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A GIS BASED SPATIAL DECISION SUPPORT SYSTEM FOR LANDSCAPE CHARACTER ASSESSMENT

By

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Copyright Statement

Abstract

A GIS BASED SPATIAL DECISION SUPPORT SYSTEM FOR LANDSCAPE CHARACTER ASSESSMENT

Faye Elanor Davey

Landscape Character Assessment (LCA) provides a structured approach to identifying the character and distinctiveness about the landscape. It is a tool used to identify what makes a location unique, a set of techniques and procedures used to map differences between landscapes based on their physical, cultural and historical characteristics.

Although the UK has committed to assessing all of its landscapes by signing the European Landscape Convention in 2006, only 60% of coverage has been achieved. The majority of LCAs are carried out by professional environment or landscape consultancies rather than 'in-house'. Geographical Information Systems are increasingly being used to collate and analyse data and produce character maps.

This research presents a Spatial Decision Support System (LCA-SDSS) based in ArcGIS 9.3 that can be used to support decision makers in conducting a LCA. The LCA-SDSS provides a method for storing data, a model base for the assessment of Landform, Ground Type, Land Cover & Cultural attributes and a method for the user to interact with the resulting maps.

Using the Tamar Valley Area of Outstanding Natural Beauty (AONB) as a study area the SDSS was developed and tested, resulting in character maps for each stage of

the modelling and a final characterisation map. These maps were compared to a LCA conducted by a professional environmental consultant and were found to have produced a good quality assessment as verified by the end user at the Tamar Valley AONB Partnership.

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Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

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List of Acronyms

ADC	Area of Distinctive Character
ALC	Agricultural Land Classification
ANN	Average Nearest Neighbour
AONB	Area of Outstanding Natural Beauty
AWI	Ancient Woodland Inventory
BAP	Biodiversity Action Plan
BGS	British Geological Society
CA	Character Area
CCC	Cornwall Country Council
CEH	Centre for Ecology and Hydrology
CPRE	Campaign to Protect Rural England
CQC	Countryside Quality Counts
CS	Countryside Stewardship
CT	Character Type
CWS	County Wildlife Site
DCC	Devon County Council

DEFRA	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EA	Environment Agency
EH	English Heritage
ELC	European Landscape Convention
ERCCIS	Environmental Record Centre for Cornwall and the Isles of Scilly
ES	Environmental Stewardship
ESA	Environmentally Sensitive Area
FC	Forestry Commission
GIS	Geographical Information System
GOR	Government Office Regions
HER	Historic Environment Record
HLC	Historic Landscape Classification
LCA	Landscape Character Assessment
LCM2000	Land Cover Map2000
LDD	Local Development Document

LDF	Local Development Framework
LDU	Landscape Description Unit
LMU	Landscape Monitoring Unit
LNR	Local Nature Reserve
MAGIC	Multi-Agency Geographical Information for the Countryside
NCA	National Character Area
NE	Natural England
NGO	Non-Governmental Organisation
NIWT	National Inventory for Woodland and Trees
NNI	Nearest Neighbour Index
NNR	National Nature Reserve
NP	National Park
NT	National Trust
OID	Object ID
OS	Ordnance Survey
PCA	Principle Component Analysis
PPS	Planning Policy Statement

RSS	Regional Spatial Strategy
SAC	Special Area of Conservation
SDSS	Spatial Decision Support System
SMR	Scheduled Monuments Record
SPA	Special Protection Area
SPD	Supplementary Planning Document
SSSI	Site of Special Scientific Interest
TVAONB	Tamar Valley Area of Outstanding Natural Beauty
WHS	World Heritage Site

Chapter 1 General Introduction

1.1 Rationale for research

Since signing the European Landscape Convention (ELC) in 2006 the UK has pledged to classify, map, describe and monitor their landscapes. This is achieved using a tool called Landscape Character Assessment which investigates what makes one landscape unique and identifiable from another landscape.

The UK has a long history with conservation matters, the intrinsic value of landscape being recognised in law from 1949 by the National Parks and Access to the Countryside Act (HMSO, 1949). This Act enabled the designation of National Parks (NPs), Areas of Outstanding Natural Beauty (AONBs) and Sites of Special Scientific Interest (SSSI). Landscapes have been assessed since the 1970s, initially in the form of landscape evaluation which focussed on what made one landscape *better* than another. This methodology was based on objective, scientific data and did not take account of visual or perceptual impacts. This approach was criticised largely because of the reductionist approach taken towards a subject as complex as a landscape (Swanwick, 2002). This led to the formulation of Landscape Assessment in the 1980s which focused on the factors that made one landscape *different* from another, the emphasis was on the 'relationship' between people and place rather than regarding the landscape as a physical or visual entity (Jensen, 2006).

The latest methodology 'Landscape Character Assessment Guidance for England and Scotland' was published in 2002 (Swanwick, 2002) and takes landscape character as its central focus and separates the classification process from description and the subsequent making of judgements (Swanwick, 2002). The framework created during the LCA process provides an important basis for the delivery of most area based policies, such as structure plans, agri-environmental schemes, conservation, landscape planning (Jensen, 2006), landscape monitoring and ecosystem services (Land Use Consultants et al., 2010).

The latest approach emphasises the perceptual concept of landscape, and how it may be viewed by different sectors of the community. In an effort to move away from 'expert' based assessments stakeholder input is required to gain local knowledge of landscape. The level of stakeholder involvement varies greatly between studies, depending on the willingness of the local authority to engage with interest groups and also whether the project budget can accommodate large community involvement projects, often only the input of the major stakeholders is included (Jensen, 2006).

The growth of Geographical Information Systems (GIS) during this time has led to a change in the way LCAs are carried out. Previously, paper maps and analogue data were collated; however digital data is now available from agencies such as Natural England (NE) or the Multi Agency Geographical Information for the Countryside (MAGIC) website (http://magic.defra.gov.uk). Although data sources and GIS software are more readily available, the majority of LCAs are still being carried out by 'experts' such as Landscape or Environmental Consultancies.

It is currently estimated that only 60% of local authorities have completed LCAs that adhere to latest guidance (Natural England, 2010), compared to 83% that had completed assessments by 1997 adhering to the previous 1993 guidance document (Swanwick, 2002). In a review of 56 current assessments, it was found that 88% of studies were completed by 17 different consultancies, and only 7 assessments were completed ‘in-house’.

This PhD research focuses on developing a Spatial Decision Support System (SDSS) that could be used as a tool by agencies such as AONB partnerships to conduct LCAs and support ‘expert interpretation’. This would enable characterisations to be completed by agencies that are familiar with their local landscapes enriching the quality of the assessment and decreasing budgetary demands that could be redirected into stakeholder participation.

1.2 Objectives of research

This research focuses on developing a Spatial Decision Support System that can be used as a tool within a GIS to produce a LCA framework. The Tamar Valley AONB (referred to as TVAONB hereafter) has been chosen as a suitable study area as it reflects some of the difficulties of obtaining a coherent LCA when dealing with issues such as cross border local authorities and ‘inheriting’ assessments that have been conducted using ‘expert interpretation’.

The main aim of the research is to create a tool that can be used by organisations such as AONBs to conduct a Landscape Character Assessment.

To achieve this, the research is structured into the following tasks:

- To understand what ‘landscape’ means today and how landscapes have evolved through physical and cultural influences
- Conduct a thorough investigation of the TVAONB landscape

- Understand the development of conservation ethics and the consequential development of landscape legislation and how it relates to LCA
- Review the methods used for and current status of LCA in England
- Investigate the use of GIS and SDSS for landscape characterisation
- Develop a LCA-SDSS to support experts in creating a LCA classification framework and produce character maps

1.3 Thesis Overview

It is essential to understand what 'landscape' means in the context of characterisation, how landscapes have evolved and how they are going to change in the future. Chapter 2 investigates what 'landscape' is and describes how landscapes have developed through the combination of natural and cultural factors, integrating the TVAONB study area as an example landscape and forming a desk study of the landscape character. Landscape evolution is synonymous with changing cultural perceptions and policies, and since the times of prehistory humans have been shaping the landscape, but it was not until the 19th Century that a 'conservation ethic' emerged. The conservation movement of the 20th Century is discussed along with recent European and national legislation relating to landscapes.

Chapter 3 provides a review of 56 LCAs collated from councils, National Parks and AONBs across England. The research focuses on how LCA is used as a tool to identify what makes a landscape unique and identifiable. The process of completing a classification is described and the data sources required to make a classification are identified, 2 main methods of assessment are discussed in the context of national landscape mapping initiatives. The current status of LCA and landscape monitoring projects in TVAONB study area is also reviewed.

In Chapter 4 a background of GIS is presented along with how GIS has been used within LCA methods in a European and UK context. A definition of SDSS is provided with examples of how SDSS have been applied in related areas of research.

The development of the LCA-SDSS is described in Chapter 5. The scope of the study and software choice is stated. The Models use several sources of data which are described in terms of their origin, accuracy and how they are prepared before they are analysed. The LCA-SDSS is made up of 4 main models to create characterisations based on Landform, Ground Type, Land cover and Settlement Pattern, a 5th model is provided in order to correct the outputs to minimise propagation of errors.

The results of the LCA-SDSS are discussed in Chapter 6 in terms of each models output and Chapter 7 presents the validation of the model outputs with a comparison of the output to the current 'expert' LCA for the TVAONB. Furthermore, the applications of the systems outputs are discussed for use with determining Landscape Character Areas (CAs) and Character Types (CTs) and how the framework can be used to monitor landscape change. Chapter 8 is a general discussion followed by the conclusions and areas for future work in Chapter 9.

Chapter 2 Landscape and Legislation

2.0 Introduction

The meaning of 'landscape' can vary between the fields of geography, ecology and the arts; therefore the definition of landscape is discussed in this Chapter in the context of the UK. It is characteristic of landscape to change and evolve (Rackham, 1986), and future landscapes will continue to be effected by changes in agriculture, forestry, housing needs & development and climate change (Natural England, 2007). Landscapes are beginning to suffering the effects of homogenisation (Washer, 2005) losing their characteristic features and distinctiveness and therefore it is necessary to identify the forces for change impacting on the landscape. The cultural perception of landscape has changed over time resulting in changing land uses and the development of legislation towards protecting the landscape and the need to monitor landscapes for changes. The TVAONB is the study area for this research and is discussed in terms of its landscape character and features.

2.1 Definition of Landscape

Landscape is a concept embedded in a range of disciplines including geographical ecological and artistic approaches. The earliest recorded *perceptual* recognition of landscape was a poem by Franseco Petrarca in 1336 inspired by scaling a mountain in France (Wascher, 2005). The term 'Landscape' was first used in the UK in the 16th Century in an artistic sense to describe a 'view'. The Shorter Oxford English Dictionary records 'landskip' in 1598 and was probably derived from Middle Dutch word ‘lantscap’. Landscape was in common usage in the English language from the first half of the 17th Century (Pryor, 2010) and has evolved to mean much more than just ‘a view’ (Countryside Agency, 2006). In 1802, the pioneering geoscientist Alexander von Humboldt defined landscape as ‘the total character of an Earth district’ (Wascher, 2005).

In relation to geographical landscapes, and those presented in this research, landscapes can be defined as ‘the arenas in which humans interact with their environment’ (Forman & Godron, 1986; Wiens & Milne, 1989) or ‘Landscape comprises the visible physical attributes of our external environment’ (Yarham, 2010) or ‘Land is turned into the concept of landscape by human perception’ (Swanwick, 2002). The word landscape implicitly implies that there should be an observer, without such the landscape would simply be land. A commonly expressed definition of landscape is from the ELC where a landscape is an ‘... area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe, 2000). Landscape is the ‘overall impression presented by the land, that involves generalisation and combination’ of different factors (Brabyn, 1996).

Landscape ecologists use definitions that generally focus on biophysical aspects such as ‘...a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in a similar form throughout’ (Forman & Godron, 1986) or, an ‘area that is spatially heterogeneous in a least one factor of interest’ (Turner, 2001), however the concept of grouping different aspects together in an area can be applied to the landscapes in this context. Figure 2.1 shows how natural, cultural and perceptual qualities come together to create landscapes (Swanwick, 2002).

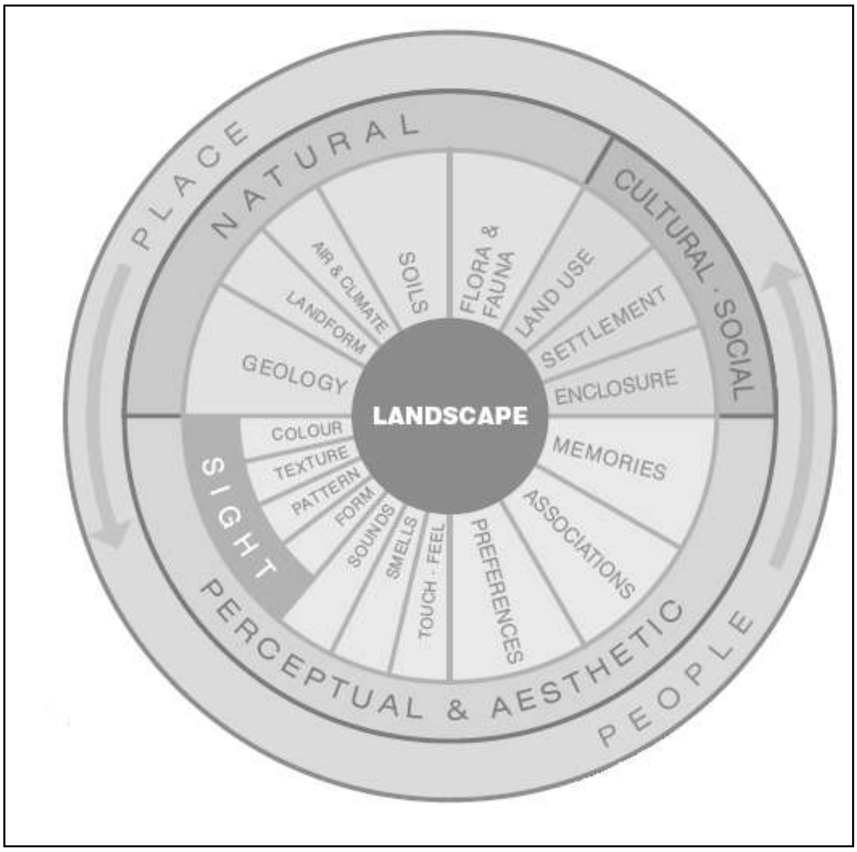

Figure 2.1 Natural, cultural, perceptual and aesthetic factors combine together to create landscapes (Swanwick, 2002)

The shape of a landscape is largely determined by the type of underlying rock and how durable that rock is. Forces such as compression causes rock to crack, slip or fold and can be eroded by wind, water and chemicals. Physical disintegration can also occur through extremes of temperature or frost. Lowland landscapes for example, feature low relief hills and valleys created through the uplift and folding of rocks and the deposition of eroded matter. They usually consist of soft rocks such as limestones, shales and clays.   Lowland rivers are often fast flowing and wide, and as the landform reduces in gradient, the river flow slows depositing the materials eroded from the upper reaches of the river creating sand and silts resulting in fertile floodplains (Yarham, 2010).

Rock contributes to the formation of soils, by providing the parent material of the soil, through the erosive forces acting on rock *in situ* or from unconsolidated deposits – previously derived from rocks in situ which have been transported by water, ice or gravity. Parent material provides the mineralogical composition of the soil, which strongly affects the vegetation that it can support, as well as determining grain size and texture (relative proportions of silt, sand and clay). This in turn affects many of the soils attributes such as, ability to retain moisture, its drainage and cation exchange capabilities. Soil formation is also affected by climate, time, the topography of the land and human influence which in turn affects the activity of the micro-organisms and insects that act to break down decomposing organic matter (Bardgett, 2005). Lowland soils that become waterlogged by either saltwater or freshwater from rivers or a high water table, give rise to areas of wetland which are largely covered by plants. Fens and bogs also appear over a great length of time and are rich in damp, peaty soils (Yarham, 2010).

The flora and fauna of a landscape are natural factors and there is often confusion between land cover and land use. A useful definition is 'Land cover is determined by direct observation… it is the physical material at the earth's surface…' while land use 'requires socio-economic interpretation of the activities that take place on that surface' (Fisher & Unwin, 2005 pp 85-86). For example, land cover could include grass, trees or bare ground whereas land use would indicate what the land is being used for e.g. a park or sports ground. Land use and land cover have many interrelated relationships, and one land cover class may be used for many things, such a trees which are used for both forestry and recreation; inversely residential land use may include a land cover of concrete, trees and grass (Fisher & Unwin, 2005).

England's land cover (See Figure 2.2) is largely represented by arable, horticulture and improved grassland (59.5%), broadleaved, coniferous and mixed woodland account for a further 10.5%, and settlements (rural, urban and industrial) account for 10.5%. The remaining 19.5% consists mainly of habitats that have a strong biodiversity value such as rough/grazed acid grass, neutral grass and calcareous grass (13.2%) (CEH, 2009).

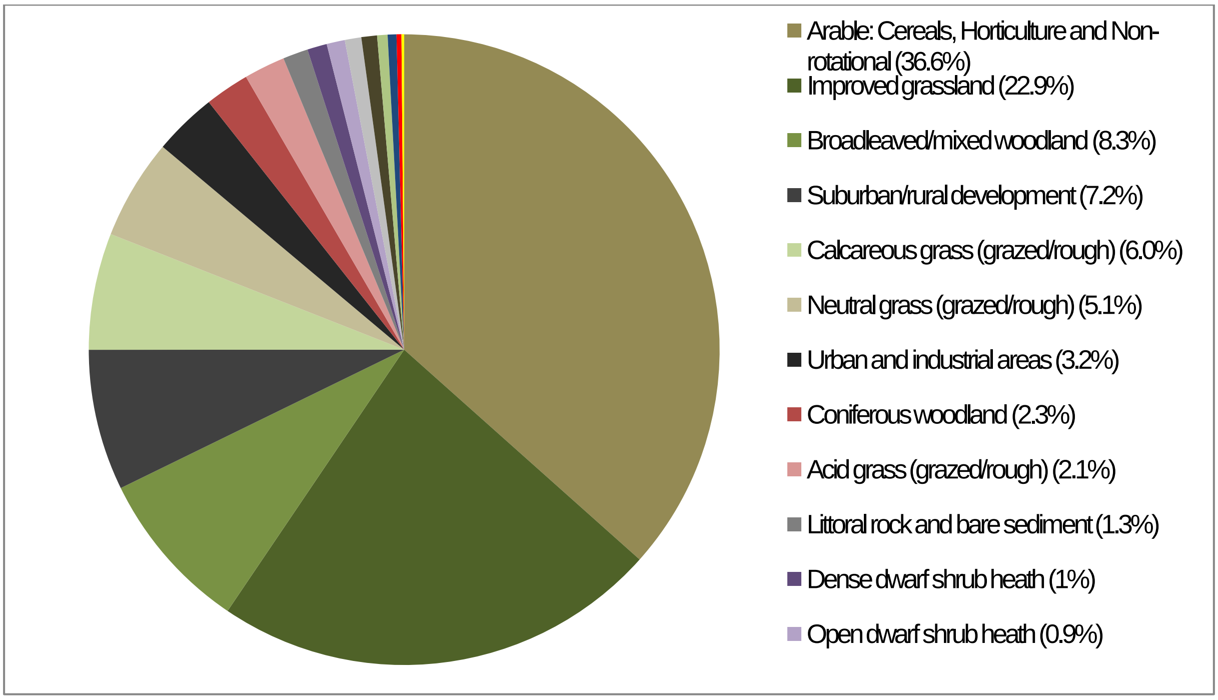

Figure 2.2 England's Land cover (Data Source: Centre for Ecology and Hydrology, 2009)

Air quality and climate also have an impact on the landscape, for example there is a marked difference between the landscapes of the Tamar Valley where sunny south facing slopes favour early production of crops (Countryside Commission, 1992) to the top of Dartmoor where frequent strong winds and poor visibility with mist and rain result in a challenging landscape for both wildlife and man (Land Use Consultants, 2010).

The cultural factors that are attributed to the making of landscape include land use, settlement patterns and enclosure patterns, there are few truly natural landscapes remaining. Widespread land use that occurs in the UK includes forestry, built-up areas, grassland and arable & horticultural (See Figure 2.3).

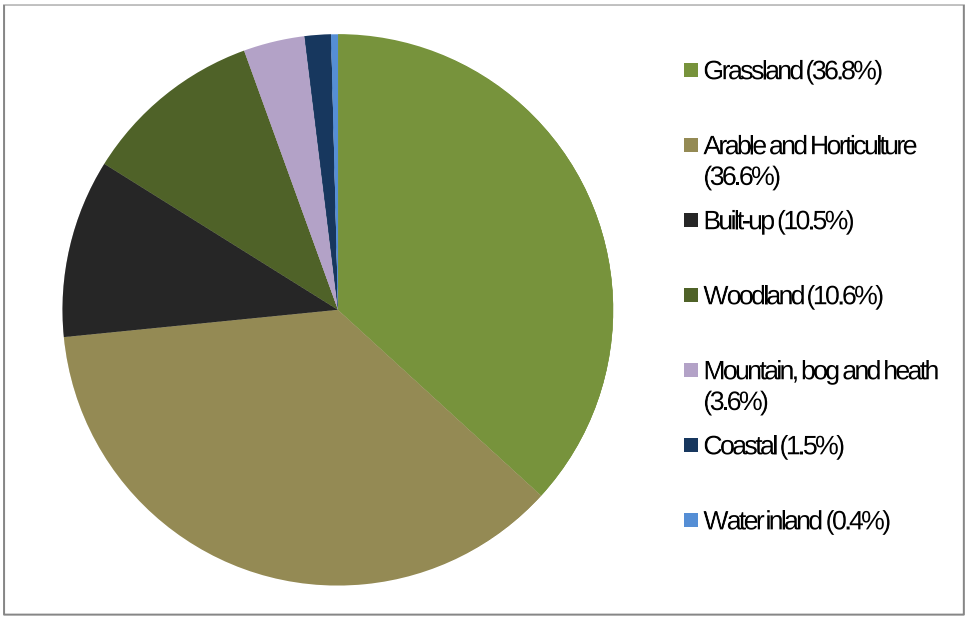

Figure 2.3 England's Land Use (Data Source: Centre for Ecology and Hydrology, 2009)

Enclosure patterns and types of enclosures can vary widely, for example there is a distinct difference in the small sinuous hedge banks found in Cornwall (Diacono Associates & White Consultants, 2007) to the network of rhynes (ditches) that are found in Somerset (Land Use Consultants, 2005). Many enclosures in Devon and Cornwall date back to medieval times (Cornwall County Council, 1994; Devon County Council & English Heritage, 2005) when a manorial system of governance was held in England. Land was divided up between favoured Lords and the more fertile areas of the landscape were divided into open field systems and compulsorily worked by peasants. Strip fields were created on common land, woods, river meadows, heaths and pasture which were worked by peasants for their own subsistence. By the 15^{th} century more land was being enclosed creating a landless peasant class who were no longer allowed to farm the commons and other ‘wastes’ (Pepper, 1996).

During the post-medieval era land and natural resources became a sought after commodity (Merchant 1982, Pepper, 1996). It became more profitable to enclose land for sheep rearing than to have peasant farmed arable land due to the rise of the Flemish woollen industry. From the early 1700s to the General Enclosures Act in 1845, parliament had passed 4000 acts of enclosure covering 23,838 km^2 of open fields and woodlands, with similar amounts being enclosed without applying to parliament (Pepper, 1996).

Settlements in the landscape can be dated back to prehistoric times and are often centred on sheltered sites with good soils and seasonal resources such as fishing and grazing land. Much of the land would probably have been covered by oak woodlands, apart from the higher moorlands which would have provided rough grazing. The earliest farms and hamlets were located on the valley sides between the moorland and the river which provided the best shelter, soils and water supplies or in areas of sparse woodland (Pryor, 2010).

The perceptual and visual aspects of landscape are also important, but more difficult to define than factors such as geology that have a clear classification. Landscapes are a meeting ground between natural and cultural influences from the past, present and future and sets the context for people's lives. Landscapes provoke both a physical and emotional response about how a landscape feels, smells, sounds and about the memories it provokes. Temporal factors can change these perceptions, such as the time of day or the season. Landscapes of complexity with variations in their pattern, texture, colours, boundaries and views are preferred to simple landscapes such as large arable fields or featureless flat landscapes (Swanwick, 2002; Natural England 2009). Landscapes are a cultural and natural asset that gives a sense of identity and of place to people, making a major contribution to health and well being (HMSO, 2007). Each person (e.g. Farmer, ecologist, tourist etc) may have a different perspective of the landscape, forming a unique sense of place.

Landscape Character can be defined as 'a distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another, rather than better or worse' or 'a distinct and recognisable pattern of elements that occur consistently in a particular type of landscape, particular combinations of geology, landform, soils, vegetation, land use, field patterns and human settlement create character' (Swanwick, 2002). Put simply it is the pattern which arises from the combination of different attributes, giving landscape a sense of place (Brabyn, 2009).

In order to reveal how different or similar landscapes are to one another a tool called LCA (See Chapter 3.1) is used to assess the landscape based on a number of natural and cultural attributes. The classification of landscape is essential to provide a framework of reference for communication in landscape management and research; it is driven by the practical need for solutions for managing landscape change (Brabyn, 2009). It can be used to strengthen institutional frameworks and promote a landscape perspective which can be incorporated into spatial planning, land-use and resource management (Natural England, 2007). LCA may be conducted for many purposes and the defined scope should always be stated at the commencement of the project (See Section 3.1.1).

An essential aspect of LCA is that it is based on the understanding of thorough research (Swanwick, 2002; Brabyn, 2009) conducted largely through a desk study (See Section 3.1.2). The TVAONB is the study area for this investigation and has been considered in terms of its physical and cultural attributes towards landscape character (See Section 2.5).

2.2 Landscape Change

Landscapes are continually changing, often in line with society's attitude and more recently government policy. It is characteristic of England's landscapes to evolve developing through a combination of social, historical and economic factors against a diverse physical background, but alarmingly it appears that it is this diversity that is being lost, resulting in the homogenisation of the landscape (Mücher et al., 2005).

Changes resulting from natural processes such as erosion or vegetation succession usually occur over a long period of time (although sudden storms or flooding can also cause considerable and rapid change). In contrast, the changes made to the landscape by human intervention can often occur very quickly (Natural England, 2009d). Future landscape will continue to change being influenced by changes in agriculture, housing & development needs, climate and progression towards a low carbon society (Natural England, 2007).

Changes in the landscape can be either large scale, such as new housing or industrial developments which also tend to be fast paced developments, or small scale, for example hedgerow or tree removal, small changes that can occur over generations which may be barely perceived at the time. The perception of landscape change and whether it is acceptable is influenced both by the scale and speed of the change. The attitude towards landscape by society has also changed over time and it has gradually been valued for its aesthetic appeal rather than just for its utilitarian purposes. Landscapes that were changed or damaged by activities such as mining are now being valued for their historical associations and biodiversity value, for example the Cornish and West Devon mining regions are now designated as a World Heritage Site (Natural England, 2009d; Cornish Mining World Heritage, 2011).

Farming intensified during the early and middle decades of the 19th century due to population growth and urban expansion, but the late 1870s saw the start of agricultural depression. A brief reprieve was seen during World War I but only lasted until World War II. During this period fewer hedgerows were cut and laid resulting in taller, wider hedges which became gappy with more hedgerow trees, from the 1880s barbed wire made an appearance on the landscape enabling hedges to be stock proofed without restorative planting (Barnes, 2006). Today fields remain the most familiar feature of an English landscape and hedges are so widespread that their presence is often overlooked until one is removed to expand field sizes or for development (Taylor, 2000).

Over the last century, landscapes have been changing as a result of decreased diversity, distinctiveness and ecological richness with much of England's landscape experiencing significant change since the 1940s with post-war growth and agricultural intensification (South West Environment Network, 2010). In some areas the process of standardisation and simplification of some of the components that result in landscape character have been gradually eroded. There has been an increase in urbanisation and the use of urban and suburban building styles and materials in rural areas. The increase of the built environment and the increase of traffic have also impacted on the feelings of remoteness and tranquillity. There has been a loss of some natural and semi-natural habitats such as ancient woodlands and unimproved grasslands, and a loss of traditional agricultural features such as farm ponds, hedgerows and traditional buildings (Natural England, 2009d). In the southwest landscapes have experienced:

- 45% Loss of wood pasture in heaths and historic parks in the last 50 years
- 22% hedgerows lost in Somerset between 1945 and 1994
- 35% Scheduled ancient monuments are at risk
- Loss of tranquillity
- Increased woodland cover, particularly forestry plantations
- Steady increase in the area of non-food crops since the mid 1980s

(Source: Natural England, 2009d).

Coastal squeeze may mean that habits such as wetlands, mudflats, salt marshes, beaches and sand dunes and the flora & fauna associated with them may be affected (Hulme, 2002). Landscapes may also see change as a result of human activities where society have planned for habitat connectively, flood management and changes in the patterns of agriculture (Natural England, 2009d).

It is predicted that impacts resulting from climate change will also alter the landscape, for example, through habitat fragmentation, changes in species composition and water resources (Deanwood et al., 2003). Society is now beginning to view landscapes as a resource for the mitigation of climate change and their use as carbon sinks and how they can be used to protect against flooding (Natural England, 2009). It is predicted that the average daily temperatures in the Southwest will increase by 2-3 degrees by 2050; this will mean that summer precipitation levels may decrease by 30% while winter levels may increase by 15%. Increased drought conditions as summer precipitation levels fall will result in an increased need for water management, reservoirs and other storage solutions (Hulme et al., 2002).

Climate change is likely to impact upon our landscapes by changing the patterns of habitats and species as they adapt to new conditions, coastal and alluvial flooding, coastal erosion and changes in agricultural productivity. These impacts are likely to be slow and subtle, unless there is a significant change felt from the increase of severe weather damage and flooding (Natural England, 2009d). The number of people at risk from river and coastal flooding could increase from the current levels of 1.6 million to between 2.3 and 3.6 million by the 2080s (Hulme et al., 2002).

Indirectly climate change may affect landscapes by the need to reduce carbon emissions or to sequestrate carbon. For example there may be an increase in wind energy developments both on and off shore, nuclear power stations, bio fuel and biomass production and there may also be an increase in the area of woodland or peat for the storage of carbon (Natural England, 2009d). The South West renewable energy targets for 2020 are for 15% - 20% of the regions energy to come from onshore and offshore wind power and tidal power (Southwest Regional Assembly, 2006). The Government is also proposing to change the permitted development rights for householders for micro generation of energy, (Department for Communities and Local Government, 2007) this is likely to impact on the local vernacular style of buildings and the local landscape character.

Agriculture and forestry make fundamental contribution to landscape character and how it changes (Rackham, 1986). Future change is likely as a consequence of the combined effect of climate change, reforms of the Common Agricultural Policy (CAP) and changing national policy. There may be an increased proportion of land cover of crops for biomass/energy by up to 20% of agricultural land (Natural England, 2009d).

2.3 Historical Overview of Landscape Legislation

The cultural attitude towards nature began to change when the demands on natural resources began to be incongruous with society's beliefs. Notions such as 'Mother Earth as the provider' and 'mining as digging into Mother Earths entrails' were disbanded and the belief that 'humans were separate and distinct from nature' emerged. In the period leading up until the 18th century there was an emphasis on creating a tamed landscape which was inhabited and economically productive with the appearance neatness, regularity and symmetry. By the end of the 18th century definitions of the picturesque were changing, complex and diverse natural landscapes were preferred to human made (agricultural) landscapes. This led to the formation of the Lake District Defence Society in 1883, which subsequently led to the development of the National Trust (NT) in 1895. In 1904 the first piece of legislation directed towards nature conservation in England was formed, when a bill was passed giving the NT the right to declare its property inalienable against development (Pepper, 1996).

In the 1920s the Council for the Preservation (now protection) of Rural England (CPRE) was formed to counter threats from urbanism and afforestation and joined other groups to press for the creation of NPs. The focus of these preservation efforts still remained largely elitist with the idea of protecting the landscapes from the people who wanted to discover bucolic rural England for themselves. During the interwar period a more scientific, managed approach to landscape and wildlife conservation emerged when ecology became institutionalised (the British Ecological Society having been formed in 1913). Politicians began to take warnings about habitat destruction seriously. The Nature Conservancy Council (later English Nature and now NE) was established in 1948 to notify the Government about which sites should become SSSIs. This was administered by scientists who were sympathetic to change in the landscape through positive management (Pepper, 1996).

In 1949 the National Parks Commission (later the Countryside Commission now NE) was formed, to conserve, recreate and enrich the scenic beauty of landscapes, with activities such as tree planting and reclamation of derelict land, with facilities for touring and the creation of long distance footpaths (Sheail, 1975).

The National Parks and Access to the Countryside Act (1949) was created to enable the protection of England’s diverse landscapes. NPs, AONBs and Heritage Coasts (non-statutory) have been created covering 23.2% of England’s territory (Natural

England, 2007a). When the first NPs were designated they were all upland areas, possibly attributed to the bias of the author of the 1945 government commissioned report on potential NPs, who was from Yorkshire Dales (Sheail, 1975). Shoard (1982) discovered that moorland enthusiasts found the wildness, naturalness (despite being created by man 4000 years ago) and the height added to the sense of aloofness and solitude.

AONBs were created and charged with a statutory duty to conserve and enhance the natural beauty of the designated area, safeguarding rural industries, forestry and agriculture along with the economic and social needs of the community. Unlike NPs, AONBs were not designated for their recreational appeal (Natural England, 2007a).

Since 1949 there have been 37 designations in England and there are 36 remaining AONBs after the South Hampshire Coast AONB was enveloped into the New Forest NP. During the 50 years that elapsed after the act was passed there had been a remarkable change in agricultural technique and a massive increase in recreation and tourism (Natural England, 2007a).

The inherent importance of landscape has shifted in the UK and Europe since the post-war period. In the 1940s and 1950s planners were largely interested in managing urban sprawl (Botequilha Leitão & Ahern, 2002) and landscapes were regarded as a medium for increased production and the recipient of emissions from human activities (Arler, 2000). There was little interest in rural planning or in the conservation of natural resources as it was believed that traditional rural practices would not cause environmental concerns and they would not conflict with interests such as conservation and recreation (Botequilha Leitão & Ahern, 2002).

The period after the 1940s saw great changes in the landscape where hedges were removed to make larger fields as tractors and combine harvesters became more widely used. Between 1946 and 1970 around 7245 km of hedgerow were destroyed in England and Wales each year from expanding fields and larger farms and in 1957 government subsidies were paid for hedgerow removal (Barnes, 2006).

In 1977 the Hedgerow Regulations (amended 2002) were established effectively bringing removal of hedgerows under the planning process. By 1982 government policy began to change and under the Capital Grant Scheme, subsidies were available for hedge planting (although hedgerows were still being lost). By 1990 funds were moved from overproduction to conservation, particularly through Countryside Stewardship (CS) where financial incentives were given to the replanting of hedges (Barnes, 2006). Environmental Stewardship (ES) schemes were created in 2005 to replace the previous agri-environment schemes. One of the primary objectives is to 'maintain and enhance landscape quality and character.' ES has two tiers, an entry level aimed at maintenance which is comprised of the Entry Level Scheme and the Organic Entry Level Stewardship and the Higher Level Scheme which is targeted at conservation and enhancement (Natural England, 2009b).

The focus of planning objectives gradually began to change from socio-economic concerns to those of the environment during the 1970s and 1980s (Roberts & Roberts, 1984). Planning policies also began to shift from the negative aspects i.e. where policies should help avoid the untoward consequences of activities onto our landscapes, to the positive view, where the natural qualities of our landscapes should be identified and mapped, so that they can be preserved or enhanced (Botequilha Leitão & Ahern, 2002).

The need to incorporate landscape considerations into environmental decision making began to develop during the 1970s, although at this stage the emphasis was very much on what made one landscape more valued than another. Landscape Assessments drew on only objective and quantifiable data to determine the 'value' of a landscape. A general consensus on how the assessment should be completed was never reached as there were arguments against reducing something as complex as a landscape into statistics and numerical values (Liddle, 1976; Swanwick, 2004).

In the mid-1980s Landscape Assessment used both objective and subjective views, establishing a difference between inventory, classification & evaluation and provided opportunities for incorporating people's perceptions of the landscape (Countryside Commission, 1987; Swanwick, 2004). In the mid-1990s LCA evolved (See Chapter 3), separating the process of characterisation; what makes an area different from another from making judgements; using the understanding of character to inform decision making (Swanwick, 2002).

LCA has become a central concept in landscape assessment, sustainable development and land management. Policy stake holders use LCA to utilise qualitative and quantitative evidence to reach management techniques for local areas (Wascher, 2005; Landscape Design Associates, 2002; Norfolk Coast Partnership, 2006; Dorset Area of Outstanding Natural Beauty, 2008), and to monitor how our landscapes are changing (Chris Blandford Associates, 2005; Diacono

Associates & White Consultants, 2007; Peterborough County Council, 2007; Chris Blandford Associates, 2008). A detailed investigation of LCA methods can be seen in Chapter 3.

2.4 Current Landscape Legislation and Policy

The European Landscape Convention is the first international treaty to be exclusively concerned with the protection, enhancement and management of landscapes (Council of Europe, 2000). The convention opened for signature in 2000 and as of April 2011 39 countries have signed with 33 ratifications. The UK signed and ratified the ELC during 2006 and it came into force in the UK on 1 March 2007(Council of Europe, 2011).

Article 1 of the convention deals with the following definitions (See Table 2.1) for the purpose of the treaty (Council of Europe, 2000):

Landscape	"means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors"
Landscape Policy	"means an expression by the competent public authorities of general principles, strategies and guidelines that permit the taking of specific measures aimed at the protection, management and planning of landscapes"
Landscape Quality Objective	"means, for a specific landscape, the formulation by the competent public authorities of the aspirations of the public with regard to the landscape features of their surroundings"
Landscape	"means actions to conserve and maintain the significant or

Protection	characteristic features of a landscape, justified by its heritage value derived from its natural configuration and/or from human activity”
Landscape Management	“means action, from a perspective of sustainable development, to ensure the regular upkeep of a landscape, so as to guide and harmonise changes which are brought about by social, economic and environmental processes”
Landscape Planning	“means strong forward-looking action to enhance, restore or create landscapes”

Table 2.1 European Landscape Convention Definitions

Article 2 of the convention states that the Act applies to all landscapes, in any condition, inclusive of land, inland water, marine, rural, urban, peri-urban, outstanding or degraded and Article 3 states the aim of the convention is “to promote landscape protection, management and planning and to organise European cooperation on landscape issues” (Council of Europe, 2000).

The implementation of the ELC through each countries own administrative arrangements is described in Article 4. To assist in delivering the broad outcomes of the convention the England Project Group (EPG) comprising of Department for Environment, Food and Rural Affairs (DEFRA), NE, and English Heritage (EH) was created. In addition to being the Government’s advisory body on landscapes, NE were charged with taking the ELC forward, working closely with the other EPG members, the Forestry Commission (FC), Non Governmental Organisations, Local Authorities, professionals and the public. The implementation of the ELC is mainly through Articles 5 and 6 which state that all landscapes will need to be identified, analysed for characteristics, forces and pressures for change, and monitoring of these changes. Each party agrees to (Council of Europe, 2000):

- Recognise landscape in law with regard to diversity of shared cultural and natural heritage
- Establish and implement landscape policies for planning, management and protection
- Involve the general public, local and regional authorities and any other interested parties in the definition of landscape policy
- Integrate landscape into planning, environmental, agricultural, social and economic polices

Article 6C1 of the ELC requires active participation in improving knowledge of its landscapes and each Party undertakes to identify its own landscapes, to analyse their characteristics and the forces and pressures transforming them and to take note of changes. Article 6C2, states that identification and assessment techniques should be guided by the sharing of experiences and best practice methodologies. Articles 8B focuses on training and education in landscape appraisal and operations with multi disciplinary training programmes for landscape policy, protection, management and planning for professionals in the private and public sectors (Council of Europe, 2000).

When signing the ELC the Government considered that the UK was already compliant with the conventions requirements (Natural England, 2007) and would further strengthen the planning policy statements already in place for the protection of the UK's landscapes (ODPM, 2005). Up until 1997 'landscape value' was largely recognised within the planning system and through the designation of NPs, AONBs and locally designated areas. A turning point was reached with Planning Policy Guidance Note 7 (PPG7): The Countryside – Environmental Quality and Economic and Social Development which prioritised ‘new ways of enriching the quality of the whole countryside whilst accommodating appropriate development’. The document states that with appropriate tools such as LCA, planning policies could be implemented that would provide sufficient protection of all landscapes without the need for rigid designations that could restrict sustainable development within rural areas (ODPM, 1997).

The Rural White Paper ‘Our Countryside: The future – A Fair Deal for Rural England’ (DEFRA, 2000) reaffirmed the notion that all landscapes should be valued and assessed. It endorsed the use of LCA as a way of informing decision making, identifying the local environmental and cultural features and for monitoring landscape change. The white paper also suggested strengthening the protection for NPs and AONBs.

In recognition of the increased pressures within AONBs and the need for continuing protection of the landscape, the Countryside and Rights of Way (CRoW) Act 2000 was created (Natural England, 2007a). The Act strengthens the position of the AONBs by ensuring the planning policies for the protection of the landscape are equivalent to those of NPs. The CRoW Act also strengthens management arrangements by requiring local authorities or conservation boards to produce management plans to provide a clear strategy for improving and enhancing AONBs.

Planning Policy Statement 7 (PPS7) - Sustainable Development in Rural Areas was published in 2004. Article 13 states local planning authorities should utilise tools such as LCA and should emphasise good quality, sustainable development which complements or enhances the local distinctiveness and the intrinsic qualities of the countryside. PPS7 also reaffirms that LCA alone should provide sufficient protection of the landscape without the need for local landscape designations (ODPM, 2004).

In 2005 Planning Policy Statement 1 – Delivering Sustainable Development (PPS1) was published stating (ODPM, 2005):

- Planning should promote sustainable patterns of development whilst protecting the natural and historic environment, the quality and the character of the countryside, ensuring sustainable uses of resources and high quality developments
- Polices and planning decisions should be based on up to date information of environmental characteristics (Article 19) and the enhancement and protection of the landscape and townscape character and historic environment should be included in development plans
- "Planning policies should seek to protect and enhance the quality, character and amenity value of the countryside and urban areas as a whole. A high level of protection should be given to most valued townscapes and landscapes, wildlife habitats and natural resources. Those with national and international designations should receive the highest level of protection" (Article 17)

Planning Policy Statement 5 (PPS5) – Planning for the Historic Environment (ODPM, 2005) underlines the importance of the historic environment in designated sites such as World Heritage Sites (WHS) as well as the broader historic environment and character of the landscape.

Although the Government considers the UK to be compliant with the ELC, further action is needed to raise the level of awareness of the measures relating to landscapes. A review by NE in 2007 concluded that although many of the national policies used the term landscape, few really 'embodied the Conventions intent' (Natural England, 2010). As planning policies and guidance are due for review these will need to be strengthened with targeted landscape measures linked to the PSA Delivery Agreement 28 which sets out a vision for a diverse, healthy and resilient natural environment with sustainable, living landscapes which have their best features conserved. Natural England's Position Statement: All Landscape Matter (Natural England, 2010a) called for land use, spatial planning and land management policies to be underpinned by up to date and comprehensive assessments of landscape at all scales, providing a sound evidence base from which judgements can be made.

2.4.1 Regional/ County Legislation

The Planning and Compulsory Purchase Act (2004) introduced a new 'spatial approach' to planning and introduced statutory regional planning for the first time.

The aim was to:

- Replace Regional Planning Guidance with Regional Spatial Strategies (RSS) taking account of a wider range of activities that would affect land use such as health, economic development and climate change.

- Replace County Structure Plans and Local Plans with Local Development Framework (LDF) which would conform with the RSS and national policy

However, in July 2010 the secretary of state announced that all RSS would be revoked with immediate effect, and that planning decisions would be primarily based on local policies contained in LDFs.

The Southwest RSS was in draft form when the announcement was made and would have replaced Regional Planning Guidance 10. The document stated that landscape provides an important setting for settlements and contributes to local distinctiveness and a sense of place and that the distinctive features and qualities that make up the southwest character areas should be maintained and enhanced (South West Regional Assembly, 2006).

LDF are made up of a number of Local Development Documents (LDDs) which may either be Development Plan Documents or Supplementary Planning Documents (SPDs). Planning Policy Statement 12 – Creating Strong Safe and Prosperous Communities through Local Spatial Planning suggests that a strong evidence base must be created. LCAs have been used as both an LDF, and adopted as SPD (Harrogate Borough Council, 2004; Northamptonshire County Council, 2005; David Tyldesley and Associates, 2007; Land Use Consultants, 2008).

An interim planning policy is currently in place in Cornwall since the six district councils and Cornwall County Council (CCC) combined to make a unitary council. The Cornwall Structure Plan 2004 and local policy is providing an interim framework until a LDF has been created. Policy 1: Principles of Sustainable Development states that development should enhance Cornwall’s character and distinctiveness and the conservation of the natural and historic assets. Policy 2: Character Areas, Design and Environmental Protection states that “The quality, character, diversity and local distinctiveness of the natural and built environment of Cornwall will be protected and enhanced”. Development throughout Cornwall should respect local character and retain elements that are important to local distinctiveness such as hedges, trees, natural and semi natural habitats. Development should positively relate to landscape character through design, positioning and the use of local materials and landscaping (Cornwall County Council, 2004).

In the Devon Structure Plan 2001 – 2016, policy CO1: “seeks to ensure that the overall quality of Devon’s landscape, including its variety and distinctiveness, is conserved for present and future generations.” Local planning authorities are to undertake more detailed assessments of how landscape character may be affected within and to identify opportunities for enhancement and/or restoration of that character. The structure plan and the adopted local plans are the interim planning guidance until each District Council produces their LDFs.

2.5 The Tamar Valley Area of Outstanding Natural Beauty Study Area

The Tamar Valley was designated as an AONB in 1995. It is located in the southwest of England on the border between Devon and Cornwall and includes the valleys of the Rivers Tavy, Lynher and Tamar which merge at Plymouth Sound. The area includes two counties, four districts and Plymouth City, crossing 24 parishes and has a population of 27,000 (Tamar Valley Service, 2010).

The TVAONB covers 161.5 km^2 split across two distinctive parts; the Tamar-Tavy section and the Lynher section (See Figure 2.4). The larger Tamar-Tavy section reaches from Tavistock and Launceston southward towards the estuary at Plymouth; it is bordered by the Dartmoor National Park to the east and Kit Hill to the west. The Lynher section extends from Saltash westwards towards St Germans (Tamar Valley Service, 2010).

