Resilience to Climate Challenges:
Avoid Rebuilding in High-Impact Areas of Postfire Debris Flow

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Debris flow is a deadly disaster occurring within the landforms of the debris catchment, the flow track, and the impact area. During the 2013 Colorado historic flood, highly impacted areas often involved postfire debris flows. The catastrophes in high-impact zones demonstrate site selection failures. Lack of knowledge also weakens the public's awareness of potentially reoccurring debris flow. Current insurance policy requests to rebuild the house 'like for like" the original one at the same high-impact spot could risk re-destruction in future debris flow attacks. By combining field investigations with geomorphic analyses, this paper discusses the dangerous nature of postfire debris flows and their inevitability in specific landforms during heavy rainstorms. Thus, residents should avoid rebuilding in high-impact areas, and relocating to safer places is the most effective strategy to enhance mountain community resilience to current extreme weather.

Keywords: postfire debris flow, high-impact areas, avoid rebuilding, landform patterns, resilience

INTRODUCTION

In recent decades, the wildfires spreading over the U.S. West have caused extensive destruction (Baker, 2009). The vast fire scar zones have covered various complex landforms and are left vulnerable to additional hazards of postfire debris flows. During the 2013 Colorado historic flood, highly impacted areas often involved postfire debris flows. Over eight days, from September 8th to 16th, 2013, 16 inches of rain poured across Boulder County (City of Boulder, 2015). The violent power of the resulting floods destroyed homes and infrastructure, wiped out small towns, rerouted water channels, and took several lives. During this flood event, localized flooding from street runoff occurred outside the 100-year floodplain. Sewer backups and groundwater infiltration caused extensive basement flooding (Rodenbush, 2014). In addition, there was an unprecedented increase in debris flows in the mountainous areas. The most highly impacted areas experienced debris flows that dumped vast debris into the water channels, causing additional flooding. The debris flows devastated communities already recently impacted by fires in the area. Property destructions and fatalities in debris flow impact zones demonstrate the lack of knowledge and limited warning systems concerning such a hazard.

Debris flows are regarded as one of the most dangerous natural hazards (Clark, 1987) and are often referred to by the media as landslides, rockslides, mudslides, or flash floods. A debris flow results from heavy rainfall combined with vast amounts of debris. Debris flows originate at higher elevations. As a debris flow descends, it collects additional debris, gaining speed and power (Takahashi, 1991). Flows can climb several feet tall, knock over houses, and devastate anything in their path. Debris flow is different from Spring runoff flooding, which usually involves water rising from Spring snowmelt which runs over the riverbanks and floods the land. Debris flow impact areas are often not mapped in the zone of the known floodplains.

Residents experiencing a 2013 debris flow disaster were shocked by “floods” originating from the heavens and not their rivers. There is confusion on the conceptual difference between flooding and debris flow due to a lack of knowledge on the causes of debris flow. Facing these fuzzy concepts about debris flow, some insurance companies used flow thickness to judge each impacted case. If the flow’s consistency was thicker than a chocolate shake, flood insurance would not cover the damage. According to the National Flood Insurance Program, a flood, in simple terms, is an excess of water on land that is normally dry (FEMA, 2013). Damages of a debris flow are not covered by flood insurance since debris flow is thought of as an earth movement. These policies could make the residents in the debris flow impact areas vulnerable.

The 2013 Colorado flood drastically impacted the Boulder community. Local and federal government initiatives spent substantial funds to repair road conditions and drainage systems and aid residents recovering from the damages of disasters. Since the 2013 flood, the Boulder government has spent approximately five hundred million dollars on disaster recovery (Lounsberry, 2018). These recovery efforts often involve reconstructing damaged homes on their original property. Our governments and insurance companies worked together to make essential contributions to help residents overcome the hardship of the 2013 Colorado historic floods. As a resident living in the foothills of Boulder for thirty years and a professor of Environmental Design, the author has experienced three evacuations from fires, and the 2013 Colorado historic floods. She greatly appreciates the public servants and firefighters, who have done a superb job with warnings, taking care of, and saving the lives of community members. Her community's tragedy in the 2013 historic floods inspired her research on postfire debris flow.

