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ANTHROPIC EROSION: AN EXAMPLE OF THE HOLISTIC APPROACH

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ABSTRACT

Anthropic erosion caused by human manipulation and interference with complex natural systems is becoming a devastating and chronic problem. One approach to understanding the real nature of the problem and possible solutions to it is a holistic analysis of all involved natural and socio-economic systems. A small scale example in an exurban mountain setting is studied to show how this approach might work.

The depletion of the soil base from erosion accelerated by human involvement in the manipulation and interference with complex natural systems is becoming a devastating and chronic problem. We see evidence of this anthropic erosion in all natural environments and in every conceivable socio-economic situation ranging from Sahelian Africa to suburban Los Angeles. The problem is acute in developing countries where the need for food causes the exploitation of the soil [1]. There is a less dramatic and dangerous yet very pervasive equivalent to the third world problem in the modern, developed societies. Toy goes so far as to state that accelerated (anthropic) erosion is the preeminent environmental problem in the United States [2].

This article will deal with the system of factors that are involved in the high and continuing erosion rates in exurban developments in the western United States. The system analysis of this example can easily be extrapolated to other erosion problem areas in developed countries.

Much work has been done on erosion rates during construction [3-5], with maximum erosion decreasing by an order of magnitude after construction is complete. Under certain environmental and socio-economic circumstances this decrease does not occur. This is particularly true in the case of exurban

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development in the western mountain states. Development on steep slopes with little or no paving of streets and roads or storm sewer systems creates a high erosion potential. Anthropic erosion in these areas will be increasing manyfold in the next few decades as people pursue the "rural" experience while maintaining their proximity to urban areas. To see the reasons for this phenomenon of high rates of anthropic erosion in otherwise pristine mountain environments one must look at all factors. The entire system of physical, political, economic, and cultural factors is involved. We must use a holistic approach to understanding environmental problems in general and soil erosion specifically.

THE HOLISTIC APPROACH

Although there are recognized gaps in the knowledge of the technical aspects of soil erosion, especially in mountain areas, there are other non-technical aspects at least as critical for solving the soil erosion problem [6, 7]. With all of the research on mountain geomorphology, little has been done to research ways to reduce the destabilization of mountain systems. Messerli feels that the concern now being shown will help promote a greater emphasis on an holistic approach to the problem [8]. In stating that "man" is now probably the major geomorphic agent in mountain environments, Ives comes to the conclusion that " . . . we need an anthropogeomorphic disciplinary approach" [9]. In other words we need to link the human and natural systems. Of overall importance is the coordination of research in both human and natural systems since both are part of the single issue of environmental degradation and instability.

A Systems Approach

A general way to approach this kind of coordination effort is Blaikie's six components of a working conservation policy [10]. These components must all be addressed to make any policy/program work. Each policy must include:

- a method to identify the geographic area of the problem and to evaluate the causes of the problem both within the area and from external areas (A);
- a way to choose the areas of concern (B);
- the choice of conservation techniques to ameliorate the problem (C);
- a means of implementing the above techniques in a political structure (i.e., who polices the implementation?) (D);
- decisions on who pays, who benefits, and who loses (E); and,
- what other factors are involved in the above decisions (e.g., tax base, pro-growth vs. anti-growth emphasis, development densities) (F).

Blaikie used these components specifically in the context of underdeveloped countries, but they apply equally well to developed countries including mountain regions in these developed countries. Messerli has produced a helpful schematic of a systems model at the regional scale (Figure 1) [8]. Each of Blaikie's components (A–F) can be found in one or more of the systems (subsystems) involved in environmental decisions.

The Natural System – The main factors of erosion in mountainous areas are vegetal, morphometric, topographic, hydrologic, and material factors. Any part of the development process which affects the vegetation commonly exerts the greatest impacts on erosion [4]. With the realization that any construction (development) will entail at least some vegetal change or destruction, the abiotic components will become the critical controlling factors.

