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GUIDEBOOK FOR

A FIELD TRIP TO OBSERVE NATURAL AND MANAGEMENT-RELATED EROSION IN FRANCISCAN TERRANE OF NORTHERN CALIFORNIA

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FIELD TRIP TO OBSERVE NATURAL AND RESOURCE MANAGEMENT-RELATED EROSION IN FRANCISCAN TERRANE OF NORTHWESTERN CALIFORNIA

A GUIDEBOOK

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COMMENTS ON GEOMORPHOLOGY IN ECOSYSTEM STUDIES

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It is easiest for me to relate some of the relevance of geomorphology to ecosystem studies by outlining a little of my history as a geologist/geomorphologist working since 1972 with the Coniferous Forest Biome research group of the International Biological Program, I started with the assignment of mapping bedrock geology in the ecosystem study area, the H. J. Andrews Experinrental Forest, near Blue River, Oregon. Although working in the same geographic area with the forest and stream ecologists in the group, my project was completely out of the mainstream of the ecosystem study--my time frame was disjunct, The youngest rocks in this area of the western Cascade Range are 3.5 million years old, Meanwhile, the longest time period of concern to the aquatic and forest ecologists was on the annual scale of nutrient budgets and physiological behavior of plants. This feeling of being out of it, time-wise, raised questions about the full range of geomorphic and vegetative variation and interaction. What sorts of geomorphology-ecosystem interactions occur over the range of time scales from days to millions of years? Where is the common ground for interaction between geomorphologists and ecologists?

Table 1summarizes some thoughts on this matter based on Douglas-fir-western hemlock forest ecosystems in the Cascade Mountains of Oregon, Major exogenous events that affect ecosystems and landscapes are arrayed by frequency of occurrence over a broad time scale. These events include climatic and geologic processes as well as major disturbances of vegetation such as fire for which ignition may be considered exogenous, but intensity and areal extent of burns may be controlled by endogenous vegetation and landscape factors. Some of these events are regular and cyclical in occurrence, while others are episodic and their frequency would be considered here in terms of average return period.

Geomorphic factors vary over this time scale, ranging from relatively frequent changes in rates of geomorphic processes to the long-term development of the physiographic province as a whole. Development of progressively larger landforms occurs on progressively longer time scales. Geomorphic response to the most frequent exogenous events listed does not involve development of landforms attributable to an individual event. At intermediate time scales, landforms of intermediate spatial scale, such as terraces, fans, and moraines, form in response to exogenous events. On still longer time frames, landform elements of greater geographic extent develop as the sum of all higher frequency geomorphic responses to exogenous events.

Vegetation is also subject to an array of changes over this broad time range. Individual plants have physiological response to daily and seasonal fluctuation of moisture regime. On the time scale of centuries, vegetation (secondary) succession occurs following major ecosystem disturbances such as fire, landslides, and extensive blowdown events. Primary succession,

Table 1. Geomorphic and vegetative variation and exogenous events affecting ecosystems and landscapes on an array of time scales. Example from Douglas-fir--western hemlock forests in Cascade Mountains, Oregon.

Event Frequency (yr)	Exogenous Events	Geomorphic Variation	Vegetation Variation
10^{-2}-10^{-1}	Precipitation-Discharge Event	"Base-flow" erosion by noncatastrophic processes	Physiologic response of individual plants
10^{0}-10^{1}	Annual water budget moderate storms		
10^{2}	Extreme storms major disturbances of vegetation, e.g., fire	Periods of accelerated erosion — Slide scars, channel changes	secondary succession
10^{3}-10^{4}	Climate change Glaciation	Intermediate scale landforms: terraces, fans, moraines, etc.	Primary succession Migration Microevolution
10^{6}	Episodes of volcanism	Gross morphology of major drainages and constructional (volcanic) landforms	Macroevolution
10^{7}-10^{8}		Development of physiographic province as a whole	

shifts in the range of species and plant communities, and microevolution occur, in part, in response to and on the time scale of major climate change. Most significant macroevolution takes place over still longer time periods.

