Earth observation and GIS to support humanitarian operations in refugee/IDP camps

Petra Füreder
Department of Geoinformatics – Z_GIS, University of Salzburg
petra.fuereder@sbg.ac.at

Stefan Lang
Department of Geoinformatics – Z_GIS, University of Salzburg
stefan.lang@sbg.ac.at

Michael Hagenlocher
Department of Geoinformatics – Z_GIS, University of Salzburg
michael.hagenlocher@sbg.ac.at

Dirk Tiede
Department of Geoinformatics – Z_GIS, University of Salzburg
dirk.tiede@sbg.ac.at

Lorenz Wendt
Department of Geoinformatics – Z_GIS, University of Salzburg
lorenz.wendt@sbg.ac.at

Edith Rogenhofer
Ärzte ohne Grenzen / Médecins Sans Frontières (MSF) Austria
edith.rogenhofer@vienna.msf.org

ABSTRACT

Critical information on refugee/internally displaced people (IDP) camps can be provided to humanitarian organisations to support planning of emergency response and relief using multi-temporal and multi-scale information from satellite imagery and GIS data. Since 2011 we are providing Earth observation-based information services to Médecins Sans Frontières (MSF) on demand. A service on population monitoring has already reached an operational stage. Thereby indicators on population are derived by automated dwelling extraction from (multi-temporal) very high resolution (VHR) satellite imagery. Based on such information, further added-value products are provided to analyse internal camp structure or camp evolution. Two additional services to support groundwater extraction and assess the impact of the camps on the environment are currently under development. So far twenty-five sites in nine countries have been analysed and more than a hundred maps were provided to MSF and other humanitarian organisations.

Keywords

Geospatial information products, satellite imagery, OBIA, humanitarian operations, refugee/IDP camps

INTRODUCTION

Over the past years, the humanitarian community has adopted geospatial techniques rapidly. From grassroots to governing levels, including Non-Governmental Organisations (NGOs) and United Nations (UN) institutions, GIS and Earth observation (EO) have become one of the key enabling technologies in humanitarian action. Supporting logistics in humanitarian mission planning and disaster mitigation, geospatial methods and tools have emerged from a niche to crowd technology. On a specialized level, geospatial technology is used for more complex and analytical analyses, for instance the monitoring of crises onsets and related population displacement or the environmental carrying capacity of a region to host large numbers of refugees.

We have supported and partly initiated these technological trends by developing workflows and dedicated tools for population monitoring, groundwater exploration, environmental impact assessment or land degradation. These dedicated geospatial information products are mainly designed for supporting humanitarian operations in refugee camps and camps for internally displaced people (IDP), when the required mission-critical information cannot be gathered in a proper timeframe by actors on the ground. In contrast to conventional field mapping and information gathering on the ground, there are several benefits of using EO data. Other than field data, remotely sensed data can be acquired for non-accessible areas nearly all over the world, they are an objective source of information that can - depending on the spatial resolution - cover large areas under equal conditions and provide up-to-date information. Additionally, remote sensing imagery provides up-to-date information and can be used for constant monitoring of future time steps and – if available in the archives - be acquired for past time series to see how a situation looked like before a critical situation emerged *(Lang, Füreder, Kranz, Card, Shadrock and Papp, in press; Hagenlocher, Lang and Tiede, 2012)*. In awareness of these benefits, we have developed an EO-based service for population monitoring within refugee/IDP camps and temporary settlements, operationally available and used by Médecins Sans Frontières (MSF) since 2012. This service utilises (multi-temporal) very high resolution (VHR) satellite imagery to derive information on amount and spatial distribution of dwellings, dwelling density, camp extent, internal camp structure as well as general growth of the camp. Two more EO-based information services are currently under development – on water exploration and environmental impact. Besides these services, ad-hoc information derived from EO data is requested by MSF from time to time. So far, this included land cover information for HAT (Human African trypanosomiasis/Sleeping sickness) and malaria vector control program planning to display the natural habitats of the Tsetse fly and Anopheles mosquito, support for cholera intervention and information on regular flooded areas for planning suitable sites for hospitals. Since 2011 EO-based information was provided to MSF for twenty-five sites in nine countries, with a main focus on IDP camps in the Republic of South Sudan (see Figure 1). More than a hundred map products were delivered to cover more than fourty requests.

