# A Multitemporal, Multivariate Index to Dynamically Characterize Vulnerability of Children and Adolescents in Nepal

Using Science in Humanitarian Response

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## Summary

A large number of children and adolescents (population under the age of 20 years) in Nepal have been negatively impacted by the 7.8$M_w$ earthquake of April 25, 2015 and its many aftershocks, particularly the 7.3$M_w$ on May 12. Thousands of children, adolescents, and vulnerable people have been displaced from their homes, unable to attend schools, lacking access to health care facilities and dealing with psychological trauma from the event. The already vulnerable population has been weakened by the earthquake events and currently faces multiple imminent perils: the constant threat of more aftershocks and the possibility of flooding and more deadly landslides from the current monsoon rains. Furthermore, the type of negative effects the children and adolescents have suffered often become long-standing issues in poverty stricken countries such as Nepal (GAR, 2009 and Seballos, 2011). However, with timely threat-identification and proper preventative action, some of these threats can be lessened or alleviated. The discussion below lays out a method to identify these potential future impacts through a series of GIS overlays in an online atlas of “Stories of Nepal”.

## Background

Children and adolescents are particularly vulnerable to negative effects of major natural catastrophes. In its statement for the *Third Annual UN Conference on Disaster Risk Reduction*, UNICEF asserts that negative impacts of disasters are felt most strongly by those already living in poverty, particularly children. In Nepal, “Two thirds of the children are severely deprived and just under forty percent live in absolute poverty (UNICEF, 2010).”

Issues relating to lack of access to schooling, healthcare and safe accommodation are prevalent in the response and recovery stages of disasters. Compounding this, evidence from previous disasters demonstrates that children are at an increased risk of child trafficking, sexual or physical abuse, and psychological trauma post-event and therefore prioritizing aid to children, adolescents, and vulnerable populations is time critical (UNICEF, 2015). According to the *2011 Global Assessment Report on Disaster Risk Reduction* (GAR11) “Disasters negatively affect children’s medium-term development when schools are destroyed or damaged and household assets and livelihood assets are lost.” Disrupting education can have obvious effects, such as diminished future educational achievement, as well as less obvious effects: schools often provide food for students and those students living in poverty could further suffer malnutrition and weakened immune systems without the school meals. In the Nepal earthquake and aftershocks, many schools were reported as damaged or destroyed. While school was not in session at the time of the main earthquake (a Saturday), potentially saving many lives, significant damage to residential structures, especially in rural areas, resulted in hundreds of thousands of displaced children and adolescents. With many schools incapacitated and no permanent homes to live in, these children and adolescents remain vulnerable to present and future hardships, and significant delay in returning to some level of normality.

Damage to healthcare facilities not only inhibits the medical community's ability to serve those in immediate need of medical care, it makes long-term care of the total affected population difficult and unlikely. In this case, children's medical needs, such as childhood vaccinations and infant check-ups, are often not met.  Healthcare facilities were greatly impacted by the Nepal earthquakes and the relocation of children and adolescents to temporary accommodation in internally displaced persons' (IDP) camps has resulted in a lack of immediate availability of health care.

In addition to the hardships directly caused by the earthquake the Monsoon season has begun; monsoon rains in Nepal typically increase the threat of landslides and flooding, especially in the mountainous regions to the north, west and east of the Kathmandu Valley. With an estimated 1-2 million[1] people displaced from their homes and many of them living in temporary shelters like tents and makeshift shelters, the rains pose a more significant threat than usual. Rain induced flooding and landslides as well as the increase in the number of landslide-induced dams and the ever-present danger of aftershocks all combine to threaten access to many rural communities, thus restricting provision of schooling, healthcare and security to children and adolescents.

## Indicators of Vulnerability

Given the conditions discussed above, we propose developing the following impact factors to characterize existing vulnerability of children and adolescents in the earthquake-affected regions of Nepal. The multivariate index described here provides the initial framework for a broader index that could incorporate any number of indicators of vulnerability to children and adolescents. It is designed to provide a multi-temporal assessment of risk throughout the initial response and early recovery time periods.

The factors can be developed for any level of geographic resolution, but for the purposes of this study are set to Village Development Committee (VDC) level:

1) ***Displaced Population (Children and Adolescents) Impact Factor*** *(0-1):* The Displaced Population (Children and Adolescents) Impact Factor is an index ranging from 0 to 1, with 0 indicating no displaced children or adolescents, and 1 indicating 100 percent of children and adolescents in that area have been displaced. It is estimated through state-of-the-art methods that incorporate the distribution of building damage and Government of Nepal census data. The building damage functions used for modelling were modified damage functions from HAZUS2 and were applied to four development types that are observed in Nepal: 1) sparsely populated, 2) rural, 3) dense development, and 4) urban development. Each region was classified (in part) using remotely-sensed imagery/data.  Structural classifications (breakdown) were identified for these areas based on an extensive review of Kathmandu, the World Housing Encyclopedia (EERI)[3], various earthquake studies for Nepal, and web resources.

