A New Approach For Landscape Mapping

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Abstract. A new approach for describing the morphological character of a continuous landsurface is introduced. This new approach uses recent geocomputation advances as a fillip for reassessing geomorphological theory. During this paper three important components of the new approach that distinguish it from most pre-existing mapping frameworks are outlined. Firstly, the new spatial information application considers a landscape to be inherently complex, and so intends to describe diversity as well as to generalise. For this purpose the new spatial information application uses an information database approach, with multiple layers, filtering from raw analyses through to synthetic interpretations. This contrasts with approaches that only produce a single static classification map. Secondly, several geomorphic domains are considered, both separately and then in combination, to provide an overall landscape description. These domains are: the general shape of each location across a landscape, the attributes of each location in relation to relevant geomorphic processes, and the properties of each location in relation to its catchment position. The use of these three domains contrasts with frameworks that only consider general shape in a simplistic manner. Finally, for describing broad-scale morphology the new approach uses digital morphological data, made available through developments such as DEMs. This contrasts with frameworks that use surrogate information sources, such as photographic imagery, to deal with large mapping areas. The principle of using digital morphological data reflects the aim of the new application: to be a rigorous framework for the creation of physically meaningful landscape descriptions.

1. INTRODUCTION

I think that the surface of the Earth (Figure 1) is interesting. Apart from being so inextricably linked to the narrative of humanity, the landsurface is interesting because if you look at it, it has a tendency to be organised, structured, and yet at the same time it is chaotic, often intricately so. In this paper I hope to answer the following question: what is a good way to describe and in particular map the Earth's landsurface. This is the bottom line: should landscape descriptions treat the landsurface as a mosaic of discrete, internally consistent units? Or should they treat it as a complex entity, with a mixture of chaotic and organised characteristics?

Some people treat the landsurface as a mosaic of discrete units. They even reify this conceptual approach, actually believing that landscapes are made up of homogenous landsurface tiles. There has been a major landscape mapping style since the 1930's (with roots from philosophies before that I believe) that supports this mosaic suggestion. After admitting that: "it is not universally accepted … that … homogenous land areas are either consistently identifiable entities, or reliable indicators", J.G. Speight goes on to pledge his allegiance to the mosaic suggestion in the 1998 Guidelines for Conducting Surveys.

In contrast, I will argue strongly with as much detail as possible, that the second, complexity suggestion is correct. Landscapes are best expressed not as patchworks but as being organised, into catchments with dominant process zones; and underlying that is complexity. The organisation that I am talking about is geomorphology.

Figure 1: Is the surface of the earth a mosaic of discrete, internally consistent units, or is it a complex entity, with a mixture of chaotic and organised characteristics?

In this paper I will not be showing you the results of scientific studies exploring significance of one or other technique. I hope that I will do something more important than that. I will argue a philosophy for looking at and thinking about landscapes that I believe is good sense. What I will argue is that previous methodologies: classify and generalise, using surrogate data sources to produce a single information layer, treating landscapes simplistically, whereas my methodology uses a rigorous flow chart, filtering information to produce multiple information layers, uses topographic data itself, and treats landscapes as complex entities.

1.1 Background

Let me clarify what I mean by "landscape". For the purposes of this research I have defined landscape as: "the configuration of the continuous landsurface". In other words, I am talking about the arrangement of the land surface extended over many landforms.

Let me reiterate why an understanding of landscape is important. The landscape is a key influence in natural and human environments, because it is the template on which a wide range of biophysical and social processes act and interact (Brierley and Fryirs, 1997). Also, it is conducive to wide-scale and in-depth data coverage. Combine these characteristics, and we have a potentially powerful information source.

So how has wide-scale and in-depth topographic information been produced? To tell you the truth, the action of getting regional topographic information has been very challenging. By definition, the area covered is bigger than a single view from your back verandah. Topographic data such as contour maps were available, but the combination of the fine amount of detail with the large areas dealt with provided for, especially in the absence of computers, a very large amount of work. The other option was to cheat.

