Radar Images and Geographic Information Helping Identify Water Resources During Humanitarian Crisis: The Case of the Chad/Sudan (Darfur) Emergency

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Abstract – The United Nations High Commissioner for Refugees (UNHCR) in collaboration with the United Nations Office for Project Services (UNOPS, UNOSAT program) developed a project using satellite images (optical and radar images) and Geographic Information System (GIS) to identify surface/ground water resources to assist Sudanese refugees in Chad. Water access is essential for refugee survival in Darfur. Radar images were used as they can penetrate soil/alluvial deposits up to 20m deep. Together with a GIS, which allows the combination of information sources and thematic layers such as slopes (using a digital elevation model from Shuttle missions), rivers (wadis), soil types, and geological information; radar is a powerful tool for humanitarian personnel working in Darfur. This is the first time, in a refugee emergency situation, that radar technology has been successfully used to identify surface/ground water to increase water access to refugees and has helped UNHCR to optimize planning and relocation of refugee camps.

Keywords: radar, satellite imagery, GIS, hydrogeology, refugees, emergency, Darfur, Chad

1. INTRODUCTION

Water access is essential for human survival. In the case of refugee situations, water availability and its rapid access are always the first parameters that UNHCR is looking for during a refugee crisis before establishing a refugee camp. If water is not present near the camps, one has to find the means to bring it. For example, in 1994, during the Rwanda crisis, the 800,000 refugees living around Goma city were provided with 9-13 liter/day/refugee of water – brought by truck on a daily basis from lake Kivu during more than three years. The average cost of the water program for this operation was about 7-8 million USD/year (Sanders, 2005). This demonstrates how crucial the water component is during an emergency situation. In the context of the Darfur crisis, where more than 200,000 refugees fled Sudan in 2003, 2004 (and still continuing in 2005), water is even more critical, as the workers are operating in a desert-like climate. At the beginning of the crisis, during the summer/fall of 2003, hundreds of villagers were arriving from Darfur which was under constant attack by the rebels. The border and the area concerned with the operation is about 650 km long, and covers about 84,000 km^2 (surface area approximately the size of Portugal).

According to UNHCR (UNHCR, 2000) and Sphere standards (The Sphere Project, 2004), it is expected that the minimum standard for water required for a person living in a refugee camp should be 15 liters/person/day. This means that in a refugee camp of 20,000 people, the amount of water needed every day should be around 300,000 liters. In the Chad situation, an amount of 3,000,000 liters/day for a total refugee population of 200,000 people is therefore needed. For a refugee camp of 20,000 people, the reservoir required per year would be equivalent to a volume of 3 meters deep, 50 meters wide and 739 meter long (Salas, 2004). It also means that all these parameters should be multiplied by 365 days. Experience has shown that when a refugee situation starts, it is almost impossible to predict when the refugees will be able to go home (some refugee camps have been in existence for more than 20 years). Unfortunately this is not the only problem to solve during a refugee crisis. Not only does enough water need to be found, but the geological context should be favorable enough to allow sustainability in terms of water distribution for several years. In fact, this is the current situation, as the Darfur emergency started in mid-2003 and by mid-March 2005, the emergency continues as refugees are still arriving in Chad. Finally water sustainability for the refugees is an important element, but it is also essential to remember that refugees are hosted by Chad, the asylum country, and that depletion of natural resources (in this case fresh water) is also affecting the life of the local communities living in the eastern part of the country. Therefore a clear plan of action should always look at both situations: the sustainability of refugee camps and sustainability of the local communities.

2. A LARGE GEOGRAPHICAL AREA TO COVER. A CHALLENGE TO BE MET. SATELLITE IMAGES AS THE ONLY ALTERNATIVE

Since the beginning of the operation, it was clear that access and sustainability of fresh water for refugees and the local population was a major challenge for all workers operating in the region.

Figure 1. The Darfur area with refugee camps in Chad

As indicated in figure 1, the area is vast and roads/tracks are almost nonexistent. It became increasingly evident that to be able to meet both (a) the challenges of the ongoing emergency and (b) the immediate needs of water for the population, innovative methods would have to be found. Traditional methods for ground water (such as vertical electric soundings (VES)), combined with existing information (traditional topographic maps, old aerial photography, geological maps, and existing information on boreholes) were immediately used. But due to the large area to cover (84,000 km^2), in an emergency mode, new methods were needed in order to rapidly have a good understanding of the entire region, in particular its geological context and detailed information about where to drill to locate and find enough fresh water.

Satellite imagery in this particular context was responding to the following challenges and operational needs:

- To be able to cover a large geographical area in a very short time.
- To be able to provide relevant and up-to-date information concerning geological features essential for water resources, and only detectable with the help of satellite images (parameters such as faults, watersheds, or indirect indicators such as vegetation response linked to potential ground water resources, etc.), and which were not always indicated on the older topographic or geological maps covering the area.

