is suitable for students at upper secondary level II and university (Clark University, 1995 and Eastman, 1992).

2.1. Didactical key principles[2]

The training of appropriate *ecological action and behaviour* among students that are harmless to the environment is the main aim of environmental education (KMK, 1980). This includes three main foci:

- developing an educational consciousness on the basis of an ecological basic knowledge (*environmental knowledge*)
- developing v ews on the necessity for environmental protection and conservation (*environmental responsibility*) and
- training environmentally conscious behaviour (*environmentally correct behaviour*).

The instruction sequence has the aim of connecting local environmental enquiries with regional aspects of remote sensing on the basis of the didactical-methodological concept for environmental education from Eulefeld et al. (1981). The transfer of the didactical-methodological principles of environmental education for instruction, which are mentioned in it, can be meaningfully supported by the possibilities of new information technologies. At the same time, selected goals of computer literacy education are accepted and are to be found in a national overall concept (BLK, 1987; cf. also Bosler, Ziebarth 1992). They have been integrated in an application-oriented manner. Details are described in table 4 and Bosler, 1995a.

2.2 Working in class with satellite data

As previously mentioned, teaching material has been produced for the following topics:

- Forests
- Lakes and
- Principals of remote sensing using the North Sea island of Sylt as an example.

A suitable structure was drafted for *different* teaching units. The teaching units are put together as *modules* so that parts can be carried out in another subject or in cooperation with other subjects. In table 5, the planned 11 modules are listed for three planned teaching units.

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2 The STS approach (STS = Science, Technology and Society) is distributed abroad - especially in North America. In the didactical key principles mentioned by Hansen (1995) on STS, a contribution by Waks (1992) is also mentioned. He refers to the work of a national STS work group in the USA and illustrates five criteria for the development of STS curricula and STS instruction units: (1) Responsibility, (2) Mutual influences of science, technology, and society, (3) Decision making and problem solving. (4) Responsible action, and (5) Integration of a point of view.

Didactical key principles for environmental education in relation to relevant aspects of information technologies	
Didactical key principles for environmental education	Aspects of information technologies
• *Situation orientation*: By dealing with ecological subject areas from the direct living environment of the pupils, emotional concern can be evoked as a prerequisite for environmentally conscience activity.	Information technologies can support the acquisition and use of information as well as the evaluation of outdoor surveys that take place on the spot. In this way, students gather individual experiences in a field of application that is both new and capable of being developed for IT.
• *Problem and system orientation:* In order to gain competency in decision and activities concerning issues on nature conservation and environmental protection, a discussion on the variety and interlinking of ecological systems is necessary. In connection with this, its vast amount of inherent conflict ability should be illustrated.	Computer modelling, simulation, data logging and processing as well as possibilities of control technologies possess great importance in ecological fields for the evaluation of results and drawing up of prognoses.
• *Interdisciplinarity*: The variety of aspects in the field of ecological problems are only recognisable, resp. a solution to the problem can only be supplied through the inclusion of knowledge and methods of different relevant scientific, human and social scientific disciplines.	Showing the chances and limitations and the creation of a consciousness for the social and economic consequences which are connected to the distribution of micro-electronics, serves the development of a rational relationship pertaining to this issue. For the problems of dealing with large amounts of information and data, ecological examinations can be used as an example.
• *Activity orientation*: competency in activity and decision making can only be trained on the basis of basic knowledge in environmental education and IT. This occurs when students are also shown common fields of activity in both areas in their direct environment and when the practical transfer also takes place in class.	

Table 4: didactical key principles for environmental education in relation to relevant aspects of information technologies.

The didactical key principles mentioned previously for both planned teaching units "Forest Use and Forest Damage" and "The Ecological State of Lake Catchment Areas" (Biotope Association) can be given a more concrete form and justified through further aspects:

- *Traditional teaching contents*: the subjects "Flowing water" and "Forests" are traditional teaching units for the subjects of biology and geography; this can be expanded.
- *Accessibility on the level of experience*: in most European countries there are forests, rivers or lakes near to educational institutions so that local examinations is possible. These eco-systems are marked by many problems.
  Forest pollution is visible e.g. in the crowns of coniferous trees and in the changes that take place in the needles. The eutrophication of lakes, changes in the border areas of stretches of water as well as sealing can be established by the students.
- *Ecological effects*: water and forests are basic requirements for our existence. Pollution causes severe economic problems, directly, e.g. on drinking water quality and on wood for building purposes, and indirectly, e.g. the purification of polluted water and for the disposal of damage caused by floods.
- *Global ecological effects*: the consequences of forest and water pollution are enormous: changes in the micro-climate, pollution of the ground water, e.g. with pesticide and the reduction of bio-diversity - to mention but a few key words.
- *Cultural aspect:* "Water" and "Forest" are deeply rooted in our culture, we have become acquainted with them from an early age. Usually we have a positive attitude to forests and water and this can be further developed through their study.