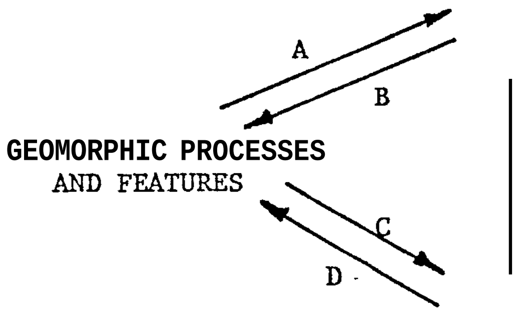
To some extent, Table 1 shows hierarchical arrangements of geomorphic and vegetative change. Change on each time scale involves both response to exogenous events at that time scale and the sum of all higher frequency variation in that system. For example, formation of terraces and alluvial fans may be facilitated by climate change and glaciation on the scale of 10^3 to 10^4, years, but the actual constructional processes occur as more frequent "base flow" erosion and pulses of accelerated sedimentation at the scales of decades and centuries.

Table 1 provides a basis to consider our original question concerning geomorphology-ecosystem interactions. Interactions occur on each time scale, but are most dramatic on intermediate time scales. On longer and shorter time frames, geomorphic setting is commonly viewed as a passive, invariant stage on which evolution and plant physiologic behavior take place. But on the intermediate scale of secondary succession, change in plant community composition, vigor, and structure can profoundly affect rates of geomorphic. processes. Geomorphic events may, in turn, set the stage for succession by creating fresh substrates and may determine to some extent the rate and type of plant community development that follows a major ecosystem disturbance,

The detailed character of geomorphology-ecosystem interactions vary from one ecosystem-landscape type to another. This interaction if particularly dynamic'in the coniferous forest ecosystems of the steep Cascade terrain where vegetation is important in regulating soil and sediment movement down slopes and streams. Historically, these forests and landscapes have experienced widespread, intense crownfire, floods, landslides, windstorms, and associated fluctuations in sedimentation. Today a major process of stand and landscape disturbance is clearcut logging,

Over the past six years the main research interests of our group have shifted from subjects on disparate time scales to focus on geomorphic and ecosystem effects of these disturbances over a period of decades and centuries. Forest and stream ecologists expanded their time perspectives; and geologist/geomorphologists collapsed theirs. This meeting in the middle has been an exciting educational process, and it has involved working on some problems that had previously fallen between the disciplinary slats, One such area of research concerns the biologic and geomorphic roles of large woody debris in streams and how debris conditions vary in space (from small streams to large rivers), and in time (after wildfire and clear-cutting) (Anderson et al. 1978, Swanson et al. in press, and Keller and Swanson in press).

The more important interactions among geomorphic processes and features, flora, and fauna are shown in Figure 1. Some research activities in our group have concentrated on the role of geomorphic processes in nutrient cycling and effects of vegetation on rates of geomorphic processes in 400 to 500 year-old stands and in clearcuts 0 to 35 years old. Different components of vegetation affect each geomorphic process (Table 2) and each vegeta-



A. Create new sites for establishment and distinctive habitat. Disrupt growth by tipping, splitting, stoning. Transfer nutrients. Determine disturbance frequency by effects on fire breaks, fire behavior, wind sensitivity.

B. Regulate rates of erosion processes. Affect soil and sediment storage. (record geomorphic history).

C Create distinctive habitat. Influence travel behavior and routes.

D. Affect soil movement by burrowing, surface travel, soil compaction, litter reduction. Affect fluvial processes and landforms--dam streams, burrow in banks, trails initiate gullies.

Figure 1. Interactions among geomorphic processes and features, flora, and fauna. Flora-fauna interactions, the subject of much ecology research, are not considered here.

Table 2. Roles of vegetation in regulating hillslope transfer process rates.

