Appendix 3.1: Models - Biomass Production

Agricultural Land Classification (ALC)

Organisation: NSRI

Date: 1988

Objectives

- To provide a framework for classifying land according to the extent to which its physical or chemical characteristics impose long-term limitation on agricultural use
- To enable informed choices to be made about the future use of farmland within the planning system
- To help underpin the principles of sustainable development

Methodology

The ALC methodology is based on long term physical limitations of land for agricultural use, primarily climate, site and soil and the interactions between them. Land is classified into five grades (Table 3.1.1) with Grades 1 to 3a forming the 'best and most versatile land' and is graded and mapped without regard to present field boundaries, except where they coincide with permanent physical features.

Grade	Classification	Description of Land
1	Excellent	No minor limitations to agricultural use
2	Very good	Minor limitations which affect crop yield, cultivations or harvesting
3a	Good	Capable of consistently producing moderate to high yields of a narrow range of arable crops, or moderate yields of a wide range of crops
3b	Moderate	Capable of producing moderate yields of a narrow range of arable crops, or lower yields of a wider range of crops, or high yields of grass
4	Poor	Severe limitations which significantly restrict the range of crops and/or level of yields
5	Very poor	Land with very severe limitations which restrict use to permanent pasture or rough grazing

Table 3.1.1: Grades of Agricultural Land Classification

Input requirements

- landuse
- minimum soil depth
- series
- floodrisk
- texture
- wetness class
- field capacity days
- slope
- altitude

- average annual rainfall
- climate code

Results

The model was implanted for the Eden (Figure 3.1.1) and Tern (Figure 3.1.2) catchments. The Macaulay Institute has a separate model which was implemented for the Lossie catchment (see below).

Literature references

MAFF (1988), Agricultural Land Classification of England and Wales: Revised guidelines and criteria for grading the quality of agricultural land

Defra (2003), Agricultural Land Classification: Protecting 'the best and most versatile agricultural land', http://www.defra.gov.uk/environ/landuse/alcleaflet.pdf

