USE OF EARTH OBSERVATION AND ALLIDED TOOLS – OPERATIONAL CHALLENGES, AND LESSON LEARNED FROM NEPAL EARHTQUAKE OF 2015

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ABSTRACT:

Space technology and remote sensing is often the main source of updated information in space and time before, during and after disaster events. Global and regional mechanisms like International Charter for Space and Major Disaster (ICS) and Sentinel Asia has immensely contributed in leveraging satellite images available without cost during the event. Between 2000 and April 2014 there has been 436 cases of ICS activation out of which 14% is related to disaster in Hindu Kush Himalaya (HKH) countries. Similarly out of 129 activations of Sentinel Asia between 2007 and 2012, 24% of the cases is related to disaster in Hindu Kush Himalaya (HKH) countries. Both mechanisms were activated during Nepal Earthquake of 2015 through which high resolutions images were leveraged and used for mapping damages infrastructure and geo-hazards (landslide, river damming). The effort to provide up to data and accurate information was challenged by technical and infrastructural limitation namely inadequacy in spatial and temporal resolution, image registration issues, cloud cover, and accessibility to name a few. The use of microwave data to map deformed pixel using interferometry, as proxy to damage houses is a new concept which has potential for damage mapping in all-weather condition. There opportunity for use of space technology and remote sensing is not just confined to disaster response. Need for data and information for preparedness in spatial framework using GIS and satellite data constitute a key component of risk assessment.

Third world infrastructures are often not optimum to reap technological benefit. Despite the availability of the high resolution images, accessibility remained the biggest challenge. Investment on better communication system is imperative to leverage earth observation data and products. The absence of Standard Operating Procedure (SoP) and one window interface to disseminate remote sensing derived data and product is another challenges. Realizing the need for one central platform to assimilate the data and information from myriad sources, ICIMOD helped Ministry of Home Affairs (MoHA) develop Nepal Earthquake 2015: Disaster Relief and Recovery Information Platform (NDRRIP) (http://drrportal.gov.np/) a one window system to disseminate information related to Nepal Earthquake 2015.

1. INTRODUCTION

The need for updated information on ongoing disaster event and ensuing activities after the event renders traditional data collection approach futile. Alternatively Earth Observation (EO) and allied tools has provided a possibility of monitoring disaster event and damage assessment (Myint et al., 2008; Vu and Ban, 2010) in near real time, effectively improving response interventions. Measurements from these satellites provide valuable additional input that can be used for a multitude of applications in support of disasters management (CEOS Earth Observation Handbook for WCDRR). The International Charter for Space and Major Disaster (ICS) and Sentinel Asia (SA) has immensely contributed in leveraging satellite images for free during disaster event. Between 2000 and April 2014 there has been 436 cases of ICS activation out of which 14% is related to disaster in Hindu Kush Himalaya (HKH) countries. Similarly out of 129 activations of Sentinel Asia between 2007 and 2012, 24% of the cases is related to disaster in Hindu Kush Himalaya (HKH) countries. This is testimony to the fact that satellite based monitoring is now an integral part of disaster response phase, indeed all phases of disaster management.

The April 25 earthquake of 7.8 Mw, epi-centered in Barpak village of Gorkha, Nepal (Figure 1), and several subsequent aftershocks were deadliest earthquake in recent history of Nepal, in terms of extent of damage. In total about 9000 people lost their lives and 22,300 people were injured, and lives of eight million people, almost one-third of the population of Nepal, have been impacted by the April 25 event and several aftershocks that followed (PDNA, 2015). The PDNA report puts the loss and damage caused by the earthquakes in the order of NPR 706 billion or its equivalent of US$ 7 billion. The event invoked international humanitarian engagement to support Government of Nepal in immediate response. In total 134 international Search and Rescue (SAR) teams from 34 countries responded to Nepal's request for help. (PDNA, 2015). Looking back in retrospection we were not prepared for such a mega event, partly because prognosis of an earthquake scenario prior to 25 April Nepal Earthquake event projected dire situation in Kathmandu city while it remained silent on the rural areas.