Vegetation	Component	Total Biomass	Living Vegetation			Aboveground Biomass		Roots		Living and Dead Groundcover
	Function	Loading of Slope	Water Uptake	Nutrient Uptake	Regulation of Snowmelt Hydrology	Medium for Transfer of Windstress	Source of Litterfall	Vertical Anchoring	Lateral Anchoring	Surface Obstruction
Hillslope Transfer Processes	Solution	0	-	---	0	0	0	0	0	0
	Litterfall	0	0	0	0	0	+++	0	0	0
	Surface erosion	0	0	0	0	0	0	0	0	---
	Creep	+	--	0	-,0,+	0,+	0	--	--	0
	Root throw	0	0	0	0	+++	0	---	---	0
	Debris avalanche	+	0	0	++,0,--	++	0	---	---	0
	Slump/earthflow	-,0,+	--	0	+,0,-	0,+	0	0	-	0

Sense of vegetation function
+ Vegetation function increases transfer process rate
- Vegetation function decreases transfer process rate

Significance of vegetation function
+,- Questionable, slight
++,-- Significant
+++,--- Substantial

tion component is likely to recover along a different time trajectory following disturbance. Consequently the rate of each process will vary with different magnitude and timing in response to ecosystem disturbance and revegetation. A hypothetical example for a steep 10-ha western Cascade watershed might show a longer duration increase in debris avalanche potential as regulated by root strength than the more rapid recovery of surface erosion rate as the organic litter layer builds up or a lag armor of coarser soil particles forms (Figure 2). Erosion by root throw in the clearcut area is reduced until trees are large enough to be blown down and rate of denudation by transport of material in solution is checked by nutrient uptake as biomass production takes place during revegetation.

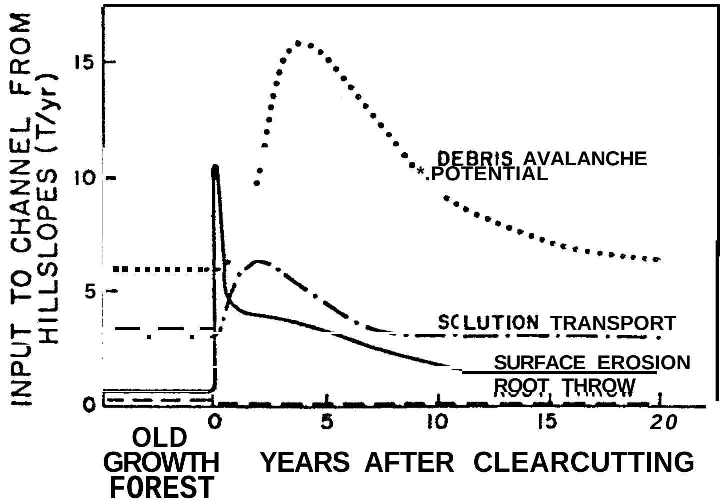


Figure 2. Hypothetical rates of selected processes of soil input to channel before and after logging of steep, 10-ha Watershed 10, H. J. Andrews Experimental Forest (from Swanson et al, in press).

Geomorphic response to ecosystem disturbance is further complicated by the complex in-series and in-parallel relationships among processes that transfer oranic and inorganic material (Figure 3). This view of the soil-sediment routing system has been simplified by excluding storage elements, such as debris avalanche "hollows" (Dietrich and Dunne 1978), fans, and deposits in floodplains and behand large organic debris, Rates of inflow and outflow and overall capacity of these soil-sediment storage compartments vary with vegetation conditions.