The natural factors are even more important in mountain environments than in lowlands. Because of steep slopes, shorter growing seasons, rapid climate changes with elevation, and broken relief, mountain environments are much more sensitive to natural and human induced perturbations [8]. Extremely rapid environmental degradation can take place if these factors are not considered by the socio-economic system during and after development in mountain areas.

The Socio-Economic System – As complex as the natural system is in mountains, the socio-economic system is probably more complex and more important in terms of the soil erosion problem (Figure 1). To quote Blaikie, "... techniques get evaluated and researched but programmes and policies do not, with the result that the 'social factors' which block policies tend to go unresearched ..." [10]. Not only do we have internal political, economic, demographic, and cultural components, but we also have the influence of external factors from the marketplace and other governmental jurisdictions. This complex situation tends to promote progressive instability in the entire natural/socio-economic system. Gijon lists three types of environmental instability in mountain areas [11]:

- natural endogenous instability where irreversible changes occur during natural succession;
- natural exogenous instability where irreversible changes occur because of natural disturbances; and,
- anthropic instability due to human influence.

This last type is the most detrimental in most cases because of the speed and intensity level at which change occurs.

A CASE STUDY

Keeping the above discussion in mind, a specific example of the system interactions is appropriate. The best way to test this holistic approach is by analyzing a small, local system which has relatively few extraneous inputs.

