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VISUALISING TRADITIONAL BOUNDARIES IN PAPUA NEW GUINEA USING GIS 'ZONES OF UNCERTAINTY'

A dissertation submitted by

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Abstract

There is a real and current need in Papua New Guinea (PNG) for accurate landowner maps to facilitate the visualisation of land controlled by 'incorporated land groups' (ILG). Disputed areas in these maps are better depicted using GIS 'zones of uncertainty' rather than the Western cadastral-style of boundary. PNG's *Land Groups Incorporation Act 1974* (*LGIA*) was enacted to enable customary landowning groups to incorporate into ILGs and thus negotiate with all the legal responsibilities and privileges of a corporation. Its implementation since 1974 has elicited a number of problems and challenges. One of these is described as 'disputed areas', which occur along shared boundaries of two or more ILGs, and result from either mixed ownership or disputed ownership of common resources.

Current maps of ILG boundaries typically show Western cadastral-style boundaries, with 'disputed areas' displayed as a non-spatially defined polygon encompassing the area. This paper contends that the *LGIA* does not implicitly or explicitly prescribe a Western cadastral-style depiction of boundaries, and that using GIS 'zones of uncertainty' produces a more accurate and relevant map for the purpose of visualising 'disputed areas'. GIS 'zones of uncertainty' are a vector form of the raster fuzzy sets more commonly found in GIS. Fuzziness allows us to capture the multi-valuedness of our thinking (e.g. hot/warm/cold), rather than being restricted to the yes/no, zero/one categories of Boolean logic. It allows us to work with qualitative notions of space, like those found in descriptions of cultural boundaries between indigenous clans. This contrasts with the quantitative notions of space more commonly depicted by Western cadastral boundaries.

Visualisation using maps is not only important as a communication tool, but also as a means to analyse and understand ownership. Almost all key stakeholders in the ILG process have been influenced in their thinking by the Western cadastral-style of depicting boundaries. A more accurate visualisation method gives these stakeholders the opportunity to revisit and possibly revise their thinking on the creation of ILGs. Accurate maps produced using GIS 'zones of uncertainty' can meet the current need in PNG to address issues of ownership in 'disputed areas' for the purpose of creating and defining ILGs.

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Glossary of Terms

Note: The information in this glossary is taken in part from the *Land Information System Tasmania Glossary*, en.wiktionary.org, en.wikipedia.org, and wordnetweb.princeton.edu.

Agnatic	Of the male line; related to the father's side; patrilinelal; for example "a paternal aunt".
Boolean	A variable that can hold a single true/false value (or, equivalently, 1 and 0 respectively) as their only possible values and operations on such values.
Cadastre	A public register showing details of land boundaries that define separate holdings of land.
Cloud (data cloud)	Off-premise data storage and technological capability typically served via the Internet.
Counter-mapping	Mapping against dominant power structures, to further seemingly progressive goals; typically occurs as a bottom-up village-led initiative.
Cultural	Denoting or deriving from or distinctive of the ways of living built up by a group of people.

Customary title	Land tenure that is unalienated and communally owned, existing to permit the indigenous owners to practice their customary activities.
Freehold	The status of land held under an estate in fee simple following alienation from the Crown; the title holder has the right of exclusive possession and unrestricted rights to sell the land.
Fuzzy	Logic or sets that deal with reasoning that is approximate rather than precise, in contrast to binary or Boolean logic; data ranges between 0 and 1 and is not constrained to the two truth values of true/false.
Georeferencing	The process of defining the position of geographical objects relative to a standard reference grid.
GIS	Geographic information systems; a system for capturing, storing and using data which is spatially referenced; often a specific set of information technology components.
GNSS	Global navigation satellite systems; generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage; incorporates GPS, GLONASS, GALILEO, etc.
Heads-up digitising	A manual tracing of lines directly on the computer screen using a scanned or otherwise raster image as backdrop.

ILG	Incorporated Land Group; a corporation created by registering under the *LGIA* having all the rights and obligations of a corporation.
LGIA	*Land Groups Incorporation Act 1974*
Matrilineal	Based on or tracing descent through the female line.
Patrilineal	Based on or tracing descent through the male line.
Raster	Data expressed as an array of pixels with spatial position implicit in the ordering of the pixels.
Shapefile	A data format that stores nontopological geometry and attribute information for the spatial features in a dataset.
Sliver	A gap or overlap that is generated by combining two or more coverages that are not perfectly coincident.
Traditional	Pertaining to beliefs, customs or doctrines taught by one generation to the next; a specific practice of long standing.
Vector	Positional data in the form of coordinates of the ends of line segments, points, text position, etc.
Visualisation	A process of displaying graphical data; the construction and use of mental images; a map or graphic found in a GIS.

Visual-thinking	The common phenomenon of thinking through visual processing using the part of the brain that is emotional and creative to organise information in an intuitive and simultaneous way.
Zones of Uncertainty	A vector form of the raster fuzzy sets more commonly found in GIS.

Chapter 1
Introduction

1.1 Statement of the Problem

There is a real and current need for accurate land-owner maps in Papua New Guinea, the style of which is not prescribed in the *Land Groups Incorporation Act 1974*. Using GIS 'zones of uncertainty' should produce a more accurate and relevant map than the currently used Western cadastral style of boundary, from both a visualisation and analysis perspective.

1.2 Project Rationale

The land administration legacy of Australian colonisation of Papua New Guinea continues to be felt in the *Land Groups Incorporation Act 1974*. With only 3% of land alienated as freehold title it can be argued that the existing land administration and cadastral system are manifestly unsuitable. With the increasing use of GNSS positioning technology within PNG the traditional visualisation of boundaries using cultural knowledge is being overtaken by cadastral definitions, not only on paper but also on the ground. If this new definition is only being adopted to facilitate better communication with Western stakeholders then it is incumbent on the GIS community to at least advise that other methods of visualisation exist, including ones perhaps more culturally aligned with the traditional way of defining boundaries in PNG. In the process of comparing Boolean and fuzzy approaches to visualising boundaries, this study attempts to provide a means to communicate those alternatives.

1.3 Objectives

The goal of this project is to produce a map output of the current traditional boundaries of at least two adjacent groups in Papua New Guinea, that:

- uses GIS 'zones of uncertainty' to visualise boundaries created by mixed ownership of common resources (for example, a dividing river or creek having different degrees of ownership by neighbouring clans); and

- can be compared for effectiveness and accuracy against a Western cadastral style map currently being used to depict boundaries. This includes visualisation and analysis of resource ownership.

Several specific objectives that will facilitate the achievement of the project aim include:

1. To determine the context for the current mapping of boundaries in PNG, especially as it relates to applications of Papua New Guinea's *Land Groups Incorporation Act 1974*. The need for this project's research should be revealed through this objective, in that there is an internationally recognised problem with dispute resolution relating to applications of the Act, and that the current mapping style is inadequate to help solve this problem.

2. To design a GIS that uses 'zones of uncertainty' to map boundaries based on cultural rather than cadastral definitions of ownership. This objective includes sufficient data collection and analysis to create the GIS output.

1.4 Scope and Limitations of the Study

To enable this project to be completed in the allotted time a number of assumptions had to be made. Further analysis that could be undertaken to expand this project is discussed in Chapter 6. The major assumptions constraining the study were:

- Due to the limitation on the size of the study it was not possible to obtain field data, either new or from previous anthropological studies. It was decided that hypothetical culturally-appropriate data would be sufficient and this was obtained in consultation with Mr Lewi Karu of PNG University of Technology.

- The cultural approach to defining traditional boundaries in PNG is through oral transmission. In the absence of specific anthropological studies it is assumed that these oral definitions of shared ownership can be translated to mathematical ratios or percentages.

- For the purpose of comparing results within this study it is assumed that resource companies can and do pay per square metre of resource used. While this is sometimes the case it is by no means the only way compensation is determined.

It is relevant to note that the satellite imagery used for this study (refer Figure 3.1) was chosen solely for its geophysical properties and in no way is meant to represent a political or socio-cultural reality for that particular location. The author apologises to relevant parties if any offence has been given by the choice of this imagery.

1.5 Organisation of the Dissertation

This dissertation is organised into six main chapters and ancillary material. Chapter Two provides an overview of current uses of vector-based fuzziness within GIS, some anthropological background on the use of the *Land Groups Incorporation Act 1974* and associated issues with the creation and use of Incorporated Land Groups, and some discussion on the importance of visualisation as an influence on the visual-thinking process. Chapter Three outlines the research methods used, including the data used and processing and analysis of that data. Chapter Four presents the results of the visualisation method and the underlying attribute tables. Analysis and discussion of the results are presented in Chapter Five, with recommendations for future applications and research discussed in Chapter Six.

Chapter 2
Current GIS and Anthropology Literature

2.1 Introduction

This literature review has identified current research that supports the need for this research focus, through the identification of existing controversy with dispute resolution and use of incorporated land groups (ILG), the power of maps to influence visual-thinking, and methodology for mapping and visualising fuzzy and uncertain boundaries.

Papua New Guinea's *Land Groups Incorporation Act 1974* (*LGIA*) has a number of sections dedicated to dispute resolution, in recognition of the limitations of the Act itself to fully meet the needs of the stakeholders. The Act allows for the incorporation of relevant groups for the purpose of owning culturally defined land, but does not include a mechanism for how that land will be physically defined. The translation of a cultural understanding to a physical definition is excluded, apart from allowances for dispute settlement.

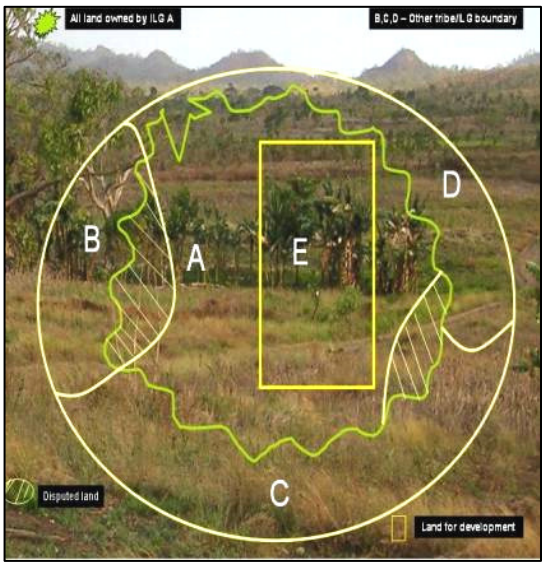

Figure 2.1 – Disputed areas now have to be shown on compulsory maps submitted with ILG applications (NRI 2010)

This dispute resolution has become so complicated that recently new legislation has been passed to try to more specifically address it. The new Act now has a requirement that an ILG application must include a sketch of the boundaries of all land belonging to the clan. It also has an allowance for any boundary disputes amongst adjoining clans to be defined and clearly marked on the maps (refer Figure 2.1). While this was conspicuously absent from the previous legislation, it still does not address specific ownership issues within the disputed areas, especially if a resource development area (refer area "E" in Figure 2.1) includes part of the disputed area. It is in this aspect of mapping the disputed area that the application of GIS 'zones of uncertainty' and fuzzy boundaries can be best applied.

2.2 Anthropological Background

Papua New Guinea has been studied from an anthropological perspective for a considerable time (Morauta 1979) and the data has been used for much research. New and ongoing research needs to be sensitive to the needs of the PNG community, to the extent that research permits are required, so it is incumbent on the researcher to review the literature that already exists before commencing new work.

2.2.1 Incorporated Land Groups

'Customary corporations' are defined by Kalinoe (2001) as already being in existence before being legitimised through statutory enactments like the *LGIA*. Dispute settlements are therefore left to customary practices. An incorporated land group (ILG) that is created through the Act has a formal and legal right to negotiate with resource companies regarding their customary land. Kalinoe (2001) goes on to identify abuses that are occurring in the ILG formation process, where original ILGs are splitting up and forming new spurious ILGs for improper purposes. This is sometimes motivated by a diminishing respect for elders and their leadership, or dissatisfaction with uneven distribution of royalty payments. Weiner (2007) describes 13 new ILGs being created out of the original Foi and Fasu ILG. Kalinoe (2001) argues that the reason for this abuse of the ILG process is due to ILGs now solely being used for resource development and distribution, rather than as the original legitimising process for an existing 'customary corporation'.

The Papua New Guinea *Forestry Act 1991* allows for the creation of Forestry Management Agreements (FMA) with customary land holders for the purpose of

managing the timber resources on their land. This Act requires the land and resource owners to be in ILGs before negotiating with the PNG Forest Authority (PNGFA), with the inclusion of detailed maps showing land boundaries in order to clearly demarcate the timber resources within the FMA area (Kalinoe 2001). This suggests that it is not the Land Groups Incorporation Act itself that requires validation of ownership of blocks of customary land, but that it was only intended to incorporate social groups for the purpose of holding, managing and dealing in land. It is only the application of Acts like the Forestry Act and the Papua New Guinea *Oil and Gas Act 1998* that require detailed mapping of customary land for the purpose of negotiating with resource companies.

One approach to reducing the proliferation of spurious ILGs was suggested by Oil Search Limited in 2000, in the form of zone incorporated land groups (ZILGs). These are intended to be 'umbrella ILGs' (Kalinoe 2001) for the purpose of accommodating the cluster of clans all related to the main clan. Oil Search Limited hoped that the ZILGs would help address the problem of unfair distribution of royalties, compensation and other benefits, and ultimately reduce the seeming rampant subdivision of ILGs. However Kalinoe (2001) identifies a number of problems with this approach under the *LGIA*, including that the ZILGs would solely be used as a benefits payment distribution mechanism (not a purpose of the Act) and that the ZILGs would not improve "certainty of title", rather adding confusion to existing customary land ownership structures (for example, in the Komo Basin "*tenes*" are land-owing clans, "*yamuwinis*" are land-use right holders, and "*walihaga*/*igiri*/*yango*" are lesser rights holders). This reinforces a premise of this thesis, which is that the processes that apply these Acts (like FMAs) require accurate detailed maps and not the Acts themselves. The Land Groups

Incorporation Act does not include an explicit requirement for a map of customary land, and certainly not one using the Western cadastral style of Boolean demarcation.

2.2.2 Cultural Definitions of Boundaries

Before discussing how groups define ownership and boundaries in a cultural sense, it is relevant to look at how groups themselves are determined. Burton (2007) describes a range of group determinancy, and includes mechanisms like genealogy, geology and politics as being initiating factors. In the latter case groups can be formed for the sole purpose of gaining recognition from a court, and might actually describe a group of people spread over a diverse geographical area. It has been argued by a number of authors (Kalinoe 2001, Fingleton 2007, Weiner 2007) that the registration of landowner groups is almost always oriented towards managing resource rents and incomes, rather than management of the land itself. Many local landowners disassociate the process of registering an ILG or landowning group from anything to do with ownership or management of customary activities on the land. Perhaps this disassociation has contributed to some of the disputes resulting from defining the land associated with these ILGs using non-culturally relevant definitions. If the two activities were seen as being more closely related then the definition mechanism could be examined and changed to be more relevant, as suggested by the results of this project.

The social organisation of many people groups in PNG, like the Huli in Southern Highlands Province and the Ipili of Porgera Valley, does not lend itself to “the registration of discrete, non-overlapping units of property holders” (Weiner &

Glaskin 2007). Another issue is that of non-unilineal descent, which also does not lend itself to discrete social groups. Filer (2007) raises the question of "whether land boundaries are more or less substantial, flexible, or porous than group boundaries", suggestive of the problems associated with trying to create a discrete definition for either.

It is common for clans and sub-clans to split, although the ILG process does appear to have accelerated this (Goldman 2007, talking of the Kutubu region). However, regardless of their size, it should be possible, though not always desirable according to Goldman (2007), to define the pre-existing social structure and allow this to be mirrored as a form of external recognition in an ILG registration. To do this the social structure needs to be examined.

As an example, the Huli people in Southern Highlands Province have three categories of people who can reside on any clan or sub-clan land, each with a different set of land rights (Goldman 2007). The land is notionally owned by the community, yet individuals have the right to do with the land what they want, including sub-letting or granting rights or title to tracts by gift, deed or inheritance. The only limitation is that clan land can not be permanently or irrevocably alienated. This inevitably leads to the scenario where (a) almost all neighbouring landowner groups or clans are related, and (b) a lot of bordering land has mixed ownership due to usage grants.

The three categories of resident on Huli land are (Goldman 2007):

(1) *Tene* – meaning 'source', 'origin' or 'main stem', are the patrilineal clan members living on their own clan territory;

(2) *Yamuwini* – meaning 'born of woman', are related through descent from a female clan member and are resident on a permanent or temporary basis out of their natal clan territory; and

(3) *Wali haga* ('where women stayed'), *igiri yango* ('male friends'), or *tara* (others) – are those who have no direct blood ties but are linked by marriage or friendship and are resident on a permanent or temporary basis out of their natal clan territory.

Over a period of generations a complex combination of ownership is created. Members might still be *tene* of one area but be considered *yamuwini* or *wali haga* of another area, with a single Huli clan scattered in several areas outside its own ancestral land (refer Figure 2.2).

