No shovel needed: a theoretical approach to determining the sensitivity of the PECOS Project study area

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Abstract: These are the musings of a novice process geomorphologist who delved headfirst into the world of theoretical geomorphology in order to carry out the necessary research and writing of "The Thesis". Personal experiences and tribulations are related, including the difficulties of "Believing is Seeing" and the important mantra of "Time, Space, Space-Time, Scale". Finally Sensitivity is defined and the idea of "Resistance verses Disturbance" is revealed.

Introduction

Geomorphologists are generally thought to be the adventurous sort when it comes to research. What geomorphologist worth their salt would not gladly pack up the truck and run off to do fieldwork? During their ever so mandatory fieldwork investigations, geomorphologists are obsessed with the observation and measurement of landforms and processes, with detailed analysis and interpretation of the collected data occurring afterwards for months on end. This interest in "getting out there" extends to fledgling geomorphology students, who lace up their hiking boots and cram into vans full of equipment and baggage to venture forth on field trips. It can be argued that fieldwork (and by extension field trips) are both necessary and enjoyable pursuits for geomorphologists. Somehow it just isn't geomorphology unless you romp about and get your boots muddy.

With the quantitative revolution in science occurring during the latter half of the 20th century, geomorphology has taken to the collection of thorough numeric data of landform and process variables, resulting in a lot of number crunching to obtain results. Since it is important that geomophologists accumulate as much accurate and precise data from the piece of land they are studying, the focus usually ends up being very localized and quite specific over a brief period of time. It is a matter of practicality; it is hard to measure and analyze too many variables like slope angles, soil horizon depths, grain size compositions, pH levels, fluvial sediment loads, vegetation density, precipitation amounts, etc., etc., for a large area over a long time period.

With the intense focus on data collection, most budding geomorphologists learn all about the techniques of geomorphology, such as using field equipment correctly and the proper gathering and processing of samples. The analysis and interpretation of data that follows is often in quantifiable results; for example, the average slope angle is whatever degrees, the average rate of erosion is this per year, the deviation is this much, etc. It seems that data and results are somehow not valid unless there's a number attached to it. Woe be it the geomorphologist who needs to use theory and ideas to solve a problem at hand, and are sorely lacking in the philosophical and methodological tools needed.

What? I Don't Need a Shovel?

The scenario of a novice process geomorphologist running headfirst into a theoretically based topic, and getting horribly confused as a result, became reality for the author with a beastly thesis dealing with determining the sensitivity of the geomorphic systems within the PECOS project study area. In the process of investigating and researching a solution to this thesis problem, a number of very "alarming" issues (alarming in the sense they were issues that seemed difficult, if not impossible, to overcome) kept cropping up. Little did I know that the major problem was not the thesis, per se, but the investigator; I was looking at it all wrong...

The first “alarming” aspect of the thesis was the fact the study area chosen by the PECOS (Prarie Ecosystem Study) people was a very large, very geomorphologically diverse area in south western Saskatchewan (Appendix 1). The second “alarming” aspect was that it was expected that the entire study area was to be investigated, with no exceptions. The third “alarming” aspect was that I personally did not know what exactly sensitivity was! The root cause of all this anguish was a personal lack of understanding of the theoretical background and strategy needed to approach the problem.

The thesis was not going to be completed through the “normal” route of gathering data of specific physical/process variables from sample points during fieldwork and then the statistical analysis to obtain results. Instead, the thesis research was going to be conducted by following spatial and conceptual paradigms that see landscapes holistically over long time spans and large areas. The reasoning behind this was that since the study area was very large, strategically its size should be used to our advantage. The variables to be examined must not be specific at all, and in fact all the variables and possibilities should be very basic, whittled down to the lowest common denominator (the forthcoming mantra is a good example).

Very simple questioning form the basis of the research, and should start with: “what is this place like?” and “what is going on?”, and ultimately ending with “why is this place the way it is?”. Ideally the focus should NOT be on the actual gathering of data (although it is “fun” during fieldwork), but the interpretation of data; what does it all mean? The first conflicting encounter with this change in approach (and a very annoying and alarming experience) was a visit the study area in order to conduct fieldwork and data gathering, without a shovel in sight...

