Top-down and bottom-up – A global approach to strengthen local disaster resilience

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Abstract*— The main message of international disaster frameworks as well as the political agenda is clear: Every player in the humanitarian domain should aim for a paradigm shift from managing disasters to pro-active disaster risk management. In practice, however, this process can be very complex: Tailored technological solutions require collaborative developments and related organizational adaptions. Early warnings must be linked to early action while local communities need to be involved and trained to strengthen their disaster resilience. In collaboration with the German Aerospace Center (DLR) and Deutsche Post DHL, SOS Children's Villages International (SOS-CVI) put in place a dedicated online near real-time disaster risk management platform named Resilience360 (R360). With the overall objective of transforming the disaster management cycle into a feedback loop that aims at avoiding repetitive mistakes, R360 supports operational decision-making based on different sources of information. They range from risk indicators that direct the pre-positioning of vital resources in the most vulnerable villages to near real-time incident information on armed conflicts as well as satellite-based damage assessments to estimate the impact of natural disasters. However, the decisive strength of R360 lies in its feedback mechanism. Local staff are not only automatically notified about potential threats; they can also report incidents themselves, which, depending on their severity, are forwarded to national, regional and/or global emergency coordinators within the organization. Based on the example cyclone Dineo, a tropical category four storm that led to large-scale damages and displacements in Mozambique in February 2017, we show how SOS CVI and its partners improved their decision-support based on early warnings and the integration of satellite-based damage assessments into R360. The official roll-out of R360 including dedicated training packages is planned for fall 2017.

Keywords – disaster risk management, decision-support, satellite technology, risk assessment, damage mapping

I. Introduction

The rhetoric on humanitarian action has, historically, embraced child protection and the specific threats to children in conflict and disaster situations as a mainstay of its funding appeals. Adverts featured on televisions and displayed on billboards in the global north habitually feature sad-eyed children, as their plight resonates with audiences. The unfortunate reality, however, is that this focus does not extend down to the actionable level: child protection is critically under-practiced and underfunded in the humanitarian field. According to the financial tracking service of UN OCHA (https://fts.unocha.org/), annual funding for child protection receives the smallest portion of its humanitarian funding, excluding "other" expenditures. From January to June 2017, 13.8 Mio US$ were spent on child protection, with mine action coming in second-to-last with 32 Mio US$ (Fig. 1).

This trend is problematic, not least because missed opportunities in child protection in emergencies led to "lost generations", whose trauma and disenchantment can negatively affect the peace and prosperity of their communities for decades. In addition, chronic poverty, AIDS and war result in long-term physical and psychological impacts that threaten the success of child protection programs [1].

Since it was founded in 1949 to provide families for children orphaned by World War II, SOS Children's Villages (SOS-CVI) has pursued its vision of a world where "every child belongs to a family and grows with love, respect and security". In nearly 70 years of work SOS has expanded its activities substantially, and now operates 571 Children's Villages (CV) in 135 countries and territories (http://www.sos-childrensvillages.org/where-we-help). Alongside its village-centered care, SOS-CVI has also adopted SOS-supported foster or transit homes, family strengthening programs (FSPs), SOS-operated kindergartens, primary and secondary schools,

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vocational training centers and social centers into its global program.

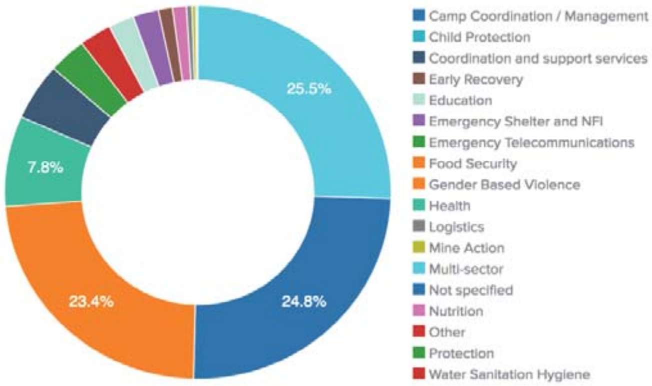

Fig. 1 UN OCHA Humanitarian funding from January to June 2017 (as of 22 June 2017)