2) ***School Availability Impact Factor*** *(0 to 1):* The School Availability Impact Factor is an index ranging from 0 to 1, with 0 indicating no impact on schools, and 1 indicating 100 percent of the schools closed for repair or destroyed. Damage to schools are inferred from general building damage

[1]http://weather.msfc.nasa.gov/sport/disasters/gorkha/damageAndVulnerabilityMaps/buildingdamage/buildingdamage_20150522.html

[2] FEMA DHS loss estimation program

[3] www.world-housing.net

estimates calculated at each VDC. Schools in each VDC are assigned different damage states according to the probabilities generated for the overall building exposure. All schools in extensive or complete damage state are considered to be non-functional with enrolled students having no access to these schools.

3) ***Healthcare Availability Impact Factor*** *(0 to 1):* The Healthcare Availability Impact Factor is an index ranging from 0 to 1, with 0 indicating no impact on health care facilities, and 1 indicating 100 percent of the facilities closed for repair. Damage state probabilities are generated per VDC using the same approach as schools, and applied to healthcare facilities. Healthcare facility capacity is reduced by its probability of being in an extensive or complete damage state, which is used as the Healthcare Availability Impact Factor.

4) ***Maximum Combined Impact Factor*** *(0 to 1):* Given that all the indicators above range from 0 to 1, with 1 indicating all of the population impacted and 0 indicating none of the population impacted, the scores can be combined by taking the maximum to indicate the greatest impact on children and adolescents from these factors.

The methodological steps used to develop each index are discussed later in this document, in the *Methodology* section.

## Indicators of Hazard

The vulnerable population's exposure to three specific hazards - landslides, avalanches, and debris flow, is increased given 1) the current monsoon season and 2) the potential for further aftershocks. Landslides have already occurred, further exacerbating these three hazards. For this study, three indicators of hazard will be examined:

1) Landslide potential given precipitation and flooding (LF)
2) Landslide potential given seismicity and aftershock forecasts (LA)
3) Existing landslides in post-quake conditions (LE)

## Developing a Risk Index for Children and Adolescents

Given the above approach to identifying children and adolescents at risk and the presence of hazards, we recommend the following approach to assessing risk:

Children and Adolescents Risk Index = (Vulnerability Index) × (Hazard Index),

where,

Vulnerability Index = *Maximum (Indicators of Vulnerability)* or the *(Maximum Combined Impact),*

Hazard Index = Landslide potential given flooding (LF) + Landslide potential given aftershocks (LA) + Existing landslide conditions (LE),

therefore,

Children and Adolescents Risk Index = *Maximum (Indicators of Vulnerability)* × *(LF + LA + LE).*

The approach is flexible to enable multiple methods of combining each of the indices depending on the desired vulnerabilities to estimate. This approach also is conducive to developing a weight-based combination of indices where one parameter can be weighted more than others.

## Spatial Resolution

The Risk Index will be calculated and presented at the VDC (Village Development Committees) level. Analysis at the spatial unit of a VDC will be large enough to reduce the impact of misregistration or data eccentricities at the local level, but fine enough to identify specific areas of concern in the coming months. VDC is an appropriate spatial resolution given the existing program activities and reporting requirements in Nepal.

## Available Data

The availability of data is critical to the generation of a multivariate index. The following table describes known datasets that can inform each indicator as well as potential sources for additional datasets.

| Indicator | Available Data | Notes |
|---|---|---|
| **Schools** | GFDRR, Open Cities Project, OSM vectors (polygons), Nepal's Education Profile from HDX | Data in the form of school building footprints, spreadsheets on number of schools and enrolment by district |
| **Healthcare Facilities** | 3W files, NGA | Data derived from OSM, DFID, MapAction, governmental data |
| **Access to Short Term Shelter** | IOM IDP camps and shelters, NGA IDP camp data (points), OSM (polygons), TomNod shelter and tents | Additional sources include UN-HABITAT, Habitat for Humanity |
| **Flood hazard** | JBA, SSBN | Commercial sources of probabilistic flood data |
| **Landslide hazard** | NASA, ICIMOD, BGS, Durham University | |
| **Population data** | CIESIN, Nepal National Census | |
| **Population movement data** | FLOWMINDER (mobile phone-derived) | |

*Note. Not all these data sources were used in calculation of the vulnerability indices*

## Methodology

The following describes the type of basic tasks for preparation of the data to best inform the individual child vulnerability indicators and the hazard indices that are used to develop the final Children and Adolescents Risk Index:

## Vulnerability

***1) Displaced Population (Children and Adolescents) Impact Factor (0-1).*** The methodology to create this index consists of the following steps, 1) estimate the number of damaged buildings (slight, moderate, extensive, and complete damage) in each VDC, 2) estimate the number of displaced persons in the VDCs –estimated as the number of surviving population who were living in structures (Census 2011 data from Center for International Earth Science Information Network (CIESIN), Columbia University, USA) that were extensively damaged or destroyed by the earthquake,3) estimate the number of displaced children and adolescents in the VDCs by using the per-district proportions of population age 19 or under, and lastly, 4) calculate the Displaced Population (Children and Adolescents) Impact Factor by determining the ratio of the displaced population age 19 and under to the total population age 19 and under in each VDC. The Factor ranges from 0 to 1, with 0 indicating no displaced children or adolescents, and 1 indicating 100 percent of children and adolescents displaced (see figure 1).

