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Learning the role of biodiversity monitoring in a biosphere reserve

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Supporting Information Placeholder

ABSTRACT: Biosphere reserves have long been considered a place for learning about the environment, biodiversity and conservation, and sustainable development. While environmental education can be one of their man- dates, many other institutions or organizations can play a contributing role in this matter. In this paper, I present how my UNESCO Chair and Brock University decided to contribute to this learning function through the development of a course called "Biodiversity in a biosphere reserve". This course is based on experiential learning and aims to give students practical skills in how to monitor ecosystems. The use of permanent biodiversity monitoring plots allows for the possibility to accumulate data over time and therefore monitor how diversity on terrestrial and aquatic ecosystems near Brock University varies over time. Such courses are being developed in other universities and allow to contribute to the learning function of the biosphere reserves. They should be promoted not only in universities but also in colleges and other institutions.

Keywords: education, biodiversity, field course, experiential learning, monitoring, permanent biodiversity plots

Introduction

Environmental education has been promoted since the 1970's with the recommendation 96 of the Plan of Action adopted by the UN Conference on Human Environment held in Stockholm. This recommendation requested that UNESCO and UNEP work together to develop an inter- national program in environmental education (Kassas 2002). Since, several actions have been undertaken to integrate environmental education in different programs at the international level. Another program launched in 1971 would also contribute to environmental education. This program, the UNESCO's Man and the Biosphere (MAB), aims to be the "interface between nature conservation, interdisciplinary research and monitoring and educational prerogatives in the ecological and environmental sciences" (Ishwaran et al. 2008, p. 119). In Rio Summit in 1992, additional concepts were introduced and encouraged to be part of any environmental education programs. This included the concept of sustainable development and with the adoption of the Convention for Biological Diversity, the importance of biological diversity conservation.

Environmental education has taken different forms de- pending on the emphasis of the educational programs and the audience (Kassas 2002) as well as which institutions or organizations are promoting it. In universities, for ex- ample, environmental education may target many disciplines such as biology, sustainability science, environ- mental studies, education, and social sciences. In each case, the content may differ and emphasis can be put more on ecological concepts in biology than in education where a more general concept can be used. In biology, assessing biodiversity aids in understanding the ecological health of a system. For example, invertebrates and plants share important and distinct roles in maintaining ecosystem function and services. Equally important is their response in species richness and abundance following changes in the ecosystem's environmental factors. Monitoring community properties allows us to see the change in composition over time in response to alterations to physical factors, and renders crucial information on the ability of an ecosystem to respond to change and how its overall health and functionality are affected over time.

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Through these different iterations of international conventions and changes in environmental education programs, organizations such as UNESCO also evolved. For example, the MAB program has modified its mandates over time and integrated several of these new conventions or concepts (e.g., sustainable development and climate change). For example, the Seville Strategy emphasizes the importance "to support demonstration projects, environmental education and training and research and monitoring related to local, national and global issues of conservation and sustainable development" in biosphere reserves, thus adding sustainable development in their agendas (UNESCO 1995). Over time, the functions of education, research, and long-term monitoring remain important but with variations in how it should integrate various concepts. In the Lima Action Plan (MAB 2017), education remains central and expressed in its strategic objective #3 "Facilitate biodiversity and sustainability science, education for sustainable development (ESD) and capacity building" (p. 17).

In this paper, I describe the development of a course related to environmental education that examines mainly biodiversity and ecosystem health in a biosphere reserve. This course was developed as part of the proposal of the development of my UNESCO Chair in Community Sustainability: from Local to Global. I discuss how this type of course can be used in many other formats in connection to biosphere reserves. There are already a few others but the number could increase over time and the possibility to link them as a network could present a great opportunity for exchanges and collaborative learning.

Developing the course at Brock

Brock University was built before the establishment of the Niagara Escarpment Biosphere Reserve (NEBR) in 1991. This means that when the core area was delimited, some of the buildings that were already present at Brock were included. The campus is therefore in a unique situation as there is an opportunity to link some of the man- dates of biosphere reserves with the environmental educational experience on campus. Interestingly, during the development of my UNESCO Chair, I discovered that very few courses at Brock mentioned this unique situation and examined and educated some of the mandates of a biosphere reserve. Environmental education being one of the mandates of UNESCO programs, including the Man and Biosphere program, it was felt that there was an opportunity to develop a course that would encompass concepts such as biodiversity, ecological monitoring, ecosystem health, and sustainability (Box 1). The reasons for creating a new course came from students in the Ecology stream at Brock requesting more practical and experiential courses in the field and few of our courses dealt with the interdisciplinarity required for new graduates working in ecological / environmental fields. The other reason was why not take advantage of being directly related to a bio- sphere reserve to develop a course that would enhance the awareness and knowledge of biosphere reserves, importance of conservation and sustainability. The learning objectives of this course are included in Box 2 and many of them are directly related to practical skills.

The development of the course is based on my experience with the defunct Ecological Monitoring and Assessment

Box 1. Course Description
Introduction of the concepts of Biosphere Reserves and the importance to protect biodiversity. This course deals with the issues of ecosystem survey and long-term monitoring of changes due to human activities and environ- mental factors (natural and anthropogenic). It examines natural versus urban ecosystems based on integrative studies from the biological, geological, geographical, management, social, and economic perspectives. The course will introduce students to sampling design and techniques, treatment of data incorporated in fieldwork, labs, lecture-discussion, and integration of various concepts through team projects and report preparation.

Network of Environment Canada and the protocols that have been developed over the years including the establishment of permanent biodiversity monitoring plots. The course includes several components related to the topics of biosphere reserves, biodiversity, ecosystem monitoring, and sustainability. The first day starts with training in field safety and the basic concepts of Biosphere Reserves, biodiversity and ecosystem health. Students also learn about rapid assessment, field practices and installation of the biodiversity monitoring plots. The importance of appropriately recorded information, observations and data is introduced and independently kept field

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journals and computer files are assessed at the end of the course. The students also enjoy the presentation by the Niagara Escarpment Biosphere Reserve by someone from the Niagara Escarpment Commission, so they understand the background related to biosphere reserves, their mandates and principles and what the Niagara Escarpment is. Most of the rest of the two full weeks (12 days) are spent in the field.

Box 2. Learning Objectives of the Course

- Acquire general knowledge and understanding of the concepts, theories and methodologies in ecological monitoring of biodiversity and the importance of biosphere reserves (interdisciplinary issues)
- Ability to collect data in the field in different ecosystems;
- Ability to use data for analysis and ecosystem health interpretation, i.e. critical thinking
- Ability to integrate ecological knowledge using the appropriate methodologies with other disciplines such as mathematics, geography, sustainability science, etc.
- Ability to synthesize information and communicate appropriately (in writing and orally)
- Understand the limits of knowledge in monitoring but its essential role to assess human impacts on ecological systems
- Ability to write and work in teams or individually

The format of the course is based on participative learning in the field. It is expected that students will be actively participating in the field activities throughout the course. Attendance is therefore mandatory as data are collected in the field in teams. Because of the importance to maintain standards, students learn and must work in a safe, collaborative and integrated manner. To excel in this class, students must bring their own expertise and with appropriate preparation are able to effectively use the appropriate techniques. Participation level have also demonstrated students' capacity to do teamwork which is essential in research and monitoring. They learn how to identify, measure, and map trees in their plots, inventory of shrubs and ground vegetation, monitor salamander populations, conduct insect and bird surveys, etc. They also collect soil samples to measure basic soil properties and nutrients. The locations of these permanent monitoring plots are in the Niagara Escarpment directly and in another younger forest located on Brock and HydroOne properties. The advantage of having two sites is that students can com- pare two forests of different ages and having had various human activities (as Brock was farmland previously).

The course is not limited to terrestrial systems. The second part of the course examines the aquatic ecosystem of Lake Moodie, which is adjacent to Brock and has had a history of human activities that makes it interesting to monitor. In this case, students learn about shoreline vegetation, and collect benthic and water samples for analyses in the lab. For most of these analyses, we used the standard protocols that are currently in use such as the Ontario Ministry of Natural Resources protocols for salamanders (under the Brock University approval by the Animal Care Committee) and benthic sampling, and point counts for bird surveys. All plots and sampling transects are also georeferenced using a GPS unit. Brock University has a map library and access to ArcGis and therefore students have also a training component on the geo- graphic information system and learn to produce their own maps with the locations of their plots and transects.