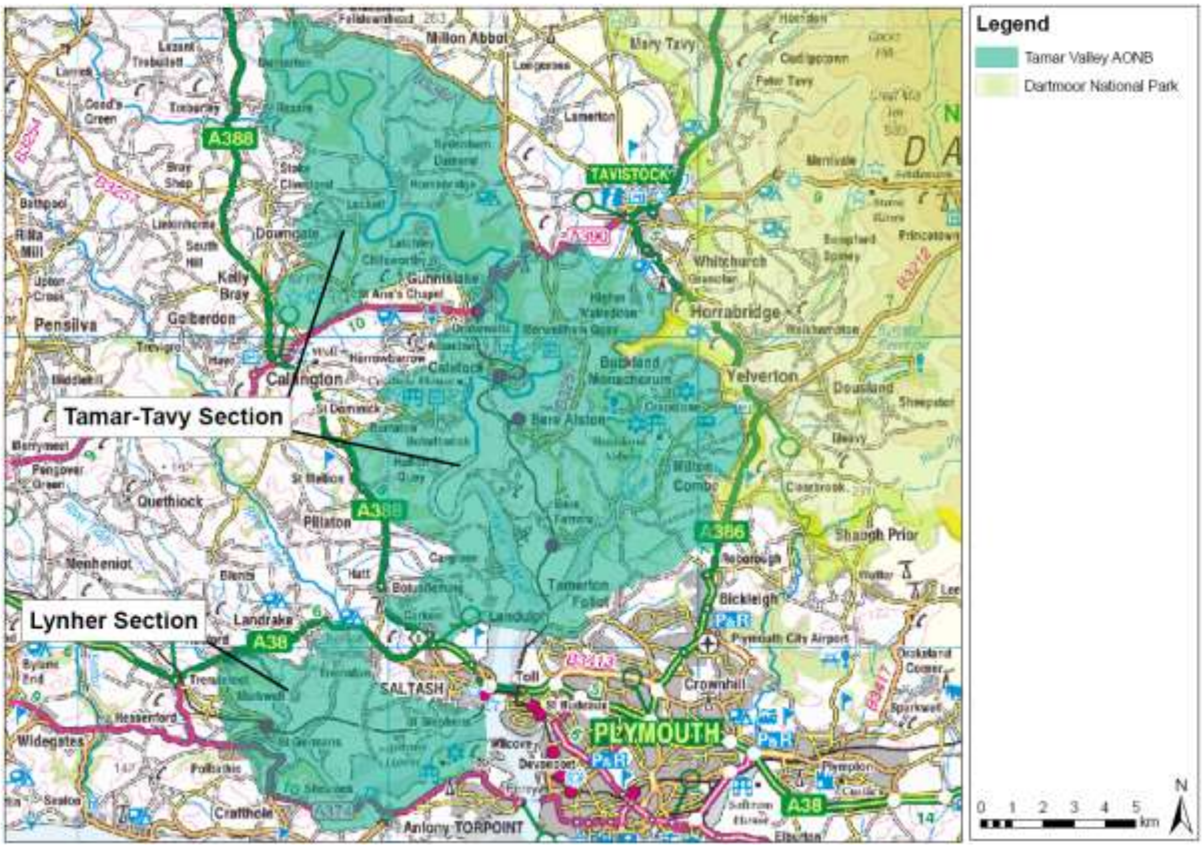

Figure 2.4 The Tamar Valley Area of Outstanding Natural Beauty is located on the border of Devon and Cornwall and forms 2 distinct sections: The Tamar-Tavy section and the Lynher. (Data source: AONB Boundary, Natural England (2011); Ordnance Survey Map, © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service)

The Tamar Valley was designated for its national significance as; an unspoiled river valley and estuary complex, its value as a wildlife resource, its visual quality and its artistic & public appeal. The valley landscape is diverse, contrasting between a slow meandering river running through agricultural floodplains, to a faster flowing river cutting through sections of cliffs and steep sided wooded hills to a gentle meandering river passing through pasture land and ending in an expansive estuarine landscape. A series of leats, weirs, quays, viaducts, lime kilns and stone bridges line the river, showing how important the river was for the transportation of food and crops, for mining activities and for recreation. The pattern of small farms, woodland and settlements have been preserved by land management practises leaving the farmed countryside with much of its medieval structure intact (Tamar Valley Service, 2004).

2.5.1 Physical Influences of Landscape Character

2.5.1.1 Geology

The geology of the TVAONB is dominated by the occurrence of Upper Devonian and Lower Carboniferous sedimentary rocks, including mud rocks, sandstones, cherts and volcanic sequences (Tamar Valley Service, 2004). The creation of the Tamar Valley occurred 400 million years ago in the Devonian period, millions of years before the granites were formed. The land was covered in a warm ocean, coral reefs grew and volcanic eruptions occurred. Mud and sand gathered around the reefs and the volcanic formations right into the carboniferous period where the rate of reef building declined and the accumulation of sands increased (Perkins, 1972). Towards the end of the Carboniferous period all the Devonian and Carboniferous material folded in a mountain building period known as the Amorican or Hercynian. The coral reefs formed limestone and the mud became shale and slates and together with the volcanic ashes, lavas and the sandstone, the majority of Devon and Cornwall were created (Perkins, 1972; Balchin, 1983).

Around 290 million years ago, Granite intruded between the folds of the sedimentary rock, resulting in the formation of Bodmin Moor and Dartmoor, with minor outcrops of granite appearing at Kit Hill and Hingston Down. Igneous intrusions through the granite and into the overlying sedimentary rock resulted in the formation of tin, copper, silver and lead during the cooling process (Perkins, 1972).

2.5.1.2 Landform and Hydrology

The TVAONB is a valley and water landscape which is representative of a classic lowland English river system. The source of the river Tamar can be found north of the designation at Woolley Barrows in Cornwall (Perkins, 1972). It has two main estuarine tributaries, the River Tavy and the River Lynher (Countryside Commission, 1992).

The Tamar is an ancient antecedent river which has maintained its course through the uplifting of the surrounding rocks. The high valley sides can be attributed to retreat of the high sea level in the early part of the glacial period about 1.5 million years ago. The slow lifting of the rock allowed the down cutting of the river into a deeper channel, therefore maintaining its course and flowing southwards along the borders between Cornwall and West Devon, rather than northwards towards the nearer north Cornish coast. At Greystone Bridge the river has the appearance of flowing into an area of land with a greater elevation (Perkins, 1972; Countryside

Commission, 1992). Large volumes of water were released during the ice retreat over the northern hemisphere flooding the lower reaches of the river to form rias, at the mouths of the Tamar, Tavy and Lynher rivers (Countryside Commission, 1992).

The geological structure has given rise to a river system that is diverse over a relatively small area. The lower reaches of the river are tidal exposing mudflats at low tide and an extensive waterscape at high tide (Tamar Valley Service, 2004). The open waters of the estuaries are surrounded by low, rounded hills which flatten out blending in with the salt marshes and mudflats (Countryside Commission, 1992).

In the middle valleys around Bere Alston and Calstock, there is a mixed landscape of steep wooded slopes with high cliffs, rocky outcrops and side creeks contrasting with sections of a slow meandering river passing through stretches of pasture land. The main valleys are enclosed by ridges either side which become steeper and higher towards the north. In areas where the ridge is particularly wide, such as the Bere Peninsula and the northeast of the Lynher, the landform becomes gently rounded and plateau like in character (Countryside Commission, 1992; Tamar Valley Service, 2004).

Further north, the river is deeply incised through the most prominent landform in the Tamar Valley - the high ridge that runs between Callington and Tavistock (Countryside Commission, 1992). The valley is at its highest here with Kit Hill reaching 331m above sea level (See Figure 2.5). In the upper Tamar Valley the river flows along a flat valley floor, with rounded hills and small incised valleys, creating a classic lowland pastoral landscape (Tamar Valley Service, 2004).

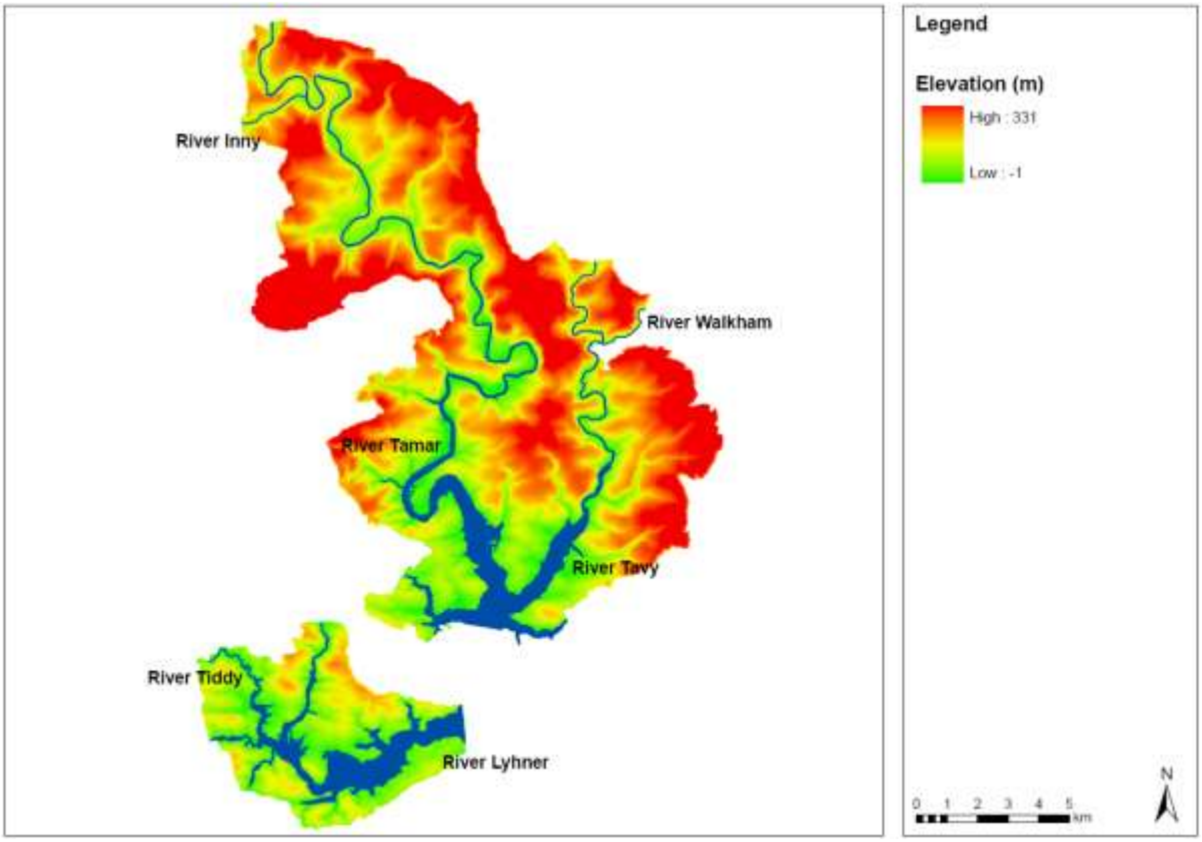

Figure 2.5 Elevation of the Tamar Valley Area of Outstanding Natural Beauty (Data Source: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service)

2.5.1.3 Soils and Agriculture

The soils of the TVAONB are generally loamy with good drainage. Flood plain soils occur along some parts the river, and there are patches of wet acid loamy and clayey soils. A localised occurrence of very acid loamy upland soil with a wet peaty surface is found at Chilsworthy (See Figure 2.6).

Soil quality combined with favourable climatic conditions has influenced the land use in the Tamar Valley. The Agricultural Land Classification (ALC) (See Figure 2.7) identifies mainly Grade 3 and 4 Agricultural land (Natural England, 2002; National Soil Resources Institute, 2010) which are generally well suited to dairy farming and growing cereals (Countryside Commission, 1992). Over the granite ridge, loamy soils appear over rock (National Soil Resources Institute, 2010) and are used for rough grazing land (Countryside Commission, 1992).

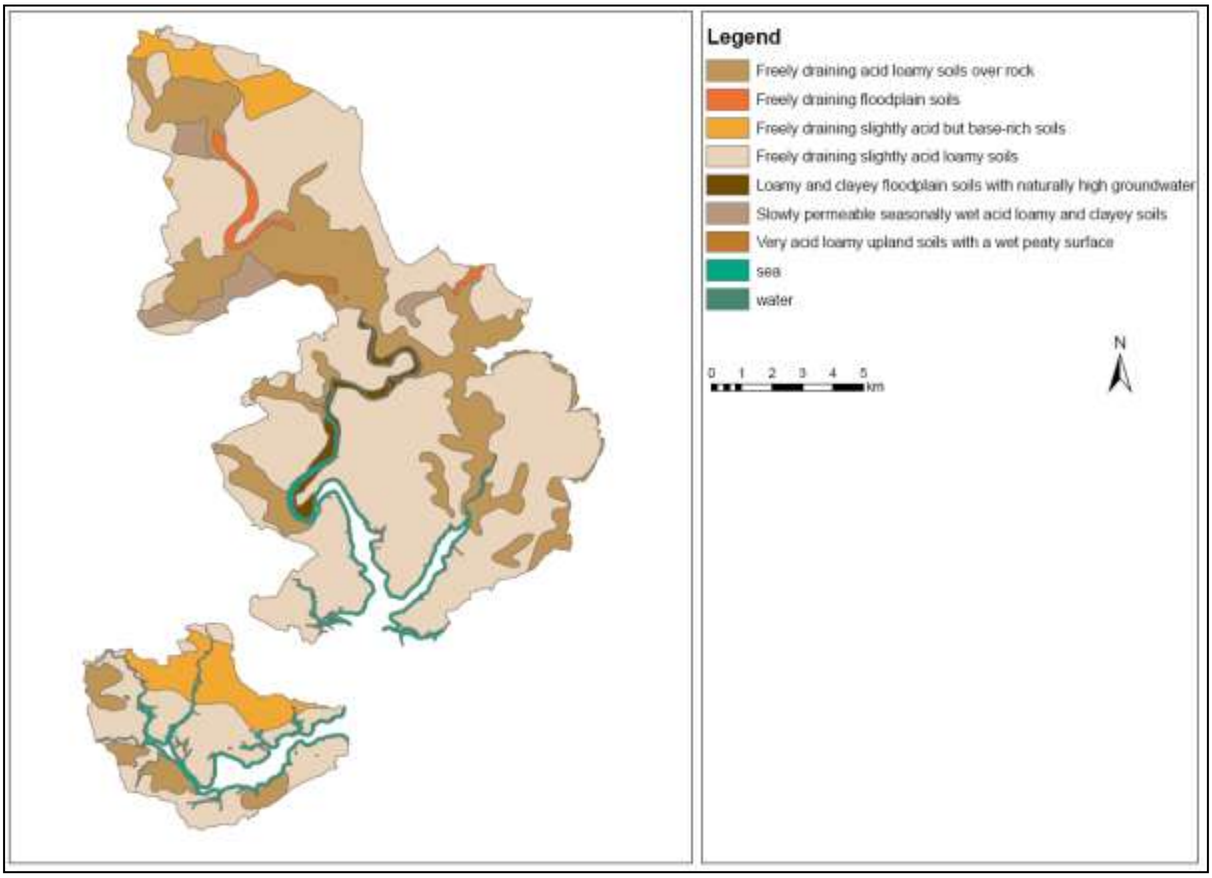

Figure 2.6 Soils of the Tamar Valley (National Soil Resources Institute, 2010)

The area experiences cool summers, mild winters and a high yearly rainfall. The transition between seasons is gentle with little variation between daytime and night-time temperatures. Cattle can be kept out all year round and on the south and east facing slopes, fruit can be ripened two weeks earlier than elsewhere in the country. Market gardening dominated the valley sides around Calstock and on the Bere Peninsula, though this industry is now also in decline (Land Use Consultants, 2008a).

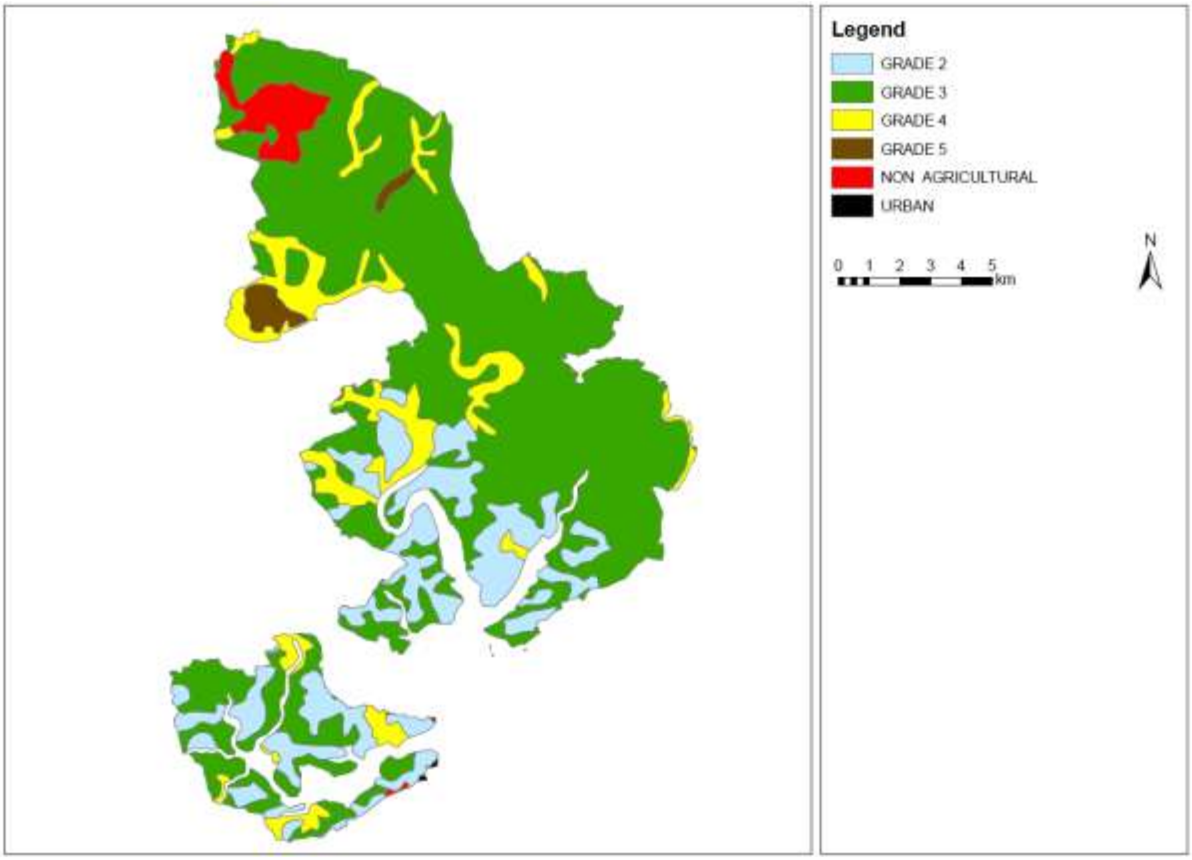

Figure 2.7 Agricultural Land Classification (Natural England, 2002a)

2.5.1.4 Ecological character

The Natural Area (NA) initiative is used as a framework for setting local objectives and priorities for nature conservation (See Figure 2.8). The TVAONB falls across two NAs: The Cornish Killas & Granites and South Devon (Natural England, 2010a).

The Cornish Killas & Granites NA is characterised by a mild climate with above average rainfall and strong salty winds. The landscape consists of undulating farmland, valleys and heaths with past and present mineral workings. There is an environment of mixed farmland with associated hedges, copses and woodland, with areas of outstanding parklands (Natural England, 2010a).

The South Devon NA has an undulating landscape of rolling hills with many river valleys. The geology of the area is important and there are and have been many quarries and mineral workings. The NA supports habitats such as ancient woodlands, lowland farmland and hedgerows (Natural England, 2010a).

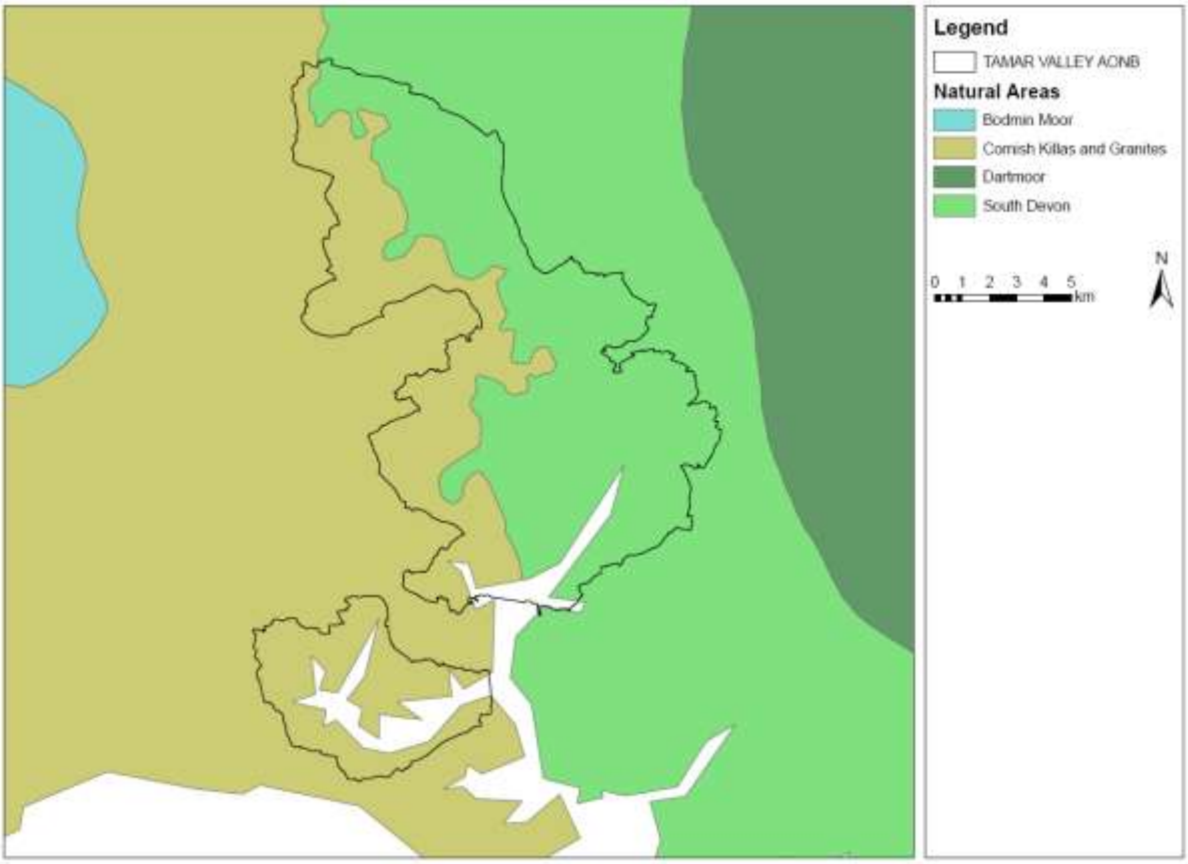

Figure 2.8 The Tamar Valley Area of Outstanding Natural Beauty falls into two Natural Area Profiles: The Cornish Killas & Granites and South Devon (Natural England, 2010a).

Within the TVAONB there are also several statutory nature conservation designations (See Figure 2.9) with many of the designated areas overlapping, for example the estuary is a Special Protection Area (SPA) and a Special Area of Conservation (SAC). A national designation of Site of Special Scientific Interest (SSSI) also covers and extends beyond these areas. There is also Local Nature

Reserve (LNR) at Lopwell Dam. Overall 10.3 % of the area of the AONB is under a statutory nature conservation designation (See Table 2.2).

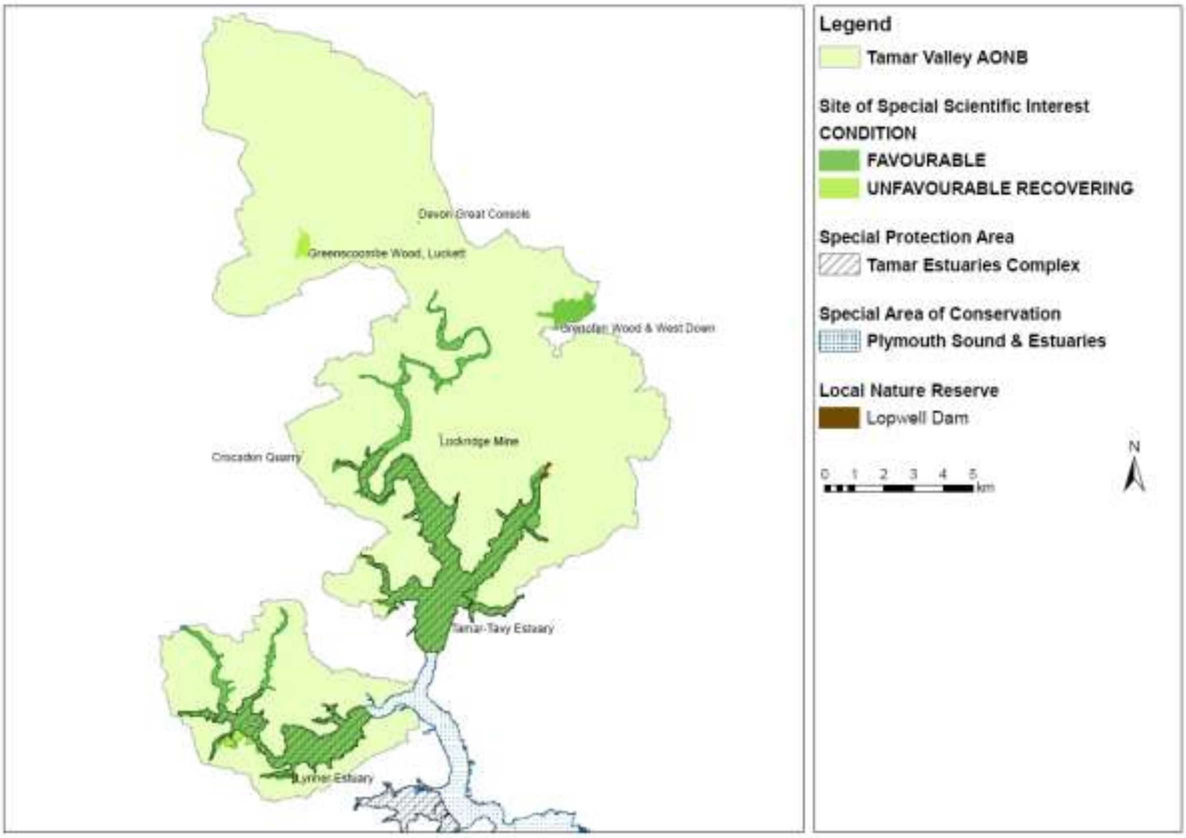

Figure 2.9 Nature Conservation Areas in the Tamar Valley Area of Outstanding Natural Beauty (Data Source: Natural England, 2011)

Designation	Sites within AONB		% of AONB area
	Area (km^2)	Number of sites	
Site of Special Scientific Interest	20.23	7	10.3
Special Area of Conservation	19.79	1	10.0
Special Protection Area	14.86	1	7.5
Local Nature Reserve	0.04	1	>1%

Table 2.2 Nature Conservation Designations

Analysis of the Landcover Map 2000 (LCM2000) (Centre for Ecology and Hydrology, 2009) reveals that the land cover of the TVAONB (See Figure 2.8) is 22% improved grassland and 27% arable (horticulture and cereals) this can be compared to the total coverage for England (See Table 2.3) and reveals a higher proportion of improved grassland and a lower proportion of arable land. Acid, neutral and calcareous grassland are also less common. Both broadleaved and coniferous woodland coverage is higher in the Tamar Valley. There are also some semi-natural habitats such as dwarf shrub heath land and saltmarsh. Additionally 17.7 km^2 (9%) is covered with ancient woodland (Natural England, 2009a). The proportion of land covered by developed land (urban and rural) is 5.81% lower than the total for England.

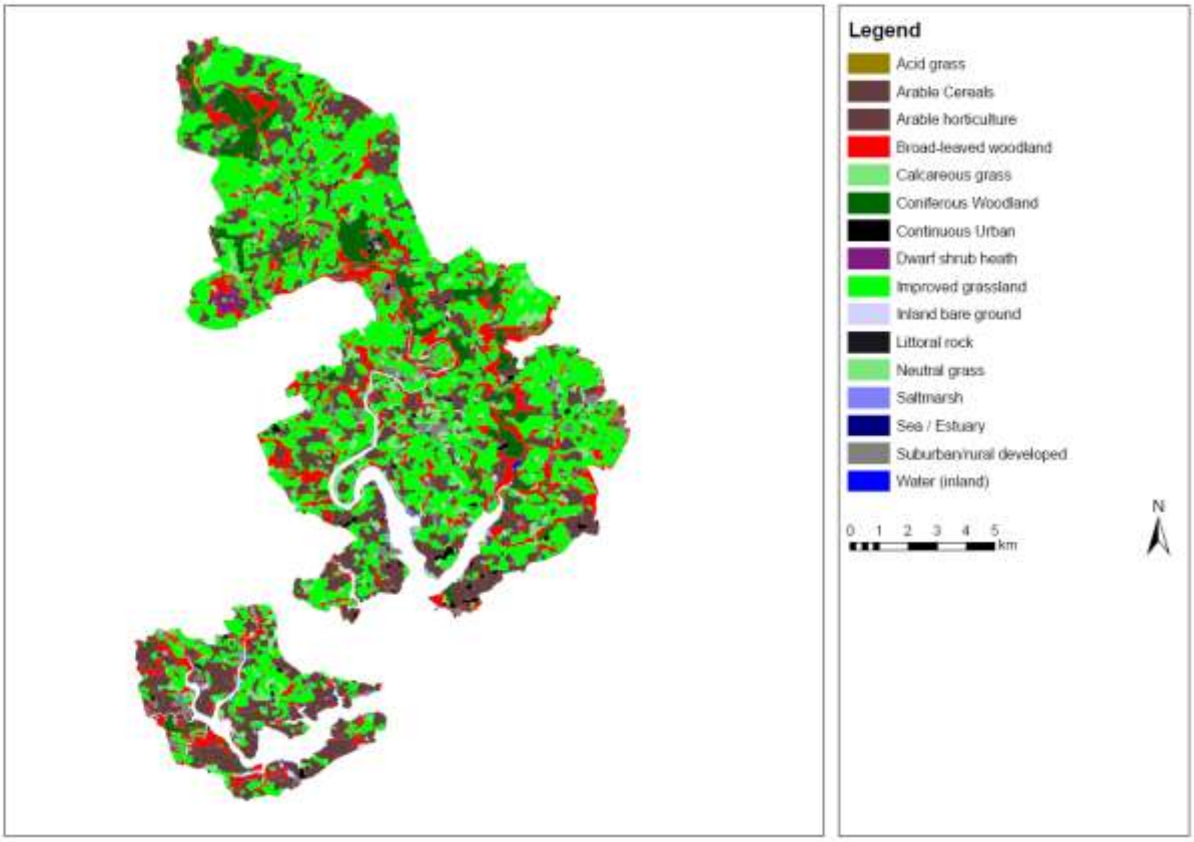

Figure 2.10 Land cover of the Tamar Valley Area of Outstanding Natural Beauty (Centre for Ecology and Hydrology, 2009)

	Tamar Valley		England	Difference
Land cover	**Area (km^2)**	**(Area %)**	**Area (%)**	
Improved grassland	72.06	37.3	22.85	14.45
Arable Cereals	26.61	13.77	36.55	-9.65
Arable horticulture	25.55	13.22		
Broad-leaved woodland	24.29	12.57	8.3	4.27
Coniferous Woodland	12.88	6.67	2.2	4.47
Calcareous grass	7.69	3.98	5.9	-1.92
Suburban/rural developed	6.9	3.57	7.2	-3.63
Sea / Estuary	5.14	2.66		
Littoral rock	5.09	2.54	1.2	1.34
Continuous Urban	1.97	1.02	3.2	-2.18
Acid grass	1.72	0.89	2.1	-1.21
Neutral grass	0.89	0.46	5.1	-4.64
Dwarf shrub heath	0.82	0.42	0.9	-0.48
Salt marsh	0.82	0.42	0.2	0.22
Inland bare ground	0.58	0.3	0.8	-0.50
Water (inland)	0.19	0.1	0.4	-0.30

Table 2.3 Land cover of The Tamar Valley Area of Outstanding Natural Beauty (Centre for Ecology and Hydrology, 2009)

2.5.2 Cultural Influences of Landscape Character

In addition to the physical influences on the landscape, human settlement and land use have also shaped the landscape. The geology and topography of the area has largely influenced how the land has been used by humans for settlement, farming and industrial activities.

2.5.2.1 Prehistory (Neolithic- AD c600)

Although there is little prehistoric influence on the Tamar Valley landscape, evidence of prehistoric settlement can be found at Kit Hill where a Stone Age long barrow exists (Countryside Commission, 1992). A Roman fort was also discovered near Calstock in 2008. This indicates that the Romans may have had an interest in the mineral resources of the area (Claughton & Smart, 2008) with Cornwall being the principle source of tin to northern Europe at the time (Cornish Mining World Heritage, 2011).

2.5.2.2 Medieval (AD c600 – AD c1600)

In the 9th century Hingston Down was the setting for a border battle between the Celts and the Saxons. The Tamar River has remained the border between counties since this time. Celtic chapels and Celtic crosses remain as visible evidence in the landscape today (Countryside Commission, 1992).

Evidence of medieval enclosures is widespread in the landscape, with rare examples of strip fields from within the medieval open field system near Latchley and St Dominic. In later medieval times narrow curving strip-fields from the enclosure of open fields with hedge banks can be found in places such as Bere Ferres, as can the ancient hedge banks that were used to enclose new fields. These types of enclosures are characteristically small and have sinuous boundaries (Devon County Council & English Heritage, 2005). There are also many areas of ancient woodlands that may date from this period, for example, Morwell Wood and Hatch Wood in the parish of Gulworthy.

Cotehele House in Cornwall is a fine example of a medieval estate which is now owned and maintained by the National Trust. The estate including its gardens, woodlands and parklands have remained protected from development (Balchin, 1983; National Trust, 2008).

Medieval settlements can also still be found in the Devon and Cornish landscape, in the form of farmsteads, hamlets and small villages, though many of the farmstead buildings may have been replaced in the 16th century. Medieval bridges can also be found, for example Greystone Bridge (built 1439), Horse Bridge (built 1437) and New Bridge (built 1530) which are located on the River Tamar (Countryside Commission, 1992).

The first documented case of mining occurred in 1292 at Bere Ferres, which was worked for the north-south aligned silver lead nodes. Tin mining for manufacturing both bronze and pewter became increasingly important in this period. Outcrops of tin and copper lodes can be traced from Callington and Kit Hill, crossing Calstock, Gunnislake and Luckett eastwards towards the edge of Dartmoor. The most successful mines of the area were the Devon Great Consols and Bedford mines to the east of the River Tamar and Drakewalls and Clitters mine on the west of the river (Claughton & Smart, 2008; Cornish Mining World Heritage, 2011). There is little evidence of medieval mining to be found in the landscape today, even though silver mining continued up until the 19th century (Perkins, 1972).

2.5.2.3 Post Medieval (AD c1600 – AD c1900)

Post medieval enclosures are present in the landscape and are characterised by straight field boundaries that were mainly laid out in the 18th and 19th century and were often as a result of subdivision or reorganisation of medieval field systems (Devon County & English Heritage 2005).

The effects of the Enclosure Act were felt at a lesser extent in Devon and Cornwall than much of the country, with no official acts of enclosure being granted during this time, however there were 71 awards made in the Devon County records for enclosures on ‘wastes and commons’ (Devon County Council & Devon Hedge Group, 1997).

Particularly fine designed 18th century landscapes can still be seen at Anthony House and Port Elliot in Cornwall which feature on the English Heritage (EH) ‘Register of Historic Parks and Gardens of Special Historic interest in England’ (English Heritage, 2010).

For many centuries and throughout the modern period land either side of the river Tamar has been owned by several large landowners which meant that the landscape remained largely unspoiled (Countryside Commission, 1992). The Abbots of Tavistock and later the Duke of Bedford and Earl of Mount Edgecombe had an interest in land and good husbandry and despite receiving royalties from the mining activities they regarded the industry as a nuisance. Even when the mining industry was dominating the scene the landscape remained mainly untouched with the exception of Calstock and the slopes around Gunnislake. The visible evidence of the mining industry that remains in the valley today comes from the copper and arsenic mining of the 18th and 19th centuries. The steep valley sides were perfect for building adits from the mines in the hills to the rivers below, and chimneys were sited away from homes and gardens (Perkins, 1972). The landscape was also conserved largely due to the lack of coal to fuel ancillary industry. Extracted copper had to be shipped to South Wales for smelting, avoiding the unsightly slag heaps of other mining districts. Once the minerals ran out the industry disappeared leaving only the legacy of its industrial archaeology (Perkins, 1972; Countryside Commission, 1992).

The boom of the mining industry drove a requirement for nearby settlements with Gunnislake being formed mainly during 1842 – 1882 as a direct result of the need of the miners and their families for housing, shops, commercial buildings and chapels. The workers housing was built in and amongst the industry, quarries and mine dumps, with that the result of the industrial and domestic architecture was interwoven (Cornwall County Council Historic Environment Service, 2004).

Calstock was already established as an important settlement before the industrial expansion of the 19th century. Calstock was flourishing due to the proximity of the river and the ability to import lime, agricultural goods and export produce. The introduction of more quays, the availability of building materials, the viaduct which linked the railways, the increase in shops, cottages, inns and chapels all served to increase the town’s wealth, fuelled by the need to export the produce of the local mines, and import their supplies. Calstock was unusual in that it was a significant inland river port that was becoming more significant in a time where ports were being moved to coastal areas rather than on river systems (Cornwall County Council Historic Environment Service, 2004a).

Alongside the mining industry, horticulture had also been important where produce was sold to local markets, however it was the arrival of the railway coupled with the rising unemployment rate due to the closure of the mines that prompted a boom in the industry. In 1889, 300 tons of strawberries, 4500 tons of potatoes and 8000 tons of broccoli were exported via the railway (Pryor, 2010)

2.5.2.4 Modern (AD c1900 – Present)

The tarmac roads of the early 20th century in conjunction with the addition of the railway which reached as far as Plymouth in 1849 (Paige, 1984; Patrick, 1989) saw the decline of transportation on the River Tamar. The overhead railway at Devon Great Consols was taken up and sold as scrap in 1903 and its dock was already silting up. The tidal nature of the river made other forms of transport more convenient and many quays ceased to operate unless they could be reached by motor boat. Morwellham quay ceased to operate on a commercial basis; some of the buildings still remain such as the Ship Inn, the chapel and the cottages. Vegetation began to regenerate and cover many of the industrial scars such as the arsenic and copper ore spoil heaps and the tranquillity of the pre-industrial age returned (Patrick, 1989). Throughout the mining era and around the mines, brickworks and mills, much of the landscape remained largely horticultural and used as a tourist destination for river trips and picnics (Perkins, 1972).

Modern enclosures were created as a result of hedgerow removal or reorganisation of early field boundaries into larger often arable fields. Modern enclosures also occur where there has been a change in land use, for e.g. a post-medieval orchard, water meadows, parkland or woodland have been turned into fields. Conifer plantations, areas of broad leaved plantations, replanted ancient woodland sites and woodland that have developed from scrub also date from this time (Cornwall County Council, 1994; Devon County Council & English Heritage, 2005).

Present-day settlements throughout the valley are varied but remain dispersed with many farmsteads and hamlets outside of the larger settlements such as Calstock, Gunnislake and Bere Alston (Roberts & Wrathmell, 2000).

2.6 Conclusion

Landscapes have been evolving for millions of years, and are still evolving and changing. The recent change in our landscapes has prompted a conservation ethic which has grown from protecting a small number of 'special landscapes' to the need to assess and protect all of our landscapes. LCA has evolved as an essential tool in this process, allowing landscapes to be identified and mapped for use in defining land management priorities and objectives and for use in monitoring future changes to our landscapes. The need to assess our landscapes has become imbedded in recent UK legislation.

Chapter 3 Review of Landscape Character Assessment

3.0 Introduction

LCA provides a structured approach to identifying the character, distinctiveness and making subsequent judgments about the landscape. In this Chapter the LCA methodology is described and examples given from a review of 56 LCAs have been sourced from district councils, AONBS and National Parks.

The National Landscape Typology and National Character Areas Maps are discussed as examples of two different classification methods, followed by a review of the current situation of LCA for the Tamar Valley AONB study area.

3.1 Landscape Character Assessment

Landscape Character Assessment is a tool to identify what makes a place unique and provides a method by which local communities and other stakeholders can contribute towards the decisions that affect their local surroundings (Landscape Character Network, 2006) and through which local authorities can gain a better understanding of the landscapes within their administration (Lee et al., 1999).

The Landscape Character Assessment Guidance for England and Scotland (Swanwick, 2002) outlines the main principles which are to:

- Focus on landscape character
- Identify areas of distinctive character by classifying and mapping them
- Define landscape Character Types (CTs) and Character Areas (CAs)
- Operate as a hierarchy, working with different scales and detail

- Link to historical landscape classification
- Involve stakeholders, and include their understanding of the landscape

LCA requires the identification and description of individual elements and consistent patterns of these elements within a landscape. Landform, field boundaries, soils, geology, vegetation, land use and human settlements make a landscape distinct and recognisable, and form a sense of place particular to a locality. Landscape character must be examined in a structured and systematic manner and be separated from the concept of landscape value. LCA is concerned with identifying areas of distinctive character, classifying, mapping and describing the character. Judgements of landscape value and informed decision making can then be based on the characterisation (Swanwick, 2004).

In 1997 it was estimated that 83% of counties had carried out assessments, the majority being after the 1993 Landscape Assessment Guidance (Countryside Commission, 1993) was issued (Swanwick, 2002). In 2010 only 60% of local authorities have completed LCAs that adhere to the approach in the most recent guidance (Natural England, 2010).

Landscape CTs and CAs are the typical output from the assessment. CTs are areas of landscapes relatively homogenous in character and are generic in that they may occur in different parts of the country. They share similar combinations of elements such as geology, topography or drainage patterns. CAs are discrete geographical areas of a particular landscape type that have individual character or local identity although in broad terms may share generic characteristics with other landscape types (Swanwick, 2004). CAs are used to communicate initiatives and information at a broader landscape scale (The Living Landscapes Project, 2006) and can be used to communicate a sense of place and identity which is relevant to people's lives (Natural England, 2007a). LCA aims to act as a hierarchical tool, where work at different scales is in a 'nested series' increasing in detail the smaller the scale (Swanwick, 2002).

During the characterisation the scope of the assessment is defined, followed by a desk study to create maps of common character and field survey work to confirm boundaries and add richness to the assessment though written descriptions. Judgments about landscape policy and land management ultimately lie with planning authorities, land managers and other stakeholders, the characterisation is used to inform this process (Swanwick, 2002).

3.1.1 Defining the Scope

Before the characterisation stage can begin, it is important to define the scope of the study. This includes the purpose of the study, the scale and level of detail, the audience, the resources and the outputs from the study.

3.1.1.1 The Study Purpose

LCA is used by policy stakeholders to combine qualitative and quantitative evidence to derive management practices relevant to local landscapes (Wascher, 2005). It is used as a tool within planning to inform development plans, to assist with identifying sites for future development, and informing the design considerations for development proposals such as housing, renewable energies or industry (Swanwick, 2002). LCA can also be used for landscape monitoring for the early recognition, assessment and prediction of landscape change and can focus on the human impact to landscapes (Sybre et al., 2007). Landscape conservation, management and enhancement are also important uses (Swanwick, 2002).

A review of the primary reasons stated for conducting an LCA (Since the 2002 LCA guidance was issued) revealed that most studies had several objectives (See Table 3.1). The most frequent purpose was to act as an evidence base for LDF, to be adopted as part of the LDF, used as a SPD or used to inform other development plans. Guiding future management plans and policy decisions was also cited, as was assisting in development control, planning decisions and appeals. For NPs and AONBs in particular, highlighting the special qualities of the landscape was important, as was informing management plans, guidance for land management decisions, conserving and enhancing landscape character, identifying forces of landscape change and monitoring landscape change.

PPS7 – Sustainable Development in Rural Areas (ODPM, 2004) states that LCA should provide sufficient protection to areas that have a high local appeal, without the need for rigid local designations. 2 of the studies cited ‘review of local landscape designations’ as being a primary purpose of the assessment and whilst Peterborough County Council (2007) did not cite this as a primary reason for the study, as a result of the assessment any reference to Local Landscape Designations have been removed from the Peterborough County Structure Plan.