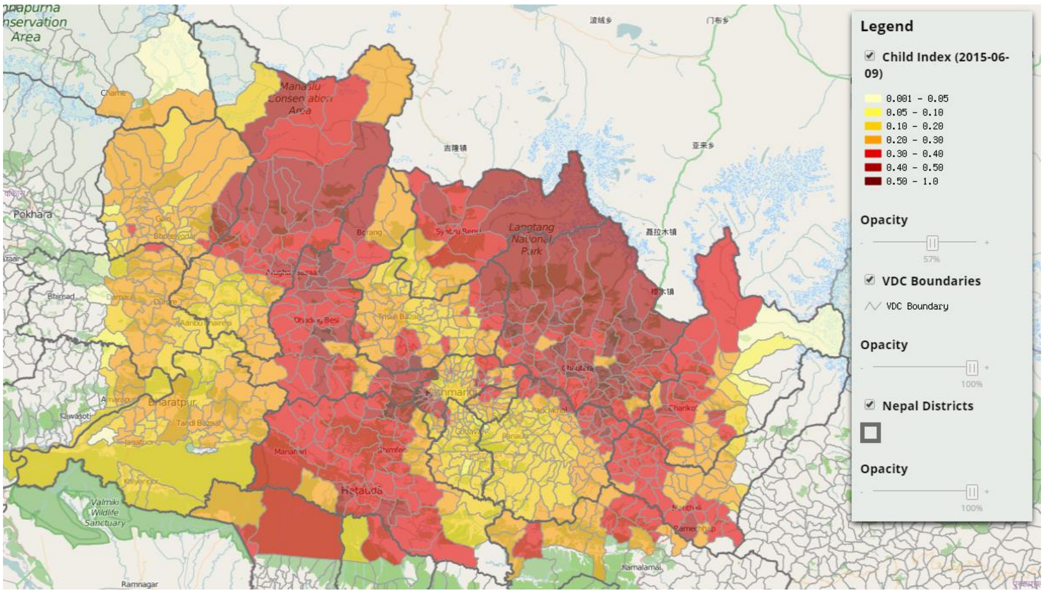


**Figure 1. Map showing displaced population (children and adolescents) impact factor. Darker reds show a higher vulnerability score, with light yellows showing areas of least vulnerability.**

**2)** ***School Availability Impact Factor (0-1).*** The methodology to determine the School Availability Impact Factor consists of the following steps, 1) use data on the number of schools from Nepal's Education Profile (data from the Humanitarian Data Exchange), 2) estimate the number of school buildings in the quake affected region by the level of damage (slight, moderate, extensive and complete) in each VDC, 3) estimate the number of enrolled students impacted by extensive and completely damaged schools, and lastly, 4) determine the School Availability Impact Factor using the ratio of enrolled student s without access to schools and the total number of enrolled students in a VDC. The index rating ranges from 0 – 1, with 0 indicating no impact on schools, and 1 indicating 100 percent of the schools closed due to damage or for repair (see figure 2).

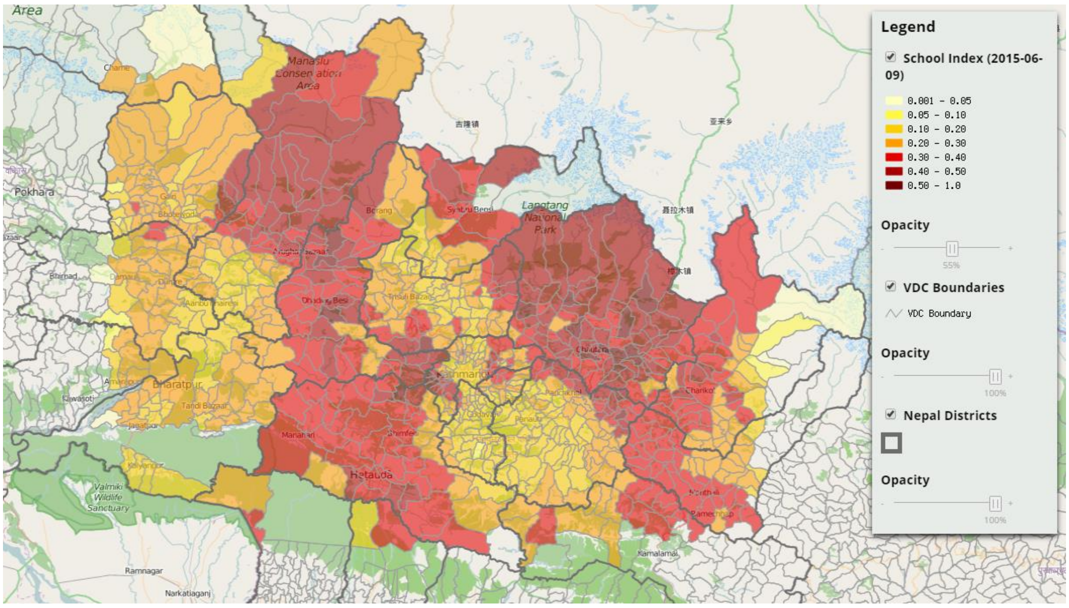


**Figure 2. Map showing school availability impact factor. Darker reds show a higher vulnerability score, with light yellows showing areas of least vulnerability.**