Niagara is mainly located in a rural region where many activities can impact on biodiversity conservation and sustainable development. During the course, a few field trips are also organized to give other perspectives of the different zones of the NEBR. For example, we usually hike the Niagara Glenn where students are observed different flora as well as discuss the challenges related to tourism in such a fragile environment (as well as the issue of noise pollution coming from helicopter rides and speed boats for the Whirlpool of Niagara River). Since the rural component of the region is quite significant with vineyards and farms, visits have been organized in sustainable vineyards and organic farms. In each case, students can learn how some farmers are changing their way of farming to improve sustainable practices and protecting the environment. From these visits, students have to reflect in their journals on the advantages/disadvantages of hu- man's proximity to nature and how coexistence can be achieved through more environmentally friendly practices.

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The last part of the course includes a project that as a team they must define and carry out. This gives students the opportunity to go further in examining a specific aspect of the ecosystem using the scientific method. Projects can be quite diverse from testing a bryophyte inventory protocol and compare between both forests to comparison of different insect or benthic communities in other locations in the Niagara region with their own data from the permanent plots. They then write a report and present to the rest of the class their results (both components being evaluated). Evaluation of the students also includes an essay on topics that are added on a yearly basis such as climate change and invasive species as well as the comparison of sets of data coming from previous years to assess data quality and changes over time.

The advantage of having permanent monitoring plots is that students can return to these plots every two years (as the course is now taught every two years) giving the opportunity to examine changes over time. This has been an important issue as the younger forest at Brock was mainly composed of ash trees, which suffered in 2015 the infestation of the Emerald Ash Borer. This infestation has significantly thinned the forest and over the next decades, it will be possible to monitor its recovery.

Opportunities for experiential learning in biosphere reserves

Practical learning in the field is not limited to Brock University as several other universities have established field courses on various ecological disciplines. The proximity of a biosphere reserve can give another spin to a course by adding a more interdisciplinary component such as sustainable development. Such courses should not be limited only to universities as many colleges may have the same capacity. It appears that biosphere reserves may have been a missed opportunity for environmental education. Some institutions (e.g. Waterloo and Queen's) have also taken advantage of the biosphere reserve system and have shown that courses can take different formats. Opportunities are limitless.

To ensure a more sustainable and resilient socio-ecological systems, education and life-long learning should be a central activity in communities worldwide. Acquired awareness and knowledge may help people understand the importance for conservation and sustainable development to enhance resilience of communities (Lundholm and Plummer 2010). The education system, from elementary schools to universities and colleges, all have roles to play in enhancing awareness to these concepts of biodiversity, conservation, sustainability and resilience. How- ever, due to very tight curricula, in most educational systems, these concepts are not often promoted. For example, examining the curricula in high schools in Ontario and interviewing teachers in Niagara, Janzen (2016) reports that such concepts are often left for the last month of the academic year in grades 11-12 due to lack of time to cover the mandatory basic modules. Due to limited resources, lack of time, and sometimes expertise of teachers, the capacity to bring students outdoors and deliver experiential learning on the environment has been reduced (MacMillan 2014). In many cases, awareness and knowledge are left to life-long learning organizations such as nature clubs or some summer camps. While these organizations may help promote experiential learning, they are limited to few interested participants. This means that people tend to become more and more disconnected to nature and awareness of its benefits are more difficult to convey (MacMillan 2014).

With the approval of the recent UN 2030 Agenda and the SDGs, it was suggested that biosphere reserves can serve as models where such activities that be promoted and examined to determine how they can be implemented in other communities. Educational institutions within or ad- jacent to a biosphere reserve can certainly engage with it and find ways to promote the concepts discussed in this paper. While field courses can be a very effective way to not only educate and train people in concepts such as biodiversity and ecological monitoring, they can help sup- port the monitoring function of the biosphere reserve by accumulating and sharing data. Other modes of delivery can also contribute to specific projects or ways to promote the biosphere reserve activities. In the past few years, with the adoption of the UN Declaration of Rights of Indigenous Peoples and in Canada the Truth and Reconciliation Commission Recommendations, indigenous knowledge has also been introduced in the mandate of biosphere reserves as they represent an opportunity to learn and share knowledge on biodiversity. In the next iteration of my course at Brock, it is planned that indigenous knowledge will be introduced and students

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will be able to learn about its importance for conservation, ecosystem health and sustainable development.

Ideally these activities are not only contributing to environmental education per se but also to a more social learning environment that stimulates critical thinking and reflection and can lead to potential actions and changes in behavior (Schultz and Lundholm 2010). However, in an international survey of 79 biosphere reserves, Schultz and Lundholm (2010, p. 658) report to have "identified three BRCs that seem to combine learning through adaptive co-management and environmental education on the ground". However, should the burden of environmental education and social learning only be supported by the biosphere reserve organization? As the biosphere reserve can be considered as a partnership of organizations and institutions including the private sector in a specific area, it is therefore important for the managers of biosphere reserves to target the groups or institutions that can help support their mandates regarding environmental education. Indeed, as stated in the objective #3 of the Lima Action Plan (MAB 2017): "At a biosphere reserve level, this requires collaboration between all the different stakeholders, including scientists, policymakers, members of local communities and the private sector. ESD promotes the inclusion of key sustainable development issues in teaching and learning, to motivate and empower learners to change their behaviour through acquiring new skills, competencies and values, and to take action for sustainable development. Biosphere reserves, particularly through their coordinators, managers and scientists, have key roles to play in operationalizing and mainstreaming sustainability science and ESD at local and regional levels, in order to build scientific knowledge, identify best practices, and strengthen the interface between science, policy and education and training for sustainable development" (p. 19). In the future, for biosphere reserves, it is possibly a question of looking at how institutions and other organizations related to life-long learning can be involved in the environmental education and even monitoring mandates of the biosphere reserves. This can be a way for them to become more sustainable and more effectively promoted in their region, a challenge that most biosphere reserves are facing. In my case, I believe that through my UNESCO Chair I could at least contribute in a small way to this objective.

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Space2Place – An E-Learning Module to Empower Stakeholders of UNESCO Sites

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ABSTRACT: With World Heritage Sites, Biosphere Re- serves and Global Geoparks, the UNESCO has declared a huge variety of places that are worth being preserved in almost all countries. An increasing number of these sites are “in Danger”, being affected by environmental pro- cesses, or impacted by climate change and human devastation. The adaptive e-learning module Space2Place gives stakeholders of UNESCO sites the opportunity to benefit from advantages of Earth observation and to improve the management of their respective UNESCO sites. Space2Place is embedded in a larger e-learning environment and is connected with the online remote sensing analysis application BLIF. As e-learning module independent of time and location, it provides an introduction to Earth observation data and gives clear guidelines on how to incorporate such information into daily working routines of stakeholders of the various UNESCO sites. The gained knowledge can empower stakeholders to specifically claim help and formulate demands for future activities. It contributes to determine the needs of UNESCO sites and communicate their specific requirements. Accordingly, the e-learning module can have an impact on future developments with regard to the implementation of the Sustainable Development Goals and the Global Agenda 2030.

Keywords: UNESCO, UNESCO sites, Sustainable Development Goals, MAB Program, e-Learning, Earth Observation

Introduction

Nowadays, Earth observation plays a major role in documenting, analyzing, and monitoring our environment. Many applications have left the trial phase, e.g. change detection approaches and Interferometric Synthetic Aperture Radar (InSAR) (Cerra et al., 2016; Tapete & Cigna, 2017). They became constant workhorses by an increasing number of end-users.

However, only a small portion of the United Nations Educational, Scientific and Cultural Organization (UNESCO) sites constantly benefit from the advantages that Earth observation offers, e.g. quick first analysis, near real-time data acquisition, large area coverage, different sensors for specific applications, and retrospective analyses. The Copernicus Programme is currently the most comprehensive global Earth observation programme and the flagship of the European Union’s Earth Observation and Monitoring programme (Showstack, 2014). Based on a variety of technologies, Copernicus

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delivers operational data and services for a wide range of applications. These include applications in the fields of agriculture, energy, security, transportation and information to protect and safeguard cultural and natural heritages sites worldwide (European Commission, 2015).

UNESCO currently incorporates 1 073 World Heritage Sites (UNESCO, 2018f), 669 Biosphere Reserves (UNESCO, 2018a), and 127 Global Geoparks (UNESCO, 2018e) all around the world. The World Heritage Convention, adopted by UNESCO in 1972, has proven to be widely acknowledged and was adopted by 193 countries worldwide. By signing the convention, state parties ensure the protection of cultural and natural heritage by e.g. integration into regional planning, financing of staff and related services, and promotion of research as well as monitoring on a daily basis (UNESCO, 2018d). The Man and the Biosphere Programme was launched in 1971 and focuses mainly on natural sites. The label UNESCO Global Geoparks was born in 2015 with rapid development in recent years.