Eight years since the hazard event, Boulder has recovered and is as beautiful as ever. The recovered environment presents the desire to rebuild homes and the effort supported by state and federal government funds. In the fall of 2021, the author reinvestigated several high-impact areas affected by the 2013 postfire debris flows. Surprisingly, in several high- impacted areas, new buildings were built upon the same spots where debris flows destroyed the original buildings. Likewise, some buildings damaged by the debris flows were repaired to their former state. The lack of knowledge on debris flows can influence insurance policies and weakens the public’s awareness of potentially reoccurring debris flows.

By discussing the dangerous nature of postfire debris flow and its reoccurring in specific landforms, this paper suggests that avoiding rebuilding in highly impacted areas is an effective strategy to enhance mountain community resilience to climate. This research method includes 1) a literature study of geomorphic research on debris flows and postfire debris flows, as well as when and where debris flows occur; 2) Field investigations in the high-impact areas of debris flow, which contain two parts: a) damage evaluations and identifying landform patterns in 2014, one year after the 2013 historic floods, and b) investigating recovering and rebuilding situations In 2017 and 2021, and 3) conducting interviews within the community to listen to their tragic experiences and opinions on enhancing future resilience; and also communicating with the staff of insurance companies to understand the insurance policies on debris flows and their viewpoint on dealing with natural hazards in the Colorado mountains.

LANDFORMS POSE DEBRIS FLOW THREATS TO RESIDENTS

What Is Postfire Debris Flow?

According to Takahashi, major debris flows begin with dense mud and stone flows, increasing their solid concentration and size as they proceed downstream, and finally developing into a full debris flow. A minor occurrence in a gully where the unstable deposit on the bed can be mobilized and become a debris flow by the appearance of surface water flow (Takahashi, 1991). Scientists and local governments recognize and mitigate many major debris flows (Li, 2004). The minor debris flows that often occur in a gully on a local hillside may still cause death and destruction of property. During the 2013 Colorado floods, most cases involving debris flow attacks belonged to the minor debris flows, which were often unexpected and without warnings.

Debris flows following wildfires are common; these are called postfire debris flows. The surface soil on a burned slope is loosely compacted and easily wet-able. This layer is formed by burned organic molecules, which coat the soil particles and repel water, preventing it from filtering into the regolith. When it rains, pores between the loose soil grains begin to fill with water. The water in the pores puts downward pressure on the soil and causes a failure, excavating a rill. Surface water flows into the rill and runs downstream (Wells, 1987). When a fire burns mountain vegetation, it kills the ground cover and loosens debris. Dead trees fall more quickly during heavy rains, levering out the soil and producing more debris. These logs are washed into creeks, generating further volume and power within the flows. Geomorphic research indicates that a significant amount of heavy timbers cause landslides and the destruction of property (Reneau and Dietrich, 1987).

The three primary factors to trigger postfire debris flows include 1) the area receives heavy and consistent rainfall; 2) the site has experienced a wildfire at a higher elevation; and 3) the area contains abundant debris, and its landform triggers debris flow. Debris flows begin on steep slopes and basins at higher elevations and then descend through debris flow channels and canyons. When arriving at a lower elevation plane, the flow releases vast debris that can destroy homes and take lives at the impact areas.