On its own, however, a development-centered approach to child protection is no longer efficient. Referring to the global humanitarian outlook, the United Nations [2] stressed that “the world today spends around US$ 25 billion to provide life-saving assistance to 125 million people devastated by wars and natural disasters. While this amount is twelve times greater than fifteen years ago, never before has generosity been so insufficient.” Global food demand is projected to increase by at least 60 percent until 2050 (compared to 2006). Simultaneously, climate change could increase the number of people living in poverty to 122 million people by 2030 [3], with sub-Saharan Africa disproportionately highly affected [4]. These conditions tend to increase the overall vulnerability towards natural disasters, but also lead to socio-economic conflict. There is a strong link between climate-change related disasters, growing in both frequency and severity, and armed conflict. One example is the current conflict in Syria, where a perennial drought led to displacement, which in turn contributed to the conflict [5].

Its global reach and integration into the world’s poorest communities has meant that SOS-CVI often stands in the epicenter of these disasters and conflicts, and in response SOS has long operated emergency programs. In recognition of the increasing incidence and destructiveness of emergencies, the formulation and management of global emergencies has been formalized with the approval of an SOS-CVI emergency policy in 2016. During that year, SOS-CVI conducted 23 emergency programs globally, providing 317,000 services to people in need through child-friendly spaces, medical and mental health programs, family reunification, and the provision of food and other basic humanitarian needs. A further six programs are set to start in 2017. The emergency policy reflects the shifting perspectives on SOS-CVI’s role in emergency, reaffirming its commitment to child protection, guaranteeing children’s rights, and keeping families together, but also stressing the importance of managing disaster risks. In line with the Hyogo/Sendai Frameworks for Action, the Global Bargain and similar international frameworks, SOS-CVI is shifting its focus from purely development assistance oriented work towards pro-active humanitarian assistance.

Doing so poses new challenges for the organization on all administrative and geographical levels. These challenges were the main motivation for the development of a new strategy to 1) increase disaster preparedness based on in-depth risk and vulnerability assessments, 2) efficiently transform early warnings to early action, and 3) establish a two-way emergency communication strategy from local to global level. The strategy is based on the following key elements:

- Adaptation of an emergency management platform named R360 for the specific needs of SOS-CVI, (originally developed by DHL to support supply chain monitoring);
- Collaboration with academia and private industry to use satellite-derived information in data-sparse regions as well as weather/climate forecasts;
- Creation of tailored, user-friendly and flexible solutions that complement existing services, such as GDACS (Global Disaster Alert and Coordination System) or FEWSNET (Famine Early Warning Systems Network), which are often used to confirm current conditions rather than to inform preparedness activities, as they were intended to be;
- Development of scenario-based trainings and research-based solutions to translate early warnings into early action.

II. THE ROLE OF SATELLITE-DERIVED INFORMATION

According to Voigt et al. [6], the number of post-disaster maps produced for humanitarian purposes is increasing; simultaneously, the time taken from activation to the acquisition of the first satellite image, and time taken from the acquisition of the first satellite image to the production of the first map, is decreasing. Having gained first-hand experiences with satellite-based emergency mapping over the course of several disaster situations in the past few years, and having witnessed the high operational and communication value gained from a rapid satellite based situation analysis, SOS-CVI has decided to develop a dedicated satellite emergency mapping (EMMA) strategy, which allows SOS-CVI access to early satellite analysis products in a systematic manner. In addition to ex-post damage assessments, the SOS-CVI strategy also includes the use of datasets that can be employed to predict anomalous conditions or extreme events. A prominent example is satellite-derived soil moisture [7], which cannot only be used to validate satellite rainfall estimations [8], but to support drought monitoring [9] or flood forecasting [10]. However, only if the strengths and limitations of satellite data are clear to users will they provide an added value for decision-making support.