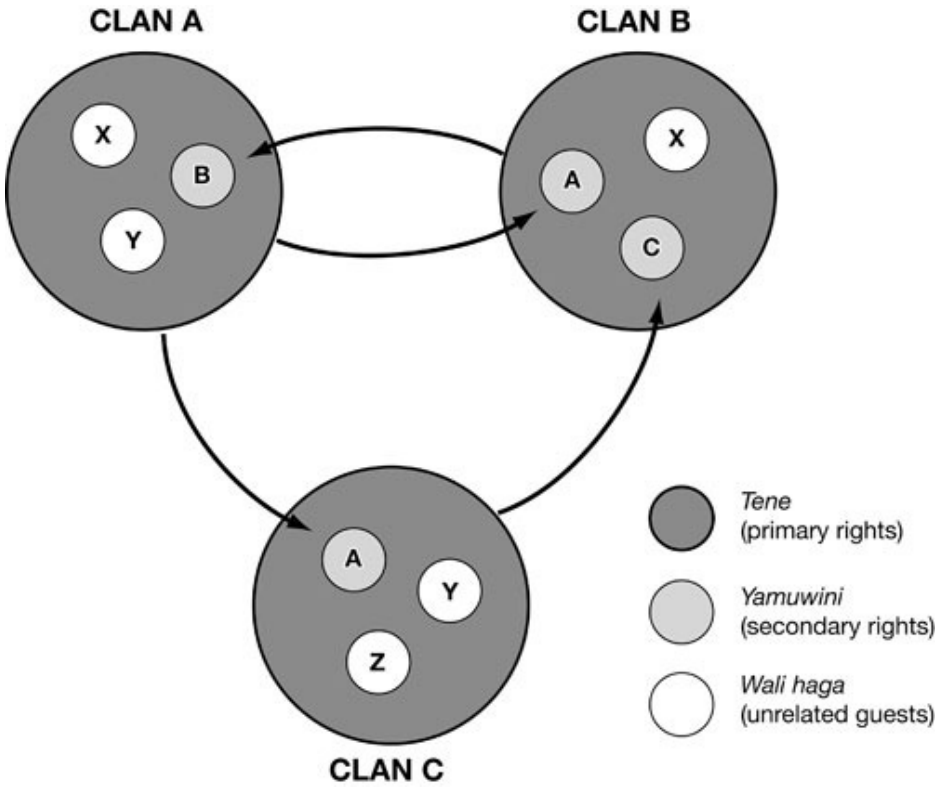

Figure 2.2 – A simplified model of the Huli descent and residence system (Goldman 2007)

Groups define their cultural or social boundaries using patrilineal and matrilineal descent as shown in the above Huli example, and traditionally do so orally (David 2008). The boundaries can be fluid as groups appear to split and reform (Weiner 2007). The physical attributes or landmarks used are often tree copses (for example, sago-palm), ridgelines, creeks and rivers, hunting grounds, gardens and villages (Lamb & Barker 2009; David 2008). Quite apart from the ILG process, these boundaries are most often negotiated and acknowledged by local elders, with the process sometimes facilitated by government Lands Officers (Burton 2007). In the social context, land can have a number of owners. In the ILG context Burton (2007) calls this "encumbered ownership", but for this study it has been termed "mixed ownership" to place the emphasis on its social inception.

2.2.3 Disputed Areas

Made up of 20-22 provinces, PNG consists of 97% of total land area under customary land tenure (Oliver & Fingleton 2008). This is land that can only be owned by a community or group, and not alienated as freehold to an individual owner. One of the considerations for this tenure type, as with all types, is dispute resolution, and in 1972 the Commission of Inquiry into Land Matters was established to investigate this issue, amongst others. Two relevant Acts were drafted based on the recommendations of the Inquiry, namely the *Land Groups Incorporation Act 1974* and the *Land Disputes Settlement Act 1975.*

Land is acknowledged to belong to a group when the boundary is acknowledged by the neighbouring group (Weiner 2007, referring to a judgement in the *Hides Gas Project Land Case* [1993]). However, land customs differ from location to

location, and as of 2008 no official attempt had been made to record those customs in relation to land, apart from the Native Land Registration Ordinance introduced in 1952 (Oliver & Fingleton 2008). These different land customs impact on perceptions of land ownership and usage, and can result in disputes and conflicts. Baker (2003) proposes two initial questions in his model of land ownership: (1) Is the land claimed or said to belong to a group? (2) If so, are the boundaries enforced to the degree that groups use only their own territories? Translated into the context of PNG, certain combinations of answers to these and other questions can result in encumbered or mixed ownership (Burton 2007; Weiner & Glaskin 2007).

For the purpose of this study, the disputed areas referred to in the amendments to the *LGIA* (refer Figure 2.1) have been differentiated into 'disputes resulting from disputed single-group ownership' and 'disputes arising from mixed ownership'. Whereas the former case involves two distinct groups claiming sole ownership of a common area, the latter deals with the land administration conflict that arises from translating a social definition (shared use and ownership) into a cadastre. It is in this mixed ownership area of dispute that this study aims to produce meaningful results.

2.2.4 Historical Change towards Cadastral Boundary Definitions

In much of PNG land rights have been traditionally interpreted flexibly, in a society that has been described as having an individualistic and egalitarian ethos (Sillitoe 1998). Traditionally, this led to land being used for subsistence and short-term crops, rather than the long-term perennial cash-crops like coffee that are now found throughout PNG. Land is owned by the community and worked by

individuals and, as such, any definition of ownership boundaries needs to also be flexible. The conflict arises when land registration becomes a requirement to negotiate with resource companies, leading to a "new reality" for the landowners (Weiner & Glaskin 2007). Not only is the cadastral style of land administration foreign to most landowners in PNG but, up until recently, the very idea of land registration itself was foreign. Before European contact PNG people did not think of themselves as belonging to named regions, but rather as being allied to other individuals in other areas through kinship and associated ties (Sorenson 1972).

Western anthropologists tend to emphasise the huge differences within PNG (for example, over 800 distinct dialects), and it is true that there is a large cultural diversity within the population of six million. However, authors like Morauta (1979) point out that within PNG there is a strong desire to emphasise cultural unity, in order to create a national political unity; to use traditional culture as a basis for national pride and identity; and to promote distinctively PNG forms of development. This internal emphasis conflicts with pressures from external cultures as introduced by commercial and industrial companies becoming established in PNG. Some of the influence is readily identifiable and mitigated if necessary, but other areas of influence are less obvious. One of these is the introduction of satellite positioning technology and its incorporation into the existing non-traditional Western style of identifying boundaries.

While it is true that the cementing of customary institutions can cause a stasis that can lead to undesirable consequences (Hiatt 2007), it seems fair to argue that a society has the right to at least explore those customary institutions before automatically succumbing to the evolution of a concept. Ironically, it is the

evolution in GIS technology that can now enable PNG society to explore the feasibility of mapping their cultural boundaries in a way that is compatible with their customs (Weiner & Glaskin 2007), facilitated by the use of GIS 'zones of uncertainty' and fuzzy boundaries.

2.3 Technical Background

This section addresses the application of both fuzziness within GIS and the power of visualisation as a tool to influence visual-thinking. With an understanding of both it is then possible to utilise the potential of visualisation using GIS fuzziness to influence visual-thinking and provide an alternative to a mono-cultural approach to mapping.

2.3.1 GIS Fuzziness

GIS 'zones of uncertainty' are a vector form of the raster fuzzy sets more commonly found in GIS. Fuzziness is described by Albrecht (2007) as allowing us to capture the multi-valuedness of our thinking (e.g. hot/warm/cold), rather than being restricted to the yes/no, zero/one categories of Boolean logic. It allows us to work with qualitative notions of space, like those found in descriptions of cultural boundaries between indigenous clans. This contrasts with the quantitative notions of space more commonly depicted by Western cadastral boundaries.

Fuzziness can be analysed to a great degree of depth (ed. Lodwick 2008). Fuzzy numbers relating to height (how tall is tall?), temperature (how hot is hot?), pollution, etc. can be analysed using fuzzy set theories like the Vertex Method or fuzzy arithmetic (ed. Lodwick 2008) and modelled and visualised using a raster surface. However, the fuzziness described in this thesis is fairly simplistic, and primarily relates to the question, "Who does that resource belong to, and to what degree?" As this does not involve a raster surface it is most likely best analysed in a vector model, and then either transformed to raster or retained as vector for visualisation. A further advantage of initially working with vector data is that a

sub-pixel scale can be utilised, given that Landsat imagery is the only one currently available to the author (30m resolution).

2.3.2 Fuzzy Models

Atkinson & Foody (2002) identify the importance of defining uncertainty, of which fuzziness is a subset, and state that it relates to what is 'not known or not known certainly'. They divide uncertainty into vagueness and ambiguity, where vagueness relates to sets that are fuzzy or rough rather than crisp, and ambiguity is associated with the hard classification of crisp sets. Ambiguity is best expressed as probability, which is used in this thesis in the form of percentages of ownership.

Edwards (1999), citing Goodchild et al. (1992), differentiates his vector polygon error model, relating to data sets derived from photointerpretation and/or map generalization, from Goodchild's, which he identifies as being more applicable to data derived from remotely sensed images. Unlike the errors leading to 'sloppy boundaries' discussed by Edwards (1994, vol. 1; 1999), which he claims both prevail in many forms of spatial data and are poorly represented by strict geometric models used in most GIS software, the boundaries in this thesis are deliberately uncertain. Rather than errors in boundary location relating to spatial geometry, this study attempts to model the uncertainty of boundaries resulting from disputed and/or mixed ownership, a sociological or third aspect of mapping uncertainty.

'Super Ground Truth' is a model foundation discussed by De Groeve, Lowell and Thomson (1999) as a means to visualise boundary uncertainty (refer Figure 2.2). The model is based on the method of using multiple best interpretations, and so might have applications for this thesis for boundaries that have disputed mixed-

ownership. The conclusion that the mapped areas of uncertainty become the most accurate is interesting and is based on the conjecture that the 'certain' boundaries have not been checked for errors. The authors have not included any verification of this theory using ground-truthing (they used a forestry example) but it should be possible to do so.

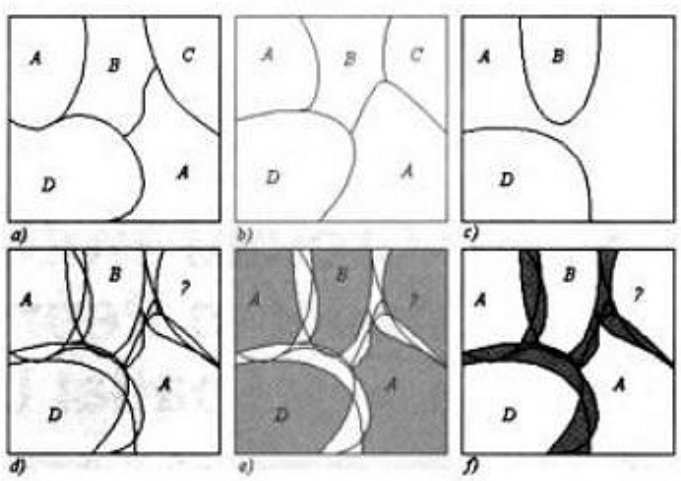

Figure 2.3 – The 'Super Ground Truth' vector visualisation proposed by De Groeve, Lowell and Thomson (1999, p. 190)

Hunter, Qiu and Goodchild (1999) propose a model based on the premise of comparing the output from distorted input data (positional error fields) with uncorrected vector data to create the probabilistic distortion of each point, line and polygon features. The variations are studied to assess the degree of uncertainty associated with the output data set. While this method cannot be applied directly to this thesis application, it does suggest one of the ways that the accuracy of the newly mapped disputed boundaries can be checked.

The model proposed by Edwards & Lowell (1996) for photointerpreting uncertainty boundaries includes the concept of two components: discrimination and variability. In the context of this thesis, discrimination would refer to the

ability to identify the different classes of ownership as applied to different clans, while variability would refer to the possible different sociological interpretations of the different classes by the clans. This is a valuable concept and can help build the modelling framework required for future work on this thesis topic.

2.3.3 Proposed Methodology

A modification of the methodology proposed by Edwards (1994, vol. 1, pp. 234-235) can be applied to this thesis in the form of a two-layered approach to the GIS. The first layer would consist of the individual boundary interpretations, which could be numerous for disputed mixed-ownership boundaries or singular for undisputed mixed-ownership boundaries (non-mixed ownership lacks sociological uncertainty), as well as any algorithms for clustering, extracting and polygon representation. The second layer contains the vector-to-raster conversion for easier visualisation of the fuzzy polygons (Lowell 1994, vol. 2, p. 935).

The final part of the methodology is to verify the conclusion that not only are the uncertainty boundaries now more accurate than the undisputed boundaries, but that their visualisation is more accurate than the previously used cadastral-style spatial geometry (De Groeve, Lowell and Thomson 1999).

2.4 Visual-Thinking

As well as a visual communication tool, maps also play a significant role in influencing our visual-thinking. High interactivity and abstractness in mapping facilitates the user's ability to explore and conceptualise the reality as presented in the map (O'Looney 2000). In the act of reading a map the viewer places themselves in relationship to the perspective conveyed by the map. Maps reduce the complexity of the world to produce an abstraction of a set of spaces and relationships (Wainwright & Bryan 2009).

Social theory researchers use maps, but as Perkins (2003) argues, they have little appreciation for how they work. Cognitive research seeks alternatives to cartographic communication, including investigating appropriate interfaces for visualising, analysing, presenting and exploring data in innovative ways (Cartwright et al, cited in Perkins 2003, p. 343). The results of this research then need to be disseminated into other areas to make better use of this knowledge. The impact of the map on visual-thinking needs to be better appreciated (refer Figure 2.4).

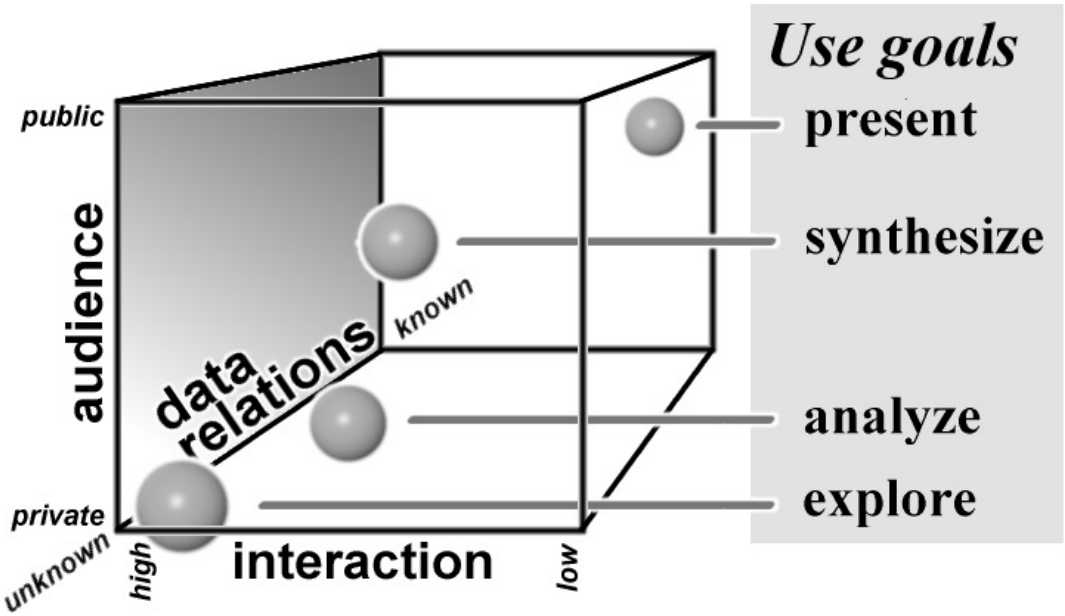

Figure 2.4 – Different levels of visualisation and communication of spatial information (MacEachren & Kraak, cited in Ahlenius 2000)

By learning how maps work and the interaction between the map and the viewer, the relationship between maps and ideas is gradually being explored further in the social sciences (Starling, cited in Perkins 2003, p. 346). Research is looking at how the process of mapping itself, rather than the outcome, can be part of a subjective performance, instead of an objective tool (Perkins 2003). These are some of the important areas that the humanities and social sciences can contribute to in the theory of GIS and visual-thinking.

Perkins (2003) discusses the power of maps in the construction of imagined communities of nationhood; the role of maps in military power; property relationships; the power of media and maps to reinforce narrative; and the application of critical geopolitical methodologies to mapping. There is a connection between mapping and the law that, for cartographers and geographers working with indigenous communities, is avoidable (Wainwright & Bryan 2009). Neither the law nor maps are "mere tools to be used instrumentally"; they are powerful social relations that demand the involvement of the mapmaker and viewer alike.

The emancipatory approach of counter-mapping engages in bottom-up village-led initiatives and can be central in any land reform process (Peluso; Harris & Wiener; Anderson, cited in Perkins 2003, p. 344). While counter-mapping does not necessarily remove the problems of power, inequality and representation, nor does the external mapping of traditional lands, so the purposes and processes of creating maps needs to be clear (Wainwright & Bryan 2009). By drawing lines delineating relationships between people and places, maps contribute to the production of community (Wainwright & Bryan 2009). Drawing border lines, even fuzzy or indefinite, helps frame the

community, as much by what was not drawn as what was. It is apparent therefore that defining boundaries in maps can cause both contention and conflict.

Visual-thinking is powerful, and the maps' influence on it is well documented. The responsibility for the use of maps to define and influence communities falls not only on the shoulders of the GIS and geography field, but also on the social sciences and other users of the technology. Whether it is counter-mapping by indigenous groups, or reinforced narrative in the media, the power of GIS visualisations to influence visual-thinking needs to be recognised and used to positively affect the outcomes of the contexts in which it is used.