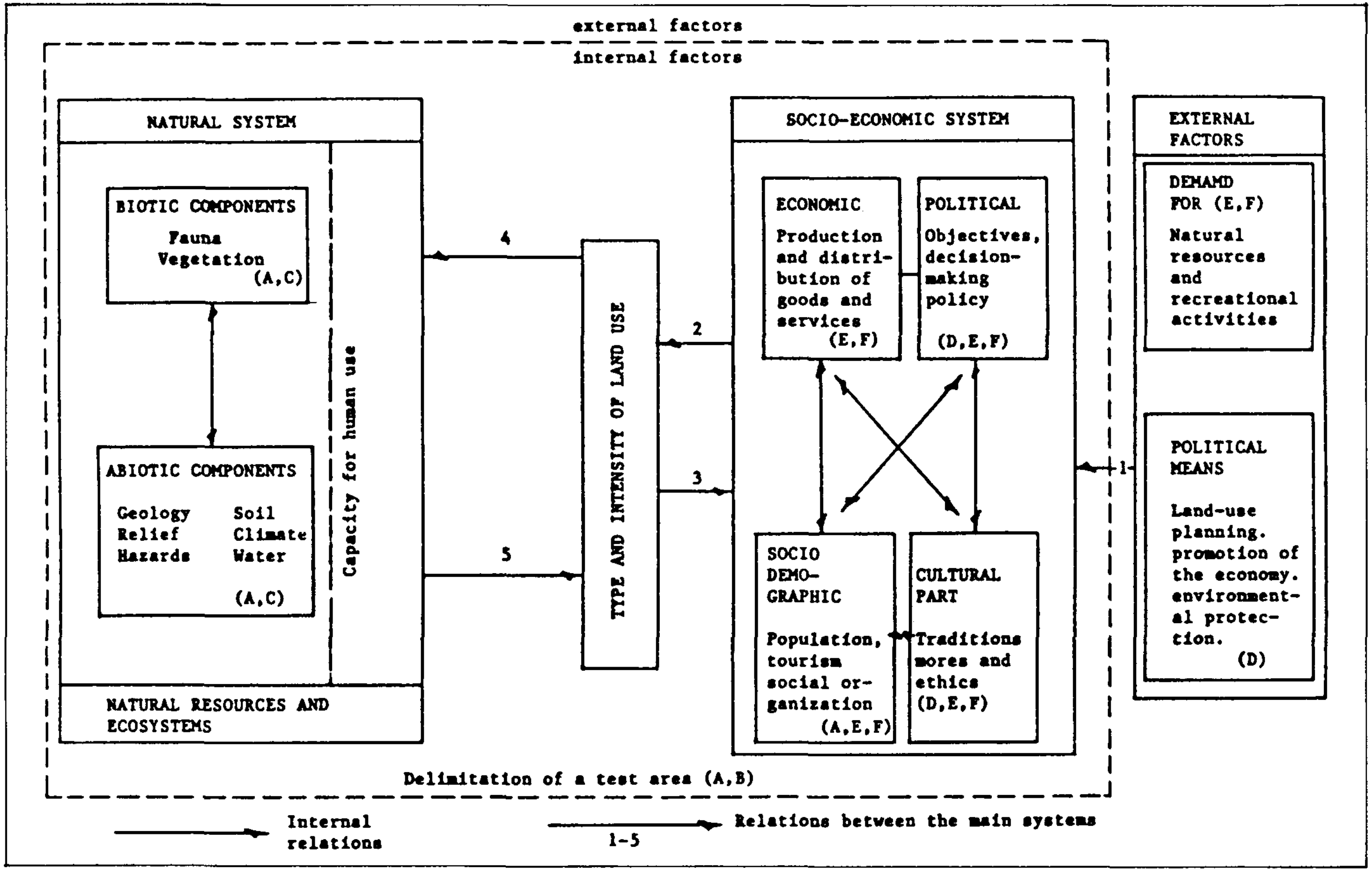

Figure 1. Regional-ecological system with components of conservation policy (A–F) [8, 9].

Study Area

The representative example chosen is a small (41.2 hectare) drainage basin located 24 kilometers southwest of the Denver, Colorado city limit. Administratively, the basin is part of the small town of Morrison, Colorado but is physically related to the town of Conifer (Figure 2). The basin is in steep sloped mountainous terrain and lies between 2378 meters and 2616 meters above sea level (Figure 3). The drainage has a steep gradient (9 degrees) and flows generally to the east. Ponderosa pine *(Pinus ponderosa)*, Douglas fir *(Pseudotsuga menziesii)*, and Gambels oak *(Quercus gambelii)* are the main indicator species of vegetation on the valley walls. Quaking aspen *(Populus tremulodes)* and various willows *(Salix spp.)* are dominant in the valley. There is little understory vegetation with needle-leaf litter being the primary organic matter in the upper soil horizon.

Most of the land is underlain by Precambrian metamorphic gneisses and schists with very well drained, sandy soil. The Soil Conservation Service soil survey of the area lists all of the soil series as being extremely erodible and requiring extensive vegetal cover to preclude severe erosion [12]. Slopes in the

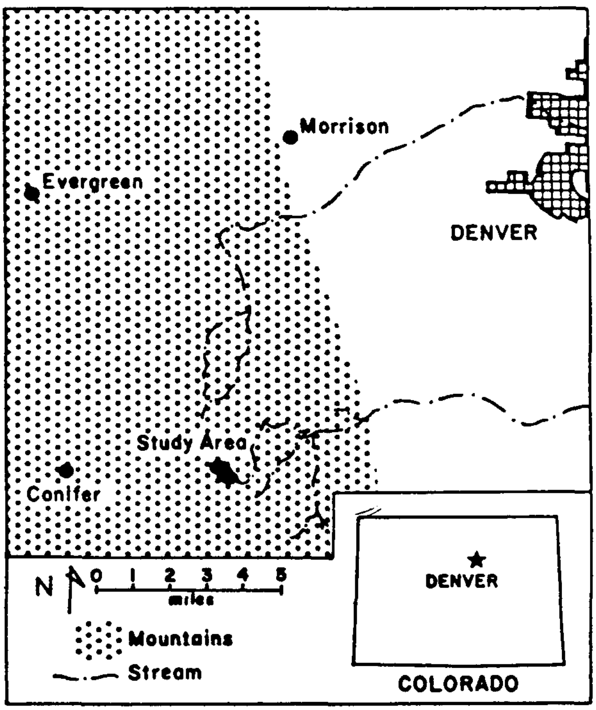

Figure 2. The study area location in relation to Denver, Colorado.