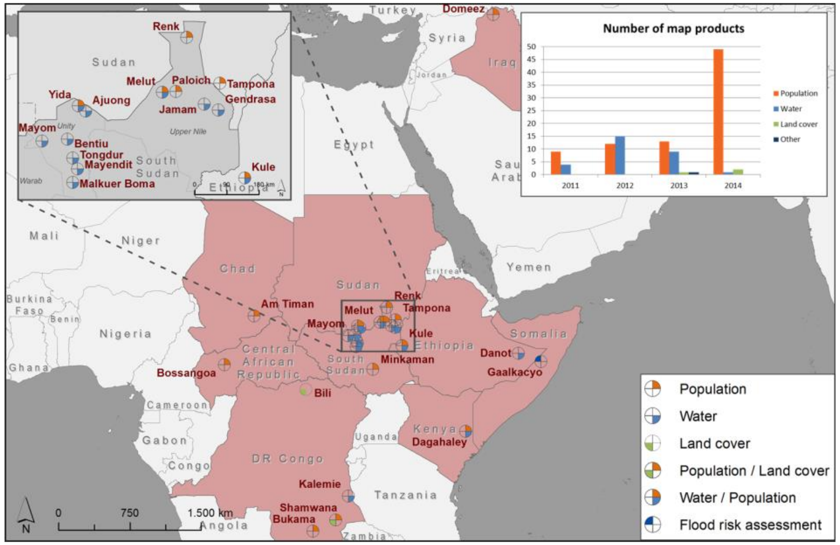

Figure 1: Overview of sites where EO-based information on population, water and/or land cover has been requested by MSF between 2011 and 2014.

EO-BASED POPULATION MONITORING

EO-based information on camp population and camp development can be provided in each phase of humanitarian crisis response (Figure 2). In the emergency phase, when humanitarian aid workers start to arrive on site or information about the number and exact location of displaced people is only vague, satellite images provide fast information on the situation on the ground. This can save important time and resources (staff, logistics and cost) as humanitarian organisations do not have to send their teams to areas where no indications for displaced people are found. For camps in the setup and construction phase with high dynamic and self-settling activities, satellite images can be used for monitoring the camp evolution, providing indicators for population estimates and assisting in planning logistical infrastructure and services such as health care or vaccination campaigns. This information can also be valuable for semi-permanent camps in the care and maintenance phase. These camps can still have spontaneous influx of refugees/IDPs if e.g. the security situation is worsening or extreme drought events are threatening food security, and information from the field might be unreliable.

Figure 2: EO-based information to fulfil different requirements of MSF field teams in different phases of humanitarian crisis response.

Object-based information extraction

The majority of EO-based information in the context of disaster management is currently retrieved by visual image interpretation if the focus is on detailed analyses (e.g. buildings/dwellings, roads, infrastructure facilities, etc.) *(Lang et al., in press)*. Visual interpretation is performing quite well at sites where individual structures are clearly distinguishable, however, their robustness is limited for complex situations (e.g. attached roofs, different roof materials, clouds or interpretation of multi-spectral information). The critical issues of visual interpretation are the time and costs needed for interpretation, which are increasing with the area and amount of features to extract respectively *(Checchi, Stewart, Palmer, Grundy 2013, Spröhnle, Tiede, Schoepfer, Füreder, Svanberg and Rost, 2014)*. In addition the results might be quite inconsistent if the interpretation is carried out by various analysts *(Voigt, Schoepfer, Fourie and Mager, 2014)*.