Despite all success of the different initiatives, many designated sites are “In Danger”, inscribed in the “List of World Heritage in Danger”. As part of the World Heritage Convention (article 11, 4), the World Heritage Committee is responsible to keep this list updated and include necessary actions or requested assistance (UNESCO, 2018d). Other UNESCO sites do not currently fulfil necessary requirements for their evaluation and reaffirmation. Based on a two years consultation with experts, in 2008 UNESCO compiled a list of 14 primary factors that can affect the value of World Heritage properties (UNESCO, 2018c). This list includes, amongst others sudden ecological or geological events, urban sprawl or impacts of climate change. But also manmade destructions including terrorism or civil unrests are causes for sometimes irreversible destruction. In 2003, UNESCO and the European Space Agency (ESA) signed the “Open Initiative on the Use of Space Technologies to Support the World Heritage Convention”, which was also joined by the German Aerospace Centre (DLR) (UNESCO, 2018b) as partner in 2007 (Ito, 2011).

Despite establishing networks between space agencies, research institutions, and the UNESCO in order to facilitate the use of Earth observation data for heritage sites with various examples (Cerra et al., 2016; Hernandez et al., 2008; Patias, 2007; Remondino, 2011), currently only a limited number of UNESCO sites benefit from the above-mentioned advantages. Well-known potentials of Earth observation are not yet fully exploited. Site managers are often unaware about these potentials including free and open data access. This is aggravated by a lack of knowledge about basics of remote sensing and related image analysis skills.

Space2Place tries to build capacity on Earth observation and to provide stakeholders of UNESCO sites with a learning environment on how Earth observation data can be used. By attending the module, stakeholders of UNESCO sites should be empowered to incorporate Earth observation data in their daily working routines. Furthermore, based on an increased awareness about the subject, they can request specific assistance and cooperation more easily. By incorporating Earth observation data, UNESCO sites will benefit from a faster and more reliable documentation of their sites as well as from a more accurate analysis and improved monitoring. Additionally, the derived information can be prepared for public relations, tourism, and education purposes. The impact of the e-learning modules should finally contribute to prevent UNESCO sites from being endangered and to safeguard existing sites. This will be a chance of UNESCO sites to fulfil their objectives and contribute to the Sustainable Development Goals (SDGs) and the Global Agenda 2030.

Educational Concepts

Backbone of Space2Place is an e-learning environment established in the framework of the project “Space4Geography”, funded by the DLR from 2013 – 2017. Based on previous studies (Ditter, 2014; Siegmund, 2011), the project developed a comprehensive adaptive e- learning environment, in particular for secondary schools in Germany. This e-learning environment is called *Geo:spektiv*. Depicted topics as well as included materials and methods contribute to building the competences prescribed by Germany’s national education standards and federal curricula (Deutsche Gesellschaft für Geographie (Hrsg.), 2014; Kultusminister Konferenz, 2018). The e-learning modules of *Geo:spektiv* are widely used in schools, at DLR_School_Labs, and in courses offered by the Department of Geography itself. Since the

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launch of the website (www.geospektiv.de/) in late 2015, more than 2500 students attended the various e-learning modules. The success of the project-was strongly supported by considering the general interest and high motivation of students who work with satellite images and digital datasets. Further distribution is envisaged to raise awareness of future teachers and to improve the skills of today's teachers (Ditter et al., 2012). Accordingly, barriers to access Earth observation data and tools should be reduced (e.g. BLIF - Blickpunkt Fernerkundung – "Remote Sensing in Focus") as well as to offer applications with limited complexity to access broader target groups.

The e-learning module Space2Place was implemented by the UNESCO Chair on World Heritage and Biosphere Reserve Observation and Education at Heidelberg University of Education. It offers the user a brief introduction to Earth observation and related applications. The module provides several key features:

- Optimized presentation of the learning units on different end user devices to assure flexible utilization
- Introduction to various Earth observation applications, e.g. deforestation, forest fire mapping, drought mapping, monitoring of air pollution or surveillance of agricultural land
- Integration of various optical satellite images, e.g. Sentinel 2, Landsat 8, MODIS, and RapidEye
- Following an interactive approach and integration of different media, incl. photos, videos, and satellite images
- Adaptive course content to allow personalized learning paths and varying speed
- Interim and final quizzes to check learning success
- Total length of the learning unit is about 90 minutes to allow flexible utilization
- Learners receive a certificate based on their test results

Another key feature is the cross reference of learning units with the online remote sensing application BLIF. Participants practice their understanding and knowledge with the online remote sensing application using real satellite images. One more very important feature is the adaptability of the e-learning environment, as shown in figure 1. Modules implemented in *Geo:spektiv* can be dynamically combined to personalized learning paths with real-time adaptation of content and complexity, depending on the student's performance in test units. The approach takes into account the heterogeneity and varying speed of a learning group. It can thus be seen as a meaningful advancement of traditional one-size-fits-all approaches.

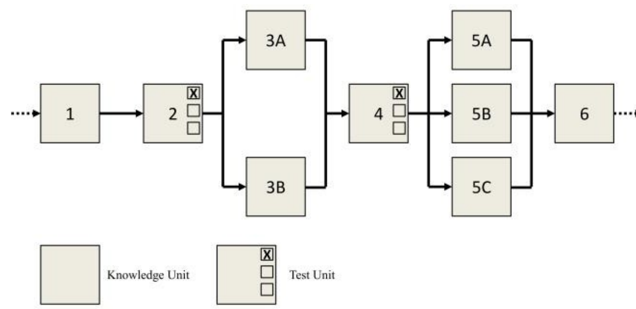

Figure 1. Adaptive approach with individual learning paths (Source: adapted from (Wolf et al., 2016).

The Learning Module Space2Place

The Space2Place e-learning module includes 21 units in total. The module is designed for participants without any extensive prior knowledge and an estimated duration of approximately 90 minutes to pass the whole module. Based on a general introduction into the learning module and the expected outcomes (figure 2a), the course starts with knowledge units about Earth observation applications and their relevance for stakeholders of UNESCO sites. A separate knowledge unit leads to the SDGs and the Global Agenda 2030 including their specific indicators. Hereafter, the Copernicus programme with its fleet of Sentinel satellites is introduced. Based on the current amount of free satellite data for a large diversity of applications, a particular emphasis was placed on images from the Sentinel satellites. Following this background introduction, remote sensing in general and its advantages are described, accompanied by an introduction of different radar and optical satellite systems. After introducing the most important past and currently available satellites, satellite images themselves are explained more in detail (figure 2b). By using various examples, spatial, spectral, temporal, and radiometric resolutions are further described. A short intermediate quiz

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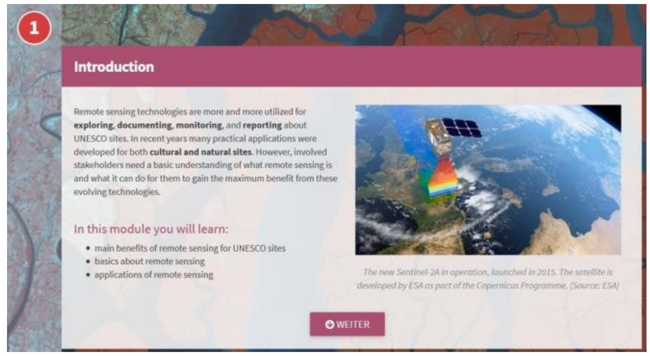
afterwards assesses the learning success that was achieved so far.

After these introductory units, the focus is set on image enhancements and analyses with small quizzes in between. Colour composite and contrast enhancements are explained and carried out by the participants within the linked BLIF application. Vegetation indices, especially the well-established Normalized Difference Vegetation Index (NDVI), are introduced and tested by participants in a practical exercise. The same applies for manual and automatic classification approaches including an example of centre-pivot irrigation in Kansas (USA). An introduction to change detection with related examples illustrates the last topic of the module (figure 2c). A final quiz will assess the learning success of the participants and will summarize and return the score in the certificate. The last unit is used to motivate participants to incorporate Earth observation techniques in their daily working routine by presenting more advanced applications that can benefit from remote sensing techniques, such as forest fire monitoring, archaeology and 3D modelling by drone technology.

