

---

# Applying Satellite Imagery and Geospatial Techniques to Explore Patterns of Buruli Ulcer Prevalence in Central Cameroon

Elisabeth SCHOEPFER<sup>1</sup>, Konstanze LECHNER<sup>1</sup>, Edith ROGENHOFER<sup>2</sup>, Hannes RÖMER<sup>1</sup>, Lena HÜTTEN<sup>1</sup>, Alexander MAGER<sup>1</sup>, Kristin SPRÖHNLE<sup>1</sup>, Stefan VOIGT<sup>1</sup>, Andreas PAPP<sup>2</sup>, Eric COMTE<sup>3</sup> and Genevieve EHOUNOU<sup>3</sup>

<sup>1</sup>German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Oberpfaffenhofen/Germany · elisabeth.schoepfer@dlr.de

<sup>2</sup>Médecins Sans Frontières (MSF) Austria, Vienna/Austria

<sup>3</sup>Médecins Sans Frontières (MSF) Switzerland, Geneva/Switzerland

This contribution was double-blind reviewed as extended abstract.

## Abstract

Geospatial information obtained from satellite data can contribute in various ways in assessing and dealing with prevalence of diseases. In this study, patterns of Buruli Ulcer (BU) in Central Cameroon were analysed using satellite imagery and GIS techniques in order to provide a better understanding of spatial characteristics and possible transmission mechanism of BU. First, geospatial mapping of BU case data was performed to assess spatial patterns. Second, a qualitative assessment was conducted based on environmental factors and exposure variables to address the (relative) infection risk for BU in the study area.

## 1 Introduction

Buruli Ulcer (BU) is a neglected infectious disease caused by *Mycobacterium ulcerans*. The disease has been reported in more than 30 countries with tropical and subtropical climates (WHO 2012). There is still little knowledge on the distribution and mode of transmission of BU which can partly be explained by the fact that mostly poor rural communities are affected, leading to a poor documentation and reporting of cases. In 2002, the Médecins Sans Frontières (MSF) Health Centre in Akonolinga, Central Cameroon, was set up. During 2002 and 2010, more than 1100 patients have been treated in a dedicated BU programme. In order to be able to forecast and avoid BU infections in the future, a better understanding of the disease, its geospatial distribution, causes of infection and mode of transmission is still needed. This study comprised the mapping of BU case data in order to visualise the distribution of recorded BU cases in the study area, and furthermore, to identify spatial clusters and patterns which may indicate areas with an increased infection risk. Moreover, satellite imagery and geographic data were used to spatially map possible environmental

factors, e.g. land use / land cover, terrain elevation, population distribution, in order to model and possibly predict potential infection risk areas of BU.

## 2 Study Area and Data

The study area is located in the southeastern part of the Central Province of Cameroon, in the Department of Nyong-et-Mfoumou and covers an area of 69,000 sqkm. Mainly the two Arrondissements of Akonolinga and Endom (4,197sqkm) were analysed. Akonolinga is also the name of the provincial capital of Nyong-et-Mfoumou with 27,500 inhabitants. The town is located approximately 80 kilometers east of the Cameroonian capital Yaoundé.