Automated methods are still limited for operational applications of complex situations but have their advantages in being scalable (regarding size and amount of features to extract), transferable *(Lang et al., in press)* and extendable to new satellite sensor types (e.g. 8-band WorldView-2 data). Monitoring large and highly dynamic camps demands automated analysis. Using object-based image analysis (OBIA, see e.g. *Blaschke, Hay, Kelly, Lang, Hofmann, Addink, Queiroz Feitosa, van der Meer, van der Werff, van Coillie and Tiede, 2014*) we have developed algorithms for dwelling extraction over several years for various camps mainly located in Eastern Africa (c.f. *Tiede, Füreder, Lang, Hölbling and Zeil, 2013*). These algorithms are coded in Cognition Network Language (CNL) within the eCognition development environment (Trimble Geospatial Imaging). They are continuously improved for increasing the robustness and degree of automation (cf. *Lang, Tiede, Hölbling, Füreder and Zeil, 2010*). OBIA has advantages if applied to VHR images, where image-objects are visually composed of many pixels: OBIA addresses the individual objects (here: dwellings) making use of features including the spectral and spatial characteristics (size, form), as well as their relations to others (neighborhood, hierarchical properties etc.) Results are provided in GIS-ready format as polygon layers.

Depending on the camp situation, different dwelling types are distinguished according to their spectral behaviour (i.e. colour), as well as size and form: white/blue tents, dwellings with iron roof, traditional round huts (tukuls), dark/brown dwellings, large/small structures. The algorithms were tested in real-time exercises and benchmarking studies, before being applied operationally *(Tiede et al. 2013)*. The degree of automation depends on the camp structure (e.g. dwelling types and their spectral response, dwelling density), image quality, image resolution (spatially and spectrally), geographical setting and season (e.g. contrast of dwellings can be lower in dry season) (*Füreder, Tiede, Lüthje and Lang, 2014*). For complex situations (e.g. dwellings with low contrast to the surrounding, attached dwellings, different building materials used etc.) manual refinement is needed to provide reliable results in an operational context. To refine the results of the automated classifications we developed a toolbox for object-based manual post-classification *(Tiede et al. 2013)*, supporting interpreters by segmentation and semi-automated digitizing.

The information on single dwellings can be further enriched by spatial analyses and the integration of additional GIS data (see Figure 3). Distance maps, e.g. how many dwellings are within a specific distance to boreholes, hospitals, latrines, etc., can be calculated to support camp planning. Aggregated information of single dwellings often provides a better overview of a situation as well as certain patterns in the arrangement of the dwellings within a camp. Dwelling density calculations show where the population in a refugee camp is concentrated, while the aggregation of dwellings to camp zones provides additional important information for camp planning. Camp structure analyses show predominant dwelling types within a flexible reporting unit (e.g. regular grids, hexagons). For monitoring purposes, multi-temporal analyses assist change assessments between two or more time stamps. These changes can be reported on single objects for smaller and highly dynamic camps and/or for larger reporting units to provide an easy-to-grasp overview of major changes.

