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Challenges of Landslide Disaster for Development in Nepal

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ABSTRACT

The landslide in Nepal is affecting directly to the settlements threatening to life and property of people, agricultural land, infrastructures and is affecting the National goal as poverty alleviation and the Gross Domestic Product (GDP) by 4%. The ten years data analysis from 2009/10 to 2018/19 of Ministry of Home Affairs (MoHA), exhibits the average toll death due to landslide disaster covers 105/year (about 22% of total casualty) and average property loss due to landslide becomes more than 143million rupees per year. This situation of landslide disaster is challenging for the development of Nepal. The landslide disaster can be reduced by the application of appropriate technologies which need the preparation of the basic data map like an inventory map with a degree of hazard, selected hot spot and hazard map with the zoning of landslide. But those are not yet established in Nepal due to the absence of appropriate institution, whereas, the disaster focal institute, the Ministry of Home Affairs (MoHA) is focusing mainly on immediate response sector as rescue and relief works only. Thus, the major purpose of this paper is to find out the appropriate way forward to solve the issues of landslide disaster management in Nepal.

JEL Classification: O21, O33, H1

Keywords: Landslide, Disaster, Management, Implementing Institute, Development of Nepal

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1. Background

A natural disaster is a major adverse event resulting from natural processes of the earth. It is a common phenomenon in various parts of the world and Nepal is one of those affliction countries. Natural disasters such as geological disasters- landslides, earthquake, volcanic eruption; hydrological disasters-floods, tsunami; meteorological disasters-typhoon, cyclone, heat waves, thunderstorms, droughts; and wildfires and so on are the major disaster phenomena found in different countries. The natural disaster generates a severe loss of life. It damages the properties and infrastructures as well and shows adverse impact on the development and growth of nations (Sarafoglou & Kafatos, 2019).

Nepal measures about 880 kilometres along its Himalayan axis by 150 to 250 kilometres across and covers an area of 147,181 square kilometres. More than 80% area of Nepal consists of rugged mountain topography with fragile geology of the young Himalayan Mountains. The steep slopes of the hilly region, unstable geology due to active tectonic movements and excessive rainfall in the region are enhancing the rapid occurrence of landslides in the area. The hilly areas of Nepal located in the Siwalik, Mahabharata range, Mid-land, and the Himalaya region are more vulnerable to landslides due to the steep topography and their delicate ecosystems. These areas are subject to three different types of mass movement disasters as slow moving landslide, slope failure and debris flow that causes the loss of lives and properties and environmental degradation each year. Moreover, the climate change induced disasters due to unscheduled torrential rainfall are destructing towns, national infrastructures like bridges, highways, hydropower, irrigation canal, and agricultural land, giving threats to development of the country.

The Siwalik Hills which is the southernmost hill range of the Himalaya consisting of mainly unconsolidated conglomerate, sandstone, and mudstone. So, the geology in this range is very weak and fragile. Moreover, the deforestation is increasing in this area due to encroaching by village and farmland. Thus the Siwalik range is becoming more vulnerable and prone to slope failure and debris flow as well as flash floods in Nepal (Upreti & Dhital, 1996).

The average annual precipitation is around 1600 mm of which almost 80% occurs during the period of June-September. The rainfall ranges from less than 300 mm in the rain shadow dry region to around more than 4000mm per annum in the wet region. The annual rainfall pattern of Nepal shows, the comparatively high rainfall occurrences are concentrated in the eastern and central parts of the country. So, the water induced landslide disasters are also distributed in the same areas and synchronize the casualties as well.

In these circumstances, Nepal is a highly vulnerable country with various types of natural disasters. The Ministry of Home Affairs (MoHA) identified more than 10 types of disastrous phenomena in Nepal such as geological disasters- landslide, avalanche, earthquake; hydrological disasters-floods, glacial lake outburst flood (GLOF); meteorological disasters-windstorm, hailstorm, lightning, heat waves, drought; fires; epidemics and so on. Among them, landslide, flood, fire and epidemic are the major disasters which occur each year.

The casualties due to different disasters in Nepal vary from year to year. As per the disaster data from Ministry of Home Affairs in year 2016/17 AD, (Government of Nepal [GoN], 2019), the total casualties due to different disaster in Nepal were 526 and the casualties due to only landslide and flood (water induced disasters) covers about 50% of the total loss of human lives (see Figure 1).

The Figure 1 exhibits 9 different disasters in the year 2016/17, out of which the major disasters as Landslide, Flood, Fire and Epidemic cover casualty by 28%, 19%, 10% and 4%, respectively of the total casualty where, the highest percentage of casualty was due to landslide. Among the four major disasters, Flood is managing through Department of Hydrology and Meteorology, former Department of Water Induced Disaster Management (this time it does not exist) and Department of Water Resources and Irrigation. Similarly, the Fire and Epidemics are managing though the Municipalities of the local government and Department of Health and Population respectively, whereas, there is no such institution which will manage the landslide disaster.

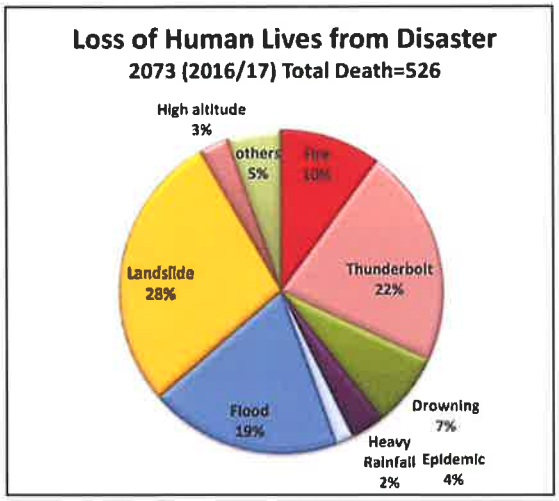

Figure 1. Casualties due to different disasters in 2016/17(GoN, 2019).