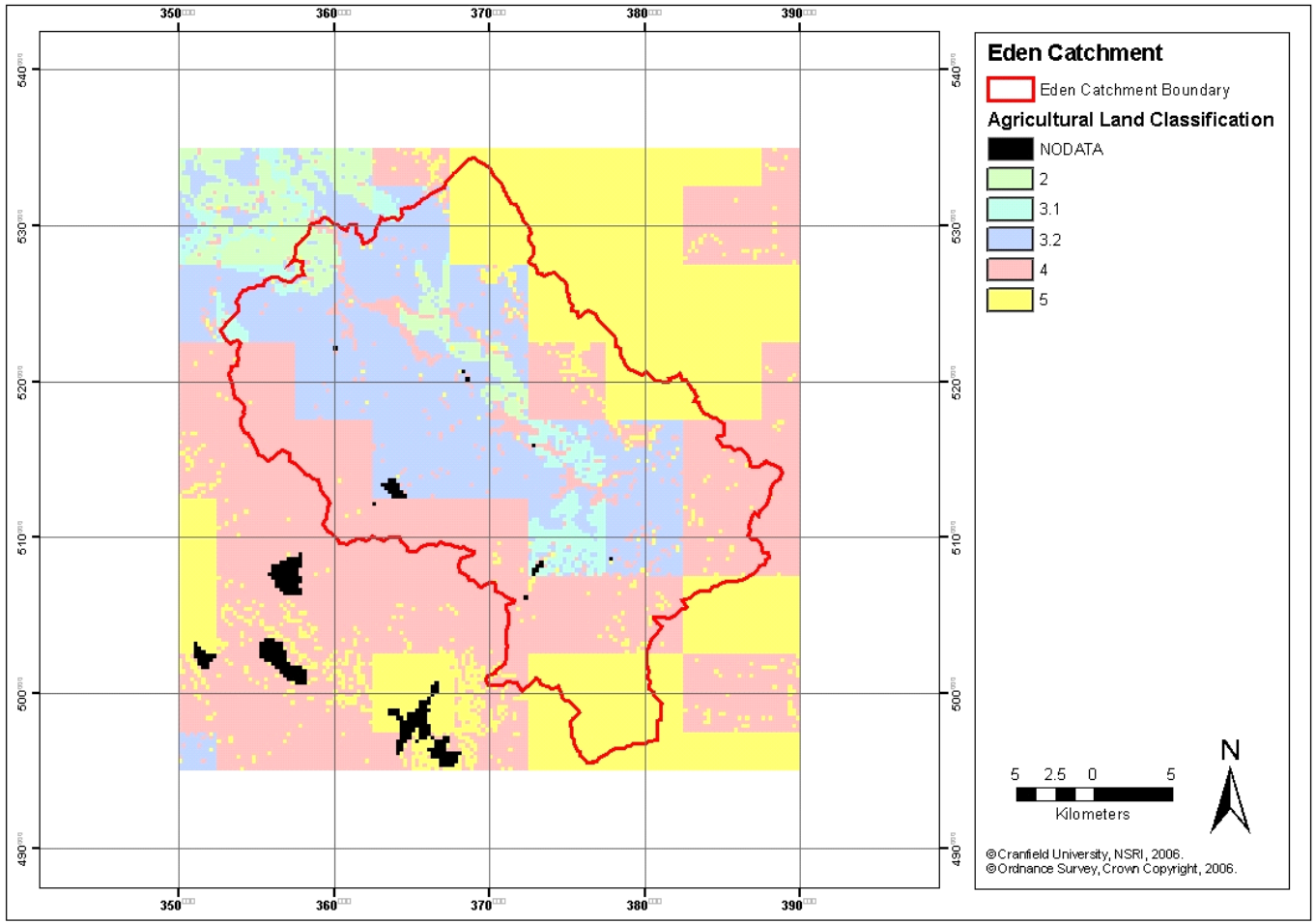

Figure 3.1.1: Agricultural Land Classification for the Eden catchment

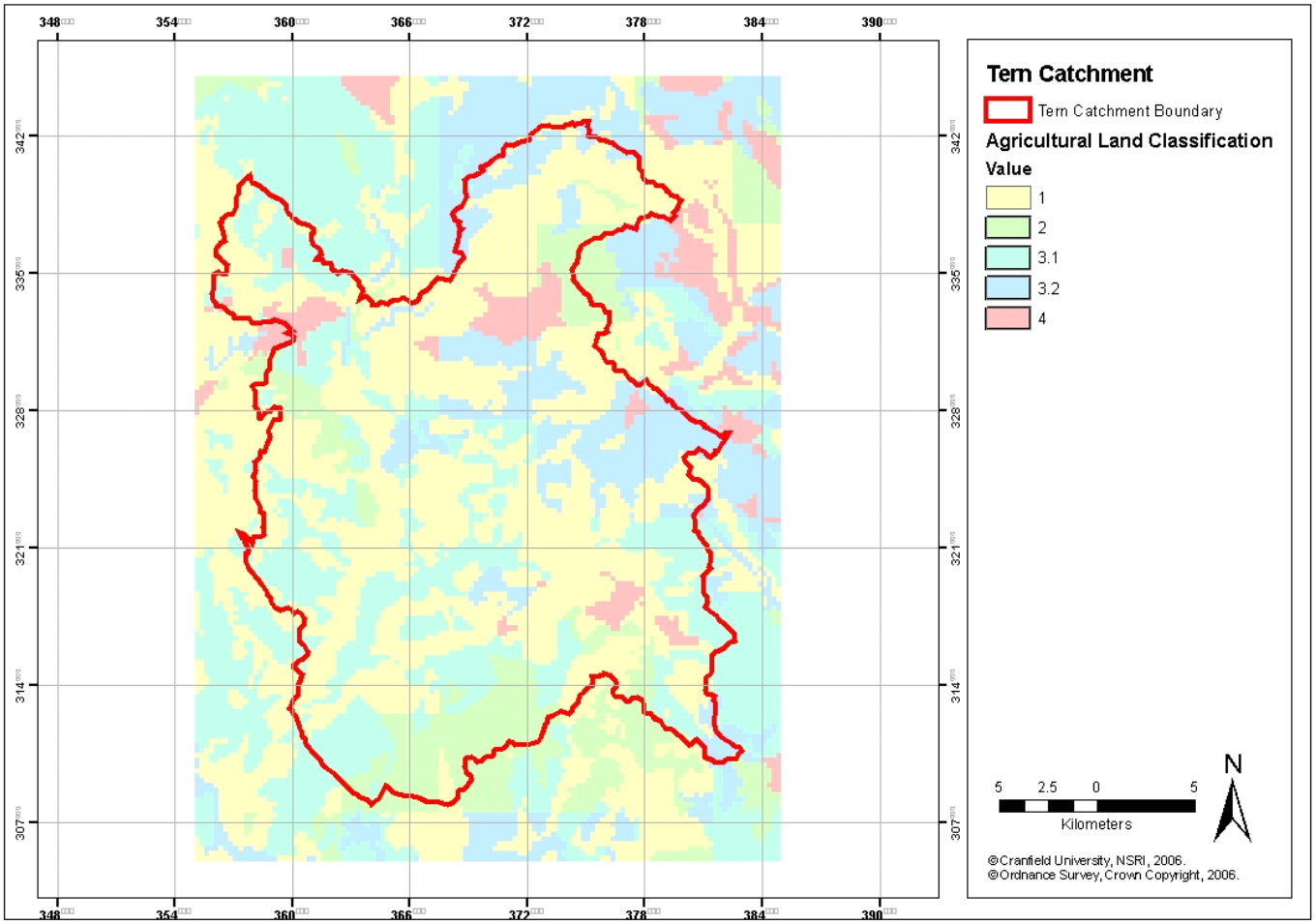

Figure 3.1.2: Agricultural Land Classification for the Tern catchment

Land Capability for Agriculture

Organisation: Macaulay Institute/NSRI

Date: 1982

Objectives

- to assess the potential of land for agricultural use determined by the extent to which its physical characteristics impose long term restrictions on its agricultural use