High resolution satellite imagery from Landsat 5 and Landsat 7 were acquired at different dates between 1987 and 2011. While imagery from the years of 2001, 2002 and 2008 were used to extract land cover types and to detect land cover changes, imagery for 1987 and 2011 was applied for verification of extracted classes. Land cover was mapped for the entire study area in order to identify potential risk areas of infection. For a more detailed picture of the complex landscape and to validate the land cover information derived from Landsat imagery, a very high resolution QuickBird satellite image acquired on March 06, 2008 (© European Space Imaging / DigitalGlobe) with a spatial resolution of 0.6 m was analysed. In addition ancillary geographic data sets were used in this study. Data containing the location of villages, roads, rivers and land cover information for Cameroon was mainly derived from Global Forest Watch (MINEF et al. 2005) and complemented and extended by points of interest and single buildings, extracted by visual interpretation of the QuickBird satellite imagery. The administrative boundaries for the country, departments, provinces and Arrondissements of Cameroon were derived from the Database of Global Administrative Areas (GADM 2011). Additionally, MSF provided GPS coordinates for 99 villages with corresponding names. A digital elevation model (USGS 2004) as well as demographic data for the years 2002, 2004, 2008 and 2010 (UT-BATTELLE & LLC 2013) were included for the investigation of the risks of infection. Additionally, the human footprint (HFP) on the environment was obtained through the Columbia University's Center for International Earth Science Information Network (WCS, CIESIN & CU 2002). The HFP is the human influence index normalized by biome and realm. It was applied as an indicator for the degree of urbanization and to estimate local drinking water treatment capacities in the study area. The HFP was also used for assessing the risk of infection in the study area. BU case data was provided by MSF comprising anonymised cases that were treated at the MSF Health Centre in Akonolinga town. The cases were localised using the village names recorded with the cases.

## 3 Spatial Patterns Analysis

As a first step, the BU case data was visualised in a map. Each case was assigned to the home village of the corresponding patient, resulting in an overview of the spatial distribution of all cases. The cases are not evenly distributed among the villages. A clear concentration or clustering of BU cases can be detected around Akonolinga town, where the MSF Health Centre is located. A strong spatial clustering of BU cases was detected by

using geo-statistical measures. These results should not be misinterpreted as an indicator of an increased prevalence or risk of infection near Akonolinga town. According to the empirical study carried out by PORTEN et al. (2009), these findings are mainly the result of a general low level of awareness and lack of information about the presence of the MSF Health Centre for those people living in remote areas. Financial issues and the distance to the hospital were also mentioned as reasons for not consulting the health centre (PORTEN et al. 2009). A correlation analysis was carried out to investigate the statistical relationship between the number of cases and the distance to Akonolinga town, measured as the road distance as well as the direct Euclidean distance. For both distance measures, a clear negative correlation (significant for the 0.05 level) was detected with a correlation index of  $r = -0.50$  for the Euclidean distance and  $r = -0.57$  for the road distance. This indicates that the clustering around the MSF Health Centre might be biased by the location of the health facility.

#### 4 Qualitative Assessment of the Risk of Infection

A qualitative assessment of the risk of infection of BU was conducted based on environmental factors (EF) assumed of possibly having a significant impact on the risk of infection. Additionally, selected exposure variables (EV) were further integrated in order to assess both, habitat related factors derived from EVs, as well as aspects of behaviour, following the concept of human ecology as described in MEADE & ERICKSON (2000). Thus, in regard to the components of risk, habitat related factors represent the hazard, whereas the component of behaviour addresses the exposure component of risk. The applied approach to select EF was performed on the basis of a systematic evaluation of epidemiological studies documented in the literature. A total of 67 epidemiological studies on BU, with a regional focus on central Africa, were analysed. The survey showed that the occurrence of BU and many disease vectors are closely related to aquatic environments. High turbidity of water leads to increased water temperature and a high protection of *Mycobacterium ulcerans* against UV-radiation. These environments are partly a result of human activities, such as deforestation and agricultural / irrigation practices leading to an increase of surface water bodies and soil erosion. The latter can be seen as a cause for an increase of suspended sediments in surface water bodies. The geospatial distribution of environmental factors was derived from available satellite data (Landsat 5) and geospatial data sets. A differentiation between indirect<sup>1</sup> and direct<sup>2</sup> EF was carried out, depending on whether a factor was closely related or only a proxy for a specific habitat condition. Consequently, all indirect factors were treated as one factor and weighted less than the direct factor as they are only indirectly related to the underlying biophysical processes. The EF were used to map the qualitative potential risk of infection with BU (hazard component), not considering the spatial distribution of population which is exposed to this risk. Thus, this information was further combined with exposure variables (EV), in order to estimate the actual infection risk in the study area. The EV include the population as derived from demographic data for the years 2002, 2004, 2008 and 2010 (UT-BATTELLE & LLC 2013) and the HFP. The HFP was used

---

<sup>1</sup> Presence of natural surface water bodies, wetlands, swamps; population density.