The International Centre for Integrated Mountain Development (ICIMOD), an inter-governmental agencies working for Hindu Kush Himalayan countries (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan), based in Kathmandu, sprung to action mobilizing volunteers to generate much sought after data and information using satellite data. These data and information thus generated were channelled to response parties like Ministry of Home Affairs (MoHA), Nepal Army (NA), Nepal Police (NP), UN agencies (WFP, FAO, UNICEF), non-government agencies (Mountaineering Association, etc.). ICIMOD provided rapid response mapping support to member states since the Koshi flood of 2008, but this certainly was unprecedented in terms of intensity and scale of engagement. There are many learnings from this engagement, and an attempt to document it in this paper under the title "Use of Earth Observation and Allied Tools – Lesson Learned from Nepal Earthquake of 2015" is made.

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2. MATERIAL AND METHOD

2.1 Study Area

The discussion and deliberation in this paper are based mostly on experiences during the recent April 2015 Nepal earthquake, which had affected 31 out of 75 districts of Nepal, out of which 14 were declared "crisis-hit" (PDNA, 2015). Events in the past in region beyond Nepal viz. earthquakes in Haiti, Pakistan, China, and Chili has been used to compare and contrast.

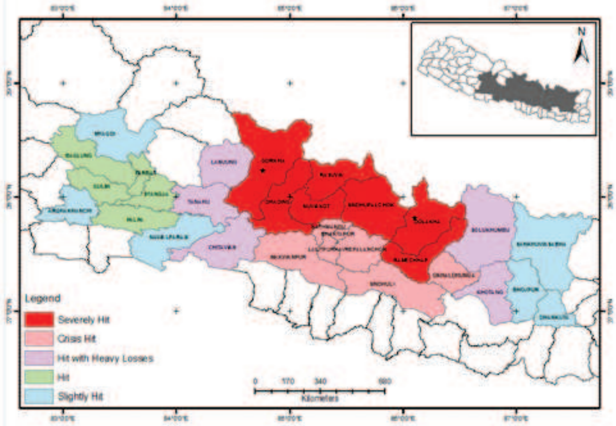

Figure 1. Categories of earthquake affected districts of Nepal (based on PDNA, 2015). Black filled star represents epicentres of April 25 (in Gorkha district) and May 12 (in Dolakha districts) events.

In order to draw comparisons across past events, review of articles and websites were done and comparison for relevant experiences were made. The method used to compare and contrast is therefore subjective at best and influenced by authors experience while responding to 2015 Nepal earthquake.

3. OPERATIONAL CHALLENGES & LESSON LEARNED

3.1 Availability and accessibility of satellite data

Disaster response, for that matter disaster management begins with an assessment of damage. Satellite data has been used for mapping damaged infrastructures by earthquake (Arciniega et al., 2007; Sertel et al., 2007; Chaabane et al., 2007). Damage assessment is key to comprehend scale of devastation, and appropriately plan response strategies including deployment of relief and response interventions. Rapid damage assessment is only possible through remote sensing using satellite data due to accessibility challenges, time constraint, and risky environment. Experience from April 25 earthquake and past events makes it apparent that availability of satellite data during disaster of such kind is never an issue. There are standard protocols like ICS and SA, and other forthcoming and generous support (USGS, NASA, JAXA, ISRO, etc.) when requested provided large volumes of pre and post event satellite images. Footprint of the high resolution images gained access by ICIMOD made available through above sources are mapped in Figure 2. It summed up to about 1.5 TB of data (See Figure 2). It is far from complete repository as we must have surely missed some of the provided images. In case of Haiti Earthquake, USGS provided through the Hazards Data Distribution System (HDDS) about 54 TB of data (public and restricted), including aerial imagery and reference datasets (Duda and Jones, 2011). Although there are no ready reference on the volume of satellite data made available for other events, the situation must be not so different.