Methodology

The methodology comprises a series of published guidelines (Bibby *et al* 1991) that allows land to be classified into seven classes based on the limitations imposed by soil, climate, topography and interactions between them. It is similar in approach to the LCf classification and there are a number of assumptions that underpin the classification that must be borne in mind. The final classification depends on the most limiting factor rather than on an average of all the factors.

Class	Classification	Degree of limitation
1	Land capable of producing a very wide range of crops	No or very minor limitations to agricultural use
2	Land capable of producing a wide range of crops	Minor limitations
3	Land capable of producing a moderate range of crops	Moderate limitations
4	Land capable of producing a narrow range of crops	Moderately severe limitations
5	Land capable of use as improved grassland	Severe limitations
6	Land capable only of use as rough grazing	Very severe limitations
7	Land of very limited agricultural value	Extremely severe limitations

Table 3.1.2: LCA classes

In addition, Classes 3 and 4 are subdivided into two divisions, Classes 5 and 6 into three divisions.

Input requirements

A range of soil, climatic and topographic data and assessments are required including:

- Accumulated temperature above 0 degrees C (January to June)
- Maximum potential soil moisture deficit (mm)
- Wind speed
- Soil structure
- Soil rooting depth
- Soil stoniness
- Soil droughtiness – interaction between soil and climate parameters
- Wetness - interaction between soil and climate parameters
- Flood risk
- Erosion risk
- Assessment of pattern (variability of conditions)

- Vegetation (Class 6 only)

Results

The model was implanted for the Lossie (Figure 3.1.3) catchment. NSRI has a separate model which was implemented for the Eden and Tern catchment (see above).

Literature references

Bibby J S, Douglas H A, Thomasson A J and Robertson J S (1991). Land Capability Classification for Agriculture. Macaulay Land Use Research Institute, Aberdeen.

