TRANSFERABILITY OF OBIA RULESETS FOR IDP CAMP ANALYSIS IN DARFUR

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ABSTRACT:

The analysis of refugee and IDP (internally displaced persons) camps from VHSR (very high spatial resolution) satellite imagery can assist humanitarian relief organisations by providing population estimations and camp structure analysis based on automated dwelling extraction. Since smooth transferability of rulesets in a fine scale and high complexity environment is limited, we present an approach of developing and transferring master rulesets. The master ruleset aims to automate OBIA (object-based image analysis) tasks which can be seen as more or less independent from different sensors and geographic areas, such as adapted segmentations based on edge densities to delineate man-made structures or classifications based on shape and context. Only some steps within the classification process which are based on hard-coded values (size constraints, spectral thresholds) have to be adapted. This approach reduces the time required to analyse different IDP camps or the same camp at different times. In previous work, the master ruleset has been developed for the IDP camp Zam Zam in Darfur, Sudan, using QuickBird imagery. In the study presented, the transferability of object-based image analysis rulesets was tested in a demonstrator exercise according to a request posed by the World Food Program (WFP). The aim was to extract dwelling structures and variations in dwelling densities in three IDP camps in West Darfur for estimating population figures using GeoEye-1 imagery. Results were validated using independent visual interpretation, showing high agreement for all dwelling density classes and absolute numbers of extracted dwellings (15,349 automated dwelling structures versus 14,261 visually extracted dwelling structures) for the IDP camp Um Dukhun. In the other two camps, however, the areas of higher dwelling density were apparently underestimated by the automated approach.

1. INTRODUCTION

1.1 Internally displaced persons

According to the United Nations High Commissioner of Refugees (UNHCR), approximately 42 million people are forcibly displaced because of conflict, violence and human rights abuses, including 26 million people which have been displaced within their countries (internally displaced persons, IDPs; UNHCR, 2009). These IDPs are people who had to flee or to leave their homes but stayed within their country of origin without crossing any international state border (IDMC, 2009). Darfur is only one of many conflict areas in Sudan, the country with the single largest internally displaced population in the world (4.9 million IDPs by the end of 2009; UNHCR, 2009).

1.2 Remote sensing of IDP camps

The analysis of refugee and IDP camps from VHSR (very high spatial resolution) satellite imagery can assist humanitarian relief organisations by providing population estimations and camp structure analysis based on automated dwelling extraction (Lang et al., in press). This is especially true in a regional crisis context where security constraints are hampering the work on the ground. By now, some studies have exemplarily shown that such IDP and refugee camp analyses are methodologically sound (e.g. Giada et al., 2003; Laneve et al., 2006; Lang et al. 2006; Tiede and Lang, 2009), but when it comes to more operational tasks the algorithm development still requires too much effort and the transferability to different areas and different sensors is limited, especially in a fine scale and high complexity environment.

Within the EU funded GMES (Global Monitoring for Environment and Security) project LIMES (Land and Sea Integrated Monitoring for European Security; http://www.fp6-limes.eu/) the cluster *Humanitarian Relief & Reconstruction* is working towards such operational solutions (Kranz et al., 2010). Out of these experiences we present an approach of developing and transferring *master rulesets*, minimizing the required adjustments for transferability between different sensors and geographical areas. Developed for the IDP camp Zam Zam in Northern Darfur using QuickBird imagery, transferability was tested in a demonstrator exercise according to a request posed by the World Food Program (WFP) to estimate population figures for three IDP camps in West Darfur based on GeoEye-1 imagery.

2. DATA AND METHODS

2.1 Study area and data

The three IDP camps Dorti, Ardamata and Um Dukhun are located in West Darfur, Sudan (see Fig. 1). Dorti and Ardamata lie close to El-Geneina, the capital of West Darfur and are almost connected to each other. The IDP population according to the United Nations (2009) in Ardamata is about 27,300 and in Dorti approximately 9,400. The population of Dorti was nearly stable in the last years whereas the number of IDPs in Ardamata steadily increased from 22,000 IDPs in 2006 (UN,

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2006; UN, 2009). Um Dukhun is located in the south of West Darfur just next to the border with Chad and less than 30 kilometres from the border to the Central African Republic (CAR). The camp is situated around a wadi and bounded by a larger wadi in the southeast and the Chadian border in the west and northwest. Developed from a former small town before the crisis in Darfur, it consists of a mixture of permanent residents, IDPs and refugees coming from Chad and the CAR (OXFAM, n.d.). Its IDP population in January 2009 was about 55,500 (56,540 total population) which is an increase of more than 47 % compared to July 2006 (UN, 2009).