Landslide disaster is the principle disaster among the four major disasters of Nepal which occur each year in the monsoon rainy season. It killed 147 people and the economic loss was 811million rupees in the year 2016/17 (GoN, 2019). The MoHA and its related provincial and local government agencies are responsible institutes for the landslide disaster management in the rescue and relief sector. Apart from that the structural and non-structural mitigation of the landslides, study, design, mapping, capacity building, preparedness and implementation works were executed by the former Department of Water Induced Disaster Management (DWIDM). It is well known that the landslide disaster is impacting to the settlement, agricultural land, and national infrastructures each year. Moreover, it is impacting to the national goal as poverty alleviation and Gross Domestic Product (GDP) which plays direct role to the economy and development of Nepal. These circumstances show that the government does not prioritize the landslide disaster as a principle disaster of Nepal.

1.1 Issues and challenges

Less importance is given to the landslide disaster management in the planning and designing despite of sizable budget allocation being done by the Nepal Government in the field of disaster management every year. Even if treated, it is done without detailed study and investigation which further enhances the problem. Landslide events are affecting the national infrastructures like hilly highways, roads, settlements, agricultural lands and even hydropower enormously in every monsoon season which has been impacting to the development and economy of the country. So, the development of appropriate and sustainable technology suitable for various types of landslide is vital for reduction of the landslide disaster in the country (Amatya, 2016).

In this regard, the major purpose of this paper is to find out the appropriate way forward to solve the issues of landslide disaster management in Nepal.

2. Landslide disaster management

A mass (soil mass, large quantities of fractured or weathered rock mass) which moves downward under the influence of groundwater and gravity is termed as landslide (mass movement). The term landslide is widely used for almost all slope movements.

2.1 Types of landslide

There are two types of classifications for a mass movement, e.g. general classification and preventive classification. The internationally adopted scientific classification is given by Varnes (Varnes, 1978) which is globally used but from a prevention point of view, the classification used in Japan in the field of disaster prevention is very useful in landslide prevention and is adopted in Nepal as well. The classification has been established to clarify the mechanism of each phenomenon and for corresponding prevention works. The preventive classification gives three types of landslides (mass movement) as slope failure, slow moving landslide and debris flow which are some of the highly hazardous phenomena targeted by the preventive measures for sediment-related disaster mitigation (Ministry of Land, Infrastructure, Transport and Tourism [MLIT], 2007) and are the possible phenomena in Nepal (Water Induced Disaster Prevention Technical Centre [DPTC], 1999) shown in Table 1 and Figure 2.

Table 1

Types of Landslide (Mass Movement) (DPTC, 1999)

Mass Movement		
Slope Failure	Slow Moving Landslide	Debris Flow
Movement of weathered surface soil layer/rock of steep slope *Feature:* Small dimension and rapid movement	Movement of large sediment blocks which has clear slide surface. *Feature:* Large Dimension, slow and continuous movement mainly affected by ground water.	Movement of deposited or eroded sediment along the stream *Feature:* Rapid movement including large volume of water through the stream.

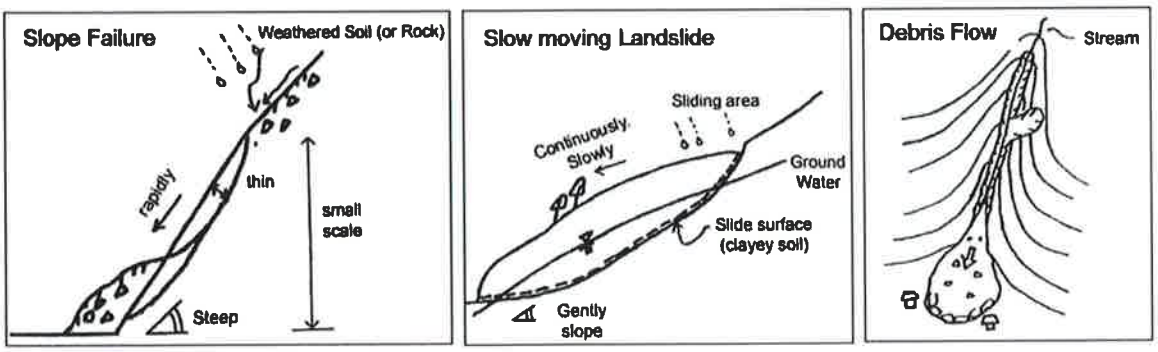

Figure 2. Three types of landslide (DPTC, 1999).

2.2 Status of landslide disaster in Nepal

More than 80% area of Nepal consists of rugged topography and fragile geology of young Himalayan Mountains. So, most of the areas in the mountain and hills are prone to the three types of landslide disasters, as slope failure, slow moving landslide and debris flow with environmental degradation each year. Moreover, the climate change reveals additional threatening of catastrophic landslide disasters as well due to the unscheduled torrential rainfall in monsoon. The landslide is affecting directly to the settlements threatening to life and property of people, agricultural land, and infrastructures like bridge, road, highway, hydropower, river-damming and irrigation canals (see Figure 3).

Figure 3. Landslide disaster affecting to a) Settlement: Tinthanalandslide, Kathmandu, b) Highway: Mugling-Narayanghat highway, c) Bridge: Mugling-Narayanghat, d) River damming: Sunkoshi River, Jure landslide, e) Hydropower: Sanima hydropower, Jure landslide, f) Agricultural land: Sildujure landslide Kaski (source: DWIDM).