Study Purpose	Landscape Character Assessment
Highlight the special qualities in the landscape	North York Moor National Park LCA (White Young Green, 2003), Chichester Harbor AONB LCA (Chris Blandford Associates, 2005) Conserving Character: Landscape Character Assessment and Management Guidance for the Dorset AONB (Dorset Area of Outstanding Natural Beauty, 2008), Norfolk coast AONB Integrated Landscape Guidelines (Norfolk Coast Partnership, 2006)
Guide future policy, decision making and management	North York Moor National Park LCA (White Young Green, 2003), Northampton Current LCA (Northamptonshire County Council, 2005), North Somerset LCA (Land Use Consultants, 2005), Braintree, Brentwood, Chelmsford, Maldon and Uttlesford Landscape Character Assessments (Chris Blandford Associates, 2006), Landscape Character and Capacity Assessment of Doncaster Borough (Doncaster Metropolitan Borough Council and ECUS, 2007) North Kesteven Landscape Character Assessment (David Tyldesley and Associates, 2007), Exmoor Landscape Character Assessment (Exmoor National Park, 2007), Peak District National Park Landscape Strategy and Action Plan 2009 - (Peak District National Park Authority, 2009), Cornwall and the Isles of Scilly Landscape Character Assessment (Diacono Associates & White Consultants, 2007) South Devon Landscape Character Assessment (Diacono Associates, 2007), Teignbridge District Landscape Character Assessment (Teignbridge District Council, 2009)
Provide a framework for more detailed assessments	East Sussex Landscape Assessment County (East Sussex County Council, 2004), Great Yarmouth Borough LCA (Land Use Consultants, 2008)
Identify pressures and problems in each Character Area	East Sussex Landscape Assessment County (East Sussex County Council, 2004), Chichester Harbour AONB LCA (Chris Blandford Associates, 2005), Lake District National Park Landscape Character Assessment and Guidelines (Chris Blandford Associates, 2008), Norfolk coast AONB Integrated Landscape (Norfolk Coast Partnership, 2006) Teignbridge District Landscape Character Assessment (Teignbridge District Council, 2009)

Figure 3.1 Stated Purposes of Landscape Character Assessments

Study Purpose	Landscape Character Assessment
Formulate landscape vision	East Sussex Landscape Assessment County (East Sussex County Council, 2004)
Landscape action plan priorities	East Sussex Landscape Assessment County (East Sussex County Council, 2004)
Use as a Supplementary Planning Document and to inform Local Development Framework or Village Design Statements and other development plans	Harrogate District LCA (Harrogate Borough Council, 2004), Chichester Harbour AONB LCA (Chris Blandford Associates, 2005), Northampton Current LCA (Northamptonshire County Council, 2005), North Somerset LCA (Land Use Consultants, 2005), Braintree, Brentwood, Chelmsford, Maldon and Uttlesford Landscape Character Assessments (Chris Blandford Associates, 2006), Landscape Character and Capacity Assessment of Doncaster Borough (Doncaster Metropolitan Borough Council and ECUS, 2007), North Kesteven Landscape Character Assessment (David Tyldesley and Associates, 2007), Great Yarmouth Borough LCA (Land Use Consultants, 2008), Peak District National Park Landscape Strategy and Action Plan 2009 – 2019 (Peak District National Park Authority, 2009), Cornwall and the Isles of Scilly Landscape Character Assessment (Diacono Associates & White Consultants, 2007), South Devon Landscape Character Assessment (Diacono Associates, 2007), Teignbridge District Landscape Character Assessment (Teignbridge District Council, 2009), Peterborough Landscape Character Assessment (Peterborough County Council, 2007)
Act as a springboard to instigate other studies	Rural Landscapes of Bath and North East Somerset (Bath and North East Somerset Planning Services, 2003)

Figure 3.1 Stated Purposes of Landscape Character Assessments (…cont)

Study Purpose	Landscape Character Assessment
To assist in development control, planning decisions and appeals	Harrogate District LCA (Harrogate Borough Council, 2004), Chichester Harbour AONB LCA (Chris Blandford Associates, 2005), Northampton Current LCA (Northamptonshire County Council, 2005),Braintree, Brentwood, Chelmsford, Maldon and Uttlesford Landscape Character Assessments (Chris Blandford Associates, 2006), Landscape Character and Capacity Assessment of Doncaster Borough (Doncaster Metropolitan Borough Council and ECUS, 2007), Landscape Character Assessment: Gloucestershire and Forest of Dean (Landscape Design Associates, 2002), Great Yarmouth Borough LCA (Land Use Consultants, 2008), Exmoor Landscape Character Assessment (Exmoor National Park, 2007), North York Moors National Park Landscape Character Assessment (White Young Green, 2003), Forest of Bowland Area of Outstanding Natural Beauty Landscape Character Assessment (Chris Blandford Associates, 2009)
Guidance for those making land management decisions, e.g. land managers, DEFRA, councils, AONBs	Harrogate District LCA (Harrogate Borough Council, 2004), Landscape Character Assessment: Gloucestershire and Forest of Dean (Landscape Design Associates, 2002), Great Yarmouth Borough LCA (Land Use Consultants, 2008), Exmoor Landscape Character Assessment (Exmoor National Park, 2007), Peak District National Park Landscape Strategy and Action Plan 2009 -(Peak District National Park Authority, 2009), Lake District National Park Landscape Character Assessment and Guidelines (Chris Blandford Associates, 2008), A Landscape Character Assessment of Tynedale District and Northumberland National Park (Julie Martin Associates et al., 2007), Norfolk coast AONB Integrated Landscape Guidelines (Norfolk Coast Partnership, 2006), Forest of Bowland Area of Outstanding Natural Beauty Landscape Character Assessment (Chris Blandford Associates, 2009), Peterborough Landscape Character Assessment (Peterborough County Council, 2007)

Figure 3.1 Stated Purposes of Landscape Character Assessments (...cont)

Study Purpose	Landscape Character Assessment
For the conservation and enhancement of character	Chichester Harbour AONB LCA (Chris Blandford Associates, 2005), Northampton Current LCA (Northamptonshire County Council, 2005),North Somerset LCA (Land Use Consultants, 2005), Landscape Character and Capacity Assessment of Doncaster Borough (Doncaster Metropolitan Borough Council and ECUS, 2007), Landscape Character Assessment: Gloucestershire and Forest of Dean (Landscape Design Associates, 2002), Conserving Character: Landscape Character Assessment and Management Guidance for the Dorset AONB (Dorset Area of Outstanding Natural Beauty, 2008), Norfolk coast AONB Integrated Landscape Guidelines (Norfolk Coast Partnership, 2006), Cornwall and the Isles of Scilly Landscape Character Assessment (Diacono Associates & White Consultants, 2007), South Devon Landscape Character Assessment (Diacono Associates, 2007), Teignbridge District Landscape Character Assessment (Teignbridge District Council, 2009)
To inform the AONB management plan	Chichester Harbour AONB LCA (Chris Blandford Associates, 2005), Exmoor Landscape Character Assessment (Exmoor National Park, 2007), Peak District National Park Landscape Strategy and Action Plan 2009 (Peak District National Park Authority, 2009), North York Moors National Park Landscape Character Assessment (White Young Green, 2003), Forest of Bowland Area of Outstanding Natural Beauty Landscape Character Assessment (Chris Blandford Associates, 2009), South Devon Landscape Character Assessment (Diacono Associates, 2007)
Develop Baseline datasets	Northampton Current LCA (Northamptonshire County Council, 2005), Landscape Character Assessment: Gloucestershire and Forest of Dean (Landscape Design Associates, 2002)
Review Local Landscape Designations	Landscape Character and Capacity Assessment of Doncaster Borough (Doncaster Metropolitan Borough Council and ECUS, 2007), North Kesteven Landscape Character Assessment (David Tyldesley and Associates, 2007)

Figure 3.1 Stated Purposes of Landscape Character Assessments (…cont)

Study Purpose	Landscape Character Assessment
To involve communities in development planning	North Norfolk LCA (North Norfolk District Council, 2009), Lake District National Park Landscape Character Assessment and Guidelines (Chris Blandford Associates, 2008)
Conservation and grant aid schemes	Peak District National Park Landscape Strategy and Action Plan 2009 -(Peak District National Park Authority, 2009), North York Moors National Park Landscape Character Assessment (White Young Green, 2003)
Monitoring Landscape Change and Landscape Condition	Chichester Harbour AONB LCA (Chris Blandford Associates, 2005), Lake District National Park Landscape Character Assessment and Guidelines (Chris Blandford Associates, 2008), North York Moors National Park Landscape Character Assessment (White Young Green, 2003), Forest of Bowland Area of Outstanding Natural Beauty Landscape Character Assessment (Chris Blandford Associates, 2009), South Devon Landscape Character Assessment (Diacono Associates, 2007) , Peterborough Landscape Character Assessment (Peterborough County Council, 2007)

Table 3.1 Stated Purposes of Landscape Character Assessments (…cont)

3.1.1.2 The Scale and Level of Detail

'Landscape scale' is a term widely used throughout planning policies, strategic plans and management plans and is generally regarded to indicate 'a large scale' (Forestry Commission, 2008; Natural England, 2008; Natural England, 2008a; South West Regional Assembly, 2006). The Draft Regional Spatial Strategy for the Southwest (South West Regional Assembly, 2006) stated that landscape scale 'can vary in size from a relatively small patch of woodland, to a large expanse of lowland grassland.'

The term is frequently used in an effort to recognise the wider setting and move away from site based conservation efforts such as fragmented habitat patches, to include areas of land that are more diverse and encompass many habitats i.e. all the habitats that may be occupied in an animal's life cycle (Natural England, 2008). The notion that landscapes are a 'distant view' can help when deciding what level of detail to capture i.e. 'Small objects such as snails and frogs are not part of a distant view. At a distance, vegetation form is distinguished but not particular plant species' (Brabyn, 2009).

LCA can and should be applied at different scales, for example the European Landscape Classification – LANMAP2 was created at a scale of 1:2.5M (Mücher et al., 2005). National scale assessments are typically at a scale of 1:250,000, for example, The Character of England's Landscapes, Wildlife & Cultural Features Map (Natural England, 2005) and the Landscape Typology (Warnock, 2002). Local authority LCAs are usually conducted at a scale of 1:50,000 or 1: 25,000 and local scale studies are conducted at a scale of 1:10,000.

When deciding on the scale of the study it is important to have established the reason for conducting the assessment, for example regional scale (1:50,000 or 1:25,000) study would be more appropriate when looking at planning applications.

The level of detail required then needs to be decided. CTs can be used to developed generic guidelines, however, CAs may be required to develop more place specific strategies (Swanwick, 2002). If a greater level of detail is required Landscape Description Units (LDUs) or Land cover Parcels can be produced which nest within the CAs or CTs.

76% of the reviewed LCAs created both CA and CT of these 32% also used a finer grain of mapping such as LDUs. 21% of assessments identified CA only, of these 2 included LDU analyses. Currently only one study was found to be published that identified only CTs with LDUs (Diacono Associates, 2007).

The LCA guidance (Swanwick, 2002) document suggests that LCA should be 'nested' with CTs being at a higher level with CA identified within them. For example, a CA identified at a national scale would be subdivided into CT at a regional scale, which in turn would be subdivided into regional CAs and so forth (See Figure 3.1). In practice, CAs and CTs seem to be identified at different scales, for example the Peak District National Park Strategy (Peak District National Park Authority, 2009) identifies Regional Character Areas and Regional Character Types within them. However, the Lake District National Park LCA and Guidelines (Chris Blandford Associates, 2008) identify 17 CTs with Areas of Distinctive Character (ADC) defined within them, in addition the ADC do not always nest with the CT and may include parts of different CTs.

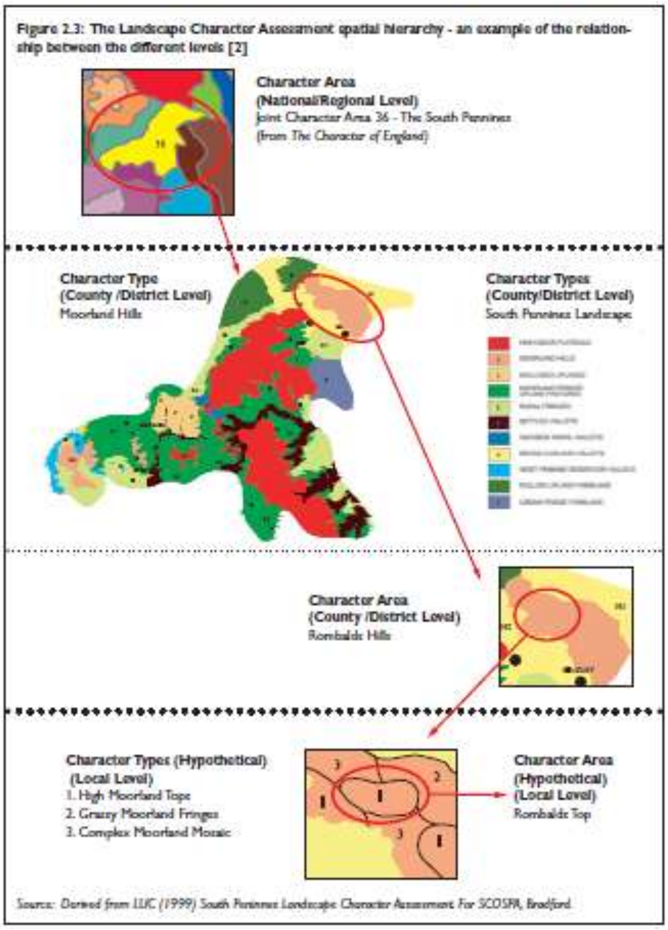

Figure 3.1 Landscape Character Assessment Spatial Hierarchy (Swanwick, 2002)

Assessments should also form a seamless transition across administrative boundaries (Swanwick, 2002) however this can be difficult and expensive to achieve. For example, the Cornwall County assessment (Diacono Associates, 2007) defined LDUs and CA, whilst Devon County Council defined LDUs and CT; this resulted in the Tamar Valley AONB which lies across the County boundaries to have mismatching LCAs. An additional study that defined CA on the Devon side of the designation had to be commissioned for consistency, and a further project is expected to be commission to identify CTs on the Cornwall side of the designation.

In 2006 Norfolk Coast AONB appointed a consultant to advise on the development of a coordinated approach to landscape planning across the authorities that were within the AONB area. These include four planning authorities and the Broads Authority which were all at different stages of the assessments. 3 of the completed LCAs referred to LDUs, 3 of the studies referred to CT, 1 referred to CAs and 1 had defined both CAs and CTs. Of the already completed assessments only 1 study had a good cross border correlation with another authority, and two of the studies had a moderate correlation. The report recommended a methodology to integrate the studies, including standardised labelling and descriptions (Chris Blandford Associates, 2006a). The Norfolk Coast AONB Integrated Landscape Guidance was subsequently produced in 2006 (Norfolk Coast Partnership, 2006) and included CTs and CAs, LDUs were not used as they had not been completed by all of the authorities within the designation.

3.1.1.3 The Audience

It is also important to identify who the intended audience is to the LCA, this will assist in deciding what outputs are required from the study. For example the Mid Bedford District LCA (Land Use Consultants, 2007) is intended for a wide audience, but mainly directed at planners with a defined scope of helping with planning control and decision making. The output of the study is access to a PDF version of the LCA through their internet site, and it has been integrated into their LDF. Exmoor National Park identify a wide ranging audience such as: Exmoor National Park staff, consultancies undertaking work on their behalf, landowners, land managers, local authorities, government agencies, environmental trusts, charities, pressure groups, students and the public. The output of the study is accessible from the website (http://www.exmoor-nationalpark.gov.uk/index/learning_about/looking_after_landscape/landscape_character_assessment_2007.htm) and a newsletter is also produced focusing on summarising projects focused on assessing, conserving and enhancing landscape character (Exmoor National Park, 2007).

3.1.1.4 Resources

The resource implications of conducting a LCA need careful consideration, for example the time taken to complete the project, the experience of staff, and the cost of the project (Swanwick, 2002).

The majority of LCA are conducted by consultants (88% of studies reviewed), shared between 17 different consultancies. 7 assessments were conducted by in-house departments such as Bradford's Metropolitan District Councils Landscape Design Unit who produced a LCA as a SPD for their LDF (City of Bradford Metropolitan District Council, 2008).

Durham County Council (2008) also undertook the desk study stage in-house using consultants to conduct the field work element of the assessment. The output of the Durham LCA is highly detailed, identifying character down to the scale of Local Landscape Types and is highly accessible through the internet site as an interactive mapping tool (http://www.durhamlandscape.info/landscape/usp.nsf/pws/landscape+-+landscape+character).

3.1.1.5 LCA Outputs

The end product of a LCA will usually include a map of the identified areas of character (which may be CAs, CTs or LDUs or a combination of these) together with a relatively value free description of character, the key characteristics which really define the area and the forces for change that are likely to impact upon the character (Swanwick, 2002).

The outputs from LCAs vary widely depending on the stated objectives of the project and the resourcing allowed. For example, assessments may be integrated into planning documents (Land Use Consultants, 2005; City of Bradford Metropolitan District Council, 2008) or reports may be made available through hardcopies and downloads of PDFs (Buckinghamshire County Council, 2007). In the case of the Dorset LCA an interactive map is provided as well as links to downloadable documents and GIS data (www.dorsetforyou.com/landscape).

A detailed output schedule should be agreed with consultants if they are commissioned to produce the assessment. For example, Harrogate Borough Council (2004) specified they required an A4 wire bound copy of the assessment bound in plastic covers, with a strong colour image on the front cover. All maps were to be made available in GIS with appropriate titles, north arrows and legends.

3.1.2 The Desk Study

The desk study involves information gathering to provide the context of the assessment. The current guidance suggests that the different layers of information are combined and maps produced to begin the process of identifying areas of common character which can either be done by eye or using a Geographical Information System (GIS) (See Section 4.2). After the layers are interpreted and analysed, new maps are created to show either CAs or CTs which can then be confirmed at the field survey stage (Swanwick, 2002).

3.1.2.1 Data Sources

Many data sources are required to gather adequate information about the study area to begin to get a picture of the character of the landscape. Most LCAs use data about physical factors to complete the assessment (Wascher, 2005) however the human influence on the landscape also makes a major contribution to the landscape character. This can be assessed by looking at land use and management, settlements and building styles and pattern and types of field enclosures. It is also important to notice the time depth of the features to determine how features have survived and how different stages throughout history have influenced the landscape (Swanwick, 2002).

In a review of European LCAs, Wascher (2005) found that biophysical factors are used as the basis for the LCA in almost every example. Socio-economic-technical factors are the next most widespread, particularly land use, field, farm and settlement patterns, historical development and heritage factors. Only a small number of studies used the human-aesthetic and policy dimensions such as in Countryside Character Initiative (England), Scottish National Programme of LCA and the LCA of County Clare (Ireland). Despite there being an increase in the understanding of what factors are significant and the amount of data available, the more recent projects which use more developed technology with automated methods have focused highly on the biophysical dimension. The most comprehensive of the LCAs appeared to stem from expert interpretation of biophysical, socio-economic, aesthetic and policy dimensions (Wascher, 2005).

The majority of LCAs in England use information from national data sets where the information is readily available and is likely to be periodically updated. The cost of purchasing additional data sets is usually prohibitive to smaller organizations such as AONBs, as is the collection of primary data which may also be too time consuming and possibly difficult to repeat again in the future. From the studies reviewed the following Information sources were used:

- Agricultural Census
- Ancient Woodland Inventory
- Areas of County Geological Interest
- Aerial Photographs
- Biological Notification Sites
- Boundaries e.g. County, AONB, NP
- Character of England Map
- Conservation Areas
- Common Land
- County Wildlife Sites
- CSS Schemes
- Definitive Footpaths
- Drainage
- Environmentally Sensitive Areas
- Field Size and Regularity
- Geology (solid and drift)
- Grassland Inventory
- Habitat Surveys
- HLC
- Land cover
- Land use
- Listed Buildings
- Local Nature Reserves

- National Landscape Typology
- Registered Battlefields

Once the available data sources have been gathered analysis should then take place in order to create map overlays to show:

- Landform Geology and Soils
- River and drainage systems
- Land cover
- Land use
- Settlement pattern
- Field patterns

3.1.2.1.1 Landform, Geology and soils

One of the main influences of landscape character is the landform, particularly in hill and upland areas. Many LCAs derive this data from Ordnance Survey (OS) data at the scales of 1:50,000 or 1:25,000 which contain contour information. The most common method of producing a landform map is to extract the contour data from the other data and analyse by eye the different topographical areas. Digital data is also available for this purpose in the form of contour lines and also digital terrain models (DTM). The use of DTMs may produce a more accurate analysis with slope and aspect data being easily derived using a GIS.

The BGS is the primary source of information for geological information and is available at the scale of 1:625,000 for national mapping, 1:50,000 for regional mapping and 1:10,000 for local scale mapping. This data is continually updated and readily available in GIS formats.

Soil data and geology data is frequently derived from paper maps (East Devon District Council, 2008; White Young Green, 2003; Julie Martin Associates et al., 2007; Environmental Consultancy University of Sheffield, 2006), however digital data is available such as the NatMap Soilscape series.

3.1.7.1.2 Rivers and Drainage Systems

Hydrology also forms an important part of landscape character as rivers and drainage systems help to shape the landscape. Hydrology data can also be used in helping to define areas such as valleys, and plateaus which can then be mapped as landform units. They are closely related to underlying geology and can often be combined in map overlays (Swanwick, 2002). Information about water courses can be derived from OS data although more detailed information about floodplains and river courses can be obtained from the EA in paper or digital format.

3.1.2.1.3 Land Cover and Land Use

There are many sources of data that can be used to derive vegetation cover including Phase 1 Habitat Surveys which are generally prepared by the County Councils and Wildlife Trusts, the availability of this data however is sporadic. In Cornwall the Environmental Records Centre for Cornwall and the Isles of Scilly (ERCCIS) produced a land cover map in 1988 and 1995. This information was gained from site surveys, interpretation of aerial photographs and digitised to a scale of 1:10,000 broadly based on Phase 1 Habitat definitions. NA profiles available through NE provide some habitat information at the national scale (See Section

2.5.1.4). The LCM2000 provides detailed information of land cover derived from satellite data such as from the Landsat satellites, the data is available in both vector and raster formats (25m resolution) and has twenty six different land classes such as improved grassland, acid grassland, rough grass and broadleaved or coniferous woodland. The LCM2000 data can cost approximately £1430 for 200 km^2 (Centre for Ecology and Hydrology, 2009). Land Cover Map 2007 is due to be released during 2011.

Land use information can be derived from the LCM2000 data such as defining urban areas and also from the ALC which gives details of the grade of the agricultural land (See Section 2.5.1.3). Although a frequent source of information for agricultural analysis (Babtie Group, 2004; East Riding of Yorkshire Council, 2005; Northamptonshire County Council, 2005), the June Agricultural Census is no longer produced down to parish level and does not give detailed enough information at a county level (or to an AONB level in future releases) to help define LDUs.

The NIWT (Forestry Commission, 2002) gives details of the Interpreted Forest Type such as broadleaf, conifer, felled or replanted woodlands and the Ancient Woodland Inventory (Natural England, 2011a) details areas of Planted Ancient Woodland Sites and Ancient Semi-Natural Woodland.

3.1.7.1.4 Settlement Pattern

The LCA guidance document (Swanwick, 2002) recommends the use of 'An Atlas or Rural Settlement in England' (Roberts & Wrathmell, 2000) for the analysis of settlement patterns with local mapping of settlements from 1:50,000 OS Maps. However, the analysis of settlement pattern varies depending largely on the area to be studied. For example, the Hinkley and Bosworth LCA (Hinkley and Bosworth Borough Council, 2006) and Horsham LCA (Chris Blandford Associates, 2003) commissioned consultants to specifically investigate the character of the larger settlements and the effect on the landscape. Other studies such as the Shropshire Landscape Typology (Shropshire County Council, 2006) used a combination of the Rural Settlement Atlas and DEFRAs June Agricultural census to derive farm types.

3.1.2.1.5 Field Pattern

Fields and hedgerows have a large influence over the characterisation of the countryside, for example the small irregular fields of Devon surrounded by large hedge banks can be contrasted to the rigidly geometric layout of fields lined with hawthorn hedges in the East Midlands (Taylor, 2000). Despite this importance, there is no national map of hedgerows and patterns of enclosure need to be mapped from 1:25:00 OS data and aerial photographs. Some HLCs include field pattern information such as the Devon HLC (Devon County Council & English Heritage, 2005) from which the dominant pattern and age can be derived.

3.1.3 The Classification

The process of classification can happen in two stages of the assessment; during the initial desk study and after the field survey stage. If the desk study has been thorough it is likely that changes to the classification after the field survey will be mainly to refine the boundaries.

Landscape classification occurs in two ways: divisive and agglomerative. Divisive classification (such as in top down classification see Section 3.1.3.1) or geographic regionalisation is the traditional method of land classification involving the delineation of regions that are similar by drawing lines on a map, this generally occurs by subjective assessment methods based on knowledge and expert judgement (Bryan, 2003). This method has been criticised for lacking transparency and replicability (Austin & Margules, 1986). Divisive classification is the primary method used in LCA albeit this now occurs within a GIS rather than mapping by hand. Top down classifications tend to be large scale and work to identify large areas of character that are subsequently divided into smaller areas with added detail.

Agglomerative classification (Such as bottom up classification – see Section 3.1.3.2) regards the smallest spatial units as homogenous and clusters them according to similarities in the physical environment. These techniques often use quantitative numerical algorithms such as clustering analysis (Carter et al., 1999) and use multivariate environmental data. Just as divisive techniques have been criticised for subjectivity, quantitative land classification is also sensitive to the choices made during the process of the classification such as the number of classes assigned to the data (Mackey et al., 1988; Austin & Margules, 1986).

Both of these methods have been used in a national context and are discussed as examples of the methods (See Sections 3.1.3.1 and 3.1.3.2).

3.1.3.1 The National Character Area Map

Two independent national initiatives toward characterising England began in 1993. The former Countryside Commission began piloting their top down approach of assessing the character of southwest England at a large scale with the aim of identifying and describing the character of the area, and identifying where this character should be conserved or enhanced (Swanwick, 2002). At the same time

English Nature launched their NA programme which aimed at creating a framework at which national conservation objectives could be set (See Figure 2.8). Each area has a distinct character resulting from the interaction between wildlife, landforms, land use, geology and human impact. NAs also include the views of local residents to create a sense of place in the areas descriptions (Natural England, 2010b).

In 1994 a Governmental review of the two organisations resulted in their collaboration and the production of the Character of England Map (also known as the Joint Areas Map) which encompassed both the landscape and nature conservation measures in 159 National Character Areas (NCA) (Previously known as Joint Character Areas). The map (see Figure 3.2) is accompanied by a description of the character of each area and the influences on character and drivers for change (Natural England, 2007b). These NCAs have been used as a national spatial framework for initiatives such as ES and the Countryside Quality Counts (CQC) project of assessing landscape condition (See Section 3.3).

The NCAs are currently under review and are being updated to ensure they are still relevant and fit for future use (Land Use Consultants, 2011).

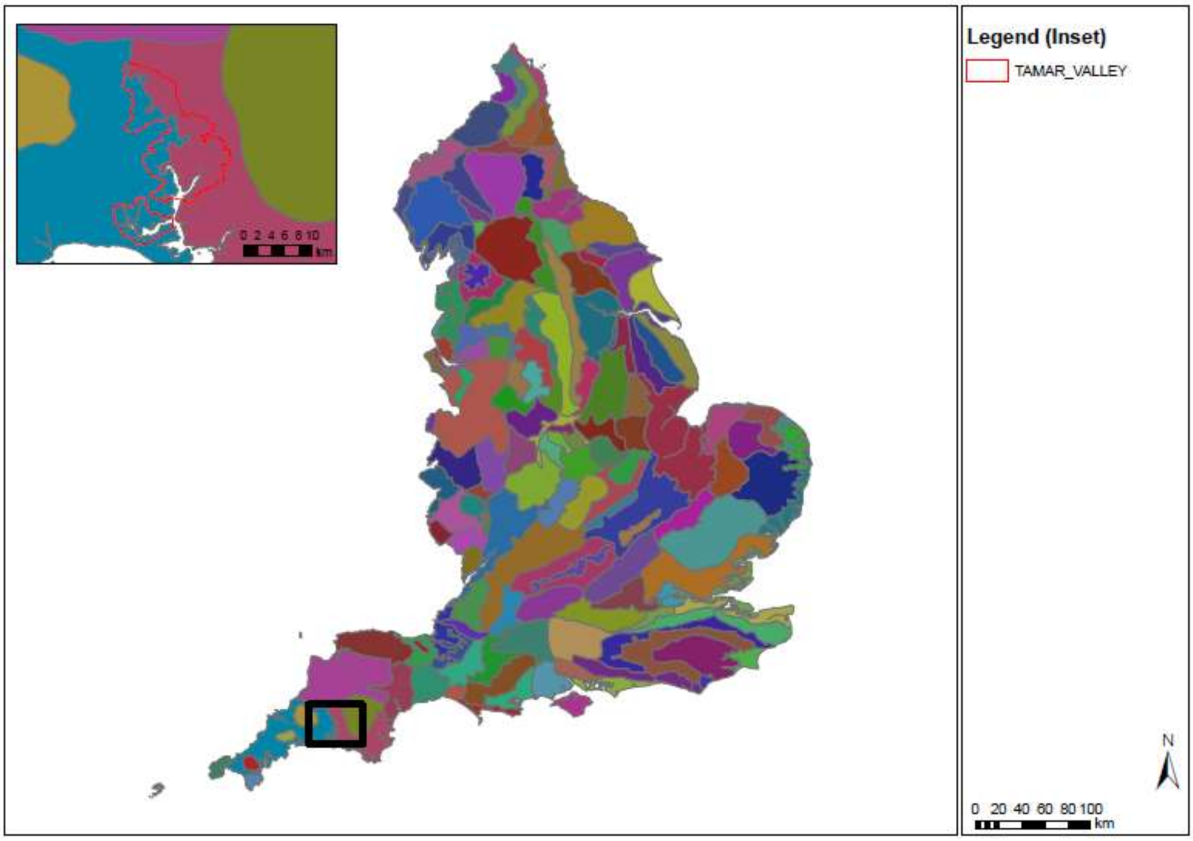

Figure 3.2 National Character Area Map with inset image of the Tamar Valley Area of Outstanding Natural Beauty (Data Source: Natural England, 2011)

3.1.3.2 The National Landscape Typology

The Living Landscape Project approached LCA using a bottom up method of using LDUs , these units are small distinct areas of land that are relatively homogonous in nature and form 'the building blocks of a Landscape' (See Figure 3.3). The definition of LDUs allows a structured spatial framework for gathering descriptive information about the landscape (Porter and Ahern, 2002, English Nature, 2004). The National Landscape Typology does not provide a description of the landscape, but provides a series of attributes.

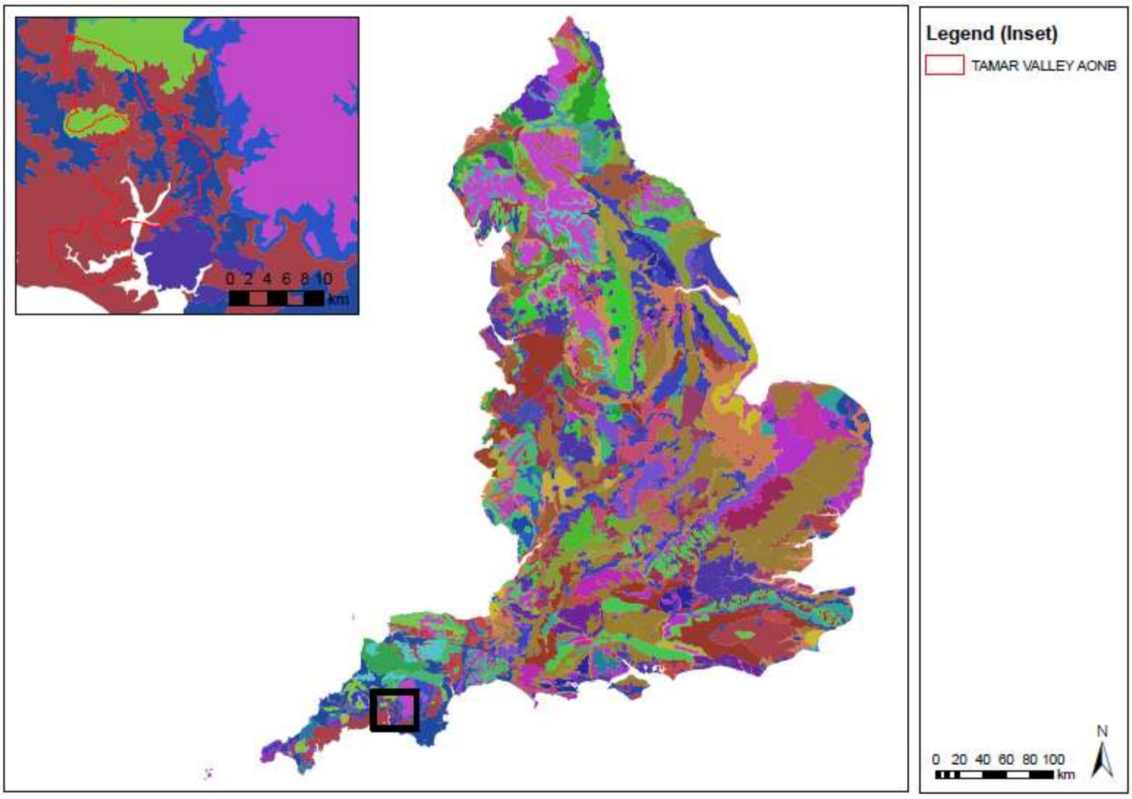

Figure 3.3 National Landscape Typology, with inset image of the Tamar Valley Area of Outstanding Natural Beauty (Warnock, 2002)

The boundaries of the LDU are identified using published map data and analysis of the definitive attributes. At the National Level (1:250,000) there are 4 attributes: Physiography, Ground Type, Settlement and Land cover. At the county/district level (1:50,000) each of the attributes is split into 2 parts, giving 8 attributes (See Table 3.2).

	Regional Level 1	County/District Level 2
Natural	Physiography	Landform Geology (Structure)
	Ground Type	Geology (Rock type) Soils
Cultural	Settlement	Settlement Farm Type (Structure)
	Land Cover	Farm Type (Cover) Tree cover

Table 3.2 Landscape Character Assessment Attributes (Porter and Ahern, 2002)

Using the Level 2 attributes allows for a finer grain of mapping while retaining the hierarchical structure of a spatial framework. For example, a LDU described as ‘soft rock low hills’ at the national scale may be split into three LDUs at the county scale such as ‘scarp edge’, ‘plateau summit’ and ‘dip slope valleys’ (Porter and Ahern, 2002).

LDU mapping is a gradual process involving data acquisition, analysis, processing and synthesis into new layers of data. The natural dimension of the landscape is mapped first providing a context for the analysis of historical evolution of the landscape and because relief, geology and soils have ‘real’ boundaries. Cultural boundaries are not so easily defined but can be mapped due to the constraints that the landscape may place on human activities such as land utilisation by slope, soil fertility or drainage that have been identified in the previous stage (English Nature, 2004).

The Living Landscapes Methodology is designed for use with GIS, however data are still being interpreted by eye and digitised by hand, which could introduce uncertainty to the accuracy of the boundaries selected for the LDU framework. For example to derive the Physiographic Units, a contour map (20m intervals) is colour coded to show altitude bands 0- 180 m as lowlands, 180m – 300m Low hills and 300 -1000m as High hills. This layer is overlayed onto a raster geological base map and broad areas of terrain types are identified such as Hard Rock (Upper Palaeozoic) terrain. Ideally boundaries are drawn to clear breaks in slope that relate to geological boundaries, but lines of best fit also need to be used (Warnock, 2002).

3.1.4 The Field Survey

According to the ELC, landscape perception is an essential part of landscape definition. How the landscape is experienced, the aesthetics and the valuation are all integral (Council of Europe, 2000). NE's Landscape experience study (Natural England, 2009) also suggests that landscape character also comes from the temporal changes in the landscape, the sounds, smells and the feelings that are evoked. Most of the data available that provides this type of information is descriptive and can only be gained from experiencing the landscape at ground level. The field survey stage can help to record aesthetic and perpetual qualities of the landscape adding information such as the dominance of landscape features and the texture, complexity and remoteness.

Therefore, field surveying is an essential part of LCA. Field surveys are undertaken to verify that the mapped boundaries created in the desk study are a 'true' reflection of what is visible in the landscape and to give a ground level view of how the landscape is perceived by people. It can also be used to identify features that were not apparent from the desk study. The comprehensiveness of the field survey will vary depending on the scale of the characterisation. For very large areas there will be less reliance on field surveying but this will become more important in smaller scale studies where more detail is required (Swanwick, 2002).

3.1.5 Written Descriptions

Once the field surveys are complete, written descriptions of each LDU, CA or CT are required to give a full picture of the landscapes character (although this stage was not completed in the National Landscape Typology). Included in the description are details of the land cover, field patterns, woodlands, local vernacular styles and settlement forms. Written descriptions aim to achieve a balance between factual information and more evocative statements of what is featured in the landscape (Swanwick, 2002). An example description is a '...gently rolling landform sloping up from the valley floor...variable size fields with wide low boundaries and irregular pattern' (Diacono Associates & White Consultants, 2008). The written descriptions of each CA or CT will be used in conjunction with the maps to give a full picture of the areas character.

3.1.6 Making Judgements

The use of LCA in making judgments will vary from study to study and should be appropriate to the scope and objectives defined at the beginning of the process. Examples of judgments include identifying landscape capacity which refers to the degree of change that can be accommodated by the landscape before the character is affected and monitoring landscape condition which refers to the physical state of the landscape, its intactness from a visual and functional point of view. The framework of the LCA along with the key characteristics and forces for which are identified in the output of the study can be used to monitor how landscapes are changing and how this is going to affect landscape character (See Section 3.3).

3.1.7 Stakeholder Participation

Stakeholders may be invited to participate in any stage of the LCA process, ideally within the characterisation stages and when making judgements. Involvement in district wide assessments is usually in the form of Community Appraisals (in the form of questionnaires), workshops or focus groups and participatory appraisals

(Swanwick, 2002). The level of stakeholder participation varies between studies depending on how local authorities choose to engage with interested parties and the budgetary constraints (Jensen, 2006). All of the studies reviewed included some form of stakeholder involvement for example, workshops arranged for stakeholders to review draft CAs and suggest key characteristics (Chris Blandford Associates, 2005; Environmental Consultancy University if Sheffield, 2006; Diacono Associates & White Consultants, 2007; Landscape Partnership, 2010) hard-copy and electronic questionnaires were also used (Landscape Partnership, 2010). It is also usual for steering groups to be formed for LCAs that are being conducted by consultants which provide guidance from the parties who have instigated the project (Swanwick, 2002; Landscape Design Associates, 2002; Diacono Associates & White Consultants, 2008).

3.2 Current Status of Landscape Character Assessment in the Tamar Valley Area of Outstanding Natural Beauty

The TVAONB has been assessed at the national level by the National Character Area (Natural England, 2011) and National Landscape Typology (Warnock, 2002) projects, and also at a county level through projects commission by Cornwall (Diacono Associates & White Consultants, 2007) and Devon County Councils (Diacono Associates & White Consultants, 2008).

3.2.1 National Character Areas

The TVAONB falls into two NCA: South Devon and Cornish Killas (using the same geographic extent of Cornish Killas and Granites and South Devon Natural Areas, see Figure 2.8).

The key characteristics listed for the South Devon area are (Natural England, 2011):

- Rounded hills, without a strong pattern, separated by steep, intricate wooded valleys
- Red and pink soils appear when parts of this mixed farming area is ploughed
- Wooded rias with large expanses of tidal water and mudflats, extending far inland
- Diverse and complex coastline with fine scenery and spectacular views, often looking deep inland along the rias
- Sunken lanes link numerous farmsteads and hamlets, with cob, slate and thatched buildings
- Wildflower rich, often treeless, Devon banks
- Villages and towns generally in sheltered valley locations, with towns located at the heads of the rias
- Distinctive landscape of ball clay extraction in the Bovey Basin
- Cliffs and long, sandy beaches

The key characteristics listed for the Cornish Killas are (Natural England, 2011):

- Undulating slate plateau with little woodland and few hedgerow trees

- Numerous broadleaved wooded valleys, varying greatly in size. Northern valleys generally narrow and densely wooded. In the south there are drowned valleys (rias) with wide estuaries
- Rugged coastal scenery. Exposed and windswept cliffs in the north with limited access to the sea, more sheltered and wooded in the south
- Outstanding historic parks, mainly in the sheltered valleys in the south
- Generally a dispersed settlement pattern of hamlets, farmsteads and small fishing villages
- Variable field pattern dominated by stone-built Cornish hedges
- Important archaeological and industrial-archaeological sites

3.2.2 National Landscape Typology

The National Landscape Typology (Warnock, 2002) identified 13 LDUs across the TVAONB (See Figure 3.4 and Table 3.3).

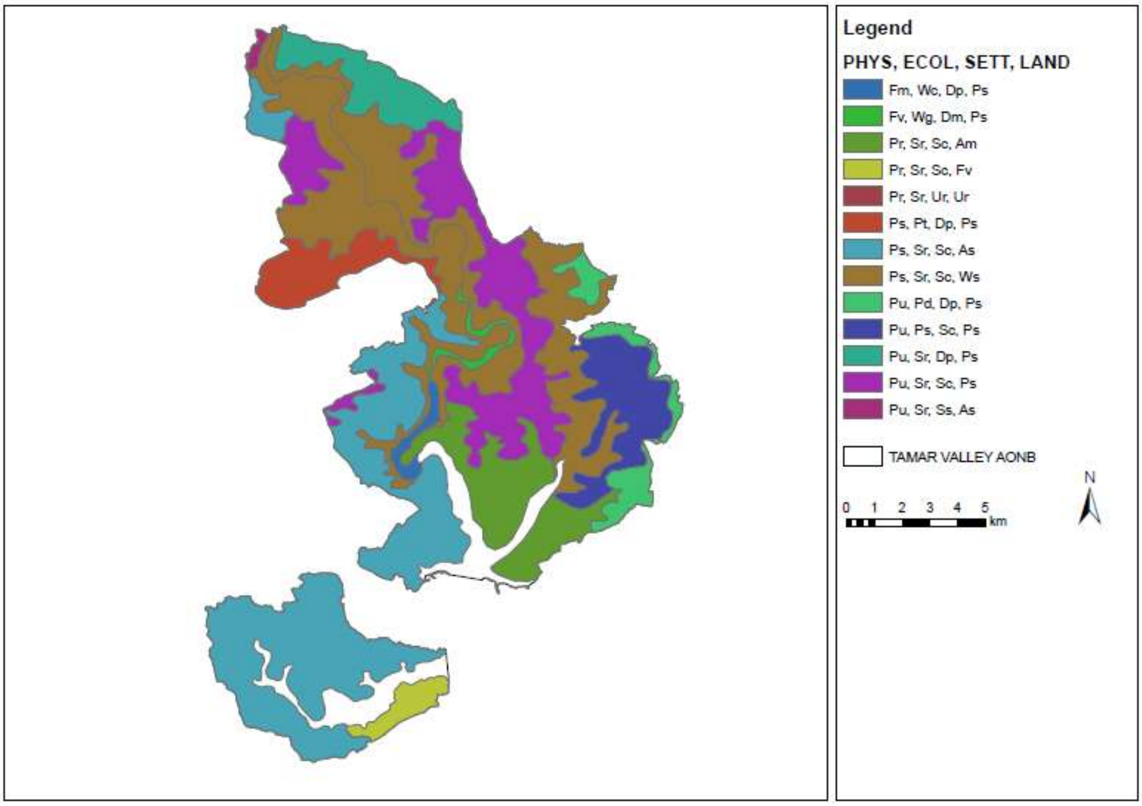

Figure 3.4 National Landscape Typology (See Key in Table 3.3) (Source: Warnock, 2002)

Natural Dimension	**PHYS**	F	Fluvial lowlands	**Landform**	m	marine/lacustrine levels
		P	Hard (Palaeozoic) rocks		v	vales & valley bottoms
					r	rolling/undulating
					u	upstanding/sloping
					s	steeply sloping
	ECOL	W	Wetland (alluvium & fen peat)	**Assoc. Habitats**	c	saltmarsh
		S	Other light land (shallow/sandy)		s	swamp & fen
		P	Moor & bog (peaty/podzolic soils)		w	wet pasture/marsh
					g	neutral (damp) pasture
					r	rough (dry) pasture
					d	heath/moor
					t	wet heath/bog
Cultural Dimension	**SETT**	S	Settled	**Heritage**	c	small/multiple villages
		D	Dispersed		s	wayside dwellings
		Ur	Urban		p	planned farms
					m	meadowland
					u	unsettled (moor & marsh)
	LAND	W	Ancient wooded	**Land Use**	v	market gardening
		A	Trees & woods		m	mixed farming
		F	Trees - arable		s	stock rearing
		P	Trees - pastoral		r	rough grazing

Table 3.3 Key to National Landscape Typology – LDUs (See Figure 3.4) (Source: Warnock, 2002)

The 13 LDU covering the area were amalgamated to make 3 CTs (See Figure 3.5 and Table 3.4)

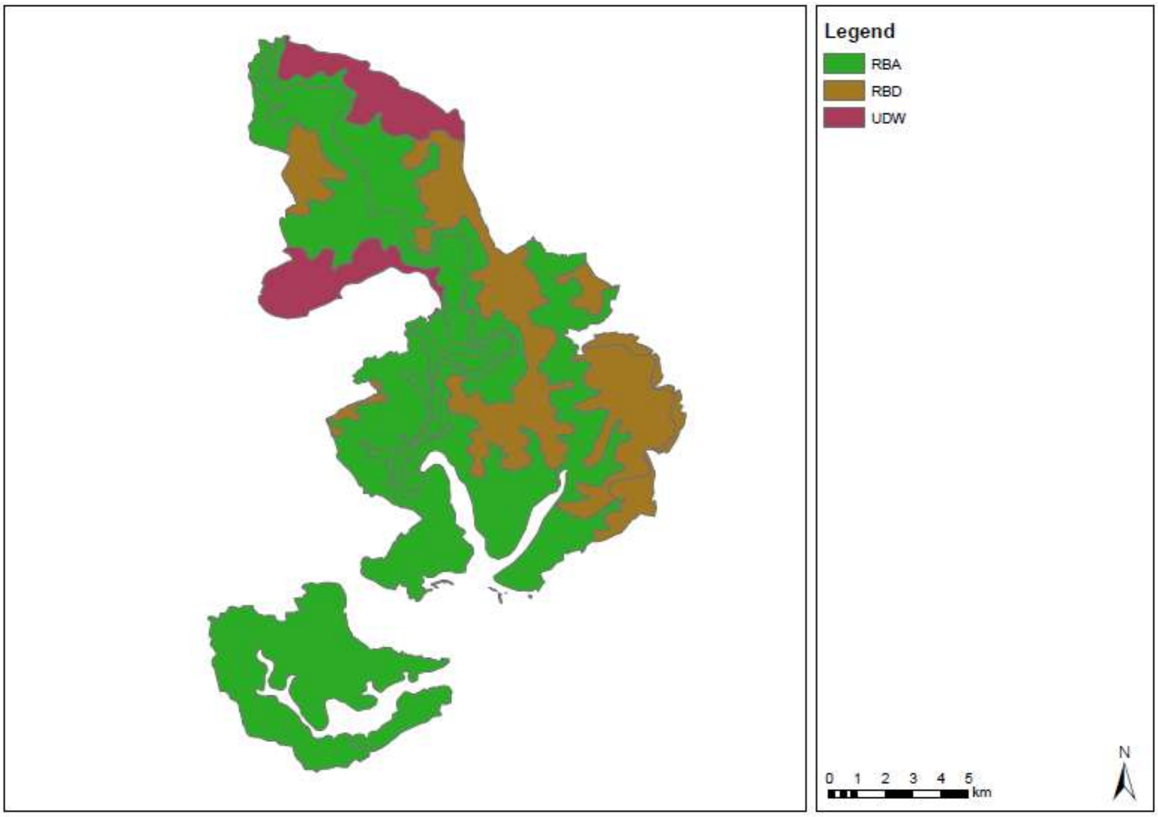

Figure 3.5 National Landscape Typology – Character Types (See Key in Table 3.4) (Source: Warnock, 2002)

Landform	**R – Intermediate**	**U – Low Hills**	
	Rolling/undulating areas, below 1000 ft, including descriptive landform classes 'low hills - plateau' and 'rolling lowland' (see below) - associated mainly with Mesozoic (Cretaceous, Jurassic, Triassic & Permian) or Tertiary rocks of sedimentary origin and glacial till.	Upstanding areas, mainly below 1000 ft, including descriptive landform class 'low hills - sloping' (see below) - associated with Paleozoic (Permian, Carboniferous, Devonian, Ordovician, Silurian & Cambrian) and Mesozoic rocks (mainly sandstones and limestones) of sedimentary origin.	
Land Cover	**B – Other Light Land**	**D – Heath and Moorland**	
	Light land associated with free-draining loamy and sandy solid developed on permeable rocks (sandstones, siltstones & mudstones), or sandy drift at elevations below about 300 meters. Within the soft rock zone, where there are few constraints to agricultural production, this ground type is strongly associated with arable cultivation. Mixed farming predominates on the shallower soils found in western hard rock areas	Land associated with nutrient-poor mineral and/or peaty soils supporting dwarf shrub heath, acidic grassland and bog habitats, or relic heath/moorland vegetation (bracken, gorse, etc.). This ground type is normally associated with sandstone, or sandy drift in the lowlands, but it is widespread on mixed sedimentary and igneous rocks in upland/hard rock areas. Often marginal in agricultural terms.	
Cultural Pattern	**A – Wooded Ancient Woods**	**D – Dispersed Wooded**	**W – Wetland/ waste Unwooded**
	Settled agricultural landscapes (dispersed or nucleated settlement) characterised by an assorted pattern of ancient woodlands which pre-date the surrounding enclosure pattern - in places associated with densely scattered hedgerow trees (typically oak).	Settled agricultural landscapes characterised by a moderate to high level of dispersal, comprising scattered farmsteads and frequent clusters of wayside dwellings. Although typically unwooded, hedgerow, streamside and other trees are often a prominent feature.	Open, sparsely settled agricultural landscapes characterised by a surveyor enclosed pattern of large rectilinear fields and isolated farmsteads. Tree cover is usually restricted to watercourses, or groups of trees around buildings.