2.5 The Knowledge Gap

Issues stemming from ILG formation and use are many and varied. For instance, is it even appropriate to try to map social constructs and relationships using methods suitable for visualising physical attributes? What, if any, land reforms are necessary to stop the prolific splitting of existing ILGs into more new ILGs? Is it possible or necessary to convince the users that the ILG model can be used for more than royalty distribution? Regarding ILG incorporation and boundary definitions, is PNG culture being subsumed in favour of a Western interpretation or simply adapting or even temporarily adopting it?

These and other related issues, while interesting, can not be the focus of this study. Rather, the small area of boundary visualisation, specifically in disputed areas of mixed ownership, has been chosen. While small, the influence that visualisation can have on visual-thinking means that this area can have a potential impact greater than is immediately apparent.

While the Western cadastral philosophy is not Boolean, in that we understand the concept of mixed ownership and appreciate its application even to freehold land, nevertheless our land administration system and visualisation thereof remains Boolean. The detail motivating this project lies in the subtle difference between the application of our cadastral philosophy and that of one better suited to the traditional understanding of land ownership and usage in PNG. The results of this study should be a tool, in the form of methods and understanding, that can be used or not by those most affected by the application of the Western philosophy to land administration in PNG.

2.6 Summary

This chapter has explored a small area of the complications surrounding the use of the *LGIA* and formation of ILGs, including the identification of disputed areas created within boundaries of neighbouring groups. Recognising the power of GIS visualisations to influence the viewer's visual-thinking, it has been established that a more culturally appropriate way of mapping mixed ownership within these disputed areas is not only feasible but appropriate.

There is little literature available specifically in the area of GIS 'zones of uncertainty' as a means to map fuzzy boundaries, but a number of papers were used to influence the methodology of this project, and to suggest areas for future work. The research methods resulting from this methodology are described in the following chapter.

Chapter 3
Research Methods

3.1 Study Area

While real data for future applications of this project will be collected from a diverse range of geographical sites, the study area for this project (refer Figure 3.1) was selected for a number of specific reasons:

- One of the limited areas of high resolution imagery of PNG available through Google Earth;
- Contains an ideal mix of geographical features suitable for creating hypothetical data.
- Contains geography that could suggest the existence of desirable resources.

Figure 3.1 – High resolution imagery from Google Earth used for hypothetical data (DigitalGlobe 2006)

The study area contains a number of physical features commonly used by traditional groups to define their boundaries by use. These include ridgelines, forested areas, rivers, current and abandoned villages, current and abandoned gardens and hunting sites. This area could also contain sacred sites but they are harder to identify from just physical properties.

3.1.1 Hypothetical Ownership

For the purpose of this project the following hypothetical ownership was used:

1. Originally one family group claimed ownership of the whole area.
2. Ownership was then passed a number of generations ago to three brothers (refer Figure 3.2).
3. In the last two to three generations Group B gained a concession from Group A to use part of their land (refer Figure 3.3). This concession is considered by both groups as ongoing and able to be inherited.
4. When a resource company expresses an interest in part of the land (refer Figure 3.4) both Groups submit ILG applications. Under the new amendments to the *LGIA* they have to submit maps with their applications and include the "disputed" area (refer Figure 3.5).

Under the previous Act an ILG could be registered without any maps showing the land in question, and certainly without identifying any areas of dispute.

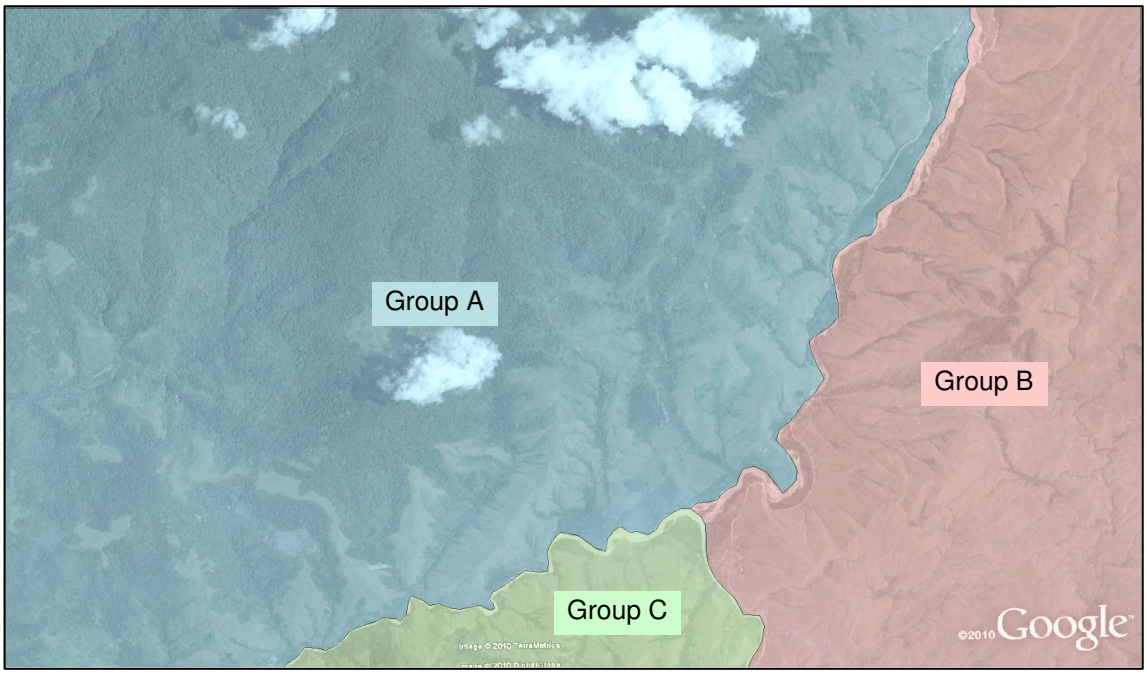

Figure 3.2 – Study area divided into hypothetical ownership

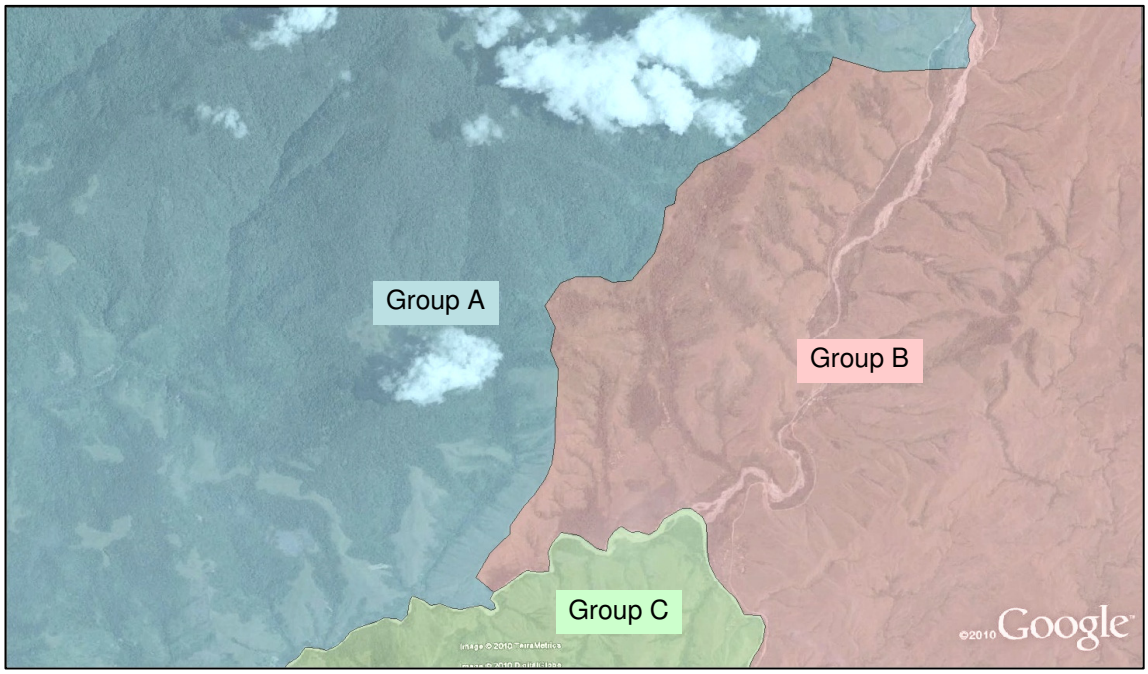

Figure 3.3 – Study area showing perpetual concession granted to Group B

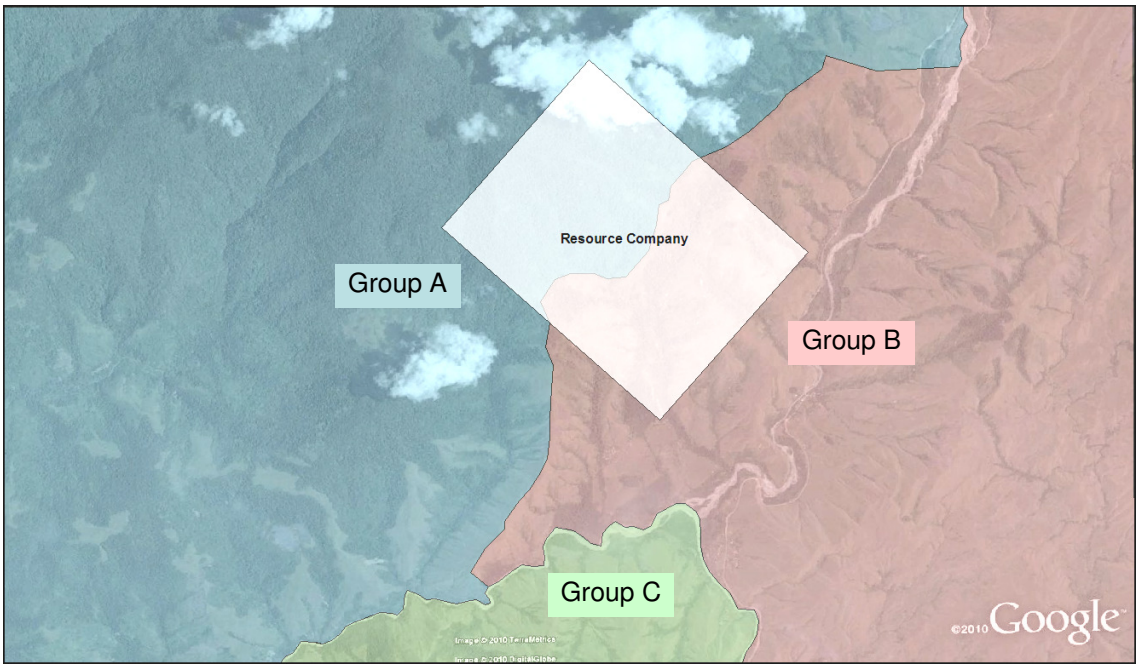

Figure 3.4 – Resource company area of interest, intersecting disputed area

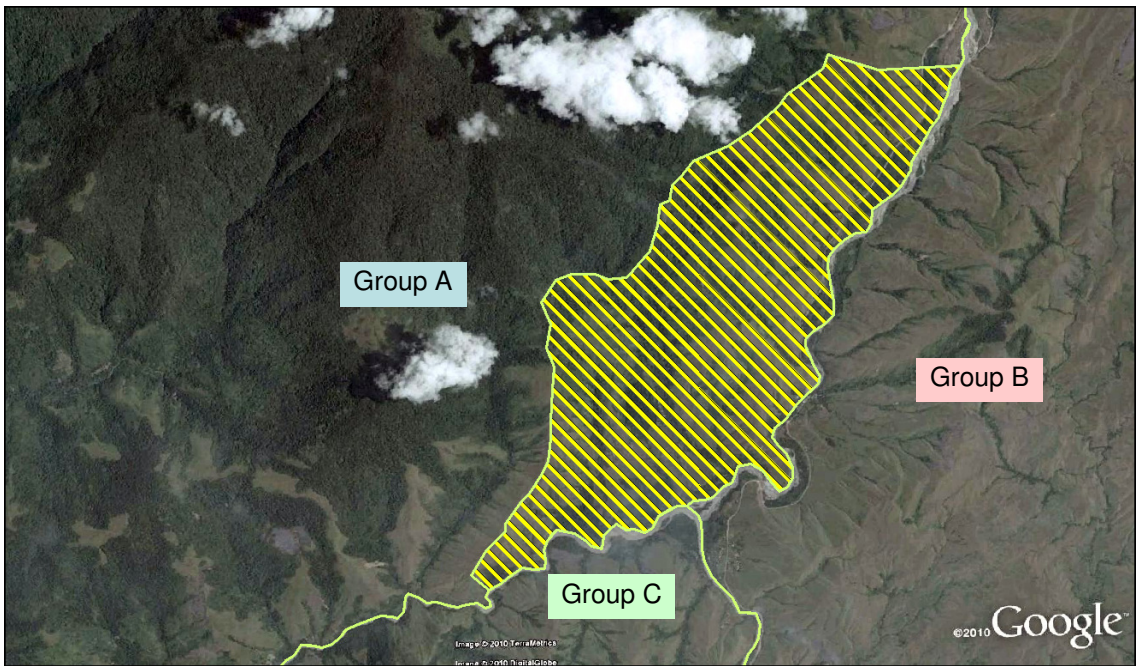

Figure 3.5 – Part of the ILG map submission now including the disputed area

3.2 Software and Hardware Used

The hardware and software used to create the GIS and visualisations included:

Computer:	Intel® Core™2 CPU
	6400 @ 2.13GHz
Memory:	2GB RAM
OS:	Windows XP
Software:	ESRI ArcInfo version 10
	Jasc Paint Shop Pro version 7.04

3.3 Data Acquisition and Pre-processing

3.3.1 Georeferencing

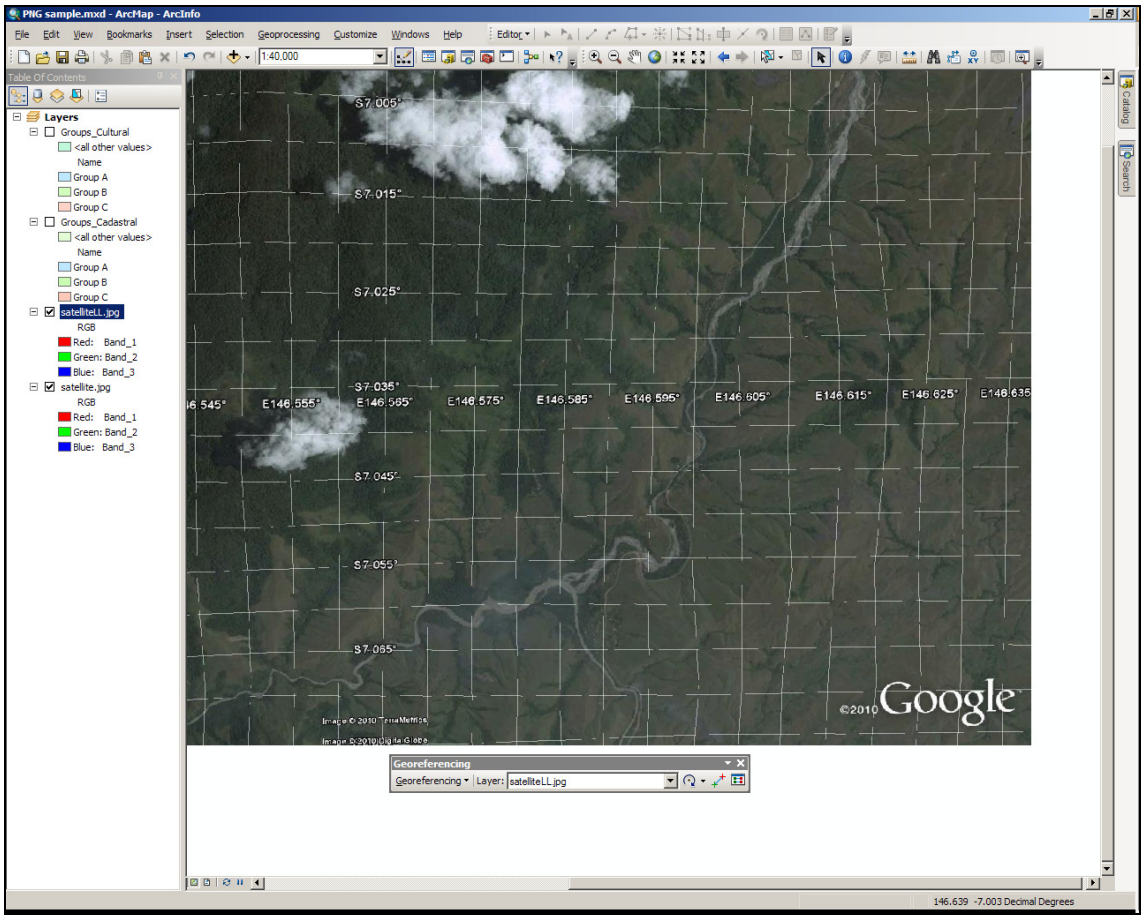

Figure 3.6 – Georeferencing Google Earth imagery using ArcGIS

While it was not important to georeference the satellite imagery for this hypothetical example the task was nevertheless undertaken as part of the research methods. The process involves capturing an image from Google Earth without grid lines, and then a second capture including grid lines depicting latitudes and longitudes (refer Figure 3.6). The *georeferencing* tool in ArcGIS can then be used to georeference the clear image, which is then used as the background layer for any future vector overlay layers. A compass orientation and scale bar has not been

included in these images as this information was deemed relative given the hypothetical nature of the data.