**3) *Healthcare availability impact factor (0-1)*.** Healthcare Availability Impact Factor is determined by the ratio of the population age 19 and under without access to healthcare facilities and the total number of people age 19 and under living in a VDC. The index ranges from 0 to 1, with 0 indicating no impact on hospitals and health care facilities, and 1 indicating 100 percent of the healthcare facilities closed due to damage or for repair (see figure 3).

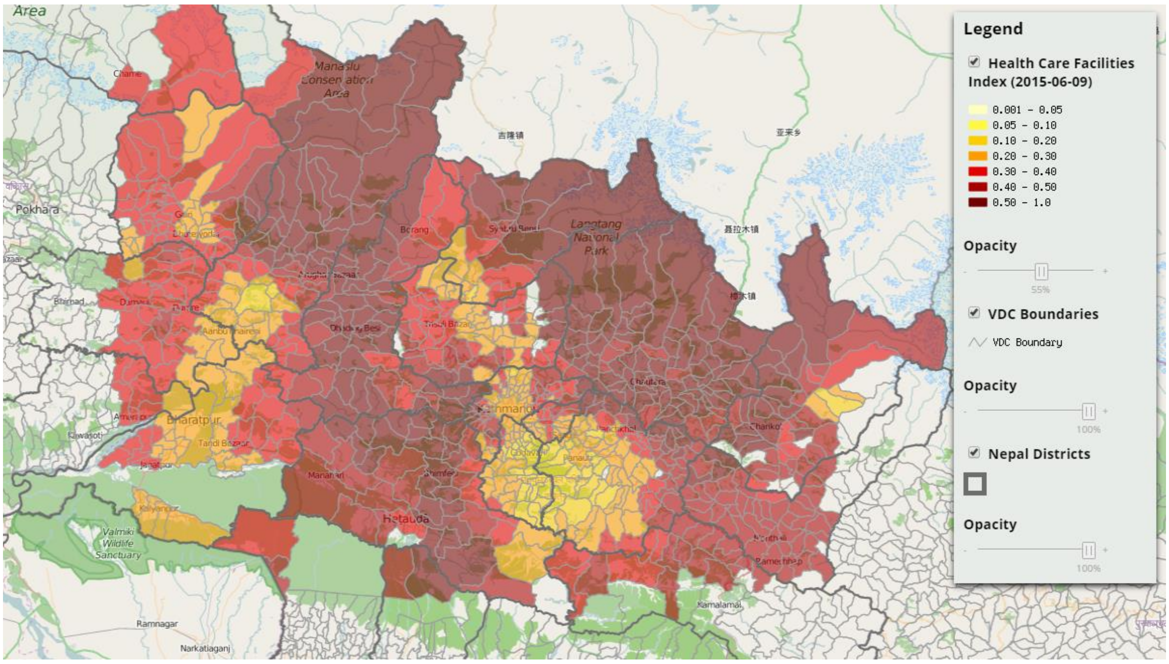


**Figure 3. Map showing healthcare facility availability impact factor. Darker reds show a higher vulnerability score, with light yellows showing areas of least vulnerability.**

**4) *Maximum Combined Impact Factor (0 to 1).*** The Maximum Combined Impact Factor is determined taking the maximum of the first 3 indicators each of which ranges from 0 to 1. The resulting index ranges from "0"indicating none of the population is impacted to 1, indicating all of the population is impacted by at least one of the vulnerability impact factors. This impact factor indicates the greatest impact on children and adolescents from all the three impact factors.

