D 3.1

Guidelines and technical specifications for the data collection through UAV

Consultancy for developing/updating of the database + web platform + geoportal | ECHO/-SF/BUD/2017/91009

General information	
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PP	Restricted to other programme participants
RE	Restricted to a group specified by COOPI
CO	Confidential, only for members of the consortium

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1.0	16/04/2018	4	Draft
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1.2	29/05/2018	9	Final version

1. Introduction to UAV-based remote sensing

The use of UAV-based remote sensing has been well established for a variety of applications in the last couple of years (Shahbazi, Théau, and Ménard 2014; Nex and Remondino 2014; Lucieer, Jong, and Turner 2014; Rango et al. 2006; Colomina and Molina 2014; Kalacska et al. 2017). One example is the application of monitoring soil erosion in Morocco with UAV-based data (d'Oleire-Oltmanns et al. 2012).

In the humanitarian sector, there are numerous initiatives going on being usually published on different platforms but rather not in scientific publications. A good overview is given online: http://drones.fsd.ch/en/drones-in-humanitarian-action/ [accessed May 2018]. There are several case studies from areas all over the world listed that support crisis situation such as flooding, hurricane events and earthquake scenarios as well as medical support initiatives and camp management by applying drones for mapping purposes and data acquisition for future analysis of the respective area. This list is continuously updated and latest results are provided online for several case studies.

Cost-effective and robust hardware that is easy to handle, developed, improved, and constantly being available on the market extends an already stable basis with regard to availability, applicability and increase of applications. Extending the mentioned range of benefits there are specific advantages for mapping areas of small to intermediate spatial extent:

- **High temporal frequency** is possible as mapping campaigns may conducted on demand and also repeated in a very short interval.
- Resulting data delivers **very high spatial resolution** and contains latest information on the current situation during the time of the mapping campaign being carried out – this is especially valuable in the context of disaster mapping such as floods.
- Derived data products enable a **much higher level of detail** on the local extents in comparison to satellite data.

2. Context of the study

The context of this study is based on the signed supply contract / Consultancy: Consultancy for developing/updating of the database + web platform + geoportal ECHO/-SF/BUD/2017/91009 made between COOPI - Cooperazione Internazionale and the Paris Lodron University Salzburg, Department of Geoinformatics – Z_GIS.

This is part of the ongoing project "Strengthening the Disaster Risk Management System at the National and District Level to reduce future humanitarian needs by decreasing risk to vulnerable population in Malawi" (ECHO/-SF/BUD/2017/91009. The Directorate General for European Civil Protection and Humanitarian Aid Operations (ECHO) grants funding for this project.

Subject of the contract is to strengthening disaster-related information management, knowledge and skills for disaster preparedness and response at National and local level in Malawi.

The aim of this deliverable is to support COOPI within their UAV data collection and have standardised guidelines available. This ensures a standardized and therefore comparable data acquisition over the lifetime of the project and ensures the generation of different data products for the subsequent tasks. The generation of these data products relies on specific requirements that have to be fulfilled during data acquisition. This includes aspects for flying height, in-track and parallel overlap, GCP distribution and measurement.

3. Technical specifications for UAV-based data acquisition

This section will focus on the technical specifications required for the data acquisition based on UAV flight campaigns. Please note that within these guidelines only consider the acquisition of optical aerial photographs based on UAV.

In order to derive meaningful data products subsequent to the data acquisition, UAV-based data acquisition must already consider certain requirements in advance to flight campaigns. These requirements relate to the flying height, photogrammetric aspects such as image overlap, which are described below. In addition, these requirements have to be adapted to the respective mapping area. Intended data products derived from aerial photographs were orthoimages mosaics as well as Digital Surface Models (DSM), which may subsequently provide the data basis for Participatory GIS (PGIS) exercises as well as runoff modelling for the identification of areas with higher flood risk.

Different types of UAV

Mainly two categories of UAV are applied, copters and airplanes/gliders. In general, there is not the one category better than the other one. Some specific properties are listed below to provide a more detailed insight.