3.3.2 Heads-up Digitising

The next stage in data acquisition involved digitising the boundaries of the hypothetical areas owned by the three related brothers. This was done using the editing and sketch toolbars and functions in ArcGIS to create three separate polygons (refer Figure 3.7).

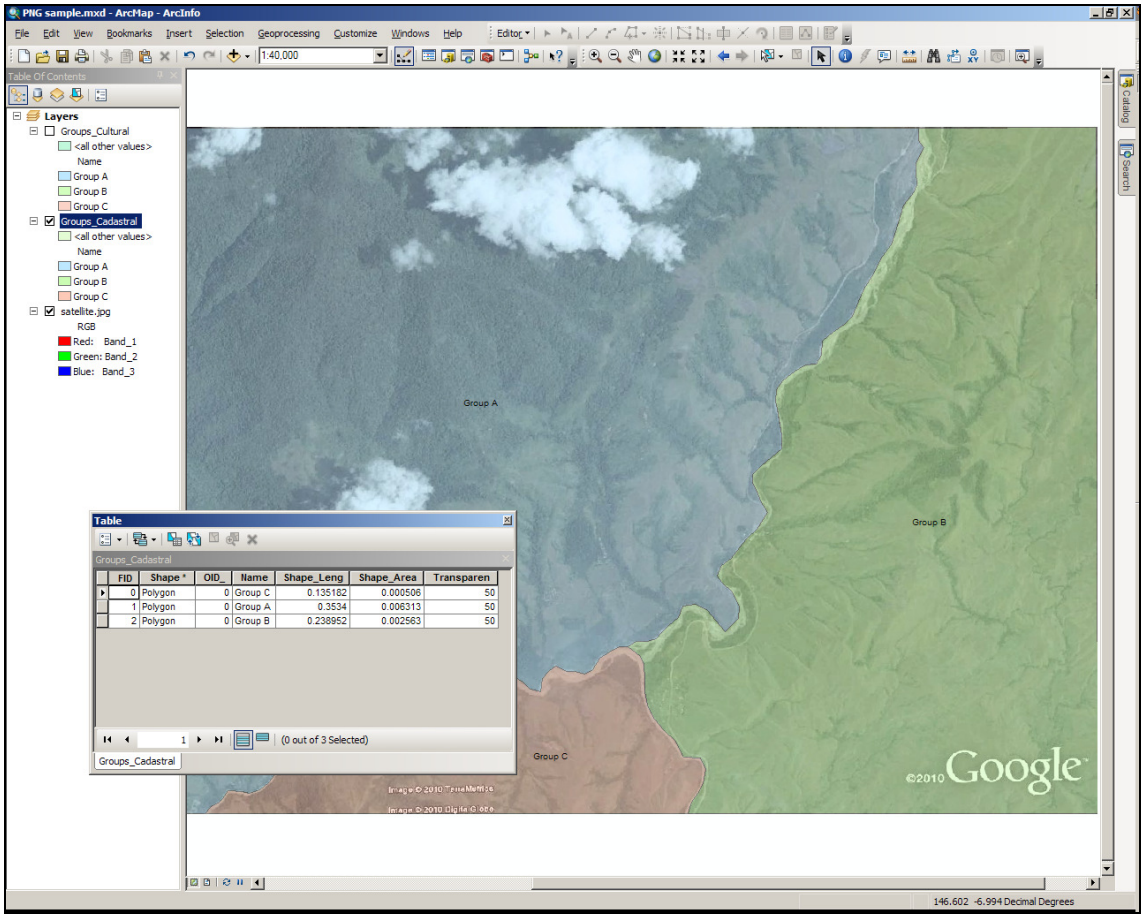

Figure 3.7 – Digitising boundaries into polygons using ArcGIS

ArcGIS version 10 provides readily accessible tools for heads-up digitising like *trace, reshape feature* and *cut polygons.* Slivers can be removed manually or using

the attribute table, or merged into the main polygon if applicable. Changing the transparency of the polygon colours allows the underlying satellite image to still be viewed.

After creating the large ownership polygons the individual landmarks were then digitised. These were first identified as hypothetical features on the satellite image based on cultural information provided by Lewi Kari of PNG University of Technology and included two hunting grounds, two gardens, two villages, a sacred site, and the surrounding "granted" lands. The traditional way of describing ownership is to use the landmarks to describe general boundaries. For example, a group might claim usage (and hence ownership) for land "from these abandoned gardens here to our hunting grounds over there" (which could be a number of kilometres away).

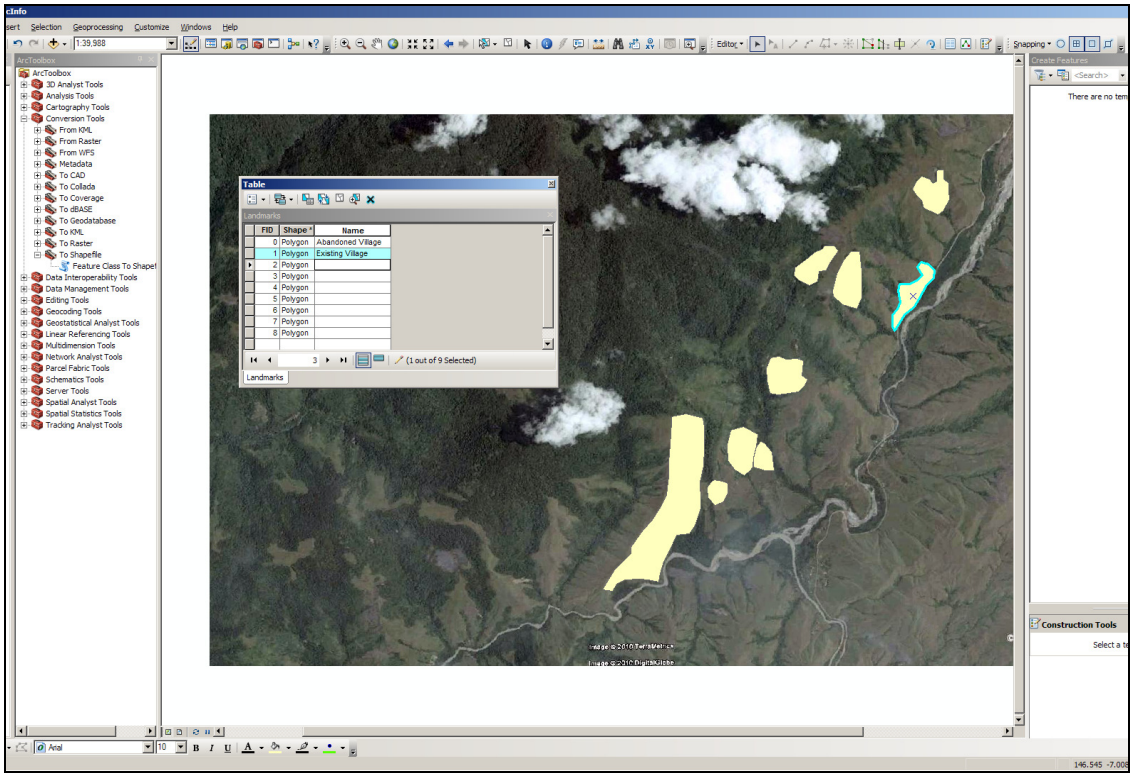

Figure 3.8 – Adding landmarks using "Create features" editing in ArcGIS

The landmarks were then digitised using the *create features* tool in ArcGIS (refer Figure 3.8) and then converted to a shapefile using the "Conversion Tools" toolbox. This new shapefile was then added to the map as a new layer. The attribute table was edited to include more columns like OwnershipA, OwnershipB and Area. To include the surrounding "granted" lands an appropriate polygon was created, then the individual landmarks were "clipped" from it (refer Figure 3.9) so there was no overlap or duplication of land use.

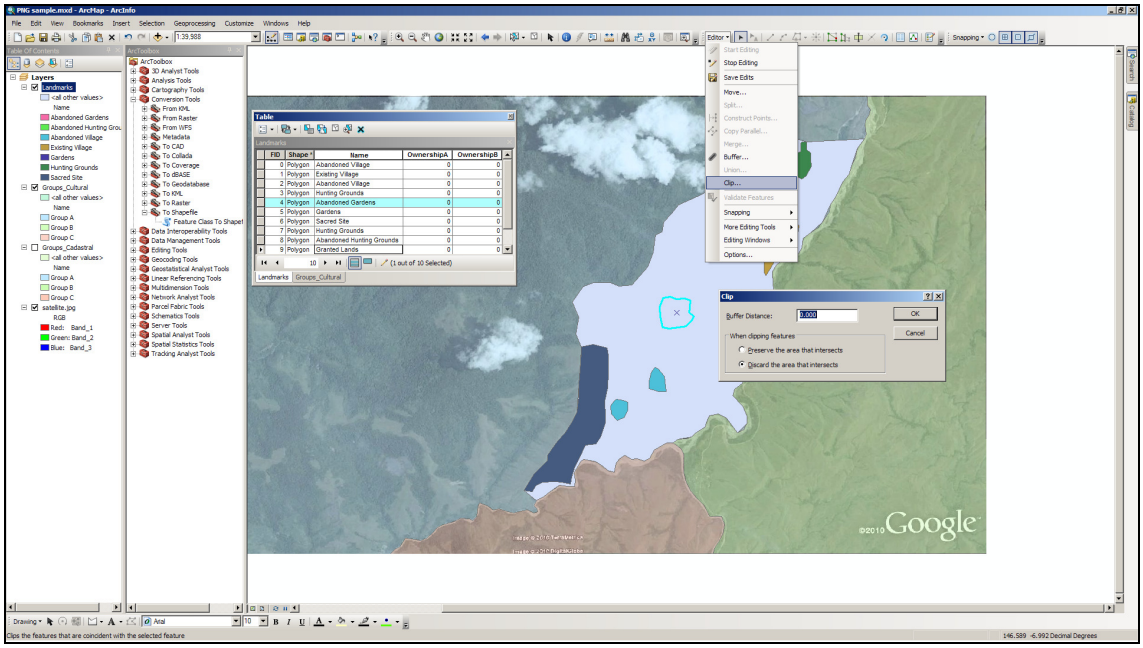

Figure 3.9 – Clipping landmarks to separate ownership using ArcGIS

This clipping process was repeated to completely remove the disputed area from the three general ownership polygons (refer Figure 3.10). Both clipping stages were important as future intersect functions would otherwise be affected. A number of separate shapefiles were now available for further processing.

To aid in visualising the number of different ownership definitions as well as acknowledging the relevant landmarks, the polygons were then merged using the

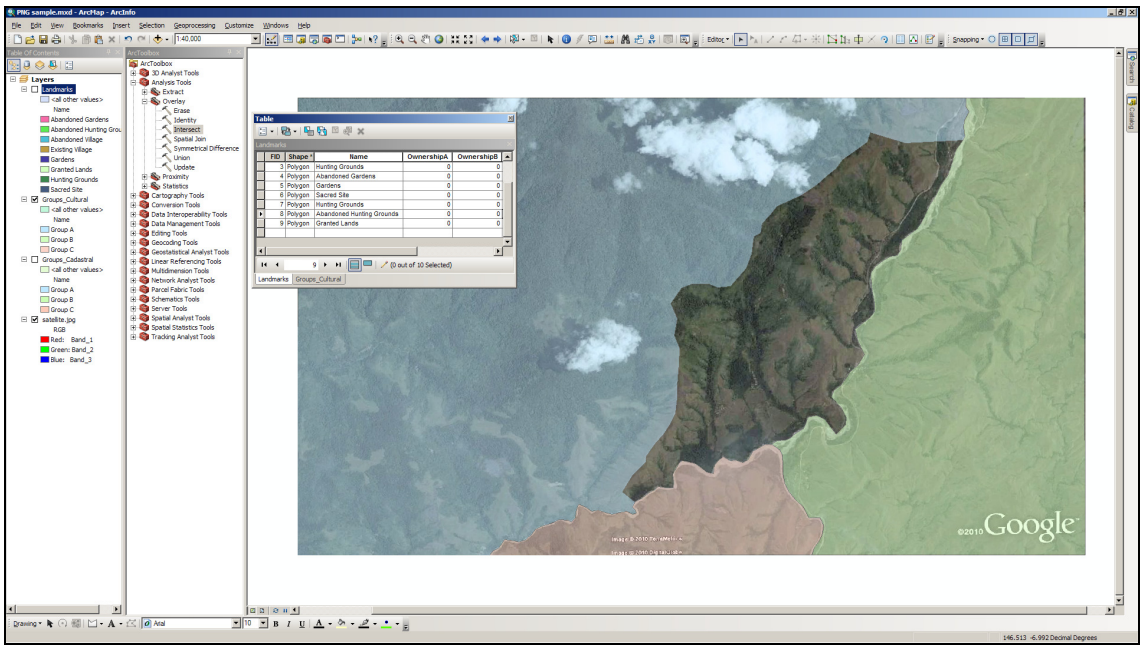

Figure 3.10 – Clipping the disputed area using ArcGIS

copying "union" function within ArcGIS (refer Figure 3.11). This resulted in a single shapefile containing all of the polygons, with no overlapping duplication, depicting ownership of the sample area and the presence of defining landmarks within the disputed area.

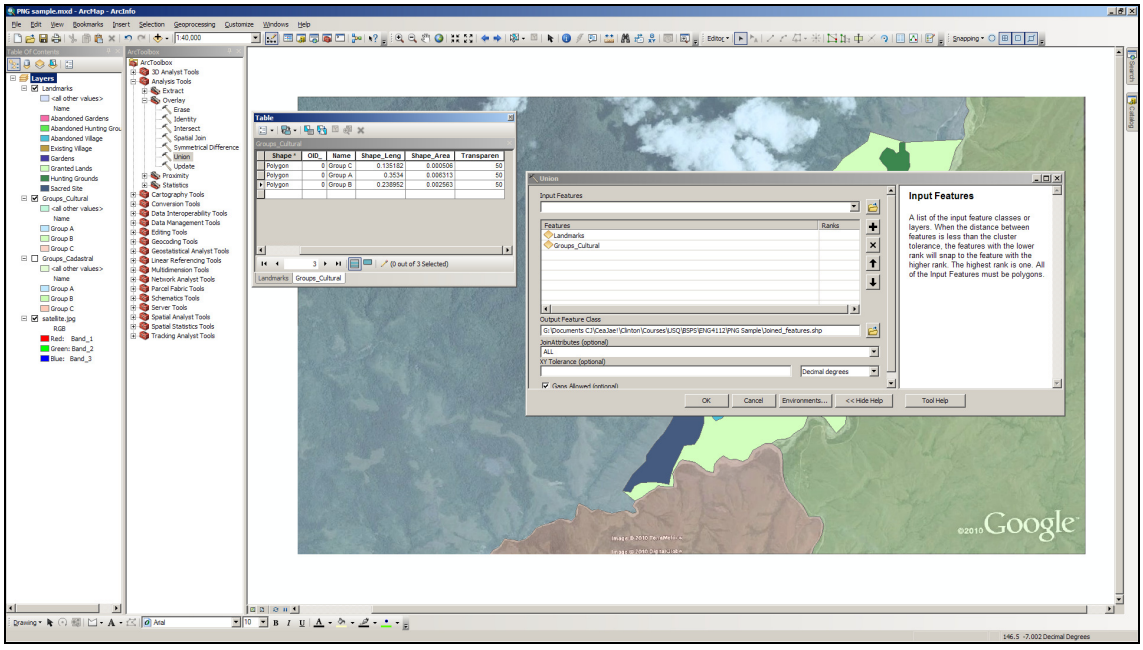

Figure 3.11 – ArcGIS "Union" function makes a new feature class containing all the polygons

3.3.3 Ownership Attributes

The final pre-processing step was to assign percentages of ownership by the Groups to the individual landmarks (refer Figure 3.12). These percentages attempt to reflect the reality of relative ownership each Group has and would result from consultation with the groups rather than be an imposed interpretation. At this stage, using either hypothetical or real data, the result is an accurate digitised map of land ownership and acknowledgement of specific landmarks affecting ownership within the area of dispute. The power lies in the underlying attribute table and what can be done with the ownership data.

