Preparing Landslide Inventory Maps using Virtual Globes

Introduction:

A landslide is the movement of a mass of rock, debris, or earth down a slope, under the influence of gravity. Landslides can be caused by different phenomena, including intense or prolonged rainfall, earthquakes, rapid snow melting, volcanic activity, and multiple human actions. Landslides can involve flowing, sliding, toppling, or falling. Many landslides exhibit a combination of two or more types of movements, at the same time or during the lifetime of a landslide. In this article, the words '*landslide*', '*mass movement*', and '*slope failure*' are used synonymously. A landslide inventory map records the location and, where known, the date of occurrence and the types of mass movements that have left discernable traces in an area which can be identified in the field, or in aerial photographs and satellite imageries. In this article, the words '*inventory*', '*landslide inventory*', '*landslide map*', and '*landslide inventory map*' are used as synonymously.

Landslide inventory maps are prepared for multiple purposes including:

(i)   Documenting the extent of landslide phenomena in areas ranging from small to large watersheds, and from regions to states or nations.

(ii)   As a preliminary step toward landslide susceptibility, hazard, and risk assessment.

(iii)   To investigate the distribution, types, and patterns of landslides in relation to morphological and geological characteristics, and

(iv)   To study the evolution of landscapes dominated by mass-wasting processes.

Despite the clear relevance of landslide inventory maps, and the fact that landslide maps have been prepared for many years in all continents, the criteria for the production of landslide maps and for the evaluation of their quality remain poorly defined. Availability of new remote sensing technologies for the detection and mapping of landslides may facilitate the production of landslide maps, and the definition of criteria to evaluate their quality.

Field methods for identification and mapping of landslides are expensive and time consuming. However, with advancement in technology and the availability of high resolution satellite imagery, it has now become possible to identify landslides and estimate the time of their occurrence through a study of multi-date images. Many virtual globes available in the public domain through the World Wide Web (www) feature high resolution multi-date imagery.

The advent in 2005 of Google Earth®, which provides worldwide coverage of high resolution and very high resolution, multi-temporal satellite images, combined with DEMs to obtain 3D-views of the terrain, has provided investigators with new opportunities to utilize Google Earth® for the identification and mapping of landslides. Google Earth's new features which include the ability to vectorize points, lines and polygons and view old satellite images are particularly useful, since these make landslide identification and mapping an easily accomplished task.

Landslides are identified from high resolution satellite images in Google earth with the help of many attributes, including colour, tone, mottling (surface roughness), texture and association. These factors depend on the light reflected by the surface, and can be used to infer rock, soil and vegetation types, the latter being a proxy for wetness. Landslides are easily recognizable immediately after a landslide event. The landslide boundaries are usually distinct, making it relatively easy to identify and map the landslide. Fresh landslide areas are

devoid of vegetation cover. As time passes, vegetation starts to cover the landslides and human activity results in the destruction of its evidence. Many landslides appear to have been reactivated and moved as time progressed.

Practical Aims

The purpose of this practical exercise is to identify and map the aerial extent of recent (and active) landslides in a part of the Kumaon Himalaya. The extent of the area is limited to the Watershed of the Goriganga River, which is 2250 sq km. You may download the Goriganga Watershed and open it in Google Earth. The aims of this exercise include:

1. Identification of landslides in the selected area from Google Earth images
2. Estimating the approximate dates when the landslides took place
3. Finding the latitude and longitude of the landslides
4. Calculating the area of a few landslides
5. Assessing whether the landslide was a one-time event, or has been intermittently active
6. Identifying the geomorphic changes brought about by the landslide