A. Strengths of satellite-derived Information

High-level satellite-derived information, meaning added-value products that are processed based on raw data (e.g. root-zone soil moisture), are usually provided as harmonized datasets. This way, researchers and practitioners can compare anomalous conditions systematically on a global scale. Some sensors provide a very high spatial resolution of up to 31 cm (e.g. the World View satellite sensors); others only allow monitoring at coarse resolutions (up to tens of kilometers), but independently from weather conditions (e.g. microwave sensors). The multitude of complementary sensors in different geostationary and polar orbits allow not only for an increased temporal resolution, but for the cross-validation of independent datasets. In this way, it is possible for instance to track the agricultural season via rainfall, soil moisture, evapotranspiration and vegetation greenness, from space. A direct link between satellite-derived datasets is also possible, for instance to predict vegetation health via soil moisture [11] or to assess the risk of epidemics, such as Malaria, via satellite-derived rainfall and temperature [12].

Finally, users benefit from datasets and disaster mapping products that are available free of charge from platforms such OpenStreetMap (reference information), the Copernicus Emergency Management System of the European Commission or the International Charter Space and Major Disasters.

B Limitations of satellite-derived Information

According to Coughlan de Perez et al. [13] the fact that most humanitarian organizations and their financial resources are still focusing on emergency response limits the incentive and ability to exploit the added-value of complex scientific data. In addition to high costs for individual images, one of the main issues with very high-resolution (VHR) optical imagery, is their dependence on cloud-free conditions. Another challenge is the non-existence of reliable algorithms that are capable of automated change detection. As a consequence, most damage assessments are carried out via time-consuming visual interpretation [14].

Sensors that work independently from weather conditions are able to relate current conditions to long-term time series via anomalies. However, in many cases critical thresholds for anomalies or even basic disaster definitions [15] are unclear, which inhibits the translation of early warnings into early action. This is particularly problematic for slow-onset disasters such as droughts.

For aid organizations that operate globally and have to handle disaster preparedness/response activities at different operational, strategic and administrative levels, two final issues need to be mentioned in the context of satellite data. First, exploiting the added-value of satellite data requires internal capacity building that must be based on a clear commitment and a sound long-term strategy. Second, publicly available disaster preparedness and response datasets are undoubtedly beneficial for the humanitarian community. However, since they are published as generic products with regard to timeliness (release of products and duration of data provision), visualization, or geographic focus, it is risky to rely on them as the only source of information.

III. ADVANCED RISK MANAGEMENT VIA RESILIENCE360

In collaboration with Deutsche Post DHL, SOS-CVI adapted the Resilience360 (R360) disaster risk management platform as a one-stop-shop covering all disaster phases of natural and manmade disasters. The main objective of R360 is to centralize information related to risk and vulnerability assessments, disaster alerts and related early warnings, disaster preparedness and emergency/damage mappings.

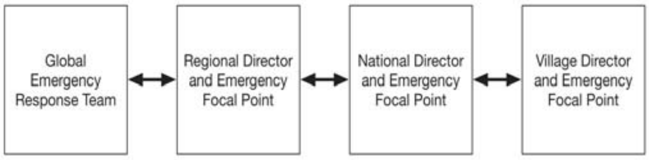

Fig. 2 Schematic flow of risk and emergency information on all SOS-CVI levels

R360 builds on an extensive back-end incident reporting facility, risk data provided by reinsurers, satellite data and local information provided by SOS staff (Fig. 2). The online interface of R360 allows all 571 CVs to be filtered by their risk profiles, emergency status, the severity of an incident as well as its timeliness (time of last update) and information source.