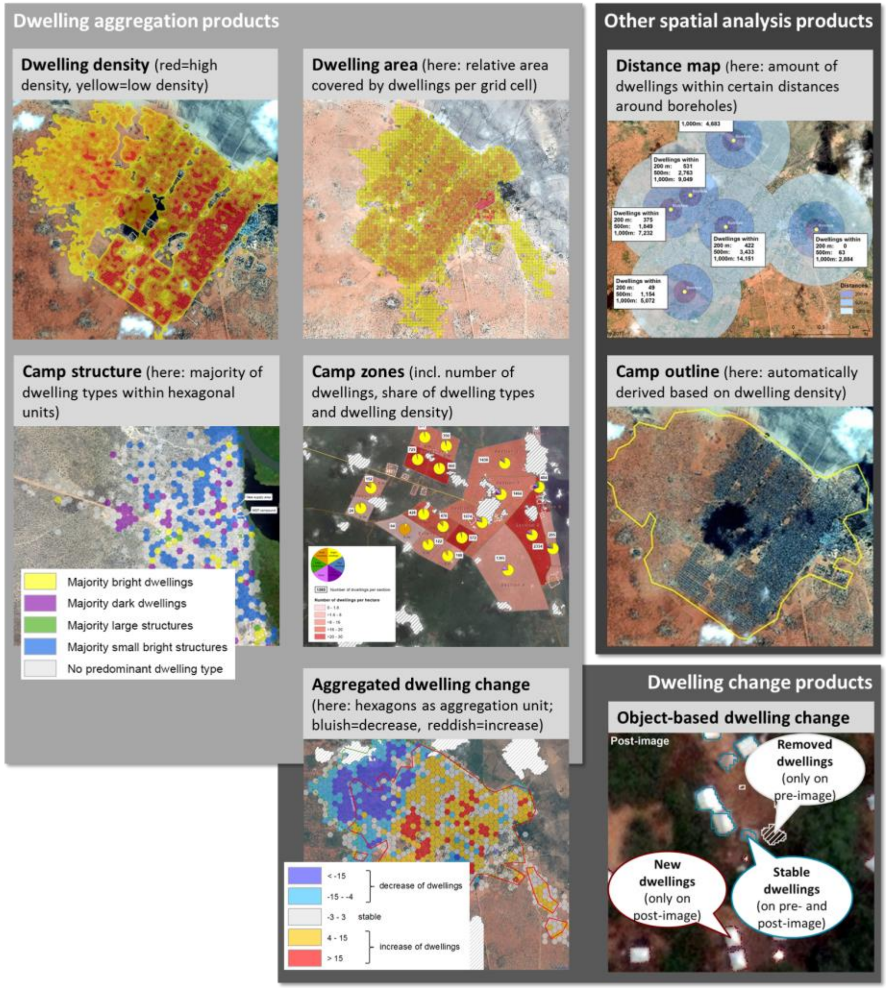

Figure 3: Added value products of dwelling extraction

A recently conducted assessment of user requirements among several humanitarian organisations revealed some additional ideas for supporting camp management: using data on extracted dwellings to assess if camp standards (e.g. from the Sphere Project) are met (e.g. distance between dwellings, distance from dwellings to tabs or latrines etc.) or providing a fast indication product, which focusses on easy-to-extract dwellings.

The final information is provided in different formats depending on the user's needs: in the form of geospatial PDF Maps (enables distance measures, retrieving coordinates and turning on/off single layers), Google Earth's KML/KMZ-Format (incl. legend, logo and satellite image streamed via ArcGIS Server), as interactive web service via ArcGIS Online and/or as GIS data layers.

GROUNDWATER EXPLORATION

One of the most important tasks for humanitarian organisations is the supply with sufficient potable water. While the immediate demand can be met by purification of surface water or transport from other areas ("water trucking"), the exploitation of local groundwater resources is usually the best option on the longer term. This requires an assessment of the hydrogeological situation within a short time frame despite missing or unavailable detailed geological or hydrogeological maps. We develop workflows and procedures to rapidly provide hydrogeological reconnaissance maps based on freely available remote sensing and geological data *(Wendt, Hilberg, Robl, Hochschild, Rogenhofer, Füreder, Lang and Zeil, 2014)*. The digital elevation model (DEM) from SRTM is used to extract the drainage system and to estimate the flow direction of surface run-off and groundwater. In hard rock environments, Landsat and ASTER imagery can be used to map rock types and to identify geological structures that are preferred groundwater conduits. In areas characterized by unconsolidated sediments, specific landforms like deltas, braided rivers or alluvial fans are mapped, as they indicate relatively coarse-grained, permeable material (Figure 4). The geological information is combined with available data on existing wells and boreholes and on potential sources of pollution, such as settlements, camps, landfills or mines. Under favourable conditions, these maps allow the planning of save and productive groundwater abstraction sites without further geological field work. In more complex situations, they act as overview maps to identify target areas for detailed field investigations, for example using geoelectric sounding methods.