Table 3.4 National Landscape Typology Key – CTs (See Figure 3.5) (Source: Warnock, 2002)

3.2.3 County LCAs

The TVAONB has also been assessed by projects commissioned by Devon and Cornwall County Councils (See Figure 3.6). The Cornwall and the Isles of Scilly LCA was published in 2007 (Diacono Associates & White Consultants, 2007) and followed the Living Landscapes Methodology of a bottom-up classification. The output of the study included LDUs and CAs along with written descriptions of each LDU and CA, an interactive map is also included and can be viewed at http://www.cornwall.gov.uk/default.aspx?page=24874.

Devon County Council (DCC) also commissioned the same consultants to complete a LCA and therefore the same methodology for creating LDUs was used, however DCC decided to use CTs. This resulted in the TVAONB having matching LDUs across the whole designation, with CAs on the Cornish side and CTs on the Devon side (See Figure 3.6). To counter this problem the TVAONB partnership commissioned the same consultants to create CA on the Devon side of the designation so they would have a coherent LCA.

Analysing the LCAs for the TVAONB highlighted several issues, firstly the difference between the assessments across counties, which has only partly been solved by commissioning a separate project to create CAs on the Devon side of the designation. Secondly some of the LDUs and CA or CTs that have been created extend far beyond the boundary of the designation for example the Fowey to West Looe Plateau CA is 287 km^2 however only 2 km^2 (0.7%) lies within the designation. It is likely that the much of the description and key characteristics would be irrelevant to the small area inside the AONB boundary, and some of the special qualities that occur within the designation may have been lost in the generalisation of the data. Additionally, when creating land management objectives or landscape monitoring objectives based on CAs, it is questionable whether it is useful to have such a small area of the TVAONB segregated when trying to achieve these goals. Further analysis of the LCA is discussed in Chapter 6.

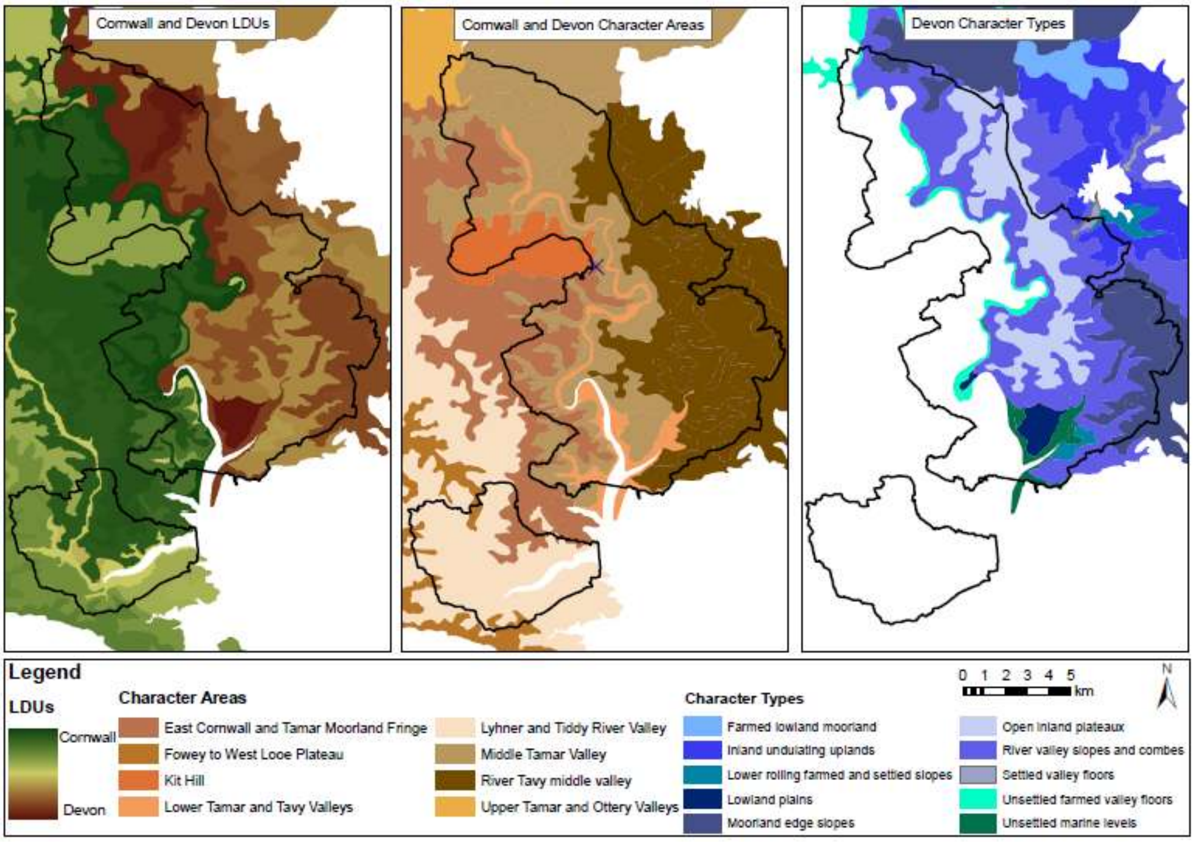

Figure 3.6 County Landscape Description Units, Character Areas and Types (Diacono Associates & White Consultants, 2007; Diacono Associates & White Consultants, 2008)

3.3 Monitoring Landscape Change

By signing the ELC the UK has committed to monitor changes in the landscape as well as defining and mapping them. The LCA framework has been used to conduct monitoring projects at both a national and county scale.

The CQC project aims to describe when the countryside is changing and how this will affect landscape character. The project is based on the framework of the NCAs and uses nationally available datasets. Vision statements were used to identify key characteristics for each NCA that would weaken or strengthen landscape character. 7 themes were chosen including: Trees & Woodlands, Boundary Features, Agriculture, Settlement & Development, Semi-Natural Habitat, Historic Features and River & Coastal. A weighting was placed on the importance of each theme per NCA by public consultation and were placed as either ‘key’ or ‘secondary’. The main weightings were applied to Trees & Woodlands, Agriculture and Settlement & Development due to the fact that they are the most likely to influence a NCA and they also have the best available datasets (Countryside Quality Counts, 2006).

Data sources used in the analysis included the NIWT, Woodland Grant Schemes and the AWI to assess the Trees & Woodland indicator. The Boundary Features theme was assessed mainly through a proxy indicator of take up of management agreements through the CS and Environmentally Sensitive Areas (ESAs) schemes. In addition information about total boundary length for each NCA was taken from the Countryside Survey data; however this is only a crude estimate as the data comes from sampling within each NCA (Countryside Quality Counts, 2006).

Agriculture was assessed based on data derived from the June Agricultural Survey to gain information on the land cover types and the size and types of holdings. This was supplemented by information from the CS and ESA schemes to determine the extent of management plans that would relate to restoration of key semi-natural habitats associated with farmland habitats (Countryside Quality Counts, 2006).

The assessment of Semi-Natural Habitats and Rivers & Costal themes came from SSSI condition data or the uptake of agreements in CS and ESA schemes. In addition for the rivers and coastal them data from the EA for water quality were used (Countryside Quality Counts, 2006).

Historic Features were assessed in only a few areas where the data has been available. The majority of data was taken from the EH historic parkland and historic farm buildings at risk data. Where data is available an assessment has only been attempted on those NCA where the historic theme was a key characteristic. Otherwise the data has been left unanalysed but has been provided (Countryside Quality Counts, 2006).

Once the data collation was complete each NCA was assessed using the key themes and judged to be (Countryside Quality Counts, 2006):

- Maintained – where the character of an area is strong, largely intact and the key themes served to sustain this, or a lack of change indicates that the important qualities are likely to be maintained in the long term
- Enhancing – where changes in the themes were restoring or strengthening character
- Neglected – If the character has been degraded by past change and the changes in the key themes were unlikely to restore the qualities that make the area unique
- Diverging – If changes in the key themes were transforming the character of an area so that distinctive qualities are being lost, or new patterns are emerging.

Over all the headline indicators for the latest monitoring period of 1999 and 2003 show that character was maintained in 51% of England's landscapes and enhanced in 10%. Loss or neglect of character was shown in 20% of our landscapes and new characteristics are emerging in 19% of our landscapes (Countryside Quality Counts, 2009).

In the NCA 152 Cornish Killas the landscape has been classified as neglected largely because of boundaries in poor condition and development pressures. Also the extent of woodland management under Woodland Grant Schemes was static and classed as neglected. Agricultural and River & Coastal elements were maintained (Countryside Quality Counts, 2009).

In the South Devon NCA 151 the overall assessment concluded that character was maintained due to the stability of the agricultural landscape, and enhancement of boundary features and woodlands. However, River & Coastal elements appear neglected and pressure from developments is creating a divergence with the landscape character (Countryside Quality Counts, 2009).

An up-to-date reporting of the period 2004 -2009 is likely to be published in 2012 through NE's new Character and Quality of England's Landscapes (CQuEL) project which has been established as a replacement for the CQCs scheme (Land Use Consultants et al., 2010).

In 2008 the Cornwall, Tamar Valley and Isles of Scilly AONBs commissioned a project to set up a methodology and base line for monitoring change in the landscape. The purpose of the study was to assess the current landscape condition in such a way that the assessment could be carried out again in the future (for example, every 2, 5 or 10 years) and the change in the landscape condition could be monitored by using landscape indicators e.g. Extent of Woodland.

During the study it was decided that the current LCA framework was unsuitable for monitoring purposes, this was due to the fact that only CA had been created across the Cornwall County (and therefore CTs were not available for assessment), and these character areas very often crossed the boundaries of the AONB area. Crossing the boundary meant that in some cases only very small areas of land were included inside the AONB and therefore would not warrant a separate set of indicators. The other issues were that the key characteristics that were identified for the CA may or may not be relevant to the section within the AONB area, and so these would need to be reviewed and updated. Using the LDUs as a framework was also discounted as there were many of them that would share indicator types and desired trajectories of change that could be more effectively managed as one group. It was therefore decided that Landscape Monitoring Units (LMUs) would be created by clustering the LDUs together by indicator and management objectives (Land Use Consultants, 2008b).

In addition to LMUs, 1 km^2 sample squares were also selected to enable analysis of aerial photography and to complete field work where needed. Two squares were selected per LMU which could cover the range of indicators selected and be broadly representative of the LMU as a whole. The resulting LMUs and the LDUs that have been included can be seen in Figure 3.7 with the selected sample squares.

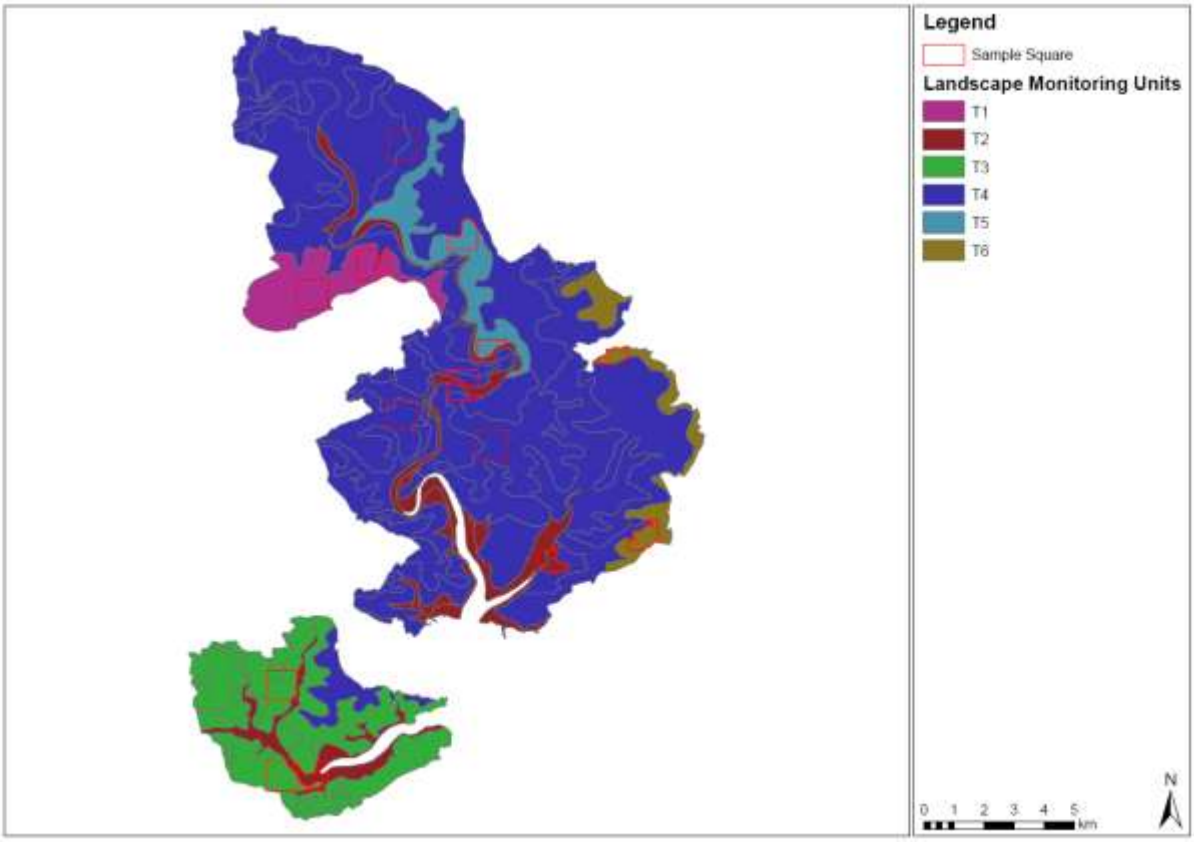

Figure 3.7 Six Landscape Monitoring Units were created with two 1 km2 sample squares within each unit (Land Use Consultants, 2008b)

Landscape indicators were defined as ‘elements of data that are collected during a monitoring programme to focus the monitoring activity and measure landscape change’. The indicators were selected by using a process of identifying the forces for change that impact on the AONB and therefore which landscape elements/features are changing/likely to change in the future (Land Use Consultants, 2008b).

Indicators were divided into three categories: Level 1 – Universal Indicators that would be used across all LMUS, Level 2 – Consistent Indicators – that reflect the key characteristics of all of the LMUs although the desired trajectory of change may differ between LMUS, and Level 3 – which were LMU specific. Examples of the indicators used are shown in Table 3.5 with the data sources used to establish the baseline condition (Land Use Consultants, 2008b).

Indicator		Data Source
Level 1	Tranquility	CPRE – Tranquility map
	Condition of SSSI	Natural England – SSSI condition monitoring
Level 2	Extent of Woodland	FC - NIWT Cornwall LIFE data (1995) CEH - LCM2000
	Agricultural Land Use	June Agricultural Survey
	Extent of Semi-natural Habitats	Cornwall LIFE (1995) CEH – LCM2000
	Presence and condition of historic landscape features	County HER/SMR
Level 3	Extent of Local Horticultural production	Tamar Valley Market Gardening data Aerial Photographic Analysis Field Survey
	Extent of Traditional Orchards	Tamar Valley Market gardening Data Field Survey
	Extent and condition of Designed Landscapes	EH – Register of Parks and Gardens Aerial Photographic Analysis

Table 3.5 Examples of Indicators and their data sources

Indicators were selected for each LMU based on the key characteristics identified. For example, in LMU T1 (The area around Kit Hill) the key characteristic ‘Scattered Trees and Sparse Woodland’ resulted in the use of indicator ‘Extent of Woodland’ (Land Use Consultants, 2008b).

For each indicator a desired trajectory of change was also identified, for the example above in ‘T1 – the extent of woodland’

- Positive: No overall increase in woodland cover
- Negative: An increase in woodland cover.

This can be compared to the same indictor being selected for LMU T2 which was selected based on the key characteristic ‘Deciduous woodland (including wet woodland) on the slopes and creek sides)’:

- Positive: Maintenance of increase woodland extent on slopes and creek sides
- Negative: Decrease in woodland extent on slope sides and creeks

The baseline of results currently gives details from which future change can be detected, for example the extent of woodland identified for LMU T1 for Conifer Woodland was 7.3 ha. This can then be compared with the extent in future surveys and scored according to whether the desired change in directory was achieved (Land Use Consultants, 2008b).

3.4 Conclusion

The process of LCA is progressing in England, with 2 national mapping programmes completed and district assessments completed for 60% of local authorities. The majority of assessments are undertaken by professional Environmental or Landscape consultancies with very few studies being undertaken ‘in-house’.

The current methodology is well established, LCA provides a systematic method of assessing landscape with all but one (High Weald AONB, 2007) of the studies reviewed using the Landscape Character Assessment Guidance (Swanwick, 2002) document as a basis for their assessment.

The advantage of the methodology is that it has resulted in a suite of LCA that are consistent in their approach and include details of the study scope and resources and include a desk study of both natural and cultural factors. The outputs of the studies are character maps of CAs, CTs, LDUs or a combination of these which have been field tested and written descriptions applied.

The TVAONB has been assessed at a national scale and at a district scale by both Devon and Cornwall County Councils. Although the same consultant was employed for each study, there is a difference between the methodologies and terminology used, resulting in mismatching CA and CTs across the TVAONB designation. This has led to an additional project being commissioned to bring the assessments together in a manner that allows the TVAONB to use the framework in their management plan and landscape initiatives. Difficulties have also been encountered when attempting to use the LCAs for a landscape monitoring programme, where separate LMUs were necessary to combat the problems of cross border correlation. This issue has also affected the assessments of the North Norfolk AONB (Norfolk Coast Partnership, 2006), North York Moors National Park (White Young Green, 2003), Cranborne Chase & West Wiltshire Downs AONB (Land Use Consultants, 2003), Chichester Harbour AONB (Chris Blandford Associates, 2005), Forest of Bowland AONB (Chris Blandford Associates, 2009).

Within the guidance documents there is also no clear method suggested for *how* patterns are identified between different layers of data. The majority of studies are undertaken by professional consultancies and detailed information of how CA/CT/LDUs are derived is not available. As LCA is further integrated into the planning process, there needs to be a transparent link between the source data and derived characterisation.

The use of GIS is now widespread for LCA however the LCA guidance (Swanwick, 2002) or Topic Paper 4: The use of Geographical Information Systems and other Computer Methods (Porter & Ahern, 2002) does not include a detailed methodology for conducting the assessment within GIS this is discussed further in Chapter 4.

Chapter 4 Geographical Information Systems and Spatial Decision Support Systems

4.0 Introduction

This Chapter presents some background information about GIS and how the technology has become integrated with LCA. The use of GIS for LCA has become widespread, although the level of use varies from study to study. A review of LCA across Europe (Wascher, 2005) identifies 4 main methods of assessment which are described with examples. Using this framework of methodologies, LCAs that have been reviewed during this period of research are also discussed.

Spatial Decision Support Systems (SDSS) have been used as tools in the field of landscape planning and sustainability, and provide a method of dealing with spatial data storage, analysis and map output. Some examples of SDSS are discussed with reference to how they could assist in the process of LCA.

4.1 Geographical Information Systems

The first GIS were developed during the 1960s, designed to store and handle large volumes of information gained from maps. They were used for performing tasks which were tedious to complete manually or required greater accuracy than could be gained by hand and to reduce the expense of producing maps (Goodchild, 2004).

The term GIS was coined in 1963 by the creators of the Canada GIS which was built to compute large numbers of area calculations (Goodchild, 2004). The world's first production line of computer produced maps was developed in 1973 by the UK Experimental Cartography Unit which published a regular series of maps with the BGS. By then end of the 1970s most major cartography agencies were using GIS, but it was not until 1995 when the first complete digital map of a whole country was produced for Great Britain by the OS (Longley et al., 2005).

During the 1980s the popularity of GIS grew due to the availability of the first affordable, commercially available software - ArcView was launched in 1981 and MapInfo in 1986. Among the first customers were forestry and natural resources managers needing to keep control of their stock and its location. By 2000 there were 1 million core GIS users and an estimated 5 million casual users, with the industry worth $7bn and growing at more than 10% per annum (Longley et al., 2005).

GIS have grown in complexity and many different applications are now available depending on the requirements, for example, ESRI produce ArcView for map creation and interactive visualisation, ArcEditor for the extra capability of multi-user editing and advanced data management and ArcInfo (the most complete package) allowing additional advanced analysis, manipulation, processing and modelling (www.esri.com).

GIS files can be in either raster or vector formats and may be referred to as 'data' or 'layers'. A vector layer is represented by points, lines or polygons, which can be used to denote features with a high level of accuracy, the data is more complex than raster files which have a more straight forward structure of cells arranged in a grid formation. The two different data structures can be used in different ways, e.g. raster data can be used with functions/tools such as 'combine' to join layers; vector layers are more appropriate for working with network analysis (Longley et al., 2005).

A typical GIS database will contain a digital representation of some selected aspects of the earth's surface, or near surface, built with the intention of solving a particular problem or scientific purpose (Longley et al., 2005). A database may be used for multiple problem solving events, or a new database may be built for each problem to be solved. Once a database is built, GIS can be used to process the data. Information can be easily joined together from different sources, or equally, separated. Data can be updated, added to or removed. Many tasks have to be performed repeatedly, therefore scripts or tools have been developed to execute a series of commands to process the data based on the input, the parameters and the output required. A GIS package such as ARCInfo contains many processing tools some of which are described in Table 5.2.

4.2 The Use of GIS in Landscape Character Assessment

The use of GIS for LCA in the UK is now widespread (Swanwick, 2009) resulting in a better end product than the traditional method of overlaying maps on acetates, and delineating boundaries by hand. The database is a flexible, re-usable and updateable resource. A LCA which has been completed with a GIS can be made available to a wide range of end users through digital datasets, or displaying on the internet. It can be accessed and used interactively making it a powerful tool for visualising, presenting and publicising the results of a LCA. The output can be varied from paper maps to online interactive maps, 3D visualisations and spatial datasets (Porter and Ahern, 2002).

GIS can be used to build up a database of digital layers allowing complex data to be collated and viewed on an OS map base. Datasets can be used to assess spatial correlations and distribution which form the basis of identifying areas of common character. 3D contour modelling can aid the understanding of the interrelationship between landscape elements such as between landform and land cover. GIS can also be used to interpret and analyse datasets in relation to one another such as looking at areas over a certain elevation with a specified amount of forest cover (Porter and Ahern, 2002).

An important component of LCA is the descriptive attributes that take account of character-based information such as building styles as well as qualitative information such as an attributes condition or vulnerability, this information can be linked into a GIS database to each CA , CT or LDU polygon (The Living Landscapes Project, 2006). Collection of digital photographic images during a LCA allows a database of images to be created within GIS, identified by a unique code, date and time, grid reference, focal length, field of view and notes. They can be used for linking to point features displayed on a GIS map interface, and can also be used to construct a visual image of the current landscape and future scenarios. Photographs of specific landscape elements can be used to construct a more realistic landscape visualisation (Porter and Ahern, 2002).

The LCA methodologies discussed in Sections 3.1.3.1 and 3.1.3.2 (Swanwick, 2002; Natural England 2002) were derived from studies at academic institutions (Universities of Sheffield and Reading respectively) however in general there are very few peer reviewed methods found in academic journals (Brabyn, 2009). The majority of LCA are carried out by consultants within England (See Section 3.1.1.4) and although there are many documents that can be found outlining the methodology used for the characterisation (e.g. Land Use Consultants, 2003 Babtie Group, 2004; Diacono Associates & White Consultants, 2007), these usually echo the Landscape Character Assessment Guidance for England and Scotland document (Swanwick, 2002) and do not include details of how the classification is actually formed, this is likely to be due to the use of ‘expert classification’ rather than defined rules.

LCA across Europe and the making of landscape typologies have become very popular in the last decade, spurred on by the loss of cultural diversity and of character across landscapes with rapid changes taking place in traditional cultural landscapes (Van Eetvelde et al., 2007). Washer (2005) reviewed 41 LCA studies across Europe and found 4 main methods:

1. Expert interpretation only – where consultants/experts use their own understanding and expression of the data
2. Expert interpretation with support of some automated analysis – A combination of expert interpretation with some GIS/modelling methodology such as clustering analysis
3. Highly automated analysis – GIS/modelling methodology only
4. Automated analysis with some interpretive refinement – GIS/Modelling techniques which have subsequently been adjusted by a consultant/expert

Method 1: Expert interpretation only was the most common method found in 16 studies, however most of these studies were conducted between the 1950s and 1980s, 6 studies were in the 1980s with only 2 studies published since 2000. The Northern Ireland Landscape Character Assessment was based on manual mapping of the landscape, drawing information from data sources and extensive field surveying, there was no GIS available. The Landscape Atlas from Belgium took a different approach to their LCA using no biophysical factors but deriving ‘vestigial zones’ and ‘anchor’ points of high historical interest.

7 studies used Method 2: Expert interpretation with support of some automated analysis. An example project using method 2 is the LANDMAP (Wales) characterisation which separated the landscape into five aspects (Geological, Landscape Habitats, Visual & sensory, Historic and Cultural). Each Aspect is classified according to an Aspect Specialist using a variety of data sources. The methods rely heavily on interpretation of data and field visits and use GIS for mapping and handling large volumes of data (Countryside Council for Wales, 2002).

Method 3 was found in 9 studies (from 5 countries), an example of this method is the LANMAP2 project (See Figure 4.1 and Table 4.1) which is a pan-European landscape typology that includes climatic regions, digital elevation model, parent material (soil) and land use data (Wascher, 2005; Mücher et al., 2005). LANMAP2 was created at a scale of 1:2.5M 1 km grid by using a composite image of four bands (climate, elevation, soil and land use) and was analysed with object orientated image classification software (eCognition) resulting in 14000 mapping units with unique combinations, and then using cluster analysis to group the units into 375 landscape types.

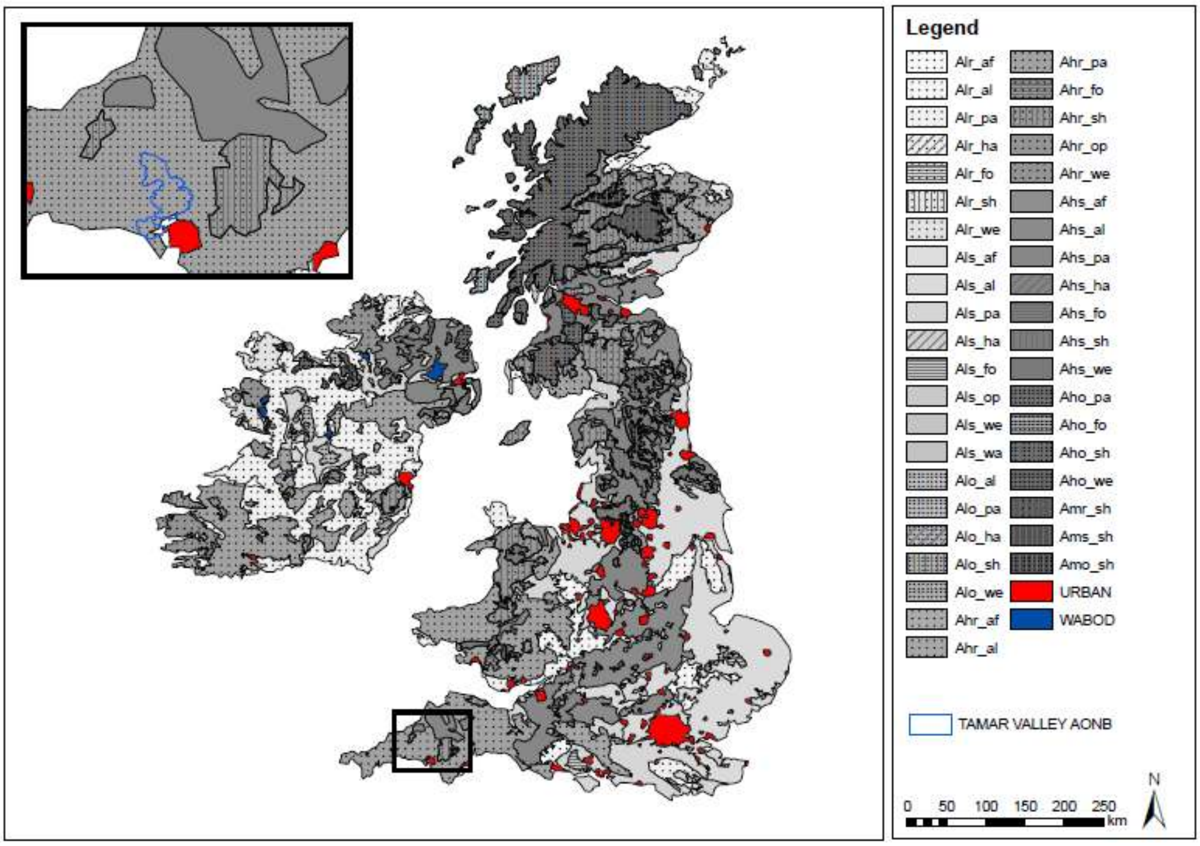

Figure 4.1 LANMAP2 – Landscape codes relate to the legend in Table 4.1, for example much of the inset picture of the TVAONB is coded Als_al which according to the legend is Atlantic, Lowland, Sediments and Arable Land. (Data Source: © Alterra, reference: Mücher et al (2005)

Climate		**Elevation**		**Parent Material**		**Land Cover**	
A	Atlantic	l	Lowland	r	Rocks	af	Artificial surfaces
		h	Hills	s	Sediments	al	Arable land
				o	Organic materials	pa	Pastures
						ha	Heterogeneous agricultural areas
						fo	Forest
						sh	Shrubs & herbaceous vegetation
						op	Open spaces with little or no vegetation
						we	Wetlands
						wa	Water bodies

Table 4.1 The LANMAP2 Key (See Figure 4.1)

The LANMAP2 typology gives a broad description of landscape CT, and provides the highest level of LCA. Simultaneously national LCAs have been taking place and have been used to validate LANMAP2, however matching the borders between assessments has been problematic and the methodology has been criticised for the land use data being the only cultural component to have been used (Van Eetvelde, 2007).

Of the studies reviewed by Wascher (2005), it was found that the higher the level of automated analyses the fewer factors were investigated using only biophysical factors such as geology, hydrology and soil data. It can be debated that the studies cannot be truly regarded as LCAs (according to the UK definition) as they do not include any cultural factors.

Method 4: Automated analysis with some interpretive refinement expanded the input factors used to include socio economic factors such as land use, spatial patterns and history/time depth however; aesthetic and policy factors were often not included (Wascher, 2005). The New Zealand LCA (Brabyn, 2009) is based on a GIS method which combines datasets that reflect: Landform, land cover, water, infrastructure, dominant land cover and water view. The landform class was created using a combination of GIS analysis and rules and the use of manual editing to differentiate between classes such as 'river valley' or 'lowland' classes that were initially classified as one landform type. Land cover was used in two ways, firstly a simplified version of a national dataset was created where groups such as 'Exotic Forest' and 'Exotic Scrub' were combined into one class, and secondly a further generalisation was created based on areas of >100 km^2 to give a broader landscape picture. Water data were derived from a national land cover dataset and generalised into 7 classes such as ‘open sea’ or ‘lakes’. The Infrastructure layer was based on the identification of features such as wind turbines or railways which had a buffer zone of 100m – 300m applied, these were then generalised into four classes: Major Utility, Minor Utility, Land and Sea. The final category Naturalness was derived from the previously mentioned datasets to determine areas that had indigenous vegetation and presence or absence of infrastructure. After each of the datasets were prepared the combine function (See Table 5.2) was used with GIS to create a layer of polygons with 6 attributes. This method is a good example of how national datasets can be taken and simplified for use with a LCA model. Another example of this methodology has been discussed in Section 3.1.3.2 for the National Landscape Typology (Natural England, 2002).

It was noted in the review that highly automated methods were not conducive to the production of LCA particularly when defining CAs and Method 4 was considered to be a state of the art technique (Wascher, 2005).

Without access to detailed methodologies it is difficult to categorise England’s LCA projects, however it is likely that they belong in methods 2 and 4. The extent to which GIS is used varies from study to study, for example, The Horsham District LCA only used GIS to map character areas (Chris Blandford Associates, 2003). The North Kesteven LCA (David Tyldesley and Associates, 2007) used GIS to prepare a series of map overlays at the scale of 1:50,000. An initial framework of CAs were produced ready for field testing using 1:25,000 scale maps and the classification subsequently updated. The output of the study was requested in the format of PDFs that were subsequently loaded into a GIS by North Kesteven Council, which was made available along with a hard copy of the assessment, PDF’s of the assessment and the maps are available to download from the website (http://www.n-kesteven.gov.uk/section.asp?docId=4250&catId=539&pageTitle=Evidence+for+the+Local+Development+Framework).

In contrast, the County Durham LCA (Durham County Council, 2008) was produced by an in house team (assisted by the Countryside Agency). The landscape of the county was defined in 7000 individual mapping units, at a scale of 1:10,000 and field tested (partly by consultants Shiels Flynn) for subsequent revision. Durham County Council aimed to make the LCA as accessible as possible allowing the information underpinning many of the landscape management plans and decisions to be examined. The County CA, the Broad LT and CA and Local LT are available for interrogation through interactive maps on the internet (http://www.durhamlandscape.info/Pages/Home.aspx). The database is also linked to the landscape strategy and other resources such as historical maps and aerial photography. Links to the management objectives are provided between the CAs and the landscape strategy and the GIS also displays the key aims of the strategy such as to 'restore, maintain or enhance' the landscape condition (Landscape Character Network, 2006a).

Northamptonshire County Council Built and Natural Environmental Service (2003) used GIS to create a Physiographic Model providing a common background on which the natural environment, historic and modern land use data can be overlaid. The data sets that were included in this study were BGS bedrock and drift data to represent geology and 10m OS contour data to represent topography. The data was pre-prepared before entering into the model, for example the BGS data was joined as it was provided in two datasets and closed polygons were created from the contour data for use with elevation. Gradients were also derived from the contour data by counting how many 10m interval contour bands crossed a 500m grid square (each band being counted only once) and deriving a steepness index of 1 (flat) – 7 (steep).

Geological divisions were used to define the physiographic boundaries as these were considered to have the greatest influence on the physiography. The physiographic model was built using MapInfo software and was completed using a series of rules that were entered as queries. Initially three areas were identified, the river valleys, the flat plateaux and the upper ground. The river valleys were then subdivided into valley floor and valley sides, and the plateaux and upper ground were further divided by their geological type. This was achieved using 30m contours as using just the geology data did not differentiate the valley floors and sides. Figure 4.2 shows the different physiographic units identified during the study.

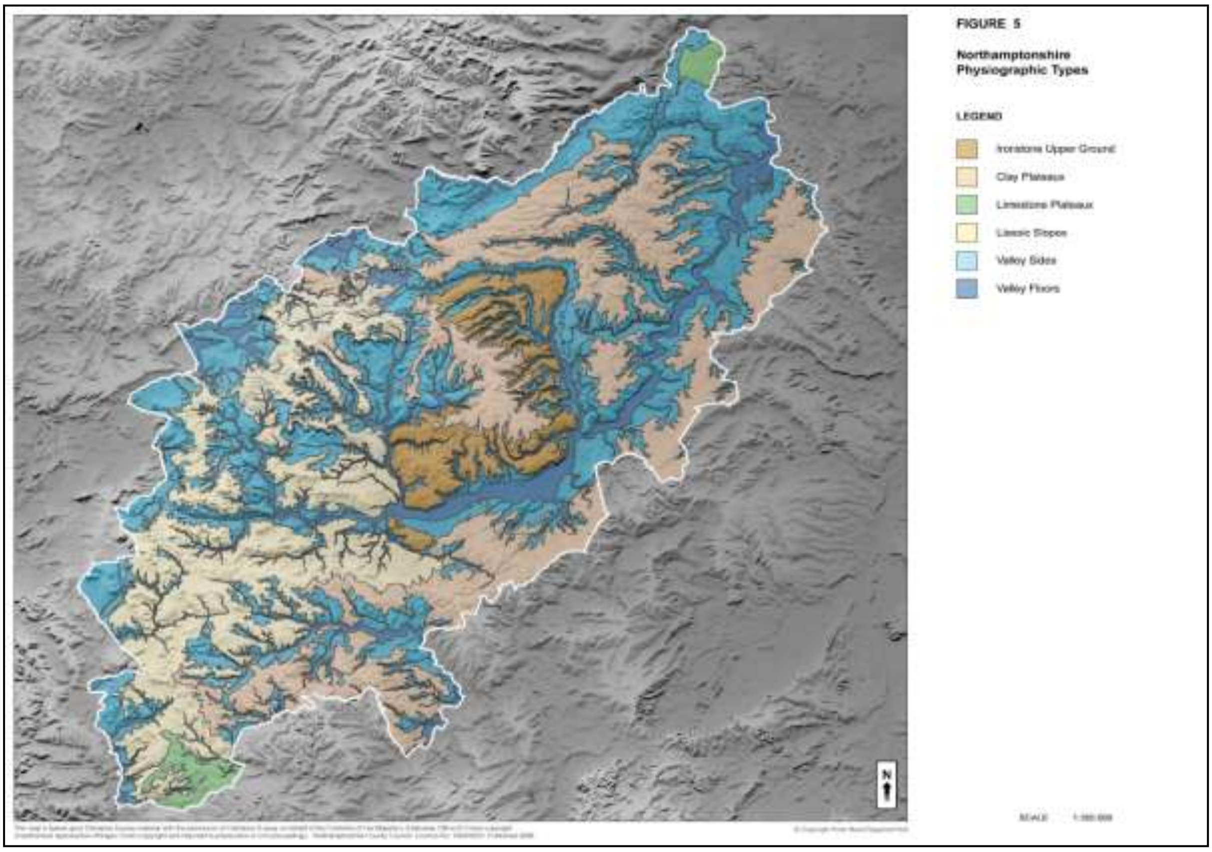

Figure 4.2 Physiographic Units identified by the Northamptonshire Physiographic Model (Data source: © RNRP CIC and OS)

Examples of the rules used are as follows:

Valley Floors: Defined as flat areas of ground, containing the river itself and composed of Alluvium and river terrace gravels.

Gradient: Steepness < = 2

Geology: Alluvium OR 1st Terrace OR 2nd Terrace OR 3rd Terrace.

Altitude: (30m contour bands used to subdivide the valleys)

The Physiographic Model was subsequently used as a primary reference data set for the Environmental Landscape and Biodiversity Characterisation studies and their digital map preparation.

The Northamptonshire Physiographic Study is a good example of how GIS can be used to model landscape character and how physiographic units can be used as a basis for adding further detail to other studies. The models shortcomings relate to the limited number of datasets used in the model, for example it was decided not to use soil data to help with the delineation of units, preferring to use the geology data as the primary source driving physiographic character. The model was based on rules entered into MapInfo of a series of queries which identified areas of common character that were then delineated by hand. This has advantages and disadvantages, hand digitising allows each unit to be assessed for correctness as the characterisation progresses allowing the rules to be changed and developed as needed, for example, it was found that the river valleys and sides could not be delineated by geology alone so therefore contour data was also used. The disadvantage of hand digitising relates to the time it takes and the level of accuracy achieved.

4.3 Spatial Decision Support Systems

Spatial Decision Support Systems (SDSS) are designed to assist decision makers with complex spatial problems, using analytical models to enhance their decision making capabilities (Densham, 1991). Decision makers using SDSS have been found to achieve solutions more rapidly that non-users and produce more accurate results (Crossland et al., 1995). Mennecke et al. (2000) found users of SDSS could produce outputs of equal quality to professionals using paper based maps, and although the accuracy was not improved by the system, the efficiency of the decision makers was greatly enhanced. It was also concluded that SDSS had an equalising effect within users of different capabilities; the performance of those with less experience often matched or exceeded those of experienced decision makers.

Decision making problems can be: well-structured - when a decision maker can fully define the problem and the desired objectives, ill-structured - where a decision maker cannot define the problem or the objectives or they can fall somewhere between to two and be semi-structured. A well-structured problem can usually be solved using a computer model without any need from interaction from a decision maker, whereas an ill-structured problem cannot be modelled at all and requires a decision maker to achieve their objectives using their own experience. SDSS are designed for semi-structured problems where a decision maker requires some computer support, where part of the problem can be automated using analytical models (Densham 1991, Malczewski, 1999),

A SDSS can be defined as “an interactive, computer based system designed to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi structured spatial decision problem’ (Densham 1991) and includes the integration of geographic data, analytical modelling capabilities, visualisation components and user friendly interface (Dye & Shaw, 2007).

According to Pavloudakis (2009) a SDSS should:

- Provide mechanisms for the input of spatial data
- Allow the representation of spatial relations and structures

- Include the analytical techniques of spatial analysis
- Provide output in a variety of spatial forms including maps

A SDSS consists of three generic components; a database management system and geographical database, a model based management system and model base and a dialogue information system (Chakhar & Mousseau, 2007). The database management system performs all data related tasks such as storage and retrieval of data and has the capability of manipulating the data to get it in the correct format. The model based system contains the models, has the ability to run the models and keep account of models already run. The dialogue subsystem allows the user to input data and information into the system and extract output data and information.

SDSS have been used in a variety of domains such as landscape planning and sustainability. For example, Bryan (2003) created a decision support tool for landscape planning using ArcView 3.3, and the spatial analyst extension. Initially 21 environmental variables such as soil, climatic and hydrological parameters modelled on both the topographical and regional scale. Principle Component Analysis (PCA) reduced the correlated data to 5 principle components covering 91% of the physical variation in the study area. A SDSS was then developed to interact with the database which would allow the user to identify areas of common environments for queries such as areas suitable for habitat restoration or viticulture site planning.

SDSS have also been applied to problems of land use change and forestry to identify areas of planting woodland for the sequestration of carbon (Wang et al., 2010), and planning for urban infrastructures (Coutinho-Rodrigues et al., 2011) with both systems integrating a GIS with external decision models.

SDSS have not traditionally been based solely in a GIS system due to objections over lack of data availability, problems of combining data of different resolution/scale, not being flexible to meet different approaches, lack of analytical power (Densham, 1991) and detachment of the user from the modelling insights and qualifications (Malczewski, 1999). However, with recent development in GIS software this is now becoming feasible. Graymore et al. (2009) found it possible to build a SDSS with the ArcGIS model builder which was introduced in ARCGIS 9 in 2004. This project involves using multi-criteria analysis for guiding sustainability measures. Dragan et al. (2003) developed a SDSS for reducing soil erosion by reallocating crops in Ethiopia. The system was developed using IDRISI 32 GIS software and multi-criteria and multi-objective decision analysis tools for the analysis of data such as soil erosion, land cover, land use, roads, trails and hydrology.

The development of a SDSS for LCA would enable a structured framework of landscape units (LDUs) to be produced from which CT and CA could be formed and descriptions written. A GIS would be capable of fulfilling the requirements of a SDSS by providing a database management system, allowing the visualisation and manipulation/processing of data, providing a model base, a mechanism in which to enter data and apply rules for analysis and a method of storing and producing output data and maps. Most SDSS tools are concerned with ranking data in order of suitability (Pavloudakis, 2009). However, in the case of LCA the decision lies in how to distinguish one landscape from another rather than ranking them in importance.

4.4 Conclusion

GIS are now widespread and the availability of digital data has also increased with many national datasets being obtainable. The implementation of a GIS based SDSS would support decision makers within AONB partnerships to conduct LCA 'in-house' with the data tailored to the designation. A consistent framework would be achieved regardless of administrative boundaries with a tool that could be run repeatedly as new data becomes available. A LCA-SDSS based on defined rules would also provide a transparent method of assessing landscape with less dependence on expert interpretation and ensuring that the output for the assessment would be consistent each time the assessment was repeated (assuming the parameters were unchanged).

Chapter 5 Landscape Character Assessment Spatial Decision Support System Development

5.0 Introduction

This chapter details the development of a SDSS referred to as LCA-SDSS (Landscape Character Assessment-Spatial Decision Support System). The aim of the system is to assist decision makers with creating a LCA classification framework and produce the required output maps.

To achieve the desired scope and outputs as described in Section 5.1 the research was structured into a number of stages as recommended in the LCA guidance document (Swanwick, 2002). Therefore, the study scope, scale, audience, resources and desired outputs are presented in this chapter. As a result of the detailed desk study of the TVAONB landscape (See Section 2.5) the key characteristics of the study area have been derived and potential data sources identified in Section 5.4. The LCA-SDSS consists of 4 Models to define Landform, Ground Type, Land cover and Cultural Pattern characteristics with an optional further rectification model, which are described in Sections 5.5 – 5.5.5.

5.1 Scope

The purpose of this study is to investigate to what extent LCA can be actioned using a SDSS, providing a support tool for experts to conduct LCA classification.

National Parks and AONBS frequently state that LCA are required for:

- Highlighting the special qualities of the landscape
- Informing management plans

- Guidance for land managing decisions
- Conserving and enhancing landscape character
- Identifying forces for change and monitoring landscape change

This research aims to produce a LCA that could be used by an AONB; therefore the intended audience would reflect that of an AONB LCA such as Land Managers, Staff and the Public. Although a full descriptive characterisation will not be completed in order to test the LCA-SDSS, the framework produced must be capable of fulfilling the needs of an AONB assessment.

A bottom-up methodology of defining LDUs and then CAs and CT has been chosen to provide a robust framework from which the study objectives could be based. The bottom-up approach lends itself to using a GIS due to its methodical layering of data to define LDUs of increasing detail.