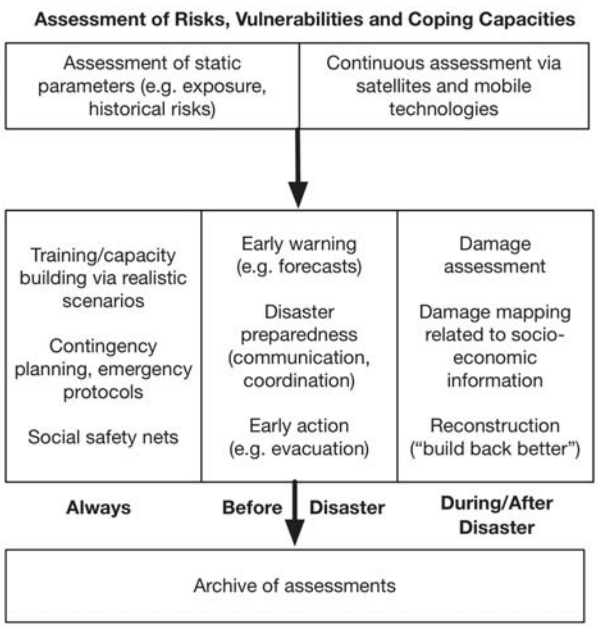

Fig. 3 Schematic overview of R360, covering risk assessment, all disaster phases and archiving of assessments

Once the rollout of the platform is completed in late 2017, staff across the institutional hierarchy will be able to access information on village risks and vulnerabilities, historical incidents, and reports produced for individual villages or entire countries. Alerts for incidents that may affect the security in and around the villages, are automatically issued and received simultaneously by all relevant staff members via email or phone. This, together with a function for manual incident reporting on critical conditions that may have been missed by other sources, establishes a strong link with local CVs. The R360-based strategy is a significant step towards bridging the pervasive communication gap between different levels of decision-making, wherein national offices often have supporting data and analyses it cannot distribute, while the field has situational insights that are not transmitted up the structure. Fig. 3 illustrates the general set-up of R360 from risk assessment through all disaster phases to the development of an archive of assessments.