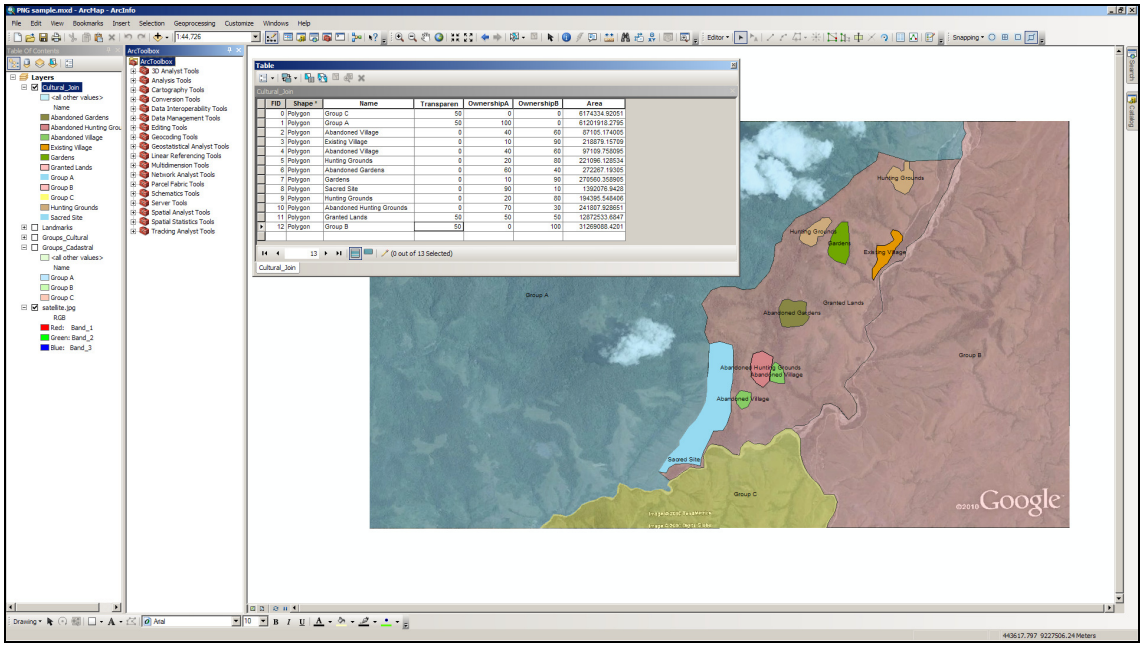

Figure 3.12 – Adding labels and ownership percentages to the attribute table

3.4 Data Processing and Analysis

Now that there are landmark features with accurate ownership data attached it was appropriate to examine more appropriate ways to visualise that data.

3.4.1 Symbology

It was decided to use the classification method in ArcGIS "Quantity by category" within "Multiple Attributes" symbology. Multiple attributes needs to be selected wherever more than two ownership fields exist, even when a field is essentially unused as in this hypothetical data (that is, Group C). Figure 3.13 shows the properties box for manipulating the symbology, as well as the additional dialog box used to vary the chosen colour ramp. It does this by setting the saturation and value of the colours in the unique values in the first colour scheme.

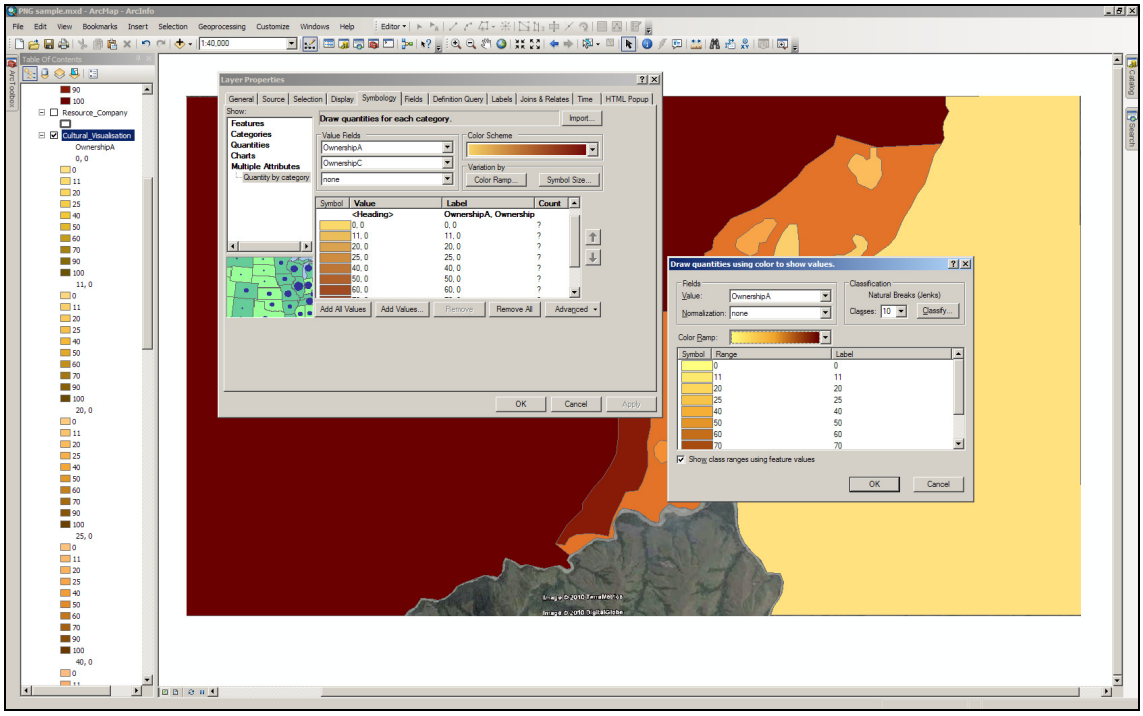

Figure 3.13 – Colour ramps and classification breaks create different visualisation effects

The colour ramp can be further manipulated by right-clicking on the scheme and editing the properties (refer Figure 3.14). For the colour scheme ultimately chosen for the ownership visualisation (refer Figure 4.5) the CIE Lab (Commission Internationale de l'Eclairage) algorithm was used as this creates a smooth ramp. This can result in some muddying of the colours in the middle of the spectrum and so needs to be adjusted depending on the difference between the starting and end colours. The first slider modifies the values of the colours by lightening or darkening them. The second slider adjusts the saturation levels, resulting in a more or less colourful colour ramp. It is also possible to directly specify the starting and ending colour of the ramp, as can be seen when comparing Figures 3.13 and 3.14 (the starting colour has been modified). Any customised colour ramps can be saved for later use.

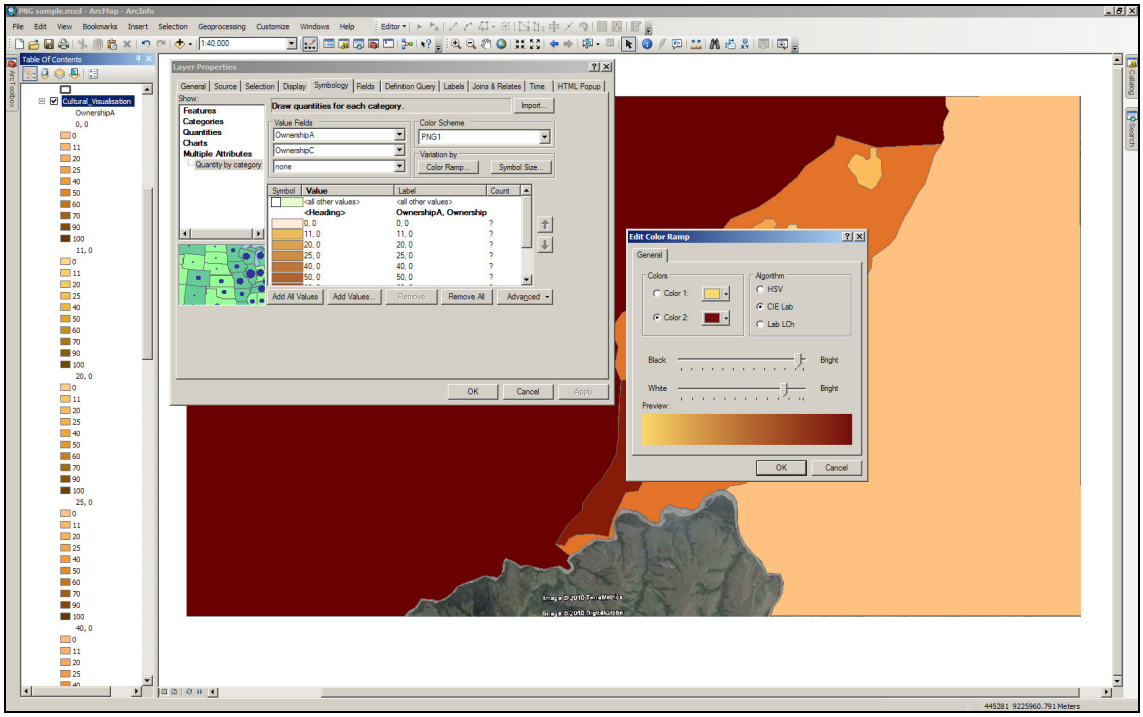

Figure 3.14 – Colour ramps can be edited further and saved for later use

3.4.2 Resources Area of Interest

To analyse the effectiveness of the visualisation and underlying attribute table it was decided to overlay a resources area of interest (refer Figure 3.15). This polygon was then intersected with the underlying layer to create a new shapefile that effectively contained new polygons corresponding with the affected landmarks and general land. This is a crucial function and is used to clearly identify the land affected, as well as for calculations relating to compensation for use of the land. It is this data that allows for a more accurate outcome based on real ownership.

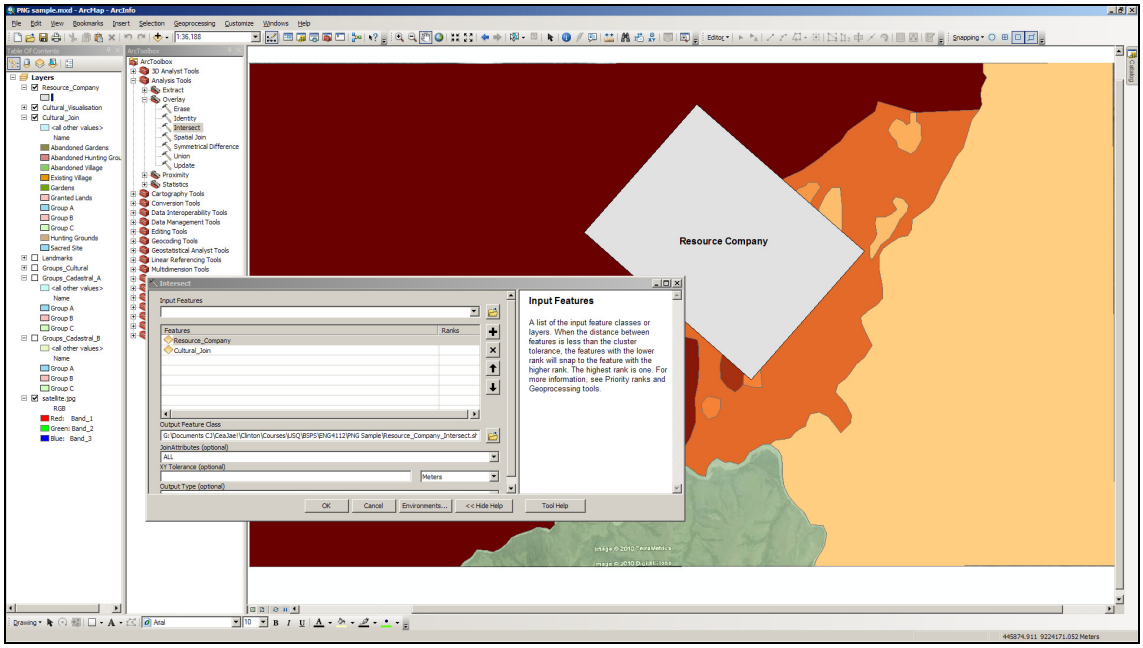

Figure 3.15 – Finding the intersect between landmarks and the resource company area of interest

3.5 Summary

This chapter has described the methods used to create and extract data relevant for visualising and analysing land ownership when a Boolean definition is not automatically assumed. The methods require a reasonable knowledge of ArcGIS and GIS theory but are not onerous. While the data used was hypothetical it was culturally accurate and is an adequate substitution for real data for the purpose of testing these methods.

Chapter 4
Results

4.1 Visualisations

A number of visualisations were created using the methods outlined in Chapter 3. These include the Boolean definitions hypothetically argued by both Group A and B when submitting their original ILG applications, as well as the more culturally accurate visualisation showing the customary understanding of ownership. Section 4.2 shows some variations of the fuzzy visualisations, while Section 4.3 describes the underlying attribute tables.

4.1.1 Using Boolean Definitions

The area between Group A and Group B is disputed due to mixed ownership based on usage. Until recent innovations in GIS software allowed accurate depiction of ownership as described in this study it was necessary to either show one owner of the land (Boolean definition) or not map it at all.

Figure 4.1 shows the map potentially submitted by Group A in defence of their ownership of the disputed area and Figure 4.2 shows that submitted by Group B. Both are accurate in that they show ownership as defined by each, and in fact both, groups, however they are not accurate in that they do not show the full ownership.

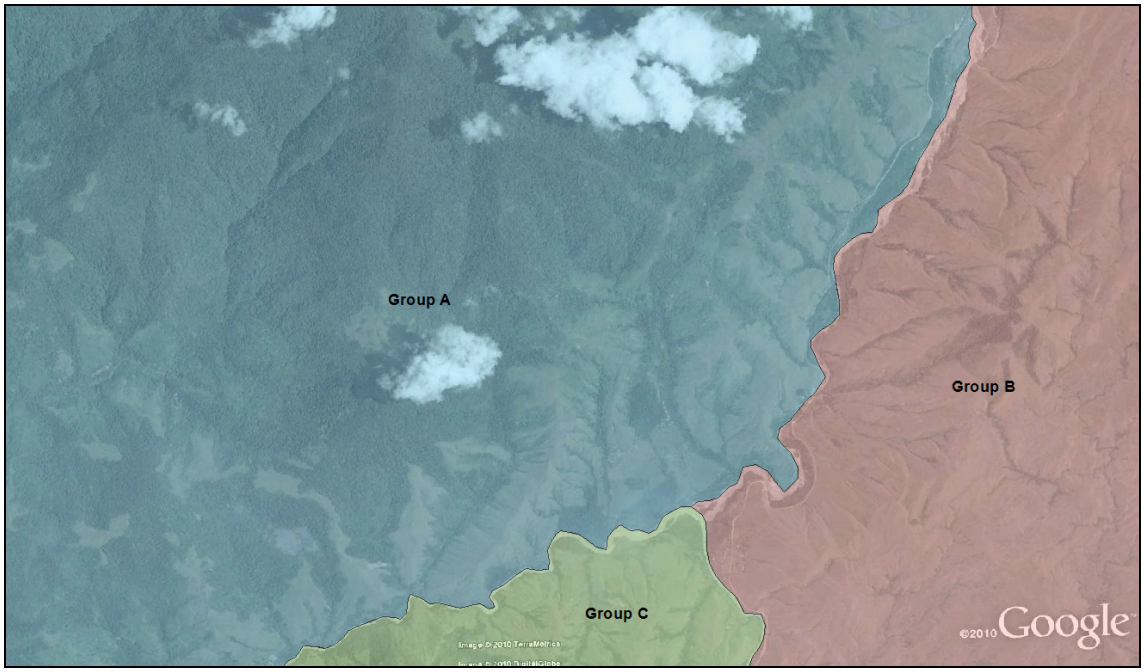

Figure 4.1 – Disputed area shown as 100% Group A owned

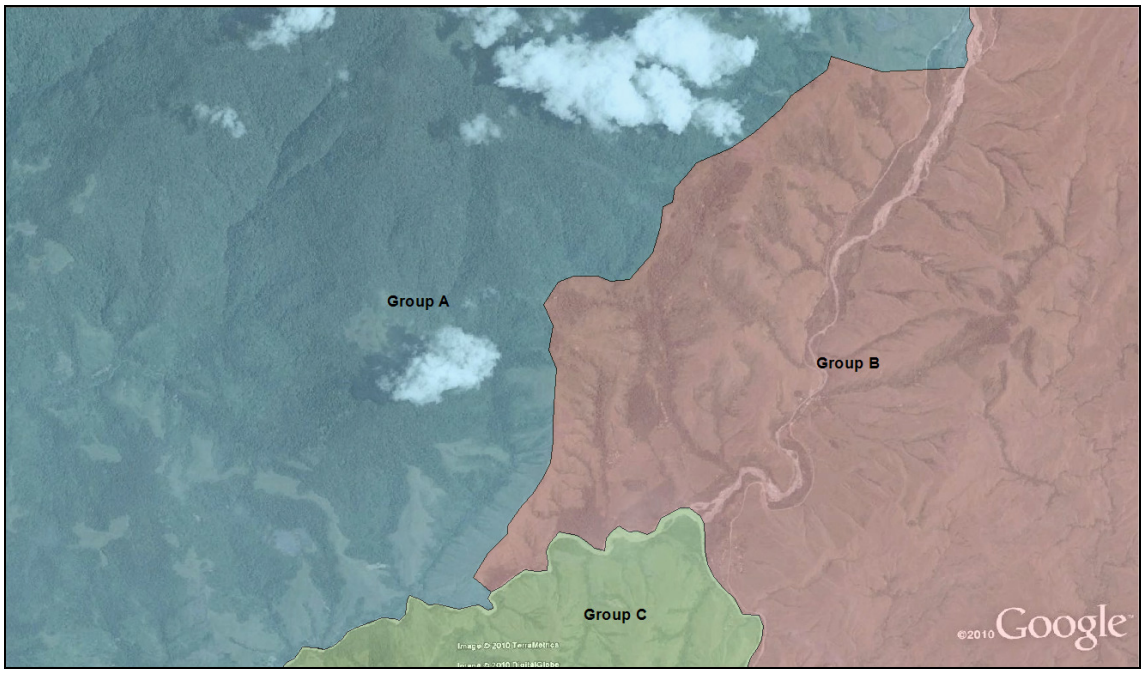

Figure 4.2 – Disputed area shown as 100% Group B owned

If the potential of GIS visualisations was not known and it was felt that a Boolean type map was still required then the user might choose to create a map based on majority ownership, at least recognising that some form of ratio of ownership existed. Figure 4.3 charts the ownership of the landmarks in the disputed area and includes a 50% threshold line to determine majority ownership.