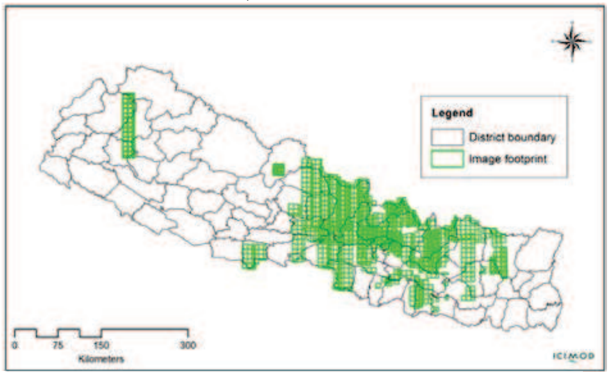

Figure 2. Footprint of satellite data accessed by ICIMOD.

While there was no dearth of satellite data, access remained a major challenge, situation echoed by Nepal Army and Nepal Police team during the post 2015 Nepal Earthquake. It is to note that by and large, internet and other communication systems were intact and remained functional, unlike in other events. The challenge however stem from bandwidth bottleneck. Despite ICIMOD HQ having better internet bandwidth (20mbps) in Nepal as compared to many organizations, downloading of those images was a major challenge. Similar experiences was echoed by Nepal Army and Nepal Police. Slicing the image scenes into multiple tiles and compressing before being shared helped overcome the bandwidth limitation. Images provided through different initiatives were first downloaded in SERVIR Coordination Office (CO) at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama Huntsville, Alabama, USA, and tiled and compressed prior to making it available through Cloud instance to ICIMOD team. The process of tiling and compressing was done using software code which makes it possible for the SERVIR team to create a predefined grid to segment the large images into subsets or 'tiles' that can be transmitted and received more easily than the large file, and to reconstruct the pieces on the recipient's side (http://www.nasa.gov/mission_pages/servir/software-developed-by-servir-interns-aids-nepal-earthquake-response.html). However, in absence of software code to re-tile, the problem on the other end was getting it recomposed. Alternatively transfer of images physically using hard drives as and when someone travelled from US to Nepal, was practical alternative although latency was an issue.

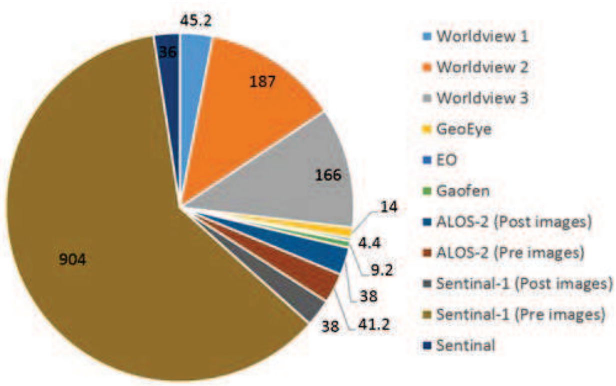

Figure 3. Data volume by sensor types accessed by ICIMOD while responding to 2015 Nepal Earthquake.

3.2 Management of satellite data

The volume of images gained access by ICIMOD in a matter of few days were unprecedented. The team as usual catalogued and archived the images in folders as it came. As the data volume increased and request for mapping products got intense, the need to keep track of geographical coverage and existing gaps warranted systematic management of the satellite data. Folder based cataloguing was not helping either to identify suitable images of particular location from series of overlapping images. The selection of suitable (cloud free and highest resolution available) images was particularly important in view of presence of cloud cover and availability of satellite data from different sensors.

To better organize satellite data and ensure systematic management, all the satellite data were managed systematically into respective folder based on the sensor type and date. In order to see coverage of the image, footprints of the data was generated using the python script and ArcGIS Version 10.3. For visualization and mapping, quality of the images were checked visually and good quality images were compiled into Mosaic Raster datasets in geodatabase. This ensured mapping of all the satellite data within a single frame which was very helpful with regard to knowing coverage areas and identify gaps. Since different users use different version of ESRI package, to make it compatible to every version, project files in ArcGIS needs to be saved in different version.