1.2 Previous Mapping Frameworks

The development of human flight at the beginning of the 20th Century, coupled with the development of photography, paved the way for systematic landscape mapping. One of the founders of landscape mapping, or photomorphic mapping as it was also labeled, RL Bourne, suggested in 1931 that landscapes could be divided into discrete, homogenous units, or ones that could be "seen to be so", whatever that means. Thus we have the break up of a landscape by delineating units. This could be done by: expert based observation, thus "are seen to be so"; or by more mathematical interrogation of the homogeneity of some attributes, or perhaps a combination of the two.

Table 1: A representative flow chart of traditional approaches to mapping landscapes

Step	Description
1. Unit Delineation	Subjective and/or Arbitrary
2. Identification of Units	Subjective and/or Arbitrary, or Unique

CS Christian of CSIRO supported this by writing in 1952 that landscapes *must be idealised* for mapping purposes. Identification of units labeled them as homogenous either by shoe-horning them into a category arbitrarily (with maths and stats) or subjectively (just because!), or by giving them a unique identifier like "Parramatta Downs". A representative flow chart of traditional approaches to mapping landscapes in held in Table 1.

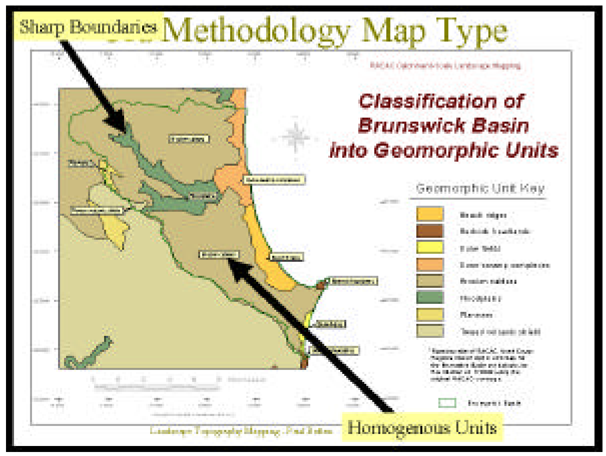

Figure 2: An example result of a recent landscape mapping effort of the Brunswick Catchment

Figure 2 is an example map of a recent landscape mapping effort of the Brunswick Catchment. I am using it as a representative of most previous methodologies. It uses the double crisp, single map methodology. Table 2 explains this "double-crisp conceptual model" that the old methodology uses.

The first crisp aspect is its boundaries. It interprets sharp boundaries, and does not distinguish between real and interpreted boundaries. In the words of Burrough and McDonnell (1998), classification, and in particular sharp classification boundaries are "a scientifically inadequate paradigm for treating natural phenomena". Real boundaries, however, can be sharp, gradational or diffuse.

The second crisp aspect is its group membership. It employs a boolean or nested mode of group membership, where entities can only belong to one group, or super-group. Many, perhaps most, landscape relationships do not behave in this way. They often overlap, sometimes coincide but then overlap again, sometimes disappear, sometimes reappear at a different scale. DA Grigg, writing in

1967, observed that "it strains credulity to believe that all the properties of the earth's surface that geographers contend make up the totality of the environment should spatially co-vary exactly". Hence, whilst there may be many areas which are distinctive enough to be called geographical regions, there must be areas which have no particular character, and can be assigned to no particular region." What Grigg means is that pigeon-holing is not straight-forward, and may lead to information corruption. To summarise: The landscape is complex.

Table 2: A representative flow chart of traditional approaches to mapping landscapes

Crisp Aspect	Description
Boundaries	The old approach only interprets sharp boundaries.
	Real boundaries can be sharp, gradational or diffuse.
Group membership	The old approach employs a Boolean or nested approach
	Landscape relationships often overlap, sometimes coincide but then overlap again, sometimes disappear, sometimes reappear at a different scale.

In general, the old approach produces only one layer, where all of the topographic characteristics of an area are generalized into a single classification unit. This has the potential of oversimplifying the description of landscape topography. To represent this I have sized the map in Figure 3 according to how much information it provides: not much.

Figure 3: Thumbnail of old approach, showing a representation of how much information is provided: not much

1.3 This New Framework

In my work I endeavored to approach landscape mapping in a fundamentally different manner. I have not prescribed a unitary model, in contrast I am suggesting open-mindedness. To this end I have recommended multiple information layers, exploring the many different facets of landscape topography. Directing the information multitude is both an appreciation of organisation and a respect for complexity.

