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Training of Experts for Sustainable Use of Land

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1 ABSTRACT

A key objective of spatial planning is the sustainable management of the resource 'land', which requires balancing competing interests such as housing, infrastructure, wildlife protection, food production, and industry. In regions with no or limited spatial planning traditions, land is often underutilized or inefficiently managed. Addressing this challenge requires specialist in spatial planning, but also experts for the acquition of geodata needed for decision-making.

Therefore, training people in data acquisition is essential for many countries. This paper shares experiences from two capacity building initiatives in Ethiopia. Both projects aim to provide materials for (in attendance, online, and hybrid) teaching with the thematic focus on geomatics. This includes the purchase of equipment such as UAVs (Unmanned Aerial Vehicles) equipped with RTK/GNSS (Real time Kinematic/Global Navigation Satellite System), a GNSS base station, a CORS (Continously Operating Reference Station), and multi-media equipment for producing educational videos and online-teaching. Teachers at four Ethiopian universities are trained in the usage of these instruments to gain competences and skills to subsequently educate their students and national professionals. In addition, joint courses were also offered. Both initiatives emphasize capacity development through hands-on field exercises, competency-based teaching approaches, and institutional collaboration. This approach ensures the long-term integration of modern geospatial tools in academic and professional practice.

Keywords: Training, Data Acquistition, UAV, Ethiopia, Land Administration

2 INTRODUCTION

A primary objective of spatial planning is the responsible and sustainable use of the resource 'land'. This requires balancing conflicting interests; aspects such as housing, infrastructure, wildlife protection, food production, and industry must all be considered. Countries with no or limited spatial planning traditions face a heightende risk of inefficient land use and resource degredation. A typical consequence of these planning gaps – frequently observed in the Global South – is the proliferation of informal settlements, which emerge when land is not allocated or managed optimally.

Dealing with these challenges requires multidisciplinary expertise. However, they depend on reliable geodata as a basis for their decision-making and for analysing complex spatial situations. While data availability is generally standard in developed nations, countries in the Global South often lack on geodata and on suitable procedures for data acquisition. This information gap hinders evidence-based decision-making and constrains efforts toward sustainable land management.

Nowadays, spatial planners have the competencies and skills to operate modern surveying equipment, such as Global Navigation Satellite Systems (GNSS) or Unmanned Aerial Vehicles (UAVs). Especially UAVs are used to gain up-to-date land information with high spatial, spectral, and temporal resolution. Data acquired by this technology, such as Digital Surface Models, ortho-mosaics, or land cover maps, are applied for planning and monitoring activities.

Not in every country, enough surveyors are available to guarantee a nation-wide, up-to-date coverage. Ethiopia, for example, is currently implementing a land registration system (MEDENDORF et al., 2014), for which it was estimated that 50,000 additional surveyors would be required until 2024 (NAVRATIL and MANSBERGER, 2017). Even though not all of them would need a full university education, the Ethiopian universities were not prepared for this challenge. Even today, only a fraction of the required workforce is available. To mitigate this shortage, specialized training can be provided to experts in similar domains, such as spatial planners. This strategy involves adapting teaching and learning materials originally developed for university surveying programs to equip these professionals with the necessary geospatial competencies.

Beyond the technical operation of surveying equipment, additional competences are required. The availability of spatial data across various sectors in Ethiopia remains a significant challenge, primarily due to the absence of a Spatial Data Infrastructure (SDI) framework. For instance, the geometric structure and positional alignment of spatial datasets often differ across sectors, such as land registration, urban planning, and city administration. These inconsistencies create significant barriers to exchange of data between public bodies and interdisciplinary sectors. Consequently, experts in all sectors need the competence to harmonise these data sets and resolve interoperability issues.

If experts lack the competences, they risk designing plans without considering the spatial characteristics of the (spatial, temporal, radiometric, and spectral) resolution of the data or utilizing inappropriate software platforms. In Ethiopia, such gaps have previously resulted in spatial shifts and geometric inaccuracies creating inconsistencies with national standards and working manuals (e.g., AACA, 2002; ERA, 2013; MoUDAH, 2016). This occurs despite national standards explicitly mandating that land registration and spatial planning must use ground surveying, aerial surveying, and high-resolution satellite images. Addressing these inconsistencies is crucial for improving land governance workflows, minimizing duplication of effort, and ensuring coherent national planning strategies. Skilled workforce is necessary to achieve this goal. Ethiopia currently is still lacking enough experts. To mitigate these problems, investment in education in this field is highly needed.