The Mantra of “Space, Time, Space-Time, Scale”

Going off on a philosophical tangent here, my main problem was that my idea of what geomorphology was supposed to be was all wrong for this thesis. I was still thinking like a process geomorphologist, so my view of things was too narrow and too technical, so as “advice” my supervisor suggested I chant this mantra to “broaden my horizons:”

“Space, Time, Space-Time, Scale.”

“It is the key to your thesis” he said. Oh yah, right, thanks Dave. But believe it or not, it has helped in keeping my focus on the essential basics of geomorphology. It is all about understanding the true nature of Space, Time and Scale. The rest is superfluous. So all of the information (data, ideas, paradigms, etc.) gathered about the PECOS study area must fit into at least one of mantra categories, and must be seen from this context.

Getting back to more tangible issues, the most difficult mantra concept to grasp was the idea of Scale. While understanding Space and Time (and Space-Time) can be thought of as making thorough investigations and inventories as to What, How and Why a place is like it is, Scale is more abstract. Scale includes both Space and Time, together and separately, plus the factors of size, resolution and complexity. Scale deals with the quality and quantity of available information and variables. Unfortunately for me, Scale is a very important issue since at different scales the same geomorphic system could have different sensitivities because of the changes in its important dependant and independent variables.

Believing is Seeing

Although having said that the research for this thesis would be theoretical and for the most part qualitative and interpretive, I was certainly not going to be an armchair geomorphologist. The call of fieldwork was so overwhelming that I ventured forth to visit the study area, not quite sure what to do once I got there. When I did get there, armed with only a notebook, pen, camera and maps of all sorts, the advice that I received from my advisor certainly struck terror into my heart. After a few sentences, I realized the gist of his speech: go out and OBSERVE. Observe?? Observe what? What

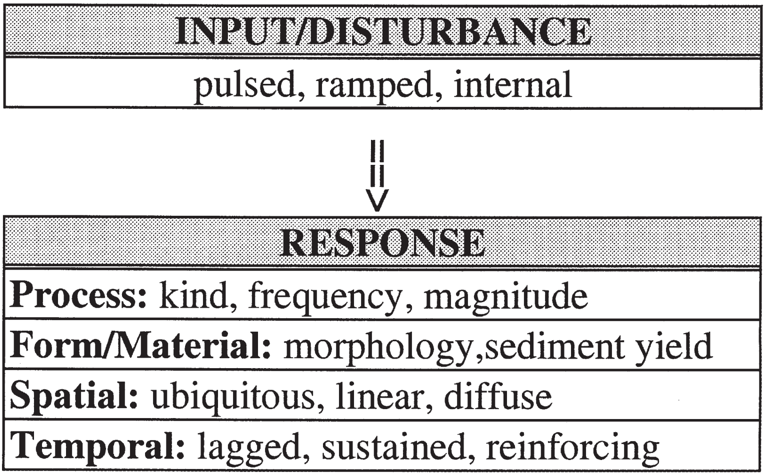

Figure 1: *Conceptual framework of geomorphic responses to climatic inputs and internal disturbances (Brunsden and Thornes 1979, from Sauchyn 1993).*

am I supposed to be looking for? Should I be seeing something important out there?

The cause of my distress was the fact that I was not well versed in the skill of interpretation of geomorphic observations. It's not exactly something you learn in school. So while I could plainly see landforms and process phenomena occurring everywhere, I realized that my task was beyond just looking around. I was supposed to critically interpret what I was seeing. So, what was I supposed to be looking for? What should I see? Moreover, what did I have to believe and understand in order to see it? It's true what they say: "Knowledge is power!"

Sensitivity Explained!

Since the thesis topic was about determining the Sensitivity of the PECOS study area, it was safe to assume that during my "fieldwork" I was supposed to be looking for "sensitivity clues" out in the landscape. Landscape sensitivity describes the nature of landscape response across time and space. It is expressed "as the likelihood that a given change in the controls of a system will produce a sensible, recognizable and persistent response" (Brunsden and Thornes 1979). So, I was supposed to be looking out for "landscape response", but what exactly is THAT supposed to be?

Brunsden and Thornes' (1979) conceptual framework for the study of responses to inputs and internal thresholds outlined the different categories of both inputs and "response" (Figure 1 from Sauchyn 1993). It should be noted that response is both a spatial and temporal phenomena. An expanded explanation of both inputs and responses is seen in Table 1.