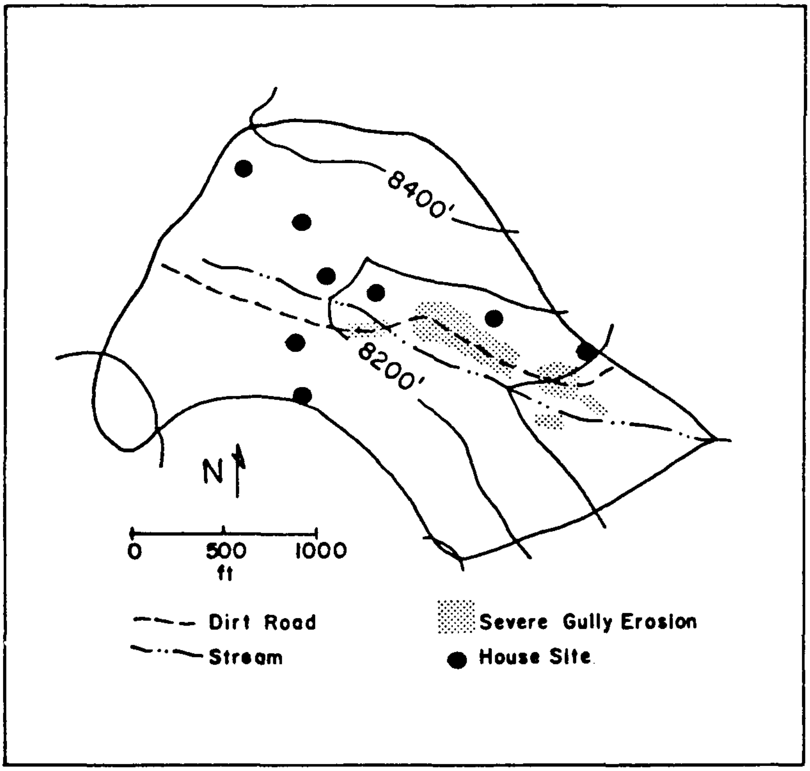

Figure 3. Topographic map of the study area.

basin are steep, averaging between 15 and 20 degrees. All roads in the drainage basin are dirt/gravel and relatively unimproved (i.e., seldom graded). The average annual precipitation is between 43 and 51 centimeters/year with most of this coming in heavy thunderstorms in the summer or heavy snowfalls in the winter.

Platting began in 1978 and only seven houses have been built in the basin since then with one more under construction. This gives a housing density of one house/5.15 hectares, a very low density.

The Natural System – The emphasis in high energy environments on gully erosion is illustrated well by Trimble and Lund [13] and Patric [14]. Once vegetation is removed and the upper horizon of soil is disturbed, gully erosion is rapid. Gully erosion is also a good surrogate for total erosion and is the most easily measured erosion form from aerial photographs [5]. Therefore, gully erosion was used in this study. Aerial photography was used because the erosion environment before development began was needed. Photos were available for the time immediately prior to development. Erosion since development was measured both on more recent aerial photos and in ground surveys of the basin. A comparison of the older photos with the more recent photos indicated where new or increased gully erosion had taken place. All gullies developing or enlarging from the time of intial construction in the basin were field checked to measure volumes of material removed. An average bulk density of 1.8, as determined from several samples, was used to convert volumes to weight.

Measurements of eroded material from gullies produced during and after construction revealed a total of approximately 6190 metric tons of debris eroded. This yields a rate of 150 metric tons/hectare for the five-year period from 1979 to 1984 or 30 metric tons/year. This is a high rate of erosion at a housing density of one unit/5.15 hectares.