Some of the catastrophic landslide disasters occurred in Nepal are listed as:

Flood and landslide in Bhotekoshi 2016: This disaster was occurred on July 6, 2016. More than 200 houses were swept away by the flood and bank cutting at Larcha to Liping of Tatopani VDC. The flood in the Bhotekoshi river was triggered by heavy rains (and could be snow avalanche) across the border in China, (The Himalayan Times, 2016).

Jure landslide and natural dam, Sindhupalchowk: It was occurred on August 2, 2014, killed 156 people and dammed the Sunkoshi River which affected Araniko highway and Sunkoshi hydropower, settlement, and agricultural lands (Amatya, 2014).

Seti river flash flood, Kaski: It was occurred on May 5, 2012, killed 72 persons. This event affected Kharapani village, Sadal Village, and Sardikhola Village Development Committee (VDC) with infrastructures and agricultural land (United Nations Office for the Coordination of Humanitarian Affairs [OCHA], 2012).

The activities for those events and similar to that were limited to rescue and relief works only and there were no any awareness and preparedness programs for them due to lack of designated authority to look after the landslide issues in Nepal. There is no such a trend to study the vulnerability until and unless the cases will be in urgency as well. Such as, the cases about the vulnerability of the Jure landslide were unknown to the related government agencies and could not aware of the people on time; as a result, 156 people were killed. The cases were similar to other landslide vulnerabilities as well.

2.3 What do the available data analysis exhibit?

Since the landslide and flood are the major disasters of Nepal which occurs each year. The ten years data of landslide and flood were collected from MoHA, (GoN, 2019) and analysed in this paper. From the analysis, casualties due to landslide and flood in 10 years from 2009/10 to 2018/19 is presented in Figure 4. This figure exhibits the casualty by landslide in 10 years is 1047 and average is 105/yr. (about 22% of total), which is more than

that of flood i.e. 880 in 10 year and 89/year. The graph in the figure exhibits that the casualties decreases after each three years in case of landslide disaster and after every two years in the case of flood disaster. Similarly the comparative analysis of losses of life and property due to landslide and flood disasters in Nepal is presented in Figure 5 (GoN, 2019). This figure also shows that the casualties due to landslide is higher than that of the flood but the property losses are much higher due to floods than that of landslides. Thus, the analysis of the 10 years data exhibits the landslide disaster is the principal disaster among the major disasters of Nepal.

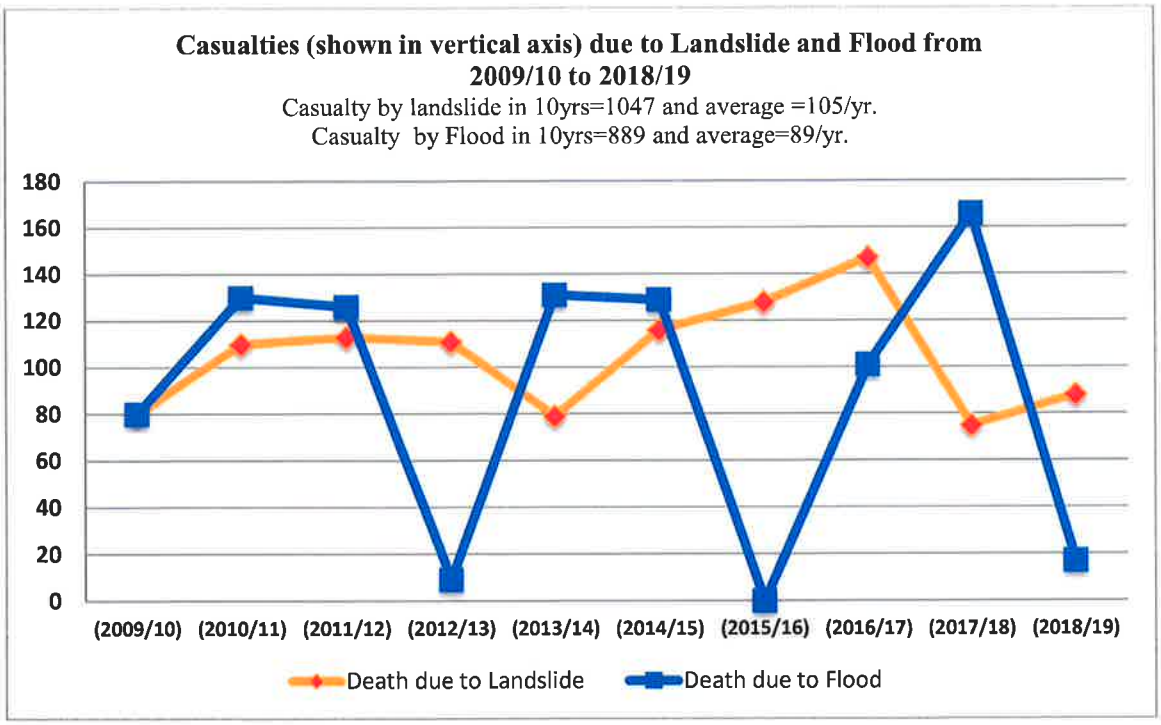

Figure 4. Casualties due to landslides and floods from 2009/10 to 2018/19 (GoN, 2019).

2.4 Impact/challenges to development and economy of Nepal

The total losses due to different disasters in Nepal is found as 41642 million rupees as analyzed from 10 years data. Out of which the landslide covers about 1426 million rupees (i.e. 143million/yr.) and flood covers 17149 million rupees (i.e. 1715million/yr.) and landslide and flood together covers about 45 percent. If we analyze the data in five years period, each five years value of losses exhibits the increasing trend (see Table 2). So, it can be assumed that the increasing trend of losses will be continued in the next coming 5 years as well.