Landforms Posing Threats of Postfire Debris Flow

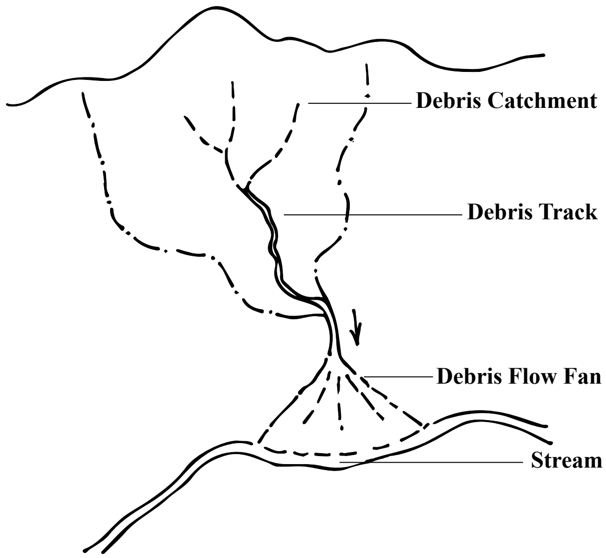
Debris flow disasters are not random and don't happen in every canyon. Debris flows occur within specific conditions. The catastrophic postfire debris flow in Montecito, California, was not an accident, as the town is built on a historical debris flow deposit area. People should not reside in these high-impacted areas, where the debris flow event will likely happen again during heavy and constant rainstorms. Debris flows in the 2013 Colorado historic flood were caused by the 16 inches of precipitation of 8 days of consistent heavy rain (City of Boulder, 2015). On January 9th, 2018, a half-inch downpour in a 5-minute interval triggered the postfire debris flows, causing 23 fatalities in Montecito, California (Mozingo et al., 2018).

High-intensity rainstorms are a known trigger for debris flows, but their spatial distribution also appears to follow a pattern. This distribution pattern has not been well studied (Lorente et al., 2002). Identifying landform patterns of areas prone to debris flow is crucial to improving the site selection process, reducing damage risks, and saving lives. Based on geomorphic studies (Onda, 2004; Clark, 1987; and Reneau & Dietrich, 1987), landforms of three areas where a debris flow initiates, develops, and ends, include the debris catchment, the debris flow track, and the debris flow fan/impact area (Figure 1). The author refers to this classification of three zones to identify the landform patterns of high-impact areas of the 2013 debris flows.

The debris catchment includes hillsides of basins and canyons, where debris and runoff accumulate. The debris flow initiates at a high elevation hillside where the soil was unstable due to previous fires or drought; these hillsides are over 35% grade. After a fire occurs, the sources of debris increase in a debris catchment area. More importantly, wildfires change the soil structure, creating a slick unstable layer (Well, 1987). The accelerating erosion process alters the debris track to be straightforward and defined, making them more powerful and worsening the overall impact.

The second zone is a debris flow track, a water channel such as a gully, dry wash, or creek. Flows generate their power by having a high volume of debris gathered from a broad catchment through a narrow debris track. The debris tracks in narrow canyons and dry washes are often full of rocks and loose soil. In these narrow channels, the debris can group and form small dams. These dams eventually break and flush downhill during heavy rainstorms, generating even more speed and strength, creating a debris flow disaster (Cui, 2012).

FIGURE 1
THREE AREAS WHERE A DEBRIS FLOW INITIATES, DEVELOPS, AND ENDS



The final area is the debris flow fan, an impact area where the slope has dropped to a plain and the debris is released. Once a slope falls under 20% grade, the debris flow takes a straighter path, changing the original creek track. Then finally, when the slope reaches less than 15% grade, the flow releases the debris, water, and mud to the lower elevation plain, causing extensive destruction. Therefore, lower elevation plains are high-impact areas.

The author's field investigations indicate that the high-risk areas of the 2013 debris flow present similar landform patterns to each other. High impact areas of postfire debris flow usually include the five zones: 1) an area below a wildfire scar zone that experienced fire before the debris flow event; 2) the plane with a gentle slope > 15% at a lower elevation where most of the significant debris is released; 3) the hillside declining slopes, causing the debris to release; 4) the area by a river, lake, or a confluence, where a debris flow deposits debris that blocks the channels and creates flooding; and 5) a place where the watercourse of a dry wash or river leads toward (Xu, 2016). We should prohibit building in high-impact areas. Once a building was demolished by a debris flow, rebuilding the building at the same lot should also be forbidden. Implementing mitigation only within the impact fan/area is not enough. The comprehensive mitigation of a postfire debris flow should also include the areas of the debris catchment, and the debris track (Table 1).