What is most disturbing is that this rate of erosion was not chiefly caused by construction but by thunderstorms which occurred *after* construction was complete on six of the eight houses. In other words the erosion rate in this area is higher *after* construction is complete than before it started. This is in direct contrast to what Wolman found in his Maryland Piedmont study where sediment yield was much lower after construction than in the natural state prior to construction (Figure 4) [15]. Langbein and Schumm showed that maximum natural erosion occurs in areas with 32.8 to 45.9 centimeters of precipitation/year [3]. The precipitation rate in the study area is slightly higher, putting the natural erosion rate here at about 13 percent less than this maximum. Along

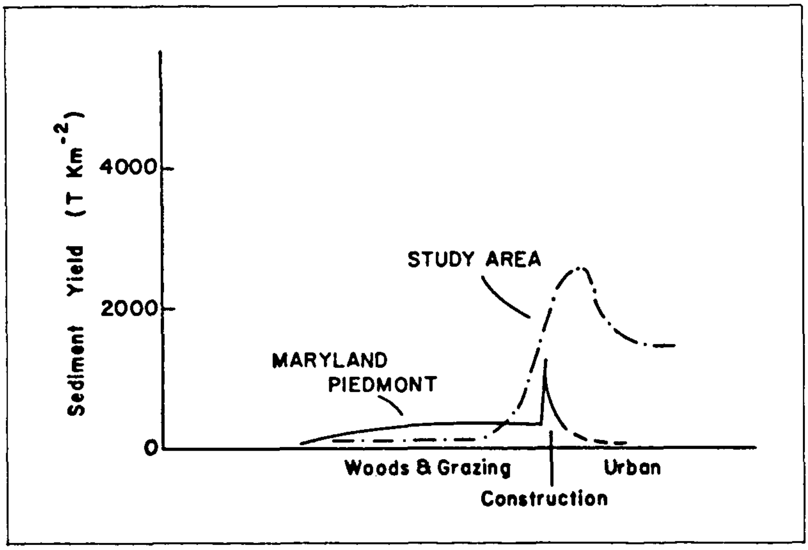

Figure 4. Graph comparing Maryland Piedmont sediment production [14] and sediment yield from gullies in study area.

with this relatively high potential we must include the factors of steep slopes and vegetal cover. Even with this high potential natural erosion rate, the calculated natural rate for the basin using the Universal Soil Loss Equation method is only 1.12 metric tons/hectare/year [12].

Thus far the discussion has emphasized the "natural system" and the "type and intensity of land use" components in Figure 1 and parts A, B, and C of Blaikie's components of conservation policy criteria. Because of the very steep slopes and the soil characteristics, the natural system is tenuously balanced. Virtually anything which upsets this balance will dramatically increase erosion rates. To see why erosion rates are so high for this basin (30 metric tons/year), the socio-economic system (Figure 1) must be incorporated.

The Socio-Economic System

Superimposed on the natural characteristics of the study area are the socio-economic characteristics. Policies and decisions made in the sanctity of legal chambers and economic choices made in boardrooms and homes have tremendous impact on how land is used. The background upon which these choices and decisions rely is the culture of a people in a region. In a very real sense, culture is an important aspect since it influences all the other human actions in the socio-economic system (Figure 1).

Our study area is not atypical of many parts of the American West. Ideologically, Joel Garreau defines the West as well as anyone [16]. In his book *The Nine Nations of North America*, he talks of the culture and ideas of "the Empty Quarter (his term for most of the West), that repository of values, ideas, memories, and vistas that date back to the frontier." The characteristics of the people and the land are tied to an individualism that is still very strong and a view of the land as being almost limitless in extent; attitudes which are generally inhospitable to strong conservation (erosion) controls.

In our study the political objectives and decisions are primarily at the local level albeit they are profoundly influenced by state, regional, and national decisions. But, if erosion control is going to be a matter of concern, local government must be involved. Kusler defines four approaches to possible regulation of sensitive lands [17]. Our study area is defined as sensitive in light of the natural system discussed above. These basic four approaches are:

- zoning regulations;
- subdivision regulations;
- building codes; and,
- special codes.

The historically accepted best approach is zoning regulation as it is the most flexible and powerful. A current method used by planners and politicians to zone sensitive, steep-sided developments has been referred to as a hillside overlay or hillside zone. The basic features of a hillside zone include, but are not limited to, the requirement for special testing of soils and engineering of structures, visibility restrictions, and specialized grading plans.