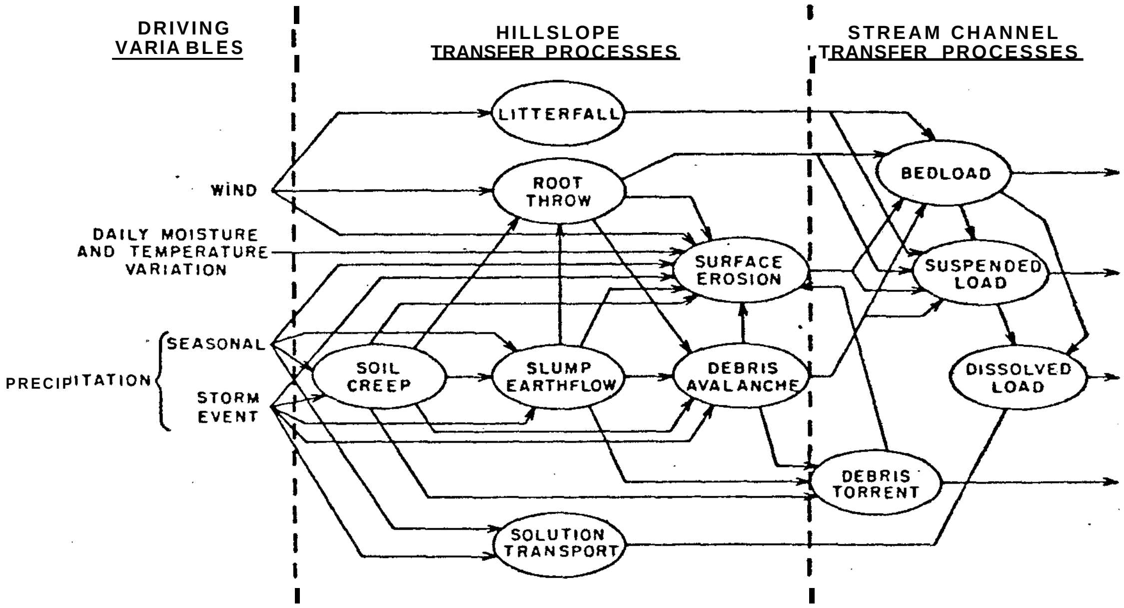


Figure 3. Relationships among organic and inorganic matter transfer processes and principal driving variables for a small western Oregon watershed. Arrows indicate that one process influences the second process by supplying material for transport or by creating instability that culminates in the occurrence of the second process (from Swanson et al. in press).

Assessment of geomorphic effects of ecosystem disturbances concerns not only magnitude and duration of response to a single disturbance, but also frequency of disturbance. This is an important consideration in comparing diverse ecosystems where disturbance frequency may be quite different and in measuring long-term impact of management activities on sediment yield. In the latter case management related disturbances of an ecosystem may differ in kind, magnitude, duration, and frequency from the disturbance regime. Hypothetical variation in several of these parameters over about a thousand years is shown in Figure 4, again using Watershed 10 in the H. J. Andrews Experimental Forest as the example. Such a long-term perspective is essential to realistically evaluate management impact on vegetation, soils, and streams,

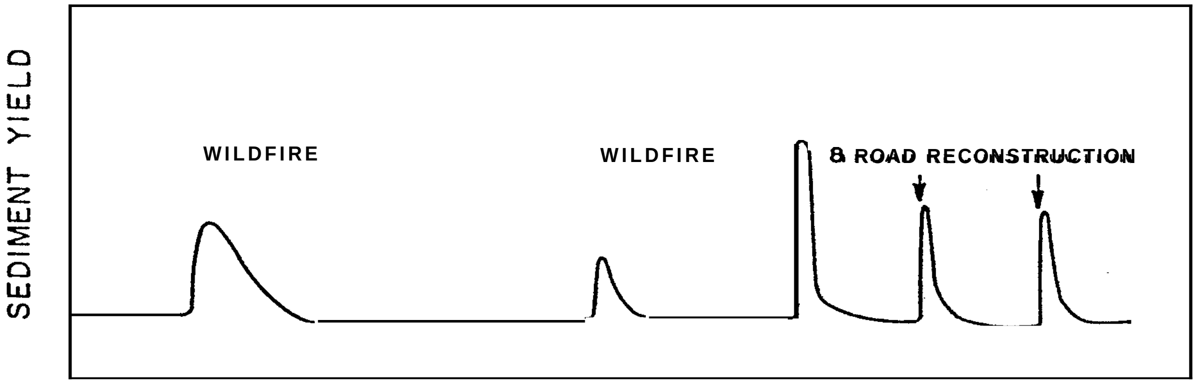


Figure 4. Hypothetical variation in sediment yield from Water–shed 10, H. J. Andrews Experimental Forest, over a thousand years of history spanning management and premanagement time (from Swanson et al. in press).

So the discussion returns to one of the most important contributions that a geomorphologist offers ecosystem research--a broad time perspective,

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