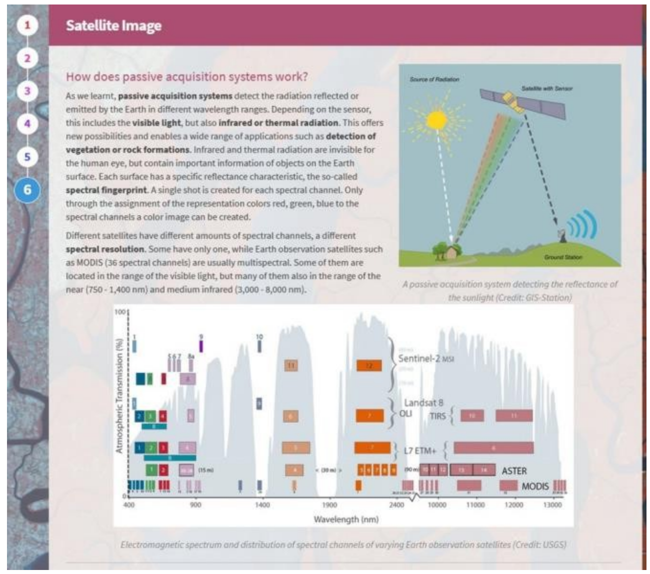
Based on increased awareness and knowledge by *Geo:spektiv*, stakeholders of UNESCO sites are supposed to request specific Earth observation applications, in particular for their respective areas and in general about Earth observation. Advertisement of the e-learning module is planned on various occasions. First feedbacks were promising and a global distribution is envisaged.

Prospects and Outlook

Based on evaluation of the project Space4Geography, usage behaviour of participants of *Geo:spektiv* modules, and specific requests by colleagues and partners, several existing e-learning modules will be translated from German to English in the near future.



(a)



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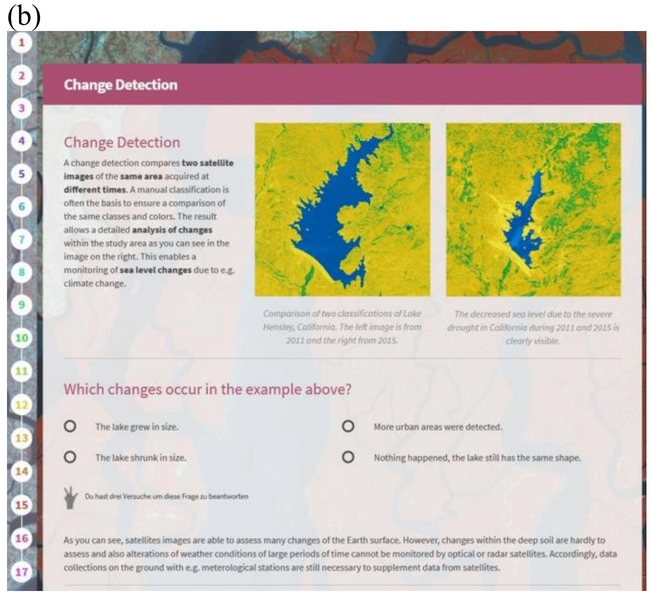

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Figure 2. Screenshots of different Space2Place units; a) Introduction unit; b) Knowledge unit "Satellite Image"; c) Knowledge and test unit "Change Detection"

These modules can then be used for educational purposes on an international level. After catching the low-hanging fruits, further translations into Spanish and French will follow. Besides e-learning modules for students, Space2Place is the first English module especially designed for stakeholders of UNESCO sites. It contains important basic information about Earth observation and will raise the awareness of stakeholders of UNESCO sites on its potentials. After launching and advertising Space2Place at the beginning of 2018, feedback from participants for further improvements will be collected and evaluated. At the same time, two more specific e- learning modules in English will be created.

The first module will focus on the relation between Earth observation and the topic of health. Together with different partners, it will provide an overview about opportunities given by satellite systems and their potential applications within the health sector. This e- learning module addresses SDG 3 in particular and is intended to facilitate the use of Earth observation data especially in the global south. Simultaneously, the module emphasizes the importance of the health sector for sustainable development in and around UNESCO designated sites, such as biosphere reserves. A key aspect of this module will be the detection and monitoring of malaria transmission in Africa based on Earth observation data. Early studies in the 1990s revealed relations between specific environmental factors, detectable by Earth observation, and factors influencing the transmission of malaria (Thomson et al., 1996). However, secure monitoring and standardized services are still missing. Similar relationships were already discovered for other diseases (Bavia et al., 2001). Smaller digressions allow the introduction of e.g. other health related environmental impact factors such as air pollution. They can be monitored on a regional scale by using innovative satellite systems such as Sentinel 5P (Ingmann et al., 2012).

The second module will examine the value of Earth observation data for UNESCO cultural heritage sites. Documentation, monitoring, and analysis of changes as well as communication are key aspects for actors and involved stakeholders. Earth observation data from Synthetic Aperture Radar (SAR) satellites or Unmanned Aerial Vehicle (UAV) can play a vital role for these tasks (Schreier & Dech, 2005). Recent examples and publications indicate that applications are already successfully used on large scales (Negula et al., 2015). However, despite a significant INSAR geoinformation stock and available clusters of knowledge and innovation, the involvement of practitioners and heritage stakeholders is still limited (Tapete & Cigna, 2017). Accordingly, despite these potentials, an area-wide deployment is still missing. In collaboration with other partners, the module will give an introduction on well-established applications as well as state-of-the-art developments in the field of 3D modelling and geo-archaeology. Those new courses will be available in mid-2018.

By attending the course, stakeholders of UNESCO sites and actors in the field of cultural heritage management will benefit from a better understanding of the opportunities and limitations of Earth observation data. By raising their awareness and interest, the creation of new contacts, professional links and projects will be promoted. By constantly evaluating the feedback given by participants, new ideas and requests can be integrated into the existing portfolio.

Summary

Digital geomedia are currently in vogue. This is confirmed by the rising number of massive open online courses (MOOCs) and knowledge sharing platforms on this topic. *Geo:spektiv* is an excellent and frequently used example on how Earth observation data can be implemented in classroom activities, currently mainly in Germany. Space2Place is based on these foundations and contributes to the empowerment of stakeholders of UNESCO sites on an international level. By integrating key factors, such as cross-links with online remote sensing applications and personalized learning paths, Space2Place will facilitate the use of Earth observation data and gives information on its inherent benefits. Additionally, the Copernicus Programme supports the initiative by providing its valuable amount of free data for a wide range of applications.
The offered courses will be constantly improved and extended by more specific modules. By increasing the

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dissemination of e-learning modules the existing knowledge will be shared. Cooperation with UNESCO, national space agencies and other partners will ensure a dynamic exchange to provide necessary feedback. A key driver will be the active involvement of practitioners and stakeholders of UNESCO sites. Besides conferences, workshops, and face-to-face training events, e-learning platforms such as Space2Place will empower stakeholders to better manage their sites, providing a contribution to achieve the SDGs and to safeguard existing UNESCO sites. Additionally, the presented e- learning module will be a contribution to engage heritage stakeholders and to facilitate the knowledge transfer between Earth observation experts and non-experts.

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Poaching in the Mount Elgon Trans-Boundary Ecosystem

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ABSTRACT: This article assesses poaching in the Mount Elgon trans-boundary eco-system. The study employed a social survey research design. One hundred households were sampled and interviewed using questionnaires. Secondary data was collected from KWS and UWA wildlife offices and key informants in Kenya and Uganda. Household survey results showed that the wildlife class mostly targeted in poaching is mammals. Traditional weapons are still dominant in poaching. Use of firearms occurs mainly when the target is large animals. The main drivers of poaching within the study area were need for a protein source, need for income and cultural beliefs and attachment. Human-wildlife conflict was also found to be a driver of poaching. Poaching within the study area takes place in both the core zone and the buffer zone. Poaching in the buffer zone occurs when wildlife come out of the core zone to raid farms. Seasonality/temporal patterns of poaching occur in the study area. The peak poaching seasons were the wet season in the Kenyan (Biosphere Reserve) BR and the dry season in the Ugandan BR. This article presents a comparison of responses from respondents in either BR. There are valuable lessons that can be learnt from this article. It is my hope that these lessons will be incorporated in the formulation and improvement of policies related to poaching and conservation of wildlife.