However this map visualisation still has severe limitations in that it cannot show 50/50 ownership (for example, Granted Lands) where both groups have 50% ownership. Also, the visualisation is still less than accurate and is a compromise regarding the reality of landmark ownership (refer Figure 4.4).

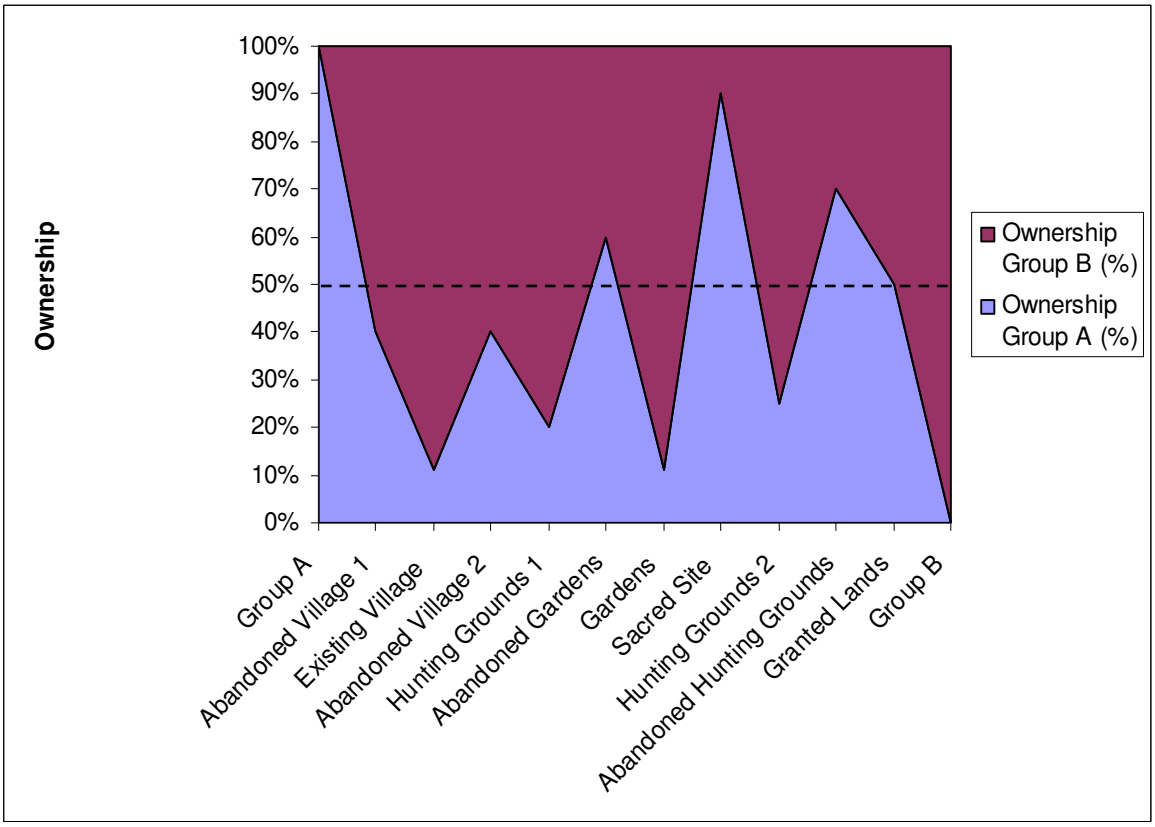

Figure 4.3 – Chart of ownership with 50% threshold line

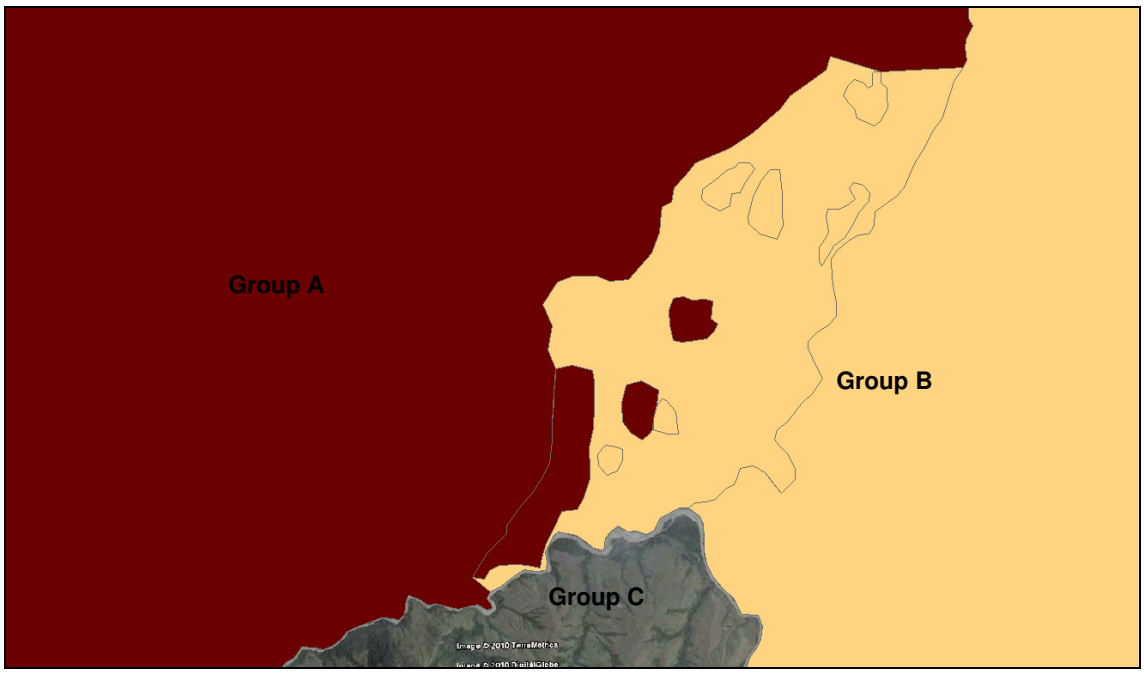

Figure 4.4 – Disputed area shown by majority percentage ownership

4.1.2 Using Fuzzy Definitions

By making use of the potential of GIS to create a variety of visualisations, from Boolean to fuzzy, the 'zone of uncertainty' (the disputed area) in the study was able to be mapped to portray an accurate visualisation of ownership (refer Figure 4.5). As the hue changes from red to buff ownership is indicated as moving from Group A to Group B. The closer the colour is to red the more Group A owns it, and likewise the closer to buff the more Group B owns it.

The visualisation is no longer an imposition on reality like the Boolean type maps, but is now an accurate depiction of the cultural reality that is acknowledged by both groups.

Variations of this fuzzy visualisation are shown in Section 4.2.

Landscape Name	Ownership Group A (%)	Ownership Group B (%)
Group A	100	0
Abandoned Village 1	40	60
Existing Village	11	89
Abandoned Village 2	40	60
Hunting Grounds 1	20	80
Abandoned Gardens	60	40
Gardens	11	89
Sacred Site	90	10
Hunting Grounds 2	25	75
Abandoned Hunting Grounds	70	30
Granted Lands	50	50
Group B	0	100

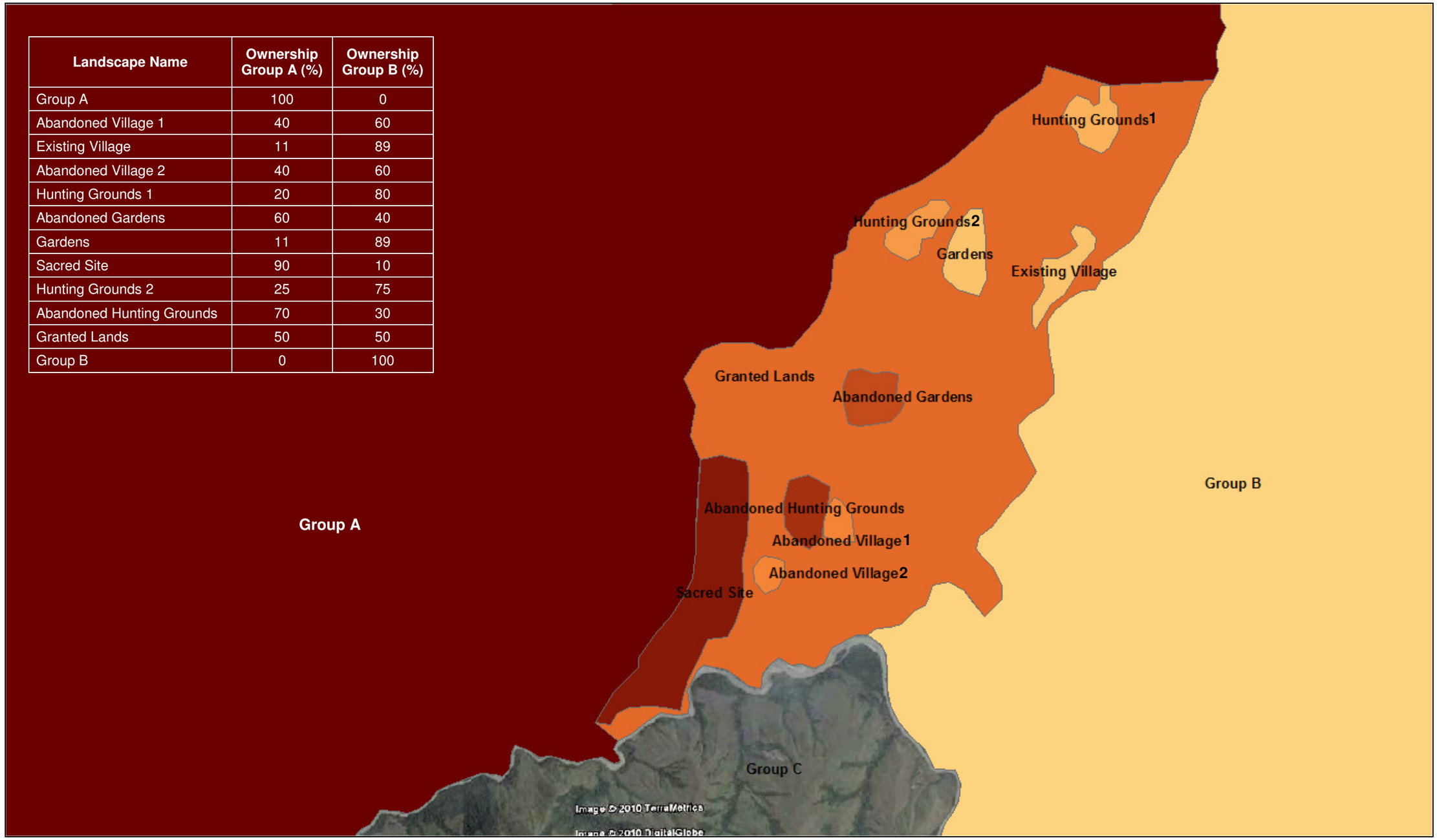

Figure 4.5 – Accurate visualisation of cultural understanding of landmark ownership using GIS 'zones of uncertainty'

4.1.3 With Resources Area of Interest

Overlaying the resource company area of interest allows a clear visualisation of the impact on the mixed ownership landmarks and land (refer Figure 4.6). A closer look at the site in Figure 4.7 reveals the affected landmarks, including portions thereof.