The LCA-SDSS is intended to address the following:

1. Store data collected during the desk study in a logical format making it accessible to the SDSS models through a GIS
2. Provide a user friendly tool, that is flexible and can be run repeatedly
3. Produce an LDU framework for Land Cover, Ground Type, Land Cover and Cultural units and final combined LDUs
4. Produce output maps for: Landform, Ground Type, Land Cover and cultural units and final combined LDUs
5. Enable the creation of CA, CT and landscape monitoring units by using the LDU framework

6. Enhance field verification by using the LDU framework to identify additional landscape attributes

5.2 Resources/Software

ESRI ArcInfo v9.3.1 (esri.com) was chosen as the software in which to build the LCA-SDSS. This software fulfils the requirements of a SDSS by providing a database management system to store, organise, retrieve and convert geospatial data. The model builder component allows the development, storage and running of complex models, utilising many advanced tools for processing geographic data (Geoprocessing), for example to overlay layers of data, convert data formats, perform reclassification analysis etc. A full list of tools used throughout the project can be found in Table 5.2. Each of the Models within the SDSS can be executed in the same manner as any other Geoprocessing tool, providing a mechanism for data input, classification rules (where applicable) and data output.

The software was also selected as it is the same software that the TVAONB, Devon County Council and Cornwall County Council use and therefore there would be no compatibility issues when obtaining data. Data is also readily available in the supported shapefile and raster formats from sources such as the MAGIC website (http://magic.defra.gov.uk/) which includes information from DEFRA, EH, NE, EA, FC and Communities & Local Government. NE also has its own website for data downloads (http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp).

5.3 System Overview

The LCA-SDSS consists of a GIS database and five interacting models to reflect the stages in defining LDUs (See Figure 5.1). The database stores each of the data layers obtained during the desk study (See Section 5.4). 8 different data sources are used within the LCA-SDSS. The natural dimension is mapped by a combination of landform which is an expression of relief and geology, and ground type which is an expression of geology and soils. The cultural dimension subsequently mapped using a combination of land cover (an expression of woodland and agricultural data) and cultural pattern (an expression of historic land use and settlement). The GIS database also stores the output from each model.

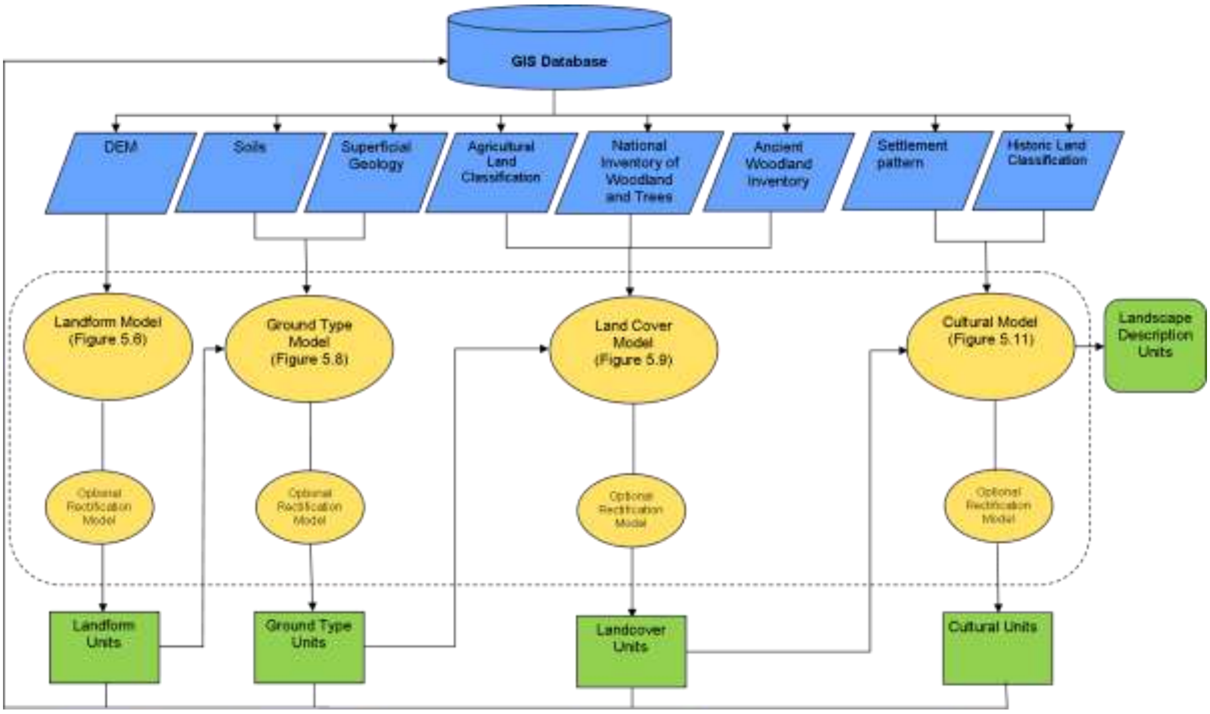

Figure 5.1 Overview of System – data inputs are displayed in blue, the model base in yellow and the outputs in green

- Model 1 – Landform: uses a DEM and produces Landform units, the output is used in Model 2 and stored back in the GIS database
- Model 2 – Ground Type: for further subdivision of the LDUs using soil and drift geology data. The output from Model 2 are used for three purposes; i) to create a Ground Type units, ii) to feed back into the GIS database for use analysis of settlement pattern (See Section 5.5.4.1) and iii) as an input for Model 3 and is stored in the GIS database
- Model 3 – Land Cover: uses ALC and woodland data to further define the LDUS, the output is used to create Land Cover units and to feed into Model 4
- Model 4 – Cultural: uses the previously defined units from Model 3 with the settlement pattern data and the HLC data, this output is used to create Cultural Units and also the final LDU map
- Model 5 - Optional Rectification Model: Enables the user to examine and rectify each output layer from the four models. During the processing sliver polygons of data may be created where different sources of information have slightly different boundaries, or are created at slightly different scales. For example the areas that can be identified as woodland from the ALC and NIWTs are not in alignment with each other. Examining the data output after each model has been run allows these errors to be corrected rather than being propagated on into the next stage of the LDU definition. In addition some polygons are too small to be useful as LDUs in themselves, for example areas < 1 km^2 can be combined into a larger class.

Sections 5.5.1 – 5.5.5 describe each of the models in detail, including which of the data sources discussed in Section 5.4 are being used and how they are processed for use in the model, what information is being derived and how they are being analysed in the Model.

5.4 Building the Database

The GIS database was held in a workspace (file system folder) and managed through ArcCatalog which enables the efficient storage of data in separate folders according to the theme (e.g. Landform, Landcover etc), whether the data has been processed and model outputs. Much of the data was gathered during the initial investigation of the TVAONB landscape. From this investigation the key landscape characteristics were summarised (See Table 5.1) and used to identify data sources for use in the models and to evaluate the model outputs. In addition aerial photography from 2005 is used to analyse the accuracy of the data sources and verify the output from the Models (Provided by Devon and Cornwall County Councils).

Key Characteristics		**Data**	**Scale**	**Source**
Geology	Hard Rocks and superficial 'drift' geology	BGS Geology - Bedrock and Superficial	1:50,000	Edina Geology Digimap
Landform	A river valley and estuarine landscape with steep valley sides and plateau top, Kit Hill being prominent and the highest point in the Tamar Valley	OS-Landform Profile DTM	1:10,000	Edina Digimap

Table 5.1 Key characteristics of the Tamar Valley Area of Outstanding Natural Beauty

Key Characteristics		Data	Scale	Source
Ground Type	Typically freely draining loamy soils, flood plain soils along the river. A localised occurrence of very acid wet upland soil with a wet peaty surface	NatMap Soilscape	1:250,000	University of Plymouth Tamar Geodatabase
Land Cover	An agricultural landscape with wooded valleys, ancient woodland and a large area of conifer plantation.	ALC Common-Land AWI NIWT	1:250,000 Not stated 1:50,000 1:25,000	NE NE Forestry Commission
Cultural Pattern	A landscape largely made up of enclosures from medieval, post-medieval and modern times. 18th Century Parks and Gardens. Presence of mining heritage. A clustered settlement pattern of hamlets and farmsteads outside larger settlements.	HLC OS Address-Point	1:25,000 1:25,000 or 1:10,000	Devon County Council Cornwall County Council Devon County Council

Table 5.1 Key Characteristics of the Tamar Valley Area of Oustanding Natural Beauty (…cont)

The scale of the input data sources differ from each other, however ArcGIS can reproject datasets of differing scales on the fly, which makes processing the data much easier than if paper maps are used. Re-projection of the data to a smaller scale does not however increase the accuracy. The soil and ALC data was created at a large scale, however as the model looks for patterns across a landscape rather than at specific sites this was judged to be off sufficient detail. During the processing of the data all raster files that were created (with the exception of the DEM) were at a resolution of 10m. This was judged to be of significant detail for a regional study. The scale of the study is to be viewed at 1:25,000 in common with most regional/district assessments, which allows the smaller polygons to be clearly identified on the map. If it is necessary to view the map at a scale of e.g. 1:10,000 (local scale) it should be considered whether a site/parish based LCA may be more appropriate that would include additional characteristic details such as hedgerows, farm buildings or arable fields (Swanwick, 2002).

On examination of the data sets to be used in the LCA-SDSS, it was found that each data set has been created using a different geographic extent, therefore there was either additional data or missing data along the boundary line of the rivers. Within ArcGIS, each layer was compiled over an aerial photography to determine which data source was the most accurate, resulting in the Environment Agency data being selected for the definitive river outline (See Figure 5.2).

Figure 5.2 Differences in boundaries used in various data sources (Data Sources: Aerial Photo - This image is an extract from the Millennium Map (TM) which is copyright Getmapping PLC)

All of the datasets provided included data that was outside of the study area, therefore a data layer consistent with the boundary of the AONB designation (as defined by the Natural England) and the river line was required, from which each dataset could be compared and adjusted to. Therefore, the EA data sets for tidal waters and the river line data were merged and used as a definitive outline for the tidal and non-tidal sections of the rivers in the TVAONB. This was joined with the TVAONB boundary that can be obtained from the MAGIC website (http://magic.defra.gov.uk/). Once the datasets were joined, it was found that the boundary of the TVAONB slightly overlapped the river outline along the south of the designation. The boundary was edited to match the river line to avoid slivers of data being created while using the boundary to CLIP other datasets. A boundary file with the river sections removed was also created to enable other data sets to be processed with the CLIP tool where data extruded into the river area (See Figure 5.3).

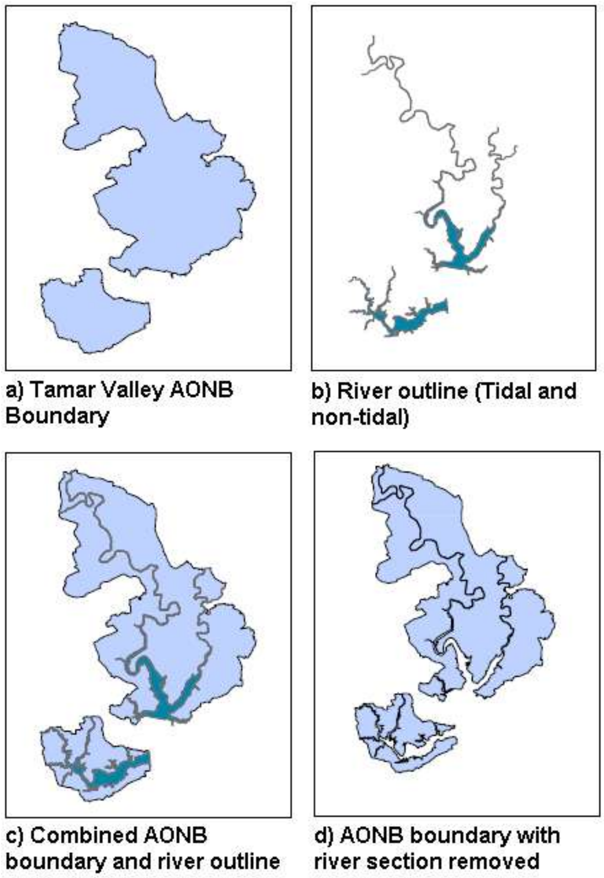

Figure 5.3 a) AONB boundary as downloaded from http://magic.defra.gov.uk/ b) River outline and Tidal data c) Combined AONB boundary and River data d) AONB boundary with River Class removed, this dataset was used as the definitive boundary to which all other data was adjusted

Each dataset used with the Models were adjusted to match definitive extent of the TVAONB. In addition some pre-processing was required before they could be used in the models. Details of the amendments made to the data are discussed with the appropriate model in section 5.5.1 – 5.5.4.1.

5.5 Developing the Model Base

The Models are built within ArcGIS Model Builder; an application in which you can create, edit and run models. Within the Model Builder data layers are added and connected to tools (processes) and an output file is created ready to store the processed data (See Figure 5.4).

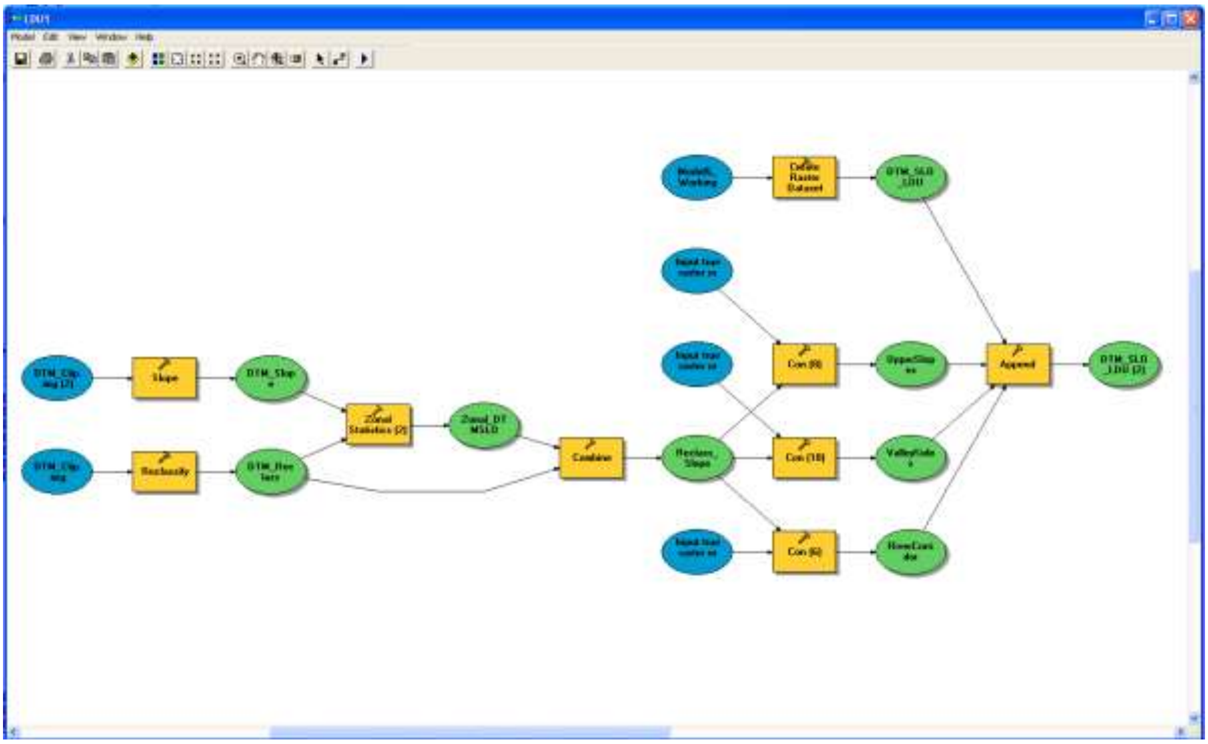

Figure 5.4 Image of Model 1 – Landform. Data inputs are displayed in blue, tools are shown as yellow and outputs are in green. This model shows the process of deriving the Landform LDUS from the DEM.

There are many Geoprocessing tools used within each model. Their function is described in Table 5.2, for clarity, when a tool is mentioned throughout the chapter in is written in capital letters e.g. CLIP or CLIPPED.

Tool	Function
Append	Adds multiple datasets into an already existing dataset (Point, Line, Polygon, and Raster). Input features remain intact (unlike the UNION tool that planarises features into one output)
Clip (Analysis)	Extracts the input features that overlay the clip features (Polygon, Line, Point)
Clip (Data Management)	Creates a spatial subset of a raster dataset based on a template extent or by choosing minimum and maximum X and Y coordinates
Combine	Combines multiple raster datasets to create a new dataset with a unique output value for each unique combination of input values
Con	A condition if/else rule is applied to the input cells of raster datasets
Eliminate (Data management)	Selected polygons are merged with the neighbouring polygon which either has the longest adjacent border or largest area
Feature Class to Feature Class	Converts a shapefile, coverage feature class into a shapefile or geodatabase file
Feature to Raster (Conversion)	Coverts a feature dataset into a raster dataset
Make Feature Layer (Data management)	A temporary feature layer is created from an input feature class (needed in the model for use with Select Layer by Attributes)
Merge	Combines the input features from multiple point , line or polygon feature classes
Mosaic	Joins multiple raster datasets into one raster file
Multipart to singlepart (data management)	Separates polygons that have shared unique input features into individual polygons with individual attributes
Raster to Polygon (Conversion)	Converts polygon features into a raster dataset based on a selected field
Select Layer by Attributes	Adds, updated or removes a selection of data based on an attribute query (Does not work with feature classes in a model builder therefore the Make Feature Layer tool has to be used prior to this tool)
Slope (Spatial analyst)	Identifies the maximum change in Z-Values (height) and the distance from each cell to its neighbours and calculates the slope value in ° or %
Reclassify	Changes the values in a raster
Zonal statistics	Calculates the statics of raster input values based on a defined area (zone) of analysis from another dataset

Table 5.2 Geoprocessing Tools Used in the SDSS

For each of the tools that are added there will be a number of variables that can be changed. For example, using the RECLASSIFY tool (See Figure 5.5), the 'input raster' field is displayed automatically having been defined by using a connector arrow in the model builder, the 'Reclass field' requires the selection of a field within the attribute table to be used for the reclassification and then the method of reclassification can be determined by using the 'classify' button. The old and new values are then displayed. The 'output raster' field allows the filepath to be entered to define where the data will be stored and how it will be labelled.

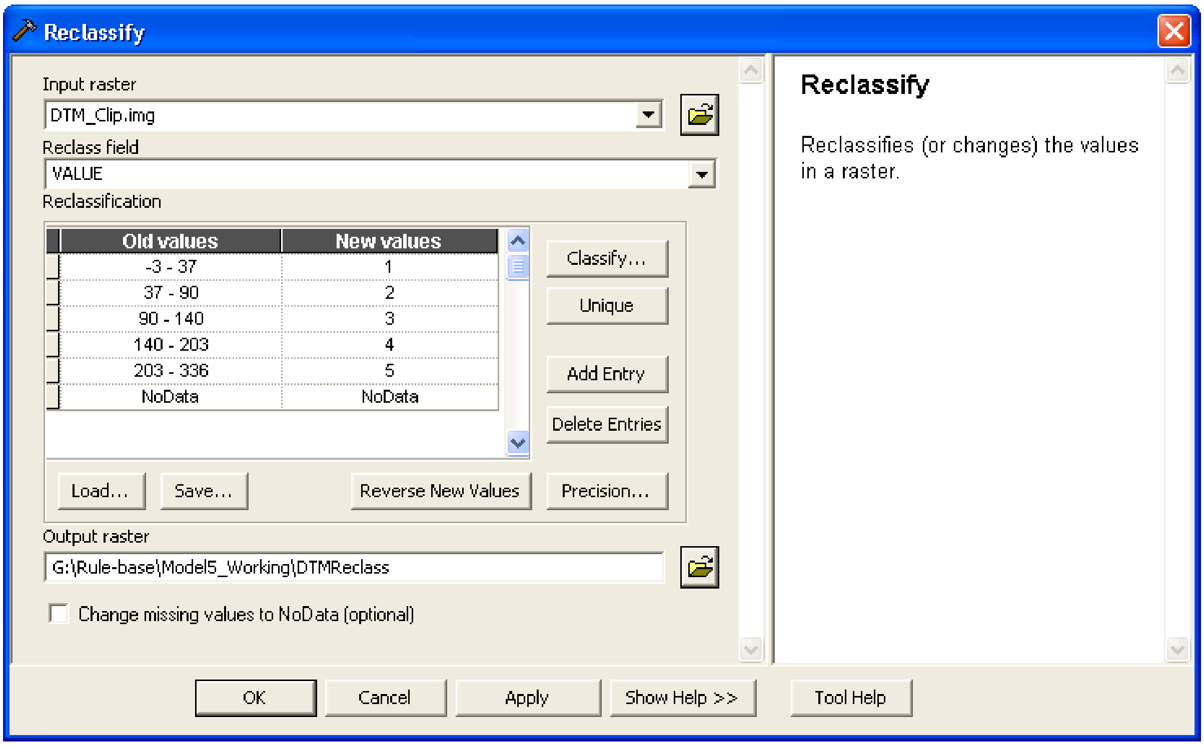

Figure 5.5 Reclassify Tool Window – Raster files can be reclassified based on a defined field in the attribute table

5.5.1 Model 1 – Landform

The first stage in defining the LDUs involves deriving landform information (See Figure 5.6). From the information gathered in the desk study for the TVAONB study area it can be determined that the landform contains river corridors, valleys and a plateau top (See Table 5.1). Defining the landform LDUs was achieved by using a DEM to investigate elevation data and to derive slope data. Unlike the Northamptonshire Physiographic model study (Northamptonshire County Council and Build Environment Service, 2003) which used geology as the starting point for LDU definition (See Section 4.2) elevation and slope were considered to have the most influential effect on the character of Tamar Valley's landscape and were therefore used as the primary datasets for beginning the derivation of LDUs. For use in other AONBs, Model 1 would need to be tailored to the area based on the attributed identified during the desk study stage.

5.5.1.1 Preparation of the Data

A DTM was selected for the analysis of the relief in the study area to allow for increased accuracy in defining LDU boundaries and also to enable slope information to be derived. The OS Landform-Profile DTM at a scale of 1:10,000 was chosen for analysis of elevation. This data set has been produced by interpolation of 5 m contour lines into 10m grid of height values, with an accuracy of +/- 2.5m depending on the terrain complexity. This data set has been chosen above the OS Land-form Panorama data at a scale of 1:50,000 to increase accuracy and as the data is no longer being produced or updated.

The data was provided in NTF format in 5 km tiles, these were converted to .asc files using MapManager for use in ArcGIS. The multiple rasters were joined together using the MOSAIC tool to create single DTM which was then processed with the

CLIP tool and the Tamar Valley AONB boundary file to exclude data outside of the study area (See Figure 5.6a). The SLOPE tool was then used to create a slope file with inclinations calculated in degrees (See Figure 5.6b).

Figure 5.6 Model 1 – Landform (See File 2012Davey309253phd-Figure5_6)

5.5.1.3 Model Development

A Natural Break Classification was used with the DTM to investigate where there were breaks of slope which could be identified by divisions that were inherently in the data. Five zones were optimal for delineating the river, the valley sides, the plateau and the highest point of the Tamar Valley; Kit Hill (See Figure 5.7). Too few zones meant a loss of information around the river, and too many zones created many small polygons highlighting individual hill tops rather than the whole plateau.

Using five zones with the RECLASSIFY tool enabled a simplified file to be created outlining just the five classes of elevation zones, the new classes were defined as (See also Figure 5.6b):

- Class 1 -1 m– 34m
- Class 2 34.1m – 80m
- Class 3 80.1m – 128m
- Class 4 128.1m – 198m
- Class 5 198m – 331m

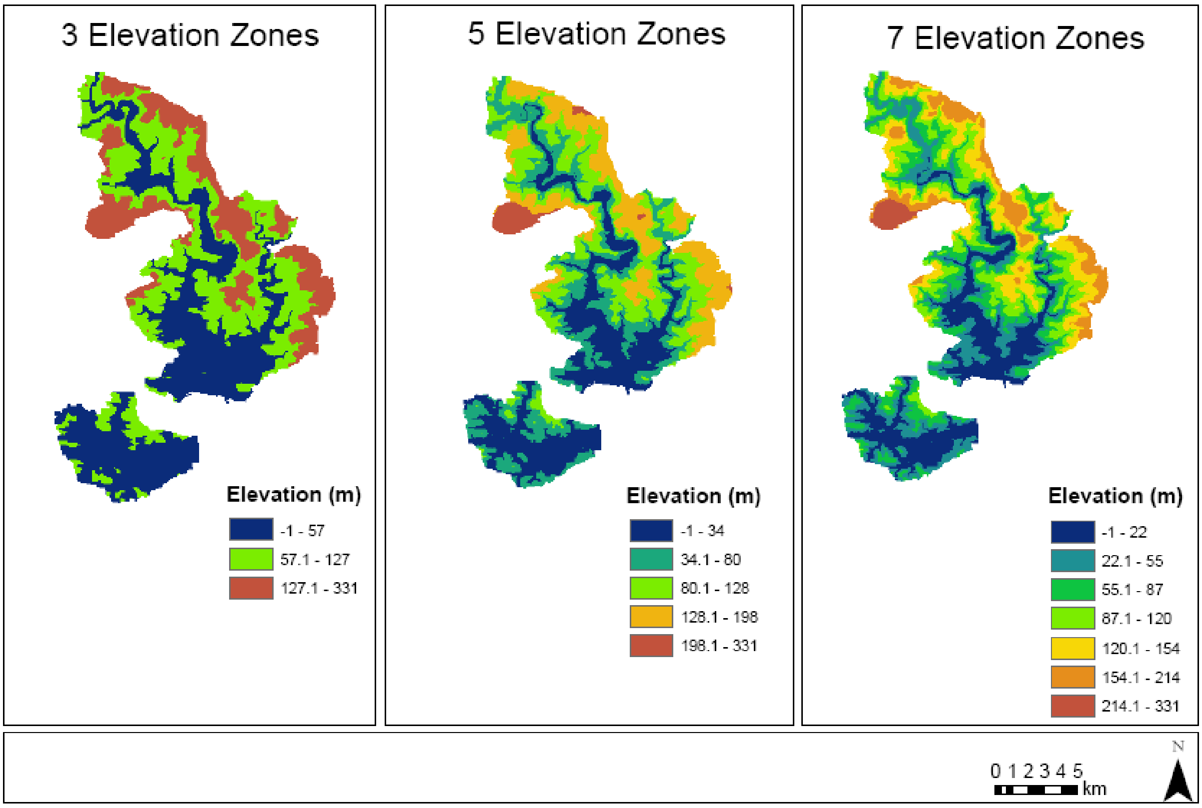

Figure 5.7 Different classification levels of the DTM. 5 zones give a good representation of the river, valley sides and plateau top

SLOPE values were then derived from the DEM, as can be seen in Figure 5.6c. This process assigns a slope value to each pixel. The information at this stage is too detailed for LDU classification, therefore, ZONAL STATISTICS are performed using the five elevation classes that have already been extracted from the DEM (Figure 5.6d). For each class, the average slope value is calculated and then the two datasets are COMBINED to give one file with both the elevation class and the average slope information (Figure 5.6e).

Using a series of rules the CON tool was used to process the combined elevation and slope data into landform LDUS. Elevation Class 1 (<37m) with nearly level (1°) slopes were classified as River Corridor, Elevation Class 2 (>=38m and <= 90m) with strong slopes (10°) were classified as Steep Valley Sides and Elevation Classes 3, 4 and 5 (>90m) with gentle to moderate slopes (4-7°) were classified as Upper Slopes (Figure 4.8e). These 3 classes were then APPENDED together to make one file containing the Landform LDUS (Figure 5.6f). This was adjusted using the rectification model (See Section 5.5.5)

5.5.2 Model 2 – Ground Type

The Ground Type analysis involved using the simplified NatMap Soilscape data and the simplified BGS Drift Geology data (See Figure 5.8).

5.5.2.1 Data Preparation

A 1:50,000 scale bedrock dataset was downloaded from Geology Digimap (http://edina.ac.uk/digimap/) providing information about mostly consolidated natural rocks of pre-Quaternary age (older than about 1.8 million years) Details provided include the BGS Lexicon and Rock Classification names and geological time scales.

Examination of the dataset revealed the TVAONB to consist of Paleozoic rock of the Devonian and Carboniferous eras. The rock is mainly Siliciclastic Argillaceous rock with Sandstone with small areas of Granite. For the purposes of the LCA these rock types can be classified as hard rock which covers the whole of the TVAONB and a separate data layer reflecting this was considered unnecessary as it would not help delineate the LDU boundaries.

Superficial Geology or ‘Drift’ Geology concerns unconsolidated natural in-situ superficial or surface deposits of the Quaternary age (younger than about 1.8 million years). Data is available at a scale of 1:50,000 which have been generalised from maps of a scale of 1:10,000. Data of this scale is suitable as a guide for identification of areas of drift geology as it is not being used for site specific analysis.

The Tamar Valley has some drift geology in the form of sand, silt, clay, gravel which are generally localised around the river and in the valleys.

The data was supplied from Geology Digimap in four tiles for Ivybridge, Plymouth, Dartmoor and Tavistock, these files were merged together to make one working file and then clipped to the extent of the Tamar Valley. The dataset was then merged with the Tamar Valley AONB boundary file to gain coverage of the whole site rather than just the polygons where drift geology was present. A raster dataset was produced with a 10m cell size this was reclassified to create a data file with the value of '0' where no drift geology was present and '1' where drift geology was present (See Figure 5.8c). Soil data can be derived from data sets such as the NatMap Soilscape by the National Soil Resources Institute. This is a simplified version of the national soil map providing generalised soils information at a scale of 1:250,000. The attributes included with the data are; soil type, texture, drainage, fertility and associated land cover and habitats information.

The NatMap Soilscape dataset also includes classes for 'water' and 'sea' which were unnecessary for this study. Therefore the data was clipped to the TVAONB boundary to remove all the areas that were known river. Small polygons remained along the edges of the river area that had been assigned to the 'water' or 'sea' classes which needed to be merged into the correct soil classes. The file was processed with the MULTI-PART TO SINGLE PART tool to separate all of the polygons to ensure that each small polygon had the greatest chance of being merged into the correct neighbouring class with the longest adjacent border using the ELIMINATE tool. The DISSOLVE tool was then used to create a simplified dataset with just soil texture and drainage information (See Figure 5.8a).

5.5.2.2 Model Development

The output from the Landform Model was initially COMBINED with the soils data to create one file with both the Landform Classes subdivided by the soil type. This was then processed with the rectification model to remove sliver polygons (See Figure 5.8a and 5.8b).

The corrected feature class of Landform and Ground Type data was used to create individual areas for ZONAL STATISTICS to be performed with the Geology - Drift presence (Value 1) and absence data (Value 0). By calculating the mean score for each polygon the data could then be reclassified to show 3 classes, where Class 1 <= 0.10 indicating little or no drift present, Class 2 => 0.10 and <= 0.49 where some drift was present and Class 3 where >=0.5 indicated that large amounts of Drift were present (See Figure 5.10c).

Finally, the Landform/Ground Type LDU file and the Drift Class files were COMBINED to create a Ground Type LDU file, now containing landform, soil and drift attributes (See Figure 5.10d).

The Rectification Model was used to identify polygons of < 1 km^2, however it was noted that many of the polygons selected were along the river and were small due to being split from their adjoining polygon across the river, therefore the SELECT BY

ATTRIBUTES tool was adjusted to exclude the polygons appearing in the River Corridor Class. The remaining polygons were merged into the appropriate classes.

The Ground Type LDU file is used at this stage to conduct the settlement pattern analysis as described in Section 5.5.4.1.

Figure 5.8 Model 2 - Ground Type (See File 2012Davey309253phd_Figure5_8)

5.5.3 Model Three – Land Cover

The TVAONB is essentially a farming landscape consisting of grass and arable land with broadleaf and conifer woodland which largely occurs in the valleys. The ALC, Registered Commons, NIWT and the AWI were used to create land cover classes (See Figure 5.9).

5.5.3.1 Data Preparation

The ALC data has been used in several LCAs (East Devon District Council, 2008, Peterborough County Council, 2007, Northamptonshire County Council, 2005, East Riding of Yorkshire Council, 2005, White Young Green, 2003) and has the advantage of being freely available to download from Natural England's website (http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp).

Agricultural land is classified into 5 grades by NE. These are Grades 1, 2, 3 and 3a which are classed as good agricultural land and have greater planning restrictions, Grade 4 which is classed as poor agricultural land and can still be used for pasture and some arable crops and Grade 5 which is very poor agricultural land, usually used as rough ground. Other classifications that may be used include: Urban, Non-agricultural Land, Woodland, Agricultural Buildings, Open Water, Land not surveyed. The land is assessed based on temperature, rainfall, aspect, frost risk, exposure, gradient, and soils. The scale of the data is 1:250,000 which were digitised without reference to underlying OS detail, the stated precision is 1m.

When the ALC was compared to the TVAONB boundary it was found that the ALC data protruded into the river in some areas, or did not extend right down to the river in other areas (largely due to the difference in scales between the data sources). A comparison of the data set with aerial photographs revealed that the data could be adjusted to reflect the definitive river outline and still accurately depict the ALC.

The original ALC dataset was clipped using the new TVAONB boundary; this ensured that any areas where the ALC encroached the river were removed. The data was transferred into a personal geodatabase with the TVAONB Boundary file by using the FEATURE CLASS to FEATURE CLASS tool. The files were processed together in a new typology where the ‘must be covered by’ rule was applied to produce a table of polygons that would be needed to extend the ALC data to match the river outline. The new areas were then merged into the neighbouring polygons using the polygon that had the longest adjacent border, during this process the new areas took on the attributes of the closest neighbouring data and a complete coverage of the TVAONB was achieved (See Figure 5.9e).

The Registered Common Land data is produced by NE and freely available to download from the MAGIC website (http://magic.defra.gov.uk/). The dataset contains parcels of land that have been registered under the CRoW Act and were designated as common land under the Commons Registrations Act 1965 (HMSO, 2011). The data was clipped with the TVAONB boundary to exclude data outside of the area; very small fractions of the edge of Rodborough Down remained and were removed, as was the ‘Land at Harewood Lane’ in Cornwall which was only 1605 m^2.

The Union tool was used to create a file that included both the ALC data and the Common data and was converted into a raster dataset (See Figure 5.9i).

The FC NIWT is at the scale of 1:25,000 covering all woodlands with an extent of greater than 0.02 km^2 (2 ha), this was derived from the interpretation of OS data and aerial photographs and ground truthing at random sample sites.

The AWI is freely available through the NE website (http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp), and also covers woodlands greater than 0.02 km^2 (2ha). The inventory shows areas of ancient semi-natural woodland and plantations on ancient woodland sites. The data is based on maps at the scale of 1:50,000 and 1:25,000 but are digitised to be accurate to the OS MasterMap Boundaries (Natural England, 2009).

Each of the woodland datasets were clipped to exclude areas outside of the study areas and processed with the TVAONB boundary file to reflect both wooded and non-wooded areas. Each file was converted into raster format (See Figure 5.9a and 5.9b).

Figure 5.9 Model 3 - Land Cover (See File 2012Davey309253phd_Figure5_9)

5.5.3.2 Model Development

Initially the NIWT and AWI were reclassified to reflect the presence/absence of woodland and ancient woodland (See Figure 5.9a and 5.9b). The classes were changed as per Tables 5.3 and 5.4.

Original Value	Original Class	New Value	New Class
0	Broadleaved	1	Wooded (Secondary)
1	Coniferous	1	Wooded (Secondary)
2	Mixed	1	Wooded (Secondary)
3	Felled	1	Wooded (Secondary)
4	Young Trees	1	Wooded(Secondary)
5	Shrub	1	Wooded (Secondary)
6	Non-wooded	0	Non-Wooded (Secondary)

Table 5.3 Reclassification of the National Inventory of Woodland and Trees data into presence/absence data

Original Value	Original Class	New Value	New Class
0	Non-Wooded	0	Non-Wooded (Ancient)
1	Semi-Natural	1	Ancient Woodland
2	Replanted	1	Ancient Woodland

Table 5.4 Reclassification of the Ancient Woodland Inventory into presence/absence data

Using values 0 for Non-Wooded (Secondary and Ancient) and 1 for Wooded (Secondary) or Ancient woodland cover, enabled the mean level of cover to be calculated for each polygon created in the previous model for the Ground Type LDUS using ZONAL STATISTICS. Each new statistic file was reclassified as follows (See Figure 4.11c and Figure 4.11d):

The NIWT data was split into two classes; >20% woodland cover and <20% woodland cover. This level was chosen to reflect areas that were heavily wooded as per the method in the English Nature Living Landscapes Project report (English Nature, 2004).

The AWI data was split into two classes at a level of <1% and >1%. This level was set to accurately reflect the location of the majority of the ancient woodland. Using purely presence and absence data created LDUs that only had a very tiny fraction of ancient woodland within it and was therefore not representative of the whole polygon.

The ALC was also simplified by being reclassified as per Table 5.5 (See Figure 5.9e).

Original Value	**Original Class**	**New Value**	**New Class**
0	Grade 2	1	Agricultural
1	Grade 3	1	Agricultural
2	Grade 4	1	Agricultural
3	Grade 5	2	Poor Agricultural
4	Non Agricultural	3	Non Agricultural
5	Urban	3	Non Agricultural

Table 5.5 Reclassification of the ALC

The 3 reclassified files were then COMBINED into one single file containing all three attributes, a series of rules were then applied to create land cover classes in Table 5.6 (See Figure 5.9f):

Class	ALC Value	AWI	Woodland Cover
Ancient Wooded Agricultural Land	1, 2	Presence	<20%
Non Agricultural Land	3	Absence	<20%
Wooded (Secondary) and Ancient Wooded Agricultural Land	1, 2	Presence	>20%
Wooded (Secondary)	3	Absence	>20%
Wooded (Secondary) Agricultural Land	1, 2	Absence	>20%
Agricultural	1, 2	Absence	<20%

Table 5.6 Land Cover classes

Each of these land cover classes were appended into one Land Cover file (See Figure 5.9h) and was then combined with the Common Land data and the Ground Type LDUs to give Land Cover LDUs. This was then processed with the Rectification Model (See Figure 5.9i).

5.5.4 Model 4 – Cultural Pattern

A settlement pattern map was prepared (See section 5.5.4.1) which was COMBINED with the Land Cover LDUs (See Figure 5.11). This gave each LDU the additional attribute of either clustered, dispersed settlements or unsettled (See Figure 5.11a). This was then analysed with the HLC data to give additional attribute of Historic Land Type and Period.

5.5.4.1 Data Preparation

Roberts and Wrathmell (2000) produced the Atlas of Rural Settlement in England which can be used to identify area of settlement based on attributes such as dispersion. The TVAONB falls into the Northern and Western Province where the dominant rural theme is townships with dispersed patterns of farmsteads and hamlets, surrounded by wood-pastures or open heaths and moors.

In order to gain a more specific picture of the settlement pattern throughout the TVAONB the OS Address-Point file was obtained and Average Nearest Neighbour (ANN) analysis was undertaken within ARCGIS. This enabled the settlement pattern to be classified as dispersed or clustered.

The OS Address-Point dataset are vector files with a unique point for each residential, commercial and public postal address in Great Britain. It is originated from Royal Mail Postcode Address Files for daily mail delivery purposes and has been combined with large scale topographic and transport network datasets. In urban areas the data has been captured and maintained at a scale of 1:1250, in rural areas 1:2500 and in moorland areas 1:10,000. The positional accuracy of each point is 0.1m. Address-Point is updated every three months and is available by Government Office Regions (GORs). The cost for supply of the data for 1 GOR for a one year licence is £1656.25 and is provided in .CSV format.

The Address-Point data was provided for use by the TVAONB and this study by Devon County Council and was provided in a Microsoft Access Database (.mdb file). This was uploaded into ARCGIS using the MAKE XY EVENT LAYER tool. As the data provided did not include an Object ID (OID) for each data point the FEATURE CLASS to FEATURE CLASS tool was used to create a permanent feature class with OIDs. This enabled the data to be processed further and was clipped to exclude all addresses outside of the TVAONB.

Before the ANN analysis can begin a framework is required which will provide the appropriate spatial extent from which the points will be analysed. Initially parish boundaries were trialled however this resulted in a ‘false’ boundary being incorporated into the LDUs that related purely to an administrative border rather than a change in landscape character. Therefore the Ground Type LDUs that are produced in Model 2 of the LCA-SDSS is used as a framework (See Section 5.5.2).

The Address-Point data was separated into 45 files using the SPLIT tool based on their location within each Ground Type LDU, each file was then analysed with an ANN script within ArcGIS.

ANN analysis is used to calculate whether a collection of data points are dispersed or clustered in nature. The analysis measures the distance between each feature and its nearest neighbour and then averages each of the distances. If the average distance is less than the hypothetical random distribution, the placement of the data being analysed is considered dispersed. A Nearest Neighbour Index (NNI) is expressed as the ratio of the observed distance divided by the expected distance (expected distance based on the same number of features being randomly distributed in the same study area). If the NNI is less than 1 the pattern is considered clustered, if the index is greater than the 1 the pattern is considered dispersed.

In order to ensure the pattern is not due to random chance each ratio is also assigned a Z-score which is a test of significance allowing the user to decide whether or not the null hypothesis can be rejected. The null hypothesis in this case being that ‘there is no pattern in the settlement data; the pattern is due to random chance.’

Z scores are a measure of standard deviation and are associated with a standard normal distribution. For example, if a Z-score is calculated as +2.5, this can be interpreted as 2.5 standard deviations away from the mean, the further your Z-score is away from the mean the less likelihood that the pattern is due to random chance. Using a confidence level of 95% would give you the critical Z-scores of -1.96 and +1.96 standard deviations, therefore in this example a Z-score of +2.5 would allow you to reject the null hypothesis that the settlement pattern is due to random chance.

The formula used to calculate the NNI and the Z-scores are based on the assumption that the data points are free to locate anywhere in the study area, and that all data points are independent of one another, the analysis is also sensitive to changes in area, therefore for each set of data points being analysed the associated Ground Type LDU area has been calculated for use.

The ANN tool in ArcGIS outputs the statistical analysis into a text window or can be displayed graphically however, as 45 datasets needed to be processed, a table output was preferable. A script was obtained from the ESRI support forum (Posted by Luke Pinder at http://forums.esri.com/thread.asp?c=93&f=983&t=233103) which allowed processing of multiple files with the outputs collated in a .csv file. This script was tested with multiple files and found to be working correctly. The script was adapted slightly to include the output of P-scores to be assessed for significance (See Appendix A).

Once the analysis was complete the results were examined for statistical significance (P-score). On two occasions the tool could not be run due to single addresses within the polygon, these were manually classified as dispersed. On three occasions the pattern was not statistically significant, visual inspection of the areas was completed resulting in the polygons being classified as dispersed. A raster dataset was created based on three criteria; dispersed, clustered or unsettled (See Figure 5.11).

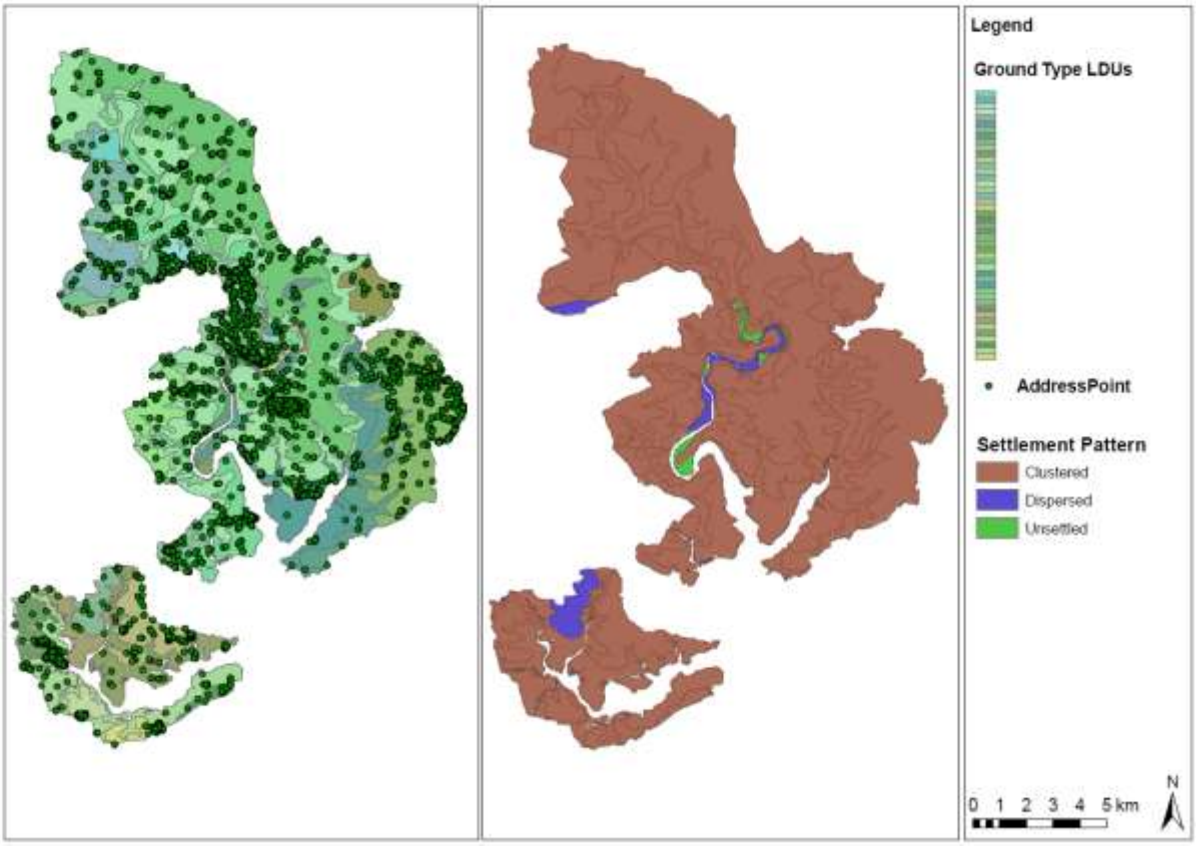

Figure 5.10 The settlement pattern of the Tamar Valley is mainly clustered with some areas that are dispersed or are unsettled (Data Source: Ordnance Survey)

HLCs have been produced for both Cornwall County Council (1994) and Devon County Council (Devon County Council & English Heritage, 2005). The Cornwall HLC was the first large scale study to be undertaken in the UK. HLCs group features together such as field boundaries, lanes and farms that are linked by their historical development and are then mapped. Unlike the Historic Environment Record individual features are not identified. The present day landscape is examined using modern OS maps and are characterised into Types. In the Cornish study 14 Landscape Types were identified within the TVAONB area and 17 Types occurred within the Devon study. In order to join the data for use in the LCA-SDSS the files were compared and the types combined across counties. Where no period data was available for the Cornish study the period 'mixed' was used, as it was stated in the Cornish HLC guidance that the Rough Ground class for example, could be from many periods. Table 5.7 shows the comparison of Types between the studies and the classes chosen for the combined data (See also Figure 7.7).