TABLE 1
FACTORS CAUSING POSTFIRE DEBRIS FLOW AND ITS IMPACT AREA

Factors causing postfire debris flow		When it happens	Where it happens	Where the high impact-areas are	Mitigation
Heavy and constant rainfall		X		Leading impact	X
Fire before debris flow		X	Fire burned at hillsides	Leading impact	X
Landforms	Catchment		•abundant/debris •Steep hillsides >35%	Leading Impact	X

			•Fire burned slopes •Dead timbers •Several miles canyon		
	Flow track		•Creek /gully •Initiates in high mountain •Passing narrow canyon	Leading impact	X
	Impact fan/area		•Area below fire scar zone •Downstream plane <15% • By lake, river or at confluence •Hillsides declining slope • Place where the water course of a gully or river leads toward	Combining factors: • Area below fire scar zone. •Downstream plane > 15% • By lake, river or at confluence •Hillsides declining slope •Place where the water course of a gully or river leads toward	X

REBUILDING ON HIGHLY IMPACTED AREAS WOULD REPEAT SIMILAR TRAGEDY

In the fall of 2021, the author carried out field investigations in several high-impact areas from the 2013 Colorado historic floods, which were affected by debris flow, particularly the postfire debris flow. This section utilizes four highly impacted areas as examples to explain that the disaster in those areas demonstrates the failure of site selection. To rebuild houses in the highly impacted areas would repeat the mistakes and tragedy.

Jamestown, CO.

Jamestown experienced drastic impacts during the 2013 flood. The entire town was evacuated. Many houses were damaged, one large home had a third of its structure knocked down, and one person died. During the 2013 heavy rainstorm, Little James Creek generated a debris flow. Originating in mountains several miles away, the debris flow passed through a narrow and steep canyon. It collected vast debris, eroding its track bank and eventually dumping the debris in the impact area. The 2013 debris flow climbed over seven feet, leaving marks on the bank. Also, the existence of confluence in Jamestown increased the flood impacts. The Little James Creek and the James Creek meet west of the town center. James Creek partially knocked down the house at the confluence (Figure 2a). In addition, at the north of the town, a high hill with dry and thin soil and rocks provided an abundant source of debris. The 2011 fire on this hill burned the vegetation and changed the soil structure making it more susceptible to erosion. During the heavy rain of the 2013 flood, the debris was washed down directly to the river, aggravating the flood damages. The combined landform factors made Jamestown one of the highest impact areas of the 2013 Colorado historic floods.

Surprisingly, the part of the house destroyed during the 2013 flood is now rebuilt in the same spot (Figure 2b). Eight years have passed, and the site is the same. The surrounding river, creek, mountains, and hills are the same. The debris in the higher elevations is still abundant. Once heavy rainfall occurs again, a similar tragedy will be repeated.

FIGURE 2
COMPARISON OF HOUSE PHOTOS AT SAME SITE IN JAMES TOWN

a. (Photo by Ping Xu, 2014).

b. (Photo by Ping Xu, 2021).

Drake, Big Thompson Canyon, CO.

Drake, a small town located at a confluence, is prone to debris flows. During the 2013 floods, all eight houses were flooded. The flows over four feet high left mud marks on buildings. At the west end of the area, a family home experienced the most damage. Everyone was evacuated by helicopter. Flows from the North Fork of the Big Thompson River attacked the small community after passing through the steep canyon and collecting vast debris along several miles upriver in the violent current. One year after the tragic event, the damages from debris flow were still visible. The narrow canyon was full of fallen trees, shredded vehicles, and vast chunks of rock. Some boulders, over 10 feet in diameter, caused catastrophic damage as they rolled through the canyon. The Big Thompson River points directly to the site, making it vulnerable to flood and debris flow attacks. In addition, the hill north of the town provides abundant debris of dry soil and small rocks. This hill also experienced the 2011 fires. Like Jamestown, Drake's landform factors pose threats to the residents.