Copters	Airplanes/gliders
 Md4-1000 (microcopter)	 ebee (sensefly)
Usually 4, 6 or 8 rotors	2 wings or winglet construction
Vertical take-off and landing	Landing strip required
payload affects flight time	
Well-suited for limited areas such as canyons, river valleys or mountainous areas	Well-suited for covering larger extents such as plains, vast agricultural areas and similar
Sensitive to winds	Winds do not affect too much the flight
Wet weather conditions usually to be avoided	

Photogrammetry in a nutshell

The American Society for Photogrammetry and Remote sensing (ASPRS) defined Photogrammetry as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena (ASPRS online).

A special case is stereophotogrammetry that enables to derive the third dimension from acquired aerial photography. This requires the study object or study site respectively to be contained within at least two different aerial photographs. To ensure that no data gaps are evident the in-track and parallel overlap of aerial photographs should be around 70-80%.

For the triangulation of the images the orientation in all three dimensions is required, the precisely measured locations of ground control points (GCP) and a software environment being capable of processing this data. d'Oleire-Oltmanns et al. (2012) provide a more detailed description of this workflow. The article is freely available as OpenAccess pdf document (see reference at the end). There are several software environments available. Pix4D (pix4d.com) and Agisoft Photoscan (agisoft.com) are two that are rather well established on the market. There are also solutions that are freely available which require profound knowledge on the theoretical concepts of image analysis as well as programming skills and are therefore not further focussed here.

Spatial resolution (per-pixel resolution)

The spatial resolution, i.e. the per-pixel resolution of the acquired aerial photographs is on a very large spatial scale level: per-pixel resolution ranges between 2 cm and 15-20 cm per pixel. Lower resolutions may also be applied, this depends on the intended analysis and further usage of the acquired data. Several aspects relate to the spatial resolution:

Flying height - The flying height above ground limits the spatial resolution of the resulting aerial photographs. The more distance between the area to be mapped and the UAV, i.e. the higher the UAV flies above ground, the lower the per-pixel resolution. The overall footprint of the image covers a larger area while the number of pixel remains unchanged. Hence, the area to be covered per each pixel increase which results in a lower per-pixel resolution.

Camera chip - The chip of the camera defines the footprint of one aerial photograph on the ground according the dimensions of chip itself and the flying height above ground. Furthermore, the number of pixels on the chip limits the per-pixel resolution. The higher the number of pixels the higher the per-pixel resolution of the resulting aerial photograph: one pixel has to cover less area of the footprint on the ground.

Lens – The zoom level of the lens should be fixed to avoid distortions. In addition, there should not occur any aberrations to avoid blurred parts within the aerial photographs that hinder a precise triangulation and subsequently reduce the overall quality of the resulting data products.

Georeferencing /Ground control points (GCP)

A precise georeferencing of the acquired aerial photographs ensures a high quality for several aspects: Firstly, the spatial positioning of the image block, the resulting orthomosaics, and further data products. Secondly, the orientation in the third dimension improves which is important for approaches that include monitoring and change detection aspects such as flood risk mapping. Thirdly, a well-established georeferencing approach from the beginning enables an iterative orientation of aerial photographs that ensures an objective comparison of the different data products according to equal spatial positioning, i.e. georeferencing.

A pragmatic approach for georeferencing is the distribution and measurement of ground control points (GCPs). It depends on the overall accuracy aimed at, how many GCPs are necessary (Mike R. James et al. 2016). The workflow is as follows: the distribution strategy for the respective area to be covered has to be defined in advance. Chosen locations of the GCPs have to be easily accessible on the hand

and should not be affected by exterior impacts on the other hand, so that the applicability for iterative flight missions is ensured. Two different types of GCPs may be used: natural objects such as rocks or similar that have a distinct position and are easily recognized on the aerial photographs (Jagt et al. 2015). In addition, the usage of temporary elements as GCPs may be considered to arrive at a stable distribution of GCPs (d'Oleire-Oltmanns et al. 2012; M.R. James et al. 2017).

Measuring the position of the GCPs may be done by applying a differential GPS device, which arrives at a horizontal positional accuracy of around 5 - 10 cm. The availability of a correction signal and/or the opportunity of post-processing the measured locations has be ensured.

If there are official surveying points available, one may also link the measuring to these points. The measuring device may also be a total station with the respective positioning options.

Nowadays, few available drones are already equipped with an on-board RTK system. RTK refers to real time kinematic which means a precise real time positioning of the drone. If such a system is included to the drone, then each of the centre points of every acquired aerial photograph may be used as a GCP. The measurement of additional GCPs in the field may not be required in this case.