The 15th National Plan for FY 2019/20-2023/24 has a target to improve the poverty alleviation from 18.7% to 11% in the next 5 years. Similarly, the Gross Domestic Product (GDP) will develop from 6.8% to 9.6% up to the next 5 years. But, until and unless the losses from the disasters will be decreased and the disasters will be mitigated, it will continue to affect the national economy and development and to the poverty alleviation and GDP of the country. In addition, it was found that the losses due to disasters in Nepal are affecting by 4% percent of the GDP which was analyzed from the disaster data of the Desinventar Database in Disaster Risk Reduction (DRR) Portal, MoHA from 1971-2017 (Adhikari & Adhikari, 2019), (National Society for Earthquake Technology-Nepal [NSET], 2008).

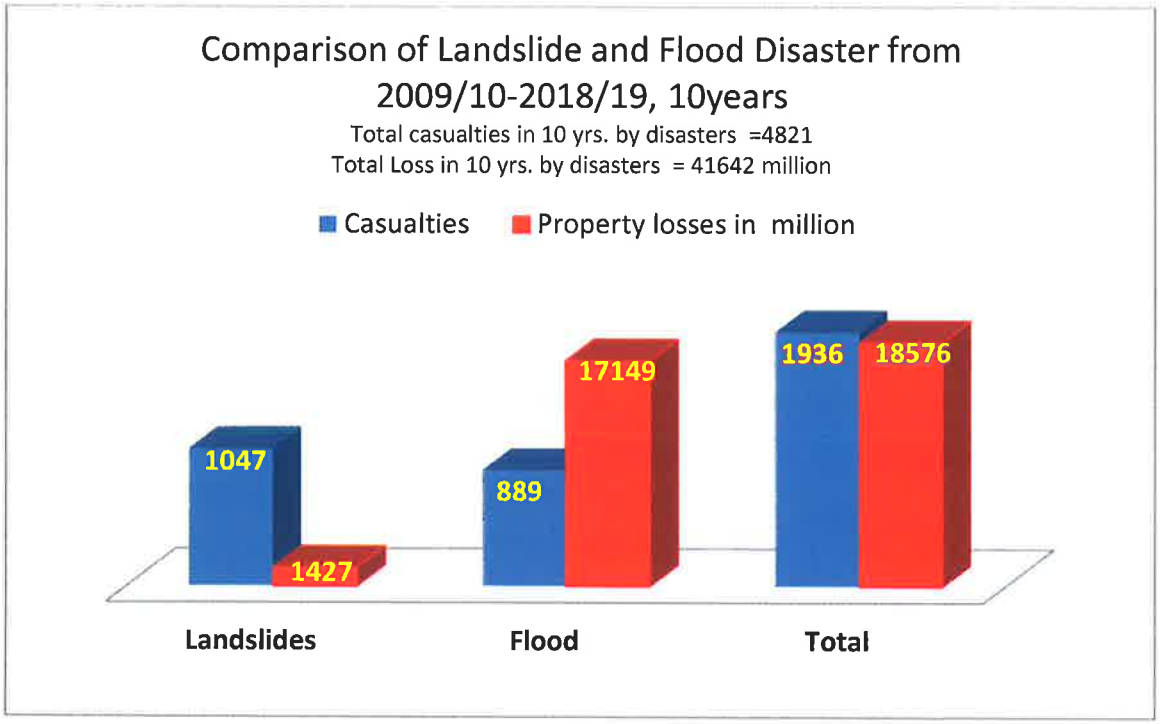

Figure 5. Comparison of landslide and flood disasters from 2009/10 to 2018/19 (GoN, 2019).

Table 2

Casualties and Losses due to Different Disasters in Interval of 5 Years (GoN, 2019)

No. of Year	Total Death due to different Disasters	Total Loss due to different Disasters in (MRs)	Total Loss due to Landslide in (MRs)	Total Loss due to Flood in (MRs)	Total Loss due to Landslide and Flood in (MRs)	%
2009/10-2013/14 5Yrs	2458	14157.80	396.70	2123.40	2520.10	17.8
2014/15-2018/19 5Yrs	2363	27484.90	1030.10	15025.90	16056.00	58.4
Total in 10 years	4821	41642.70	1426.80	17149.30	18576.10	44.6
Average in each year	482.1	4164.27	142.68	1714.93	1857.61	

Note: Exchange rate: 1USD=109.74NPR. (On May 27, 2019) as per Nepal Rastra Bank (NRB), Central Bank.

2.5 How the National Planning Commission (NPC) addresses landslide disaster management in Nepal?

The 8th National Plan was the first plan of the democratic government which explains a few words about Water Induced Hazard Control (National Planning Commission [NPC], 1992). The 9th Plan explains a few words about landslide and flood adaptation (NPC, 1997). In the same way, the 10th Plan spelled firstly about the Disaster Management in Nepal clearly

under Water Induced Disaster Prevention heading including floods and landslides management (NPC, 2002) and it was continued up to 11th Plan (NPC, 2007). But, the 12th, 13th and 14th Plan did not spell about priority of landslide disaster management works (NPC, 2010), (NPC, 2013), (NPC, 2016). The recent 15th Plan explains about the general disaster management of Nepal but it does not mentioned about the priority of landslide disaster management works separately, (NPC, 2019).