3.3 Damage mapping using satellite data

Damage assessment is invariably the first step towards post disaster intervention, based on which deployment coordination of search and rescue (SAR), and relief distribution and response activities are effectively put in place. There are different levels of satellite based mapping products in rush mode service (EC-JRC, 2011) addressing different needs. Higher level maps (Reference Map and Delineation Map, refer EC-JRC, 2011) do not encounter resolution issues as information requirement is at coarser granules. Grading Maps which provide an assessment of the damage grade is often challenged by inadequate resolution of the image and nadir view angle. Both optical and microwave sensors has been widely used for damage assessment in the past (Ye et al. 2014; Kerle and Hoffman, 2013; Ozisik and Kerle, 2012). However, owing to large presence of optical sensors, ICIMOD team attempted to map damaged buildings using high resolution (0.5m to 2m) satellite images in urban and rural setting. Although several automatic or semi-automatic techniques exist to identify collapsed building or debris after an earthquake, a visual interpretation approach was adopted in 2015 Nepal earthquake, also reported in case of Haiti earthquake (Boccardo and Tonolo, 2012). The method adopted entailed digitization of damaged building based on visual identification in multi-spectral images in ArcGIS environment.

This was not straight forward mainly due to two reasons. Firstly many houses with soft storey collapse, and roof completely to largely intact are not detectable by near vertical images since building facades are not visible, also reported by Booth et al., 2011. For efficient damage detection particularly in case of earthquake event, high resolution temporal and spatial data with oblique view angle is highly preferred, view also echoed by Liou et al., 2010. Secondly closely spaced houses in rural areas cannot be segregated from one another. These inherent limitations resulted in errors, mostly underestimation of damaged houses/infrastructures. Boccardo and Tonolo, 2012 reckoned factors such as sensor type, ground sample distance, off-nadir angle, and spectral resolution that influences accuracy of EO based damage assessment. Accuracy of remotely sensed damage assessment is reported to vary from 60% to 70% (Corbane et al, 2011; Ajmar et al, 2011).

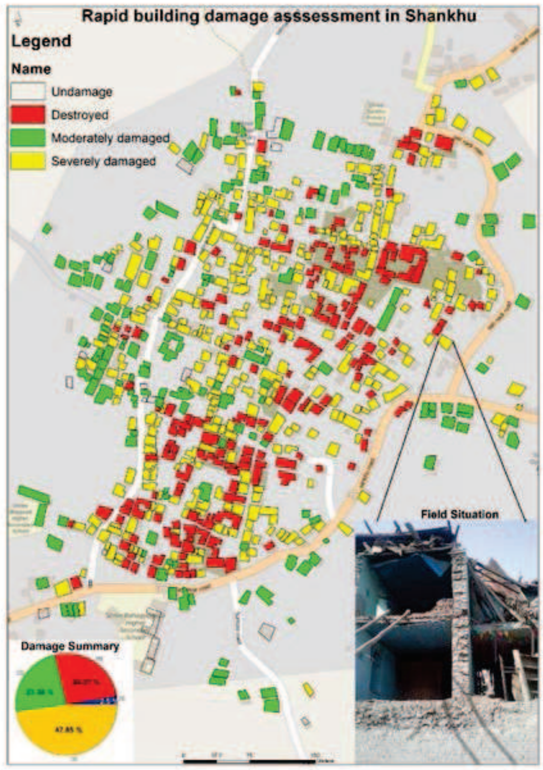

Figure 4. Damage assessment map of Shankhu prepared using UAV.