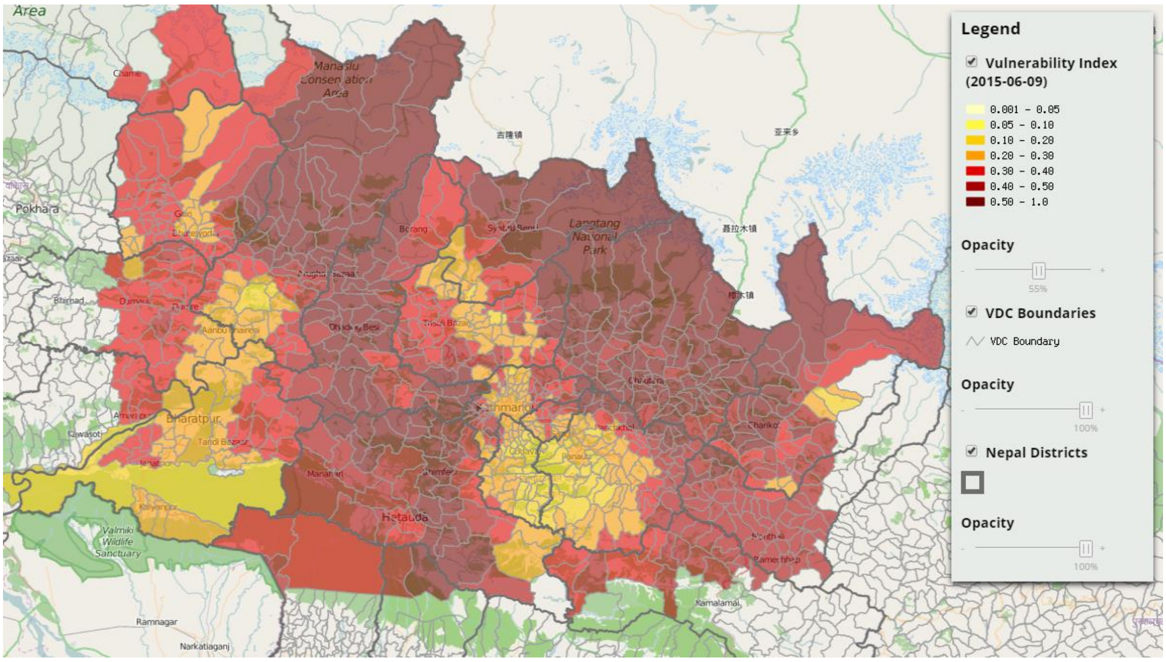


**Figure 4. Map showing combined impact factor. Darker reds show a higher vulnerability score, with light yellows showing areas of least vulnerability. Mountainous areas and those VDCs to the immediate west and east of the Kathmandu Valley show significant levels of vulnerability.**

## Hazard

**1) Landslide potential given precipitation:** This hazard layer (Global Risk Data Platform[4]) provides an estimate of annual frequency of landslide triggered by precipitation. It depends on the combination of trigger and susceptibility defined by six parameters: slope factor, lithological (or geological) conditions, soil moisture condition, vegetation cover, precipitation and seismic conditions. Unit is expected annual probability and percentage of pixel of occurrence of a potentially destructive landslide event x 1000000. This product was designed by International Centre for Geohazards /NGI for the Global Assessment Report on Risk Reduction (GAR). It was modeled using global data. Using this dataset on the estimated annual frequency of landslide triggered by precipitations, a binary IN or OUT hazard score was computed at the VDC level (see figure 5).

[4] http://preview.grid.unep.ch/index.php?preview=data&events=landslides&evcat=2&lang=eng (GIS processing International Centre for Geohazards /NGI)

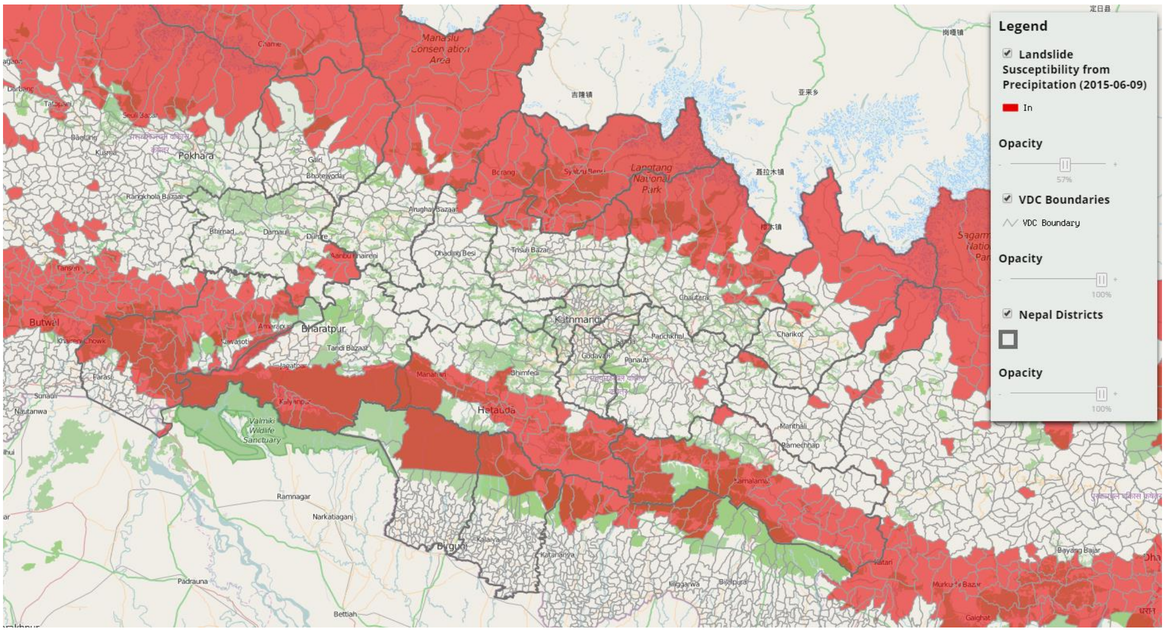


**Figure 5. Landslide potential given precipitation at the VDC level. Vulnerability is shown by a binary In/Out determination. VDCs in red are deemed to be vulnerable to precipitation-induced landslides.**

