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"GLOKAL CHANGE": GEOGRAPHY MEETS REMOTE SENSING IN THE CONTEXT OF THE EDUCATION FOR SUSTAINABLE DEVELOPMENT

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Abstract
The web-based learning platform "GLO*KAL* Change" (www.glokalchange.de), which is currently developed at the University of Education Heidelberg, Germany, highlights four topics of environmental changes in terms of sustainable development. In interactive learning modules, adolescents aged 10 to 16 years learn to evaluate economic, ecological and social impacts of recent environmental changes occurring in different geographic areas worldwide and in Germany. Information is provided by remote sensing data and other media. Users compare, visually analyze and interpret satellite imagery to obtain spatial information on the development of the three dimensions of sustainability. Subsequent to the example areas in the modules, learners examine their individual local surroundings at home on a satellite image mosaic of Germany as well as by performing geo-scientific fieldwork on site. "GLO*KAL* Change" supports an original encounter by providing worksheets and methodology papers on various fieldwork methods, and by the application of a micro-drone for taking their own aerial imagery.

Keywords: Web-based Learning Platform, Remote Sensing Data, Geography, Education for Sustainable Development, Geoscientific Fieldwork

1. INTRODUCTION

Human society needs resources for its economic prosperity and social well-being. In the last century, the combination of global population rise and continuous growth of the world economy caused an ever increasing consumption of resources. At the same time, spatial needs for different land-use types such as living space, industry, services, infrastructure and

agriculture diminished the area of natural ecosystems on earth. Both processes, provision of resources and reshaping of natural landscapes, have led to profound interventions into the earth's natural state all over the world. Many of these interactions between human society and environment are very complex in structure as they have simultaneous impacts on economic prosperity, ecological equilibrium and social well-being in a geographic region.

In 1987, the Report of the World Commission on Environment and Development *Our Common Future* (available at http://www.un-documents.net/wced-ocf.htm), known as the Brundtland Report, highlighted the environmental and developmental concerns of present human-environment-interactions, whose characteristics are not sustainable regarding the future. As a reaction to the report the United Nations Conference on Environment and Development (UNCED) launched Agenda 21 in 1992. This comprehensive political action program aims at implementing a more sustainable development in the 21st century. To achieve this objective increasing economic effectiveness needs to be combined with more ecologic compatibility and growing social equity as prerequisite to give future generations the same chances to meet their material needs (UN 1993, UNESCO 2011).

One of the most important keys to more sustainable behavior in our society may be a „…reorientation of the education towards more sustainable development…" (Gross & Friese 2000, Bahr 2007). The importance of Education for Sustainable Development (ESD) has been emphasized in chapter 36 of the Agenda 21 (UN 1993). Education for Sustainable Development enables people to „…apply their knowledge on sustainable development and to be aware of the problems of non-sustainable development…", i.e. to identify the mutual dependency of the three dimensions of sustainability as well as to make decisions and act sustainable oneself based on this awareness (cf. Programm Transfer-21 2007, de Haan & Gerhold 2008). In the Lucerne Declaration on Geographic Education for Sustainable Development drafted by Haubrich et al. (2007) the authors stress the necessity „…for the paradigm of sustainable development to be integrated into the teaching of geography at all levels and in all regions of the world.". For Gross & Friese (2000), Hemmer (2006a, 2006b) and Bahr (2007) the subject geography is of importance in the context of ESD due to the analyses of human-environment-interactions and their implications on a geographic area conducted in the subject. Hence, the subject geography is bound to teach for sustainability, i.e. to comprise the concept of ESD in its subject-specific education (DGfG 2010), as almost all topics of the UN Decade of Education for Sustainable Development (UNDESD) 2005-2014 possess a geographic dimension (cf. Haubrich et al. 2007).

In the concept of ESD, education represents a notion of individual competences (BLK 1998, de Haan & Gerhold 2008). Evaluation and media competences for example are both necessary for individuals to comprehend and practice sustainability comprehensively (de Haan & Gerhold 2008, Programm Transfer-21 2007). In Germany, the national educational standards for the school subject geography demand the promotion of both competences: students should be able to obtain information from different media, e.g. satellite imagery, and to evaluate human interventions into the environment concerning their economic, ecologic and social/political compatibility (DGfG 2007). The web-based learning platform (LP) "GLO*KAL* Change" has been developed to focus on fostering both competences: learners are requested to evaluate environmental changes in terms of sustainable development by analyzing given information such as remote sensing (RS) data.