Usually a hillside zone ordinance is most effective during the construction phase of a development. Rules on vegetation removal, grading limitations, and visibility are all meant to curtail problems during construction and provide for sound environmental characteristics for the final development. Jefferson County (where our study basin is located) does not have an ordinance of this type. In any case a hillside ordinance would have done little to ameliorate the erosion problem here unless more restrictive design specifications were included which would have altered the road and trail network thus providing structural drainage facilities such as storm sewers, paved roads, and curb and gutter installation. These facilities were not constructed in the basin. The problem was not only the construction but the legacy of that construction: increased runoff velocities and volumes downslope onto vulnerable land features (e.g., dirt roads, trails, home sites).

The demographic character of the Denver Metropolitan area is a significant factor in our system. It is widely recognized that suburban growth is far outstripping central city growth throughout the country. Denver is no exception. The Denver SMSA increased in population between 1970 and 1980 by 32.0 percent while the central city of Denver *decreased* by 4.4 percent. In this same period Jefferson County increased in population by 59.5 percent. Close to 10 percent of this population is in the rural areas of the county. Since there are virtually no farmlands in Jefferson County, most of this rural population is exurban households who commute to Denver or other areas in the SMSA for employment. Therefore, a considerable amount of land is brought into development in 2 to 4 hectare plots in areas similar to the study basin.

According to Berry [18],

> . . . the time-eliminating properties of long distance communication and space-spanning capacities of new communication technologies are combining to concoct a solvent which has dissolved the agglomeration advantages of the industrial metropolis, creating what some refer to as an urban civilization without cities.

The demand for land in suburbs and exurbs is increasing and will continue to increase. In economic terms this makes land in the rural areas of Jefferson County a scarce resource. Most of the land in the mountains of Jefferson County is part of the Pike National Forest which reduces even more the available private land for development. With the increase in demand for land comes the requisite change in land-use patterns which in turn affects the physical resistance of soil to erosion. As seen above, Brown et al. elaborate on changes in soils during changes in land-use [4]. The suburbanization of these mountain areas dramatically affects the vegetation cover (e.g., excavation for homesites, utility corridors, and roads) of the land consequently exerting maximum impact on erosion and deposition.

In our particular case study, the external factors in Figure 1 are intertwined with the socio-economic system such that these specific outside factors are difficult to assess. Obviously improved real income, transportation, and communication are not totally locally determined. The external factors are inextricably linked to the local area, and therefore, an attempt to separate these from the local socio-economic system is not attempted.

CONCLUSIONS

Messerli's systems diagram (Figure 1) [8], together with Blaikie's components of a conservation policy [10], make a sound, general framework for analyzing soil erosion characteristics in any given area. It is a suitable avenue of analysis for use in very disparate regions such as relatively poor third world countries and the affluent exurbs of North American cities. The powerful combined influences of the natural system and the socio-economic system on soil erosion (as an example of environmental degradation) make it imperative for researchers to use both systems if any reasonable hope can be garnered for solution of difficult environmental problems.

Our case study looked at a small, rather isolated, example of soil erosion in an exurban drainage basin in the mountain West. Erosion was shown to be dramatically affected by the two systems interacting. No final solutions are forthcoming from this study yet the mere analysis of what the soil erosion problem entails is a significant step in the recognition and/or solution of the problem. No technological fix will eradicate erosion in this basin without concurrent cultural, political, and economic commitments to soil erosion control.

The holistic analysis applied in this article reveals the complexity of the soil erosion problem at a small scale. However, if we were to extrapolate this to large areas of erosion (e.g., Nepal) and places where erosion is a legitimate life-threatening matter (e.g., Sahelian Africa), these same analytical techniques would apply. It should become the accepted norm that all inputs to a system where humanity and nature interact be studied to determine the effects any one action or set of actions will have on the system as a whole.

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