This paper reports on the experiences of two ongoing capacity-building projects in Ethiopia. Both initiatives focus on the development of learning and teaching materials and the training of the teachers. Furthermore, the projects integrate the concept of Lifelong Learning (LLL) by creating modular course materials which can be reused for LLL activities.

3 PROJECT OVERVIEW

Currently, the authors are involved in two capacity-building projects in Ethiopia: “Implementation of Academic Geomatics Education in Ethiopia for Supporting Sustainable Development (Edu4GEO2)” and “Land Information for Land Management (Li4LaM)”. Edu4GEO2, financed by the Austrian Development Agency (APPEAR program), aims at creating a master curriculum in Geomatics at the Debre Markos University. Li4LaM, funded by the European Union (ERASMUS+ program), aims to improve the teaching environment and teaching methods at four Ethiopian universities: Addis Ababa University, Bahir Dar University, Debre Markos University, and Woldia University. The Austrian partners involved in these projects are Technische Universität Wien and BOKU University Vienna. The University of Agriculture in Krakow and University of Ljubljana are additional partners in the Li4LaM project.

Both initiatives aim to develop materials for live, online, and hybrid teaching, with a focus on surveying and data management. This includes the purchase of UAVs (Unmanned Aerial Vehicles) equipped with RTK/GNSS (Real Time Kinematic/Global Navigation Satellite System), a GNSS Base Station, a Continously Operating Reference Station (CORS), a camera equipment for creating educational videos, and a basic setup for E-Learning and online teaching. Teachers at the Ethiopian universities are trained in the usage of these instruments and equipment to gain the competences and skills to subsequently train their students and national professionals. Both initiatives emphasize capacity development through hands-on field exercises, competency-based teaching approaches, and institutional collaboration. This ensures the long-term integration of modern geospatial tools in academic and professional practice.

A significant challenge in Ethiopia is country’s diverse demographic structure, characterized by the wide variety of ethnicities and languages. This can cause barriers for education. The Li4LaM project tackles these barriers through spreading awareness of potential challenges. The lack of available hardcopy textbooks is addressed through electronic learning material ensuring a broader, more flexible access to education. In recent years, inter-ethnic conflicts have further complicated the educational landscape, occasionally making traveling dangerous. This volatility culminated in a regional university shutdown during the winter term 2022/23, when for safety reasons, universities had to prevent students to come to the university. During such periods, distance learning techniques are essential, as they allow for educational continuity while students remain in safe locations. Distance learning enriches Ethiopia's current learning environment and fosters a LLL-culture on- and off-campus. The aim is to create tailor-made and flexible education and training systems and solutions to deliver more learner-centred, accessible, and inclusive learning.

A goal of Edu4GEO2 is the implementation of a master curriculum on geomatics at Debre Markos University. This includes the creation of new courses (usually based on courses already existing at other universities) with theoretical and practical modules as well as with test questions. The modules typically contain textbook materials, presentation slides, and practical case studies, which allow students to carry out various professional tasks. Examples are parameter estimation, production of DSM and ortho-mosaics using UAV photogrammetry, spatial data analysis, or gender and land rights. Parts of these courses (or complete courses) can be offered as LLL courses, too.

4 TRAINING CONTENT

Both projects incorporate a train-the-teacher approach. The workshops and training sessions covered a diverse range of topics, tailored to a specific audience. The identification of learning outcomes or modern educational concepts as well as the development of curricula for example, are more relevant for people teaching at universities than for practitioners. Other trainings focused on the practical operation of the hardware acquired through the project. To maintain the project's strategic focus, certain peripheral topics were excluded from the scope.

The depth of instruction varied according to the technical requirements of each subject. For example, machine learning principles were covered only to the extent necessary for utilizing existing online platforms. In contrast, photogrammetric principles received more rigorous treatment, given their critical impact on flight planning and data accuracy.