<sup>2</sup> Presence of artificial dams / standing water bodies; intensity and type of agricultural practices; deforestation; topographic characteristics; urbanization / drinking water treatment.

as an estimator for urbanization and for local drinking water treatment capacities respectively. An explicit assessment of the vulnerability was not conducted in this study, however, relationships to vulnerability aspects arise from the use of the HFP data. The resulting maps of this qualitative assessment approach clearly show an increasing potential BU risk near the Nyong river in the centre as well as along the Nanaga river in the North of the study area. However, considering also the exposure variables, there are only few areas actually showing a high actual infection risk for BU.

## 5 Conclusions and Outlook

In this pilot study the potential of using satellite and geospatial data to contribute to a better understanding of spatial characteristics and possible causal mechanism of BU was identified. There are still uncertainties regarding the transmission of BU and research focuses on proofing of hypotheses and on spatial modelling of infection risk of BU. Thus, future investigations should combine systematically collected BU case data with satellite derived environmental and geographic data to enable better correlation and more significant geostatistical analysis allowing pre-identification of priority areas for medical interventions.

## References

- GADM DATABASE OF GLOBAL ADMINISTRATIVE AREAS (2011), GADM database of Global Administrative Areas. <http://www.gadm.org/home>.
- MEADE, M., S. & EARICKSON, R. J. (2000), Medical Geography. The Guilford Press, New York.
- MINISTRY OF ENVIRONMENT AND FORESTS OF CAMEROON (MINEF), TECSULT INC. & CANADIAN INTERNATIONAL DEVELOPMENT AGENCY (CIDA) / WORLD RESOURCES INSTITUTE (WRI) (2005), Global Forest Watch. <http://www.globalforestwatch.org>.
- PORTEN, K., SAILOR, K., COMTE, E., NJIKAP, A., SOBRY, A., SIHOM, F., MEVA'A, A., EYANGO, S., MYATT, M., NACKERS, F. & GRAIS, R. F. (2009), Prevalence of Buruli Ulcer in Akonolinga Health District, Cameroon: Results of a Cross Sectional Survey. *PLoS Negl Trop Dis*, 3(6).
- UNITED STATES GEOLOGICAL SERVICE (USGS) (2004), Shuttle Radar Topography Mission, 3 Arc Seconds scenes N03E011/N03E011/N04E012/N04E012, Unfilled Unfinished 2.0, Global Land Cover Facility, University of Maryland, College Park, Maryland.
- UNIVERSITY OF TENNESSEE – BATTELLE MEMORIAL INSTITUTE (UT-BATTELLE) & LLC (2013), LandScan 2002, 2004, 2008, 2010, developed under Prime Contract No. DE-AC05-000R22725 with the U.S. Department of Energy.
- WILDLIFE CONSERVATION SOCIETY (WCS), CENTER FOR INTERNATIONAL EARTH SCIENCE INFORMATION NETWORK (CIESIN) & COLUMBIA UNIVERSITY (2002), Last of the Wild Project, Version 1, 2002 (LWP-1): Global Human Footprint Dataset (Geographic), Socioeconomic Data and Applications Center (SEDAC), Columbia University, Palisades, NY.  
[http://gcmd.gsfc.nasa.gov/records/GCMD\\_CIESIN\\_SEDAC\\_LWP\\_HFP\\_IGHP.html](http://gcmd.gsfc.nasa.gov/records/GCMD_CIESIN_SEDAC_LWP_HFP_IGHP.html).
- WORLD HEALTH ORGANIZATION (WHO) (2012), Number of new cases of Buruli ulcer reported. [http://apps.who.int/neglected\\_diseases/ntddata/buruli/buruli.html](http://apps.who.int/neglected_diseases/ntddata/buruli/buruli.html).