And so if each of the maps from this new methodology produced, for arguments sake, an equivalent amount of information as an old methodology map, then the total amount of information produced by the new methodology (see Figure 4) will be an order of magnitude larger.

Figure 4: Thumbnail of information provided by new approach.

Other points that I should make are: one of the maps within the new methodology is a rough equivalent of the one map provided by an old methodology. I shall talk more about this later in the presentation. Also, I am not suggesting that in every document you are working on you jam twenty-five maps in between the contents and the background. No, what I am suggesting is that land managers have a choice in the information they get, that they can access a tailored and targeted product rather than being force fed a potentially sub-standard landscape description.

2. THE NEW FRAMEWORK IN DETAIL

There are at least three important components of the new methodology that make it significantly different.

First, the information sources are different. I recommend using morphological or topographic data rather than using surrogate data sources. Second, the information formats are different. I recommend having information flow with several types of mapping form, rather than a single, static classification. Finally, the information subjects are different. I recommend looking at several landscape domains, rather than just a landscape's general shape.

The three topic areas just listed are how this paper is structured. The order that I explain them in does not matter, as each constrains and drives the others. For example, subject matter drives what sources a mapper wants and is looking for, and the data sources available in turn constrain what subject matter can be dealt with. Similarly, mapping form is also constrained by subject matter, as the characteristics of what you are describing should influence how you present it, and mapping form is also constrained by data sources, as most data, at least in the first place, has a preferred form of presentation.

2.1 Information sources: surrogate or morphology itself

The first difference between the new methodology and many previous methodologies that I will explain is what input you use in the mapping procedure, the data sources. Remember that the process of getting morphological data has traditionally been very challenging. Thankfully, we now have computers to help us in the mapping process. Please note that I have not said that computers do the mapping for us. On an aside, I think that the idea that computers are a panacea of all our ills is a gross misconception. The label: decision-support system is often misconstrued as a decision-making system. In general, humans make much better decisions than computers. Anyway, back to morphological data.

In the new methodology I am proposing that morphological data itself be used in preference to surrogate information sources. Morphological data has been made available recently through new technological developments such as Digital Elevation Models. Figure 5 shows four variations on the DEM theme: contours, triangulated irregular networks, grid DEM, and an irregular contour based model. These new technologies have meant that the broad-scale description of morphology can now be carried out efficiently and effectively.

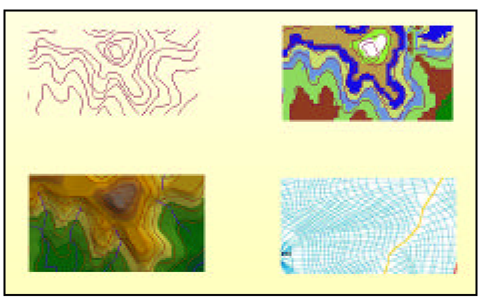

Figure 5: Data sources for morphology: contours (top left), grids or DEM (top right), triangulated irregular network or TIN (bottom left) and irregular contour based model (bottom right).

The principle of using morphological data reflects the aim of the new methodology: to be a rigorous framework for the creation of physically meaningful landscape descriptions. What I mean by this is that the source of the reasoning behind decision making with the landscape description should be accessible to a 3rd party.

Some people might say that this raises the issue of objectivity versus subjectivity. I don't believe so. I argue that yes, objectivity is most often better than subjectivity, but that subjectivity of itself is not inherently bad, avoidable, or undesired. It is only when decisions are poorly justified, which is possible with objective decisions also, that we should be wary. So, as I say, if the source of your decision-making is open and transparent, in particular if it is within the project itself, this is a good thing.

This contrasts with the use of surrogate information sources, such as shadowing in satellite and photographic imagery (as demonstrated by Figure 6), to deal with large mapping areas. This traditional methodology is both slow, overly subjective, and in the most part non-rigorous. And this process has probably been the dominant strategy for landscape mapping of large areas from the 1930's till today.