As air borne sensors are relatively of higher resolution and oblique viewing as compared to space based images, it perform better in terms of damage mapping. An attempt to test unmanned aerial vehicle (UAV) was made for small urban setting (Sakhu town) in Kathmandu valley, using locally assembled quadcopter. The image (Figure 4) thus generated was from 5 cm spatial resolution image which allowed visualizations of debris from collapse building façade, a proxy for damage condition, thus improving the accuracy of the output. Owing to better resolution enhanced detection of one building from other also improved the output. It is however to note that radial distortion on other hand resulted in locational displacement of the mapped elements (buildings). Therefore, use of existing baseline building footprints database in tandem with UAV images will improve the accuracy performance. Limitation with UAV survey is in not being able to cover large area due to very small swath width.

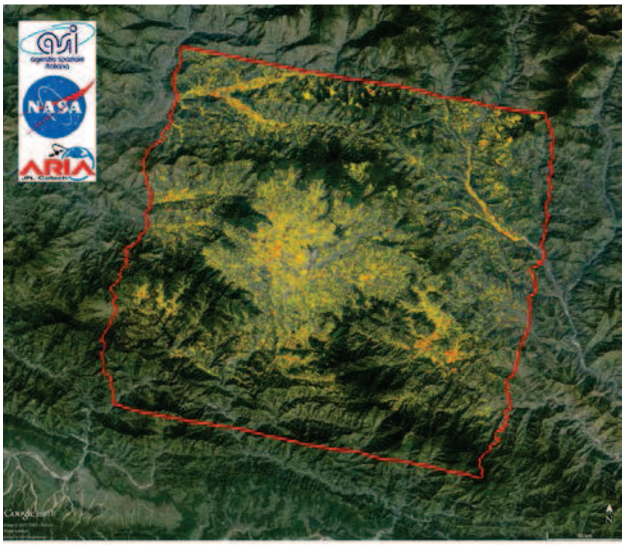

Figure 5. Damage Proxy Map (DPM) generated using synthetic aperture radar (SAR) interferometric by NASA and Caltech scientists.

Microwave satellite data has advantage over optical sensors for being all weather capability, and more importantly having both the amplitude and phase of backscattering information from the objects on the earth's surface. Interferometric analyses using the phase information of microwave satellite data successfully provides the quantitation of the relative ground displacement level due to natural disasters. Since the spatial resolution of many operated satellites is about 30 meters, it is difficult to identify the backscattering characteristics of individual buildings (Matsuoka and Yamazaki, 2004). However, it is possible to detect the groups of damaged buildings. The Advanced Rapid Imaging and Analysis (ARIA) team at JPL and Caltech developed Damage Proxy Map (DPM) (Figure 5) using X-band interferometric synthetic aperture radar data from ASI's COSMO-SkyMed satellite constellation. The technique uses a prototype algorithm to rapidly detect surface changes caused by natural or human-produced damage. More details can be found at http://www.nasa.gov/jpl/nasa-generated-damage-map-to-assist-with-2015-gorkha-nepal-earthquake-disaster.

Since the DPM uses surface change as damage proxy, closer view revealed high damage indication in pixels not associated to buildings. This will likely to overestimate damage area. However, significant improvement can be made and more realistic assessment done if existing building database is used as filter in tandem with DPM.

3.4 Field based mapping of damage infrastructure

Post Nepal Earthquake of April 25, 2015, saw many agencies chip in to support government of Nepal in responding to emergency situation. The Nepal Engineering Association (NEA, http://www.neanepal.org.np/), an independent non-profit organization of Nepalese engineers for example mobilized trained engineers to undertake rapid visual assessment of damaged buildings. The team used check list to collect information based on visual assessment. The volunteering effort collated excellent set of information on damaged buildings but lacked spatial information (location) and pictures. Digital version of the check list, something that can be easily implemented, could have allowed better information enumeration, added with locational information and geo-tagged pictures. Recently, numerous successful studies and approaches can be found in the literatures, which works through large-scale locally administered (Laurila et al., 2012; PhoneLab, 2014) and application store based distribution (Miluzzo et al., 2010). Indeed ICIMOD and Kathmandu University (KU) teamed up to develop a mobile (smart phone) version of data collection application (Figure 6).