**2) Landslide potential given seismicity and aftershock forecasts:** This hazard layer (Global Risk Data Platform) provides an estimate of the annual frequency of landslide triggered by earthquakes. It depends on the combination of trigger and susceptibility defined by six parameters: slope factor, lithological (or geological) conditions, soil moisture condition, vegetation cover, precipitation and seismic conditions. Unit is expected annual probability and percentage of pixel of occurrence of a potentially destructive landslide event x 1000000. This product was designed by International Centre for Geohazards /NGI for the Global Assessment Report on Risk Reduction (GAR). It was modeled using global data. Using this dataset on estimate of the annual frequency of landslide triggered by earthquake, a binary IN or OUT hazard score was computed at the VDC level (see figure 6).

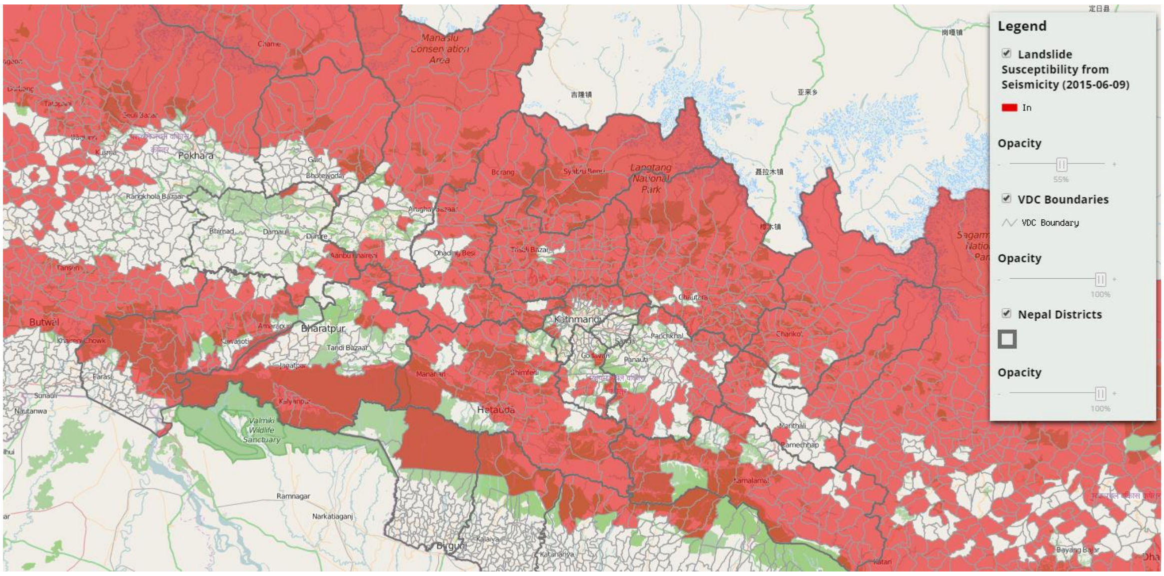


**Figure 6. Landslide potential given seismicity and aftershock potential at the VDC level. Vulnerability is shown by a binary In/Out determination. VDCs in red are deemed to be vulnerable to seismically-induced landslides.**

**3) Existing landslides in post-quake conditions:** ICIMOD, NASA, British Geological Survey-Durham University-Earthquakes without Frontiers team and international volunteer teams used high-resolution satellite imagery (NASA, Japan Aerospace Exploration Agency (JAXA), Digital Globe, International Charter on Space and Major Disasters) to identify landslides that affected villages and landslide-dammed rivers that could lead to severe downstream flooding if the dam is suddenly breached. Given the large loss of life and property during and after the earthquake, ICIMOD and its collaborators aimed to provide knowledge that can help prevent future disasters in the affected areas. To date, the response teams have identified over 3,000 landslides and assembled a database of over 250 identified landslides and other large mass movements, focusing specifically on those that were generated by the earthquake and its aftershocks or other secondary effects. Using this dataset on actual incidents of landslide triggered by the April 25th earthquake and its many aftershocks, a binary IN or OUT hazard score was computed at the VDC level (see figure 7).