Table 1: *Details of Brunsden and Thornes' (1979) conceptual framework of inputs and reponses.*

INPUT/DISTURBANCE	
Pulsed:	external; extreme episodic event; "brief"
Ramped:	external; changes sustained at new level
Internal:	exceeding threshold limits, transitional
RESPONSE	
Process:	
kind-	change/shift in dominant type
frequency-	timing of occurrences
magnitude-	"force" or "strength" of event
Form/Material:	
morphology-	the actual "shape"
sediment yield-	measurable level of process "effectiveness"
Spatial:	
ubiquitous-	everywhere! widely distributed response
linear-	along sensitive erosional axes eg.rivers
diffuse-	waves of aggression away from linear axes
Temporal:	
lagged-	negative feedback; restored to previous state
sustained-	adjustment to a new level/characteristic state
reinforcing-	positive feedback; initiation of change

$$\frac{\text{Barriers to Change (RESISTANCE)}}{\text{Energy for Change (DISTURBANCE)}}$$

The three possible outcomes are:

<1	unstable, since disturbance is greater
=1	meta-stable, since both are equal
>1	stable, since resistance is greater

Figure 2: *Landscape change safety factor (from Brunsden and Thornes 1979 and Brunsden 1993).*

It quickly became obvious to me in the field that response (and therefore Sensitivity) is definitely not consistent over Space, or through Time for that matter. The reasons for this are because the variables are not the same everywhere you go. Different responses occur due to variations in the spatial and temporal distribution of the incoming “disturbing” forces and the “resisting” forces present in the landscape (Brunsden and Thornes 1979). So how do you “rate” or determine what an area’s Sensitivity is?

Resistance Versus Disturbance

As the sensitivity definition states, landscape response is triggered by a change in the controls of the “system”, and in this case it would be a geomorphic system. A geomorphic system is comprised of both landforms and processes and the interactions occuring between them. One approach to understanding and assessing the sensitivity of an area is to use a ratio of the resisting and disturbing forces that are present within geomorphic systems. This ratio, which is called a “landscape change safety factor” (Brunsden 1993), is the ratio of the mean magnitude of barriers to change versus the mean magnitudes of the disturbing forces (Figure 2).

The application of this ratio will result in a continuum where at one end there are “stable” landscapes (>1) where the controlling

Table 2: *Categories of resistance (Brunsden 1993).*

BARRIERS TO CHANGE
Strength resistance properties of the rock/surficial materials
Morphological resistance shape of things: slope, relief, elevation; level of avaliable potential energy
Structural resistance design of the geomorphic system: locational resistance, proximity to processes; transmission resistance, ability to transmit impulse of change; coupling configurations, relationship between system components and process domains
Filter resistance how kinetic energy is transmitted: absorption by dissipation; utilization by adjustment of form; deflection by armouring; filtering across sub-system boundaries; diffusion across space
System-state resistance uniqueness of history, predisposition along the path of time

resistances are such that they either 1) prevent a disturbance from having any noticeable effect (a very "resistant" landscape) or 2) arranged as to restore the system to its previous state (negative feedback; lagged response). At the other end are "unstable" landscapes where the disturbance is stronger than the resistance (>1), and there is either reinforcing response (positive feedback) or a transitional adjustment to a new level of input (sustained response) (Brunsden 1993). In the middle are "meta stable" landscapes that appear to be stable but are near a threshold (=1) and therefore have a higher propensity to become an unstable area.

Brunsden (1993) categorized and listed five types of resistance present in the landscape (Table 2). It was while reading this excellent paper that my advisor asked "Could you recognize resistance in the landscape if you had to?". It was not a hypothetical question since it is vital that resistance is identified in the landscape. So not only was I looking for "response" in the PECOS area, I was also looking for, and had to believe in, "resistance".

Final Musings

To further my "burden", I realized that resistance, response and ultimately sensitivity could be seen and interpreted not only during fieldwork, but also through the study of variables expressed in maps, air photos, remotely sensed images, etc. It is a question of knowing what you should be looking for and what it all means. Hopefully, there will be a sequel to this paper that lists the findings of this (successful?) approach.

References

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Appendix 1: The Beast which is PECOS

The Prairie Ecosystem Study (PECOS) was a multidisciplinary research project supported by the Eco-research Program of Environment Canada's Green Plan. Originally named "Sustainability of the Semi-arid Prairie Ecosystem", the overall objective of the project was "to evaluate the sustainability of the semi-arid prairie ecosystem in terms of the health of the land and the well being of the people and their communities, and to explore the prospects for a way of life that does not jeopardize these."

