Interaction Among Forests, Mass Movements, and Streams and Implications for Aquatic Habitat

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Thanks to: Shannon Hayes, John Green, Christine May
**Objective:** Quantify the effect of the forest on debris flows and sediment and examine the implications for aquatic habitat.

**Questions**

- Do trees matter for landslide initiation?
- Do trees and wood matter for debris flow runout?
- Does wood matter for sediment storage?
- Does wood matter for sediment output to larger, fish-bearing streams?
- Does the importance of history overwhelm our ability to derive meaningful information from simulations?
- Debris flows are a natural process to which local fauna have adapted. Can we so alter this process that it threatens those fauna?
Methods

- Landscape-scale model that includes the necessary geomorphic and vegetation processes
- Field data for comparison with modeling results
Initial conditions for 3000-year simulation
How do wood and debris flows interact?

- Debris flows incorporate trees and fallen wood in initial failure.
- Wood in debris flows may increase resistance.
- Debris flows incorporate fallen and standing trees, the latter resist uprooting.
- Debris flows may scour sediment and wood deposits.
What is the effect of wood on debris flow runout?

Model experiments:

1) **Null case**: Debris flows do not incorporate wood
2) **Wood incorporation**: Debris flows incorporate wood
3) **Root-rip**: Debris flows incorporate wood + resistance of standing trees
4) **Wood resistance**: Debris flows incorporate wood + resistance of standing trees + resistance proportional to wood constituent

Field data:

- debris flow runout lengths and deposit map
- wood and sediment deposit volumes
$x_{dep}=151\ m$

$\text{Null case}$

$\text{Wood incorporation}$

$\text{Root-rip}$

$\text{Wood Resistance}$
Simulation results: Debris flow runout lengths

Cumulative distribution functions of modeled runout lengths compared to field data
Debris flow triggering events
intensity (mm/hr)

Sediment & wood storage
mass/area (kg/m²)

Sediment output
mass/area (kg/m²)

Simulation timeline: Null case

Debris flow triggering events

Sediment & wood storage

Sediment output

Hydrograph

Time (years)

Sediment output dominated by debris flows
Simulation timeline: Wood case

**Debris flow triggering events**
- intensity (mm/hr)

**Sediment & wood storage**
- mass/area (kg/m²)

**Sediment output**
- mass/area (kg/m²)

**Hydrograph**
- Time (years) 200 400 600 800 1000
- Sediment output dominated by fluvial transport

- Sediment output dominated by fluvial transport

- Soil
- Sediment
- Fallen wood
- Deposited wood
- Trees

- Debris flow triggering events
- Fire
- Landslide event

- Simulation timeline: Wood case

- Sediment & wood storage
- Mass/area (kg/m²)

- Debris flow triggering events intensity (mm/hr)

- Sediment output mass/area (kg/m²)
How does wood affect sediment storage and output?

- Wood in debris flow deposits forms dams that trap debris flow sediment.

- Wood dams trap sediment transported from other sources.

- Channels incise deposits when wood dams decay.
Simulation with smoothed initial profile: Debris flow runout lengths

Comparison of observed and simulated runout lengths

Mapped in the field

P(runout length ≤ L)

L, meters

1995-1999
1979-1995 no slides identified
1972-1979
1968-1972
1962-1968
1956-1962
pre-1956
Deposited wood suppresses sediment output.
Animation of 3000-year simulation
Post-fire

Soil and deposit depth (m)

Time = 200

200 meters
Valley storage and main channel profile measured in the field…
...and simulated over time
Post-fire (200 yrs)
Post-fire + 100 yrs
Evolution of valley storage cross-sections

- Maximum storage
- Flow direction

Evolution at:
- Time = 200 years
- Time = 300 years

Diagram showing the evolution of valley storage cross-sections with layers indicating surface, wood, sediment, and bedrock.
Next step: Forest harvest effects
Simulation of riparian buffer prescriptions: Preliminary results
Conclusions

• Trees matter for landslide initiation.
  ➢ Decreased root strength increases landsliding.

• Trees and wood matter for debris flow runout.
  ➢ Wood removal may increase debris flow runout lengths by 100% or greater.
  ➢ Longer debris flows would lead to altered and more direct impact to fish-bearing streams.
Conclusions

- Wood matters for sediment storage:
  - Wood from debris flows forms dams that hold back sediment.
  - Woody dams increase sediment storage and residence times.
  - Much old sediment is stored high in the system behind debris dams.

- Wood matters for sediment output:
  - Wood slows release of sediment from small channels.
  - Slow release decouples hillslopes and channels.
  - Wood may “stall” disturbance-generated sediment pulses (“dynamic capacitance”).
Conclusions

- The simulations, coupled with field work, have much to teach us, but the lack of an “initial history” still leads to some uncertainty.

- Debris flows are part of a natural process that has effects necessary to maintain good aquatic habitat, but we have the capacity, through wood removal, to drastically alter that process. The effects of that alteration are still unknown because the presence of “legacy wood” delays the impacts of our actions.