3. PHYSICAL CHARACTERISTICS OF THE AREA

The area covered by this study is about 84,000 km2. It starts north at a latitude of 16 degrees North with a saharo-sudanese desert type climate with less than 160mm of precipitation per year and terminates in the South at a latitude of 11 degrees North close to a humid inter-tropical climate type with around 700 mm of precipitation per year. There is a short rainy season from June to August. The geological environment belongs to the granitic basement of the Western Nubian Shield.

4. SATELLITE IMAGERY AND METHODS USED

Due to both the climatic conditions and the nature of the work, it was decided to use radar images for this particular study. This was the first time that radar images were used by UNHCR in the context of an emergency refugee situation for the purpose of ground water resources identification. In the past UNHCR used satellite images (Landsat and Spot images) at the end of the 1990s in the context of the Western Sahara potential repatriation. A full coverage of Spot images of the entire territory was purchased at that time. Such imagery was used as a complementary tool for ground water detection (UNHCR, 1999).
In the present case two types of satellites were used.

a. Optical satellite (Landsat 7) for its capability to cover a large area at a low cost and with the aim of exploring and mapping structural geology, faults, structure, lithology, watersheds, hydrology and vegetation.
b. Radar images (ERS and JERS) to have direct access to parameters such as: dielectric coefficient (water content, porosity and permeability) and geometry of the imaged ground surface.

Eight Landsat images were purchased from existing archives (dated 1999-2001). Classical treatments were applied to them in particular the "Sultan" treatment to identify geology and the NDVI index for the vegetation (Gachet, 2004).

Forty five JERS images were acquired from August and September 1996. A special image treatment, developed by RTF and called WATEX (patent is pending), was applied to the radar images to highlight only the soil's residual humidity and remove unnecessary noise and roughness of the images. Ideally images from the end of the dry season would have been better (to identify areas which still present a high potential of water during this period of time) but no images over the area were available for these months. Sixteen ERS images were acquired from existing archives (dated November 1998) at the beginning of the dry season. A digital elevation model (DEM) (50 m altimetry resolution) was also acquired for the area, which, combined with the radar images, provided the project with a good identification of the watersheds and their boundaries.

Radar images were used because some of the sensors have the capability to penetrate through dry sediments. Radar sensors (in particular the L band) can penetrate up to 18-20 m in depth inside sediments (figures 2 and 3), especially in dry "wadis" (alluvial plains) and therefore the method developed by RTF is able to detect ground water reserves which could be hidden or located very deep, but with a potential "roof" located around 10-20 m.

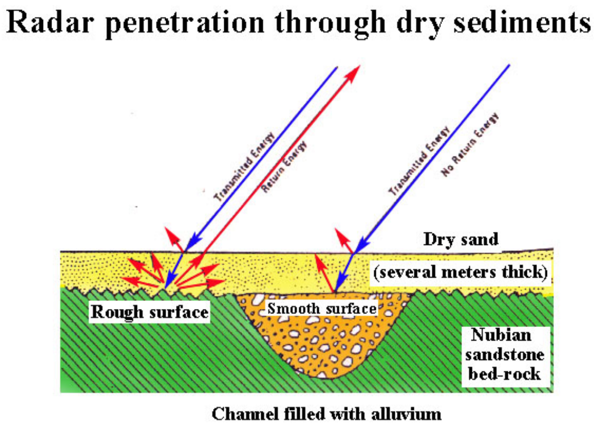

Figure 2. Radar detection of hidden water

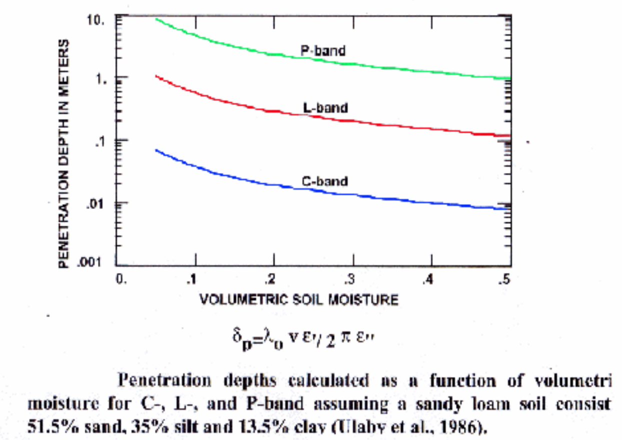

Figure 3..Calculated penetration depths shoring buried moisture can be detected up to 20 m in L band and 50 m in C band..