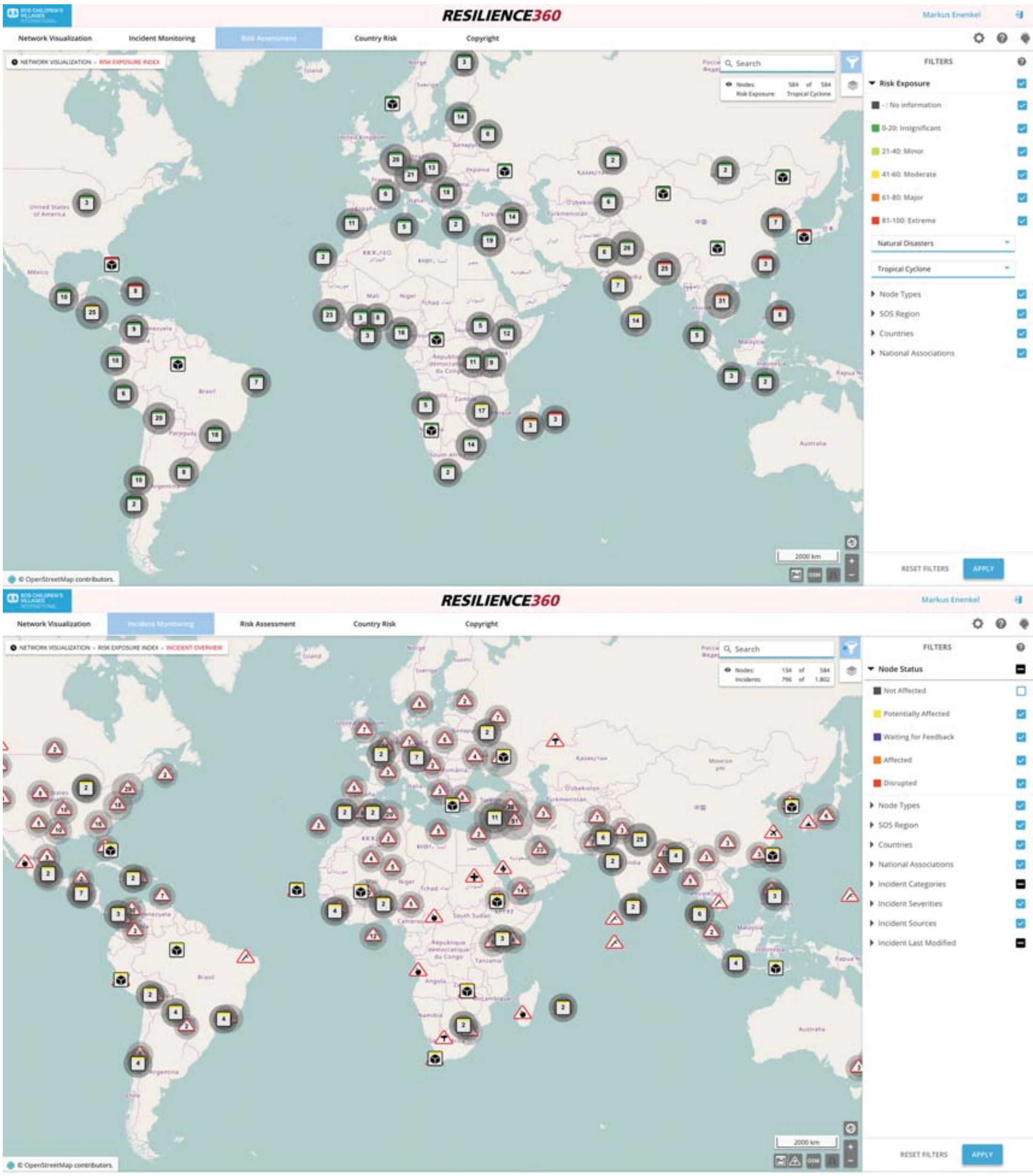

Fig. 4 Top: Overview of all CV in R360, filtered by risk category (natural disasters) and sub-category (tropical cyclones); colors indicate the risk exposure from insignificant (green) to extreme (red). Bottom: corresponding incidents (red triangles) filtered by timeliness (last 24 hours) and category (all except ground transportation and labor, strikes) for all severities as of 14 August 2017.

Fig. 4 shows examples of the R360 web interface for risk assessment (top) and near real-time incident monitoring (bottom). CVs are displayed as squares. The number inside the square represents the number of CVs represented by the square. With regard to risk assessment (tropical cyclones are used in the example) a traffic light system (red = high risk) relates risk exposure to individual villages. In the incident monitoring view the colors represent the status of the CV between black (not affected), yellow (potentially affected), purple (waiting for feedback), orange (affected) and red (disrupted).

IV. CASE STUDY CYCLONE DINEO IN MOZAMBIQUE

Cyclone Dineo made landfall in the Inhambane province of Mozambique on February 15th 2017. It is an example of an event that had been announced via warnings from GDACS. However, despite the severity of the event, which led to the displacement of more than 551.000 people and affected nearly 30.0000 hectares of cropland according to the World Food Programme [16], the International Charter Space and Major Disasters was not activated.

Fig. 5 SwissRe CatNet historical cyclone tracks

The general risk profile based on the CatNet (Catastrophe Network) Service of SwissRe (Fig. 5) shows that over the previous decades, most tropical cyclones have hit the eastern coast of Madagascar. Only very few strong cyclones (orange and red tracks) came close to the coast of Mozambique. These conditions are also reflected by the risk assessment in Fig. 4; the CVs in Madagascar are illustrated in red, corresponding to a very high exposure to tropical cyclones, while the villages close to the eastern coast of Mozambique are classified as medium risk (yellow). The GDACS forecast (Fig. 6) clearly indicated that the cyclone would affect regions close to CV Inhambane (blue icon) and more than half a million people for wind speed category 1 (=130 km/h). The general vulnerability was assessed as high. As a consequence, the EMMA was already activated before the cyclone made landfall to collect reference information about critical infrastructure (points of interest) and VHR reference imagery.