The facts explained in sections 2.2, 2.3 and 2.4 above confirmed that the landslide disaster is the principal disaster among the major disasters of Nepal. In this relation, it reveals that the National Planning Commotion (NPC) did not put the landslide disaster in priority. The possibility of this situation could be the void of geological disaster experts and its importance in the team of NPC.

2.6 Act and policies related to landslide disaster management

The Sendai Framework for Disaster Risk Reduction 2015–2030 in which Nepal is signatory and has proposed seven targets for global disaster risk reduction until 2030 at the Third UN World Conference in Sendai, Japan, on March 14-18, 2015, (The United Nations Office for Disaster Risk Reduction [UNISDR], 2015). Similarly, the International SABO Symposium 2015 in Sendai recommends all the countries to promote sediment disaster risk reduction (SDR) for sustainable development with priority on climatic change adaptation strategies, documentation of SDR, development of hazard mapping/forecasting, evacuation, training and education to communities, (MLIT, 2015).

The major act and policies related to the disaster management in Nepal established by the government addressing the Sendai Framework for Disaster Risk Reduction 2015-2030 are listed as:

The National Strategy for Disaster Risk Management (NSDRM), generalized all the disasters available in Nepal. The disaster management will be addressed by the proposed structure the National Commission for Disaster Risk Management (NCDRM) as the highest level institution. The National Authority for Disaster Risk Management (NADRM) will be the highest executive agency under NCDRM for the implementation and monitoring of emergency response, recovery and disaster rehabilitation and reconstruction of social and physical infrastructures (NSET, 2008).

The Disaster Risk Reduction and Management Act 2017 (DRRM Act 2017), was established by the government on 2017 replacing the Disaster (Relief) Act 1982. The National Disaster Risk Reduction and Management Authority (NDRRMA) was established according to the DRRM Act 2017 which will be under the National Council for Disaster Risk Reduction and Management (NCDRRM). The execution of all the disaster management is mandated to the NDRRMA with support of related line institutions, (National Law Commission [NLC], 2017).

The Disaster Risk Reduction National Policy 2018, generalized all the disasters of Nepal is managed by the government with necessary research study, development and implementation, (GoN, 2018).

The Disaster Risk Reduction National Strategic Action Plan 2018-2030, explains its short term, mid-term and long term plan up to 2030. It also explains about the individual disaster management plan up to 2030. All the landslide study, research, mapping, monitoring and so on will be executed by the NDRRMA and the implementation of mitigation works will be implemented with the support of related line institutions, (Ministry of Home Affairs [MoHA], 2018).

The execution of the landslide disaster management is well defined specially by the DRR National Strategic Action Plan 2018-2030.

2.7 Status of responsible institute

Since the establishment of Water Induced Disaster Prevention Technical Centre (DPTC) in Nepal on October 7, 1991 with financial and technical support of JICA/Government of Japan, the landslide disaster management works as study, modeling, preparation of hazard maps with zonings, inventory, monitoring, preparedness, landslide early warning systems, planning, design and implementation of structural and non-structural countermeasures were initiated as an authentic institution. It was continued up to July 2016 as Department of Water Induced Disaster Management (DWIDM). The Water Resources Strategy of Nepal 2002 and the National Water Plan 2005 had given a mandate to the DWIDM to implement the water induced disaster management in Nepal and the government formulated Water Induced Disaster Management Policy 2072 (2015) to support the DWIDM as well. But, the DWIDM was merged to the Department of Water Resources and Irrigation (DWRI) as Water Induce Disaster Division with a nominal budget. Before DPTC, the Department of Soil Conservation and Watershed Management (DSCWM) was doing the remedial works of small and shallow landslide in watershed which was continued up to July 2016. The DSCWM was merged to the Department of Forest and Watershed Management (DFWM) as Landslide and Watershed Division with a nominal budget.

If we look at the Disaster Management Cycle, (see Figure 6), we can find three phases of disasters as before disaster, during disaster and after disaster. During the disaster mostly we cannot do anything. Just after the disaster quick response like rescue and relief works have to be done. That work is doing by MoHA. Then the rehabilitation and reconstruction works which are implementing by National Reconstruction Authority (NRA) addressing to the Gorkha Earthquake 2015 only.

Before disaster phases as capacity building, prevention, mitigation, preparedness, and early warning system were executed by implementing institutions like DWIDM and DSCWM in case of landslide disaster management. But now, both of them do not exist.

Recently, the National Disaster Risk Reduction and Management Authority (NDRRMA) is established based on the Disaster Risk Reduction and Management Act 2017 under MoHA. The NDRRMA has full authority to implement all the disaster management in Nepal with the support of related line institutions.

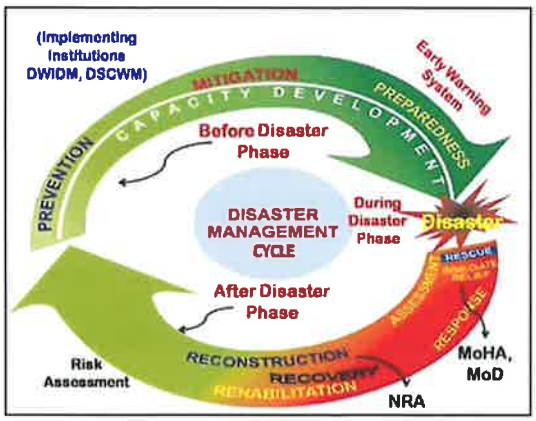

Figure 6. Disaster management cycle [modified after (RV Sir, 2016)].

So, it is clear that the NDRRMA needs to have the support of related line institutions for the implementation of structural and non-structural countermeasures with research and development works like DWIDM before.