Not all relevant topics, however, could be taught during the workshops. An important aspect in surveying or geoinformatics curricula is geographical reference frames and spatial data infrastructures (SDI). These topics, extremely relevant for the collection of data, are more time-consuming than the pure training in the use of technology. They require a thorough understanding fundamental theoretical concepts and knowledge of practical implementation. This includes concepts like the Geoid, practical questions like the atmospheric impact of data collection, or implementation issues like dealing with soil movement during the setup of a nation-wide reference frame.

4.1 Use of Surveying Equipment

An important component of modernizing instructional capacity was the acquisition of Unmanned Aerial Vehicles (UAVs) equipped with RGB cameras as well as the purchase of a GNSS (Global Navigation Satellite System) base station to enable operating the drones in a DRTK (differential real time kinematic) GNSS modus.

For administrative reasons, the UAVs first were purchased by the European partners using the project money and afterwards donated and delivered to the Ethiopian partners. This procurement strategy was necessitated by the limited local availability of specialized and up-to-date hardware in Ethiopia as well as by the gained experiences from the previous EduLand2 project ("Implementation of Academic Land Administration Education in Ethiopia for Supporting Sustainable Development") that Ethiopian market prices are significantly higher than those in Europe partly caused that Ethiopian universities often are not getting academic discounts.

For some applications, additional spectral bands in the cameras would be of interest (e.g., the near infrared for vegetation studies). Equipment like UAVs with an infrared or thermal sensor are usually classified as dual-use equipment. This means that equipment can be used for both military and civilian applications. This dual-use equipment would need an export permission by the responsible ministry of the sending country. The DJI Mavic 3 Enterprise with a RGB camera, which is not classified as dual-use equipment, was selected for the Ethiopian universities as the donation require the export of the hardware from European countries and this selection avoid delays or even the denial of the export.

Efficient use of this hardware for teaching and science requires operational skills. These were provided in two steps:

- Before the delivery of UAVs to Ethiopia: A 3-days workshop in Addis Ababa focused on the process of data acquisition using UAVs. The workshop was held in small groups (5-6 persons) training the whole process from flight and mission planning to carrying out photo flights and the postprocessing of the image to generate digital surface models and orthophoto mosaics. This training adopted a single UAV owned by the Agricultural University in Krakow. It was sufficient to teach the use of the software, explain the principles, let the experts get hands-on experience in flight planning, and allow the trainees to experience the complete workflow. The training was organized on the campus of the Addis Ababa University and with the consent of the nearby ministry.
- After the delivery of UAVs to the Ethiopian universities: A 4-days workshop held at the border of Addis Ababa focused on the use of the provided equipment (see Fig. 1). All four Ethiopian universities used the equipment they received through the project. This allowed the trainers to check the completeness and configuration of the UAVs and how to update the settings and the software. Each Ethiopian university sent 2 staff members to experience the handling of the DJI Mavic UAVs.

Fig. 1: Workshop instructor Piotr Wężyk and one of the Drones in Ethiopia (Photo by Wężyk).

For this 4-days workshop, the following objectives were formulated by the project partners:

- Shared Terminology: Develop a common understanding of standard photogrammetry terms to ensure effective communication among all project members.
- Equipment Readiness: Verify the completeness and operational status of UAV and GNSS hardware delivered to Ethiopian universities, including necessary software updates.
- End-to-End Photogrammetry Projects: Collaborate on the planning (Fig. 2) and execution of UAV flights, 3D model reconstruction, and the generation of high-quality orthophotos.
- GNSS Accuracy: Share technical expertise to achieve high-precision measurements using GNSS equipment.
- Educational Materials: Produce high-quality instructional videos and presentation slides for use across all partner universities.
- Strengthen Institutional Partnerships: Foster deeper collaboration and long-term networking between project members and participating universities.

Fig. 2: UAVs Flight Information with DRTK.