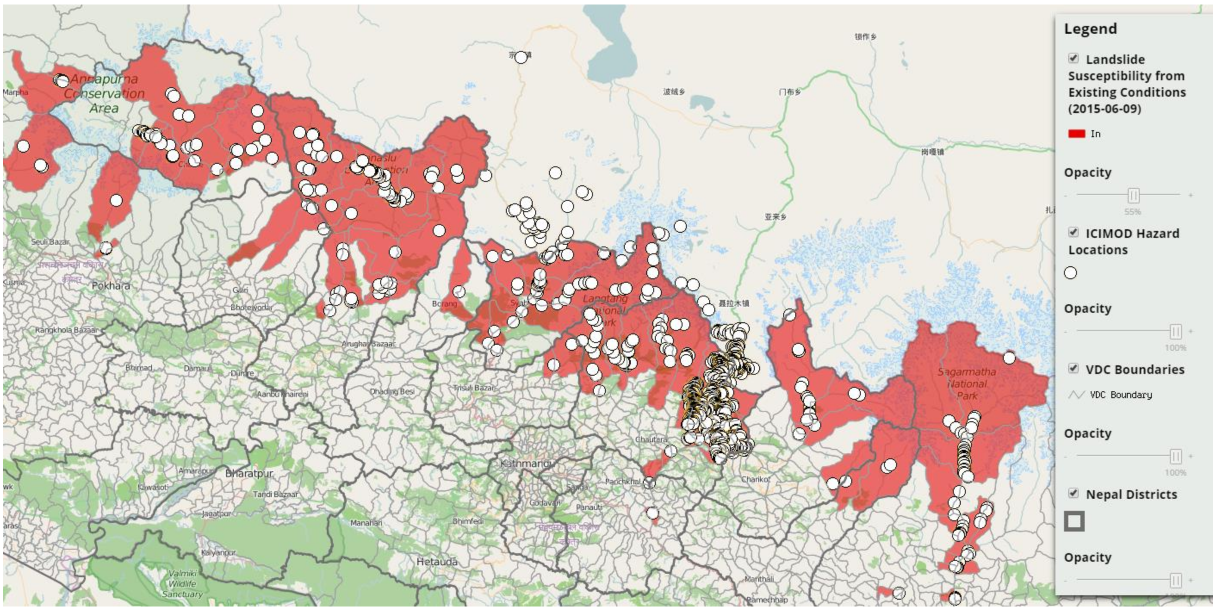


**Figure 7. Existing landslides in post-quake at the VDC level. Vulnerability is shown by a binary In/Out determination. VDCs in red are deemed to be currently vulnerable to landslides.**

**4) Combined Hazard Score**: This index indicates an overall hazard score from the existence of landslide hazards from precipitation, earthquakes, or post-quake incidents: 1 indicates single type of landslide hazard while 3 indicates all three types present at the VDC level (see figure 8).

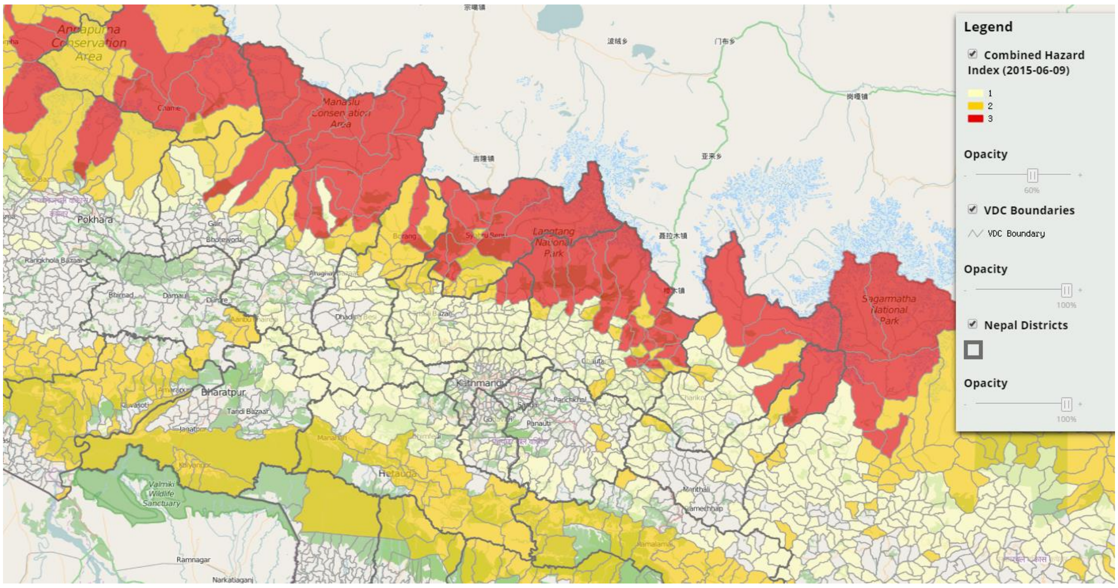


**Figure 8. Combined hazard score map. VDCs denoted in red are at risk of all three identified hazards (LF, LA, LE) and typically correlate to particularly mountainous VDCs to the north of the Kathmandu Valley.**

## Children and Adolescents Risk Index

This is developed as a product of the combined vulnerability index and the total hazard score- see figure 9. Children and Adolescents Risk Index = Maximum (Indicators of Vulnerability) $\times$ (Combined Hazard Index)