Cornwall HLC Type	Devon HLC Type	Devon HLC Period	Combined HLC Type	Combined Period
Ancient Woodland	Ancient Woodland	Medieval	Ancient Woodland	Medieval
Communications			Communications	Mixed
Farmland C20	Enclosures	Modern	Enclosures	Modern
Farmland Medieval	Enclosures	Medieval	Enclosures	Medieval
Farmland Post-Medieval	Enclosures	Post-medieval	Enclosures	Post-medieval
	Enclosures (Strips)	Medieval	Enclosures (Strips)	Medieval
	Horticulture	Modern	Horticulture	Modern
Industrial disused	Industrial (Mining) Industrial (complex)	Post-medieval	Industrial	Post-medieval
Industrial working	Industrial (complex)	Modern	Industrial	Modern
Military			Military	Post-medieval
Ornamental	Park/Garden	Post-medieval	Park/Garden	Post-medieval
Plantation and Scrub	Conifer Plantation	Modern	Conifer Plantation	Modern
Rough Ground	Rough Ground	Medieval Post-medieval Modern	Rough Ground	Mixed Medieval Modern
Settlement C20	Settlement	Modern	Settlement	Modern
Settlement Older Core (Pre- 1907)	Settlement	Medieval Post Medieval	Settlement	Medieval Post-medieval
Water Natural	Intertidal Marsh Water Meadow	Medieval Medieval, modern Medieval	Intertidal Marsh Water Meadow	Medieval Medieval, modern Medieval
	Orchard	Post-medieval Modern	Orchard	Post-medieval Modern
	Other Woodland	Post-medieval Modern	Other Woodland	Post-medieval Modern
	Quarry	Post-Medieval	Quarry	Post-Medieval
	Recreation	Modern	Recreation	Modern

Table 5.7 Historic Landscape Classification Classes

5.5.4.2 Model Development

The Settlement data derived from the Address Point file was added to the Model in a raster format and COMBINED with the Land Cover LDU. This produced a file with settlement pattern data applied to each Land Cover polygon.

To ensure that each polygon was discreet and available for analysis at the next stage of the modelling process the file was converted from a Raster file to a polygon file and processed with the MUTIPART to SINGLEPART.

Individual polygons were then available for use as with ZONAL STATISTICS tool and the HLC data. Majority Statistics were applied to calculate which Historic Character Class and Period covered the majority of the polygon (See Figure 5.11b).

The resulting map of HLC zones were converted back into raster format to enable the COMBINE tool to join the data with the Land Cover file which contains the attributes for Landform, Ground Type, Landcover and Settlement Pattern data.

After the completion of Model 4, each of the LDUs has all of the attributes gathered from each of the models and forms the final map of LDUs (See Figure 5.11c). This was processed with the Rectification Model.

To add LDUs for the rivers, the data for the Tidal and Non-Tidal river sections (See Figure 5.3b) were combined with the final output (See Figure 6.1).

Figure 5.11 Model 4 Cultural Pattern (See File 2012Davey309253phd_Figure5_11)

5.5.5 Model 5 - Rectification Model

The rectification model can be used at any stage during the process where an output file needs altering to remove small polygons that have been classified in error. Using the model can be an iterative process. For example, when merging polygons into a neighbouring feature class, there may be some polygons that cannot be merged during the first iteration as their only neighbouring polygon also needs to be reclassified. An example of how Model 5 is used for the output of Model 1- Landform is described.

To enable the inspection of individual areas of the Landform LDU data the file was converted from a RASTER TO POLYGON file (See Figure 5.12a) and the MULTIPART TO SINGLEPART tool was used to separate spatially discrete polygons that shared the same attributes (See Figure 5.12b). The CALCULATE AREAS tool was used to add an ‘area’ field to the attribute table (See Figure 5.12c). The area in m^2 was calculated highlighting many small polygons of less than 1 km^2 that had been created in the data which can be merged into their neighbouring classes.

The layer was then processed with the MAKE FEATURE LAYER tool; this creates a temporary working file that can then be used with the SELECT BY ATTRIBUTES tool. The polygons selected were those whose areas were <1000000 m^2 (1 km^2).

The ELIMINATE tool was used to determine which class the polygon should belong to by identifying and merging into the neighbouring polygon with the longest shared border. Once the correction of the file is complete the file is converted from a FEATURE TO RASTER to enable the insertion of the data into the next model (See Figure 5.12d).

Figure 5.12 Rectification Model (See File 2012Davey309253phd_Figure5_12)

5.6 Conclusion

Using the key characteristics of the TVAONB identified during the desk study, allowed appropriate datasets to be sourced for inclusion in the LCA-SDSS and a database to be developed. To enable an accurate assessment, each of the input data sources was processed by the same definitive boundary file.

Some data preparation was needed in addition to tailoring the data to the study area, in particular, the settlement analysis data needs to be completed after Model 2 has been completed and before Model 4 can be run.

The Model Base contains 4 models to produce a framework of LDUs with attributes for Landform, Ground Type, Land cover and Cultural Pattern and an additional Rectification Model to allow sliver polygons to be merged into neighbouring classes.

The results of each model are presented in Chapter 6.

Chapter 6 Results

6.0 Introduction

The culmination of running each model is a map of LDUs. Each LDU polygon has a linked attribute table outlining the Landform, Ground Type, Land cover and Cultural Pattern. The final map can be displayed within a GIS by the LDU number or any of the linked attributes. In order to test the results of the SDSS, each model's output will be examined in the context of the findings in the desk study (Table 5.1).

6.1 Landform

The Landform Map (See Figure 5.6) has been created using a combination of elevation and slope analysis derived from a DTM. Initially 5 zones of elevation were identified which highlighted the river corridor, valleys, plateaus and individual hill tops. The slope values further defined the LDUs by identifying the break of slope between the river corridor, valley sides and the plateau tops, and allowed individual hill tops to be combined in the upper slopes class.

Three classes were identified:

1. The River Corridor – Low lying (below 37m) flat land with gentle slopes
2. Steep Valley Sides – Steeply sloping land between 37m and 90m elevation
3. Upper Slopes – Gently sloping land above 90m elevation

The three classes give a good overview of the structure of the Tamar Valley. The river corridor class clearly identifies the areas that contain the Tamar, Tavy and Lynher rivers. In particular, the nature of the river corridor is highlighted as it flows from the north in a narrow winding channel into the expansive areas of the low lying land around the mouths of the rivers Tamar and Lynher.

The Steep Valley Sides flank the rivers giving the impression of the mirroring effect in the landscape and then lead onto the Upper Slopes and the prominent plateau tops of the Bere Peninsula, Kit Hill and the edge of Dartmoor.

6.3 Ground Type

Ground Type is an expression of soil types together with an indication of the drainage and the presence of drift geology.

Seven Classes were identified during the Ground Type analysis from a soil map and drift geology data (See Figure 5.8).

1. Freely Draining Loam with Large Presence of Drift – Soils with a mixture of sand, silt and clay sized particles which readily absorb rainfall and allow it to drain through to the layers below. A large presence of drift (>50%)
2. Freely Draining Loam with some drift present – Soils with a mixture of sand, silt and clay sized particles which readily absorb rainfall and allow it to drain through to the layers below. Drift present within the LDU.
3. Freely Draining Loam with Little or No drift present – Soils with a mixture of sand, silt and clay sized particles which readily absorb rainfall and allow it to drain through to the layers below. Little or No Drift present within the LDU (<10%).
4. Loamy Soil with Impeded Drainage - Soils with a mixture of sand, silt and clay sized particles, with compact subsoil which impedes the drainage of water becoming water logged after heavy rainfall. Little or No Drift present within the LDU (< 10%).
5. Naturally Wet Loam, Large Presence of Drift - Soils with a mixture of sand, silt and clay sized particles which are naturally wet owing to the high ground

water level resulting from the drainage of the surrounding landscape. Large presence of drift (>50%).

6. Naturally Wet Loam, Some Drift Present - Soils with a mixture of sand, silt and clay sized particles which are naturally wet owing to the high ground water level resulting from the drainage of the surrounding landscape. Some Drift present (between 10% - 49%)
7. Peaty Soils with Surface Wetness, Some Drift Present– Predominately organic surface layer, which holds water throughout the winter causing surface wetness, but being reasonably dry underneath. Drift present (between 10% - 49%)

The 7 classes described during the process account for the variation in the soil type cross referenced with the presence of drift. Using both datasets allows the variation in the classes for freely draining loam which would have been a single class if drift were not accounted for. Ground Type Classes 2 and 3 allow the LDUs to reflect that the presence of drift is greater along the river corridor than on the steep valley sides or upper slopes. Ground Type Class 1 is a very small area off of the Lynher River that has been classified as having a very high proportion of drift. This LDU has been created as it is split off of the neighbouring polygon by the river and was excluded from the rectification model as due to its location along the river line. Further analysis of the LDU reveals that it also carries a different Land Cover class to its neighbouring polygon so therefore it was left as a separate LDU.

Class 4 identified three areas that were prone to impeded drainage; to the south of Kit Hill, at Morwelldown Plantation and at Gunoak Woods.

Classes 5 and 6 identify the areas around the river that would be expected to be naturally wet. Class 6 has been created due to a small polygon next to the river that has a little presence of drift while across the river there is a large presence of drift. Whilst the polygon is very small it is relevant and provides part of the framework for use in the next stage of the analysis.

Class 7 identifies an area of peaty soils around Chilsworthy, which would have very low fertility.

6.4 Land Cover

Land cover is an expression of the agricultural land use, forestry, ancient woodland and common land. Using the NIWT allowed statistical analysis of each Ground Type LDU using the rule of >20% woodland coverage as defined in the Living Landscapes Project (English Nature, 2004), building this into the model resulted in each LDU being classified rapidly and accurately into each class. The presence of ancient woodland was considered very important due to its influence on the biodiversity of the area and its heritage.

In total, 7 different classes were identified based on the grade of the agricultural land, the presence of ancient woodland, and the dominance of the woodland cover (See Figure 5.9).

1. Ancient Wooded Agricultural land - Agricultural land used for crops or grass with < 20% secondary woodland cover. Features areas of semi-natural or replanted ancient woodland.

2. Non -Agricultural Land – Areas of land that could be returned to agricultural uses, usually golf courses, private parkland, public open spaces, sports fields allotments, active mining land or refuse tips - with < 20% secondary woodland coverage
3. Wooded (Secondary) & Ancient Wooded Agricultural Land - Agricultural land used for crops or grass featuring coverage of secondary woodland > 20% and presence of semi-natural or replanted ancient woodland sites.
4. Woodland - Areas of non or poor agricultural grade land covered with > 20% woodland (Secondary). Features areas of semi-natural or replanted ancient woodland
5. Wooded (Secondary) Agricultural Land - Agricultural land used for crops or grass with > 20% woodland cover.
6. Agricultural - Areas of agricultural land used for crops or grass with < 20% secondary woodland cover.
7. Common Land - with less than <20% secondary woodland cover.

Classes 3 and 6 account for the majority of the land cover in the Tamar Valley, 83 km^2 (47%) is classified as Agricultural Land which is mainly located on the Upper Slopes, and on the Steep Valley Sides of the Lynher section. 76 km^2 (38%) is covered by agricultural land that also features prominent woodlands and areas of ancient woodland such as the River Corridor and Steep Valley Sides and two small areas of Upper Slopes.

The other classes make up the remaining 12 km^2 (6%) of the area. The Woodland category reflects the large area of woodland of Gunoak and Wareham woods to the north of the designation, much of the site is classified as either replanted ancient woodland or semi-natural ancient woodland and is now a mixture of broadleaved and conifer species. Another small area in this category was identified at Morwellham Quay.

Two small polygons along the river edge were identified as Ancient Wooded Agricultural Land; these contain areas of land that are identified on the AWI but not on the NIWT, using aerial photography confirms that there is a small amount of woodland within the polygon which is classified as ancient woodland but there is not a large coverage of secondary woodland and therefore the categories were deemed correct. The area around St Germans was identified as Wooded Agricultural Land which includes the estate lands of Port Elliot, but did not have areas of ancient woodland.

6.5 Cultural Pattern

The Cultural Pattern Model used settlement data and the HLC to identify a cultural pattern with three contributing attributes: Settlement pattern, Historic Character and Period (See Figure 5.11).

Three classes of settlement were identified (See Figure 5.10):

1. Clustered Settlement
2. Dispersed Settlement
3. Unsettled.

The majority of the AONB is classified as Clustered Settlement pattern with a few areas of Dispersed Settlements to the north of the Lynher, south of Kit Hill and along the River Corridor. Several polygons along the River Corridor were identified as Unsettled.

Using the Zonal Statistics processed with the HLC data resulted in 12 classes being identified (See Figure 5.11):

1. Ancient woodland, Medieval
2. Conifer Plantation, Modern
3. Conifer Plantation, Post-Medieval
4. Enclosures, Medieval
5. Enclosures, Modern
6. Enclosures, Post-Medieval
7. Industrial Complex, Post Medieval
8. Marsh, Post-Medieval
9. Military, Post-Medieval
10. Other Woodland, Modern
11. Park/Garden, Post-Medieval
12. Rough Ground.

Much of the Tamar Valley is covered by a Medieval or Post-Medieval Enclosure pattern, with areas of Modern Enclosures in the Lynher. The LDUs around Port Elliot, Anthony House and Endsleigh were identified as Park/Garden. The combined settlement pattern and HLC data create 17 classes:

1. Unsettled, Enclosures, Medieval - This class accounts for 1 LDU bordering the river just north of Calstock, this LDU shares the medieval enclosures field

pattern with the neighbouring LDUs however it is distinguished by being Unsettled.

2. Unsettled, Enclosures, Post-Medieval – This class occurs around the Calstock area on the Devon bank of the River Tamar, and also on the Devon side of the River to the south of Halton Quay. These LDUS are distinct from the neighbouring class of Post-Medieval Enclosures by being Unsettled. West Down Common is also included in this class.
3. Unsettled, Enclosures, Modern – A small LDU near Bohetherick was identified as distinct from its neighbouring LDU by having a Modern Enclosure pattern. This is contrasted to the neighbouring polygon covering Bohetherick that has a Medieval Enclosure pattern around the market gardening areas.
4. Unsettled, Industrial Complex, Post-medieval – This LDU is at Newquay on the Devon side of the river. The area is distinct as an area of industry and is Unsettled.
5. Unsettled, Marsh, Unsettled – an area of marsh identified at Halton Quay
6. Unsettled, Rough Ground, Mixed – This class is contained in one polygon to the east of Calstock on the Cornwall bank of the river. The area is characterised by Rough Ground which differs from the surrounding Medieval Enclosure pattern. The area is Unsettled.
7. Unsettled, Ancient Woodland, Medieval – This class is formed of one LDU which follows the bends of the river in the Wareham Wood area. This contrasts to the surrounding Park/Garden and Conifer Plantation classes and is Unsettled.

8. Unsettled, Conifer Plantation, Modern – This LDU identifies an area around Inny Ham which is a modern conifer plantation in contrast to the surrounding class which is ancient woodland.
9. Dispersed Settlement, Enclosures, Medieval – Two areas are identified in the Lynher section of the Tamar valley. One small LDU is located within the boundary of the designation by the village of Tideford, and is distinct from it neighbouring class of Park/Garden. A larger LDU is found at Markwell extending up to Landrake, the historic pattern is the same as the surrounding area however the settlement pattern is dispersed, with few buildings.
10. Dispersed Settlement, Enclosures, Post-Medieval – This Class is identified to the south of Kit Hill, it has the same historical pattern as the other LDUs around Kit Hill however there are few buildings which are dispersed in nature.
11. Clustered Settlement, Enclosures, Medieval – This class covers a large amount of the Tamar Valley totalling 78 km^2 (48%). It largely covers the Cornwall side of the designation and much of the north section of the Lynher. It also occurs on the Devon side of the river along the northern section of the River corridor and Steep Valley Sides classes.
12. Clustered Settlement, Enclosures, Post-medieval – This class covers 80 km^2 (49.5%) and is mainly located on the Devon side of the AONB on the Upper Slopes. There is also an area around Kit Hill.
13. Clustered Settlement, Park/Garden, Post-medieval – There are three areas that have been identified in this class around the Endsleigh, Anthony and Port Elliot estates.

14. Clustered Settlement, Military, Post-medieval – This is a small LDU on the south-east of the Lynher above Torpoint.
15. Clustered Settlement, Ancient Woodland, Medieval – This class covers a heavily wooded area including Wareham and Gunoak woods following the river to Castlepark Hill. The area includes two clusters of settlements at Carthmartha and Trecombe.
16. Clustered Settlement, Conifer Plantation, Modern – This small LDU is located at Leigh Woods and contrasts to the neighbouring polygons that are classed as Ancient Woodland in the Cultural Pattern.

6.1 Landscape Description Units

A total of 58 LDUs were created made up of 48 unique classes (see Figure 6.1). The area of the LDUs ranged from the smallest of 0.29 km^2 (LDU 48) which is along the river corridor, to the largest (LDU 43) covering 35.8 km^2 over the Bere Peninsula. The majority of the LDUs that were under 0.5 km^2 were along the river or on the edge of the designation with the exception of the LDUs around Gunoak Wood.

Each LDU has linked attributes for example; LDU 34 at Bere Ferres is classified as having:

- Steep Valley Sides
- Freely Draining Loam, Some Drift Present
- Wooded (Secondary) and Ancient Wooded
- Clustered Settlement
- Enclosures, Post-Medieval

A full list of the attributes linked to each LDU can be seen in Appendix B.

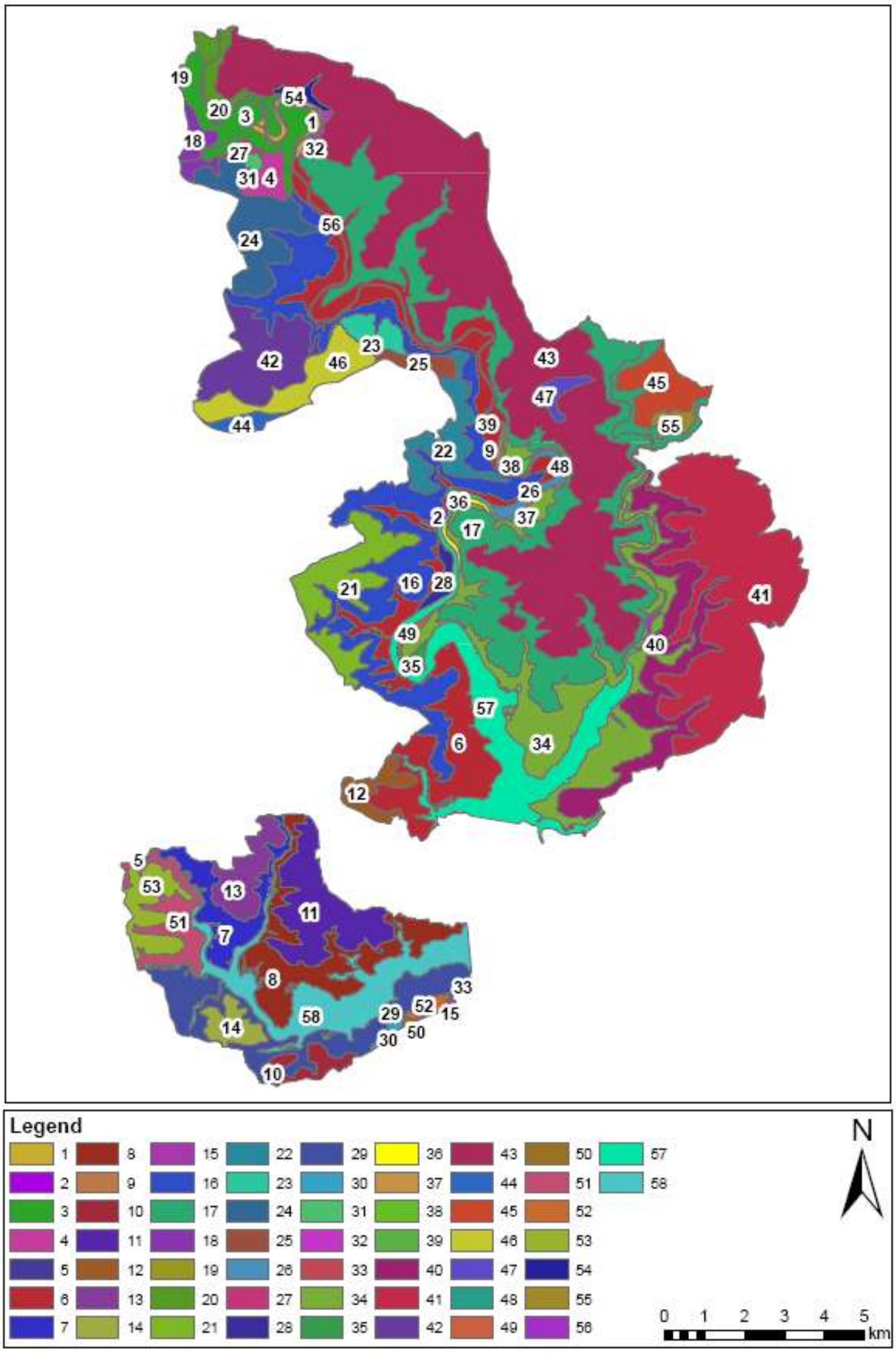

Figure 6.1 Landscape Description Units

Chapter 7 Evaluation of the Spatial Decision Support System

7.0 Introduction

The verification and validation of a SDSS is an important part of its development. Verification is typically iterative and takes place throughout the development process (Finlay et al., 1998; Matthews et al., 1999) and field surveying is also conducted to test the SDSS outputs in situ. Verification can also be achieved by changing input parameters and observing the effect on output of the system (Graymore et al., 2009). Validation involves testing the appropriateness of the system in supporting real-world decision problems. Since it is not possible to prove that the models present a truthful representation of the real world, validation is concerned with demonstrating that the system has appropriate underlying relationships to permit an acceptable representation Validation can be carried out by assessing the individual components of the system, the system as a whole and how it can be applied to different decision problems (Finlay et al., 1988).

The verification and validation of the model was sought in several ways (See Table 7.1). The validation process can be carried out by testing against existing case studies (Sailors, 1996; Matthews et al., 1999) and in this research the LDUs and the output of each model will be examined and compared to the results from the LCAs conducted by the consultants Diacono Associates & White Consultants for Devon and Cornwall (Diacono Associates & White Consultants, 2007; Diacono Associates & White Consultants, 2008). A comparison between the data sources used by the consultant and the SDDS and an outline of the methods used in the consultants assessments is also discussed.

To test that system as a whole and how it can be applied to different decision problems, CA, CT and Landscape Monitoring Units have been created with brief descriptions of the landscape character collated during the field verification.

Verification	Ongoing throughout Model Development	Many iterations of the models were completed using different combinations of rules and data sources (See Table 7.2 for examples)
	Field Verification	84% coverage achieved in the field testing to: • Check the LDU boundaries were appropriate • Test the LDU framework, and the additional data provided on the field sheets (See Table 7.3)
Validation	Comparison to the expert interpretation	Each model output was compared in detail with the LCA conducted for Devon conducted by the consultants Diacono Associates & White Consultants for Devon and Cornwall (Diacono Associates & White Consultants, 2007; Diacono Associates &

		White Consultants, 2008). See Appendix D for detailed results.
	Application of outputs	Creation of CA, CT and LMUs

Table 7.1 Verification and Validation Method

7.1 Verification of the Spatial Decision Support System

Verification of the LCA-SDSS was partly achieved during the developmental stage. An extensive review of LCAs and a detailed investigation into the study of the area ensured that appropriate data was gathered for integration into the database, in common projection (British National Grid) and at an appropriate scale for producing a LCA at a regional level. During the development of the models, where established rules were not available (Such as for Woodland Cover –See Section 5.5.3.2) different rules were applied and outputs examined to ensure the most appropriate characterisation was achieved (For examples, See Table 7.1).

		Methods
Verification	**Landform**	The Landform LDUs drive the rest of the classification and therefore it was imperative that the output from this model gave the most appropriate representation of the area. Several levels of classification were trialed for example see Figure 5.7.
	Ground Type	• Bedrock Data – Initially Bedrock data was included in the model and then later excluded due to delineation of LDUs that were irrelevant as all the rock types can be classified as 'Hard Rock'

		• Soil Data – Simplification of the Soil dataset to give just details of the soil texture and drainage. Initially the model was run with each full soil description which resulted in many LDUs that were very similar in nature. • Superficial Geology – Classifications adjusted to give the best representation of the location of the drift after the averaging process.
	Land Cover	• Ancient Woodland - Classifications adjusted to give the best representation of the location of the drift after the averaging process. • Agricultural Land Classification – Initially the model was trialed using each original grade, however this gave rise to polygons that were not sufficiently different in character • LCM2000 – discounted for use after trialing the data in the model. Too many polygons were produced. The data was also simplified into classes such as, agriculture and the semi-natural habitats, where again too many polygons were produced where small pockets of habitat sat within the landscape.
	Cultural Pattern	• Settlement Pattern – A settlement map was created based on the Settlement Morphology methodology of Bibby & Shepherd (2001) using the address point data. This resulted in a density map for the area, which was effective

		at highlighting the built up areas, however there was no difference in the characterisation of the dwellings outside of the settlements. The density map was also difficult to integrate into the model without introducing boundaries around the settlements themselves which distracted from characterising the settlement as 'within' the landscape. • The ANN method was trialed using parish boundaries, to create a map with a dispersed/clustered pattern. However this also introduced 'false' administrative boundaries into the LDUS outputs.

Table 7.2 Verification Process

Field verification was undertaken for two reasons, firstly to check that the boundaries and LDUs that were created were appropriate, and secondly to gather further information to confirm the characterisation of the landscape into CA and CT.

Before the field work commenced the LDU framework was used to gather information from additional data sets to give an enhanced preview of what would be found in the field, and add finer details that are omitted during the modelling. This process provides an insight into features that are present in the landscape such as individual monuments or listed buildings that are important to the LDUs character, but do not help in the delineation of LDUs and could be overlooked when attempting to field survey a large area of land. The following data sets were used:

- Devon and Cornwall HLC
- LCM2000
- Tamar Valley Market Gardening
- English Heritage Listed Buildings
- English Heritage Scheduled Monuments
- English Heritage Registered Parks and Gardens
- SSSI, SAC, SPA, LNR, NNR
- National Trust
- World Heritage Site
- Mine Sites.

This was achieved by creating a data file that contained just the LDU number using the DISSOLVE tool and then batch processing all of the above datasets with the IDENTITY tool. The HLC, LCM and Market Gardening files were then processed with the DISSOLVE tool to obtain data by LDU number and feature, this enable multiple occurrences of the same feature class to be merged into a multi-part polygon. This allowed the feature to be treated as a whole, while retaining the same spatial extent within the layer. The total area covered for each feature within each LDU could then be calculated by adding a new field to the table and using the Calculate Geometry function. Area calculations were also carried out for Parks and Gardens, SSSI, SPA, SAC, LNR, NNR, National Trust and WHS.

Each attribute table was then exported into an ASCII file using the EXPORT FEATURE ATTRIBUTE TO ASCII tool in a batch process. These files were then imported into Microsoft Excel as comma delimited files and complied by LDU number. For each of the datasets that needed to have a % cover calculated a simple percentage function was used within Microsoft Excel using the area calculated for each LDU. The count function was also used on the Market Gardening file to calculate the number of orchards, building etc. per LDU.

The Mine, Listed Buildings and Record of Scheduled Monuments data were not analysed by area, as they were either provided in a point file where an area cannot be calculated or the area is not relevant as they single occurrences of a feature such as a single listed building. Due to the small number of these features it was also appropriate to leave them listed by each occurrence rather than just providing a feature count. For example, LDU 34 has the features listed in Table 6.1.

This method of analysis allowed information such as the occurrences of orchards, salt marshes and scheduled monuments to be highlighted before the field work commenced, as they were not included in the LDU attributes, but are important for landscape character.

Data Source	Feature	Area (m^2)	% Cover	Count
HLC	Medieval Ancient Woodland	768990	6.73	
	Medieval Enclosures	1430841	12.53	
	Medieval Intertidal	56457	0.49	
	Medieval Marsh	53328	0.47	
	Medieval Settlement	29132	0.26	
	Medieval Water Meadow	109422	0.96	
	Modern Conifer Plantation	943319	8.26	
	Modern Enclosures	1536029	13.45	
	Modern Horticulture	7	0.00	
	Modern Marsh	174594	1.53	
	Modern Orchard	28452	0.25	
	Modern Other Woodland	412907	3.62	
	Post-medieval Conifer	10074	0.09	
	Post-medieval Enclosures	4281255	37.49	
	Post-medieval Industrial	87003	0.76	
	Post-medieval Industrial	142291	1.25	
	Post-medieval Marsh	405789	3.55	
	Post-medieval Orchard	137666	1.21	
	Post-medieval Other	368180	3.22	
	Post-medieval Park/Garden	261462	2.29	
	Post-medieval Settlement	73773	0.62	
	Post-medieval Water	797	0.01	
LCM2000	Acid grass	65361	0.57	
	Arable Cereals	2232427	19.55	
	Arable horticulture	1217791	10.66	
	Broad-leaved woodland	2222408	19.46	
	Calcareous grass	770438	6.75	
	Coniferous Woodland	968306	8.48	
	Continuous Urban	282459	2.47	
	Dwarf shrub heath	20027	0.18	
	Improved grassland	2883592	25.25	
	Inland bare ground	61870	0.54	
	Littoral rock	134813	1.18	
	Neutral grass	36564	0.32	
	Salt marsh	178230	1.56	
	Sea / Estuary	16886	0.15	
	Suburban/rural developed	309461	2.71	
	Water (inland)	17652	0.15	
Listed Buildings	Church Of St Andrew (Grade 1)			
LNR	Lopwell Dam	2361	0.02	

Table 7.3 Features for LDU 34 Bere Ferres

Data Source	Feature	Area (m^2)	% Cover	Count
Market Gardening	Building	1438	0.01	8
	Market Garden	192858	1.69	10
	Orchard	1451922	12.71	45
	Rumleigh Farm	66	0.00	1
Mines	Gawton 1853 -1920			
	Lady Bertha 1855 -1899			
	Maristow 1822 -1822			
	North Hooe 1840 - 1905			
	South Hooe 145- 1882			
	South Lady Bertha 1859 -			
	South Tamar 1849 - 1855			
	South Ward 1868 - 1878			
	Morwellham			
	Tavy Consols 1723 -1891			
SPA	Tamar Estuaries Complex	684455	5.99	
SAC	Plymouth Sound & Estuaries	84936	0.74	
SSSI	Tamar-Tavy Estuary	1130699	9.9	
	Grenofen Wood and West	849699	7.44	
Record of Scheduled	Battery at Wearde Quay			

Table 7.3 Features for LDU 34 Bere Ferres (…cont)

A field sheet was created based on the example in the Landscape Character Assessment Guidance for England and Scotland (Swanwick, 2002). An example field sheet from LDU 34 at Bere Ferris is shown in Appendix C.

A coverage of 84% of the TVAONB landscape was achieved by surveying 20 LDUs. The LDUs not surveyed were generally small or more inaccessible, for example the LDUs along the river line and around Gunnoak wood (See Figure 7.6). These LDUs were confirmed by double checking the attributes and comparing them to aerial photography.

No revisions were made to the boundaries as a result of the field work. However in some cases it was difficult to confirm boundaries were correct if they were obscured by features such as woodland. Figure 7.1 shows the view from Lopwell across the River Tavy. The boundary of LDU 34 can be clearly defined; however the boundary between LDU 17 and 43 is obscured.

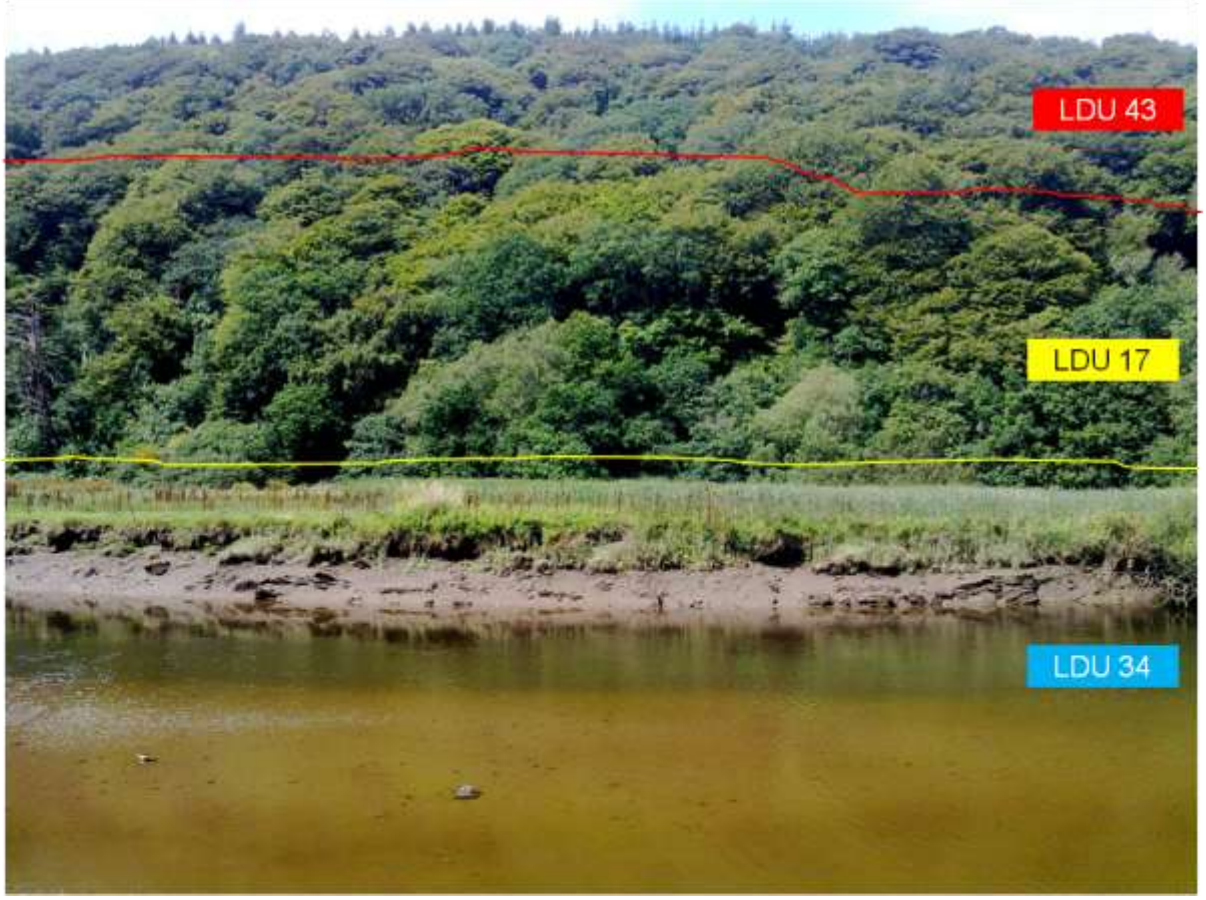

Figure 7.1 View from Lopwell Across the River Tavy (Data Sources: Aerial Photo - This image is an extract from the Millennium Map (tm) which is copyright Getmapping PLC)

The information gathered at the field work stage together with the list of attributes that were produced for each LDU also allowed the initial CTs and CA to be confirmed and a preliminary set of characteristics to be drawn for each CT and CA (See Section 7.2.6.1 -7.2.6.2).

7.2 Validation of Results

To validate the results of the model, a detailed analysis of the outputs were compared to the LCA that has been completed by the consultants Diacono and White (Diacono Associates & White Consultants, 2007; Diacono Associates & White Consultants, 2008) for both the Devon and Cornwall Counties. Each of the assessments were commissioned separately; however, the advantage of having the same consultant for each assessment meant there was cross border correlation for the LDUs. Initially Devon County Council opted for CTs to be derived from the LDUs and Cornwall Council opted for CA. The TVAONB commissioned an extension to the project to create CA on the Devon side of the designation to ensure there was one coherent assessment across the whole of the AONB.

The methodology adopted by the consultants included a bottom up analysis of the area beginning with desk based derivation of LDUs. Several datasets were used as detailed in Table 7.4, the data used in the SDSS are also stated for comparison.

	Cornwall	**Devon**	**SDSS**
Physiography (Landform)	Geology (No source given) 10m Contours	Geology –Solid and Drift (No source given) 10m Contours	DTM (OS Landform-profile)
Ground Type	Farm Census Data (University of Reading, 1995) Soil Paper Maps (No source given)	Farm Census Data (University of Reading, 1995) Soil Paper Maps (No source given)	Drift Geology (BGS) Soilscape (NatMap)

Land Cover	Farm Census Data (University of Reading, 1995) Woodland Ancient Woodland	Farm Census Data (University of Reading, 1995) Woodland Ancient Woodland Moorland	ALC (Natural England) Common Land (Natural England) NIWT (Foresty Commission) AWI (Natural England)
Cultural Pattern	Settlements HLC	Settlements HLC	Address-point (OS) HLC (Cornwall County Council, 1994, Devon County Council & English Heritage, 2005)
Additional Sources of Data	OS 1:50000 National Landscape Typology	OS 1:10000 OS 1:50000 National Landscape Typology	LandcoverMap 2000 (For verification purposes)

Table 7.4 Data sources used in the county LCA and SDSS (Source: Diacono Associates and White Consultants, 2007, 2008)

The natural dimension of the landscape is mapped first, providing a context for analysing the historic evolution of the landscape and also because the attributes of relief, soils and geology have 'real' boundaries that can be readily defined, where patterns of topography can be related to changes in soil and geology. Cultural attributes do not have such clearly defined boundaries but due to historical constraints such as slope or soil drainage it is possible to map cultural attributes using the emerging LDU polygons (Diacono Associates & White Consultants, 2008).

The LDUs are delineated by heads up digitising and manual analysis of the data to look for patterns such as where breaks in slope coincide with changes in geology. Where there are no breaks in slope a 'best fit' line is drawn related to geological changes. Once the Physiography LDUs are created, these are further defined and subdivided to create Ground Type LDUS by overlaying digital drift geology and land use data in the GIS and analysis of paper soils maps for type, drainage and fertility. The Farm Census data and HLC was then overlayed to derive the predominant land use/agricultural type and the woodland data examined for its contribution to the landscapes character. Patterns are identified and LDUs are further defined or subdivided to create the Landcover LDUS.

The last stage of the desk analysis is investigating patterns of settlement derived from OS maps, Landscapes of Settlement (Roberts, 1996), as well as the farm type derived from the June Agricultural census, and manually digitising/subdividing the Landcover LDUs.

After the initial delineation of the LDU boundaries, these are further defined after a field study which also seeks to incorporate visual/aesthetic descriptions, look at landscape condition, identify any particular qualities or problem areas and derive

CTs. Stakeholder participation was also sought to verify key characteristics, identify pressures for change and allow feedback of the LCA boundaries.

A map of LDUs for all four attributes and the final LDUs were obtained from the consultants assessments and these have been used to complete a detailed comparison of the results from the SDSS. The results of the detailed comparison can be found in Appendix D. Sections 7.2.1 – 7.2.5 give a broad description of the model outputs and discuses the model performance, data used and how the model could be used in different locations.

7.2.1 Landform

The benefit of using the model to analyse Landform using is the ability to conduct the classification rapidly and to be able to trial several different classifications to see the effect that occurs on the output polygons. Using a DTM also allowed slope analysis to take place, without the need for time consuming heads-up digitising of the areas by expert interpretation of contour lines.

The Landform classes resulting from Model 1 represent the river corridor, valley sides and the upland areas, capturing the character of the landscape by highlighting the symmetry along the river valley. The river corridor captures each of the Tamar, Tavy and Lynher rivers, reflecting the steepness of the enclosing valley sides and up to the plateau areas (See Figure 7.1).

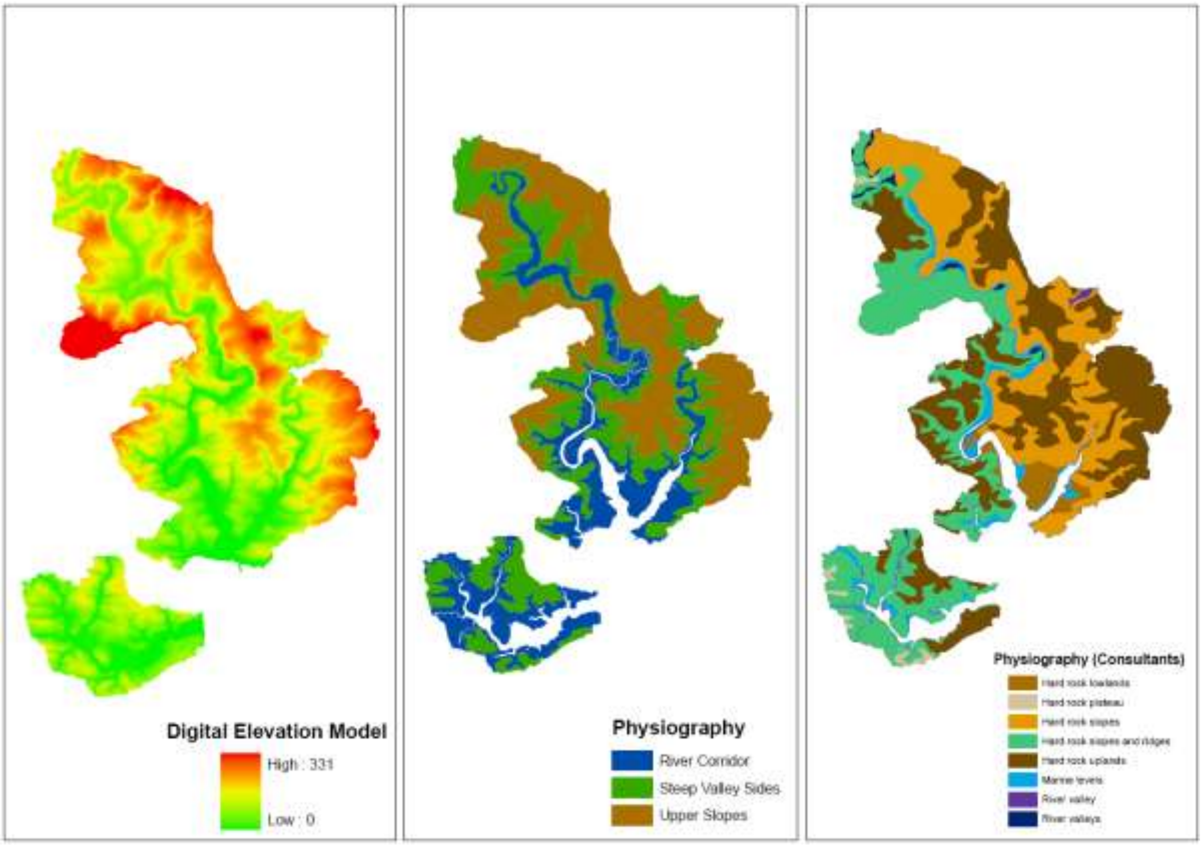

Figure 7.2 Landform

In comparison to the experts LCA broad similarities can be seen across the areas identified as uplands and slopes. The model has the retained a more distinct definition of the River Tamar to the north of the designation, however the consultants map clearly shows an additional tributary that has not been identified in the model. Due to the tailoring of the data to the AONB the small polygons that occur on the edges of the designation in the expert LCA do not occur. This is an advantage when applying the LCA framework to policy making as there are not separate areas of character identified that need managing where there are no real distinctions in the character of the landscape.

The model identifies an appropriate level of detail for the TVAONB, however when applying the model to other landscapes it would be necessary to address factors such as the hydrology and geology. For example in the Tamar Valley the shape of the landform and the knowledge of the area gathered from the desk study allow the inference of the river, although no hydrology dataset is used in the actual modelling. When applying this to an area such as the Blackdown Hills AONB it would be necessary to identify areas which are dry valleys and which are river valleys.

The Geology (Solid) dataset is also not used in the TVAONB classification as the rock types are similar across the designation, however in studies such as the Northamptonshire Physiographic Study (Northamptonshire County Council Built Environmental Service, 2003) it was identified as being the primary factor in driving character and therefore the model would have to be altered to account for this factor.

7.2.2 Ground Type

The data used for the Ground Type analysis varied between the Model and the Expert LCA. A digital soil map was simplified for use in the model compared to only paper maps being made available to the consultant for the expert interpretation. The model has the advantage of being able to utilise soil boundaries that are accurate in accordance with the National Soil Resources Institute.

The different methods largely agree on the location of loam soils (See Figure 7.2) and the location of poorly drained soils, although the extents differ.

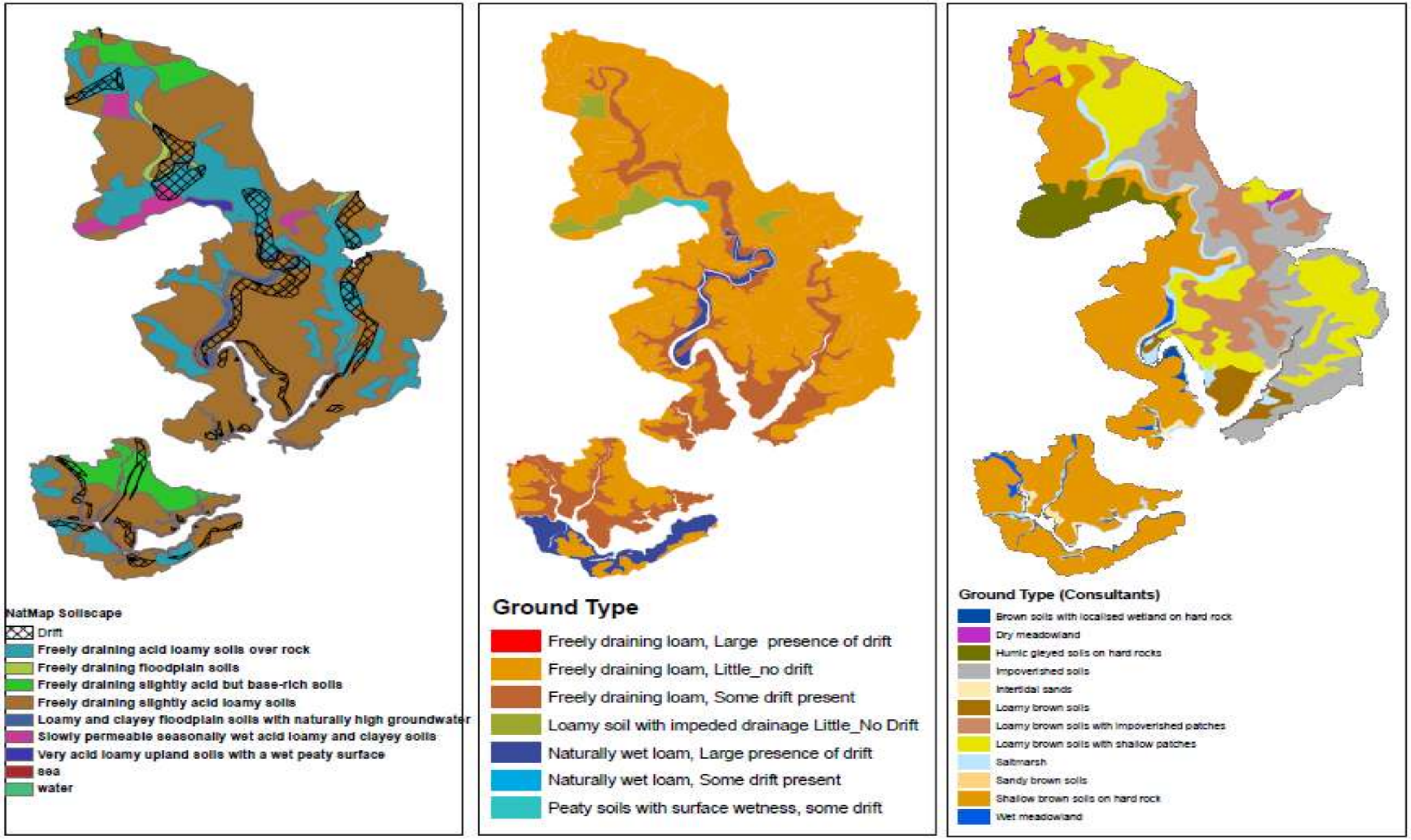

Figure 7.3 Comparison of NatMap Soilscape data and Derived Ground Type Classes from the model and the Expert Landscape Character Assessment

The use of Drift Geology data has allowed the model to identify the areas that have a large presence of drift which occur along the rivers, several levels of classification were trialled to gain the most appropriate representation of the presence of drift. The output from the model defines and area not identified in the expert LCA. Conversely, in the expert LCA the presence of drift has been referred to in the written descriptions of the polygons and identifies two areas of drift not accounted for in the model. This could be improved upon by inserting a hydrology dataset into the Landform Model which would present polygons for the two minor tributary rivers that could then be used for drift analysis at this stage.