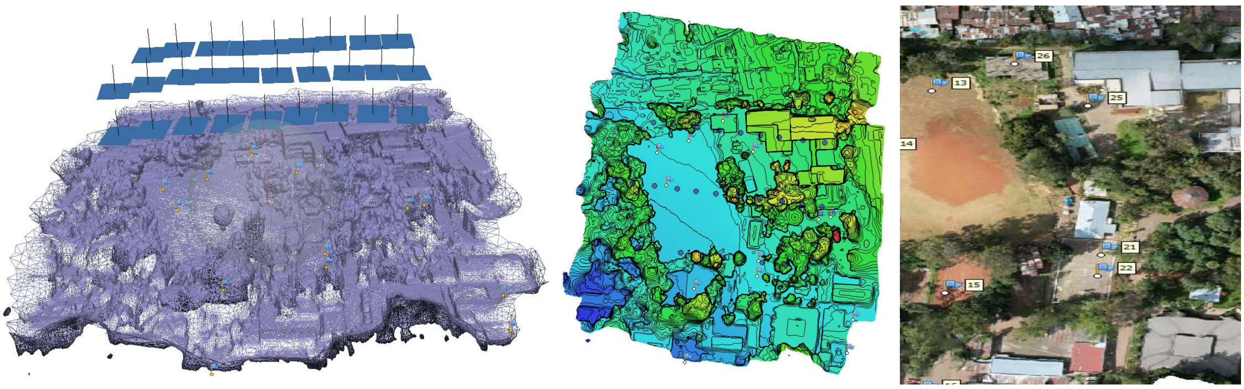

Fig. 3: Example for the results of a flight.

The training started with flight planning, where the path for the UAV is defined. Fig. 2 shows screenshots of this procedure. The trainers explained the effect of the various parameters, discussed advantages and challenges of different settings, and communicated starting values that proved to be appropriate in the past. Tasks necessary before flying also require correct setup of the GNSS base station and the marking of ground control points. The photo flight itself is an automated process. The last step is the data analysis. It includes merging the different images, generating digital surface models and producing orthophotos followed by subsequent steps, like object classification. Fig. 3 shows one of the created images of the classification in the model. The left image in Fig. 3 shows the terrain model and the positions where images were taken and the image on the right shows the 3D model created from the images. Results like these can be used to analyze thew current situation, identify clusters that need to be protected, detect challenges, and develop solutions.

4.2 Spatial Data Handling

The training on the handling of spatial data was focused on two topics:

- Image Classification using Machine Learning: This task often follows orthoimage production. An expert from BOKU University demonstrated how to use the Google framework for analysis, while an expert from the TU Wien explained how to use local implementations. Both approaches offer unique advantages and disadvantages. In the global South both might be highly relevant.
- Point Pattern Analysis: Observational data often relates to specific sites or areas with high incident frequencies – such as crime hotspots – that require precise identification. Hot-spot analysis enables GIS users to identify these areas and to rasterize the results to merge them with classifications derived from the orthoimages. This approach demonstrated the participants an effective method to combine raster- and vector-data formats.

During the practical sessions, participants also received other relevant information, e.g., how to handle a change of the reference frame or to carry out local transformations. These topics are also relevant for LLL modules with a focus on data integration.

4.3 Improving Teaching Qualities

During a 4-days workshop in Krakow in 2023, aspects of E-Learning were practiced. The workshop aimed to achieve the following objectives:

- Shared Terminology: Develop a common understanding of terms used in learning management systems (LMS) and video production.
- Moodle Course Set-Up: Provide knowledge on setting up a course within the Learning Management System 'Moodle'.
- Moodle Content Tools: Raise awareness of the content tools available within Moodle.
- Independent Course Creation: Enable project members to independently create Moodle courses and add topics in various formats.
- Open-Source Video Tools: Provide Ethiopian project members with an overview of existing (open source) software tools for producing educational videos.
- Video Production Skills: Train participants in video capturing, screen recording, audio recording and editing, and video editing.
- Workshop Documentation: Enable project members to produce a video documenting the workshop.
- Video Platform Management: Equip Ethiopian university teaching staff attending the workshop with the knowledge to host videos on a video platform (e.g., YouTube Studio).

The focus of the whole workshop was the creation of educational videos and the use of E-Learning tools. Both topics were first theoretically introduced and then practically trained. Only open-source software was used in the workshop to later avoid any problems with software licenses.

During the video production part, social media experts of the University of Agriculture in Krakow provided tips and tricks how videos should be produced (see Fig. 43). In addition, the colleagues from BOKU University, who have experience in the creation of educational videos, demonstrated the software used for video editing. Participants then were tasked with producing their own videos to get some experience for video production using pictures and videos documented with their own smartphones, music, text elements, and screen recordings.

