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Some comments on research design in field process studies

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Some comments on research design in field process studies

Abstract

This paper outlines some problems of research and experimental design commonly encountered by those undertaking process studies in environmental science. Some general guidelines for determining appropriate data collection strategies in field process studies are suggested. Special reference is made to research design for post-graduate projects.

1. Introduction

Good research design is the key to success in field studies. It ensures that data are collected both efficiently, without waste of effort, and in a form that can be used, without constraint, in subsequent analysis. The first step in research design is to consider the purpose of a study. It is useful, therefore, to begin this paper with a review of the purposes of three common 'types' of process study. These are; (i) the 'magic number' type, (ii) the 'SPSS' type and (iii) the 'scientific' type.

(i) Magic Number type.

In the magic number type of study the making of the field measurement is the only purpose of the study. This type of project requires that the accuracy of measurement is high and that confidence limits for measured values can be defined. The greatest problem with this type of study is that in the natural field setting experimental control can only rarely be achieved. That is, field studies tend to be <u>observational</u> rather than <u>experimental</u> and as such require the use of some sampling design to provide estimates of spatial or temporal variability in process and site parameters. The problems of sampling design in field studies are considered in section 2.

Whilst 'magic number' measurement studies require the least understanding (on the part of the researcher) of the process(es) being recorded, they are a very difficult type of study to satisfactorily complete. This is because the sample size required to quantify the temporal/spatial variability of the measured process(es) is extremely large. It is usually the case that field work over a short period (e.g as part of a 3 year PhD study) by a single researcher generates too small a data base for reliable estimates of such variability to be made. It follows that PhD students should not attempt 'observational' magic number studies (although 'experimental' studies of this type can be completed in PhD time).

(ii) SPSS (Several Probably Spurious Statistics) type.

In the SPSS type of study the purpose of the study is to use the field data to establish relationships between processes and environmental parameters. As with the 'magic number' type field work is usually observational and once more the problem of obtaining a representative sample is of paramount importance, although in this case it is compounded by the additional assumptions about the data set implicit in the statistical method being used. The most common method of 'analysis' used in this type of study is linear regression. Errors in the estimation of the true population mean and variance using sample data will affect both coefficients and exponents in regression relationships.

The SPSS type of study is a poor research design which frequently leads to abuse of a data set. First the purpose of the study is not specifically defined. Second, embodied in the research design, there is an inherent lack of scientific method. That is, data are collected with the intention of establishing hypotheses rather than to test them. Without a hypothesis developed from theory or previous knowledge it is not possible to <u>objectively</u> determine which variables should be measured in the field or included in subsequent regression analysis. Thirdly the assumptions (about the data set) of the statistical methods being used may be difficult to test (and are frequently ignored). Finally, the existence of some relationship between two variables does not necessarily indicate a causal link between them. All too frequently correlation and causality are confused in the inferences drawn from the results of SPSS studies.

(iii) <u>Scientific type.</u>

The purpose of the scientific type of study is usually either:

(i) Test a conceptual model/theory in general terms.

or (ii) Collect data with which to calibrate a simulation model

or (iii) Validate a simulation model developed using a previous data set.

Problems of field data collection and analysis for this type of study are the same as for the SPSS type of study with one important difference. In this case, the purpose of the study will define the variables and relationships examined and the theory/model tested defines the form of relationship that is expected. Even if the expected result is not found, interpretations of residual errors can have great value for generating new hypotheses/models. Alternatively, where poor agreement between model and data exists, but the model is known to be valid, comparison of observed and predicted values can serve to demonstrate the scale and trend of process variability in the natural setting. An additional advantage of using field data to test hypotheses is that appropriate statistical methods can be selected for the type of data that it is possible to obtain. Where data are in nominal, ordinal or ratio form or where the 'quality' of interval data are low, non-parametric statistical methods can be used.

2. Some guidelines for research design in process studies

The discussion above shows that only the 'scientific' and 'magic number' (where estimates of temporal and spatial variability are given) are worthwhile types of study. For post-graduate studies, if the success of a project is measured in terms of the repeatability of the results obtained, it would seem that only the scientific type of study can be 'successfully' completed by a research student in 'PhD time' (excluding results obtained from 'experimental' projects). Why then is it that so many projects fail to even test conceptual models and hypotheses and instead end up as a jumbled assortment of magic numbers and

SPSS results?. The answer to this question appears to be that the purpose of the study is imprecisely defined by the researcher. All too often a research student in environmental science might summarize the purpose of his/her study as:

(1) to get a PhD.

(2) to make a contribution to knowledge of the ecological/hydrological/geomorphological/development/functioning/history/processes/quality* of x and its relationship to environmental factors/parameters*.