Significance of Identifying Landslides

Landslides are a serious natural hazard and can result in major loss of life and property (Error! Reference source not found.). In many regions, the damage caused by landslides can be severe. With a good landslide inventory, citizens can begin to understand landslides processes, assess risk, and prevent damage from the threats they pose.
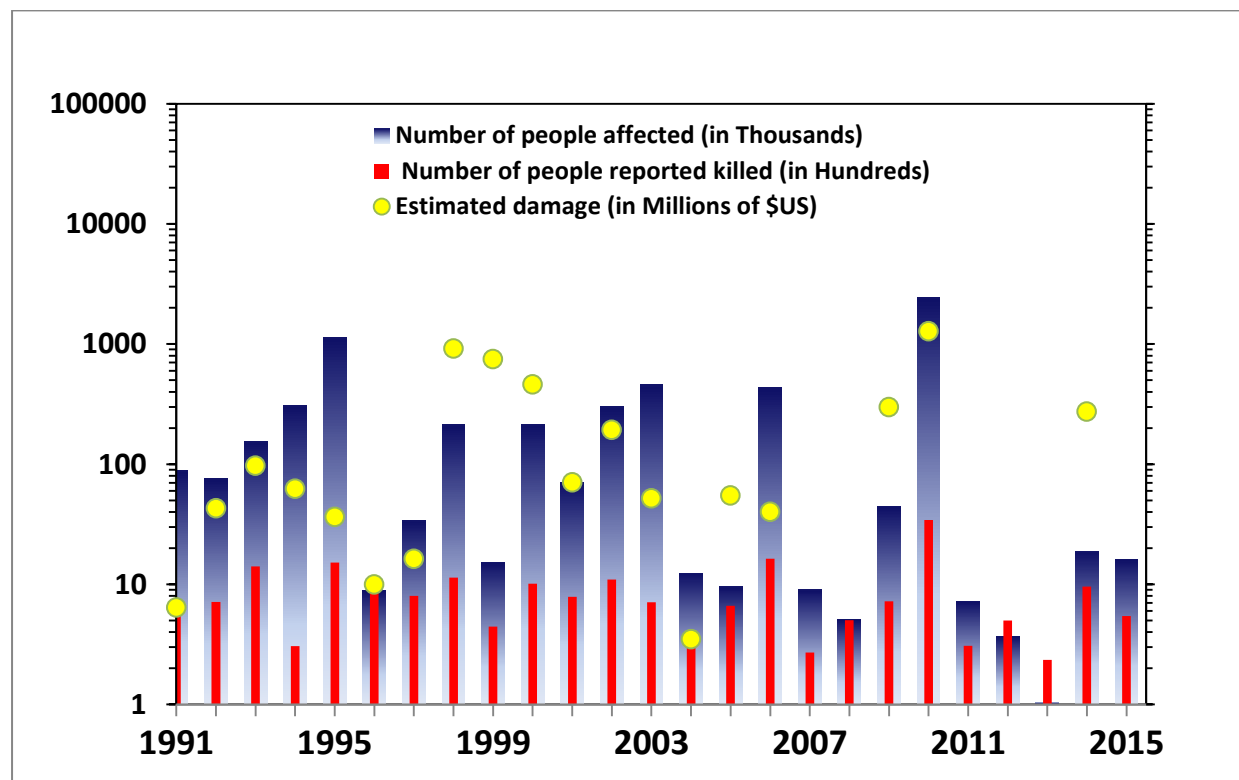

Figure xx: Total number of people reported affected and killed yearly, along with estimated yearly damage due to landslides worldwide (1991-2015). Data for 2015 only upto July. Source International Disaster Database maintained by the Centre for Research on the Epidemiology of Disasters (CRED) with support from the WHO and the Belgian Government (www.emdat.net).

The global population has grown from 1 billion in 1800 to 7.36 billion in 2015. It is expected to keep growing to reach 10.1 billion by the end of the 21st century (Ezeh *et al.*, 2012). Increasing population has resulted in scarcity of space and people moving to hazardous areas, without knowing about the hazards. Landslide identification is one of the first steps in identifying potential hazard for the future. The landslides which are identified using satellite images, aerial photos and field studies, can be used for landslide susceptibility and risk mapping. These maps can then be used by planners and policy makers in restricting construction in hazardous areas, and ultimately reduce the impact of landslides.

Significant portions of the Goriganga Basin are comprised of sloping, barren ground, and most of this land is subject to landslides and other types of slope failure. Nearly a thousand landslides – ranging widely in age, size, type and degree of activity – can be identified within the Goriganga Basin.

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A detailed look at Lumati landslide reveals that the landslide is very clear in March 2004 images, particularly at the upper tip of the landslide. Very few terraces can be identified in the November 2014 images. However, a look at 2010 and 2011 images shows new vegetation, houses and new terraces coming up on the landslides.

Figure 2: Two oblique views of a landslide affected area in sub-basin 28 of the Goriganga, (29.931636° N; 80.298164° E) (Google Earth, 2015). As can be readily seen from this figure, a ten-year period is sufficient to obliterate the scars of a landslide. A) Imagery date 05.03.2004; B) Imagery date 23.11.2014.

# Measuring landslides in Google Earth

In this practical, we will demonstrate how to measure the area of a landslide (and observe its change over time, and its profile) using Google Earth. We will use as an example a landslide from Lumati in Uttarakhand. Later, in Section 3, you will be given three examples of regions where landslides have occurred that you can explore using Google Earth. The Lumati landslide that we will use, is one of many hundreds of landslides (mainly rock falls and rock slides) triggered by heavy rains and earthquakes in the region. The landslide changed the course of the Goriganga River. We will look at the Lumati landslide and try to answer some basic questions. Finally we will prepare a report on few landslides (other than the Lumati landslide).