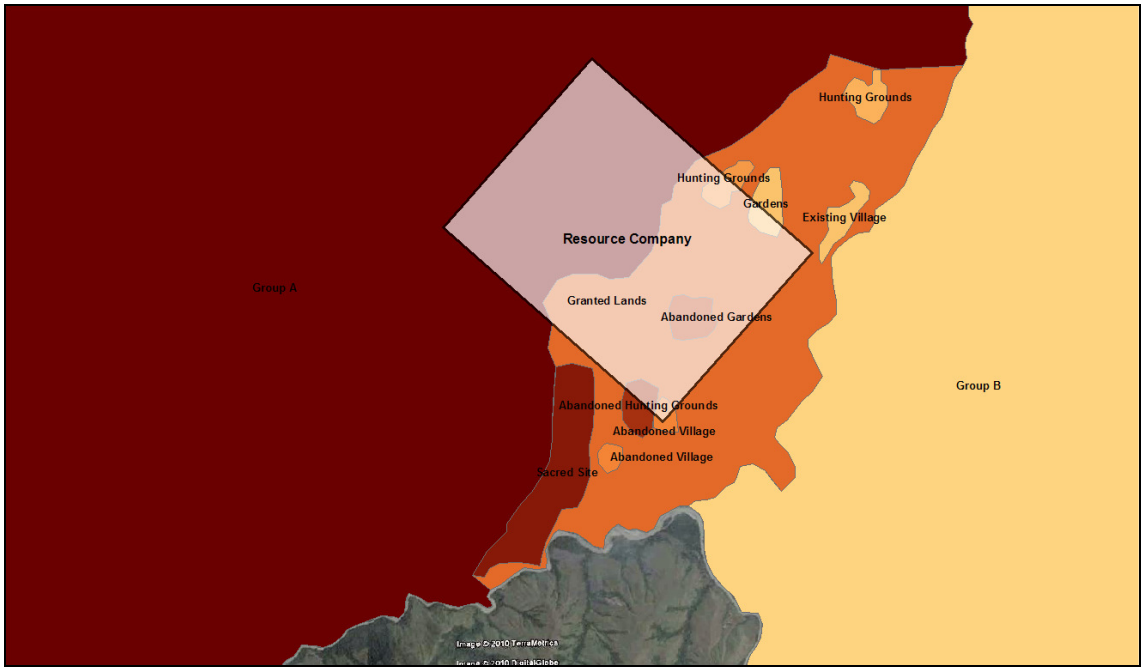

Figure 4.6 – Overlay of resource company area of interest

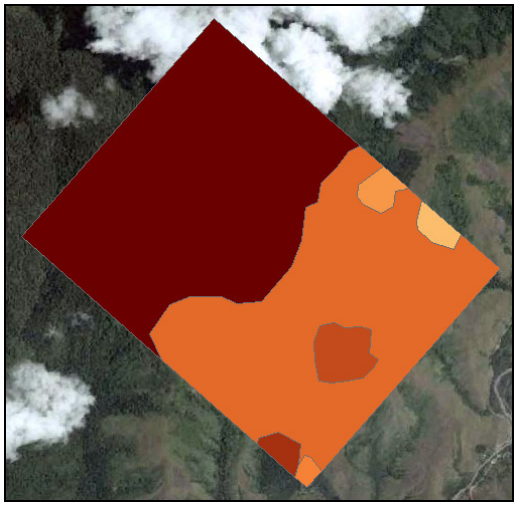

Figure 4.7 – Resource company area of interest showing affected landmarks

4.2 Variation in Fuzzy Visualisations

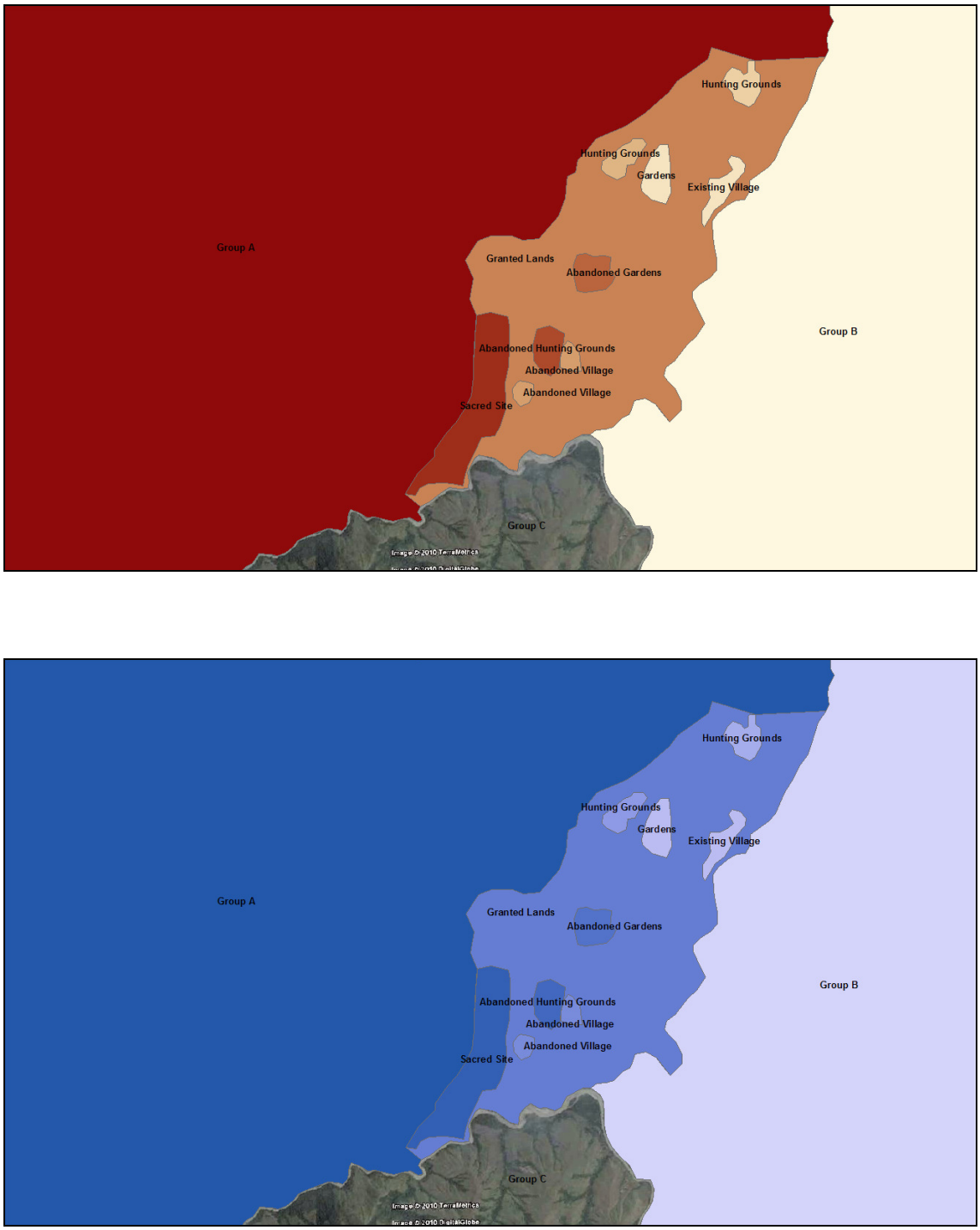

Figure 4.8 – Two variations of colour ramps for visualising mixed ownership

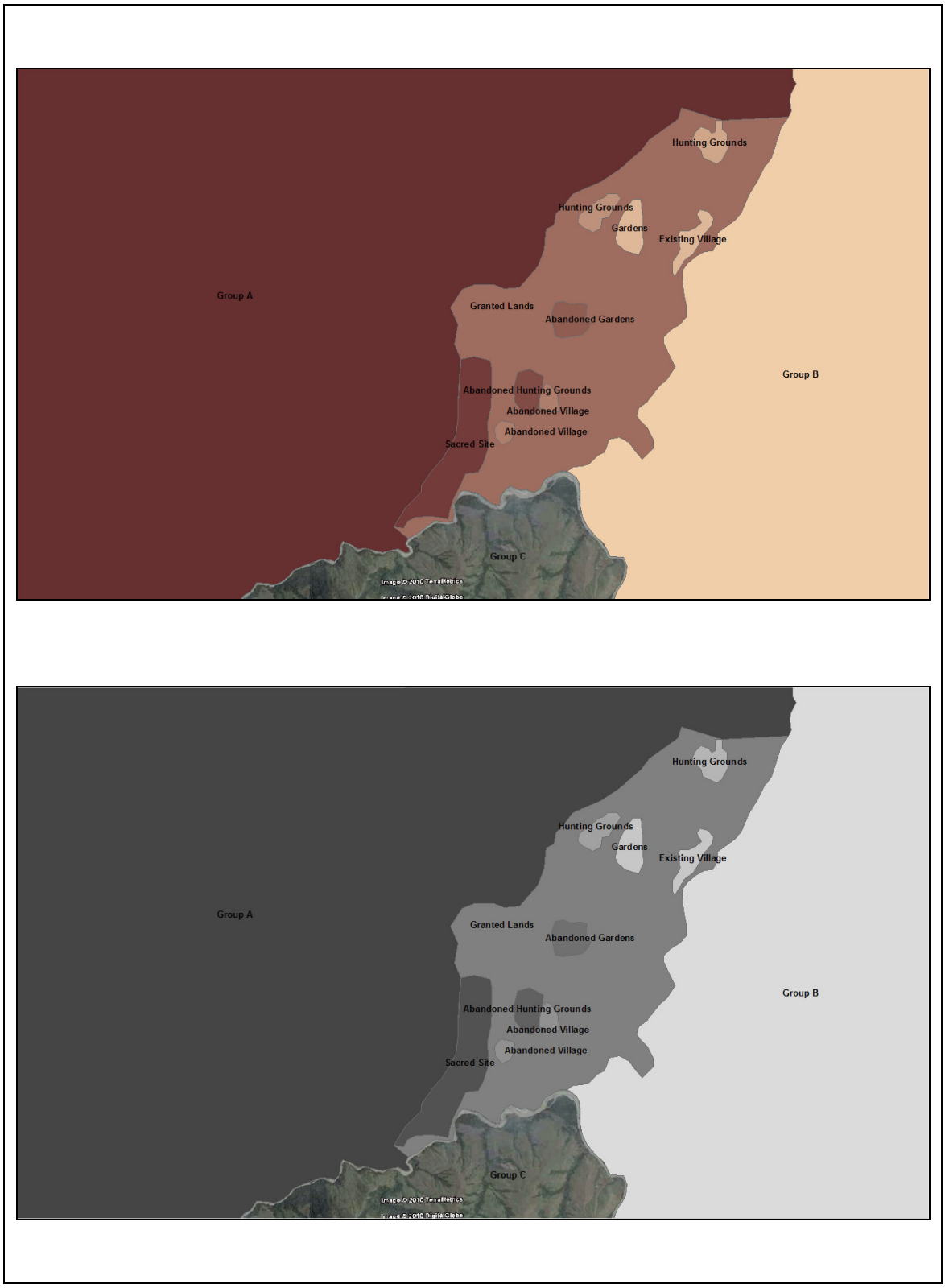

Figure 4.9 – Another two variations of colour ramps for visualising mixed ownership

4.3 Attribute Tables

Part of the power of a GIS is in the underlying attribute tables. These allow much more spatial analysis and data manipulation than a straight-forward visualisation.

Table 4.1 shows the fields and attributes of all the vector polygons shown in Figure 4.5. The Area field was first created by editing the attribute table and adding the new field. It was then calculated by right-clicking on the field name in the attribute table and selecting *Calculate Geometry.* More complicated calculations can be performed by selecting *Field Calculator.*

Table 4.1 – Attribute table of visualisation of full area

Landscape Name	Ownership Group A (%)	Ownership Group B (%)	Area (m^2)
Group A	100	0	61,201,918
Abandoned Village 1	40	60	87,105
Existing Village	11	89	218,879
Abandoned Village 2	40	60	97,110
Hunting Grounds 1	20	80	221,096
Abandoned Gardens	60	40	272,267
Gardens	11	89	270,560
Sacred Site	90	10	1,392,077
Hunting Grounds 2	25	75	194,396
Abandoned Hunting Grounds	70	30	241,808
Granted Lands	50	50	12,872,534
Group B	0	100	31,269,088
TOTALS			**10834 Ha**

By creating a separate shapefile for the intersection between the resource area and the underlying landmarks we are able to perform the same area calculation on the new polygons, which include portions of the original landmarks (refer Table 4.2). It is this attribute table that is then used to calculate further fields like compensation to be paid (refer Chapter 5).

Table 4.2 – Attribute table of visualisation of resource area of interest (refer Figure 4.7)

Landscape Name	Ownership Group A (%)	Ownership Group B (%)	Area (m^2)
Group A	100	0	5,125,897
Abandoned Village 1	40	60	43,784
Abandoned Gardens	60	40	272,267
Gardens	11	89	100,576
Hunting Grounds 2	25	75	121,035
Abandoned Hunting Grounds	70	30	94,101
Granted Lands	50	50	4,299,174
TOTALS			**1006 Ha**

4.4 Summary

The results shown in this chapter have shown a clear contrast between Boolean and fuzzy visualisations. As well as contrasting the visualisation styles, results were shown for when an area of interest for resource development was overlaid on the disputed area. This example highlighted the effectiveness or lack thereof of each visualisation method. A discussion of the effectiveness of these visualisation types, as well as the consequences on compensation for resource use, follows in the next Chapter.

Chapter 5
Analysis and Discussion of Results

5.1 Definition Comparisons

Results in Chapter 4 showed that there were a number of ways to visualise ownership, based on whether a Boolean or fuzzy definition was used. These had an impact not only on the visual-thinking of the viewer, but also on the usefulness of the map for determining compensation to owners for the use of resources.

5.1.1 Accurate Ownership Visualisation

As has been discussed in Chapter 2, it is important that GIS provide accurate map visualisations where the data exists and the use requires it. It is no longer acceptable that incorrect or misleading meanings are conveyed through the use of inappropriate mapping styles. Modern GIS and cartography enables us to fit the map to the purpose, rather than manipulating the data or purpose to fit the map. This is especially relevant when the context in which the map is being used is already a complicated one; the map should serve to simplify or enhance understanding, not add to the complexity.

The process of creating an ILG, and then what it means to be a part of that ILG, is very complex and even confusing. Part of the complexity arises from the disassociation between the land-owning corporation that is formed and identification of the actual land owned. In the past this has not been made easier by maps that have relied on Boolean definitions of ownership (refer Figure 5.2). To

try to compensate for this the new amendments to the *LGIA* now require a clear map of the land owned, with identification of any disputed areas. However, this still uses a Boolean definition of ownership and fails to accurately map the cultural understanding of ownership that has traditionally been transmitted orally for generations. The new mapping requirements should go further and require an accurate map of any disputed area, making use of modern GIS techniques like those discussed in this study.

The use of GIS 'zones of uncertainty', a vector form of fuzzy visualisation, provides the means to provide this accurate map. The fuzzy map is not only accurate where the Boolean map is not, but its use within a GIS enables it to be used for more than just visualisation. Where a Boolean type map that depicts ownership with a yes/no definition imposes a false reality on the 97% of land in PNG owned under customary title, the visualisation created using GIS 'zones of uncertainty' facilitates an accurate depiction of the cultural reality. This cultural reality exists apart from how it is mapped, so it is incumbent on the mapmaker to visualise it as accurately as possible to avoid inadvertently altering the reality.

When comparing the different visualisations of ownership presented in Chapter 4 we can therefore see that the Boolean definition is inaccurate, misleading, and simplistic to the point of contributing to the confusion and complexity found in the context of its use. The fuzzy visualisation provides an accurate visualisation that is sensitive to the cultural reality of orally transmitted definitions of ownership. Its colour ramp can be varied to suit the audience and it is a powerful tool to help the visual-thinking of stakeholders trying to understand the complexities of ILG incorporation.

5.1.2 Fuzzy or Boolean Definitions for Resource Compensation

Maps created in a GIS can be used for more than visualisation, as powerful as that aspect is. Tools exist to allow for further analysis of the data and for calculations based on that analysis and data.

A Boolean-style map can be readily created in a graphics software program and in the correct context can be accurate and useful. However, in the case of ILG definitions in PNG, they are neither accurate nor useful. To then translate this style into a GIS is wasteful, short-sighted, and ignorant of what a GIS can do. If this incorrect GIS visualisation is then used for further analysis, as can be expected when using a GIS, the results are also inaccurate and misleading. Thus, it is very important to not only check the accuracy of the data entering a GIS, but also to check the accuracy of the visualisation and use of that data.

An extension of this idea is shown in Chapter 4, where ownership information exists for the landmarks affected by the resource area of interest. However, by seeking to depict this information in an inappropriate Boolean style of yes/no ownership the results are misleading and subsequent calculations are incorrect. Figure 5.1 shows an attempt to “flatten” the ownership data into majority ownership, but this process is not suggested by the data itself. Rather, it is the preconceived mapping style that is dictating this manipulation. When the outcome can be very real injustice or conflict between stakeholders then the preconception needs to be addressed and a tool found that is better suited to the task.

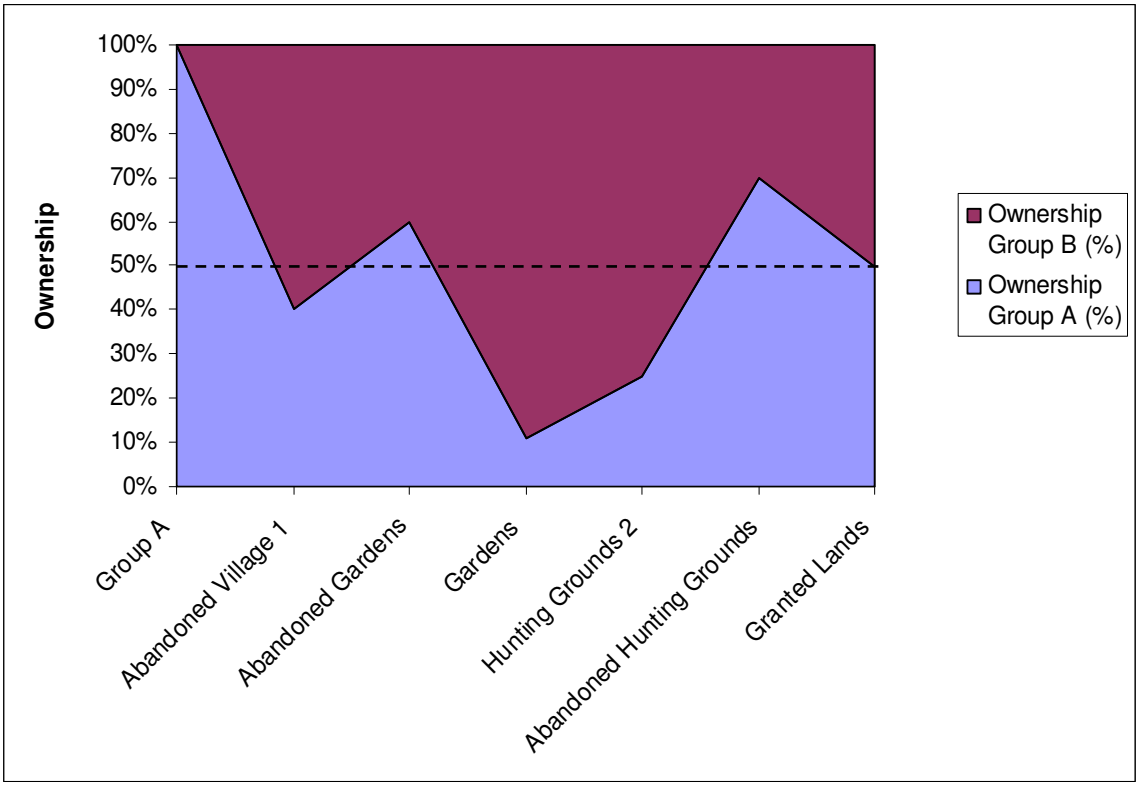

Figure 5.1 – Chart of ownership of landmarks within resource area with 50% threshold

When the flattened data from Figure 5.1 is used for calculating compensation due to stakeholders for the use of resources (in this case using a price per m^2) a skewed result is found (refer Table 5.1). While the skew is not dramatic in this example a different set of data could easily accentuate it, depending on the size of the landmarks affected and the percentage or ratio of ownership by each group.

Table 5.1 – Distribution of resource compensation using majority ownership Boolean definition

Landscape Name	Group A (%)	Group B (%)	Area (m^2)	Price Per m^2	Pay To Group A	Pay To Group B
Group A	**100**	0	5,125,897	$0.10	$512,590	$0
Abandoned Village 1	40	**60**	43,784	$0.10	$0	$4,378
Abandoned Gardens	**60**	40	272,267	$0.10	$27,227	$0
Gardens	11	**89**	100,576	$0.10	$0	$10,058
Hunting Grounds 2	25	**75**	121,035	$0.10	$0	$12,103
Abandoned Hunting Grounds	**70**	30	94,101	$0.10	$9,410	$0
Granted Lands	**50**	**50**	4,299,174	$0.10	$214,959	$214,959
TOTALS			**1006 Ha**		**$764,186**	**$241,499**

Likewise, the calculations resulting from using the straightforward Boolean definition of ownership (refer Figure 5.2), each of which could have been submitted by the Groups with their ILG applications, are also inaccurate and give results that are at best unjust, and at worst could lead to considerable conflict. Table 5.2 shows the compensation granted 100% to Group A, based on their claim of full ownership (refer Figure 3.2). This contrasts with Table 5.3 which shows compensation more evenly distributed.