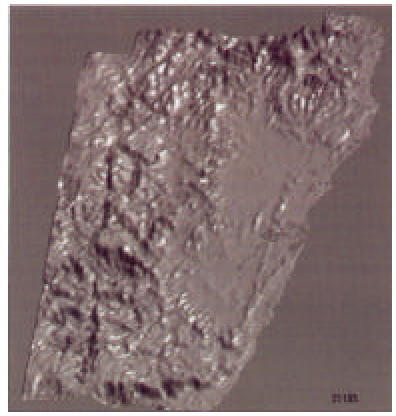

Figure 6: Before wide coverage digital data sources were able to be used, the surrogate information source of shadowing in imagery was used for landscape mapping

The problem with using surrogate information sources, like shadowing, is that there is a significant margin of error introduced in its translation to dealing directly with the arrangement of a landscape. Certainly I would say that in the absence of other more efficient mechanisms, this strategy for mapping could be treated as best-practice. However, as I have mentioned, we <u>do</u> now have better.

If our mapping process is fully or even partially brought into the digital realm, there are a few omni-present mapping issues that take centre stage. Scale and resolution are definitely big issues for mapping.

What I would suggest is that one needs to work out good mapping practice on a case-by-case basis. Factors that should be taken into account are: the quality of data available, the computer power required, and the presentation detail wanted.

This leads to the other end of the mapping process, where what mapping formats and arrangements are worked out.

2.2 Mapping Forms

I suggest that what mapping formats are used in regional landscape description should be worked out on a case-by-case basis also. You will remember that most previous methodologies exclusively use the mapping format of classification. This, I argue, oversimplifies landscapes by suggesting that they are made up of a mosaic of discrete, internally consistent units.

The new methodology, in contrast, highlighting that real landscapes are both complex and organised, aims to describe diversity as well as to generalise. For this purpose the methodology uses multiple information layers, with a framework for filtering from raw analyses through to synthetic interpretations. The purpose of this is to retain the integrity of the data as we create layers with more user input. I will go through this list step by step.

First, instead of jumping straight into a classification, the new methodology starts with quantitative depictions, what I have coined parameterisation. A calculator could be used as an analogy for parameterisation.

For the purposes of this research I have defined 'parameterisation' as quantitative analysis that treats a study area completely. Parameterisation is a conduit between raw data and synthesis, which retains the integrity of landscape attributes, because of its non-complicated arrangement. For example, the digital elevation model in Figure 7 has minimal interpretation in the data.

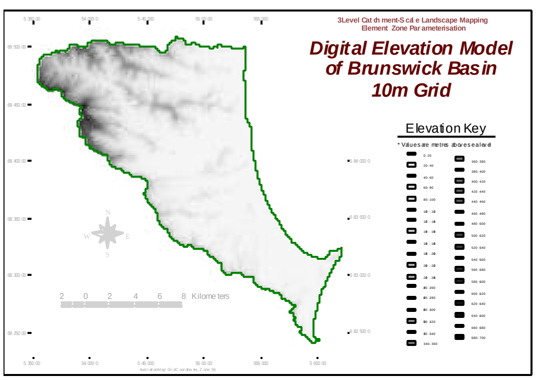

Figure 7: A parameterisation layer of elevation (of the Brunswick Catchment of far north NSW

A few other observations: The parameterisation descriptive mode does not involve considerations of group membership. Data is stored on a continuous scale. This gray-scale presentation here is used only in the presentation, conferring elevation grading. Parameterisation is suitable for the use of GIS and automation.

This quantitative information is then used as input into more subjective mapping, where important features of a landscape are highlighted. I have labeled this characterisation. The drawing of the distinguishing features of a cat could be used as an analogy for characterisation.

Within this methodology, characterisation involves the selective synthesis of information from other pre-existing layers. Characterisation: can deal with features, patterns, and trends, separately or in combination, and is used because of its flexibility in highlighting landscape character.

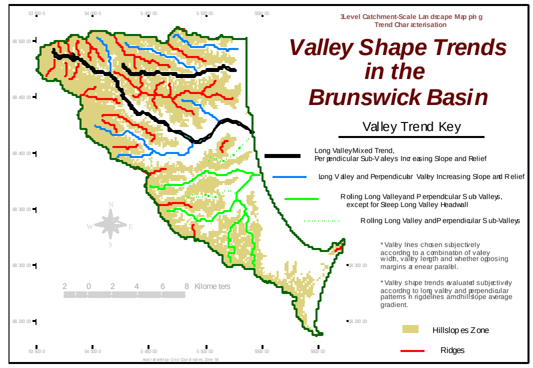

Figure 8: A characterisation layer of valley-shape trend (of the Brunwick Catchment of far north NSW)

For example Figure 8 shows a valley-shape trend characterisation of the Brunswick Catchment. Please note that I have included a justification for my decision-making on the map itself. If this were in a database, that information could be also be stored in meta data. Importantly, observe that characterisation does not describe the whole of the study area. Only the major valleys of the basis are described.