Fig. 6 GDACS warning for tropical cyclone Dineo from 16 February

Fig. 7 shows the damage assessment for CV Inhambane and its surroundings, based on a comparison of pre- and post-disaster VHR imagery from World View 3. Cloud cover delayed the acquisition of an image that allowed the detection of damages in the selected region of interest.

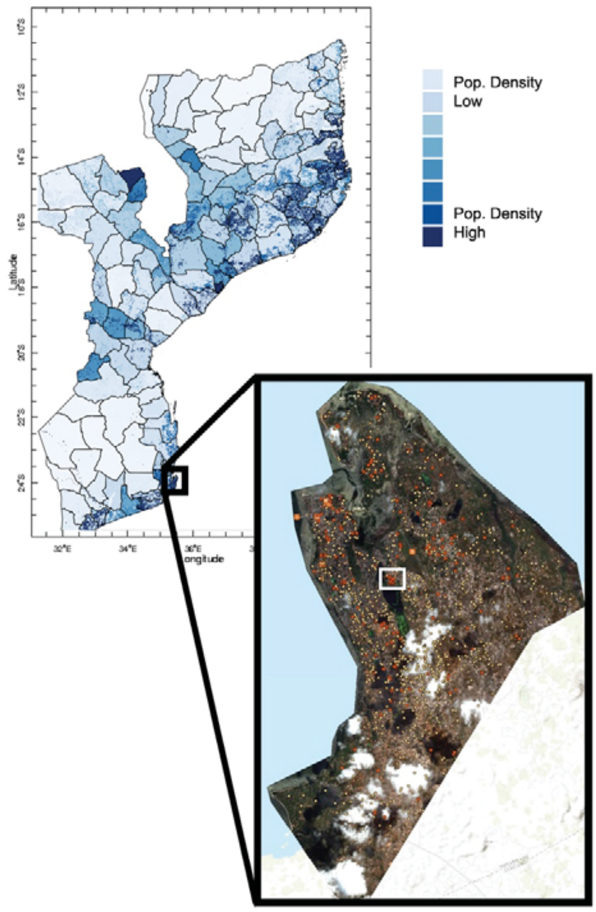

Fig. 7 Population density in Mozambique at 100m spatial resolution extracted from http://www.worldpop.org.uk/ (left) and satellite-based damage assessment for CV Inhambane (white rectangle in the right image); red dots represent destroyed houses, orange dots damaged houses.

However, despite delays of several days it was possible to get a cloud-free image that provided a first indication of the damage extent to local staff. Children and staff could be evacuated before Dineo struck Inhambane, but most houses in the CV were severely damaged.

V. DISCUSSION AND CONCLUSIONS

SOS-CVI is undergoing a transformational process towards disaster risk reduction and disaster preparedness. To this end, the organization has joined forces with academia (e.g. Columbia University, University of Salzburg), technical partners (e.g. DLR) and the risk units of re-insurers (e.g. SwissRe) to develop a new global disaster risk management strategy. This strategy, consisting of a series of projects that cover all segments of the disaster risk management cycle, facilitates direct communication between all levels of the institutional hierarchy (global, regional, national, village) to evaluate the individual risks and vulnerabilities of CVs and to efficiently translate early warnings into early action. While the disaster risk management platform R360 is capable of alerting staff about small- and large-scale environmental and manmade incidents, there is always a chance the severity of an event may be misclassified or that events are missed. The reports and assessments of local staff are therefore indispensable for decision-making.