KEYWORDS: Poaching, fauna, wildlife, Mount Elgon, Kenya, Uganda

Introduction

In Africa, wildlife resources offer many important benefits for ecosystems and rural communities found within or near wildlife areas. Various ecosystem processes such as plant regeneration, food webs and plant diversity are dependent upon the presence of fauna. Rural communities use wildlife products as a source of food, medicine, in traditional ceremonies and a source of income (Scoones *et al.,* 1992). In Central and West Africa, bush meat is often the only source of protein in addition to being a source of income and safety net during times of hardship (Bowen-Jones *et al.,* 2003). 15-72% of average household income in Gabon is obtained through hunting. Trade in bush meat is also a significant contributor to the economies of countries in this region though it rarely figures in national economic statistics (Bowen-Jones *et al.,* 2003). In Eastern Africa more specifically in Tanzania, bush meat hunting is an important economic activity (Mfunda and Roskafti, 2010) while a research carried out in Kenya established that 25% of meat in Nairobi butcheries was bush meat (Okello and Kiringe, 2004: Olupot *et al.,* 2009).

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Human pressure on wildlife resources is however increasing (Wilfred and Maccoll, 2015) especially due to increasing human and cattle population around wildlife areas (Ijeomah *et al.,* 2013). Africa's population largely depends on natural resources for their livelihoods (Syed *et al.,* 2015). Agriculture which is a major practice in Africa (Nkamleu and Manyong, 2005) requires land and with the increasing population has led to deforestation. Deforestation fragments and degrades wildlife habitats increasing human wildlife conflicts (Hill, 2004) leading to revenge killings and poaching. There is also increasing demand for bush meat and animal-based products which coupled with development and dissemination of modern firearms and other more effective methods of hunting, and increased access to remote forests is continuously putting pressure on the wildlife resources (Swamy and Pinedo-Vasquez, 2014).

Poaching is one of the major threats facing wildlife in Africa (WWF, 2014). The UNESCO-Encyclopedia of Life Support Systems (EOLSS) defines poaching as all the illegal taking of wildlife species, species being either terrestrial or aquatic, both vertebrates and invertebrates, prompted by reasons that differ across localities, social and political conditions, traditions, and animals themselves that are the objects of poaching. Poaching therefore includes instances where the poacher does not have a license or permit, the animal is not in season for hunting or was killed on land that does not allow hunting, illegal weapons or hunting practices were used, hunting the animal is forbidden by law and the poacher is selling the animal or parts for profit. Based on this definition, two forms of poaching emerge, that is subsistence and commercial poaching.

Subsistence poaching involves hunting of wildlife mainly for provision of food inform of bush meat for households of poachers/hunters involved. It also involves hunting as rites of passage where young men hunt and kill wildlife to prove their manhood. Commercial poaching is done mainly for income. The wildlife parts and products are sold to willing buyers in available markets. Depending on need, poachers can either work alone, in groups or under command (Neale and Stiles, 2011).
Bush meat hunting either for household consumption or local commercial trade is a major threat to the continued viability of particular wild fauna species (Fa *et al.,* 2002) as many species are being hunted at unsustainable rates. An estimated 6 million tonnes of animals are extracted yearly for consumption in the Congo Basin alone (Nasi *et al.,* 2008) and research evidence suggests that at this rate, it is impossible to sustain the current levels of hunting in the long term (Wilkie *et al.,* 2011) and this will lead to the eventual collapse of game populations.

Poaching especially for bush meat has a significant effect on wild animal populations. According to Swamy and Pinedo-Vasquez (2014), poaching for bush meat is the primary threat to about 85% of primates and ungulates and 93% of large-bodied ground-feeding birds that are listed as endangered or critically endangered in IUCN Red List. According to Lamprey *et al.* (2003), massive hunting in the 1970's reduced the population of large mammals by 90% in Uganda. Reducing game populations ultimately reduces the availability of food and income to the people who rely on them (Bennett *et al.,* 2007; Nasi *et al.,* 2011). Other negative impacts include the imperilment of the cultural identities of many indigenous and traditional people for which hunting is part of their heritage and sense of cultural identity (Vliet and Mbazza, 2011), emptying of Africa's forests and savannahs of large-bodied species and eliminating the important ecological roles these play in the functioning of such ecosystems (Nunez-Iturri and Howe, 2007; Lindsey *et al.,* 2011).

This paper presents an assessment of poaching in the Mount Elgon trans-boundary ecosystem. This

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ecosystem comprises of two biosphere reserves – Mount Elgon, Kenya and Mount Elgon, Uganda. This article addresses the following objectives:

1. To determine the type of wildlife species poached in the core and buffer zones of the Mt Elgon trans-boundary ecosystem
2. To determine the spatial-temporal extent of poaching in the core and buffer zones of the Mt Elgon trans-boundary ecosystem
3. To determine the causes of poaching in Mount Elgon trans-boundary ecosystem
4. To evaluate the methods employed in poaching in Mount Elgon trans-boundary ecosystem

Method

The Mount Elgon trans-boundary ecosystem is the physical landscape transcending the international border between Kenya and Uganda that includes two biosphere reserves- Mt Elgon Biosphere Reserves in Kenya and Uganda. The Mt. Elgon ecosystem on the Kenyan side was declared a Biosphere Reserve by UNESCO in 2003 (Mwaura, 2011) while the Biosphere Reserve on the Ugandan side was nominated in 2005 (Makenzi, 2013). The BRs comprise three zones which are the core zone, buffer zone and transition zone (figure 1).

Within the BRs are five protected areas namely Mount Elgon National Park (MENPU) managed by Uganda Wildlife Authority (UWA), Namatale Central Forest Reserve managed by the National Forestry Authority (NFA) in Uganda and Mt. Elgon National Park (MENPK) managed by Kenya Wildlife Service (KWS), Mt. Elgon Forest Reserve managed by Kenya Forest Service (KFS) and Chepkitale National Reserve managed by Mt. Elgon County Council and KWS (Mwaura, 2011) in Kenya.

As of August 2010, the administrative boundaries of Mt. Elgon Ecosystem included areas under two Counties of Bungoma and Trans Nzoia in Kenya. In Uganda it covers eight districts, namely Kapchorwa, Kween, Sironko, Bulambuli, Mbale, Manafwa, Bududa and Bukwo (Mwaura, 2011; Makenzi *et al.*, 2014).

Rainfall on the mountain ranges from 1,500 – 2,500 mm per year (Nakakaawa *et al.,* 2015; James *et al.,* 2014). Mid slope locations tend to receive more rainfall than the lower slopes or the summit. The climate is moist to moderate dry. The dry season runs from December to March. The rainfall pattern is bimodal with the wetter months falling between March and October (KWS, 2010; Nakakaawa *et al.,* 2015). The mean maximum and minimum temperatures are 23° and 15° C respectively.

The rocks of Mt Elgon are volcanic in origin and include tuffs, coarse agglomerates, basalts and mudflow materials. The geology of the Mt Elgon ecosystem generates a fertile soil associated with volcanic action which supports the livelihoods of inhabitants who are largely farmers (Scott, 1998; Nakakaawa *et al.,* 2015).

The vegetation of Mt. Elgon is stratified attitudinally (Van Heist, 1994) in belts commonly associated with large mountain massifs. Four broad vegetation communities have been recognised (Mwaura, 2011):

a) Zone I: mixed montane forest up to 2,500 m asl;
b) Zone II: bamboo and low canopy forest, from 2,500 to 3,000 m asl;
c) Zone III: high montane heath, from 3,000 to 3,500 m asl; and
d) Zone IV: moorland and alpine zone, areas above 3,500 m asl.