2. THE LEARNING PLATFORM "GLO*KAL* CHANGE"

Fostering students' abilities to comprehend and evaluate the impact of environmental changes on sustainability is the overall aim of the web-based LP "GLO*KAL* Change". Its development has been conducted in the Department of Geography at the University of Education Heidelberg, Germany, as an integral part of the research project "GLO*KAL* Change –

Evaluating global environmental changes locally". The LP is still open for use free of charge at www.glokalchange.de and addresses primarily German students from grades 5 to 10 as well as adolescents from extracurricular environmental education aged 10 to 16 years (both described as adolescents later on).

Due to its contribution to the ESD from the viewpoint of geography, the entire project "GLO*KAL* Change" has been marked out as an official project of the UNDESD by the German UNESCO Commission in 2010. The adolescents learn to evaluate environmental changes in terms of sustainability by dealing with each of the three modules of the educational concept of "GLO*KAL* Change" shown in Figure 1. In interactive learning modules (see section 3) they get to know the impacts of environmental change occurring in different geographic areas on the global (worldwide) and local (in Germany) scale using satellite imagery (see chapter 4). Afterwards, they use a map server containing satellite imagery of Germany to virtually discover their individual home area (see chapter 5). Subsequently, they perform geo-scientific fieldwork on site to explore their local surroundings more comprehensively (see chapter 6). In this context, a micro-drone may be applied assisting the adolescents in the acquisition of further information on their geographic area of interest through taking high resolution aerial imagery (see chapter 6.1).

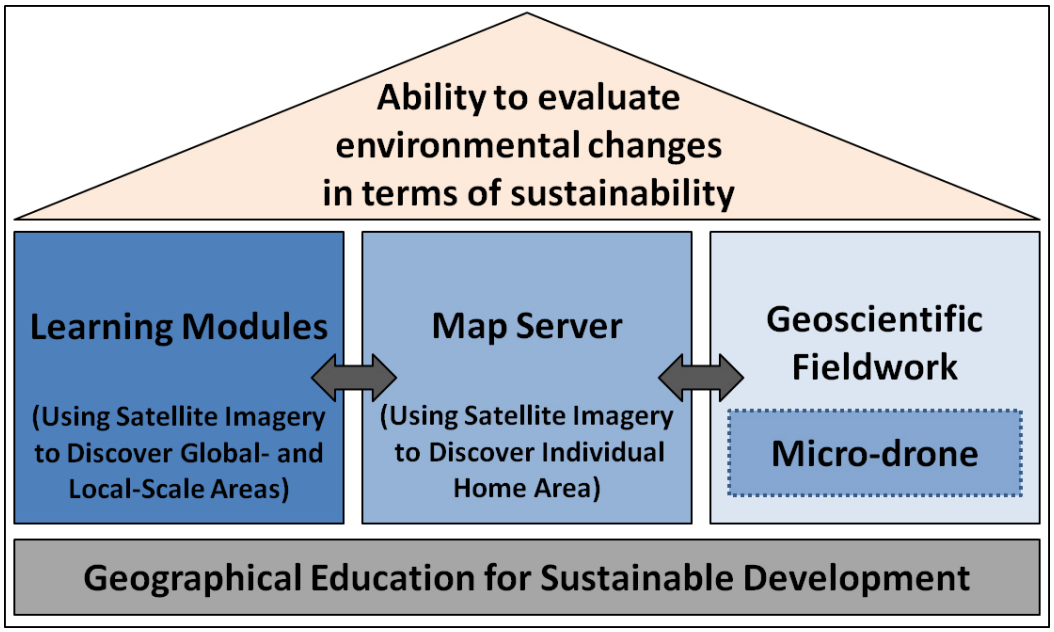

Fig.1 Educational concept of the learning platform "GLO*KAL* Change" to foster adolescents' ability to evaluate environmental changes in terms of sustainability.