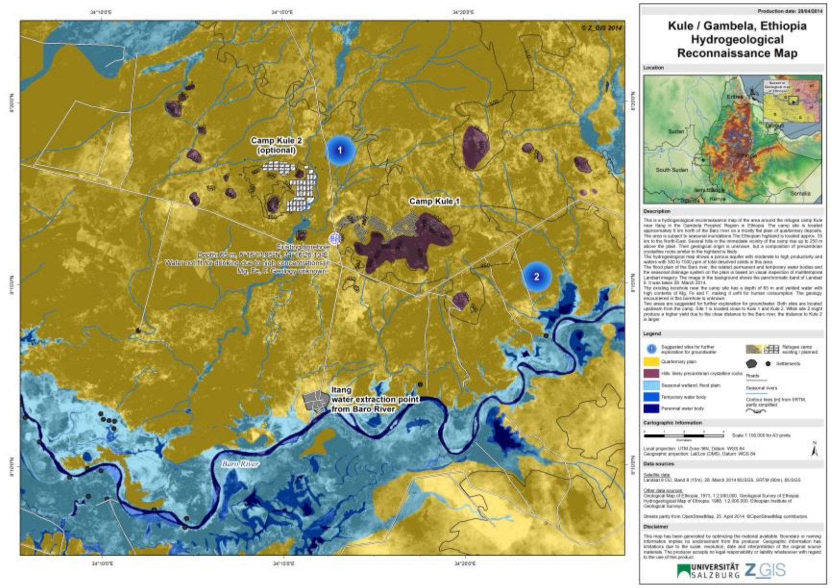

Figure 4: Example for a hydrogeological reconnaissance map in a sedimentary environment, using Landsat and SRTM data. Areas threatened by flooding, which are unfavourable locations for wells, are mapped blue.

ENVIRONMENTAL IMPACT ASSESSMENT

Evidence has shown that the sudden influx of large numbers of refugees or IDPs into an area can place severe pressure on the local environment, its carrying capacity and existing natural resources (c.f. *Hagenlocher et al., 2012*). Severe deforestation, desertification, land degradation, unsustainable groundwater extraction and groundwater pollution are impacts that can be observed in the surroundings of many refugee/IDP camps. As part of the "environmental impact service", information on the environmental impact of refugee/IDP camps is provided on three different levels. The first level consists of a basic change detection of vegetation cover between two points in time. This assessment is relatively simple and allows a fast identification of areas with significant environmental change. If required, level 2 is applied, a detailed land cover change detection showing changes of specific classes like tree cover, agricultural land, water bodies and other relevant land use/land cover (LULC) target classes. Ultimately, implications of observed environmental changes on human well-being (i.e. food and livelihood security) and ecological integrity (i.e. state of ecosystems) are assessed on level 3 *(Hagenlocher, Tiede, Wendt, Lang, submitted)*.While level 1 and 2 products are based on analysing and classifying multi-temporal optical high resolution (HR) and VHR satellite imagery using pre-classification routines and OBIA, we use the Weighted Natural Resource Depletion Index *(Hagenlocher et al., 2012)* to provide geospatial information on the implications of environmental change based on changes in selected LULC target classes.

CONCLUSIONS

In humanitarian crisis situations the people in need are the primary beneficiaries of humanitarian action. Humanitarian aid should reach those who are suffering in an effective, well-directed and rapid manner. Humanitarian aid organisations, through their mandates and missions, ensure that humanitarian action is targeted to the right people at the right place at the right time. NGOs such as MSF, rely on up-to-date (often even near 'real-time') information to plan and direct their operations and respective logistics. In this regard the usage of new technologies as applied in our collaboration with MSF can contribute to increasing the efficiency and effectiveness of the support measures carried out by humanitarian agencies in refugee/IDP camps. Direct user feedback is very important to ensure certain quality standards, further improve the products (according to user needs), and to provide the required information in the right format.