* delete as appropriate

These apparently specific aims fail to answer the crucial question :

How is the contribution, using field data, to be made?

The answer to this question is to use the field data collected to test hypotheses and models. It is clear, however, that some students answer this question too simply. An answer of; "Obtain and analyse field data" is not sufficient. Such an answer fails to provide any guidance for the project's experimental design and , in the case of geomorphology, leads directly to the all too familiar sequence of experimental design follies shown in table 1.

As can be seen from the left hand side of table 1 follies are avoided when the hypothesis to be tested is used as the starting point for research design. The following sections briefly discuss the steps of research and sampling design shown in the table.

2.1 Selecting an approach to field data collection

The first step of research design shown in the table concerns choosing the source of field data. Over the last 20 years or so working in instrumented catchments has become the standard approach to the study of geomorphological and hydrological processes . This approach has been termed the unit source watershed approach (Amerman 1965). The approach, however, gives an incomplete picture of the range, or mosaic, of process interaction and interference in an environmental system. The problems encountered in employing small catchment studies as the basis for theory or model construction have beeen reviewed in detail by Ward (1971). The greatest problem in most cases concerns the interpretation of results obtained over a short period without knowledge of the magnitude and frequency of all process activities in the catchment system.

In choosing a source for field data it should be remembered that the approach that is appropriate for any study is determined by the purpose of that study. Some examples of appropriate data sources for studies with various purposes are shown in table 2.

2.2 Choice of variables to measure

The second design question shown in table 1 concerns the selection of the variables to be measured in the field. Clearly, even if only a conceptual model is used as a guide, the variables relevant to the testing and/or validation of the hypothesis are immediately defined.

2.3 Choice of measurement techniques.

A more difficult series of design questions concerns the techniques which should be employed by the researcher to measure and record the processes being studied. An appropriate measurement technique is defined as one which can be performed often enough and in a sufficient number of sites to yield the information required given the purpose of the study. Two seperate problems to be considered are: (i) the frequency and (ii) the density of measurements.

2.4 Choice of sampling frequency.

The optimum sampling frequency for a field study can be defined as the minimum number of measurements that need be made to fulfill the purpose of the study. This optimum sampling or measurement frequency should be determined from the characteristics of the process being recorded.

Most natural 'hydrogeomorphic' processes are triggered by discrete rainstorm events and their effects pass through a landscape or landform in a manner that may be conceptualized as a kinematic wave . At any point on the land surface the level of process intensity will be observed to change as a wave pulse, the shape of the pulse changing as it moves through the landform. The sampling frequency required to record the occurrence, shape and volume of the wave depends on both its size and symmetry.

To record a wave's shape a sampling frequency must be used that is considerably less than its wavelength (the process's response time). The response wavelength of many processes is related to the duration of storm rainfall and runoff. For example, stream runoff hydrographs typically have wavelengths that vary from a few hours for flows generated as Hortonian overland flow to several tens of hours where drainage is delivered to channels by saturated throughflow.

The symmetry of the wave is another factor which will determine the frequency of observations required to record the wave's shape. As a wave becomes less symmetrical the number of observations required to describe its shape increases. If the wave is almost symmetrical around its maximum or minimum value (e.g a sine wave form) then a sampling interval between, say, 1/5 and 1/10 of the wave length would be sufficient to describe its shape. If the wave is assymmetric or skewed (e.g like an urban hydrograph) then a much larger ratio of sampling frequency to wavelength will be required. It must always be ensured that sufficient data points are obtained to record the height and timing of the wave peak. To record the shape of a wave a sampling frequency must, therefore, be determined from the excitation time (i.e time to peak) rather than the response time of the process.

A final factor that may determine the sampling frequency adopted in a field study is the relationship between process signal and background noise levels. As the noise disturbance included in a monitored process signal increases in magnitude, the task of recording the wave shape accurately becomes increasingly difficult. When the process wave amplitude to noise ratio approaches 2:1 continuous monitoring is required to do more then merely detect the passage of a wave.

2.5 Sampling density.

The density of measurements at a study site is determined by the number and layout of the sampling points.

(i) Determination of sample size.

Any sample is intended to be representative of the population from which it is drawn. The sample size required for a study is, therefore, dependent upon the distribution characteristics of that population. In environmental studies these characterisitics are usually unknown and should, ideally, be estimated from a pilot sample. Such is the degree of variability in natural environments, however, that even the size of pilot sample required is often beyond the capability of a single researcher making measurements over a short period.