3. LEARNING CONTENT AND STRUCTURE OF THE LP "GLO*KAL* Change"

As environmental changes studied in many geographic topics are often complex in structure due to extensive economic, ecologic and social interactions among each other, "GLO*KAL* Change" concentrates on certain geographic topics of human-environment-relationships that are also important to sustainable development. Each topic is presented as an interactive learning module, which has been designed for adolescents in terms of established teaching methods being used in the didactics of geography. Altogether, the LP "GLO*KAL* Change" contains the following four learning modules:

a) The module "Land use" deals with spatial conflicts between economic, ecological and social needs of using space, which have primarily been caused by urban processes, such as the growth of the city of Las Vegas, or suburbanization tendencies in the city of Berlin.
b) The impacts of the cultivation of energy crops and their subsequent transformation to biofuels are discussed in the module "Biofuels from Agriculture", for example the deforestation of the Amazonian tropical rainforest for growing sugarcane to produce ethanol fuel.
c) In "Ecosystem Forest and its Management" the consequences of non-sustainable forest management and forest replacement on ecosystem services have been picked out as a central theme, e.g. the impacts of the deforestation at the airport of Frankfurt am Main, Germany, to build a new runway, or the implications of deforestation in the Congolese rainforest.
d) The effects of mining resources in vast open pits on the economy, environment and society are given attention to in the module "Mining Resources in Open-Cast Mining", for example in the lignite mining area of the Rhineland, Western Germany, or in the Athabasca Oil Sands Area in Alberta, Western Canada.

Each learning module can be accessed from the first page of the LP (Fig. 2), they present four examples of non-sustainable environmental change in different geographic areas. In each case, two examples are located on the global scale (worldwide) and at the local scale (in Germany; Fig. 3). For every example presented in the modules, the adolescents get to know the recent development to the economic, ecological and social dimension on site as a result of the environmental changes occurring there. They learn to make statements on the dimensions' impact on sustainability. Finally, they are asked to evaluate the whole situation concerning its effects on sustainable development. Users can switch between the learning modules and geographic examples at any time. Each module begins with a short web trailer, which presents the module's topic cinematographically and introduces a set of problems related to the environmental changes occurring within the topic. After the web trailer, general information on the topic is given before users can deal with one of the geographic examples.

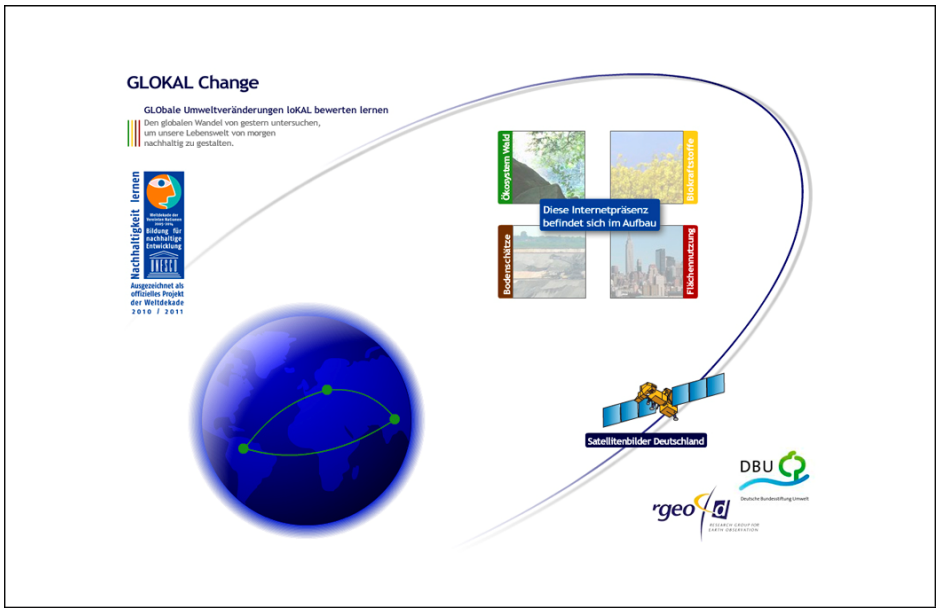

Fig.2 First page of the web-based learning platform "GLO*KAL* Change". Users can enter the four learning modules by clicking on the four images in the middle of the page as well as a map server by clicking on the earth symbol or the small satellite.