2.3 Modular structure

The content of the individual modules is described briefly below:

In *module 1*, local monitoring is introduced.

Module 2 gives an introduction into understanding of the principals of remote sensing (this understanding is developed further in module 6).

Module 3 contains instructions for the selected software. The use of Idrisi for Windows is outlined and the instructions can be extended for use with other similar software.

Module 4 is about an initial analysis of satellite images. How the reflections of some areas differ is explored. The satellite exposition image is now classified by the user (supervised classification). The result is a new image, that differentiates, for example, between the three areas: coniferous trees, deciduous forest and inhabited areas. In the cases of forests it is possible to produce a "coniferous mask" (viz. one that shows the areas with coniferous forest within which the other differentiated surveys can be continued).

In *module 5* software such as Idrisi can calculate areas of the groups classified in module 4 (e.g. "area of coniferous forests, deciduous forest and inhabited areas in hectares"). This gives, among other things, interesting insights into land use and is also of special interest when changes over several years are examined (cf. module 8).

In *module 6*, the reflections in the different bands that have been registered by satellite are examined. It is suggested to carry out these tasks selectively in the teaching units "Forests", "Lakes" or "Instruction using the North Sea island of Sylt". Using the "Forests" unit, it is possible to examine the different reflections of areas, coniferous forests, deciduous forests in the different bands, for example. In the "Lakes" unit, one could differentiate areas, including the lake itself and bordering areas - such as marshes. Taking the example of Sylt, one could analyse sand, sea and tidal shallows.
In every teaching unit, the necessary basic principles of remote sensing by satellite can be worked out and can be followed by an more detailed treatment.

Module 7 is a central area of the evaluation of satellite images. After an initial monitoring was carried out locally in module 1 this can now be very precisely expanded. Exactly defined areas (so-called "training areas") can be documented. Examples of this could be: an inventory with 70-90 year-old damaged spruces or an area with 50-70 year-old healthy pines. The areas have to be located carefully.
The training areas can now be entered onto a satellite image and a statistical projection can be carried out on the entire image using special statistical calculations (e.g. according to the Maximum Likelihood method).
All areas will then be displayed which have the characteristics of the training area (e.g. "50-70 year-old healthy pines"). This projection needs to be checked carefully - as have the local monitoring samples.

The multi-temporal approach in *module 8* has already been mentioned. It can be used for examining, for example, the changes in a lake, the amount of forest damage or the loss of sand. For this module, an older image is needed in order to make comparisons. For Germany the years 1984 to 1987 are particularly important because Landsat images from this period can be obtained free of charge.

In *module 9*, one has the option of using temperature measurements by satellite. The Landsat TM satellite carries out temperature measuring with channel 6 (with a reduced dissolution of spots from 1 pixel = 120 m * 120 m).
These measurements have an accuracy of about 0,2 °C. Warm water inflows can be established with this technique.

Module 10 deals more with the causes of damage, e.g. the increasing eutrophication or of possible causes for forest damage.

The intention of *module 11* is to distribute the results in a suitable form.