The workshop also provided hands-on experience in the creation of small learning units consisting of different parts like introductory material, literature, educational videos, self-assessment tests, exercises, etc. These units were kept small so they could be easily reused, e.g., for LLL or whenever the curriculum needs to be restructured.

Fig. 4: Presentation at the Social Media Office of the University of Agriculture in Krakow.

To use and provide teaching and learning materials, each Ethiopian university received a server with a Moodle installation that they could integrate into the campus computer network. The decision to use servers placed at the campus and not use a cloud-based solution was influenced by the frequent power outages in Ethiopia which also interrupt the connection to the Internet. The university campuses in Ethiopia are equipped with emergency power units that can support servers, workstations, and the local network. Therefore, the approach with local servers seemed to be more user-friendly. A demonstration and a training how to install and run Moodle activities were carried out during this workshop.

Already during a first workshop in Vienna in 2022, concepts like flipped classroom, support of self-studying for students, team-teaching, and other modern pedagogical concepts were presented. The Krakow workshop was an opportunity to see how material for such concepts can be created.

5 LESSONS LEARNED

The implementation of the two capacity-building projects has yielded several critical insights into international academic collaboration and the technical implementation of professional hard- and software. The following lessons can serve as a basis for future collaboration and projects:

- Cultivating Mutual Respect: The establishment of mutual respect among all project partners is a fundamental pillar for the successful implementation of a project and for achieving the expected results. Most of the participants are currently teaching at their universities, some with decades of experiences. The project does not aim to invalidate this knowledge; the focus was always on widening the toolbox as a teacher because methods working for young students might not necessarily work for LLL courses with domain specialists.
- Addressing Technical Realities: The use of unfamiliar hard- and software sometimes causes challenges not foreseen during project preparation. Hardware acquired in Europe and then shipped to a country of the global South encounters complications regarding warranty support, customer service, and software update cycles. To mitigate these risks, logistical and maintenance frameworks must be fully clarified prior to any procurement.

- Integrated Data Literacy: Training of domain experts to collect data requires training on the use of equipment, but it also needs skills on integrating various data sources. This requires integrated data literacy, such as knowledge on reference system, classification schemes, standards.
- Efficiency of Face-to-Face Training: While digital communication platforms are suitable for delivering theoretical content, the projects underscore that face-to-face training remains effective for practical skill acquisition. In-person the supervision of practical tasks allows the detection and correction of handling errors. This direct mentorship is especially important in training teachers, who must deliver the acquired skills to their students.
- Reuse of Teaching Modules: Training modules can be used for various purposes when designed as parts of a modular system. The materials used to train the trainers on flight planning, for example, can also be used for both, regular students and external experts in the context of LLL. This maximized the benefits of the work invested in the creation of the learning and teaching materials.

6 CONCLUSIONS AND FUTURE WORK

According to RAJABIFARD (2019), geospatial systems are essential for linking land-use decisions to multiple Sustainable Development Goals (SDGs). Land acts as the spatial base where environmental, social, and economic processes interact. Integrated geospatial data helps decision-makers visualize trade-offs between development and conservation to support sustainable land-use planning. Integrated systems enable coordinated monitoring of land degradation and urban growth. Overall, geospatially enabled land management improves sustainable land governance through evidence-based, spatial decision-making.

Early project observations indicate improved instructor competence and a heightened institutional readiness to support Ethiopia’s emerging spatial data infrastructure. By strengthening the human capacity necessary for responsible land governance, these efforts contribute directly to the United Nations’, specifically SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 14 (Life below water), and SDG 15 (Life on Land).

The benefits of projects like the ones presented here are manifold. Capacity-building is an established method to address challenges that require long-term sustanabiliy. The target country is enabled to train the people it needs to address the problems. Training material created in such a project are distributed between the universities and help improve their teaching. All involved teachers can provide their students with perspectives from other countries. This helps students to understand the more general implications of the materials they are learning.

The eight universities involved in the project plan to continue the cooperation, not necessarily in this large group. Information on exchange and scholarship programs was already provided. The personal bonds between the project participants, strengthend during the trainings and also the cultural events associated with the workshops and trainings will enable better collaboration and easier communication for joint research and joint poject proposals.

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