Eight years since the 2013 flood strike, the town has fully recovered. Drake appears beautiful and peaceful with blue sky, red hills, green trees, and the dry wash path -- a bit of water trickling quietly through. The Big Thompson River, with its shining ripples, flows peacefully. However, the landforms of the creek and hills that triggered the 2013 disaster remain the same. Once the heavy and constant rainfall arrives, the 2013 flood will likely repeat and cause a similar catastrophe. According to a house owner in Drake, during the 1970s, he, a young man, experienced a flash flood in this canyon. The water swept him and his friend away. The violent water killed his friend, while the house owner survived due to water pushing him up into a large tree branch. When will be the next disaster? The answer is unclear, but it will likely happen sooner than later, particularly with current extreme weather patterns.

West End of Arapahoe Avenue, Boulder, CO.

This site is located at the foothills of Flagstaff Mountain in Boulder. During the 2013 floods, a debris flow split a building into two parts, and over ten feet of mud filled the first floor and the parking lot. People were shocked that a "flood" came from heaven instead of a river. They did not realize that this beautiful site was under threat from debris flow that originates from the top area of Flagstaff Mountain, where sand and rocks are abundant. The steep hillsides of the mountains are full of small pieces of gravel, sand, fallen trees, and other debris. A straight and narrow dry wash initiated from the mountain peak and points directly towards the site. During 2013's heavy and consistent rainfall, the dry wash carried rocks, sand, and fallen trees with the water and generated a powerful debris flow, which destroyed the buildings in its path. This debris flow disaster came from a mountain peak a mile away. Unfortunately, the newly building followed the "like for like" insurance policy to build on the same site. Ignoring large-scale hazard impacts could lead the building to be destroyed in the next debris flow attack (Figure 3). Large-scale considerations are crucial in avoiding future failure (Steinitz, 2012).

FIGURE 3
A NEW BUILDING RECONTRUCTED AT SAME SITE

This location looks attractive. It is on the end of a main streets in Boulder, providing excellent access to the nearby mountains. It is surrounded by trees and hills. On occasion, the locals have spotted mountain lion cubs. On the site, mountain peaks are in view but appear far away; therefore, people do not feel the threat of the high peaks. Buildings at this attractive site will only increase in value as the real estate market in Boulder continues to rise. Do the buyers know the potential dangers hidden behind the beauty? Maybe they just do not want to think about it.

Big Elk Meadow Drive, Lyons

Big Elk Meadow contains over 100 houses, many of them second homes for summer, providing a beautiful backdrop for children to play. The Deer Creek Canyon has steep slopes that collect debris and feed into lakes. In the 2013 floods, the lakes were filled with mud and debris, raising the water level and flooding the nearby houses. A postfire debris flow destroyed a home on a steep hillside (Figure 4a); the only thing left was the garage buried in mud. The hills behind the house were affected by the 2002 Big Elk Fires, which changed the soil structure and left a rich source of debris. During heavy rain, the dead burned trees fell and levered out soil leaving large pits, which caused further erosion. A gully on this steep hillside leads toward the house. During the 2013 floods, the vast runoff carried gravel, sand, and timbers that passed through the gully, generating a debris flow. When the hill slope eased, the debris flow fanned out and destroyed the homes in front of it.

In the summer of 2017, the author revisited the site. Surprisingly, a new house has already been constructed on the same site and within ten feet of the 2013 debris flow attack area (Figure 4b). Past events have made it clear that the landforms near this site have triggered debris flows during heavy rainfall. Thus, the new structure may face similar destruction by a future debris flow event.

FIGURE 4
NEW HOUSE CONSTRUCTED WITHIN TEN FEET OF THE 2013 DEBRIS TRACK

A. Photo 2014 by Ping Xu

B. Photo 2017 by Ping Xu

Residents who choose to live in a site that has experienced or has the potential to have a debris flow are advised to consider facing potential danger and prepare to evacuate. During the rainy season, residents in high-impact areas should consider leaving. If they cannot vacate their home, they should pay attention to the weather forecast and follow any instructions or emergency evacuations administered to the public. The heavy precipitation elsewhere can also trigger a debris flow affecting downstream areas. Debris flow can create loud thunderous sounds when passing through canyons (Chavez, 2018). The debris flow event can last for several hours, and flows can reach over 100 mph, with walls of debris rising to 30 feet (King, 2018). Residents should not go outside to witness the debris flow, as debris flow can occur or change (Matjaž, 2003). Residents need to follow evacuation mandates and not return until they are officially safe.