Agricultural Region 3B-N (as defined by the 1993 Agricultural Census of Canada) was chosen to be the PECOS project study area because it is characterized by a dry climate, contains a representative range of land use and communities and has a wide variety of landforms and soil types. However, from an earth science perspective, 3B-N is a rather inconvenient study area because it is a purely political entity with arbitrary borders (Figure A1). The study area does not restrict itself to areas with similar physical characteristics or common drainage basins, and does not conform to the Canadian NTS map sheet system. As a result, different physiographic, geomorphic and soil areas are represented within the PPSA as segments severed from the whole, and parts of five NTS map sheets (72-F, J, K, N and O) are needed to cover the entire study area. The PPSA is an agglomeration of several different geographic/ geomorphic areas (Figure A2). The total area of the PECOS study area is over 15,500 square kilometres.

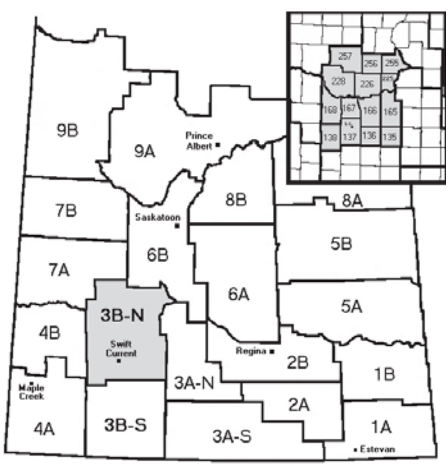

Figure A1: *Location of Agricultural Region 3B-N.*

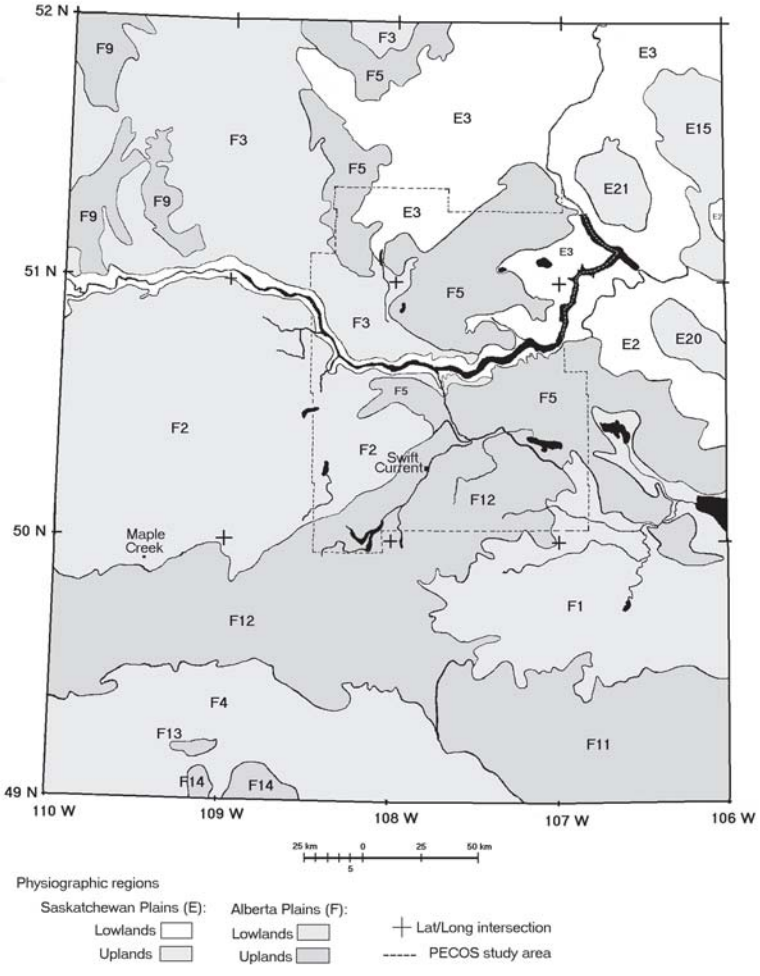

Figure A2: *Physiographic areas of Agricultural Region 3B-N.*