3. How can we overcome the issues?

3.1 By application of mitigation technologies (structural and non-structural

Since, Nepal and Japan have common physiographic conditions like rainfall, steep topography, active crustal movement and dense population in mountain and hilly areas, the landslide disaster issues in Nepal are similar to Japan. As explained in Section 2.7 above, the Water Induced Disaster Prevention Technical Centre (DPTC) was established in Nepal on October 7, 1991 with financial and technical cooperation of JICA/Government of Japan; the Japanese mitigation technologies were transferred and adopted in Nepal. The landslide disaster mitigation technologies were implemented in Mugling-Narayanghat Highway and Sindhuli-Bardibas Highway areas. As a result, still those structures are working with excellent performance.

Thus, mainly three different types of mass movements (landslides) are considered as slope failure, slow moving landslide and debris flow. The damages from those three types of mass movements (landslide) can be reduced by application of appropriate technologies.

The *slope failure* can be treated by the construction of countermeasures as listed below, (see Figure 7), (*International SABO Networks/Slope failure.).*

Gravity retaining wall works

Leaning wall works

Catch wall works

Concrete crib works

Pilling works and

Anchor works so on.

These countermeasure structures were practiced in Japan and adopted in Nepal as well. These mitigation works were applied in Prithivi Highway, Mugling-Narayanghat Highway, Sindhuli High way and so on.

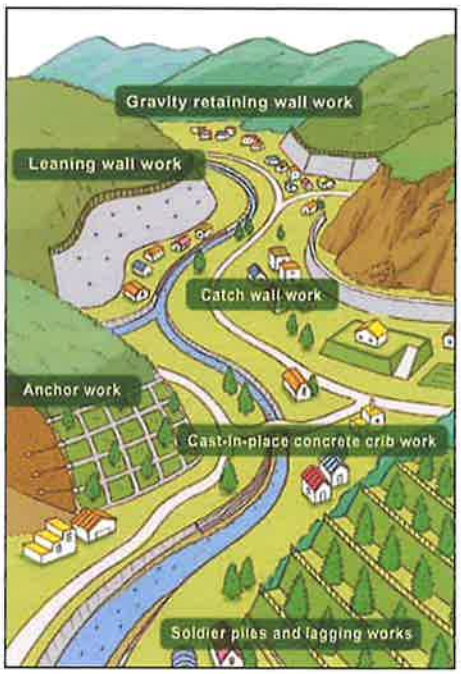

Figure 7. Countermeasure structures for mitigation of slope failure.

The *slow moving landslide* can be treated by the construction of countermeasure works as listed below, (see Figure8). (*International SABO Networks/Landslide)*

Soil removing works

Horizontal drainage boring works

Channel works

Sabo dams (check dams)

Anchor works

Steel pipe pile works

Drainage well

Drainage tunnel works and so on.

All these countermeasure works were well-practiced in Japan. Out of them, the first 4 methods are comparatively affordable to us and the next 4 methods are more expensive. So, the first 4 methods are adopted in Nepal frequently and the anchor works were used in Nepal occasionally in some highways as in Sindhuli Highway.

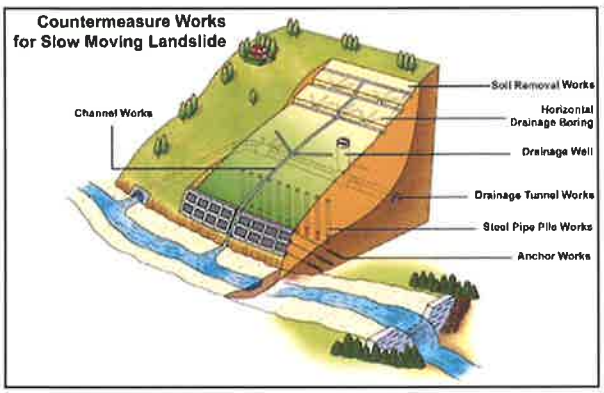

Figure 8. Countermeasure works for slow moving landslide (International SABO Networks/Landslide)

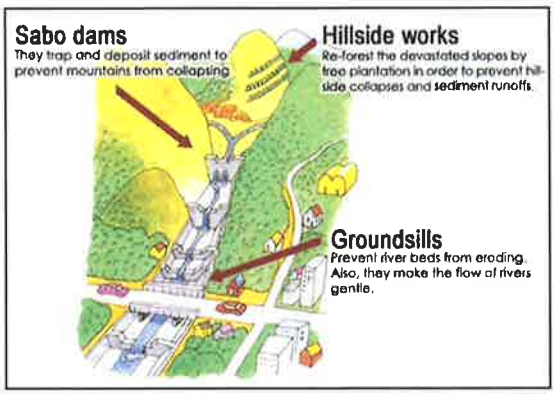

Figure 9. Countermeasure works for debris flow (MLIT, 2007).

The *debris flow* disaster can be treated by the construction of countermeasure works as listed below, (see Figure 9) (MLIT, 2007).

Construction and design of sabo dams (Check dams)

Hillside works

Construction and design of ground-sill works

These countermeasure works also were well-practiced in Japan and adopted in Nepal and practiced frequently. This type of landslide is most common in Nepal and the mitigation works were applied in most of the highways and roads to protect from the cross rivers e.g. Prithivi Highway, Mugling-Narayanghat Highway, Sindhuli High, Sindhuli-Bardibas road, Araniko Highway and so on. Examples of mitigation measures applied to three types of landslides of Nepal are presented in the Figure 10.

Establishment of Landslide Early Warning System: The early warning system is a non-structural countermeasure technology of landslide disaster. The early warning methods for the different types of landslides are different from each other.