While preparing the report, it would be good if you can include some snapshots of the landslides you have identified. Taking snapshots is very easy in Windows 7. Click on PrtScn on the keyboard and then click the right mouse button and select paste at the designated place.

We now illustrate, through a series of 14 steps, an exploration of how the landslide has changed with time.

2.1. Start Google Earth: Start Google Earth by double clicking the desktop shortcut icon.

2.2. Search: Enter the name of location (Lumati, Uttarakhand in this case) in the Search panel (top left) and click Search. The Google earth will automatically zoom to Lumati, a small village along the Goriganga River.
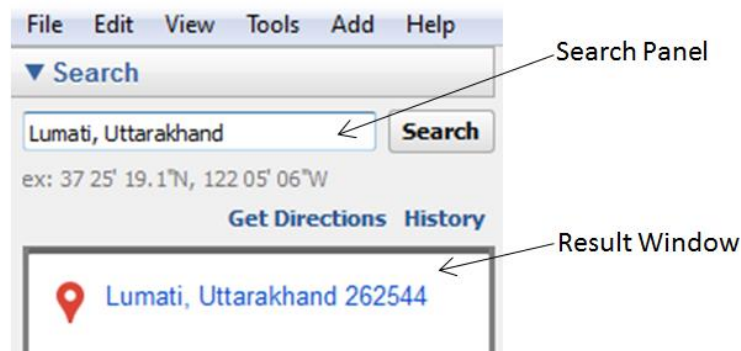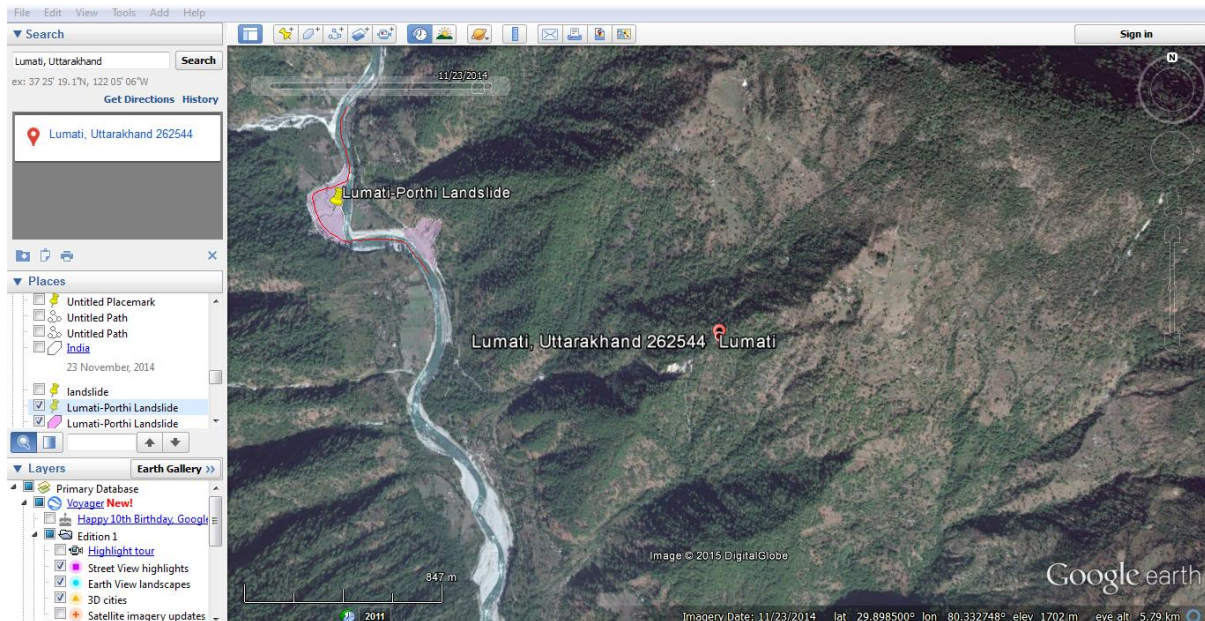
Zoom out a bit and you will see a big landslide to the WNW of Lumati village.

2.3. Pan or Move Around: Now we will move around the landslide and see it more closely. You can navigate or move around the landslide in Google earth by holding the left mouse button and dragging it to the desired location.