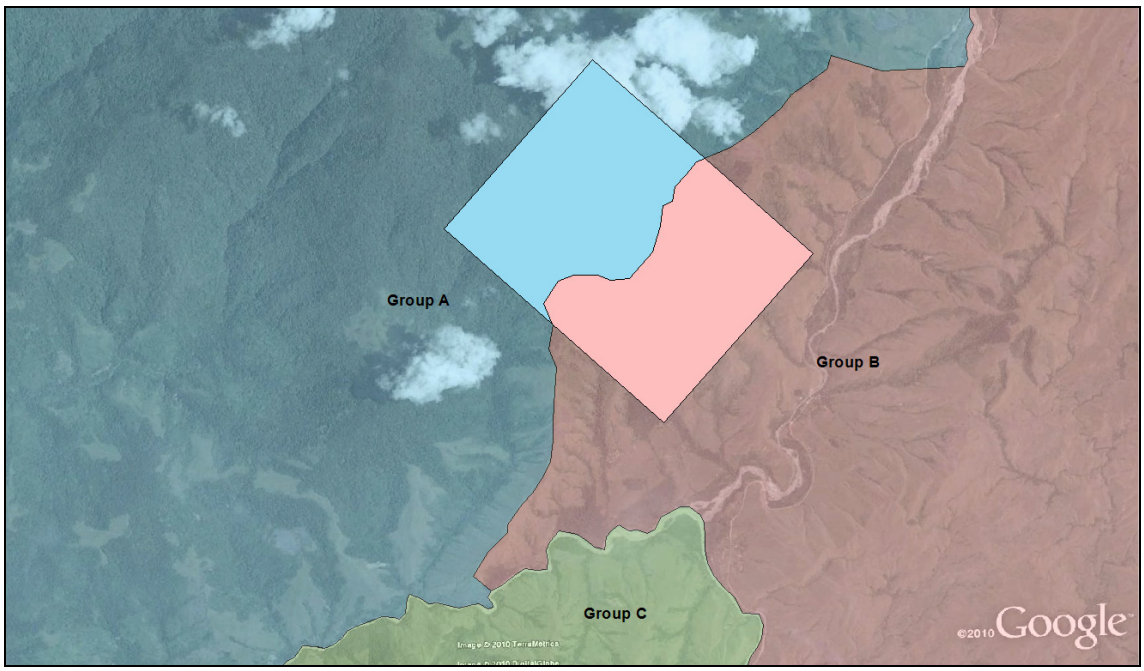

Figure 5.2 – Boolean ownership definition in resource area

While this even distribution might seem the "fairest", because it is not an accurate reflection of reality as understood by the actual landowners it can still be a cause of considerable conflict. This might be hard to understand from the resource company's point of view, especially considering the negative impact on visual-thinking that incorrect visualisations can have. However, once an accurate visualisation is examined it can become obvious how an equitable distribution of compensation can be achieved.

Table 5.2 – Distribution of resource compensation using Group A Boolean definition

Landscape Name	Ownership Group A (%)	Ownership Group B (%)	Area (m^2)	Price Per m^2	Pay To Group A	Pay To Group B
Group A	100	0	10,056,835	$0.10	$1,005,684	$0
TOTALS			**1006 Ha**		**$1,005,684**	**$0**

Table 5.3 – Distribution of resource compensation using Group B Boolean definition

Landscape Name	Ownership Group A (%)	Ownership Group B (%)	Area (m^2)	Price Per m^2	Pay To Group A	Pay To Group B
Group A	100	0	5,123,770	$0.10	$512,377	$0
Group B	0	100	4,933,065	$0.10	$0	$493,306
TOTALS			**1006 Ha**		**$512,377**	**$493,306**

When a GIS is used to intersect the resources area of interest with the underlying land (refer Figure 5.3) an attribute table can be generated that shows the ownership and size of the affected landmarks. Further calculations can then be made to determine the actual compensation due to each stakeholder, accurately based on the understanding of ownership that pre-existed both the resource company and the map itself (refer Table 5.4).

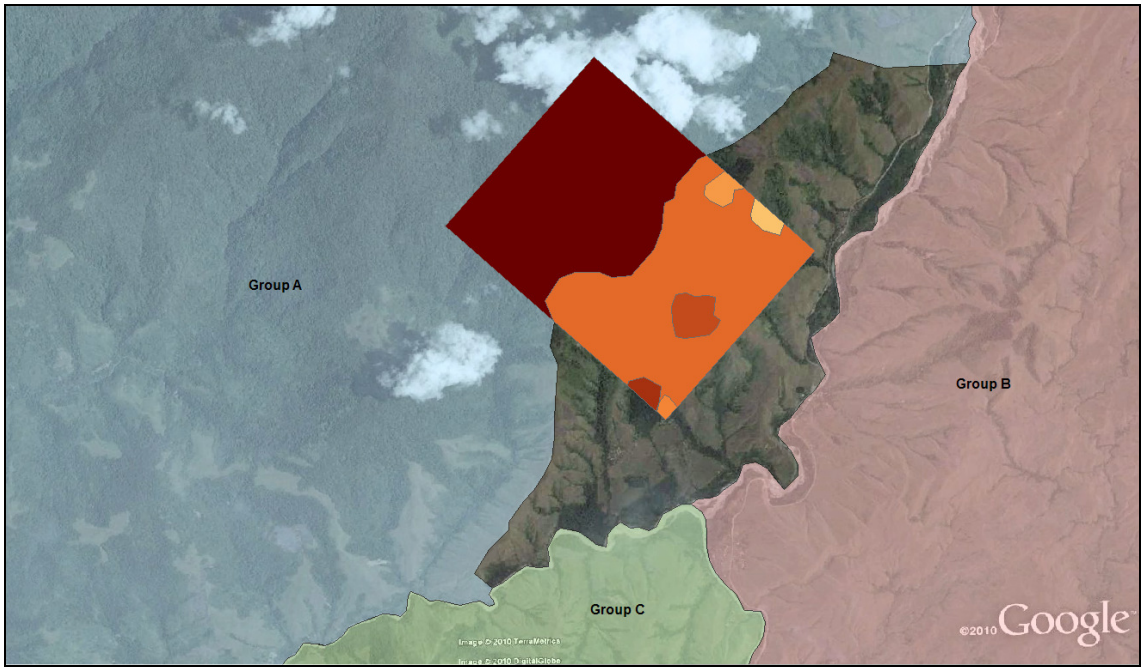

Figure 5.3 – Fuzzy ownership definition in resource area

Table 5.4 – Distribution of resource compensation using cultural ownership fuzzy definition

Landscape Name	Group A (%)	Group B (%)	Area (m^2)	Price Per m^2	Pay To Group A	Pay To Group B
Group A	100	0	5,125,897	$0.10	$512,590	$0
Abandoned Village 1	40	60	43,784	$0.10	$1,751	$2,627
Abandoned Gardens	60	40	272,267	$0.10	$16,336	$10,891
Gardens	11	89	100,576	$0.10	$1,106	$8,951
Hunting Grounds 2	25	75	121,035	$0.10	$3,026	$9,078
Abandoned Hunting Grounds	70	30	94,101	$0.10	$6,587	$2,823
Granted Lands	50	50	4,299,174	$0.10	$214,959	$214,959
TOTALS			**1006 Ha**		**$756,355**	**$249,329**

By using GIS 'zones of uncertainty' and the associated accurate attribute table, an amount of compensation is arrived at that is now equitable and just, and helps to minimise rather than aggravate potential conflict. As it is just a reflection of the understanding that already exists between the landowners, rather than an imposed definition, it leaves little room for misunderstanding and misuse. In this light, it is obviously the more suitable visualisation method for determining compensation to stakeholders based on maps of affected landmarks.

5.2 Suitability Analysis

5.2.1 Resource Overlay

Results shown in Chapter 4 and the above discussion have shown that using GIS 'zones of uncertainty' are a viable way of depicting ownership based on customary title, especially as it relates to mixed ownership within disputed areas. The method's suitability is further emphasised when used for additional analysis like calculating compensation due to respective landowners based on affected land.

However, it should be noted that a fairly simplistic compensation model was used and the visualisation method has not been checked against a more robust model.

5.2.2 Real Data

The hypothetical data and processing of that data used for this study has proven to be suitable. A successful method was determined to visualise the data and to then perform analysis on that data. It is envisaged that this method could be readily adapted to the use of real data, assuming that that data was framed in a similar way as the hypothetical data. It is currently uncertain whether ownership data exists in this form, given that its collection would likely need to be pre-informed by the methodology if this study. Further research would determine if existing data was able to be adapted to suit this visualisation model or not.

5.2.3 Effectiveness of Colour Ramp

It is difficult to determine the effectiveness of the colour ramp used in the fuzzy visualisation of ownership. Each viewer sees colour differently (Kenly & Beach 2004) and the combination of colours might suit one viewer but not another. With practice it is relatively easy to adjust or alter the colour ramps within ArcGIS, but it certainly is not intuitive. Ideally there should be a mechanism with this study's model to rapidly adjust the colour ramp to suit the viewer's preference. In lieu of that further research could be conducted on theories of colour and graphic design to determine the best combination of hue and saturation. In reality, it might not be possible to state that a certain combination is "more effective" than another equally viable combination.

5.3 Advantages and Disadvantages

As with any model there are advantages and disadvantages to using the one proposed in this study. While it has been shown to be more suitable than the Boolean style currently in use that does not automatically advocate its use for all cases.

Some of the advantages of the model include:

- It is a superior method of visualising the reality of ownership of land owned under customary title. It is accurate and allows for analysis and calculations that result in more potentially equitable and just outcomes than other methods. The visualisation is a result of the existing reality, rather than being imposed on the reality.

- The data needed for this model already exists as part of the oral tradition in PNG. Ownership is already understood and communicated amongst landowners, but to date has not been mapped accurately due to the manipulation that occurs when fitting the data to unsuitable visualisation models. The model in this study only needs the existing ownership data to be interpreted to percentages for it to be usable.

- The GIS methods used for this study are simple enough to be learned and applied by a range of users. This means that a large number of maps can be generated by different researchers. If the template from this study is followed then the maps should be compatible and adjacent areas researched by different users can be viewed.

- Because they are simple, the GIS methods allow for a flexibility that introduces a temporal element, in that ownership changing over time can also be readily mapped.

- The visualisation aspect of a GIS is readily marketed. This advantage can be used to explain the benefits of adopting this model, whereas a text-based model can be somewhat harder to advertise.

Some of the disadvantages of the model include:

- It will be time intensive (and thus possibly cost intensive) to gather the data in the form required for this model. Existing data on ownership does exist in government and anthropological studies, and a balance would have to be achieved between its use and new research. Field data collection should also be balanced with digitising landmarks from remote imagery. Regardless of the collection method used, elders within the landowning groups need to be consulted and some of these groups live very remotely.

- Visualising landmarks from aerial and satellite imagery in order to digitise them can be somewhat difficult for the unfamiliar user. A landmark that is readily identifiable from the ground might be considerably difficult to identify from imagery. The use of GNSS as part of the field data collection would be helpful in this instance (but only as it relates to locating landmarks; not in its current use of defining artificial Boolean style boundaries).

5.4 Usefulness of Results

More consultation with the stakeholders is required before determining the usefulness of the results of this study. These stakeholders include landowning groups and ILGs, governments at different levels, resource and associated companies, and other

academics working in these areas. The resource overlay, while more accurate, is only useful insofar as it is applicable and this needs to be determined in consultation with potential users.

While it is hard to measure the effectiveness on visual-thinking of this visualisation model, it is perhaps sufficient to note that it is more accurate and thus can potentially generate opportunities for a more culturally accurate way of defining ownership, especially as it relates to ILG registration. If this is the outcome then it would be justified in stating that the study results have been useful.

5.5 Summary

It has been shown through the discussion in this chapter that accurately visualising cultural boundaries using GIS 'zones of uncertainty' is superior to the current method of using a Boolean definition. Not only is the visualisation more robust and true to reality, but the associated attribute table can be confidently used for further analysis and calculations. These calculations give results that are more accurate and just, and can contribute to reducing conflict over land ownership as it relates to resource use.

While more consultation with stakeholders is required before determining the usefulness of these results, there are a number of advantages to this model that should make it an attractive option for consideration when creating maps depicting areas of dispute between adjacent landowning groups.

Chapter 6
Conclusion and Recommendations

6.1 Conclusions

This project was successful in achieving the objectives as outlined in Chapter 1. A map output was produced using GIS 'zones of uncertainty' to visualise boundaries created by mixed ownership of resources. This map was compared for effectiveness and accuracy against a Western cadastral (Boolean) style map, including visualisation and analysis of resource ownership.

Visualisation using modern mapping techniques is important as a means to analyse and understand ownership, as well as to influence thinking about cultural definitions of boundaries. Culturally accurate maps produced using GIS 'zones of uncertainty' meet the current need in PNG to address issues of ownership in 'disputed areas' for the purpose of creating and defining ILGs. There is an internationally recognised problem with dispute resolutions relating to applications of the *LGIA* and the current Boolean mapping style has proven inadequate in helping to solve it. If the visualisation method described in this study can be introduced into PNG the opportunity for a change in thinking can occur; a return to traditional thinking that could lead to the potential resolution of existing disputes resulting from applying the Boolean style of boundary definition.

Visualisation affects the thinking of the viewer. Thus, a map style using the Boolean approach of yes/no ownership influences the definition of boundaries towards a non-traditional understanding. While this might suit some stakeholders it has been shown to contribute to, rather than minimise, conflict. With the model proposed in this study it is

now possible to take the traditional thinking or understanding of the PNG landowners and influence the creation of a culturally accurate map. The map serves the user rather than the user serving the map. Its influence on visual-thinking is helpful and effective, and there is no need to re-interpret traditional boundary definitions to suit an inappropriate map style.

6.2 Recommendations for Practical Applications

Before immediate use of this model a number of areas should be investigated:

- Research should be conducted to see if this visualisation and analysis is acceptable to government and land-owning groups as part of the dispute resolution process. This step would involve considerable time and contact resources, both of which were unavailable to the author during the duration of the project.

- Research should be conducted to see if this visualisation and analysis is acceptable to resource companies for paying compensation. A more mature model could be created to include more complicated forms of compensation other than just the price per m^2 of affected landmarks calculation in the current model.

- Liaison with the PNG National Research Institute and the National Land Development Program is required to see if and how this study fits in with the land research framework. Recommendations can be made that disputed area maps required by new amendments to the *LGIA* should be as accurate as possible, within the capabilities of modern GIS. This would then extend to the suggestion that the model in this study be used where appropriate to create those accurate disputed area maps.

6.3 Recommendations for Future Research

Important areas still exist for future research to enhance or augment this study:

- Specific research should be conducted into how groups currently communicate ownership using lineage, marriage and generations, and how elders negotiate for acceptable use/ownership. This ratio should then be converted to percentages for use in this model and the resulting map checked for accuracy with the landowners.

- Having adjusted the technique and output based on feedback from the recommendations in this Chapter, field data should be collected for further testing and the results verified. A test should be included with three or more stakeholders in a disputed area.

- It would be advisable to create a more simplified GIS interface to record data and produce automatic visualisations. This could utilise a fixed template for data collection but provide flexible visualisations in the form of easily altered colour ramps. Ideally this GIS would be usable on GNSS-enabled mobile devices. It should be possible to store the data in the "cloud", or at least in a proprietary cloud within the PNG government, accessible by authorised users over the internet.

- While indigenous land ownership is somewhat different in Australia this visualisation model could be explored for use within Australia. The use of the data and visualisation will be different, but the positive influence on visual-thinking should be maintained.

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Appendix A
Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

FOR:	**Clinton Frank CAUDELL**
TOPIC:	Defining Anthropological Boundaries in Papua New Guinea Using GIS 'Zones of Uncertainty'
SUPERVISOR:	A/Prof. Armando Apan
PROJECT AIM:	To establish the historical, cultural and legal contexts for the definition of boundaries in the *Land Groups Incorporation Act 1974* (PNG) and then explore the feasibility of using GIS "zones of uncertainty" to more accurately define those boundaries.

PROGRAMME: (Issue C, 21 April 2010)

1. Research definition and application of boundaries in the *Land Groups Incorporation Act 1974* (PNG), including historical, cultural and legal contexts.

2. Research and describe a range of qualitative measures that satisfy the needs of all stakeholders in defining boundaries for land-owner groups.

3. Research and design a GIS that uses "zones of uncertainty" to map boundaries based on anthropological rather than physical definitions. This step includes sufficient data collection and analysis to create the GIS.

4. Produce a map output that shows the application of this GIS using the anthropological boundaries of the *Kesele* and *Keipte* groups as an example.

5. Compare the efficacy of this "fuzzy" map against the current cadastral map typically used by resource companies, using a range of qualitative measures.

6. Submit an academic dissertation on the research.

As time permits:

7. Seek feedback from stakeholders in the process, including a "western" user (e.g. resource company) and land-owner group regarding the useability of this mapping style.

8. Depending on the outcome of the research, examine other areas in PNG or Australia where this mapping style might be usefully applied.

AGREED: _____(Student) _____ (Supervisor)

DATE: _____

Appendix B

Extract from PNG *Land Groups Incorporation Act 1974*

INDEPENDENT STATE OF PAPUA NEW GUINEA.

Chapter 147.

***Land Groups Incorporation Act* 1974.**

ARRANGEMENT OF SECTIONS.

7. REGISTER OF INCORPORATED LAND GROUPS.

(1) The Registrar shall–

(*a*) keep or cause to be kept, in the prescribed manner; and

(*b*) retain for the prescribed period,

a register or registers of incorporated land groups.

(2) The register or registers shall contain–

(*a*) copies of all applications for recognition; and

(*b*) copies of all certificates of recognition issued under Section 5; and

(*c*) copies of all certificates of recognition issued under Section 9(1)(c); and

(*d*) all certificates given under Section 9(2); and

(*e*) all comments received under Section 6 or 9; and

(*f*) all orders made under Section 15 or 18; and

(*g*) the records of any appeal under Section 26; and

(*h*) copies of any accounts and records directed to be kept in the register or registers under Section 27(3)(c); and

(*i*) a record of any information supplied under Section 5(2) or 28; and

(*j*) copies of all statements by the Registrar under Section 5(9) or 9(3); and

(*k*) all notices given under Section 33(1); and

(*l*) all copies of accounts and records forwarded to the Registrar under Section Sch. 1.7(1); and

(*m*) such other matters as are prescribed.

(3) The production of a register or document purporting to be, or to be a copy of or extract from, a register of incorporated land groups is *prima facie* evidence of the matters contained in it.

(4) The part of a register dealing with an incorporated land group or a group the recognition of which has been applied for shall be open to inspection at all reasonable times by any person on payment of the prescribed fee.