The early warning equipments applied for slow moving landslide and slope failure are listed below from which the movement of the landslide can be monitored and able to warn to the community.

Extensometer

Sensors

Peg monitoring

Application of GPS to measure the movement of landslide

Measurement of soil moisture content which will help to find out the rainfall threshold value for landslide movement.

Figure 10. Landslide mitigation measures implemented in Nepal. A) Toe protection works to mitigate slow moving landslide, Sindhuli Road, Section I, 29+300m (Amatya & Mori, 2018), B) Slope protection works by anchoring to mitigate slope failure, Sindhuli Road, Section II, 17+600, (Amatya, 2016), C) Debris flow mitigation works by Sabo dam, Ruwa Khola, Marshyangdi Hydropower, 0+460, Tanahun (Pandit, 2009).

Similarly, the early warning equipments applied for debris flow are listed below from which the arrival of debris flow and its depth at the monitoring point can be measured and will be able to warn to the community.

Wire sensor

Flipping sensors

Vibration sensors

Optical sensors

Supersonic wave sensors

Detection based on image movement (CCTV) and so on.

Likewise, the public awareness as roving seminar and community awareness training is the next most effective non-structural mitigation method of landslide disaster.

3.2 By technology transfer program

Japan has experiences about different types of natural disasters such as different types of landslides, landslide damming, flood, earthquake, volcanoes, tsunami, and so on. They have developed many simple to sophisticated technologies to mitigate disasters. As explained

in section 3.1, Japan is a mountainous country with similar physiographic conditions of Nepal and there are many similarities between Japan and Nepal as steep topography, active crustal movement, population in mountain and hilly areas and similar rainfall. Thus, the issues in Nepal are similar to them. So their technologies could be appropriate to us. In addition, since the 1991, Nepal government established the Water Induced Disaster Prevention Technical Center (DPTC) with financial and technical cooperation of JICA/Government of Japan; many technologies were transferred to Nepal from Japan through different projects and construction of model sites and adopted in Nepal. Thus, further, the new advanced technologies from Japan can be transferred for disaster management of Nepal. Not only from Japan, can the new technologies be imported from other countries like China, India, Netherlands, and Switzerland as well. For a good example, in 2014 the Jure landslide dammed the Sunkoshi River which is the major tributary of Koshi River, creating threats to downstream settlements. That incident was a matter of worry to the downstream India as well. The dam could be breached safely with an application of siphon technology in a few days which is common in Japan. But at that time we did not have knowledge about it and we did not have the necessary materials and equipments; as a result it took more than a month to breach the dam safely by the blasting and excavation method with effort and contribution of Nepal Army (Amatya, 2014).

3.3 Preparation of inventory and hazard maps

To support the mitigation methods as expressed in section 3.1, we need to have basic data maps like landslide hazard map with the zoning of all three types of landslides, (see Figure11), landslide inventory map with the degree of hazards (see Figure 12), and selected hot spots of all over the country. These maps will help to plan, design and estimate the disaster mitigation works. Without those maps, the planning and installation of landslide early warning systems are not possible. But those maps are not yet established in Nepal due to the absence of appropriate institutions.

Figure 11. Landslide hazard zoning. A) Hazard zoning of slow moving landslide, B) Hazard zoning of slope failure, and C) Hazard zoning of debris flow. Zone1 (red) shows high hazard, Zone2 (yellow) shows medium hazard and Zone 3 (green) shows low hazard (Department of Water Induced Disaster Prevention [DWIDP], 2015).

3.4 Establishment of implementing institution

As explained in the section 2.7 about the status of the responsible institution, it is felt that the establishment of an appropriate implementation institution like Landslide Disaster Management Institute (LDMI) including research and development works is needed which will do all the landslide disaster mitigation works as mentioned in the sections 3.1, 3.2 and 3.3 above and will support to the NDRRMA as landslide disaster related line agency, so that this institute will support to the provincial and local government simultaneously. In this

regard, the National Planning Commission needs to prioritize Landslide disaster management for development.