WHY ARE PEOPLE REBUILDING THEIR HOUSES IN THE SAME HIGH- IMPACT SPOTS?

There are various reasons people rebuild their houses at the same spot where the house was damaged or demolished. Many mountain residents often lack knowledge of the dangerous nature of deadly postfire debris flows: when and where debris flows will possibly happen, and how this makes their homesites vulnerable to disaster. Some new home buyers who did not experience the 2013 catastrophe are attracted to the beautiful mountain sites, knowing little of the geological dangers of the postfire debris flows. While those who are aware of the debris flow dangers feel the houses were destroyed by a singular debris flow incident, which may not happen again in their lifetime. With the recent spike in extreme weather patterns around the globe, debris flow events are likely to occur more often.

Some residents prefer not to worry about the site of their home, as they think that evaluating the site is the responsibility of professional designers. Before building on a site, a design project first needs the site approval of geological and structural engineers. These considerations ensure building safety. However, the damages and fatalities in highly impacted areas during the 2013 flood demonstrated site selection failures. These oversights could be attributed to limiting site evaluations in a small scope of the impact areas, as postfire debris flows originate at high elevations, sometimes miles away, and cause damage at the impact areas with lower elevations. Knowing these risks, residing in a house in a debris flow zone is not acceptable. Why have we repeated the mistake?

Both the State and Federal governments have spent substantial funds to aid residents in recovering from the damages. These emergency funds rebuild infrastructure and improve road conditions and drainage systems. Insurance companies allocate funds to repair damaged homes and property in the residential sector. These policies often mandate that recovery efforts involve reconstructing damaged homes on their original property. Some insurance policies offer residents a choice: insurance can reimburse them the cost of rebuilding the house on the same property or give residents an equivalent amount of funds to invest in building on a new site. However, residents taking these deals are expected to pay for a new site out of pocket. When rebuilding, some insurance companies may mandate that a house be replaced “like for like” the original one (Simpkins, 2022).

For most residents, rebuilding the same house on the same site sounds feasible and affordable. Some residents feel that their beloved home is worth the risk, even as they experience and survive catastrophes. In fact, the potential cost of acquiring new and safer property and the lack of awareness of the recurrent nature of postfire debris flow are critical reasons why most mountain residents rebuild their damaged homes on the same land. This cycle of rebuilding and re-destruction at high-impact sites doesn’t benefit the developing community’s resilience in the long term and endangers the lives of residents. If mountain residents are convinced to find new safe places, insurance policies should shift to reflect the resilience solution.

CONCLUSION AND DISSCUSION

Enhancing Resilience

Natural hazards are often beyond human control. However, disaster impacts reflect significant mistakes in the initial site selection. Rebuilding houses within the same high-impact areas will repeat the failure because the landforms of these areas are prone to postfire debris flows. To hope a debris flow never happens again is to wish the heavy rainstorm never comes; this is not the reality. Facing climate challenges, we must find divergent paths towards a future that enhances the resilience of mountain communities.

The community’s resilience to climate change is measured by its ability to resist and recover from natural hazards, adapt to extreme weather patterns, and persevere through future challenges. The goal of enhancing resilience is to survive, sustain, and thrive. Rebuilding like the original building at the same site without analyzing when and where the disaster occurred and how to mitigate the hazard in the future could lead disasters to repeat. Although the government and insurance agencies will repay the cost of rebuilding, the cycle of rebuild-repaid-destroyed will continue. Not only is this economically unsustainable, but postfire debris flows can and have taken lives in these mountainous regions. Therefore, rebuilding “like for like” is not the way to enhance the resilience of these communities. In the future, government funds should assist in relocating people from highly impacted zones rather than rebuilding.