2.4. Zoom in: There are a number of ways you can zoom into your image.

- Zoom in and out using the mouse
  - Using mouse wheel - To zoom out scroll the mouse wheel down (toward you). Scroll the mouse wheel up (away from you to zoom in.
  - Right mouse button (or alternate mouse button) - Hold down the right mouse button and drag the mouse up to zoom out. To zoom in, hold down the right mouse button and drag the mouse down.
- Zoom in and out using the navigation controls. To view and use the navigation controls, move the cursor over the top right corner of the 3D viewer. The navigation controls automatically appear whenever you do this; they fade from sight when you move the cursor elsewhere. Zoom in by clicking on the zoom in button **(+ sign)** and zoom out by clicking on the zoom out button **(- sign)**.
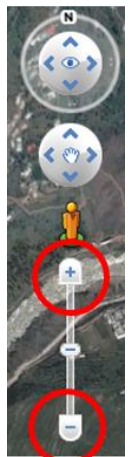
2.5. Tilt the 3D View: Hold the SHIFT key and drag the left mouse button towards you or hold the SHIFT key and press the Down key on the keyboard to tilt the viewer toward the horizon view. You will be able to see the 3D view as if you were looking towards the horizon. You can reset the view to the top-down orientation by pressing the "u" key on the keyboard.

2.6. Look Around: To look around from a single vantage point, as if you were turning your head, press CTRL and left mouse button and drag. You can reset the view to the north-up view by pressing the "n" key on the keyboard.

2.7. Rotate the view: Press CTRL and scroll UP to rotate clockwise, CTRL + scroll DOWN to rotate counter-clockwise.

2.8. Identify the coordinates (latitude and longitude): Move your cursor to the location and you will see that the latitude and longitude are displayed in the bottom right corner.
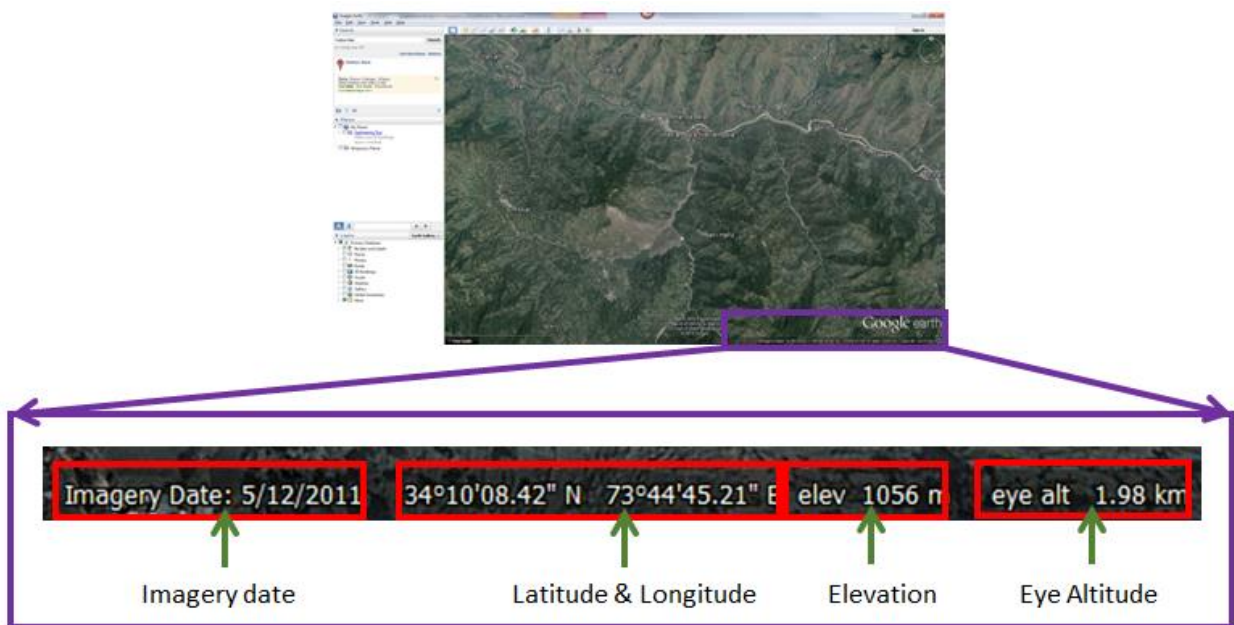
2.9. Elevation: The elevation shows the approximate elevation of the place at which your cursor is.

2.10. Eye Altitude: It is the distance (from high up) from which you are viewing the ground.