In addition the expert classification also uses the LCM2000 data, this was trialled for use in the model but rejected due to too many polygons being produced in the output. There are both advantages and disadvantages to this omission. Firstly excluding the data has meant that small areas of semi-natural habitat have not been overstated in the impact on the character of the area. For example the consultant recognises an area of Dry Meadow Land which according to the LCM2000 is mainly woodland, improved grassland and arable land with two localised occurrences of acid grassland which are not representative of the whole LDU, therefore the models description in this respect is more appropriate. The disadvantage of the not using the data is the area of saltmarsh that is not identified in the model, which does have a large impact on the character of the area. However, the expert LCA identified the area of Saltmarsh incorrectly with the related LDU extending far beyond the tidal limit of the river where no marsh land occurs.

This methodology recognises the importance of both natural and semi natural habitats and attempts to address the limitations of the model by using the final LDU framework to analyse the presence of these habitats before the field work stage commences (See Table 7.3). This enables the presence of the habitats to be included in the descriptive write up of the polygon, and also allows the field researcher to check whether the habitat is having a significant impact on character. It is possible that the model could be adapted to include a dataset derived from the LCM2000 data if the method were to be applied to an area Landscape where semi-natural habitats have much more of a landscape impact such as in the New Forest where there are large areas of Open Heath.

7.2.3 Land Cover

The Landcover model uses the ALC to distinguish between areas that are agricultural and non-agricultural land. This information is then supplemented with data from the NIWT and the AWI enabling the model to define areas of the predominant landcover (See Figure 7.4). From the investigating the LCM2000 data is noticeable that the agricultural types across the AONB are a mixture of arable and pasture, this is well interspersed and therefore the class ‘agriculture’ is an appropriate representation of the land cover. Attempting to identify areas of pasture or arable land would result in very many small polygons being created. The expert LCA has referred to these different agricultural classes but as detailed in Appendix D it can be debated whether they express the mosaic of the landcover.

The resulting Landcover LDUs identify unwooded agriculture on the upper slopes, areas of wooded (secondary) & ancient wooded agricultural land on the valley sides and river corridor, and an area of wooded (Secondary) & ancient wooded land to the north of the designation. Other minor classes reflect an area of common land, an area of wooded (secondary) land and an area of land which is non agricultural and non wooded, which can be identified as military land on the very edge of the designation.

Using data that is tailored to the designation has the advantage over the expert LCA of being completed at the same time, using the same terminology. It is noticeable that across each council's LCA there are different labels given to the same classifications, such as the 'Ancient Wooded' and 'Ancient Wooded Farmland'.

When applying to the model to areas outside of the AONB, the initial desk study will give an indication of whether there are other major landcover types that would need to be identified that could not be picked up from either the ALC or forestry data. As mentioned in the Section 7.2.2 it may be necessary to tailor a dataset to cover habitat such as Open Heath.

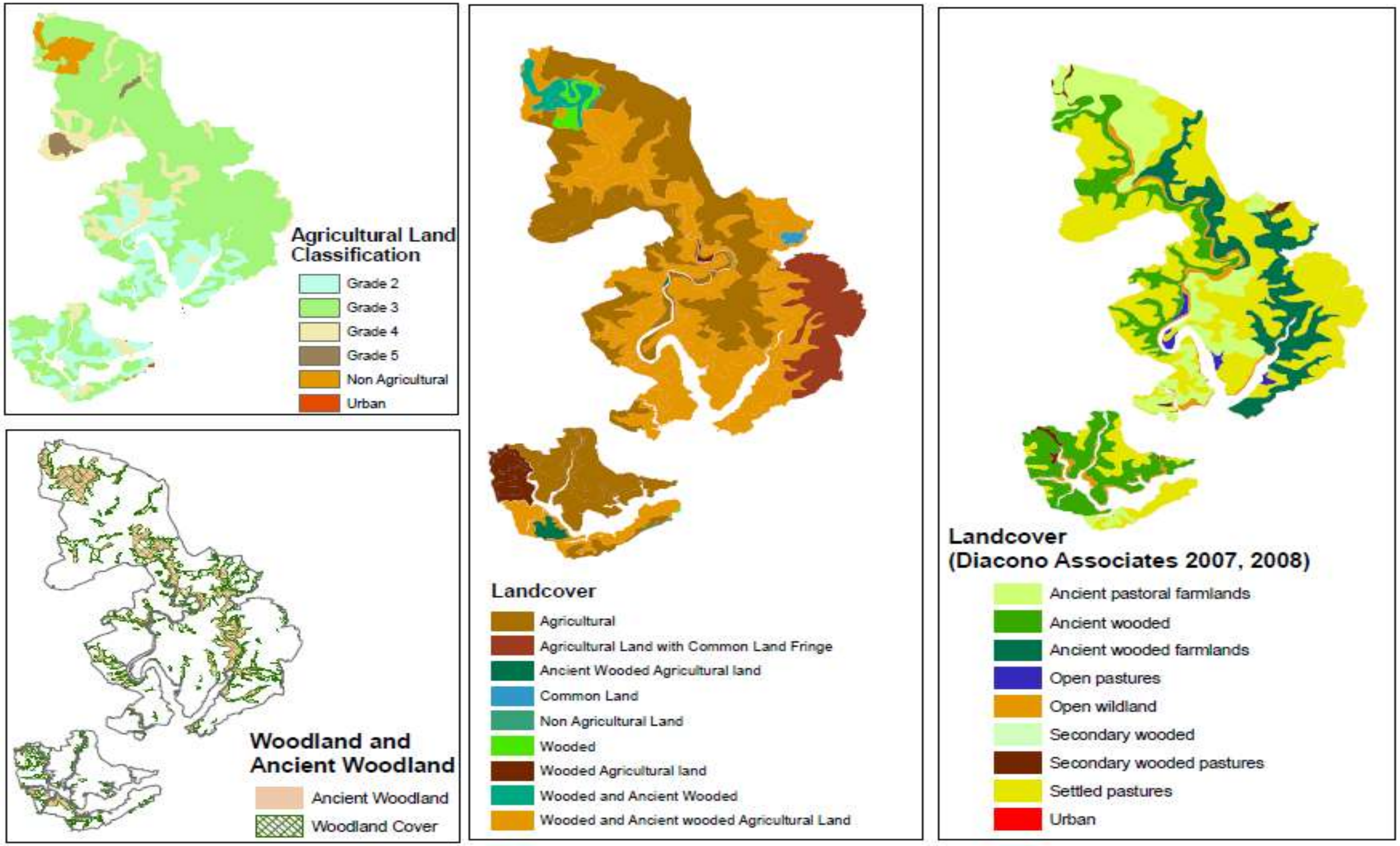

Figure 7.4 Comparison of ALC, NIWT and AWI to derived classes for Land Cover from Model 2 and the Expert LCA

7.2.5 Cultural Pattern

A settlement pattern map was created for use in the SDSS (See Figure 5.10). The purpose of the map was to statistically define whether settlement patterns were clustered, dispersed or unsettled using the already defined Ground Type LDUs as a framework. As stated in the Devon and Cornwall LCA documents (Diacono Associates & White Consultants, 2007, 2008) it is difficult to distinguish where a clustered settlement starts and an area of dispersion begins and therefore the expert interpretations method uses a line of best fit using various data sources such as OS maps and Roberts (1996) Landscape of Settlement. Using the same method of analysis against the output of the expert's assessment revealed 2 LDUS that were stated to be dispersed were statistically clustered. In addition an LDU which was defined by the experts as unsettled gave a count of 76 dwellings from the address point data.

Using the HLC data was important to imbed an aspect of time depth to the cultural analysis, resulting in areas that were defined as Enclosures, also being identified as Post-medieval, Medieval or Modern, which has a large impact on the complexity of the landscape (See Figure 7.*). In addition minor classes were also identified such as areas of Military and Industrial Complexes, areas of Marsh and Parks/Gardens. Some important areas were missed during the analysis due to the nature of averaging the data over the LDUs, such as the area of Marshland previously discussed in section 7.2.2.

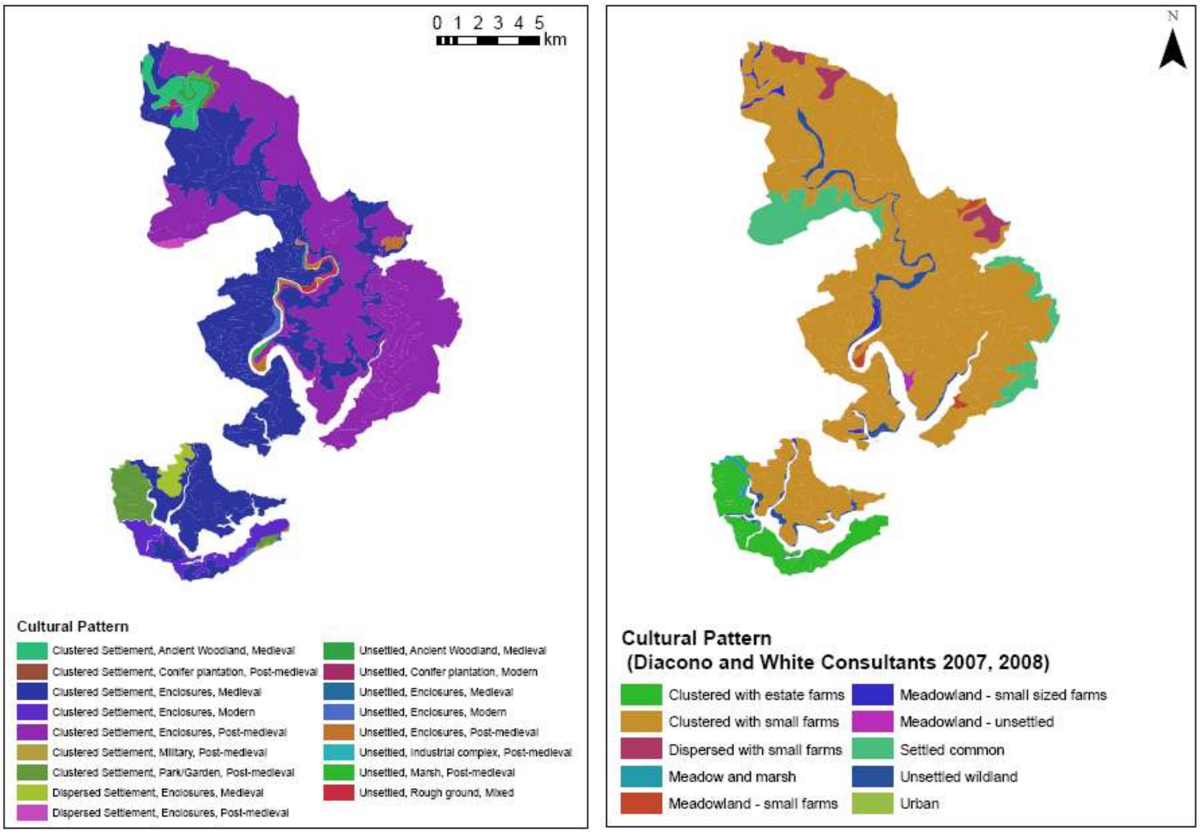

Figure 7.5 Comparison of Cultural Pattern

The consultants output includes details of Farm Size which was derived from data produced in 1995, currently it is not possible to locate up to date information of this nature, as the June Agricultural Census is not longer being produced as a small scale.

7.2.6 Landscape Description Units

The resulting map of LDUs can also be compared (See Figure 7.5). There are a very similar number of LDUs created by each method, the expert assessment identified 58 polygons (although technically 3 of these could be classed as slither polygons produced when clipping the data to the AONB). In both methods the LDUs range in size from <0.5 km along the river and urban edges up to 2 1km^2 in the consultants map and 36 km^2 in the SDSS.

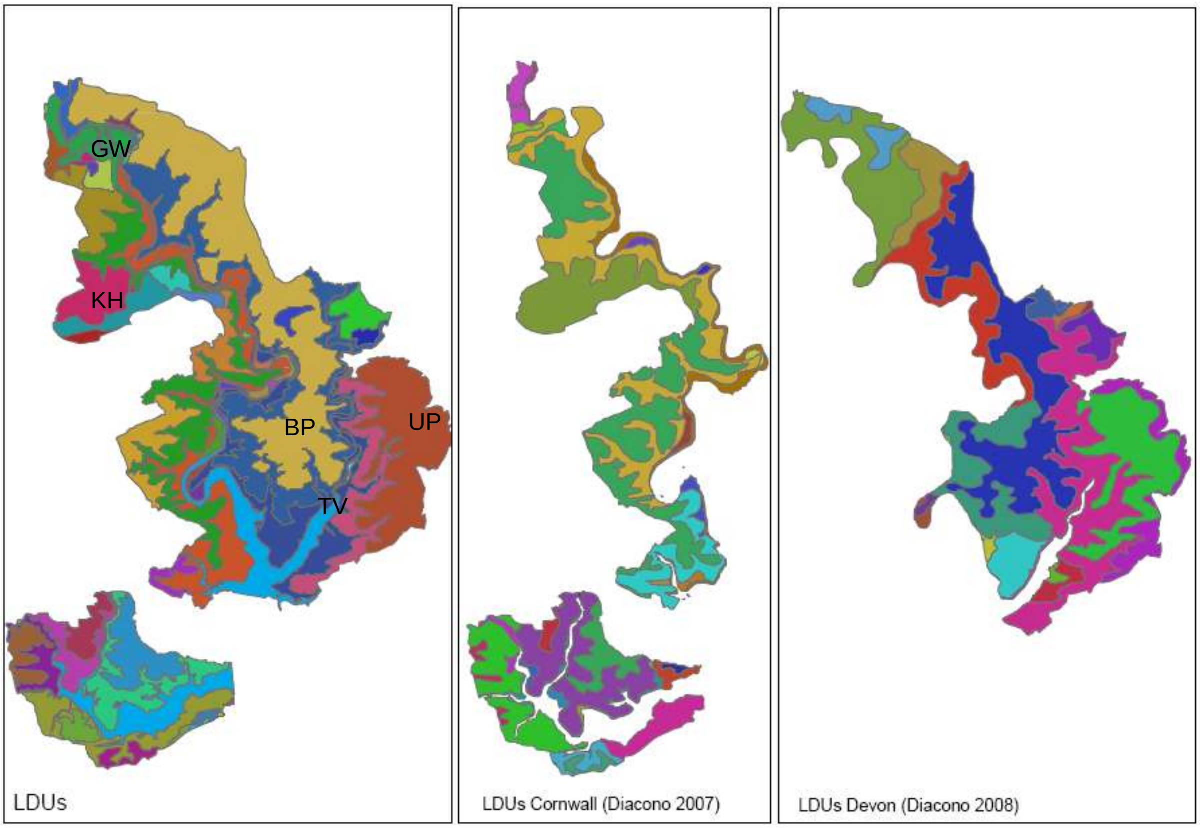

Figure 7.6 Landscape Character Assessments for the Tamar Valley Split by the Cornwall and Devon assessments (KH – Kit Hill, GW – Gunnoak Wood, BP – Bere Peninsula, UP – Upland area Adjacent to Dartmoor, TV – Tavy Valley)

Each of the assessments has similarities allowing the broad pattern of the landscape to be recognised. For example in Figure 7.2 the Bere Peninsula (BP) is prominent as is the Tavy Valley (TV) and the upland areas (UP). Gunoak Wood (GW) is also very clearly defined in the model output, which is a very prominent feature of mainly coniferous woodland. The River Tamar is also more clearly defined on the output from the model than the consultants output where it is only featured in the Cornwall assessment.

7.2.6 Application of Landscape Description Unit Framework

Further validation of the model was completed by ensuring that the results were appropriate for the intended scope of the study. The primary objective of LCAs to produce either CAs or CTs from which descriptions of the landscape can be formed and other objectives fulfilled such as using the framework for landscape monitoring objectives or land management techniques. In order to test the output LDUs from the model, CAs and CTs were created and checked during the field survey the key characteristics have been derived, but a full descriptive characterisation was not needed to test the LDU framework. The following section describes the CTs and CAs that have been produced and are briefly compared to the results from the Cornwall and Devon LCAs (Diacono Associates & White Consultants, 2007; Diacono Associates & White Consultants, 2008).

7.2.6.1 Landscape Character Types

CT's are commonly used to communicate landscape and management guidelines and set objectives. It is important to refer to the scope of the study when reaching this stage of the assessment. Examples of CT's include, Wooded Greensand Hills, Chalk River Valley (Chris Blandford Associates, 2008a), Limestone Valleys, Open Down Land (Land Use Consultants, 2005a), Limestone Plateau (Doncaster Metropolitan Borough Council and ECUS, 2007) Wooded Valley, Wooded Hills and Farmed Slopes (Landscape Design Associates, 2002). Although CT's are based on all attributes of the assessment, it is primarily the physical attributes that dictate the

CT, for example in the South Bedfordshire LCA (Land Use Consultants, 2009) although Woburn Abbey is purported to have had a large impact on the development of the landscape since the middle ages it is only included as part of the description within the Wooded Greensand Ridge CT.

LDUs from the LCA-SDSS can be amalgamated into CTs effectively due to the attributes assigned to the polygons throughout the method. For example, the models produced 58 discrete LDUs but by analysing all of the attributes it emerges that there are 46 distinct classes (each of the attributes are the same). This helps with the initial analysis. Field work is also essential to obtain a visual and perceptual guide which can highlight effects of landscape features such as woodland that may give an enclosed feel or a plateau top which could be very open.

There are broad similarities in the CT between the 2 methods, briefly, from Figure 7. 6 it can be seen that the classes Inland Plateau, Farmed River Valley Slopes, Moorland Fringe Slopes and Unsettled Valley Floors are similar. The CT wooded Valley Slopes derived from the models LDUs gives a better representation of the area around Gunoak Wood that is a strong feature in the landscape, and will have different management objectives to the surrounding landscape. A detailed description of how the CTs were derived, their characteristics and a comparison to the Expert Method is located in Appendix E.

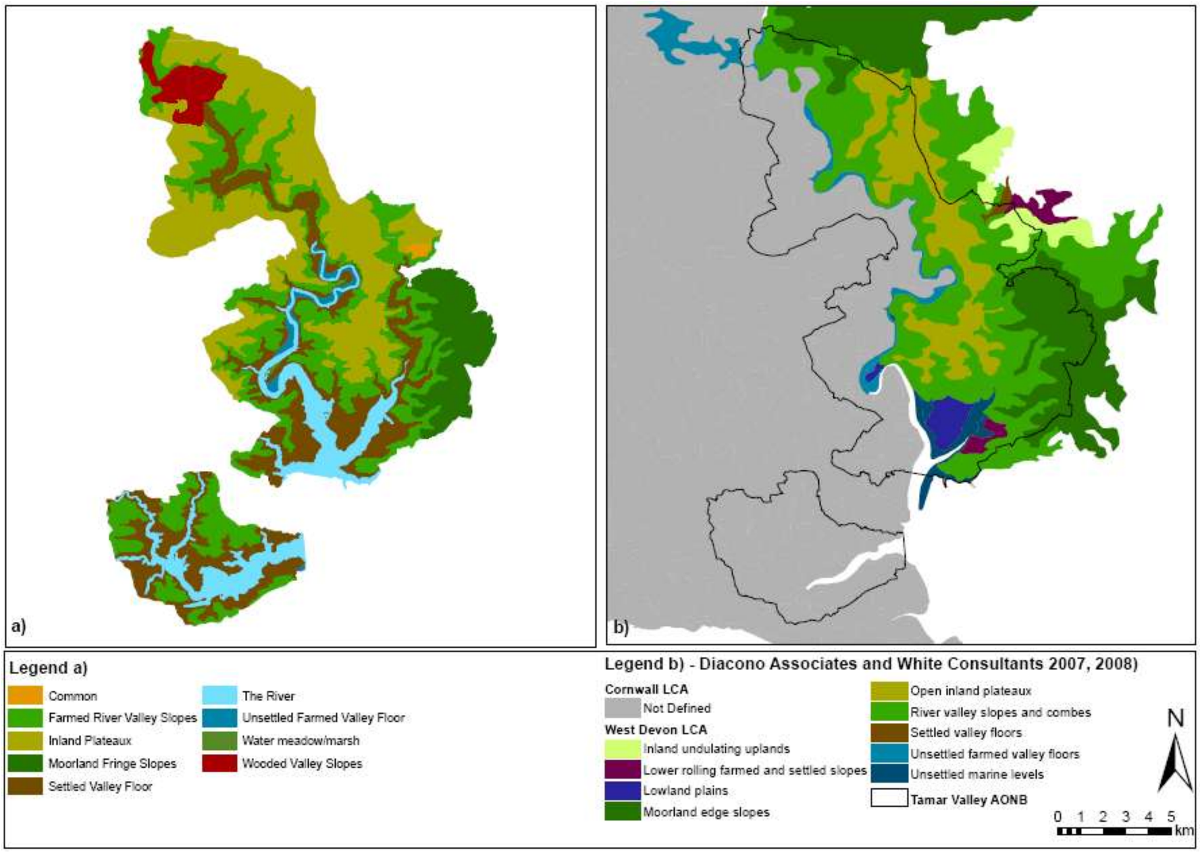

Figure 7.7 Character Types formed from the Landscape Description Units output of the Model, compared to Character Types from the Expert Landscape Character Assessment for Devon

7.2.6.2 Landscape Character Areas

CAs are geographically discrete areas that are unique and reflect local distinctiveness. Each CA has its own individual character even though it may share broad characteristics with other areas of the same character type e.g. Chalk Valley (Swanwick, 2002).

The naming of CA reflects the local area, for example the Rother Valley and Western Downs in West Sussex (Chris Blandford Associates, 2003), Kesteven Uplands in South Kesteven (David Tyldesley and Associates, 2007) Humber Estuary (East Riding of Yorkshire Council, 2005)

CAs were created from LDUs using a process of grouping the polygons into geographically discrete areas and looking at local distinctiveness (See Figure 7.11). The full description of how the CA were created and the key characteristics derived can be found in Appendix E.

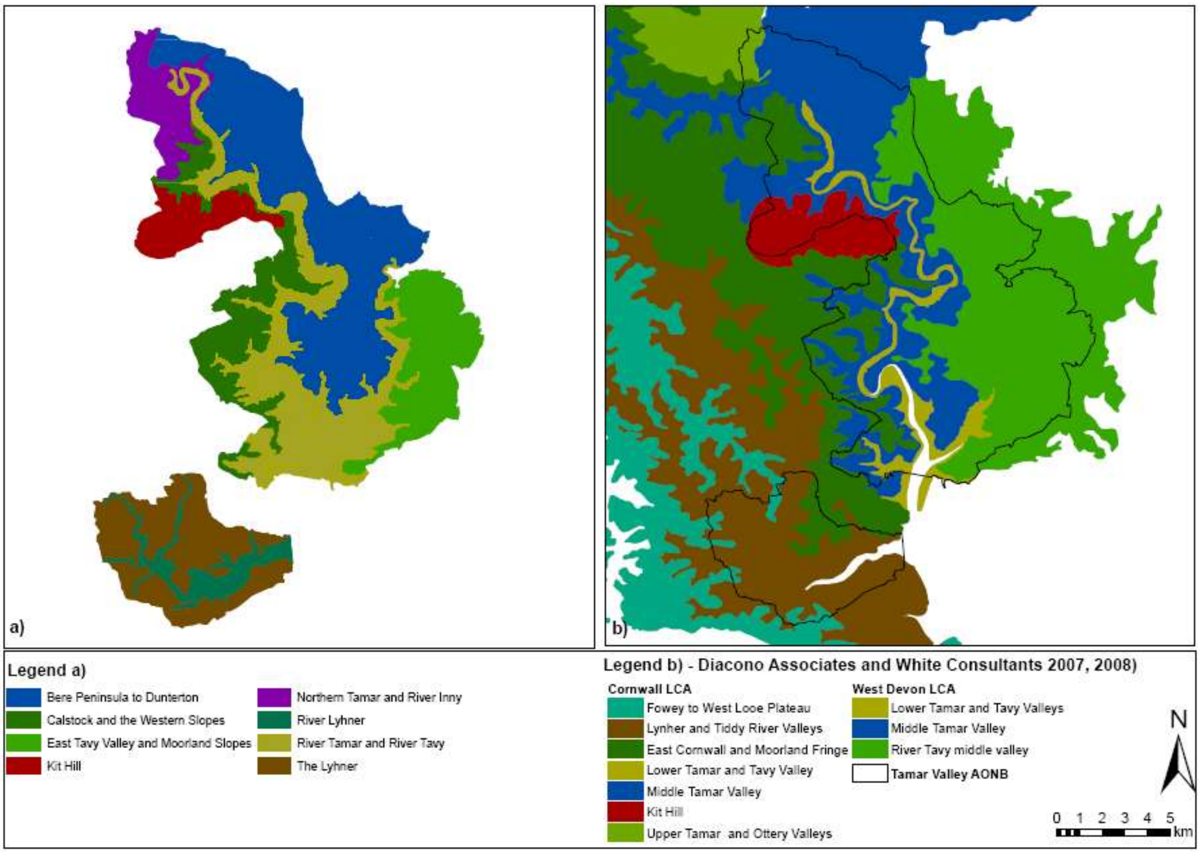

Figure 7.8 Character Areas as produced from the models Landscape Description units compared to the Character Areas produced from the Expert Landscape Character Assessment

Comparing the CAs created from the models LDUs with the consultants Devon and Cornwall LCAs (Diacono Associates & White Consultants, 2007; Diacono White Consultants, 2008) broad similarities can be seen in the Lynher, Kit Hill and Calstock and the Western Slopes areas. The Lynher differs slightly due to the inclusion of the *Fowey to West Looe Plateau* CA that reaches into the designation. The valleys of the River Tamar and Tavy have been grouped as a whole from the model output; however the Tavy River has been split across CAs in the consultant's assessment. The areas around Bere Ferres and Bere Alston has also been split into the *Middle Tamar Valley* and *River Tavy Middle* Classes rather than being grouped together in the well known Bere Peninsula area that is known locally for its walks and heritage (Devon County Council, 2011).

The CAs derived from the SDSS method have the advantage of being tailored to the AONB area, for example the CA Fowey to West Looe Plateau only appears in the AONB in small amounts, therefore many of the key characteristics for that CA may not apply within the designation.

7.2.6.3 Landscape Monitoring Units

In addition to establishing a LCA, authorities are also required to monitor their landscapes for change. AONBs and NPs in particular note this as one of the key objectives of their assessments. As discussed in Section 3.3 there are few studies in landscape monitoring.

During the Cornwall, Tamar Valley and Isles of Scilly Landscape Monitoring Project (Land Use Consultants, 2008) difficulties were encountered when attempting to use the existing LCA framework (Diacono Associates & White Consultants, 2007; Diacono Associates & White Consultants, 2008) (See Section 3.3). The output from this assessment overcomes many of the problems, for example, CA and CTs have been created for both the Devon and Cornwall sides of the designation, they are tailored to the area and therefore the key characteristics are already in place from which the monitoring indicators can be derived and they are only applicable to the areas within the designation.

In addition the CAs or CTs derived from the model do not need to be altered and therefore have the benefit of continuity for the purposes of communicating what the character of the landscape is, and how it is changing, without the need for partner organisations and the public to understand several different landscape frameworks and how they overlap or relate to one another.

Important characteristics of the landscape were identified during the Cornwall, Isles of Scilly and Tamar Valley AONB Landscape Monitoring Project (Land Use Consultants, 2008) where stakeholder workshops were held to identify which indicators were felt to be most important for monitoring landscape change. The results for the TVAONB were: Woodland Cover/Type, Extent of Arable/Pasture, Field Patterns, Settlement Pattern and Local vernacular. The model goes some way to addressing these priorities by producing the Landover LDUs and Cultural LDUs and is further strengthened by using the framework to identify the percentage cover of woodland, arable and pasture land from the LCM2000 data. In addition, the workshops also found the following criteria important: extent of semi-natural habitats, horticultural production, field boundary condition, extent of parkland, presence/absence of mining features and changes in key viewpoints. With the exception of the semi-natural habitat class which can be derived from the LCM2000 these criteria were designated as indicators that required a field survey to assess.

The model provides a framework from which LMUs can be derived and subsequent field study sites can be selected to collect this data.

7.2.6.4 End User Validation

Further validation of the model was sought from the Tamar Valley AONB partnership by providing output maps and attribute tables of the LDUs, CAs and CTs. The maps and tables were provided in advance of several meetings that were held either at the University or The Tamar Valley Partnership offices. Project Manager Rosemary Teverson attended the meetings as well as being kept informed about the project throughout the various stages of verification. Rosemary Teverson was heavily involved in the work completed by the consultants and therefore had expertise not only in the landscape itself but was also very familiar with the consultants methodology and resulting assessment.

The meetings had an open format where each stage of the output was discussed (Landform, Ground Type, Landcover, Cultural Pattern) as well as the resulting LDUs, CAs and CTs comments were recorded anecdotally and also through email.

The feedback received suggested that the characterisation produced by the model was a better 'fit' with improved cross border correlation than the assessments completed through expert interpretation only. It was also commented that there was a sharper distinction around breaks of slopes.

The comments highlighted some 'anomalies' where smaller LDUs were found along the river corridor south of Gunnislake and around Gunnoak Wood. The Tamar Valley

Partnership did not expect to see separate LDUs as although there was a minor variation in soil type there is not a marked difference in land use. They contrasted this to the LDU that covered the Lynher River where no anomalies were found.

When investigating the models to understand why these LDUs formed it was noted that the LDUs below Gunnislake occurred as they were separated off from the main LDU which was the other side of the river and became discreet LDUs. Attributes were shared up until the Land Cover Model was run, which highlighted the differences in the woodland cover and the presence of ancient woodland. It also allows the fact that the smaller LDUSs are unsettled to come through. This has not occurred around the River Lyhner or the lower part of the River Tamar as the valley bottom is so much wider.

The LDU at Gunnoak Wood is separated during the Ground Type model and further defined during the Land Cover Model, the area classified as Agricultural Land in the ALC it is therefore separated from the Non-Agricultural area of Gunnoak Wood.

Although the presence of the LDUs can be explained through looking at the modelling process it would be possible for the end user to refine the LCA by using the rectification model to amalgamate the polygons into neighbouring classes. Land management objectives and landscape monitoring take place at a CA or CT level however, and therefore the presence of the LDUs would not present a problem when defining land management objectives, and keeping the LDUs as defined by the model may present a more accurate assessment if a site based decision such as a planning application was received.

It was the intention of the study, that the TVAONB would have a useable LCA framework from which management plan objectives could be created and delivered, that would give a good description of the landscape and could be used to communicate this to the users of the AONB. While it was agreed that the outputs were more appropriate than the study from the consultants, and that theoretically the framework was fit for purpose, the current LCA is already imbedded in their management plan.

To further enhance the end user validation the database and model base could also be provided to the Tamar Valley partnership to investigate how user friendly they find the system and whether at the level of expertise they have with GIS is sufficient to understand the process and run the models.

Chapter 8 Discussion

From reviewing the literature (See chapters 2-4) it emerged that the concept of landscape has been imbedded into our culture and legal system for many years. Efforts to protect our landscapes began in earnest when the 1949 National Parks and Access to the Countryside Act was created, allowing the designation of NPs and AONBs. The concept of Landscape Assessment began 1970s evolving into the current method of LCA widely accepted and used today with the necessity to assess landscapes embedded into our the UK planning system and the ELC.

It was the aim of this research to further develop the way LCA are carried out in a GIS in accordance with the accepted methodology. The use of GIS has become much more commonplace since the guidance was produced but it is still used in varying degrees, and often to digitise boundaries derived through expert interpretation on paper maps. The review of methodologies employed to create LCA in Chapter 4 highlighted the fact that the more highly automated the processing of the data became the less detail was included. This methodology aimed to incorporate a level of automatic processing but allowing interaction from the user to further refine the assessment where needed.

The benefits of using the SDSS to produce a LCA is that the data is analysed in a quantitative and consistent manner, the model is flexible and can be adapted to meet the needs of different types of landscapes by either amending the current classification rules, or adding new data layers into the process. The Model is also dynamic, producing an output that can be examined and altered during each stage of the assessment, if any changes are made to the classification rules, the model can simply be run again and examined to ensure the changes had the desired effect.

The application of the current LCA methodology by councils and consultancies is resulting in mismatched LCA across administrative borders. While the assessments may be fit for purpose for the commissioning body, other organisations such as NPs and AONBs that ‘inherit’ the assessments are frequently faced with mismatched assessments, some of which may be CA, CT, LDUs or any combination of these outputs. Using the LCA-SDSS can address this issue by using data that is tailored to the required study area; this could be a NP or AONB boundary or the National Character Area if ‘nesting’ of the assessments is sought. Using data tailored to the study area will also reduce the occurrence of CA/CT/LDUs that appear in small fragments at the boundary of a study area. Issues of mismatching terminology across borders would also be addressed.

The issue of using boundaries for LCA has been contentious. LDUs have been criticised in the Dartmoor National Park LCA (Land Use Consultants, 2010) due to the fact that the LDUs do not follow visible boundaries on the ground, but often follow contour lines. The original LDUs that were created during the Devon County assessment were discarded and new CTs created based on field work. The Great Yarmouth LCA (Land Use Consultants, 2008) stated that the boundaries are drawn at a scale of 1:25,000 and should be treated as zones of transition. Where a distinct change in character cannot be seen on the ground a line of “best fit” is drawn based on physical features such as roads, lanes or field boundaries. This method could be criticised as being too open to interpretation resulting in inconsistency between different experts. The use of landscape units can also be justified based on the principle that people *“experience and respond to the landscape on the basis of visual units rather than individual elements. That is, humans react to scenes as a whole whose impact is greater than the mere sum of its parts”* (Schauman & Pfender, 1982). The ELC’s definition of landscape states that it is an ‘area’ and therefore it can be inferred that a landscape has a definable boundary, and can therefore be split up into variably sized landscape units depending on the requirements of the policy or study relating to that landscape (Selman, 2006). Using boundaries is important in order to understand complex landscapes and provides a practical solution to providing a framework for classification. Further interrogation of LCA at boundaries or zones of transition could be achieved using the GIS function ‘Viewshed analysis’ which allows a specific point or line to be examined for the LDUs, CAs or CTs that can be seen or would be affected by development.

The boundaries created by the model are defined by the inputs and the parameter of the models, and therefore the intuitiveness of the boundaries is lessened. For example, a LDU boundary that might appear just inside an area of woodland may be digitised along the feature boundary by an expert however the model will just ignore the feature. However, the method used in the model ensures consistency throughout the study area, it may be difficult for an interpreter to decide how far inside a feature a boundary needs to be before it is moved, or it may vary from place to place or from expert to expert. It is also worth noting that a contributing factor towards landscape character is an expression of geology and soils which are rarely visible in the landscape, but are however relevant in defining landscape units; this will result in boundaries being drawn in the landscape where there is no visible change in character even though a fundamental change has taken place.

In common with the Dartmoor National Park LCA (Land Use Consultants, 2010) the LDUs resulting from the model follow contour lines, due to elevation being the first definitive attribute used, however using the natural breaks classification in the data has allowed the breaks of slope to be identified without the confusion of visual features such as woodlands that may mask where the break of slope actually lies. Feedback from the Tamar Valley AONB partnership indicated that the break of slope identified in the model had a ‘sharper distinction’ (Teverson, 2010) than the official LCA (Diacono Associates & White Consultants, 2007; Diacono Associates & White Consultants, 2008. Although using boundary lines is debated, they are necessary in a LCA to delineate the differences in character. Peterborough LCA (Peterborough County Council, 2007) states that boundaries are often drawn based on features that are not visible such as rock or soil boundaries and should be treated as zones of transition. Boundaries within digital data should always be treated with caution, most data sets will give an accuracy statement, for example the DEM is accurate to +/- 2.5m based on the fact that the resolution is 5m. The same can be said for the model outputs as the data has been converted from vector to raster a 5m resolution was used, therefore the boundary can occur +/- 2.5m from it stated position.

Using the model to delineate the boundaries also makes the process more robust and transparent when being used in as an evidence base, as there are clearly defined rules to refer to and the process is repeatable. The same result would also be given to any individual that ran the model, unless they decided to change the parameters of the model, such as how many elevation zones were used.

Before a LCA can be commenced the scope of the study needs to be defined (See Section 5.1). For NPs and AONBs highlighting the special qualities of the landscape was an important outcome. This is reflected in the output of the LCA-SDSS by giving an appropriate classification of the landscape, deriving all of the key characteristics from Table 5.1 with the exception of the mining heritage which has a distinct presence in the TVAONB. The model could be further improved by adding a data layer with mining heritage information derived from sources such as the SMR or the Environmental Agency Mines data. The outputs from the models provided a framework from which field surveying can take place and descriptions written. The application of the LDUs into CAs, CTs allows management policies to be formed around a robust framework and be used to inform management plans. Monitoring units can also be created based on the CAs or CTs produced, enabling the assessment of landscape condition and change and the setting of objectives for the conservation or enhancement of character.

The objectives in addition to producing LDU/CA/CTs that this research was concerned with included developing a logically organised database with appropriate data being available to the model base. This was achieved by storing the data in a workspace managed through ArcCatalog which can be used to efficiently organise data into folders and to move or copy data.

The LCA-SDSS was also intended to be a flexible, user friendly tool which could be run repeatedly. When running the system it is necessary to run each model individually and in the correct order to ensure the output from the proceeding model is used as an input. Each model also contains different stages that need to be completed before the next stage can run. For example, in Model 1, it is necessary to complete the elevation and slope analysis and combine the files into a raster layer before the Con Tools can be run. Deriving the settlement pattern from the Address-

Point data, allowed digital analysis to take place rather than using paper maps, or analysing settlement patterns from OS maps or the Rural Settlement Atlas (Roberts & Wrathmell, 2000). The ANN analysis allowed the settlement pattern to be computed statistically based on the area of the LDU that the settlements fall within. The method used to derive the settlement pattern data could be easily repeated using new releases of the Address-Point data to provide a comparison over time. The disadvantage of using this method is that the statistical analysis relies on the area calculation of the LDU to perform the analysis. The point at which the analysis takes place is after the Ground Type LDUs have been created. This results in only being able to run the model to the midpoint, where a new dataset has to be created before the Cultural Model can be run. A script was adapted allow batch processing of the analysis which reduced the processing time considerably. It would be beneficial to feed this into the modelling process rather than preparing the data separately. The system however, does provide flexibility; it is possible to run the model changing the parameters as required and the exercise can be repeated as data new additions of the data sources become available. The actual processing of the models takes only a few minutes, and is considerably faster than heads up digitising which would take many hours.

The LCA-SDSS has advanced current GIS methods in LCA by incorporating both physical and cultural data sets into a model that can be processed supporting expert interpretation. The model uses a combination of re-classification of datasets, rules and statistical analysis to produce a framework of LDUs. The model is split into four stages which allow the output of the current stage to be viewed instantly and any errors such as sliver polygons to be removed before they are propagated into the next stage of the model. It is also possible to run the model without correcting the output after each stage, however this results in many unnecessary classes being created which ultimately would need to be reclassified.

Running the model again for the study area with the ALC adjusted to be aligned with the NIWT would remove many of the small polygons. Although many of the polygons could be picked up with the rectification model and merged into the neighbouring classes, this method would increase the accuracy of the LCA. This highlights two issues, firstly the difficulty in working with datasets at different scales, although the software is capable of re-scaling the datasets to match this does not increase the accuracy. Secondly, conducting a LCA based on secondary data increases the chance of errors occurring in the classification from miss-matched boundaries, or incorrect classes identified in the data. An alternative view is that sliver polygons should be not be treated as errors, but considered as zones of transition between different areas of character (Van Eetvelde, 2007).

The majority of LCAs are conducted by consultants rather than 'in-house' largely due to resourcing constraints within organisations such as AONBs where the staffing levels may not permit a member of staff or team of staff to be dedicated to such a large project, it was the aim of this research to create a tool that could be used in-house producing a rapid assessment that would reduce the amount of time needed to conduct the desk study assessment. In its current form, the model does allow a rapid classification, however there was a considerable amount of data to be pre-processed before the model could be run that would require some GIS expertise. If the data and models were provided to the AONB 'ready to be run' it is likely that this could be achieved with some simple instructions.

When applying the LCA-SDSS to other landscapes it would be necessary to complete a desk study to find out which data sources were of value to a particular area and incorporate them into the model. It is likely that the model as it is could not provide an 'out of the box' solution in every situation due to the highly varied nature of the landscape.

8.1 Conclusion and Future Work

The verification and validation of the system suggests that an appropriate characterisation of the TVAONB has been achieved.

Improvements could be made to the model by the inclusion of:

- A hydrology dataset – due to the nature of the TVAONB and the structure of the landform, it is easy to infer the presence of the larger rivers, the Tamar, Tavy and Lyhner by tailoring the data to the TVAONB boundary and definitive river outline. The minor rivers of the Inny and Walkham, however are not identified due to their elevation and slope index. The creation of an LDU for the smaller rivers would also allow a more accurate expression of the presence of drift geology in these areas.
- Mining data – Mining heritage is a influential part of the character of the Tamar Valley, with a section of the AONB being designated as a World Heritage Site. Currently the model can be applied in the field verification stage to highlight the presence of mining features however, the mining data does not form part of the characterisation process. The inclusion of the WHS boundary could be trialled to see the effect this has on the modelling process

- An amended version of the ALC – Before inclusion into the model the ALC was updated to ensure that the data matched the river line. When comparing the data to the NIWT and aerial photography it appears that the boundary around the Non-Agricultural land and the area identified as woodland are slightly different in their extents, probably due to the scale the datasets were produced at. This difference produced many small sliver polygons during the modelling process (later processed by the rectification model) which could be avoided if the ALC was updated to match to woodland data.
- Marsh land data - Separate LDUs identifying areas of Marsh could be created within the model by adding an additional layer of data for marshes extracted from the HLC and combining the data in the Cultural Pattern Model before the settlement pattern analysis begins

Updating the Cultural Model to allow the processing of the Settlement pattern within the model would enhance the user experience by producing a system that flowed more coherently without the need to stop and prepare more data half way through the process.

To further validate the model, the assessment of a different landscape would be desirable. For example, the North Devon AONB has a mainly coastal landscape and the geology of the Blackdown Hills AONB is varied. Both of these examples would require additional datasets to be sourced and inserted into the models and different classification rules would need to be investigated.

Chapter 9 Conclusion

LCA has become imbedded in UK policy as a method for classifying and describing landscapes, drawing out the patterns of natural and cultural attributes that reflect landscape character and make one landscape distinct and recognisable from another.

Signing the ELC has given impetus to landscape initiatives, prompting a review of UK policy, the updating of the National Landscape Character Mapping project and the emergence of a new landscape monitoring programme through CQuEL.

The appointment of the new coalition Government in 2010 saw almost immediate changes in planning policy, at a time when District Councils were beginning to catch up with previous planning reforms. For example, the RSS that would have replaced RPGs were still in draft format when they were revoked. This has resulted in Devon and Cornwall Council adopting an interim planning policy whilst they are producing their LDFs. LCA plays an important role in the planning system, often providing evidence for LDFs or being adopted as SPG or a LDD.

Despite the importance of landscape characterisation only 60% of local authorities have an up to date assessment. The process of completing an assessment can be expensive and usually requires an Environmental or Landscape Consultant to be appointed due to the current method of using expert interpretation of data.

The responsibility for commissioning assessments rests with local authorities, which can result in characterisations that do not have cross border correlation. Whilst this does not cause an issue for the instigating authority it can cause problems for smaller organisations such as NPs and AONBs who often have to commission independent assessment from their restricted budgets.

The use of the LCA-SDSS would potentially allow experts from smaller organisations (or local authorities) to produce their own LCA framework without needing to commission external consultancies; the local knowledge of the staff would also enhance the later stages of the characterisation such as the descriptive elements.

The LDU framework produced by the model allows the creation of CT, CA and LMUs. The application of the LDUs in this manner would allow the TVAONB to create management objectives based on either CA or CT and follow these through to judge their effectiveness in conserving and enhancing landscape character through landscape monitoring project based on the same framework. The consistency in framework for both characterisation and monitoring would make reporting easier, for example in the AONB management plan and the State of the AONB reports, and assist the AONB in meeting the requirements set out for them in the CRoW Act (UK Parliament, 2000).