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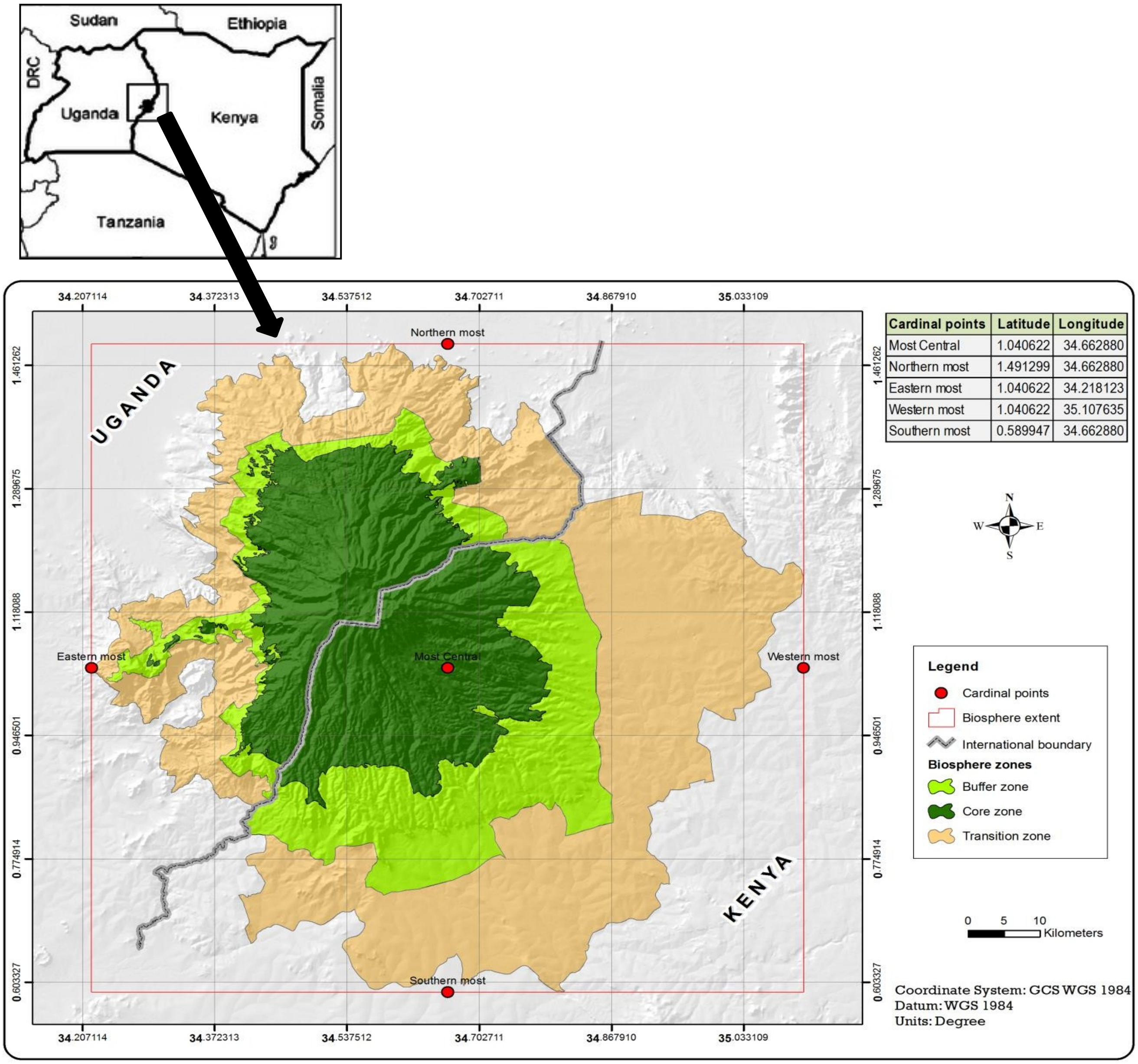

Figure 1: Location Map of the Study Area (Source: James *et al*., 2014)

This rich flora is important in providing habitat for biodiversity, acting as a tourist attraction, as well as providing plant resources that support people's livelihoods and generate forest produce.

Mount Elgon supports many fauna species of extreme conservation importance by virtue of their rarity and/or limited distributions. Mt. Elgon ecosystem is a habitat for 37 "globally threatened" species (22 mammals, 2 insect and 13 bird species). The Mt Elgon ecosystem is also home to 9 endemics, making the area a priority for species conservation (Mwaura, 2011).

This study employed a social survey research design. Social survey research design involves collecting data from respondents through a series of questions either in the form of a questionnaire or an interview. In this study, questionnaires and interview schedules were used. Qualitative and quantitative data was collected to meet the research objectives.

Primary data was collected from households and key informants. The key informants included the biosphere reserve manager/park manager, forest manager and chief (administrative) found within the core and buffer zones. They were chosen purposively for inclusion in the study.

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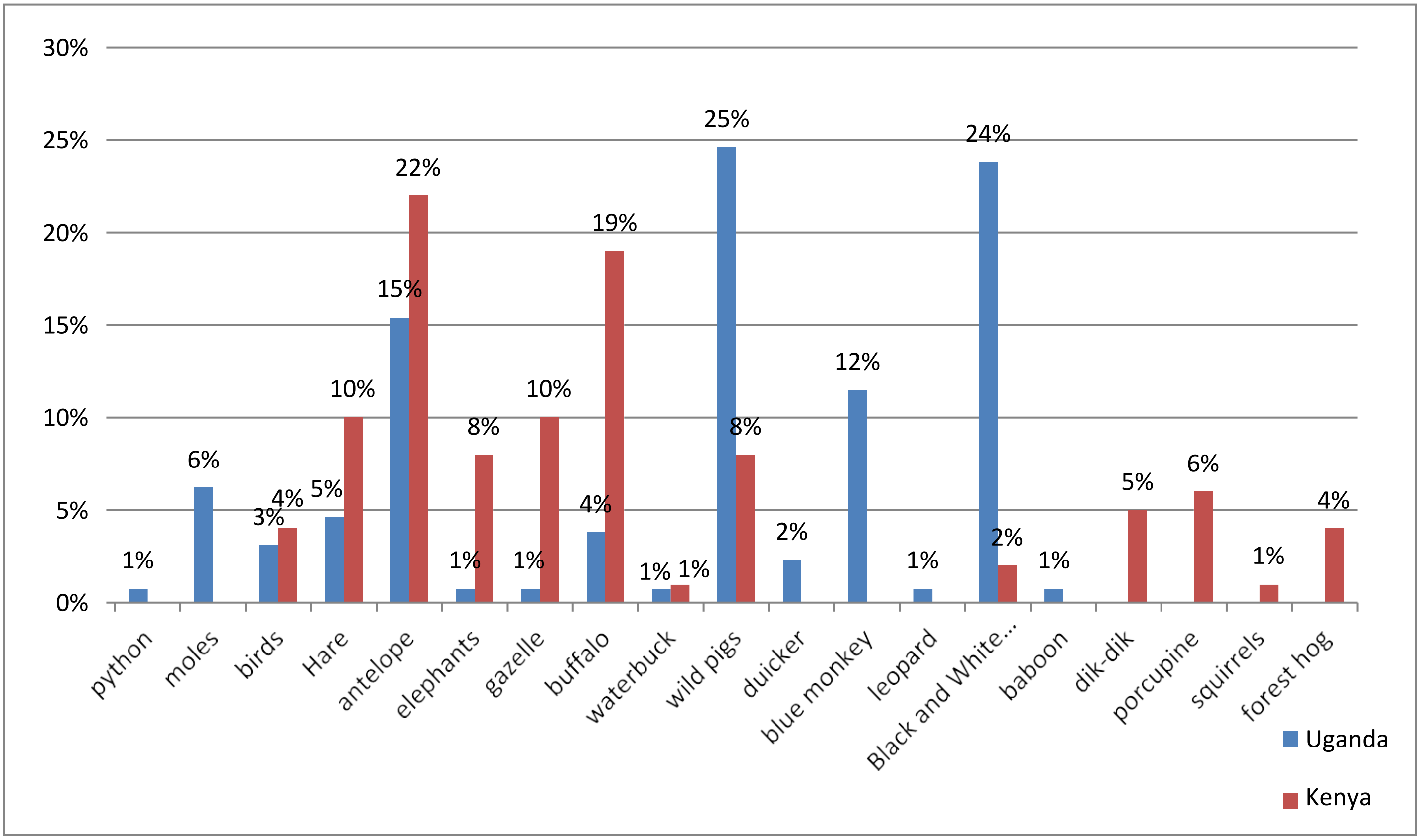

Figure 2: Wildlife species subject to poaching

Secondary data mainly on wildlife population trends, population counts and Occurrence Book records (OB) was acquired from the Kenya Wildlife Service and Uganda Wildlife Authority.

The households included those found within the core zone and buffer zone of the trans-boundary ecosystem. These households were chosen using multi-stage sampling (Stratified sampling, cluster sampling, simple random sampling and systematic sampling). Each zone was treated as a stratum. The wards in each stratum were treated as clusters and some chosen for inclusion in the study. Some villages from these wards were randomly selected using a table of random numbers and households within these villages were chosen using systematic sampling for inclusion in the sample. Kapsokwony, Kopsiro, Kimwondo (Kenya), Kapkwai, Bushiyi and Matuwa (Uganda) were selected for inclusion in the study.

The formula by Nassiuma, (2000) was used to get the sample size:

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

Where n = sample size
N = population
e= Error margin (3%)
C= coefficient of variation (30%)
The sample size will therefore be:
$n=1786831\times30^2 \div [30^2 + (1786831-1)3^2]$
$=99.99\approx100$ households

50 households were chosen from each Biosphere Reserve. The 50 households were apportioned proportionately in each of the two zones based on their population. One household from the core zone and 49 households from the buffer zone were chosen for inclusion in the study. There were no households living within the core zone in the BR in Uganda hence all the households were chosen from the buffer zone. The area of interest

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for the household surveys in both BRs was the villages up to 5 km from the protected area boundaries. The study was accomplished with the help of field assistants who were mainly community members chosen by the wildlife department or key informers. All information gathered was regularly cross validated for error.