OK, what would one call a characterisation that does deal with the whole of a landscape? I would call this classification. Parameterisation and classification information layers are fed into classifications, where a whole study area is delineated into categorical units. A box can be used as an analogy for classification, as all of the areas in a landscape go into one or more categorical boxes. I might have seemed to be against classification. Well I am certainly against simplistic classification used absolutely. However, the traditional mode of classification can be modified so that it is able to fill a powerful role, especially when it is used in tandem with other layers.

So repeating, for the purposes of this research the difference between classification and characterisation is that classification necessarily treats the whole of a landscape. Such a landscape map can be a powerful descriptive tool, because it has the potential to convey the diversity in a catchment through a single layer.

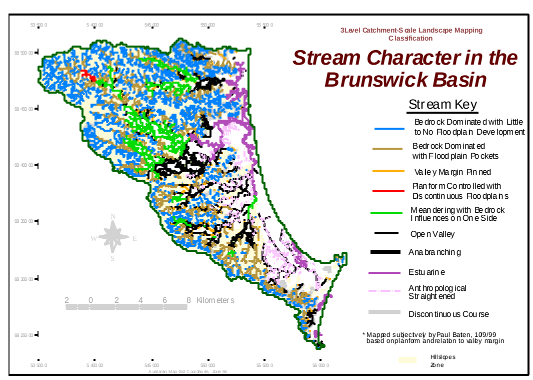

Figure 9: A classification layer of stream character (in the Brunswick catchment of far north NSW)

Within this methodology classifications are syntheses of the characterisation and parameterisation layers into meaningful information packets. For example, every length of stream in the Brunswick Catchment has been classified in Figure 9 as having one or more stream characteristics. A revised classification could have the potential of having multiple, overlapping membership classes. So in the stream-style map I have some sections of bedrock streams, and other types of streams, that are also classified as having discontinuous courses. This I think adds a large amount of valuable information whilst retaining the user-friendliness of the map.

A revised classification could also have boundaries represented as sharp, transitional or diffuse. I would like to add such things to this map. The revised version of classification acts as the final level of filtering of landscape information in a mapping methodology. There can even be a single, final synthesis, which attempts to incorporate all of the material already created, including all of the information on the various descriptive subjects dealt with.

2.3 Different Landscape Domains

The third and final topic that I will introduce to you today is the mapping subjects that the various maps within the methodology are devoted to. Guiding the type of information that is considered for an information layer is landscape organisation. After a theoretical and conceptual search of the literature I came up with three landscape domains, which can be described both separately and then in combination, to provide an overall landscape description.

Table 3: A list of the landscape domains used in the new mapping application

Landscape Domain	Examples	Type of Descriptors
The general shape of each location across a landscape	Elevation, Gradient, Aspect and Curvature	Geometric Descriptors
The properties of each location in relation to its drainage basin position	Catchment Area, Upstream Distance and Stream Order	Topological Descriptors
The attributes of each location in relation to relevant geomorphic processes	Distance from a Valley Margin on an Alluvial Plain, or the Flow Distance from the Top of a Hillslope	Special combination of geometric and topological descriptors

The domains helping to deal with landscape organisation are listed in Table 3. The use of these three domains, general shape, drainage basin location and geomorphic process attributes, contrasts with many previous frameworks that only consider general shape.