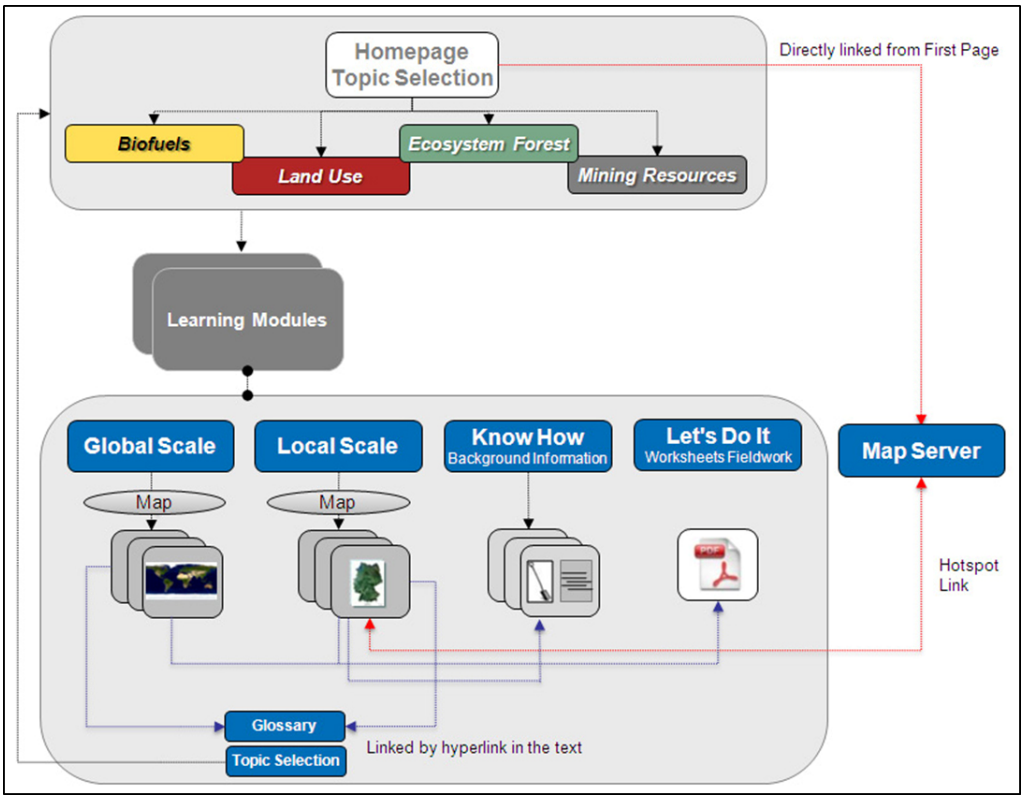

Fig. 3 Technical structure of the learning platform "GLO*KAL* Change".

For each example worksheets are available on the LP free of charge. Adolescents can use them as a basis for gathering information on the economic, ecological and social circumstances in the area they deal with. At the same time the worksheets are an opportunity for teaching staff to control the learning progress.

4. UNDERSTANDING SPATIAL IMPACTS BY USING RS DATA IN LEARNING MODULES

Young people can learn about recent economic, ecological and social changes that have occurred in the geographic examples of "GLO*KAL* Change" using a variety of media such as texts, charts, graphics, images, maps and RS data. Satellite imagery is used in the LP for two reasons: first of all, it visualizes spatial relations and changes in the geographic area of interest, which may help learners to understand the impacts on the economy, environment and society. Secondly, the use of satellite imagery induces high motivation and interest by the learners as an international comparative study conducted by Siegmund (2011) revealed. In this study, younger students especially were highly motivated and interested although their specialist knowledge about satellite imagery was generally lower when compared with older participants (Siegmund 2011). In general, factors such as image coloring, image complexity, image ambiguity and general difficulties in image understanding (Gerber & Reuschenbach 2005) often prevent inexperienced users such as younger adolescents from reading and interpreting satellite imagery successfully. For that reason, Beckel & Winter (1989) point to the importance of a gradual image analysis following instruction and/or the provision of additional information, e.g. describing image content. In the LP "GLO*KAL* Change", satellite imagery is embedded into a framework of additional information, which is thought to help

users understand and and more deeply interpret the imagery. Moreover, the worksheets described earlier (cf. section 3) contain different exercises in terms of reading and interpreting the imagery correctly. Thus, users are guided step by step towards a comprehensive image interpretation in "GLO*KAL* Change" in order to exhaust the full potential of using RS data in learning situations.