ACKNOWLEDGEMENTS

The presented work was co-funded by the Austrian Research Promotion Agency (FFG) under the Austrian Space Application Programme (ASAP) within the project EO4HumEn (contract no: 840081). Direct funding has been received by Médecins Sans Frontières (MSF) Austria and the Karl Kahane Foundation.

REFERENCES

1. Bjorgo E. (2001) Supporting humanitarian relief operations. In: JC Baker, KM O'Connell, RA Williamson (eds.) Commercial observation satellites: at the leading edge of global transparency. ASPRS RAND, Santa Monica, CA, 403-427.
2. Blaschke, T., Hay, G.J., Kelly, M., Lang, S., Hofmann, P., Addink, E., Queiroz Feitosa, R., van der Meer, F., van der Werff, H., van Coillie, F. and Tiede, D. (2014) Geographic Object-Based Image Analysis – Towards a new paradigm. *ISPRS J Photogramm*, 87, 180–191.
3. Checchi, F., Stewart, B., Palmer, J. and Grundy C. (2013) Validity and feasibility of a satellite imagery-based method for rapid estimation of displaced populations. *International Journal of Health Geographics*. 12(1), 4.
4. Füreder, P., Tiede, D., Lüthje, F. and Lang, S. (2014) Object-based dwelling extraction in refugee/IDP camps-challenges in an operational mode. *South-Eastern European Journal of Earth Observation and Geomatics*. 3 (2S), 539-44.
5. Hagenlocher, M., Lang, S. and Tiede, D. (2012) Integrated assessment of the environmental impact of an IDP camp in Sudan based on very high resolution multi-temporal satellite imagery. *Remote Sensing of Environment*, 126: 27-38.
6 Hagenlocher, M., Tiede, D., Wendt, L. and Lang, S. (submitted) An Earth Observation-based Approach for the Assessment of the Environmental Impact of Refugee and IDP Camps. *GI_Forum 2015, Geospatial Minds for Society*, Salzburg.
7. Lang, S., Füreder, P., Kranz, O., Card, B., Roberts, S. and Papp, A. (in press). Humanitarian emergencies: causes, traits and impacts as observed by

remote sensing. In: P. Thenkabail (ed.), *Remote Sensing Handbook, Volume III: Water Resources, Disasters, and Urban*, pages pending.

8. Lang, S., Tiede, D., Hölbling, D., Füreder, P. and Zeil, P. (2010) Earth observation (EO)-based ex post assessment of internally displaced person (IDP) camp evolution and population dynamics in Zam Zam, Darfur. *International Journal of Remote Sensing*. 31(21), 5709-5731.

9. Spröhnle, K., Tiede, D., Schoepfer, E., Füreder, P., Svanberg, A. and Rost, T. (2014) Earth Observation-Based Dwelling Detection Approaches in a Highly Complex Refugee Camp Environment — A Comparative Study. *Remote Sensing*. 6(10), 9277-97.

10. Tiede, D., Füreder, P., Lang, S., Hölbling, D. and Zeil, P. (2013) Automated Analysis of Satellite Imagery to provide Information Products for Humanitarian Relief Operations in Refugee Camps - from Scientific Development towards Operational Services. *PFG Photogrammetrie, Fernerkundung, Geoinformation*. 2013(3), 185-95.

11. Voigt, S., Schoepfer, E., Fourie, C. and Mager, A. (2014) Towards semi-automated satellite mapping for humanitarian situational awareness. *Global Humanitarian Technology Conference (GHTC), 2014 IEEE*, 412-416.

12. Wendt, L., Hilberg, S., Robl, J., Hochschild, V., Rogenhofer, E., Füreder, P., Lang, S. and Zeil, P. (2014) Assisting the Exploration of Groundwater near Refugee/IDP Camps using Remote Sensing and GIS. In: DGPF (ed.) *Gemeinsame Tagung 2014 der DGfK, der DGPF, der GfGI und des GiN, DGPF*, Hamburg.11.