The system is developed using native android mobile app with special features like offline Open Street Map (OSM) data, configurable damage assessment form, offline routing algorithm: closest/ shortest path to destination, Geo-fencing: notification / alert to remove duplication during collection of data, offline data save and web based dash-board to visualize data along with data collection status. The web and smart devices software has been implemented in Public Monuments and Culturally significant houses of Kathmandu Municipality City (http://118.91.160.230/nepalearthquake2015/heritage/index-leaflet.php). Similarly, data collection to identify the number and location of buildings at risk, including critical facilities such as hospitals and schools in different parts of Kathmandu. The application comes with inbuilt category for selection (damage status, houses types, etc.), map interface to geo-locate houses, and more importantly does not need internet for data collection. The punched data stored locally can be uploaded to server the moment internet is available. The application is customizable and can be tweaked with little effort to serve user specific requirement.

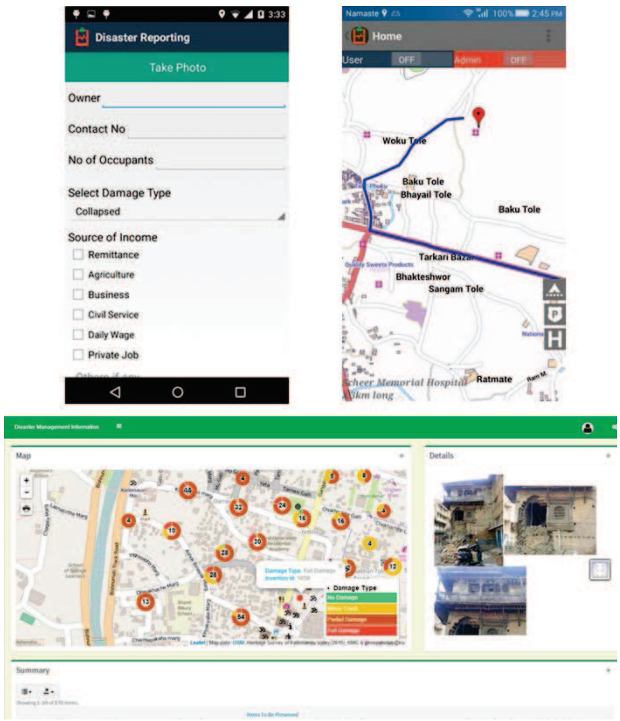

Figure 6. User interface of mobile application to collect damage information, and web based dash-board to visualize data.

Lost opportunity to collect damaged information digitally using smart phone applications (in case of NEA and others) clearly showed lack of coordination amongst the responders. Absence and lack of awareness of such tools prior to the event is testimony of gap in preparedness. Things certainly changed after the earthquake event, United Nations Development Programme (UNDP), in collaboration with Microsoft's local partner, MIC Nepal has designed the world's first app on Debris management (http://techlekh.com/). The Debris management application called as "Debris Management Programme" allows users to feed in information (length, height, width, material, etc.) of damaged infrastructure based on which volume of debris to be cleared is estimated. Based on volume of debris, resources (cost and human) is estimated to manage the debris.

3.5 Mobilizing volunteers

The scale of event was unprecedented and prompted enormous need and demand for information. Geo-spatial team at ICIMOD extending mapping support and contributing through data and information platforms, were completely overwhelmed by requests from national and international response team. To fill the human resource gap, ICIMOD mobilized close to 20 volunteers comprising of mostly students, who contributed immensely under supervision of ICIMOD experts. Unlike volunteers contributing through collaborative space like WMS services as in the case of Haiti earthquake, Nepali volunteers brought in local knowledge which was very helpful while mapping.

Internet as a medium for space for collaboration has encouraged something called "digital volunteering". Something unheard in earlier events, a team of Nepalese nationals residing in different corners of USA teamed up, and closely worked with ICIMOD mapping team, thus enhancing the performance of the rapid mapping team. Half the world apart, time difference between USA and Nepal was used to advantage to complement teams on either side. Each team used to take up from the point where team on the other side left at end of the day. Working in tandem the team performed better to serve the nation. Other excellent examples of volunteering service in post 2015 Nepal earthquake are NASA-USGS lead inter-agency landslide mapping team, and Kathmandu Living Lab (KLL, http://kathmandulivinglabs.org/).