Since the start of the Landsat program in 1972, satellite imagery of the earth's surface is available for more than 30 years, which allows for a time series analysis to get a deep insight into the spatio-temporal development of a geographic area. While Landsat imagery has a low spatial resolution of 30 m × 30 m per pixel, particular RS data such as IKONOS or QuickBird as well as aerial imagery (all less than 1 m × 1 m per pixel) provide detailed information on a geographic area, and permit spatial analysis at a small scale. As a satellite image displays an area covering at least 100 km² or more, depending on the satellite sensor that has been chosen, „…large spatial structures and environmental changes…" (Kollar et al. 2008: 70) can be identified when using these data. Furthermore, satellite imagery displays the earth's structures in its natural appearance in contrast to maps, since no artificial entries or modifications in the imagery have been carried out (Gerber & Reuschenbach 2005, Siegmund & Menz 2005). This is especially true for real color imagery displaying the earth in its natural colors (RGB). False color imagery provides image information on specific subjects of interest such as geologic/geomorphologic features or soil and vegetation properties, and allows for the differentiation of urban and non-urban areas. In general, satellite imagery can help users to make statements on single image objects, connections between these objects as well as on image structures. Thus, reading and interpreting an image correctly can provide a lot of information on the geographic area that has been mapped. The German Educational Standards in Geography for the Intermediate School Certificate point to satellite and aerial imagery as sources for geographic information, which students should be able to acquire (DGfG 2010). Brucker (2006, 178) and Doering & Veletsianos (2007) refer to RS data as suitable tools for the analysis and evaluation of alterations in economic, ecological and social dimensions. This suggests the usefulness of RS data as valuable media in terms of communicating learning content on sustainable development.

According to the explanations made here, the interpretation of RS data is an important method in "GLO*KAL* Change" for gathering spatial information on the kind and extent of changes in the field of the three dimensions of sustainability. The imagery in "GLO*KAL* Change" primarily consists of Landsat TM and ETM+ data. Besides the analysis of single images in real and false color, users can detect spatio-temporal developments or changes within the mapped area by comparing imagery of different temporal origin (Fig. 4). In the geographic example "Mining Lignite in the Rhineland, Western Germany", which belongs to the module "Mining Resources in Open-Cast Mining", spatio-temporal changes in this area can be observed in all three dimensions using satellite imagery (Figure 5): for example, the shifting of open-cast mining (economy), the loss of land due to excavation followed by reclamation processes (environment) as well as resettlement activities (social dimension). After the use of the imagery shown in Figure 5, a group of 22 sixth graders (about 12 years old) was asked "Did the satellite imagery help you to understand the topic?" Seventeen answered with "Yes.", five said "It was ok." and none of them answered "No.". In the modules "Biofuels from Agriculture" and "Ecosystem Forest and its Management", the loss of forest areas due to deforestation and transformation into other land-use types, e.g. agricultural area, infrastructure or residential area, can be detected using near-infrared (NIR) or the Normalized Difference Vegetation Index (NDVI). Both, NIR and NDVI generally allow visual conclusions to be reached about the vegetation's distribution, composition, productivity and vitality (cf. Campbell 2002, Lillesand et al. 2004). Spatio-temporal changes in urban

areas (module "Land Use") are visualized using imagery with different band combinations, especially involving NIR and mid-infrared (cf. Campbell 2002, Lillesand et al. 2004).

Fig.4 The comparison of satellite imagery of different temporal origin allows users to detect developments or changes within the mapped area in space and time like in the geographic example "City Development of Las Vegas" in the module "Land Use".

Altogether, RS data provide valuable spatial information about a geographic area including local economy, environment and society. In "GLO*KAL* Change", satellite imagery of different temporal origin and different band combinations is used for visualization purposes. Image interpretation and comparison, in combination with additional information on the topic (texts etc.), are thought to enable the young users to make a well-founded evaluation about the impacts on sustainable development.