Results

Wildlife species subject to poaching

Different wildlife species were targeted in poaching (table 1). In Kenya, Antelopes (22%) and buffaloes (19%) were the two wildlife species mostly targeted in poaching. Elephants (8%) were targeted mainly for ivory.

Respondents from the households in Uganda mentioned a number of wildlife species. The most popular wildlife species were black and white colobus (24%), wild pigs (25%) and antelopes (15%). Majority of the wildlife species are mammals (figure 2).

Spatial extent of poaching

Poaching in the BRs occurs in both the core zone and buffer zone (figure 3). In Kenya, poaching in the core zone accounted for 58% and the buffer zone 44%. The buffer zone mainly consists of farms where agriculture is practised and wildlife is poached when they enter the farms to eat the crops. Within the core zone are Plantation Establishment for Livelihood Improvement Scheme (PELIS) plots where farmers set up traps to capture wildlife that come to destroy their crops. If the wildlife captured is edible, it is used as bush meat. If it is not edible, it is killed. The community also gets an opportunity to poach when they are working in their PELIS plots.

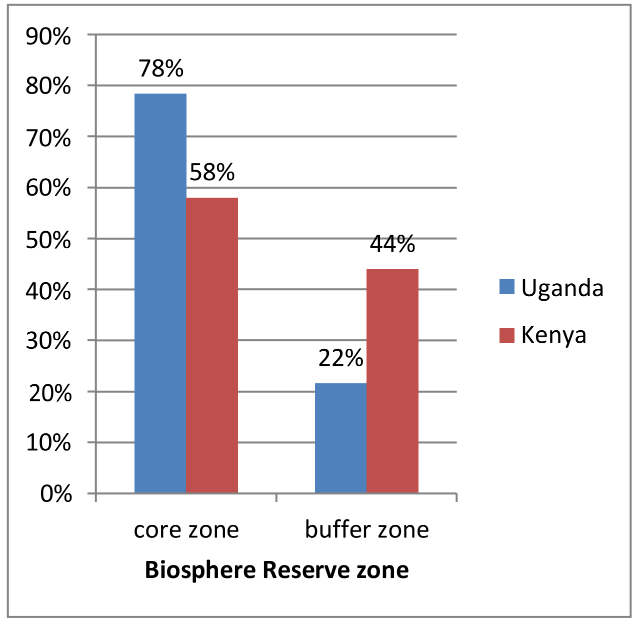

Figure 3: Spatial extent of poaching

Poaching in Mount Elgon BR, Uganda takes places mostly in the core zone (78%) with the buffer zone accounting for 22%. The buffer zone comprises of privately held farms where agricultural activities take place. Wildlife is poached when they leave the forest and enter farms to destroy crops.

Temporal extent of poaching

With regards to temporal extent of poaching, 38% of respondents from the households sampled in Kenya mentioned that it is an activity that takes place all year round. This is because the poachers are fully dependent on the activity for their livelihood. The planting season was also popular (30%) because this is the time when plants are growing in the farms and wildlife come into the farms to eat the crops. The wildlife is killed if captured by the farmers. The rainy season accounted for 22%. Poaching in the rainy season occurs mainly in the buffer zone as during this time wildlife come into the farms to destroy maturing crops and end up being captured by the community members.

In Uganda, the most popular time being during the dry season (50%) that occurs from October to March. During this time there is no food and

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people go into the core zone to hunt. Christmas festivities also occur during this time and bush meat is an important delicacy for this season.

Other seasons mentioned are every August to December (8%) before every circumcision year (even year) when people are actively looking for the black and white colobus monkey whose skin is used to make circumcision garments and May to September (20%) during the rainy season when crops are in the farms. The animals that come to destroy the crops are caught in the traps laid by farmers to protect their crops and are ultimately used as bush meat if they are edible (figure 4).

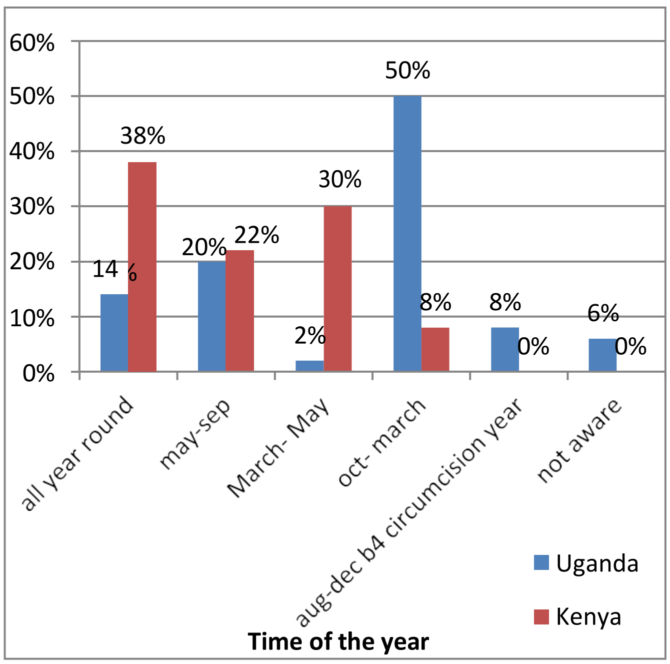

Figure 4: Temporal extent of poaching

Causes of poaching

Poaching in the Mt. Elgon BR, Kenya is caused mainly by need of food and income. Household consumption and local sale as a means of earning income accounted for 56% and 29% respectively. The main causes of poaching in the Mount Elgon BR, Uganda are subsistence (59%) and culture (31%). Wildlife is poached mainly to provide protein in the form of bush meat and skins that are used in cultural ceremonies and for various household chores such as grinding flour and making baskets. Local sale accounts for 8% and occurs when the catch is large (figure 5).

Methods used in poaching

Different methods are used by poachers in the Mt. Elgon BR, Kenya and Uganda (table 2). The most common methods in Kenya were wire traps/snares that accounted for 30% and chasing with dogs that accounted for 24%. Other methods include use of firearms, spears and pangas, bows and arrows and hole/pit traps.

In Uganda the methods used include snares (46%) which are the most popular, chasing with the help of dogs (28%) and use of spears and pangas (18%). Other methods are use of holes, pits and bows and arrows (figure 6).

Discussion

Type of wildlife species poached

This study established that mammals were the main class targeted in poaching (table 1 and figure 2). In Mount Elgon BR, Kenya respondents mentioned antelopes and buffaloes as the main species targeted. Antelope meat is preferred because it tastes like goat meat. Antelopes also enter into farms and are captured by traps or get stuck in the mud as they are being chased. Buffaloes are targeted because of the large amount of meat that can be obtained and for their tails. The tail is a cultural requirement for elderly bukusu men as a sign of prestige. Buffaloes are also a problem animal in the farms. They are dangerous hence when they stay in the farms up to daytime, they are shot down by rangers to avoid the risk of injuring community members. Buffaloes are also the main species targeted by poachers from the Ugandan side. Buffalos are locally extinct on the Ugandan side hence poachers come to the Kenyan side mainly during the dry season (October to February) and mainly target buffaloes because of the large

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amount of meat they provide. Other wildlife species targeted include gazelles whose meat is nearly similar to goat meat, porcupines and wild pigs that were mentioned as problematic animals which destroy growing crops.

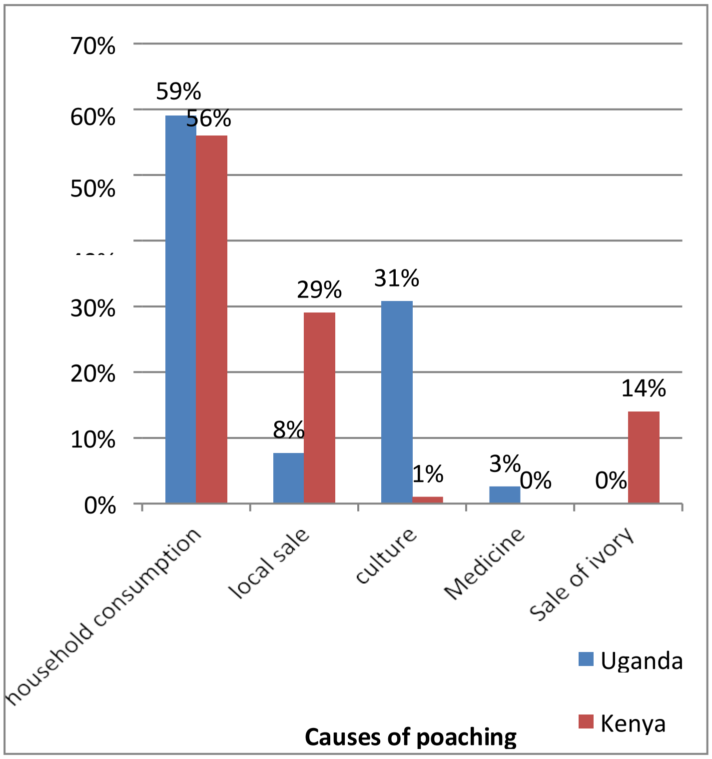

Figure 5: Causes of Poaching.