One possible solution to the problem of sample size determination for field studies in environmental science suggested by McCaig (1981) is simply to take the largest sample possible. This solution assumes that the variability of variables being measured is so great that a degree of 'undersampling' will occur no matter how large the sample taken. This crude approach to the problem seems reasonable since sampling theory shows that it is sample size, rather than sample fraction, which determines the precision of the sample mean as a estimate of the population mean. (See Stuart, 1962, p.30-32)

(ii) Determination of layout (sampling pattern)

A researcher will locate his/her measurement stations within or between study sites with the intention of ensuring that a representative range of locations/environments is sampled. As has been pointed out in the previous section, in natural field sites environment and process parameters are so variable that no matter how many samples are taken they are too few . This suggests that a simple random distribution of a limited number of measurement stations will fail to produce the representative sample required.

A standard approach to sampling from highly variable populations is through the use of a stratified random sample. The basic principles of stratified sampling are to maximize differences between strata means and to minimize within strata variance (Stuart, 1962). The distribution of numbers of measurement stations between strata should reflect the expected (intuitively assessed) variability within each stratum. In general, those strata expected to have the greatest variance, or range, in measured values should be allocated the greatest number of sampling sites. In geomorphological studies one might for instance identify strata groupings on the basis of site type e.g spur, hollow and straight slope segments.

2.6 Summary.

The steps of experimental design discussed in the preceding sections demonstrate that all aspects of a design can , at least in part, be objectively determined from consideration of the hypothesis to be tested by the data and knowledge of relevant process es.

3. Comment.

Obtaining field data for studies of processes in the natural environment is undoubtedly hard work. It is important, therefore, that all this effort should not be wasted by either collecting the wrong data or using the right data in the wrong way. The key to successful field work is to have a clear idea of the purpose for which the data are being collected i.e what its final use is to be. Successful research design also requires that the researcher has a clear, at least conceptual, model of the process mechanism/relationships that are the subject of the study.

Special attention has been given in this discusssion to the types of process study that are appropriate for post-graduate research. Given the constraints of manpower , money and equipment for PhD studentships in British Universities, it would seem advisable for students to undertake only what have been termed here 'scientific' types of study. Accuracy in measurement and ratio studies requires data sets that are both larger and longer than can usually be collected by a single worker in two or three field seasons. This is not to question the validity of measurement studies. Highly accurate and comprehensive data sets are essential if predictive process models of use in environmental management are to be ultimately developed. The provision of these data sets should, however, be the responsiblity of organisations with the manpower and resources to do the job properly, over a long period.

A type of study that should be avoided is the SPSS type. The prevalence of this type of study in environmental science shows how far disciplines such as geomorphology are from becoming respectable sciences. The only possible value in SPSS studies is that they generate more questions than they answer and so provide stimuli for hypotheses and models.

In the of light experience, the steps of project and experimental design described in the preceeding sections seem extremely obvious. It is possibly because they are so obvious to persons with research experience that nowhere (to the author's knowledge) are they formally written down. Perhaps though, the omission in the published literature of this guidance is just another demonstration of the lack of scientific rigour in environmental science.

Isn't it about time we all pulled our socks up and stopped playing at being scientists ?

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TABLE 1. SOLUTIONS AND FOLLIES IN RESEARCH DESIGN

INITIAL HYPOTHESIS FORMS BASIS OF RESEARCH DESIGN		RESEARCH DESIGN QUESTION	NO INITIAL HYPOTHESIS ESTABLISHED AT RESEARCH DESIGN STAGE	
OPTIONS	SUPPLEMENTARY QUESTION		'FOLLY' ANSWER	REASON '?'
a) instrumented catchment b) plot study c) multi-site	Is general or site specific data required to test hypothesis?	Where do I get my data from?	Instrumented catchment	The department already has one
Variable list defined by hypothesis/model		What do I measure?	Don't know until I have some data, so I'll measure everything for a while	Doesn't every-body do this? (std. method?)
a) single/multi site manual methods b) single/multi site pseudo-continuous recording c) single/multi site continuous recording etc.	What spatial/temporal resolution of data is required to test hypothesis/model?	What techniques do I use to make measurements?	Use latest auto/turbi/scani/tensi system described in BGRG technical bulletins	The designs are published and it seems popular (forms basis of 23 articles by T.Dick and H.Arry).

TABLE 2 APPROPRIATE DATA SOURCES FOR PROCESS STUDIES WITH DIFFERENT PURPOSES

Purpose of study is to determine:	Appropriate Data Source
1) Validity of models and process mechanisms	a) Plot b) Instrumented Catchment.
2) Patterns of process/landform interaction as predicted by a theory or model	a) Landform Unit b) Instrumented Catchment
3) Differences in process rates/ occurrence due to physical or topographic variables	Twinned or nested study sites (plot, landform or catchment)
4) General models of form/process relationships	Multi-site