Figure 1. IDP camps Dorti, Ardamata and Um Dukhun in West Darfur, Sudan next to the Chadian border

The camp structure is similar in all three camps. Several dwellings are bounded by fences or walls and build nearly square compounds, which are aggregated to residential blocks, separated by roads. Dwellings in the camps are either traditional round huts (known as *rondavels,* see Fig. 2) or tents. According to the cover and size of the dwellings several types can be distinguished: bright dwellings, corrugated-iron huts (e.g. market place in the southeast of Um Dukhun), dwellings with similar spectral reflectance as bare soil, large dwellings like schools, markets, clinics etc.

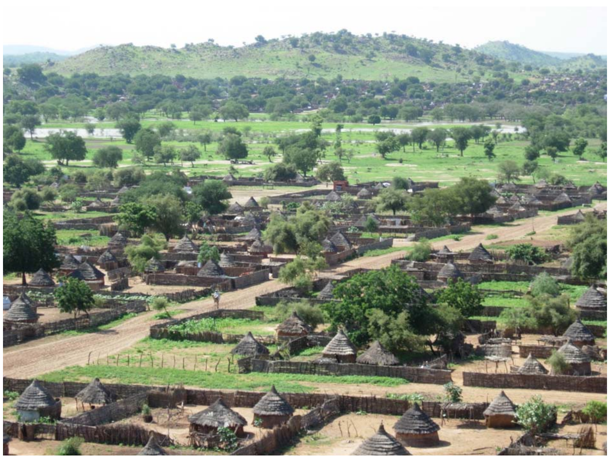

Figure 2. Traditional round huts (*rondavels*) in Um Dukhun

For the three IDP camps two GeoEye-1 satellite images were acquired from May 14th, 2009. One image covers the IDP camps Dorti and Ardamata as well as El Geneina, the other one shows the camp Um Dukhun. The images were made available in pan-sharpened (0.5 m spatial resolution) as well as orthorectified format and included a near infrared band (NIR) and three optical bands. The data was delivered in WGS 84, UTM Zone 34N.

2.2 Master ruleset development for the extraction of dwelling structures

Object-based image analysis (OBIA) relies on rulesets that allow for controlling the behaviour of segmentation and classification (sub-)routines for an explicit knowledge representation during the entire image analysis process. Since smooth transferability of rulesets in a fine scale environment with high complexity is limited, we present an approach of developing and transferring so-called master rulesets. It reduces the time required to analyse different IDP camps or the same camp at different times. The approach aims to automate OBIA tasks for the extraction of dwelling structures in IDP/refugee camps towards the use in operational tasks in the area of humanitarian relief operations.

The initial ruleset was developed for a different IDP camp (Zam Zam) in Northern Darfur, based on QuickBird imagery from 2004 (Lang et al., in press). It was designed in such a way that the number of absolute thresholds was minimized. Two other QuickBird scenes, from 2002 and 2008, were used to prove the transferability of the technique in the multitemporal case.

The master ruleset has been developed in CNL (Cognition Network Language), a modular programming language for object-based image analysis, implemented in the eCognition software environment. It relies on two main steps:

(1) Delineation of the camp margin

Edge detection algorithms were included in the ruleset as important parameters for any class description containing anthropogenic features (De Kok and Wezyk, 2008). In the case of IDP camps the anthropogenic features are not only the dwelling structures themselves, but also the typical fences or walls between the dwelling structures. Lee-Sigma filtering (Lee, 1983) was applied and the resulting layers (dark and bright edges) were included as additional object features in the classification process. Merging objects with a higher proportion of edges on a coarser scale led to a rough delineation of the camp margin. The following dwelling structure delineation can concentrate on the camp area only, avoiding the detection of false positives outside of the camp.

(2) Dwelling structure delineation and classification within the camp area

Initial object delineation was achieved by applying a region-based, *local mutual best fitting* segmentation approach (Baatz and Schäpe, 2000) within the delineated camp area. Parameterization of the segmentation can be semi-automatically supported using a tool called ESP (*Estimating Scale Parameter*s, Dragut et al. 2010). By applying *class modelling* (Tiede et al. 2010) the image objects were refined in a cyclic, adaptive manner to represent meaningful target objects, in this case the targeted dwelling structures. Spatial characteristics of the different dwelling types and their relative position to each other were utilized together with the relative spectral differences between the delineated objects. This enabled for example the identification of bright dwellings being characterised by darker neighbours, and the isolation of dark fences which were attached to dark dwelling structures (Lang et al., in press).