The SOS-CVI disaster risk management strategy is based on the paradigm that disaster risk and exposure cannot be influenced in the short-term. We can, however, limit the impact of disasters by strengthening capacities, emergency preparedness and, in case of an impact, emergency mapping and response. SOS-CVI aims to perform emergency mapping independently from the activation of public emergency services. Depending on the availability of satellite images, the first damage assessment is usually available within one to four days after request. In addition to damage assessments related to critical infrastructure in and around the CVs, flooding area and landslide maps can be generated. Based on the example of a tropical cyclone, this study shows how risk information and emergency mapping were used to support the decision-making of local staff in Mozambique.

Satellites can map at high temporal resolution (geostationary orbits), high spatial resolution (polar orbit), provide multi-spectral images and reach high radiometric accuracy. However, the choice of a satellite and the related dataset comes with certain physical limitations (e.g. energy) that prevent all of these characteristics from being combined. The need for people on the ground remains, not only to validate satellite-derived information products, such as drought indicators. Their input is crucial to issue warnings and assess situational aspects that satellites might miss, as well as to help to link socio-economic and environmental aspects (e.g. food insecurity caused by drought and other factors) that cannot be assessed otherwise.

The activation of the satellite-based EMMA after cyclone Dineo serves as an example for the importance of local feedback. Initially, cloud cover had impeded the mapping of damaged buildings. However, local staff, who had been evacuated, could immediately identify that the CV itself had been damaged. Using local capacities and relying on the expertise of local decision-makers will be a core element in the next phase of SOS CVI's disaster risk management developments.

While currently a lot of manual work is currently involved in change detection and damage mapping, future methods will not only improve automated pattern and object recognition, but real-time data processing and high-resolution video sequences from space. In addition, information extracted from social media and crowd-sourcing will provide vital complementary information for disaster situational awareness [5]. Along these lines, SOS-CVI is already preparing for the next phase that will focus on high-frequency updates via mobile technologies [17], [18] to establish regular updates, understand which conditions are "normal", and to confirm satellite-based assessments. By considering local conditions in collaboration with staff on-site it will also be possible to:

- map the location and condition of critical infrastructure
- link satellite-derived environmental anomalies to critical socio-economic thresholds for improved early action;
- identify acceptable levels of uncertainty in seasonal rainfall and temperature forecasts, and;
- explore the potential of weather index insurance and forecast-based financing to decrease the humanitarian funding gap.

Just like all other development and humanitarian aid organizations, SOS-CVI must not only focus on the strategic communication between decision-makers across all institutional levels; the communication between decision-makers and data/service providers is also crucial to exploit the full potential of all kinds of information (crowd-sourced, satellite-derived, modeled) [19]. For this to succeed, building trust, active collaboration through (vocational) trainings and participative scenario development are vital prerequisites.

In the face of very limited international funding for child protection in emergencies SOS-CVI and its partners aim to close a sensitive gap via research-based disaster preparedness and disaster risk reduction. This will not only require a commitment to ongoing developments, but the consideration of shifts in disaster risks and related vulnerabilities due to a changing climate.

REFERENCES

[1] P. Lachman *et al.*, "Challenges facing child protection, Child Abuse Negl., vol. 26, no. 6–7, pp. 587–617." 2002.