The main conclusions of this study are:

- The LCA-SDSS has been used to support the expert interpretation of an appropriate LCA of the TVAONB
- A robust framework has been successfully produced that is based on a transparent and repeatable mythology
- The use of the Model would provide support for experts to produce a LCA 'in house' producing rapid results and accurate boundary delineation

- The rectification model allows the user to interact with the characterisation at each stage to verify the output and remove unwanted sliver polygons
- End User validation reflects the quality of the output achieved

APPENDICES

Appendix A - Script for ANN analysis, items in BOLD are the adapted values.

```
# Import system modules

import sys, string, os, arcgisscripting



# Create the Geoprocessor object

gp = arcgisscripting.create()



# Load required toolboxes...

gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Statistics Tools.tbx")



# Script arguments...

Input_Feature_Classes = sys.argv[1].split(';')



Distance_Method = sys.argv[2]

if Distance_Method == '#':

 Distance_Method = "Euclidean Distance" # provide a default value if unspecified
```

```
Area = sys.argv[3]

Output_File = sys.argv[4]


f=open(Output_File, 'w')

f.write('FC,INDEX,ZSCORE,PSCORE\n')

for fc in Input_Feature_Classes:

    # Process: Average Nearest Neighbor...

    nn_output = gp.AverageNearestNeighbor_stats(fc, Distance_Method, "false", Area)

    nn_values = nn_output.split(";")

    nn_index = nn_values[0]

    nn_zscore = nn_values[1]

    nn_pscore = nn_values[2]

    gp.addmessage('%s:\n   Nearest neighbor index = %s\n   Z score = %s' % (fc,nn_index,nn_zscore))

    f.write('%s,%s,%s,%s' %(fc,nn_index,nn_zscore,nn_pscore))


f.close()
```

Appendix B – LDU Attribute Table

LDU Number	Landform	Ground Type	Land Cover	Cultural Pattern		
				Settlement	Historic Character	Period
1	River Corridor	Freely draining loam, Some drift present	Wooded	Unsettled	Ancient Woodland	Medieval
2	River Corridor	Naturally wet loam, Large presence of drift	Ancient Wooded Agricultural land	Unsettled	Ancient Woodland	Medieval
3	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient Wooded	Clustered	Ancient Woodland	Medieval
4	Upper Slopes	Loamy soil with impeded drainage Little_No Drift	Wooded	Clustered	Ancient Woodland	Medieval
5	River Corridor	Freely draining loam, Large presence of drift	Wooded Agricultural land	Dispersed	Enclosures	Medieval
6	River Corridor	Freely draining loam, Some drift present	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Medieval
7	River Corridor	Freely draining loam, Some drift present	Agricultural	Clustered	Enclosures	Medieval
8	River Corridor	Freely draining loam, Some drift present	Agricultural	Clustered	Enclosures	Medieval
9	River Corridor	Naturally wet loam, Large presence of drift	Agricultural	Unsettled	Enclosures	Medieval
10	Steep Valley Sides	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Medieval

LDU Number	Landform	Ground Type	Land Cover	Cultural Pattern		
				Settlement	Historic Character	Period
11	Steep Valley Sides	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Medieval
12	Steep Valley Sides	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Medieval
13	Steep Valley Sides	Freely draining loam, Little_no drift	Agricultural	Dispersed	Enclosures	Medieval
14	Steep Valley Sides	Freely draining loam, Little_no drift	Ancient Wooded Agricultural land	Clustered	Enclosures	Medieval
15	Steep Valley Sides	Freely draining loam, Little_no drift	Poor Agricultural Land	Unsettled	Enclosures	Medieval
16	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Medieval
17	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Medieval
18	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Medieval
19	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Unsettled	Enclosures	Medieval
20	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Medieval
21	Upper Slopes	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Medieval
22	Upper Slopes	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Medieval

LDU Number	Landform	Ground Type	Land Cover	Cultural Pattern		
				Settlement	Historic Character	Period
23	Upper Slopes	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Medieval
24	Upper Slopes	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Medieval
25	Upper Slopes	Peaty soils with surface wetness, some drift	Agricultural	Clustered	Enclosures	Medieval
26	River Corridor	Naturally wet loam, Large presence of drift	Agricultural	Unsettled	Rough ground	Mixed
27	Upper Slopes	Freely draining loam, Little_no drift	Wooded and Ancient Wooded	Unsettled	Conifer plantation	Modern
28	River Corridor	Naturally wet loam, Large presence of drift	Agricultural	Unsettled	Enclosures	Modern
29	River Corridor	Naturally wet loam, Large presence of drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Modern
30	Steep Valley Sides	Freely draining loam, Little_no drift	Agricultural	Unsettled	Enclosures	Modern
31	Upper Slopes	Loamy soil with impeded drainage Little_No Drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Modern
32	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient Wooded	Clustered	Conifer plantation	Post-medieval
33	River Corridor	Freely draining loam, Little_no drift	Wooded	Unsettled	Enclosures	Post-medieval

LDU Number	Landform	Ground Type	Land Cover	Cultural Pattern		
				Settlement	Historic Character	Period
34	River Corridor	Freely draining loam, Some drift present	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Post-medieval
35	River Corridor	Naturally wet loam, Large presence of drift	Agricultural	Unsettled	Enclosures	Post-medieval
36	River Corridor	Naturally wet loam, Large presence of drift	Agricultural	Unsettled	Enclosures	Post-medieval
37	River Corridor	Naturally wet loam, Large presence of drift	Agricultural	Unsettled	Enclosures	Post-medieval
38	River Corridor	Naturally wet loam, Large presence of drift	Wooded Agricultural land	Unsettled	Enclosures	Post-medieval
39	River Corridor	Naturally wet loam, Large presence of drift	Wooded and Ancient wooded Agricultural Land	Unsettled	Enclosures	Post-medieval
40	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Post-medieval
41	Upper Slopes	Freely draining loam, Little_no drift	Agricultural Land with Common Land Fringe	Clustered	Enclosures	Post-medieval
42	Upper Slopes	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Post-medieval
43	Upper Slopes	Freely draining loam, Little_no drift	Agricultural	Clustered	Enclosures	Post-medieval

LDU Number	Landform	Ground Type	Land Cover	Cultural Pattern		
				Settlement	Historic Character	Period
44	Upper Slopes	Freely draining loam, Little_no drift	Agricultural	Dispersed	Enclosures	Post-medieval
45	Upper Slopes	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Post-medieval
46	Upper Slopes	Loamy soil with impeded drainage Little_No Drift	Agricultural	Clustered	Enclosures	Post-medieval
47	Upper Slopes	Loamy soil with impeded drainage Little_No Drift	Wooded and Ancient wooded Agricultural Land	Clustered	Enclosures	Post-medieval
48	River Corridor	Naturally wet loam, Some drift present	Ancient Wooded Agricultural land	Unsettled	Industrial complex	Post-medieval
49	River Corridor	Naturally wet loam, Large presence of drift	Agricultural	Unsettled	Marsh	Post-medieval
50	Steep Valley Sides	Freely draining loam, Little_no drift	Poor Agricultural Land	Clustered	Military	Post-medieval
51	River Corridor	Freely draining loam, Some drift present	Wooded Agricultural land	Clustered	Park/Garden	Post-medieval
52	Steep Valley Sides	Freely draining loam, Little_no drift	Agricultural	Clustered	Park/Garden	Post-medieval
53	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded Agricultural land	Clustered	Park/Garden	Post-medieval
54	Steep Valley Sides	Freely draining loam, Little_no drift	Wooded and Ancient wooded Agricultural Land	Clustered	Park/Garden	Post-medieval

LDU Number	Landform	Ground Type	Land Cover	Cultural Pattern		
				Settlement	Historic Character	Period
55	Upper Slopes	Freely draining loam, Little_no drift	Common Land	Unsettled	Enclosures	Post-medieval
56	River Corridor	River	River	River	River	River
57	River Corridor	River	River	River	River	River
58	River Corridor	River	River	River	River	River

Appendix C – Example Field Sheet

LDU No: 34	Location : Bere Ferres	GPS:
Photo ref:	Date: 21/08/2011	

Key Characteristics: Valley floor, Rolling Hills extending from river, rural settlement

Brief Description: The small settlement of Bere Ferres is located on the lowland area of land extending upwards from the river. An open landscape with views across the wide river to the hills beyond

Topography:

Flat	Steep slopes	Lowland	Narrow Valley
Undulating	Gentle Slopes	Plateau	Gorge
Rolling	Hills	Broad Valley	

Land Use:

Agriculture	Historic Parkland	Industrial	Military
Forestry/Woodland	Residential	Mineral Workings	

Land Cover:

Arable	Broad Leaf Woodland	Scattered Trees	Marsh
Pasture	Mixed Woodland	Heath land	Gardens
Rough Grazing	Parkland	Common	Paddocks
Conifer plantation	Orchard	Scrub	Other

Field Pattern/Boundaries

Hedge banks	Fences	Geometric	Small
Hedgerows		Sinuous	Medium
Wooded Boundaries		Irregular	Large
Walls		Regular	

Hydrology

River	Stream	Inland Water

Communications:

Rural road	Footpath	Bridge
Dual carriage way	Bridleway	Pylons
Track	Railway	Communication Mast

Buildings:

Farm Buildings	Rural Buildings
Industry	Urban

Visual Assessment:

Pattern	Dominant	Strong	Weak	Broken
Scale	Intimate	Small	Medium	Large
Texture	Smooth	Textured	Rough	Very Rough
Colour	Uniform	Diverse	Simple	Complex
Remoteness	Wild	Vacant	Remote	Active
Unity	Unified	Fragmented	Interrupted	Chaotic
Form	Straight	Curved	Angular	Sinuous
Enclosure	Expansive	Enclosed	Open	Constrained
Visual Dynamic	Sweeping	Dispersed	Spreading	Channelled

Perception:

Security	Intimate	Unsettling	Safe
	Comfortable	Threatening	
Stimulus	Monotonous	Challenging	Interesting
	Bland	Peaceful	Busy

Tranquillity	Inaccessible Remote	$\boxed{\text{Peaceful}}$ Busy	Vacant
Pleasure	Unpleasant Pleasant	$\boxed{\text{Attractive}}$ Beautiful	
Landscape Character Type:			
Settled River Valley			
Landscape Character Area:			
Tamar and Tavy River			
LDU Boundary Confirmed?			
Yes			

Appendix D – Detailed Comparison of Expert Method and SDSS Method outputs

Landscape Description Units

Across both the Cornwall and Devon LCA's the consultant identified 58 LDUs, however three of these could be classed as sliver polygons that occurred when the data was clipped to the Tamar Valley AONB boundary (See Figure 7.5). This is a very similar amount of LDUs as identified by the model. The LDUs range from <0.5 km^2 located along the river and some urban edge to 20 and 21 km^2 located on the upland areas of west of the AONB and the Bere Peninsula. The largest LDU from the model was also along the Bere Peninsula, however it was larger at 36 km^2.

Each of the assessments has similarities allowing the broad pattern of the landscape to be identified. For example, the Bere Peninsula is prominent, as is the Tavy Valley and uplands adjacent to Dartmoor. Kit Hill is also evident, although it is broken down into three LDUs by the models due to the difference in the soil type in the polygon that extends from south of Kelly Bray to Coxpark where the drainage is impeded.

Each assessment has areas where more detail has brought out characteristics of the landscape, i.e. the areas identified as meadowland during the cultural analysis by the consultant, but equally the area around Gunoak wood is identified more clearly by the model.

As discussed in section 7.7.2 the LDU along the river in the consultant's assessment, reached far beyond the tidal limit, but also only appears in the Cornwall assessment there is no river LDU identified in the Devon assessment (See Figure 7.1). The model more accurately depicts the river corridor on both sides of the river, reflecting the symmetry in the valley landscape.

Landform

The Landform classes resulting from Model 1 represent the river corridor, valley sides and the upland areas accurately capturing the character of the landscape by highlighting the symmetry along the river valley. The river corridor captures each of the Tamar, Tavy and Lynher rivers, reflecting the steepness of the enclosing valley sides and up to the plateau areas (See Figure 7.1).

The classification completed by Diacono White Consultants (2008) used digital 10m contour maps and were used along with paper geology maps provided by Cornwall and Devon Councils. In the Model a DTM was analysed for elevation and slope data. The delineated boundaries were accurate which can be attributed to computer driven digitising of boundaries. Using a DTM over contour data had the advantage of a continuous surface which allowed rapid classification of elevations without the need for time consuming heads up digitising. The DTM also allows slope analysis to be performed without the need of expert interpretation of groups of contour lines.

There are similarities in the assessments where the upland areas have been identified, and also broadly where the slopes are identified. Due to the fact that the Devon and Cornwall LCA were completed separately there is some discontinuity between the names of classes, for example the Cornwall assessment identifies a class called *Hard Rock Slopes and Ridges*, and the Devon assessment identifies *Hard Rock Uplands*; this is likely to be a difference in the terminology across the councils rather than a separate landscape physiography. In addition to the *Upland* and *Slope* classes, the consultant has identified areas of *River Valley* that appear in several polygons along the river line, but there is no coherent identification of the river corridor. The *Marine Levels* class goes someway to identifying the river, however it has been extended much further north than the actual tidal limit. In comparison the Model identifies the river valley almost to the top of the designation where the river is deeply incised between the valleys. The consultant's assessment does however highlight the smaller tributary Inny River. In addition another small section of River Valley was highlighted near Tavistock where the River Tavy joins the designation, however only a short length of the river was identified.

One final class identified by the consultant is *Hard Rock Plateau* which extends into the edges of the Lynher section of the AONB. These appear as small LDUs as they have been clipped from larger polygons that cover the landscape outside of the designation. The advantage of the model is that these small polygons do not appear as the analysis has been tailored to the AONB area; they have been identified as **Steep Valley Sides** in the model and do not differ enough from the surrounding landscape to be classified separately.

Ground Type

The NatMap Soilscape data was simplified for use in the model by extracting and combining the classes for soil type and drainage. The presence of drift was derived from the Geology Digimap data. The consultant used a combination of geology and land use data and paper soil maps (Diacono White Consultants, 2008).

The LCA-SDSS and consultants assessments (See Figure 5.4) are largely in agreement about the location of the loam soils, although the consultant has split the loam classes further into areas with impoverished or shallow patches. Using the NatMap Soilscape data did not reveal these differences, and classifies the majority of the Tamar Valley AONB as low fertility. For this reason the impoverished soils class was also not included in the Model. Again the difference in the classification across the two counties creates two separate classes where perhaps only one would exist if the terminology were in agreement. There is a similarity in the Kit Hill area where a soil type with poor drainage has been identifies however the extent is different.

The approaches also differ in the analysis of drift. The consultant has included drift in the class *Wet Meadow* land stating in the LDU description "*Slowly permeable mineral soils developed on Alluvial Drift…"* The Wet Meadow land class covers the far reaches of the Lynher and some of the southern extent of the River Tamar. The rest of the river edge is classified as *Saltmarsh* defined as *"uncultivated tracts of coast marshland developed directly on unconsolidated mud/silt…)".* The class however extends right up to the northern part of the Tamar at Gunoak wood, which extends far beyond the tidal limit of the river at Weir Head. According to the LCM2000, most of the salt marsh is located south of Hooe apart from a small patch on the Cornwall bank of the river at Cotehele Quay. In contrast Model 2 identifies the River Tamar as **Freely Draining Loam with Some Drift** at the mouth of the river and following the river, with a section of **Naturally Wet Loam with a Large Presence of Drift** from just south of Halton Quay up to the Tidal limit at Weir Head. The Model reflects the classes around the river more accurately in this respect.

The Model does not use the Land cover data in this part of the analysis and therefore the areas of saltmarsh are not identified at this stage, this is picked later however when applying the use of the LDUs to the field verification stage (See Section 7.1).

An additional class used by the consultants is *Dry Meadow Land* which is used in the LDU over the River Inny, the northern most extent of the River Tamar and the LDU over the part of the Tamar just south of Tavistock. The definition of this class is *"Free-draining mineral soils developed on Alluvial Drift. Seasonal water logging …"* When comparing this to the LCM2000 the Inny and Northern Tamar LDUs are mostly woodland, improved grassland and arable land, and this can be confirmed by looking at the aerial photographs. There are however two small polygons of acid grassland, but they are not representative of the whole LDU. Therefore the class of **Freely Draining Loam** identifies the area more accurately. The consultants class does however, highlight that there is an area of drift along the River Inny. This is not picked up in the model due to the averaging during the processing and the area is classified as having little or no drift. The LDU in this class near Tavistock is again largely represented by woodland, improved grass land and arable land with two patches of calcareous grassland which is better represented by the Ground Type of **Freely Draining Loam** identified in the Model. The *Dry Meadowland* class does correctly identify the presence of drift in this polygon which is not identified in the model (classified **as Little or No Drift**), however the drift continues south along the Tavy River which is picked up by the model as **Freely Draining Loam with Some**

Drift Present. This was not identified by the consultant and the areas was classified as *Impoverished Soils* which are defined as *"Nutrient poor loamy soils, often supporting dwarf shrub heath, acid grass land or relic healthy vegetation (shrub, gorse etc)"* (Diacono White Consultants, 2008) and does not refer to the presence of drift.

Land Cover

The Land Cover Model uses the ALC, NIWT and the AWI to make the classification for Land Cover (See Figure 7.3). The ALC was useful primarily to identify areas that were used for agriculture and those that were not, such as the area around Gunoak Wood. In addition to these data sets the consultants also refer to the HLC, Agricultural Census and Land cover maps at this stage.

The model gives a good representation of the areas that are agricultural land which are largely found on the **Upper Slopes** and is similarly located to the class *Settled Pastures* used by the consultant . At this stage, where the consultants have used additional data a more detailed definition of the class is given: *'pastoral landscapes characterised by small coverts and/or thinly scattered, or small groups of trees, often associated with farmsteads, in an otherwise 'open' setting typically created by Parliamentary enclosure type of former 'waste'.* During the investigation into the accuracy of the classes defined by the model, the LCM2000 (See Figure 2.8) and the HLC were investigated. In the *Settled Pastures* class it was found that the land cover was 31% arable and 46% improved grassland which suggests that there is a large presence of arable land in the area. In the **Agriculture** Class the land cover was 48% Improved Grassland and 32% Arable land. Across the whole AONB there is a coverage of 28% Arable land and 40% Improved Grassland. The consultant has divided the agricultural land classes as either *Pasture land* or *Farmland (arable)* however the arable land is interspersed throughout the Tamar Valley making the class **Agriculture** a better reflection of the Land Cover Type.

Analysis of the HLC reveals that much of the land in the consultant's class *Settled Pastures* on the Cornwall side of the river is of a medieval enclosure pattern. The Devon HLC also suggests that although there are large areas of post-medieval enclosure many of these were formally medieval enclosures and not necessarily 'waste' (common) land. As previously mentioned in Section 2.5.2.3 parliamentary enclosure did not have a huge impact in Devon and Cornwall (Devon County Council and Devon Hedge Group, 1997).

The Tavy Valley and Devon side of the River Tamar from the Tidal limit northwards have been identified similarly by the model and the consultant's assessment, and have noted the secondary wooded land and ancient woodland combined with agricultural land.

The consultant's *Ancient Pastoral Farmland* class covers the southern extent of the river Tamar defining the landscape as having scattered woodland, much of which is ancient, which is accurate, however the agricultural type can be debated as stated above. The model reflects this areas a **Wooded (Secondary) & Ancient Wooded**

Agricultural Land and whilst it does contain scattered woodland the character/presence of woodland here is not as strong as it is further up the valleys, in this respect the extent of the consultants polygon covering this area may be a better reflection of the character, however it cannot be picked up in the model as there are no ‘solid’ boundaries in the data to use, the valley has been analysed as a whole.

Further north, the *Ancient Pastoral Farmland* class appears again, however the model highlights the area of land on the **Upper Slopes** that is unwooded more accurately and the area around Gunoak Woods.

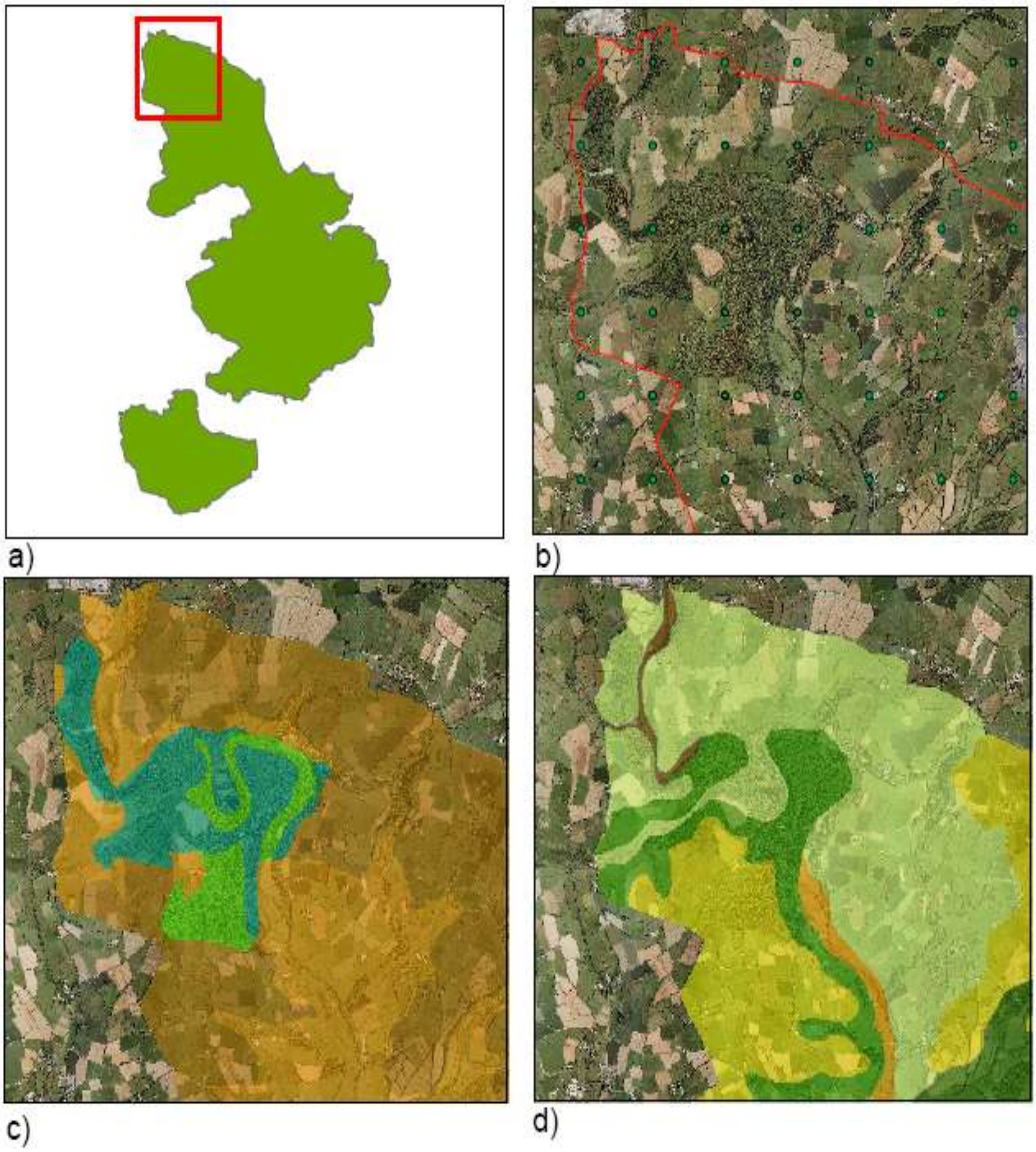

Figure D.1 Gunoak Woods: a) Location of Gunoak Woods, b) Aerial Photograph of the area, c) Classification by the Landform Model, d) Expert LCA

Figure D.1 shows the area around Gunoak woods in greater detail. Figure D.1b shows the area using aerial photography; the extensive woodland area can easily be identified and is in contrast to the surrounding agricultural land. It is also noticeably different from the ALC, NIWT and AWI in Figure 7.4. The model has created two classes that cover the area: **Wooded (Secondary)** and **Wooded & Ancient Wooded** (Figure D.1c).

Following the river northwards the consultants identify a class *Secondary Wooded Pastures* defined as *'un-wooded, pastoral landscapes characterised by scattered trees … and small patches of scrub'*. As can be seen from Figure D.1d this strip follows the northern extent of the river and a narrow margin of land along the river bank, the description of this parcel of land is accurate, however the model identifies this as **Wooded (Secondary) & Ancient Wooded Agricultural Land**. The landscape along the river corridor is not different enough to the surrounding land to need a separate polygon. In the consultants LCA there are also areas at the western extent of the Lynher and the south of Tavistock, again these areas are not very different to the surrounding landscape. These polygons would have been part of a larger polygon that extended out into Devon and Cornwall, however as the data has been clipped to cover just the areas within the AONB they appear as smaller areas. The advantage of the model here is that these small polygons are not identified.

The class *Ancient Woodland* is also identified defined as *'Landscapes characterised by extensive areas of broadleaved woodlands many ancient in origin…)'*. This class extends southwards from Woodtown (near Dunterton) following the valley sides until Halton Quay. It also covers a large portion of the Lynher (See Figure 7.4). Within the class description there is no declaration about the agricultural use of the land. It is possible that this class is the same as the *Ancient Wooded Farmland* class identified in the Devon assessment, however, the type of farmland is not defined in this assessment either which is in contrast to the other classes that either state arable or pastoral land.

The classification of the Lynher is quite different between the two methods. A large portion was identified as *Ancient Wooded* by the consultants (although there is little ancient woodland in this part) with *Settled Pastures*. The model has identified the Lynher as **Agricultural** in the northern part, which reflects the lack of woodland cover, the eastern extent is **Wooded (Secondary) Agricultural Land** which describes the area that is largely wooded. The south is identified as **Wooded (Secondary) & Ancient Wooded Agricultural Land** and an area of **Ancient Wooded Agricultural Land**.

The consultant has identified the class *Open Wildland* along the Lynher and Tamar Rivers and is defined as *"Treeless, usually uncultivated tracts of open land where natural constraints (climate and/or soils) or traditional management practices generally preclude the establishment of tree cover*". Using aerial photography to analyse this class, it is revealed that much of the polygon from the mouth of the river up to Bohetherick is within the river line, and does not include any of the land either side, up until Cotehele Quay. There are two areas near Calstock that are correctly identified however, most of the land that is included is cultivated and has hedgerows. In the Model most of the comparable polygon is not classified as it within the river boundary. Further north from the tidal limit the river banks have been included in the Model's class **Wooded (Secondary) & Ancient Wooded Agricultural Land**. The

Model has identified two small areas of **Ancient Wooded Agricultural Land** and **Wooded (Secondary) Agricultural Land**.

The consultants also classify three polygons as *Open Pasture* which is defined as *"Treeless tracts of pastoral farmland where natural constraints or traditional management practices generally preclude the establishment of tree cover".* Two of these parcels have been identified in the **Agricultural** class and is in agreement to the lack of tree cover. The third parcel was excluded from the analysis as it is part of the Tamar River.

There are two more classes identified by the model. These are small polygons of land that are on the Lynher are classified as **Non-Agricultural Land** as these cover some of the Torpoint Area. The polygons originate from the Ground Type model as they have a different soil type and have continued to be classified differently from the neighbouring polygon strengthening the fact that the areas are different enough in character to be separate even though they are very small parcels of land.

During the analysis of the agricultural and woodland data in the Land Cover Model, many small polygons are created due to the difference in the borders digitised in the ALC and NIWT data. Using aerial photography to compare the datasets, it can be determined that the NIWT is more accurate in identifying which areas are woodland and which areas are agriculture than the ALC. This may largely be down to the scale to which the datasets are digitised at, the NIWT being 1:25,000 and the ALC 1:250,000. It is also a consideration that the area may have been misclassified as

Non-Agricultural Land which is usually reserved for areas such as private parks, public open spaces, and sports fields etc rather than the more appropriate 'Woodland' class.

Cultural Pattern

The cultural pattern has been defined using firstly the Address point file as described in Section 5.5.4.1. In addition, the updated Devon and Cornwall HLCs (See Table 5.7) have also been used for analysis of the current Historic Character Type and the Period (See Figure D.2). The HLC data also gave a more detailed overview of the cultural pattern of the area rather than relying on June Agricultural Survey, this information was invaluable in identifying the main historical characteristic of the LDU.

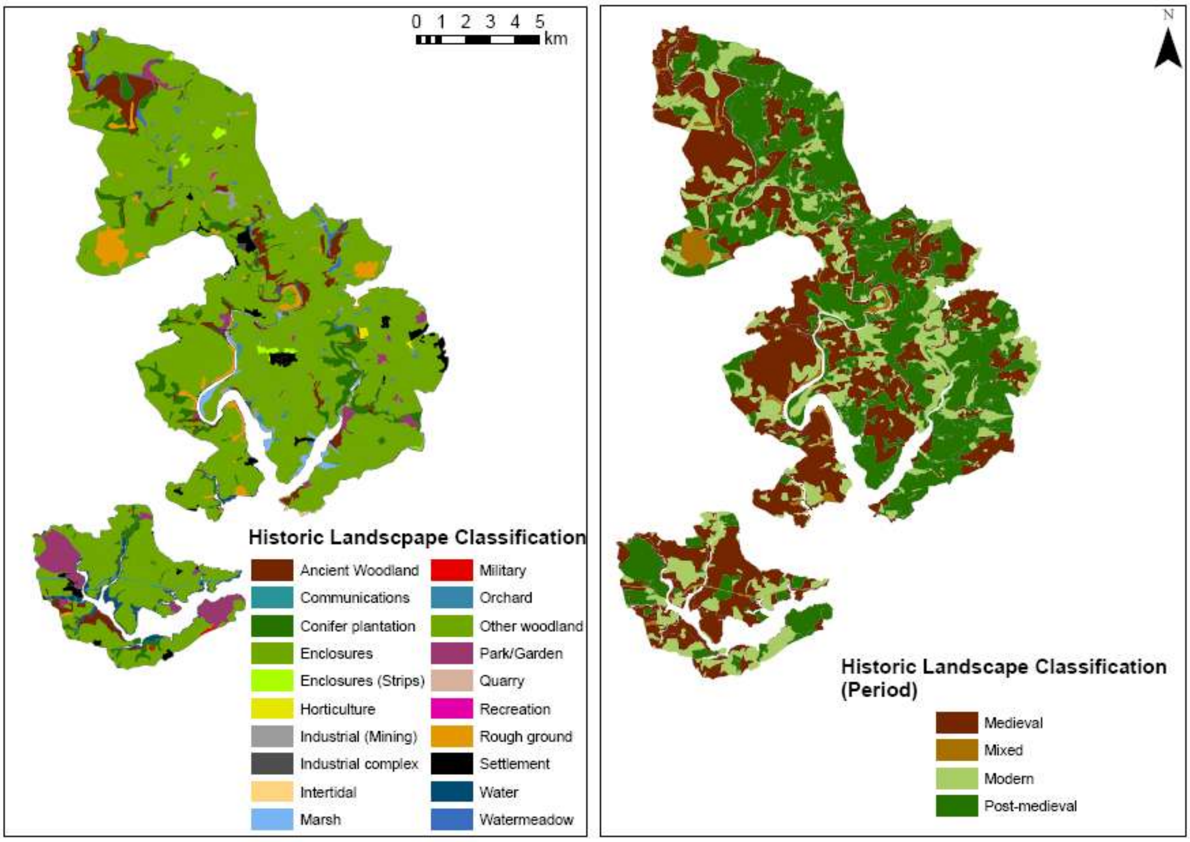

Figure D.2 Historic Landscape Classifications and Period

The data sources used by the consultant included the 1995 farm census data (where available), OS base maps and the HLC. In addition Roberts B.K (1996) Landscapes of Settlement: Prehistory to Present was also used along with some maps that were digitally derived from this work.

Comparison between the cultural patterns between the two methods is more difficult due to the HLC being used at different stages and referral back to the land cover classes defined by the consultant in the previous section is necessary.

The largest class identified by the consultant is *Clustered with small farms* this is defined as "*Settled rural landscapes characterised by clusters of wayside dwellings* *and small (<65ha* [0.65 km^2])*, mainly owner occupied farms"*. Much of the same extent is covered by the Model defined classes of **Clustered Settlement, Medieval Enclosures** and **Clustered Settlement with Post-Medieval Enclosures**. Referring back to the land cover classes the consultant has identified including *Ancient Pastoral Farmland*, *Ancient Wooded* and *Ancient Wooded Farmland*, these classes refer to the presence of ancient woodland rather than the age of the enclosures.

The classes identifying common land vary greatly between the methods. The small section identified in the model has been derived from the registered commons data, which is not identified in the consultant's assessment. There are however two areas identified as *Unsettled Common* which is defined as "*an often densely settled rural landscape characterised by loose clusters of dwellings and small (<65ha* [0.65 km^2]) *mainly owner occupied farms within a surveyor enclosed pattern of small-medium sized rectilinear field".* According to the HLCs (Figure 5.9) both areas in the *unsettled common* class have a mixture of medieval, post-medieval and modern enclosure patterns. On the Devon side although the LDU borders Rodborough Down Registered Common at least half of the LDU contains an irregular field pattern with sinuous boundaries which would indicate a medieval field pattern. Therefore, the Model is more effective in identifying areas of common land.

The *Unsettled Wildland* class has been used to describe much of the River Tamar and some of Lynher. This is defined as *"Extensive areas of uncultivated, mainly unenclosed land (including moor, heath, coastal dunes and salt marsh)* *characterised by the virtual absence of human habitation"*. However, as previously mentioned in Section 7.2.2 where the use of the class *Marine Levels* was used for this polygon for the Ground Type analysis, the extent of the polygon is questionable, as it rises far beyond the tidal limit. Furthermore examining the Address-Point data result in a count of 76 dwellings within the class.

Both methods identify several classes located around the tidal section of the river (See Figure D.3). In the Model, some of the classes have been created due to the lack of settlement, for example **Unsettled, Enclosures, Medieval**. However, other classes have been highlighted due the differences in the HLC. For example the **Industrial Complex** at Newquay was identified and areas of **Rough Ground** from south of Calstock following the river to Morwellham Quay. An area of **Marsh** was located at Halton Quay.

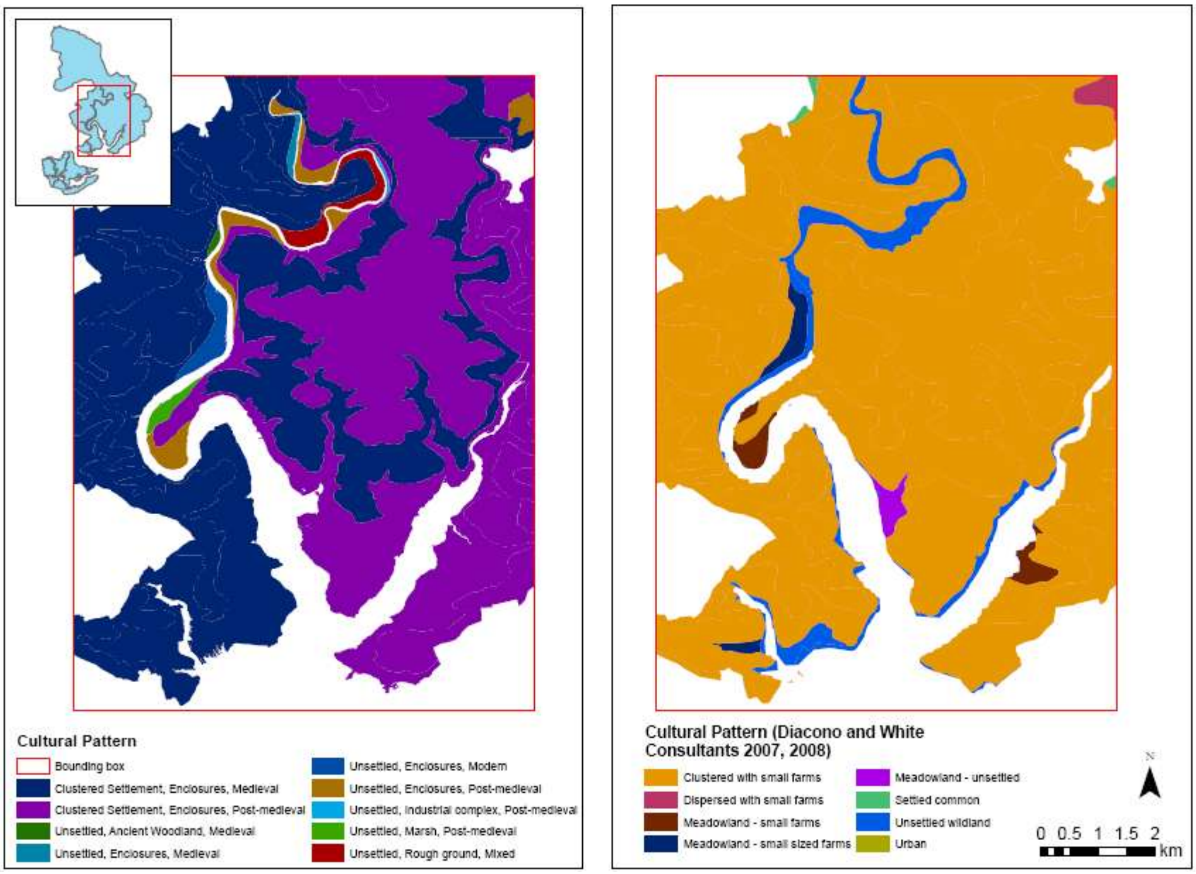

Figure D.3 Comparison of Cultural Pattern along the lower river valley (Inset picture provided to indicate magnified area)

The consultant has identified a class *Meadowland – Unsettled* to the west of Bere Ferres; this is described as *“Largely unsettled agricultural landscape often associated with surveyor enclosed pattern of large rectilinear fields on river floodplains and coastal grazing marsh”.* Much of this LDU has been excluded from the analysis by the model as it is within the used river boundary, the rest of the area has been included in the class **Clustered Settlement, Enclosures, Post-medieval**. A comparable class *Meadow with Marsh* was also identified on the Lynher in the Cornwall LCA.

The consultant also identified the class *Meadowland – Small Farms* on the river Tavy at Horsham, these LDUs identify areas that are different in character that have not been included in the class **Unsettled, Marsh, Post Medieval** in the model due to no differences being identified in elevation, soil type and the ALC. During the HLC analysis these important areas were missed due to the use of majority statistics.
Separate LDUs could be created within the model by adding an additional layer of data for marshes extracted from the HLC and combining the data in the Settlement/Historical Pattern Model before the settlement pattern analysis begins. According to LCM2000 data (see Figure 2.10) the areas identified as Marsh by the HLC are included in the agricultural classes such as Arable Horticulture and are also identified as agricultural in the ALC. Therefore the Land cover classes that have been identified are still relevant; adding the information from the HLC at this stage would produce separate LDUs that would add value to the characterisation.

The areas that have been identified as having a dispersed settlement pattern vary between the two assessments also. Using the same method of ANN analysis (See Section 5.5.4.1) within the polygons that were identified in the consultants assessment as dispersed, found 2 of them to be clustered. The LDU near Dunterton, was classed as ‘somewhat dispersed, but could be due to random chance’ and was not statistically significant. The model located two areas of dispersed settlement, one to the south of Kit Hill and the other on the Lynher section at St Erny.

The ‘Clustered Settlement, Park/Garden, Post-Medieval’ class was identified in the model, describing the areas around the large estates of Anthony, Port Elliot and

Endsleigh. In the consultants model, the class *Clustered with Estate farms* refers to *"Settled rural landscapes characterised by multiple settlement clusters and large (>65ha* [0.65 km^2]) *estate farms (defined as those areas where >50% of the land is managed by tenant farmers)"* and also identifies the areas around Port Elliot and Anthony.

Two other classes that were created by the Model include a small polygon adjacent to Saltash that was identified as a **Military** area, and the large area of **Ancient Woodland** around Gunoak Woods.

Appendix E – Character Types and Character Areas

In creating the CT's for the TVAONB (See Figure 7.10), the river was taken as a starting point. Each of the LDUs were examined, the Ground Types varied on their drainage pattern from freely draining, to naturally wet, which would be expected in a river valley context, the land cover is a mixture of agriculture and woodland and ancient wooded agricultural land, and the main historic character is enclosures of varying periods, with an area of Park/Garden. The LDU defined as marsh has been identified as CT **Water Meadow/Marsh**. The most definitive difference throughout the River Corridor LDUs is the presence and absence of settlement, from which the CT **Settled Valley Floor** and **Unsettled Farmed Valley Floor** have been formed.

The Steep Valley Sides all have the same Ground Type of Freely Draining Loam, With Little Or No Drift. The Land Cover divides the LDUs between Wooded & Ancient Wooded land which has been given the CT **Wooded Valley slopes.** The areas of Agricultural land, and Wooded & Ancient Wooded agricultural land have been given the CT **Farmed River Valley Slopes**. There are 3 LDUs that are Unsettled have been joined with the Settled LDUs due to the fact that they appear on the edge of the designation and are suffering from 'edge' effects, rather than environmental constraints to building, looking at the wider landscape for example, two of the LDUs are adjacent to Torpoint.

Examining the Upper Slope LDUs produced a CT based on a single LDU which was classified as **Common Land**. The majority of the other LDUs have Loamy soils with the exception of one LDU which has Peaty soils, this LDU has not been separated into its own CT as the land cover is still defined as agriculture, and examination of the LCM2000 has not revealed any exceptional land cover classes such as bog. The historic character is of enclosures of varying periods and all the LDUs are settled. Therefore these polygons have been defined as **Inland Plateau**.

Two CTs remain, the first, **Wooded Valley Slopes** takes account of two areas of Steep Valley Sides, and two of Upper slopes, that are purely wooded with no agricultural use, and are adjacent to each other.

The final CT is **Moorland Fringe Slopes**, and has been classified as such due to its proximity to Dartmoor and adjacent common land.

In comparison with the consultants LCA (Diacono Associates & White Consultants, 2008) there are broad similarities in the CTs, for example, the *Inland Plateau*, *Farmed River Valley Slopes*, *Moorland Fringe Slopes* and *Unsettled Farmed Valley Floors*. There are differences around the Gunoak area and common land where additional classes have been created within the model. The other differences appear around the boundary of the AONB where CT that extends into Devon occurs in small portions in the designation such as the *Lower Rolling Farmed and Settled Slopes* and *Settled Valley Floors* classes. It is possible that many of the key characteristics that have been defined for these areas will not apply within the designation, and the management objectives may also be different. The advantage of running the model using data that is tailored to the AONB boundary means characteristics from outside of the border are not included and the CA created are tailored to the AONB and thus their management objectives. CTs have not yet been defined for the Cornwall part of the AONB for comparison.

The River Corridor was grouped first to include the **River Tamar and Tavy** valleys which share many characteristics such as the mouth of the river leading into wooded valleys. This includes LDUs that were loam with a mixture of drainage patterns, the land cover was Agricultural with Woodland and Ancient Woodland, and the historic character is largely Enclosures, with the area of Marsh included and the area identified as industry at Newquay. The Key characteristics are:

- A large open estuarine landscape with extensive views at the south of the river with marshes and mudflats
- Level valley floor surrounded by gently to steeply sloping valley sides
- Narrowing to the tidal limits at Weir Head and Lopwell Dam. The rivers meander in tight loops cutting a gorge through the granite rock at Bohetheric
- Much of the area is unsettled however, clustered settlements do arise notably the village of Bere Ferres and parts of the Calstock and Gunnislake
- Mining heritage at Morwellham, Newquay and other small quays along the waterline.

The **Bere Peninsula to Dunterton** CA was defined taking into account the ridge of high ground that runs northwards encompassing the steep valley sides and plateau top. The Bere Peninsula is known for is remoteness being largely cut off from the south by the rivers, except for the Tamar Valley Railway Line (Countryside Commission, 1992). The Key Characteristics are:

- Wooded and ancient wooded steep valley side on the east of the Tamar Valley
- Located between the Tamar and Tavy rivers the Bere Peninsula is a quiet open landscape with far reaching views
- A clustered settlement pattern with many hamlets and Bere Alston being the principle village
- An area of unsettled common at West Down
- Evidence of mining heritage from Blanchdown Wood to south of Newquay, including engine houses, mines, water wheels and chimneys, encompasses much of the Tamar Valley World Heritage Site
- Parkland and Woodland at the Endsleigh estate.

The **East Tavy Valley and Moorland Slopes** includes two LDUs that encompass the Steep Valley Sides of the Tavy River and the Upper Slopes that border Dartmoor. The Key Characteristics are:

- Ancient and secondary wooded steep valley sides
- Open agricultural landscape on the upper slopes
- A mainly Post-medieval enclosure pattern with large pockets of medieval enclosures
- A clustered settlement pattern including the hamlets and the villages of Buckland Monachorum, Crapstone and Milton Combe
- A settled moorland fringe with views to Dartmoor.

Calstock and the Western Slopes CA covers the area from Botus Fleming taking in the River Tamar Valley Sides and Upper Slopes up to Calstock and beyond to Alston. The land cover is Agricultural on the Upper slopes and Agriculture with Wooded and Ancient Woodland on the Steep Valley Side. The LDU that covers Botus Fleming is not physically joined to the main CA, however this is due to 'edge effects' and would be joined if the AONB area was extended. Alternatively it could be joined to the River Tamar and River Tavy CA however, the character of the area fits better with the Calstock and Western Slopes CA due to the Agricultural land cover and lack of woodland. The Key characteristics are:

- Steep wooded and ancient wooded valley sides leading to open agricultural land which retains its largely medieval enclosure pattern
- Evidence of orchards and market gardening particularly around Bohetherick and Burraton where glass houses and polytunnels are a prominent feature
- A clustered settlement pattern with the principle settlements of Calstock and Gunnislake.

Kit Hill is the highest point in the Tamar Valley AONB at 331m above sea level, it has panoramic views reaching as far as the coast at Bude and the Plymouth Sound and to Dartmoor and Bodmin Moor. Kit Hill was formerly owned by the Duchy of Cornwall until it was given to the people of Cornwall in 1985 (Tamar Valley Service, 2004-2009; Cornwall County Council, 2010). The key Characteristics of the CA are:

- Highest point of the Tamar Valley with extensive panoramic views
- An open agricultural landscape with little woodland cover
- A patchwork of Medieval, Post-Medieval and modern enclosure
- Rough ground with Dwarf Shrub heath covering Kit Hill
- A dispersed to clustered settlement pattern with the villages of Coxpark and Chilsworthy
- Former mine sites and visible mining heritage features.

The Northern Tamar and River Inny CA covers the Steep Valley Sides of the River and the encompassing upper slopes. The landscape is largely wooded with some of the upper slopes being agricultural. The key characteristics are:

- A largely wooded landscape with recently planted conifer plantation, with areas of felled and recently planted young trees.
- Agricultural on the upper slopes, with a mainly medieval enclosure pattern with dispersed pockets of modern enclosure.
- A clustered settlement pattern outside of the wooded areas, with the village of Rezare and hamlets of Lidwell and Pempwell which have historically been surrounded with orchards.

The Lynher is separated from the rest of the AONB by Saltash and A38 road. It is an estuarine landscape with ancient and secondary woodland along the river corridor and agricultural valleys sides. The key characteristics are:

- An estuarine landscape with ancient and secondary woodland along the river.
- The valley sides are agricultural with a largely medieval enclosure pattern, there are patches of modern enclosure notably around Markwell.
- Wooded estates/parkland of Anthony and Port Elliot bordering the river edges
- Saltash and Torpoint are in close proximity.
- A clustered settlement pattern with the principle town being St Germans which includes a railway station.

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