The use of spectral threshold values for the classification process has been kept to a minimum. Thresholds based on absolute spectral values e.g. for differentiation between areas with and without vegetation (NDVI threshold) and different dwelling types were determined at the beginning of the ruleset and saved as variables; these values have to be adapted only once while being transferred to another data set. They were then used automatically in the calculations and combined with the independent spectral parameters.

2.3 Ruleset transferability

Transferability was tested in a demonstrator exercise following a request posed by the World Food Program (WFP). Dwelling structures should be extracted for three IDP camps in West Darfur based on GeoEye-1 imagery for estimating population figures. Challenges, as compared to the ruleset developing conditions, were mainly the changing sensor and slightly different dwelling types. Similar geographical conditions were supportive for the transferability. Adaptation of the master ruleset was done by visual on screen inspection of the three camp areas and the definition of the required spectral thresholds for distinguishing between the different dwelling classes and the NDVI threshold for the separation of vegetation. This reduced significantly the time required to analyse the IDP camps in a series, as ruleset development 'from scratch' is avoided.

2.4 Validation

The collection of ground truth data is a major constraint for such conflict areas, especially in the level of detail which was needed in this research. Therefore an independent manual interpretation based on the satellite images of the IDP camps was conducted by DLR (German Aerospace Center), one of the partners within this demonstrator task. Being aware that visual interpretation is also subject to errors, it was the only possibility to get comparative figures for the study areas. The results of both visual and automated detection were compared (1) in absolute numbers of the extracted dwellings and (2) in an aggregated form based density zones. For the latter the extracted dwellings were analysed using kernel density (Silverman, 1986). The kernel density (dwellings/km²) was calculated using point features - in this case the centroids of the dwelling structures - on an output raster cell size of 10 m x 10 m.

3. RESULTS AND DISCUSSION

For the area of Dorti 2,523 dwelling structures were automatically extracted, of which 1,153 were bright structures (tents or tarpaulins including 282 corrugated iron huts) and 1,316 were dark structures (mostly traditional rondavels), 54 other dwelling types were detected.

In Ardamata altogether 2,261 bright dwellings (incl. 252 corrugated iron huts), 1,575 dark dwellings and 129 other types sum up to a total of 3,965 extracted dwelling structures.

For the largest IDP camp, Um Dukhun (see Fig. 3 and Fig. 4), the algorithm found 15,349 dwelling structures in total (7,761 bright dwellings, incl. 1,610 corrugated iron huts, 6,531 dark dwellings and 1,057 others). Table 1 lists the results of the automated approach and the results of the visual interpretation.