Module	Task	Teaching unit "Forests" using the Teutoburger Wald as an example	Teaching unit "Lakes" using the Ratzeburger See as an example	Teaching unit "Instruction tips" using the island of Sylt as an example
1	Overview of the local position	Forest usage and forest damage	Lake, water quality, bordering areas	Map material, further information about the island
2	Basic understanding of remote sensing			Basic understanding of measuring from Landsat TM in 7 bands
3	Instruction tips			Examine selected satellite images, basic information on selected satellite software
4	User-defined (supervised) classification	Classification e.g. according to coniferous forests, deciduous forests, and inhabited areas	Classification e.g. according to lake, different bordering areas	Classification e.g. according to sea, tidal shallows and sand
5	Area calculation	e.g. of the areas classified in module 4	e.g. of the areas classified in module 4	e.g. of the areas classified in module 4
6	Reflection in different satellite bands	Different reflections of coniferous forests; comparison with other on the spot reflections (among others)	Different reflections of water, reflection of chlorophyll (among others)	- *optional* - Different reflections of tidal shallows; comparison with other on the spot reflections and sand (among others)
7	Exact determination of known areas and projection to the entire area	Determination of exactly known areas (form of tree-age-damage), and projection to the entire area	Determination of exactly known areas (e.g. marshes), and projection to the entire area	- *optional* - Determination of exactly known areas (e.g. tidal shallows or sand), and projection to the entire area
8	Comparison with the situation of years ago	e.g. changes of land use, increase of forest damage	e.g. changes of land use, soiling of a lake, of lake regulation	- *optional* - e.g. loss of land in the southern part of the island
9	Introduction to measuring temperatures by satellite	Temperature differences between different forms of forests, and of different types of damaged forests	Temperatures in a lake, near locations, ev. investigation of warm water inflows	- *optional* - Temperature differences between the sea, and different parts of local shallows
10, 11	Possible causes for damage; dissemination of results	Causes for forest damage; register of forest damage, and others	Human interference; water quality, warming, and others	- *optional* - Storm tides, human interference

Table 5: The modular structure of the planned teaching units. It is recommended to use the teaching unit "Island" for module 2 and 3.

3. Future developments

The following steps have been planned for the near future:

1. The completion of the "Instruction tips using the North Sea island of Sylt as an example" till March 1996 (using Idrisi for Windows). The first testing took place at the University of Lüneburg;
2. The completion of the first version of the teaching unit "Forests" by the Summer 1996. This teaching unit is currently being tested at the pilot school "Stiftisches Gymnasium" in Gütersloh;
3. The completion of the first version of the teaching unit "Water" by Autumn 1996. A first test will take place at a pilot school in early summer 1996;
4. An extension of the project among a larger number of testing schools between Autumn 1996 and Winter 1988 is planned within Germany. A revision and additions to the teaching material will take place in this implementation project which will take place in co-operation with several Ministries of Education and further education institutions of the different states.

4. References

Albertz, Jörg (1991). Grundlagen der Interpretation von Luft- und Satellitenbildern. Darmstadt: Wissenschaftliche Buchgesellschaft

Bähr, H.-P. (Ed.) (1985). Digitale Bildverarbeitung, Anwendungen in Photogrammetrie und Fernerkundung. Karlsruhe: Wichmann.

Bosler, Ulrich; Damianova, Todorka; Dillon, Justin (Eds.) (1996): IT-Assisted Environmental Education - a Monograph. Kiel: IPN.

Bosler, Ulrich (1995a):Satelliten-Fernerkundung in der Umwelterziehung - ein Überblick und Vorschläge für den Unterricht in der Sekundarstufe II und Universität, Kiel: IPN, Polyskript.

Bosler, Ulrich; Ziebarth, Wolfgang (Eds.) (1992). Schulcomputer-Jahrbuch ´93/94. Hannover: Metzler Schulbuchverlag.

Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung (BLK) (Ed.) (1987). Gesamtkonzept für die Informationstechnische Bildung in Schule und Ausbildung. Reihe "Materialien zur Bildungsplanung". Bonn: BLK.

Clark University (1995). Address: Clark University, Graduate School of Geography, Worcester, Massachusetts, 01610, USA..

Eastman, J. Ronald (1992). Idrisi - User´s Guide and Technical Reference. Worcester, USA: Clark University (available from Clark University, see Clark University).

Eulefeld, Günter et. al. (1981): Ökologie und Umwelterziehung - ein didaktisches Konzept. Stuttgart: Kohlhammer.

Hansen, Klaus-Henning: STS-Erziehung und fächerübergreifender Unterricht in Deutschland (1995). Kiel: IPN, unveröffentlichtes Manuskript.

Landauer. G.; Voß, H.-H. (Ed.) (1989): Untersuchung und Kartierung von Waldschäden mit Methoden der Fernerkundung - Abschlußdokumentation. Oberpfaffenhofen: DLR.