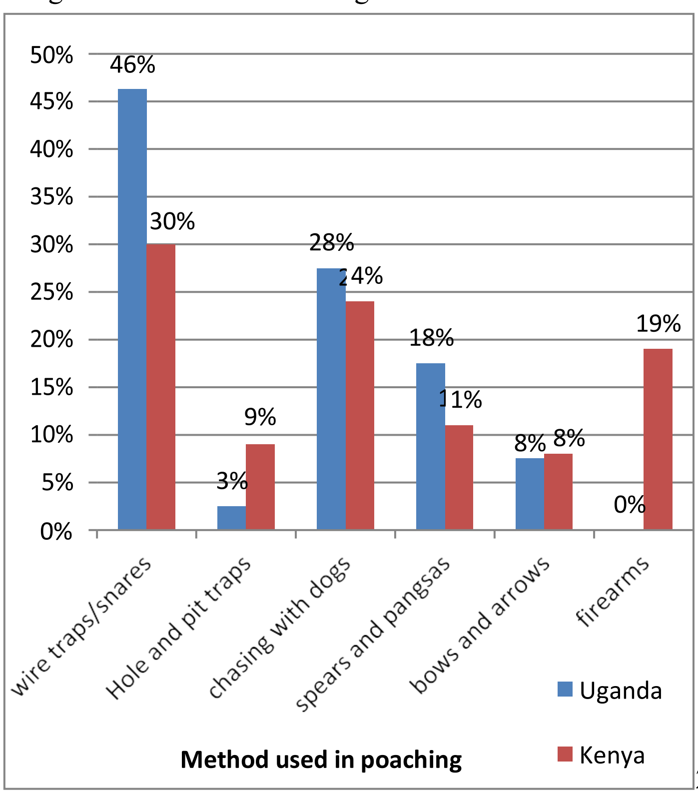

Figure 6: Methods used in poaching

Elephants which occur only on the Kenyan side of the ecosystem were subject to trophy poaching. Black and white colobus were targeted albeit to a small extent. The reason for this was assumed to be a departure from culture as most households preferred circumcising their male children in hospitals.

In Mount Elgon BR, Uganda black and white colobus, wild pigs and antelopes were the main species targeted. Black and white colobus were targeted for their skin and meat. The skin is a cultural requirement for prestige in the traditional circumcision ceremony of mainly the Bagisu. A candidate undergoing the circumcision rituals must have this skin. Wild pigs were the most encountered wildlife species. This was attributed to their high reproduction rates. They are also an aggressive species when they encounter human beings and are a problematic animal. Antelopes are targeted because of their meat which tastes like goat meat. Species like the blue monkey are targeted because of the reducing population of the black and white colobus. Their skin and meat are useful. Rodents are common just like the wild pigs.

The findings of this study were similar to others like Fa *et al*., (2006) in their study in the Cross-Sanaga region in Nigeria and Cameroon, calculated that of over a million carcasses traded in 100 sites, 99% were mammals of which 40% were ungulates, 30% rodents and about 15% were primates. These are the three most important taxa for human consumption. Other studies with similar findings include Starkey (2004); East *et al.* (2005) and Crookes *et al.* (2006).

Spatial-temporal extent of poaching

Incidences of hunting took place in both the core zone and buffer zone of the BRs (figure 3). Hunting within the buffer zones occurs when the animals come out of the core zone/ protected area

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to raid crop farms, livestock and threaten human lives. These animals are killed so as to reduce the losses. They are used as bushmeat if they are edible. This wildlife includes baboons, leopard, hyena, wild pigs (bush pigs), rodents, porcupines and black and white colobus. They damage crops at different times of the year from the planting to harvesting season. Livestock are prone to attacks all year round. Human-wildlife conflict is thus a driver of poaching for communities within the BRs. A study by Barnett (2000) also showed that increased demand for land for agriculture has led to conflict such that problem animals are poached and killed.

Seasonality/ temporal pattern of poaching is a known occurrence. In the Mount Elgon BR, Uganda, hunting was common during the dry season while in Kenya it was common during the wet season (figure 4). In addition to food being scarce during the dry season, most people are idle as most of the crops have been harvested from the farms. It is also important to note that the end-of-year festivities occur within the dry season, an important day when delicacies such as bush meat are eaten. During the wet season that is from the time crops are sown to the time they mature and are ready for harvest, most wildlife species come into the farms in the buffer zones (and core zone in Kenya) looking for food. This is a loss to the farmers who lay traps, capture the wildlife and kill them to reduce the losses. Studies with similar findings include Bennett and Deutsch (2003) who reported peaking during the rainy season and around end-of-year celebrations at the Mbam Djerem National Park in Cameroon and Owusu *et al.,* (2006) who reported climatic peaks in the Afadjato and Agumatsa Conservation Area in Ghana. A study by Olupot *et al.* (2009) in four sites in Uganda reported that hunting was common during the wet season and the dry season with off-take increasing at the end of the year during the end-of –year festivities.

Causes of poaching

The key factors causing poaching in the study area include household consumption, local sale and culture (figure 5). Poaching for food was the main reason given for poaching (59% in Uganda and 56% in Kenya). Bush meat is a protein source that is believed to be more nutritionally superior when compared to livestock meat (Hoffman 2008). Furthermore, it is considered a free and limitless resource that is just captured and cannot get finished (Eves, 1996). This was followed by cultural reasons (31% in Uganda and 1% in Kenya). Wildlife parts play significant roles in culture especially in circumcision ceremonies. Black and white colobus and buffaloes were mainly targeted under this reason for their skin and tails. The skin of the monkey is used to make mantels that are used in performing circumcision dances while the tail of the buffalo is a prestigious ornament with which high ranking men of the bukusu tribe are buried with. Poaching for income was also identified as a reason for poaching. Local sale occurs when the poachers catch is large (either a large animal or an assortment of small animals). The meat was sold undercover to community members especially in drinking dens (Kenya) or to specific households known by the poacher. In Kenya, the meat had been given names that were understood between the poachers and their customers. This naming reduces the risk of the poacher and community members being arrested. Nasi *et al.,* (2011) report these three as the main reasons for obtaining bushmeat in the Congo and Amazon Basins. Olupot *et al.* (2009) identified poverty and cultural beliefs and attachment as the root causes of bushmeat use in Uganda.

Methods used when poaching

This study found out snares, spears, bow and arrows and chasing with dogs were the main hunting methods employed (figure 6). Snares were the most common method (46% in Uganda and 30% in Kenya). They were made from wires and ropes though wires were mostly preferred because they were longer lasting. Snares targeted

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all animals from the large ones such as elephants and buffaloes to the small ones such as antelopes and were laid on the paths used by these animals. Firearms were used but to a smaller extent (19%) especially where the target was large animals such as buffaloes and elephants. Chasing with dogs (28% in Uganda and 24% in Kenya), bows and arrow, spears and pangas was most commonly used when poaching small body sized animals like the black and white colobus, wild pigs and hare. Spears and pangas were also reported as the method used for animals as big as elephants and buffaloes. Hole and pit traps targeted all mammals. They are dug and covered to disguise them. The poacher frequently checks them to see the animal that has been captured. If an animal was captured and is edible, it was speared to death. Use of snares was the most common method as is concluded in a study by Wato *et al.,* (2006) in the Tsavo National Park, Kenya and Nielsen (2006) in Udzungwa Mountains, Tanzania. The popularity of snares can be attributed to easy availability, durability and low cost (Lindsey *et al.,* 2011; Fa and Brown, 2009). These two studies and others such as Grey-Ross *et al.,* (2010), Jachmann (2008), Lindsey *et al.,* (2011) found out that snares in addition to chasing with dogs, spears, pangas, hole traps, bow and arrows were methods used when poaching wildlife.

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