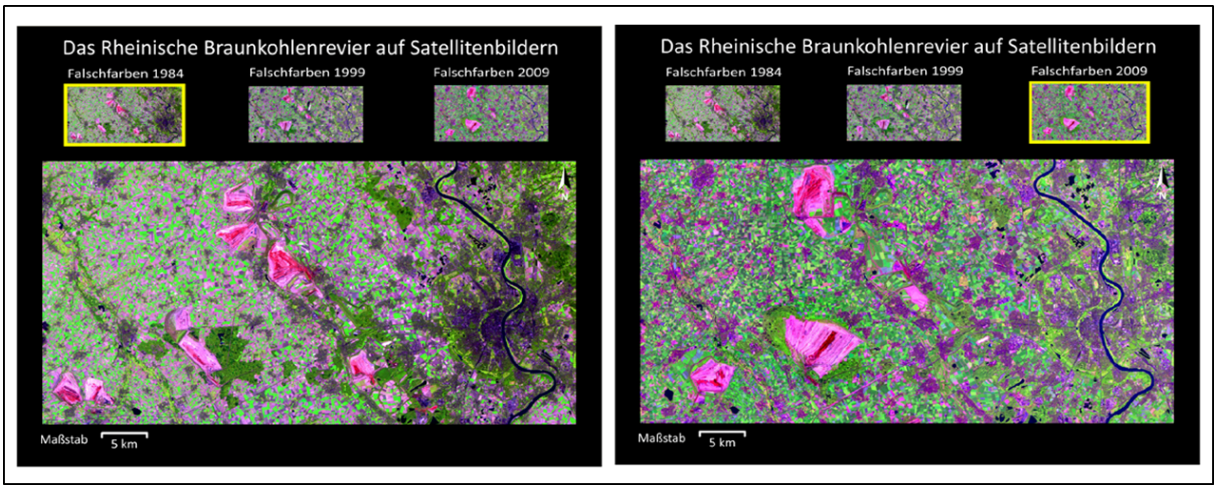

Fig.5 When comparing satellite imagery of the lignite mining area in Western Germany from different time slots, spatial changes in the economic, ecologic and social dimension are observable owing to the mining activity can be observed.

5. USING RS DATA ON A MAP SERVER TO EXPLORE THE INDIVIDUAL HOME AREA

In addition to the satellite imagery provided in the learning modules, "GLO*KAL* Change" comprises a map server containing pre-processed Landsat TM and ETM+ imagery of the entire territory of Germany (Fig. 6). Users can access the map server either from the first page of the LP (cf. Fig. 2) or from the learning modules. Imagery is available for three time slots, 1985, 2000 and 2007. For each of these slots, one real color and two false color images of Germany, e.g. imagery showing the NDVI, have been processed. Using an overlay function, two images can be viewed at the same time by setting one of them to transparency mode. In this format, the transparent image is on top of the other one, enabling users to compare the images and allowing them to recognize similarities and differences, i.e. changes in the landcape.

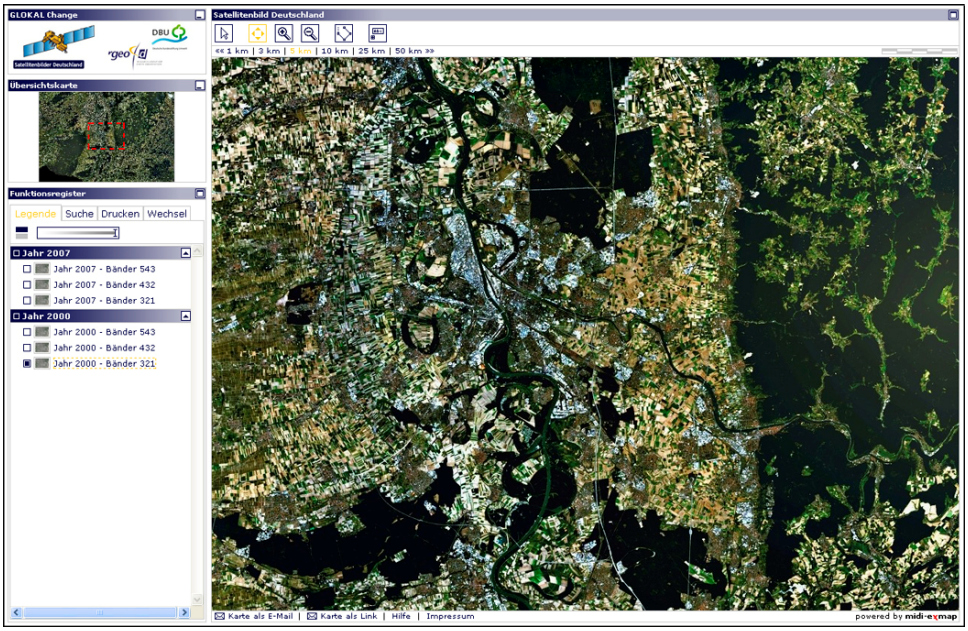

Fig.6 The map server of "GLO*KAL* Change" contains real and false color satellite imagery of Germany for three time slots.