While the role of volunteers in rapid response mapping is expected to grow, there are few learnings from Nepal experience to improve collaborative engagement. The need for standard guidelines for mapping was highly felt. Volunteers are mix group of expert and amateur with different levels of expertise, and without standardize guidelines for mapping (landslide for example) landslides were mapped the way individual interpreted. This resulted in landslide figures that varied widely, and created confusion in users mind, government agencies, and general public at large.

3.6 Crowdsourcing

Crowdsourcing as a mechanism for information collection is gaining wider acceptance in different fields including emergency management. With mobile phones becoming ever more pervasive, it is convenient for public in general to report an event quickly thus play a role of data generator. The crowdsourced information however are questioned on accuracy and reliability (Brandel 2002; Burgener 2004). Experience in 2015 Nepal Earthquake showed that agencies needing to make hard decisions are reluctant to honour crowdsourced information. In situation where there isn't better data, such data is great asset. Crowdsourcing as a data gathering mechanism needs to integrate authentication provision through moderation if the data/information is to have wider utility.

3.7 Single information gateway

The Nepal Earthquake due to shear devastation rallied support from multiple agencies from within Nepal and beyond. There were many formal and informal mechanisms to collect information from field but without a centralized system, information was far from consolidated. With larger picture missing, situation and gap (relief distribution, response interventions) analysis was lacking due to which inequitable relief and response was reported.

ICIMOD initially used a dedicated website (http://www.icimod.org/nepalearthquake2015) to disseminate rapid response mapping products generated by ICIMOD and extended team. As there was need for collaborative space to collate information from different quarters and consolidated centrally under Government stewardship, ICIMOD and MoHA developed the Nepal Disaster Relief and Recovery Information Platform (NDRRIP) portal. The NDRRIP (http://apps.geoportal.icimod.org/ndrrip) portal served as a centralized single gateway for information and helped present consolidated picture and comprehensive situation on damage and loss, relief distribution, and socio-economic and demographic characteristics of affected districts. The portal proved very useful in terms of understanding larger picture, critical for knowing gaps and needs, based on which relief and response interventions are equitably deployed.

Figure 7. Landing page of NDRRIP portal – consolidating data and information into one central access system.

4. CONCLUSION

The 2015 Nepal Earthquake caught us unaware and under prepared. Collectively we did what we could best do in that situation, but as in every experience we take learnings forward and move forward. Ordeal of such scale draws lots of humanitarian assistance from world around, but lack of basic infrastructure could act as bottleneck in reaping the generous support of global community, be it satellite data providers or relief and response providers useful. Despite the recent development in space science and earth observation with many new exciting possibilities, operational challenges remains. It needs a multi-approach and deploy data and tools from different sources in tandem to get reliable and usable information. Interferometry based damage proxy maps by team at JPL and Caltech is promising, and indicates new frontiers for applied research.

Event of such scale generates debris of data and information, and making sense of it sometime is a challenges. Data consolidation and presentation is equally important to translate data into actionable information and to knowledge. Need for a single information gateway for data consolidation, and facilitate data discovery was highly felt.

The role of volunteers and peer mapping will grow with time, and to make their engagement meaningful a mapping guidelines is felt essential.

5. ACKNOWLEDGEMENT

The article touched upon activities undertaken by different international and national agencies, to draw learnings from the experience. Appreciation to those individual and agencies who contributed in our effort to support relief and response. Large part of the experienced shared is from ICIMOD's engagement under SERVIR support, for which the team is highly appreciative to NASA and USAID. Thanks also goes to ICIMOD colleagues and volunteers who contributed immensely in rapid mapping. The support received by ICIMOD from network of partners like JAXA, ADRC, UN-SPIDER was invaluable.

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