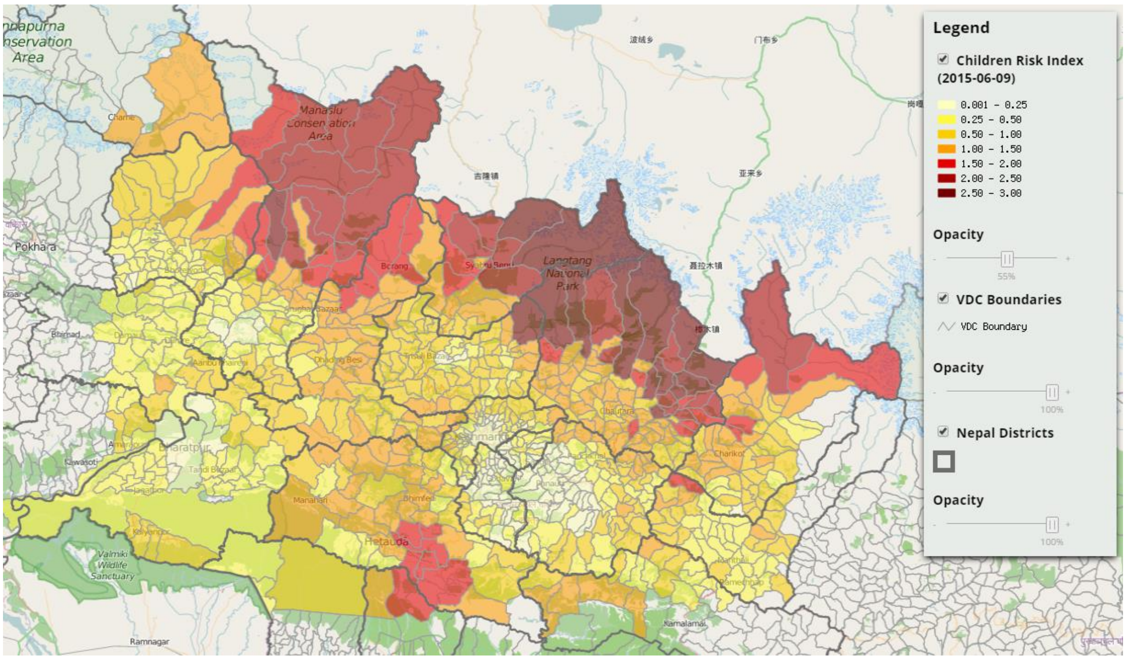


**Figure 9. Map showing children risk index**

## Additional Requirements

As new data becomes available or as new agencies become involved in the response or recovery activities, additional indicators of vulnerability can be developed and combined in the multivariate score. The index should be periodically updated as new data are published. In the immediate aftermath of a disaster, this may be frequent – multiple times per week. As response transitions into early recovery, this might typically be once a week or bi-weekly. As recovery transitions into preparedness, the index may only be updated on a monthly or quarterly basis. It is important to have a program in place to periodically renew the data that underpins this index or identify new sources of data and assess its efficacy for such an index.

## Limitations

The index proposed is quite straightforward and is designed to broaden discussion with UNICEF on the use of multivariate indices for measuring and spatially comparing districts or regions. It does have a number of limitations which should be noted.

- The method does not consider resilience or pre-event development initiatives.
- Veracity and vintage of input data – significant effort needs to be put in to make sure data is up to date and from credible sources.

## Future Work

Other potential extension to include (subject to data availability):

- Demographic: Gender proportionality of children
- Demographic: Proportion of single-parent families
- Welfare: Presence of accredited child-focused agency/NGO
- Welfare: Income/poverty indicators
- Welfare: Access to family areas/ play areas in camps
- Nutrition: Nutritional status indicators for children
- Security: Incidents of physical or sexual abuse
- Security: Incidents of child trafficking

## References

GAR. (2011). Global Assessment Report on Disaster Risk Reduction 2011
http://www.preventionweb.net/english/hyogo/gar/2011/en/home/index.html

Seballos, F., and Tanner, T. (2011). Enabling Child-Centred Agency in Disaster Risk Reduction. Global Assessment Report on Disaster Risk Reduction 2011.
http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Seballos_&_Tanner_2011.pdf

Tarazona, M. and Gallegos, J. (2010). Recent Trends in Disaster Impacts on Child Welfare and Development 1999-2009. Global Assessment Report on Disaster Risk Reduction 201.
http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Tarazona_&_Gallegos_2010.pdf

UNICEF. (2010). Nepal: Child Poverty and Disparities Study 2010.
https://sites.google.com/site/nepalchildpovertystudy/

UNICEF. (2015). Third Annual UN Conference on Disaster Risk Reduction: UNICEF Statement.
http://www.unicef.org/media/media_81306.html

UNISDR. (2011). Children and disasters: Building resilience through education
http://www.unisdr.org/files/24583_childrenanddisastersbuildingresilie.pdf