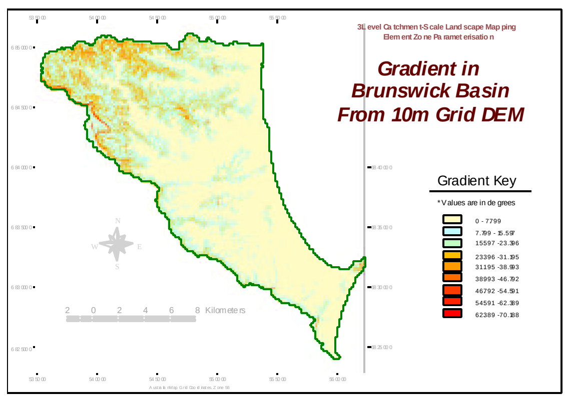

Figure 10: A gradient map (of the Brunswick catchment of far north NSW)

Figure 10 is an example of a map describing one component of general shape, gradient. It was very quickly produced using the ArcView GIS package from a Grid DEM, which the DLWC has a copy of. Remember that the parameterisation maps are by nature specialised. Therefore each of the landscape domain subjects used can have a separate parameterisation map devoted to it. When it gets to synthesising information layers with characterisation and classification then the different process zone components can certainly be mixed if the situation calls for it. Notice in this parameterisation map that every point in the study area has, in this case, had its gradient calculated. Also observe that the parameterisation layer has little to no interpretation involved in it.

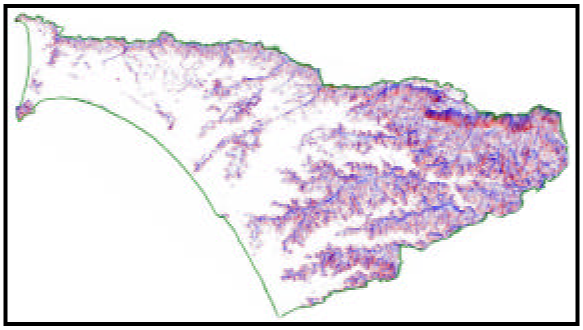

Figure 11: A 3 dimensional display of profile curvature (of the Brunswick catchment of far north NSW)

Figure 11 is another example of a general shape description layer, however in this case I have displayed it in 3D. This is one of the curvature layers: in this case profile curvature. In other words it describes whether a theoretical flow of water at each location would accelerate or decelerate. The other curvature is planform curvature, or in other words whether water flowing would converge into a location, or diverge away from a location.

There are five primary general shape measurements: elevation, gradient, the magnitude component of the first derivative of elevation aspect, the directional component of the first derivative, and both curvatures, which are the components of the second derivative of elevation.

Elevation and gradient are very common in landscape mapping methodologies that do actually involve parameterisation. The landscape domain relating to process-zones, in contrast, is probably the most absent from other landscape mapping methodologies.

Process zone descriptions, however, are so very important for getting an understanding of landscape organisation. The different process zones that I described in the Brunswick Basin were: alluvial plains, hill slopes, and coastal plain.

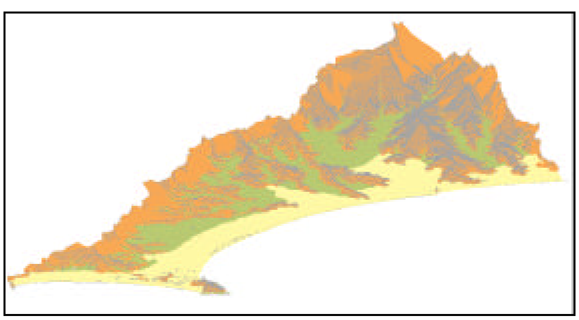

Figure 12: A 3 dimensional display of the process zones (of the Brunswick catchment of far north NSW). Orange is hillslopes, green is valley floors, yellow is coastal plain.

The 3D layer in Figure 12 shows the distribution of these different process zones within the Brunswick. Each process zone has different mapping requirements. For example, whilst distance measures are very important in each of the process zones, the distance from what entity is obviously different in each case: On the alluvial plains, distance from the valley floor margin and distance from the channel are instructive measures for understanding fluvial processes, On the coastal plain distance from the coast is for gauging beach morphology, On the hill slopes distance from the interfluve as well as distance from a channel or valley floor are instructive.

Interestingly, not only what I measured but also how I measured distances differed within each of the process zones. I measured using: Straight-line distance on the valley floors, Straight-line distance but bending around obstructions on the coastal plains, and flow path distance measured along the ground surface on the hillslopes. I have used these measures because they are physically meaningful descriptors.

The use of flow path distance within a particular process zone leads to the prospect of flow path distance across the whole of the catchment. There is a geomorphic principle that suggests that the drainage basin is the fundamental landscape concept. This certainly means that catchment descriptive layers, so often ignored, are important for understanding landscape organisation. Flow path distance from furthest ridge is certainly one of the catchment measures discussed in the new landscape mapping methodology.