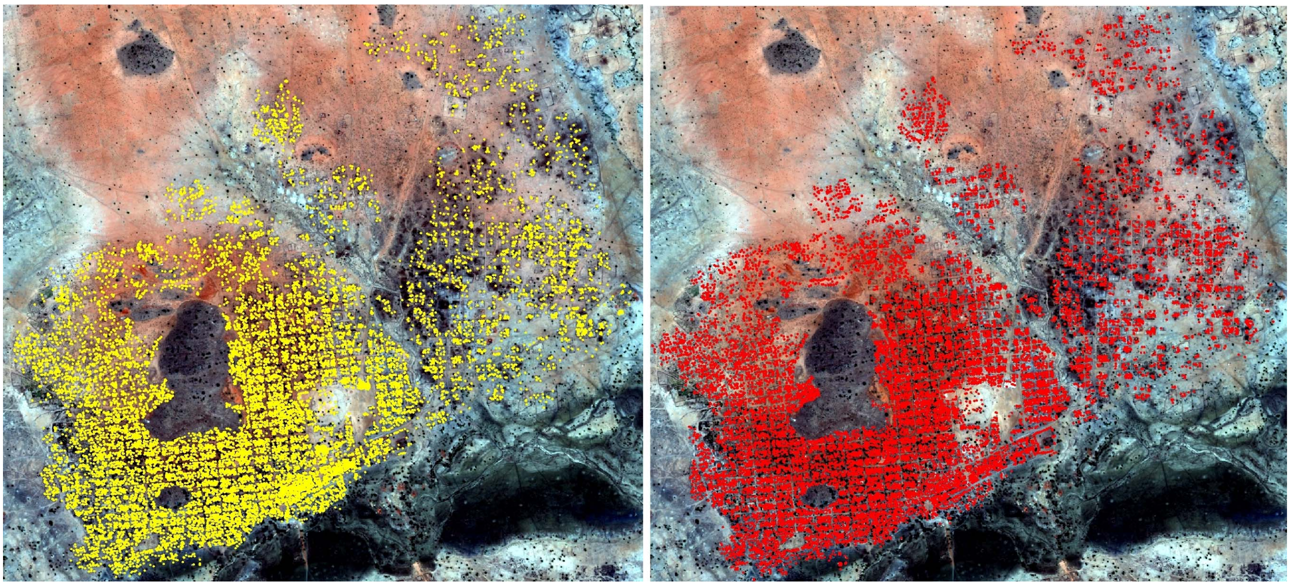

Figure 3. Automatically extracted dwelling structures for Um Dukhun (left, 15,349 dwelling structures in total) and manually digitized dwelling structures (right, 14,261 in total), not distinguishing between different classes

Figure 4. GeoEye-1 subset of the Um Dukhun area (300 m x 240 m, band combination 4-3-2, left) and automatically extracted dwelling structures for the same subset (right). Colour indicates different classes: purple = rondavels; orange = bright dwelling structures; turquoise = corrugated-iron huts; green = other dwelling types)