As in Google Earth, users can zoom in/out or navigate on the map server surface using a pan function. Beyond that, users are able to search for certain settlements by name, zip code or geographic coordinates as well as measure distances and areas. Image details that <re interesting for on-site exploration can be printed or downloaded from the map server free of charge, e.g. onto mobile devices (tablet PCs) for application in the field.

Form an educational point of view, the map server is an intermediate step between the geographic examples in the learning modules and an original encounter in the adolescents' local surroundings at home. Thus, overall the perspective shifts from the global- and local-scale examples to the individual local surroundings of the adolescents. This step is thought to increase their motivation and interest in discovering their home area, both on the satellite imagery of the map server as well as in the field.

6. PERFORMING GEOSCIENTIFIC FIELDWORK TO EXPLORE THE INDIVIDUAL HOME AREA

When users deal with the learning modules of "GLO*KAL* Change", they get to know some non-sustainable effects of environmental changes on the economy, environment and society in various geographic areas worldwide and in Germany. In the course of the modules, they also learn to analyze information and evaluate it in terms of their impacts on sustainability (cf. chapter 3). They have to pay attention to all three dimensions owing to the complex interactions between them as a prerequisite to make a well-founded, holistic evaluation. When the adolescents are in the field in the context of an original encounter they require all these abilities to investigate the economic, environmental and social issues in their local surroundings. Coming from the classroom into the field, they have to transfer the knowledge they acquired in the virtual world of the learning modules and using the map server to real situations outside. According to Kirch (1999), students will not really gain geographic knowledge and build comprehension for a geographic area without exposure to fieldwork. Obtaining primary, i.e. non-filtered, information in the field during an original encounter is an important part of the learning process as information from mass media and information systems is filtered by the authors (Haubrich 1997). Furthermore, learners gain individual experience in the field by actively observing or performing fieldwork (cf. Haubrich 1997). Bland et al. (1996, 165) once summarized the overall importance of an original encounter (fieldwork) for learning in geography as follows: „Geography without fieldwork is like science without experiments."

The LP "GLO*KAL* Change" supports adolescents in gaining individual experience and primary information on site by making worksheets available for module-specific, action-orientated geo-scientific fieldwork, e.g. interview guidelines or mapping instructions. For the accurate execution of the fieldwork, "GLO*KAL* Change" also provides papers on background knowledge concerning different geo-scientific fieldwork methods. Using these worksheets and methodology papers the learners can examine the economic, environmental and social situations to some extent, and comment upon their implications, for example regarding the impact of a small gravel pit nearby, or the construction of a road through a forested area.

Once the studetns have studied the international examples and those from Germany in the modules, they can also explore their home area in terms of sustainability. In our view, the personal reference to the home area where the original encounter takes place will be a motivating factor for them. However, they may need assistance on how to obtain meaningful on-site information on the three dimensions. This support is provided by the worksheets and methodology papers. Sometimes, specific information may be needed, which can only be

provided using up-to-date aerial imagery. In this case, a micro-drone (see section 6.1) could be applied in the context of "GLO*KAL* Change".

6.1. Using a micro-drone for the generation of specific aerial information

When the learners are in the field they will presumably be able to gather answers to most questions in their geo-scientific fieldwork. However, in some circumstances specific questions may only be answered by using special equipment. During field examinations in the context of "GLO*KAL* Change" a low-flying micro-drone can be used to gather real-time high resolution aerial imagery (Fig. 7). As part of the project, the micro-drone can be operated by teachers who take a training course to support adolescents in need of specific information from aerial imagery. The micro-drone's multi-spectral camera can map small areas such as razed forests or damage in cornfields (Thamm & Judex 2005). The micro-drone can be applied to generate information in terms of all four topics presented in "GLO*KAL* Change": open-cast mining of different size, entire forests or small forested areas, agricultural land where energy crops or other crops are grown, and several other uninhabited land-use types, e.g. building sites.