Postfire debris flow events have provided lessons for us. First, prohibit building in areas prone to postfire debris flow. Secondly, the residents in prone areas should consider relocating, even if a debris flow has not occurred yet. Once heavy rainstorms come, the disaster may arrive. Finally, to avoid rebuilding houses in the same highly impacted areas and help residents relocate to safer places. Humans have learned from previous mistakes to endure natural hazards throughout history. These climate challenges have contributed to the development of human civilization. Olgyay states that climate ranks, with racial inheritance and cultural development, as one of the most crucial factors in determining the conditions of civilization (Olgyay, 1963).

Mitigation Areas and Difficulties

Postfire debris flows occur on fire-scarred slopes. Therefore, controlling human-caused fires is essential. An open-fire ban zone should be established within the wildland-urban interface, where most population and economic interests concentrate. All fires in this area should be stopped immediately upon detection, including campfires, fireworks, debris pile burning, and other open fires (Xu, 2017). In addition, an important issue that Colorado must consider is the presence of massive logs of dead trees. These logs carried by a debris flow can destroy riverbanks, adding debris to the volume and power of the flow. These logs can also act as “weapons,” impaling obstacles in their way. The flows are often so violent that the massive trunks are pulverized to woodchips when they reach the debris flow impact area.

Theoretically, comprehensive mitigation of a postfire debris flow should include the areas of the debris catchment and the debris track. Implementing mitigation only within the impact fan/area is not enough. A debris catchment can extend for several miles and often stems from high elevation areas with steep hillsides; debris tracks are creeks, gullies, or dry washes which pass through narrow canyons. Also, clearing off thousands of thousands of burned trees on steep hillsides would be difficult. Mitigation work on such landforms is challenging and costly. Thus, the best solution to reduce the damages and risks is to relocate homes off from the high-impact areas of a debris flow.

Relocate to Sustain

Attractive mountain settings make residents reluctant to relocate homes. The residents enjoy beautiful surroundings and life qualities, but they are often unaware of the danger looming over their homeland. People love a home that they feel is a part of their life. “Rebuild our home” can be a powerful slogan to inspire a community to fight for itself. However, when the home is destroyed by a recurrent natural disaster like debris flow, rebuilding the home within highly impacted areas often leads to re-suffering its destruction. The wiser approach is to relocate for a safe and thriving life.

The fatality and homes demolished within debris flow impact zones exemplify the site selection failure. A lack of knowledge of postfire debris flow exposes the architectural and planning education weakness, in which scientific knowledge on natural hazards has only been introduced superficially. To overcome the weakness, we should require scientific knowledge of climate and natural hazards in current curriculums. An interdisciplinary approach would contribute to seeking better solutions for adapting to climate challenges.

To enhance a comprehensive understanding, the media and mountain communities should introduce the scientific knowledge of postfire debris flow and encourage residents to evaluate the landform patterns and how they could affect their safety and homes. It is essential to study all surrounding mountains and water nearby, including the debris catchment, the flow track, and the impact area. Such education would help residents in the high-impact areas understand the potential risk and why they should relocate their homes for a safe and thriving life. Considering the risk and recurrence of debris flows, paired with the expense of mitigating infrastructure, the most effective strategy for dealing with the hazard is to avoid building and rebuilding homes in areas prone to debris flow. Government funds should help the residents relocate to a safe place instead of rebuilding at the impacted site to enhance community resilience to climate challenges.

Mountain hazards are likely to occur more frequently with the onset of extreme weather patterns. It is more troubling that an increasing population is moving into these susceptible zones, which exacerbates the impacts of these hazards. Fire and postfire debris flows are natural processes. They have happened consistently throughout history and will continue to occur in the future. Once people move into the debris flow-prone zone, they are in danger. Respecting natural rules, migrating from the high-impact zones, and avoiding residing in areas susceptible to natural hazards are essential strategies to adapt to climate challenges. As Ian McHarg states, adaptations to natural laws are directed toward enhancing life by promoting harmony between humans and nature (McHarg, 1969).

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