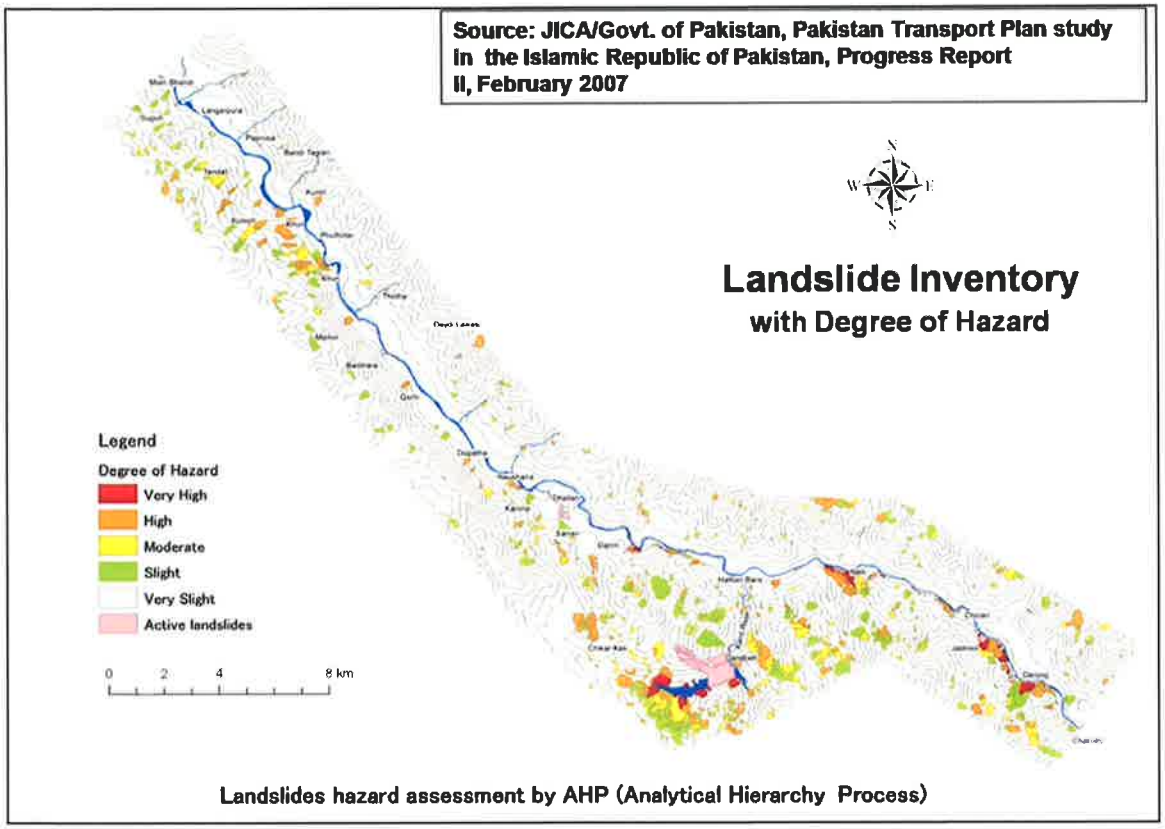

Figure 12. Landslide inventory map with degree of hazard (Japan International Cooperation Agency [JICA], 2007).

3.5 Acts and policies

To strengthen the Landslide Disaster Management Institute successfully, the establishment of acts, policies and strategies are needed to be formulated as Landslide Disaster Management Act, Landslide Disaster Management Policy and Landslide Disaster Management Strategy for short term, mid-term and long term plan. In addition, the institution should develop the landslide technical guidelines and develop model sites for technology transfer programs.

4. Conclusions and recommendations

Physiographically, more than 80% land of Nepal is rugged mountain topography which is vulnerable to landslide. These areas are subject to three different types of mass movement disasters as slow moving landslide, slope failure and debris flow. Moreover, 80% of the annual rainfall occurs during the period of June to September and the erratic average rainfall events in Nepal exhibits higher intensity of rains but less number of rainy days and unusual rain with no decrease in total amount of annual precipitation. Such events increase possibility of climatic extremes like irregular monsoon pattern which will create droughts, floods, inundation and landslides (Malla, 2008).

This circumstance of landslide disaster is creating average casualties more than 105/year and, average property losses more than 143 million rupees per year according to the 10 years data analysis of MoHA, and damaging settlements, agricultural lands and infrastructures of the country every year.

This situation is hitting to the national goal as poverty alleviation and the Gross Domestic Product (GDP) by up to 4%. Thus, the landslide disaster is the principle disaster of Nepal. But, the national plans from 8th National Plan (first plan of democratic government of Nepal) to 15th National plan (recent) did not felt necessary to put landslide disaster management in priority. The possibility of this situation could be the void of geological disaster experts and its importance in the team of NPC.

The Water Resources Strategy of Nepal 2002 (GoN, 2002) and the National Water Plan 2005 (GoN, 2005) had mandated to the former Department of Water Induced Disaster Management (DWIDM) for landslide and flood disaster management (water induced disasters) and the Water Induced Disaster Management Policy 2015 (DWIDP, 2015) was established by the government of Nepal to support the DWIDM but, the DWIDM does not exist this time.

Moreover, unavailability of the basic data map of landslide disasters like inventory map with a degree of hazard, selected hot spot and hazard map with zoning, technology development and the authentic institution for landslide disaster management is affecting directly to the landslide disaster management of Nepal. Thus, the landslide disaster is challenging to the economy and development of Nepal.

The execution of landslide disaster management is well defined by the DRR National Strategic Action Plan 2018-2030 (MoHA, 2018). The Disaster Risk Reduction and Management Act (DRRM Act 2017) authorized fully to the disaster focal institute, the National Disaster Risk Reduction and Management Authority (NDRRMA), Ministry of Home Affairs (MoHA) to implement all the disaster management in Nepal with the support of related line institutions (NLC, 2017). Hence, the NDRRMA needs to have the support of related line institutions for the implementation of structural and non-structural countermeasures with research and development works in landslide disaster management area as well.

In this regard, the following way forwards are recommended which will fulfill the disaster management cycle with satisfying the Sendai Framework for Disaster Risk Reduction 2015–2030 and the recommendation made from the International SABO Symposium 2015 in Sendai focusing on Sediment Disaster Reduction.

1. Establish authentic Landslide Disaster Management Institute (LDMI) with research and development facilities which will have direct link to NDRRMA and disaster related institutions at provincial and local level governments. The LDMI will have mandates to fulfil its responsibility before disaster phase of disaster management cycle as technology of prevention, mitigation and preparedness with EWS. The LDMI will do the following responsible works as well.
    - Prepare the landslide disaster management technical guide lines.
    - Prepare basic data maps of all three types of landslides all over the country as landslide inventory map with degree of hazard.
    - Prepare community hazard maps of hot spots of all three types of landslides: slope failure, slow moving landslide and debris flow, and prepare master plan of hot spot landslides.
    - Establish model sites of each type of landslides with application of new mitigation technologies, and capacity building of human resources (HR)
    - Establish community level landslide early warning systems and evacuation.

- Research and development of new technologies for disaster mitigation and develop technology transfer program.

2. Formulation of landslide disaster management strategies.
3. Develop landslide disaster management acts and policies.

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