As a very inaccurate and imprecise approach for georeferencing, the usage of the on-board GPS, every drone is equipped with, may be used for georeferencing the acquired aerial photographs. This would be somewhat of an emergency backup solution in case that neither the distribution and measuring of GCPs is possible, nor the used drone has an on-board RTK system. For any kind of detailed analysis, this approach is not recommended.

Data processing

Data processing includes several steps in order to derive data products such as orthomosaics and digital surface models (DSMs).

Firstly, the orientation of all aerial photographs is required. The orientation is applied for the position in x, y, z as well as the spherical orientation in yaw, pitch and roll. In case individual images are very oblique, they are removed for upcoming steps not to decrease the overall quality of the image block.

Secondly, the measured GCPs have to be assigned to each respective image contained within. The generic procedure is to import the coordinate values and manually assign the individual coordinate entries.

Thirdly, a first triangulation is taking place to receive an initial estimation on the triangulation accuracy. A quick glance at the log report enables the improvement of the image block and subsequent processing may be initiated.

Main settings for generating the point cloud usually allow different levels with regard to the point density. Here, the main concern is the total number of points. This number may heavily increase with a larger area. Another point that impacts the level of quality for the point cloud is the structure, texture and topology of mapped area. The more homogenous the area is, the smaller the impact of reducing the total number of points contained within the point cloud. For further pragmatic details on data processing see as one example the manual from Agisoft PhotoScan that is available online (www.agisoft.com).

Selection criteria for mapping areas

The criteria for the selection of mapping areas heavily depend on the intended outcome. There are a few general aspects that are valid and will be discussed more detailed in the following.

Access: Areas have to be accessible in order to enable UAV-based mapping campaigns. A minimum would be a location to start and land the UAV as well as being in a spatial location to always have a direct line of sight to the drone unless no permission for flying beyond the visual line of sight is granted.

Extent: The extent of the area has to be known. If required, the area has to be split into several mapping units that may be safely covered with one battery charge. Here, the used UAV heavily affects the flying time and has to be taken into account.

Obstacles: The area to be mapped should not contain dangerous obstacles such as powerlines or similar. The risk is two-fold: damaging the UAV on the one hand and causing substantial problems to the power network on the other hand. In addition, highways, roads should be avoided if possible.

Topology: The topology of the mapping area should enable UAV-based mapping by not containing lots of morphological obstacles such as crests or ridges that disable a continuous line of sight and or may cause unforeseen wind regimes that may affect the UAV.

Relation to the project: The mapping area should be chosen according to a meaningful relation to the project or mapping intention. A close relation may also mean that aside of the spatial location of interest, further data is available for the chosen region that may be taken into consideration for subsequent analysis steps.

4. Potential additional (data) sources to be considered

In addition to the acquired aerial photographs as well as therefrom-derived data products, the incorporation of additional available data provides a very useful approach to increase the reliability of the information within the results and findings.

One example is data provided by local stakeholders that reflect well the situation on a very large spatial scale level in the context of individual communities or natural local characteristics.

Another option is the incorporation of freely available information from databases being available online. One example were the Copernicus core services (Online: www.copernicus.eu). Also freely available data from OpenStreetMap may support the analysis (Online: www.openstreetmap.org).

In the context of this study, the application of the DSM generated by the World Bank may be an asset.

The portal of MASDAP may also provide different data that was of great use (Online: www.masdap.mw).

Please see also deliverable D1.1. Baseline Report for further information on potential data sources.

5. Disclaimer

The guidelines intend to help and support the acquisition of UAV-based data. However, the authors take no responsibility for any legal issues. All legal aspects have to be taken into account from the pilot(s) and persons carrying out the flight campaigns. This also applies for any insurance issues.

Any damage caused by the UAS applied as well as any damage to the UAS itself is under the responsibility of the pilot and persons carrying out the flight missions.

All measures that ensure the highest possible level of safety have to be established during any flight campaign carried out, in order to minimize the risk of harming any uninvolved persons.

All legal aspects have to be taken into account for any mapping mission. This includes amongst other, the flying mode of the UAV, exclusion of sensitive areas, and insurance aspects.

These guidelines were authored to the best of one’s knowledge and belief.

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