Fig.7 During the fieldwork in the context of "GLO*KAL* Change" a low-flying micro-drone, which is equipped with a multi-spectral camera, can be applied to take real-time high resolution aerial imagery (image on the right).

Beyond the practical benefit of taking aerial imagery for generating information, the micro-drone has an educational function. Before and during its application the adolescents get to know the basics of remote sensing as well as the principles and difficulties of producing RS data. For example, when they learn how an aerial image is taken they may, at the same time, start to understand the process of generating satellite imagery. Thus, the micro-drone is also thought to be an educational learning object. As the youngsters are involved in flight preparation, data acquisition, conditioning and evaluation, they may likely be more motivated and interested in performing fieldwork compared to regular field examinations.

7. CONCLUSIONS AND OUTLOOK

The LP "GLO*KAL* Change" is a multi-dimensional learning environment. By using it in school as well as during extra-curricular environmental education, adolescents can firstly obtain information on economic, ecological and social issues through analyzing and interpreting different types of media including RS data. Secondly, they can get to know examples of non-sustainable development at global and local scales before subsequently examining their own individual local surroundings, a multi-perspective approach. Thirdly, the combination of computer-assisted learning (learning modules and map server) and original encounter (fieldwork) is thought to add to the entire learning process as a multi-sensory approach covering various human sensory channels. Moreover, RS data, fieldwork and the application of a micro-drone are thought to increase adolescents' motivation and their interest

to learn effectively in the context of "GLO*KAL* Change". Following the first application of the geographic example "Mining Lignite in the Rhineland, Western Germany" ("Mining Resources in Open-Cast Mining") in school, 14 from a total of 22 sixth graders answered with "Yes." while eight said "Maybe again." when they were asked: "Would you like to learn again with GLO*KAL* Change, maybe in terms of another example or topic?".

The overall objective of the LP, which can be used in school as well as in extra-curricular environmental education free of charge, is to foster German adolescents' evaluation and media competence. In the learning modules, adolescents' overall task is to evaluate the impact of various environmental changes on sustainable development. In this context, the comparison and visual analysis of RS data is thought to be an important method in "GLO*KAL* Change" to gain spatial information on economic, ecological and social changes, improving the adolescents' competence to read and interpret satellite imagery simultaneously. Altogether, dealing with a LP like this may bring adolescents one step closer to the aims of ESD, namely (i) to apply knowledge on sustainable development, (ii) be aware of the problems of non-sustainable development, and (iii) act sustainable oneself (cf. section 1), as was intended by the developers.

Thinking of the future, interactive learning environments such as "GLO*KAL* Change" may become increasingly frequent in the study of geographic/geo-scientific content, including content on sustainable development. Haubrich et al. (2007: 248) stated that information and communication technologies (ICT) „… can contribute meaningfully to the aims of education for sustainable development in Geography teaching and learning described in this Declaration [on Geographical Education for sustainable Development] by helping students to acquire knowledge and develop competencies necessary for lifelong learning and active citizenship." Besides "GLO*KAL* Change", various RS-based online LPs have been developed or are still in development in the Department of Geography at the University of Education Heidelberg, Germany (Ditter et al., accepted), e.g. "BLiF – Blickpunkt Fernerkundung" (www.blif.de). These LPs follow established teaching methods being used in the didactics of geography, general pedagogy and computer sciences. They have been or are being designed to foster the acquisition of knowledge on and individual competences in geography/RS effectively through modern-day computer-assisted learning.

ICT are promoted by the European Union as an important key to improve education and training (cf. European Commission 2010a). The interactive LP "GLO*KAL* Change" belongs to the ICT. A review of several studies of ICT impact on schools has shown „…that ICT impacts on competency development – specifically team work, independent learning and higher order thinking skills…" (ICT Impact Report 2006). "GLO*KAL* Change" aims at fostering several of the adolescents' higher order thinking skills (see section 1) and basically allows users to deal with its learning content either by oneself or in team work. Thus, the LP "GLO*KAL* Change" follows guidelines that have been made by the European Commission to „…develop innovative education and training practices…" (cf. European Commission 2010b). Beyond that, it deals with several sustainability-related topics, which have a European dimension, for example energy supply, use of biofuels and sustainable management of forests.

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