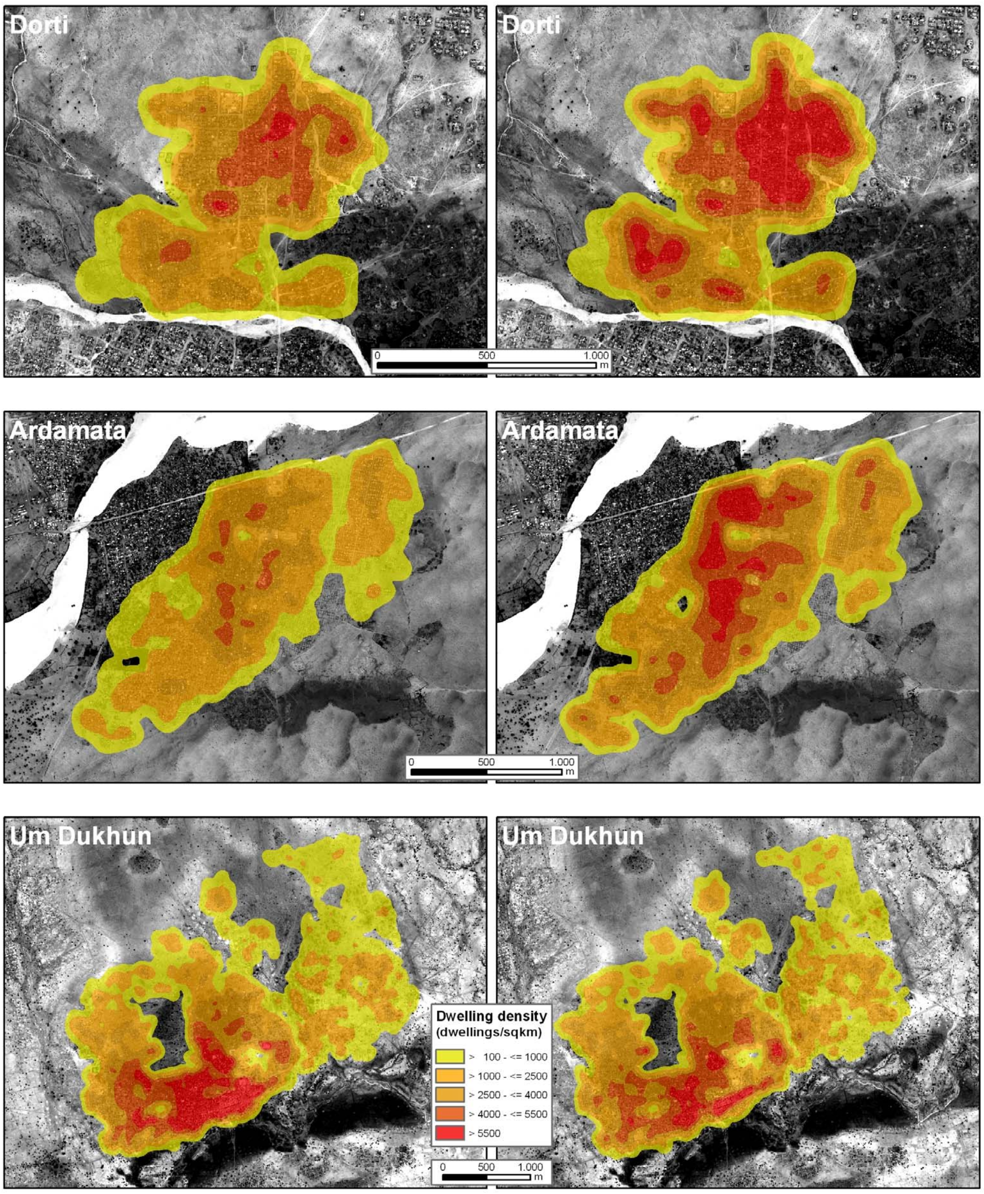

Figure 5. Comparison of density estimations for the three IDP camps based on automatically extracted dwellings (left) and manually extracted dwelling structures (right) using the same thresholds for the density zoning. Red tones indicate higher densities (see legend)

Dwelling types	Automated extraction	Visual interpretation
Dorti		
dark dwellings	1,316	1,640
bright dwellings	1,153 (incl. 282 corrugated-iron huts)	1,951
other	54	47
total	***2,523***	***3,638***
Ardamata		
dark dwellings	1,575	2,724
bright dwellings	2,261 (incl. 252 corrugated-iron huts)	3,575
other	129	100
total	***3,965***	***6,399***
Um Dukhun		
dark dwellings	6,531	6,793
bright dwellings	7,761 (incl. 1,610 corrugated-iron huts)	7,334
other	1,057	134
total	***15,349***	***14,261***

Table 1. Comparison of automated dwelling extraction and visual interpretation. Note: the automated approach included the class *corrugated-iron hut*, which was merged with the class *bright dwellings* for comparison with the visual interpretation

The comparison of the automated extraction with the visual interpretation shows an underestimation of dwelling structures for bright and dark dwelling types in the IDP camps Dorti and Ardamata and a slight overestimation for Um Dukhun. Figure 5 compares dwelling density maps calculated for both extraction methods. The density maps for Um Dukhun show a high visual agreement, indicating not only similar absolute extracted values but especially also a spatial explicit consistency. In contrast, the maps for the other two camps are showing such an agreement in the lower density classes and for the highest peaks. On the other hand, in the higher density classes an underestimation by the automated approach is clearly visible. Additional visual inspection showed that this is mainly related to dwellings with similar spectral reflectance as bare ground which are therefore not counted by the automated approach (see Fig. 6). These dwelling types are almost not occurring in the Um Dukhun camp area.

4. CONCLUSIONS

Using density zones instead of comparing single individual dwelling units was chosen with respect to higher readability and intuition of the extracted information. Since these products are meant to support humanitarian action including decision making processes under abnormal conditions, this aggregated way of presenting the extracted information has been chosen. Moreover it suppresses small errors at dwelling extraction and class assignment that happens likewise to manual and automated extraction. Here, the inspection of the agreement has been done by visual comparison; future research will seek to quantitatively assess the differences of the derived density zones by spatial analysis methods.

Figure 6. GeoEye-1 subset of the Dorti camp area (120 m x 90 m, band combination 4-3-2) showing dwelling types not recognized by the automated approach due to spectral similarities to the surrounding bare ground (red circles)

In this study it was shown that the use of *master rulsets* for the analysis of IDP camps in Darfur even in a semi-operational mode is feasible and very supportive. Reducing analysis time is valuable in such scenarios. Accuracy of the results should be improved in the future for camps where the dwelling structure differs compared to the situation depicted on the image on which the master ruleset was developed. In the present case the better resolution of the images the ruleset was transferred to, allows for some improvements even, for instance by using shadows for the detection of the underestimated dwelling type class, which shows similar spectral values as bare soil. This has to be seen as an ongoing evolution of the master ruleset, where enhancements will be incorporated within and through every (semi-)operational use. It also has to be mentioned, that the focus of the ruleset is on VHSR imagery only. Future studies will try to improve transferability for different geographical conditions (vegetation differences, climatic conditions etc.) and areas.

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