Finally, satellite images allowed an update of existing mapping documents,
in particular the geological map developed by the BRGM in the 1950s (updated based on the new information provided by the satellite images). Intensive ground truthing was also performed during the two missions which were undertaken by the experts of the RTF company.

5. RESULTS AND CONCLUSION

Based on all the existing documents (topographic and geological maps), available local sources of information, ground truthing and satellite imagery, the following results were obtained:

a. The study allowed the detection and mapping of the hidden alluvial reservoirs of the study area. The method developed by the company RTF, called WATEX allowed the identification of areas with medium and high radar diffusion concerning superficial and deep humid surfaces within the “wadies”. Such a method does not allow for estimation of the capacity of the reservoir, in particular its depth and its thickness. These parameters should be determined, at a later stage, by traditional methods such as geophysical measures. In order to validate its methodology, the RFT company used existing water information provided by the government of Chad “Direction Hydraulique du Tchad” (in particular information on 544 wells and drilling rigs) and correlated the results of the study with the locations of the wells. The results were as follows: for medium radar diffusion areas correlation was 71%, for high radar diffusion areas correlation was 89%.
b. The radar images also allowed for the detection and identification of new potential areas for ground water resources, in particular the so-called: “paleo – dunes”. These dunes seem to have high water resource potentials and correlation was also made with existing drilling rigs. The level of correlation for 37 wells was around 89%. It seems that these dunes were not mentioned in any scientific literature concerning the study area (called the “Ouaddai Oriental”).

In order to maximize the success of identifying positive and sustainable reservoirs and fulfill the needs of both the refugee and the local populations for several months or years, additional information was needed to refine the results obtained. The proposed approach was, in addition of the identification of potential suitable areas for ground water using radar images, to take into account five additional parameters which were: (1) the identified areas should be included in an alluvial system which is large enough to ensure maximum capacity and recharge mechanisms; (2) the watershed attached to these identified areas should be large enough (in surface area); (3) the existence of a “reservoir feeder” and absence of potential polluting elements; (4) the faults network which is a good indicator of the age of the network, and therefore its potential; and (5) the slope of the alluvial system.

The use of these five parameters for each identified area correlated with the presence of a refugee camp (or a potential new refugee camp) was applied in order to provide UNHCR with a level of suitability and sustainability of the existing camps in terms of ground water capacity as well as an idea of the sustainability of these resources for both the refugee and the local populations. The method was also applied to identify/validate proposed potential areas suitable for the development of new refugee camps. The study showed that for two existing camps, namely Mile and Tregine these camps were presenting high potential and where large improvements could be obtained in terms of water capacity/response. Concerning planned camps, the study was able to eliminate very quickly and with certainty some camps which were initially proposed and were not suitable, avoiding unnecessary drilling and wasted time.

Such an approach could be considered as a type of small "revolution" in the way UNHCR and some other humanitarian personnel operate during a refugee emergency. Traditionally, refugee camps were established where they could be (according the urgency of the situation) the locations where the refugees decide to settle down given the acceptance of the national and local authorities of the host country to allocate some land for these camps. Today, new possibilities are emerging with the capabilities of satellite imagery and in particular the use of radar images. If an emergency is still difficult to handle (because most emergencies are often chaotic), this study has demonstrated that the method developed by RFT, combined with geographic information systems and a DEM could be applied for two emergency refugee phases: (a) preparedness (if funds are available) and (b) the emergency itself, to help identify and select (if all parameters are available) the best suitable areas for the establishment of refugee camps according to the water resources and other important parameters such as accessibility, slope and distance from international border (Bouchardy 1995, 2003). Such method could of course be also applied for repatriation operations (such as the case of the Western Sahara).

Our study demonstrated that in a refugee emergency context, it was possible, in a very short time, to identify and evaluate potential suitable areas, and eliminate areas which were not suitable (saving time, money and the lives of refugees). The project also looked at the needs of the local population and the sustainability of the natural resources of the country of asylum. It also prevented UNHCR from initiating expensive drilling (by eliminating the risk of not being able to identify the most sustainable reservoirs). In addition, during a refugee emergency situation, time is crucial for the life of refugees. Satellite imagery combined with existing sources of information, and extensive ground truthing was also able to provide UNHCR decision makers with information concerning the suitability of potential new camps (taking into account additional important parameters such as security and accessibility) in an emergency mode.

The next step for the study will be for the technical teams on the ground to consolidate/validate the results obtained by RTF (for the existing camps), with traditional geophysical methods and to finalize the fine-tuning concerning the potential areas suitable for new camps, taking always into consideration the sustainability of these projects vis-à-vis of the local populations.

Note: the views expressed in this paper are not those of the author and do not necessarily reflect those of the United Nations or the United Nations High Commissioner for Refugees (UNHCR).

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