[2] United Nations, “Too important to fail—addressing the humanitarian financing gap; High-Level Panel on Humanitarian Financing - Report to the Secretary-General, at: http://www.un.org/news/WEB-1521765-E-OCHA-Report-on-Humanitarian-Financing.pdf, accessed 10 June 2017.” 2015.
[3] UN Food and Agriculture Organization, “State of Food Security and Agriculture 2016 - Climate Change, Agriculture and Food Security.” 2016.
[4] T. W. Hertel, M. B. Burke, and D. B. Lobell, “The poverty implications of climate-induced crop yield changes by 2030,” *Glob. Environ. Change*, vol. 20, no. 4, pp. 577–585, Oct. 2010.
[5] C. P. Kelley, S. Mohtadi, M. A. Cane, R. Seager, and Y. Kushnir, “Climate change in the Fertile Crescent and implications of the recent Syrian drought,” *Proc. Natl. Acad. Sci.*, vol. 112, no. 11, pp. 3241–3246, Mar. 2015.
[6] S. Voigt *et al.*, “Global trends in satellite-based emergency mapping,” *Science*, vol. 353, no. 6296, pp. 247–252, Jul. 2016.
[7] W. Dorigo and R. de Jeu, “Satellite soil moisture for advancing our understanding of earth system processes and climate change,” *Int. J. Appl. Earth Obs. Geoinformation*, vol. 48, pp. 1–4, Jun. 2016.
[8] L. Brocca *et al.*, “Soil as a natural rain gauge: Estimating global rainfall from satellite soil moisture data,” *J. Geophys. Res. Atmospheres*, vol. 119, no. 9, p. 2014JD021489, Mai 2014.
[9] M. Enenkel *et al.*, “Combining satellite observations to develop a daily global soil moisture product for a wide range of applications,” *Hydrol. Earth Syst. Sci. Discuss.*, vol. 12, no. 11, pp. 11549–11589, Nov. 2015.
[10] L. Brocca, T. Moramarco, F. Melone, W. Wagner, S. Hasenauer, and S. Hahn, “Assimilation of Surface- and Root-Zone ASCAT Soil Moisture Products Into Rainfall and Runoff Modeling,” *IEEE Trans. Geosci. Remote Sens.*, vol. 50, no. 7, pp. 2542–2555, Jul. 2012.
[11] M. Zribi *et al.*, “Relationship between soil moisture and vegetation in the Kairouan plain region of Tunisia using low spatial resolution satellite data,” *Water Resour. Res.*, vol. 46, no. 6, p. n/a–n/a, 2010.
[12] P. Ceccato, C. Vancutsem, R. Klaver, J. Rowland, and S. J. Connor, “A Vectorial Capacity Product to Monitor Changing Malaria Transmission Potential in Epidemic Regions of Africa,” *J. Trop. Med.*, vol. 2012, pp. 1–6, 2012.
[13] E. Coughlan de Perez, B. van den Hurk, M. van Aalst, B. Jongman, T. Klose, and P. Suarez, “Forecast-based financing: an approach for catalyzing humanitarian action based on extreme weather and climate forecasts,” *Nat Hazards Earth Syst Sci Discuss*, vol. 2, no. 5, pp. 3193–3218, May 2014.
[14] S. Voigt, T. Schneiderhan, A. Twele, M. G?hler, E. Stein, and H. Mehl, “Rapid Damage Assessment and Situation Mapping: Learning from the 2010 Haiti Earthquake,” *Photogramm. Eng. Remote Sens.*, vol. 77, no. 9, pp. 923–931, Sep. 2011.
[15] B. Lloyd-Hughes, “The impracticality of a universal drought definition,” *Theor. Appl. Climatol.*, vol. 117, no. 3–4, pp. 607–611, Aug. 2014.
[16] UN World Food Programme, “WFP Mozambique Country Brief, May 2017, at: http://reliefweb.int/report/mozambique/wfp-mozambique-country-brief-may-2017 (accessed 20 June 2017).” 2017.
[17] A. R. Bell, P. S. Ward, M. E. Killilea, and M. E. H. Tamal, “Real-Time Social Data Collection in Rural Bangladesh via a ?Microtasks for Micropayments? Platform on Android Smartphones,” *PLOS ONE*, vol. 11, no. 11, p. e0165924, Nov. 2016.
[18] M. Enenkel *et al.*, “Food Security Monitoring via Mobile Data Collection and Remote Sensing: Results from the Central African Republic.” PLos ONE, 2015.
[19] M. Enenkel *et al.*, “Drought and food security – Improving decision-support via new technologies and innovative collaboration,” *Glob. Food Secur.*, 2014.