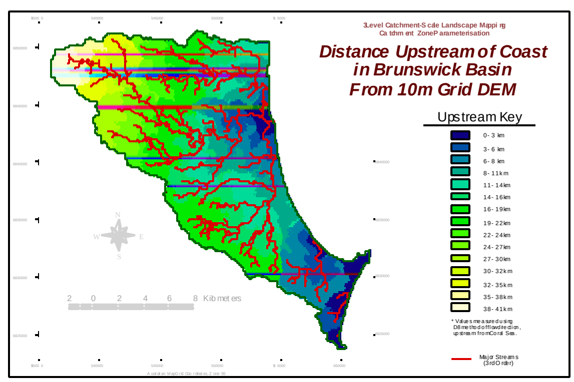

Figure 13: A catchment measure of distance upstream from the coast (in the Brunswick catchment of far north NSW)

There are many other possible descriptive layers however, and these include: stream order (a measure of upstream drainage network), streamline elevation, upstream distance (from ocean or lake), which is pictured in Figure 13, and catchment area.

3. SUMMARY

Figure 14 is a flow chart of a possible implementation of this new methodology. The Complexity Methodology, as I have labeled it, has the major steps instigated using a logical progression from straight analysis, to selective synthesis, to complete synthesis. At the parameterisation stage each of the landscape domains are described. After parameterisation their information can be combined. At the characterisation stage features, patterns and trends can be described.

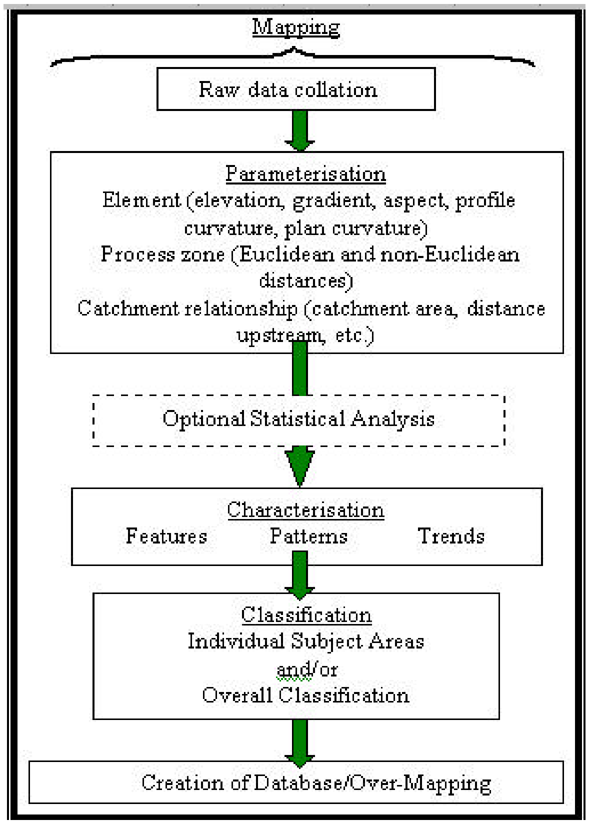

Figure 14: Flow chart of new approach

3.1 Bringing it Together

Finally, around the time of classification and database aggregation, a final overall classification can be created.

The Complexity Methodology is obviously in an embryonic stage. However, because of its dependence on other fields of knowledge, especially geomorphology and GIS, it should be seen as a living methodology anyway.

So why is this new methodology better than the old? As described in Table 4, it is better because a map that has been derived from topographic data is most likely more rigorous than one created from surrogate data sources. It is better because a database with many landscape maps has more generic value than a database that has only one map. It is better because maps that take into account landscape organisation are more physically meaningful that those that do not. Finally, it is better because broadly labeling a landscape as "Type A" patronises that landscape.

Table 4: Advantages of new application over old

Topographic data should be used when describing topography
Characterisation is excellent for presentation
Parameterisation is good for arranging and developing information
Classification can still be used, but with different ground rules to its traditional format
Process zones and catchment measures give excellent insight to catchment organisation, and certainly should be used in concert with general shape
General shape measures provide an insight into the complexity within a landscape

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