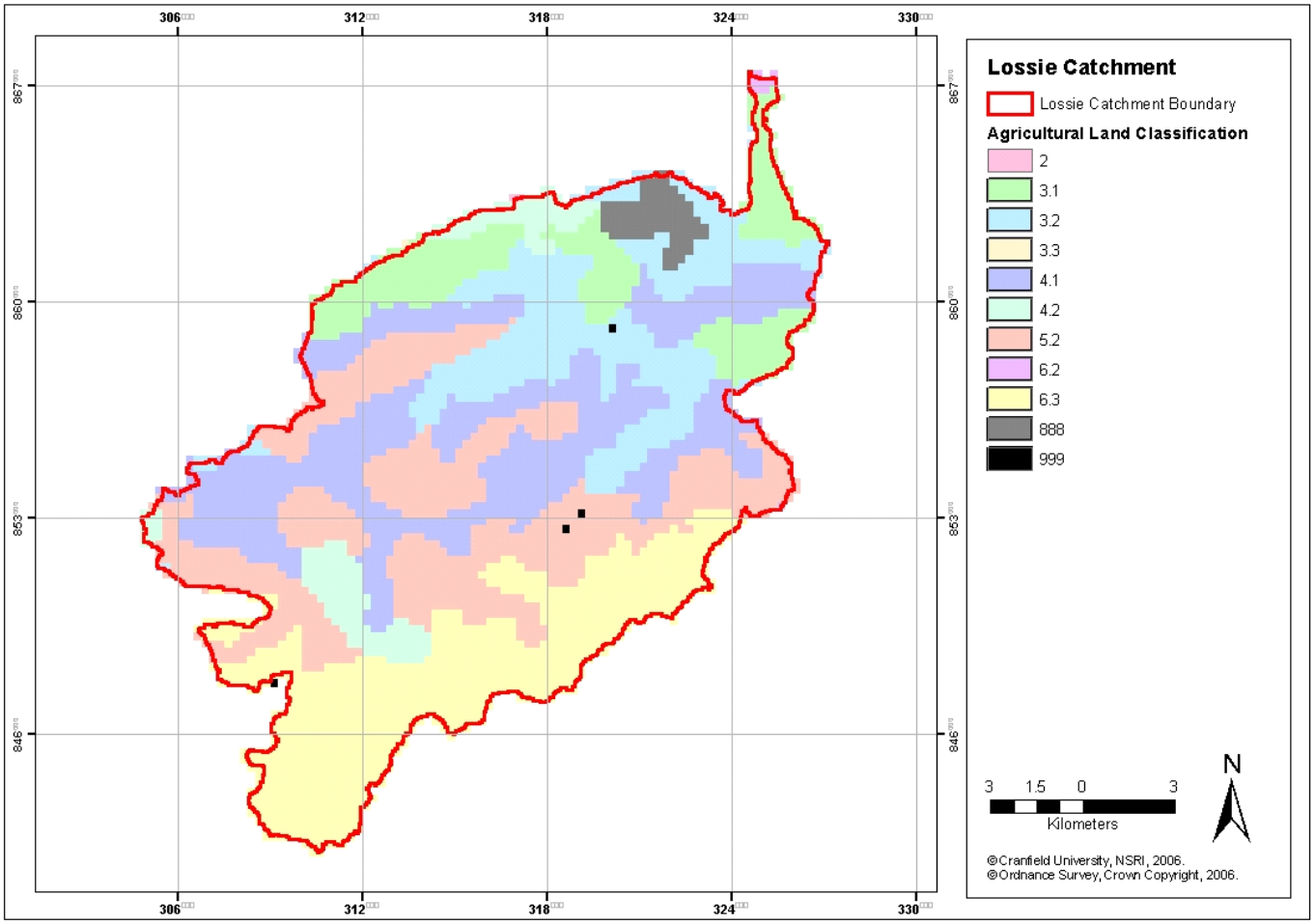

Figure 3.1.3: Agricultural Land Capability Classification for the Lossie catchment

Arable Crops Suitability Model

Organisation: NSRI

Date: 1986

Objectives

- To assess suitability of land for common agricultural crops
    - Sugar beet
    - Winter cereal
    - Forage maize
    - Maincrop potatoes
    - Oilseed rape
    - Barley
- To make general predictions of productivity

Methodology

This methodology is based on whole farm crop data and some data from experimental plots and is applied to soil map units at scales of 1:25,000 to 1:250,000. It is designed to use available soil and climatic information as statistical averages and generalised crop phenology (Figure 3.1.4).

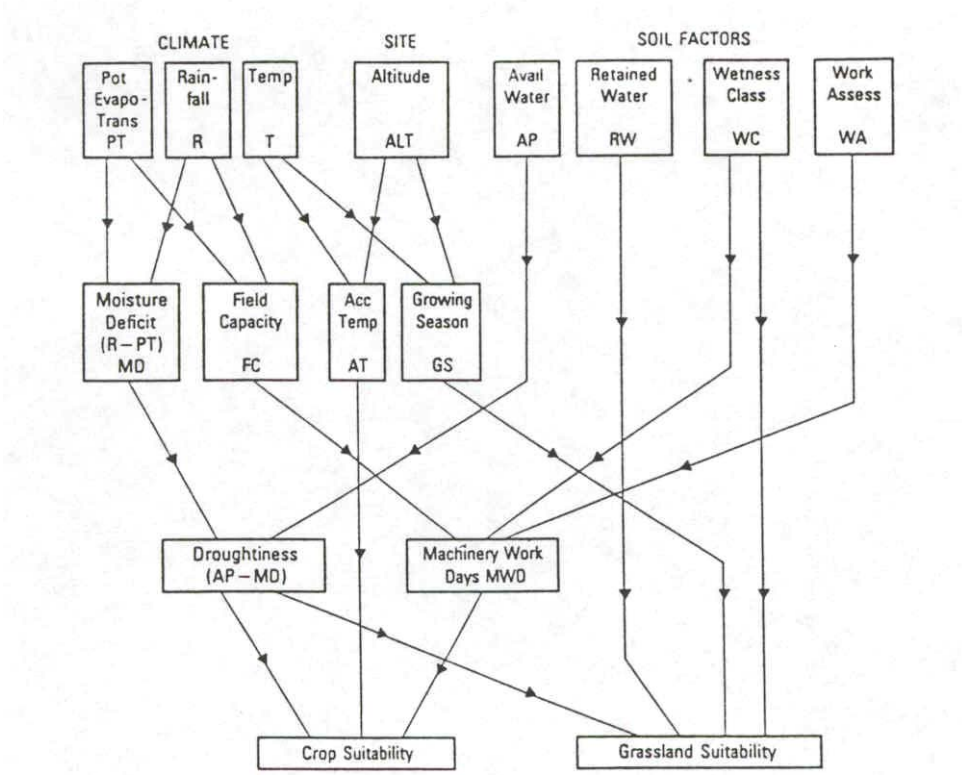

Figure 3.1.4: Databases needed for crop suitability assessment (taken from Jones and Thomasson, 1986)

The degree of suitability is based on:

1. workability – the opportunity to establish and harvest the crop defined as number of potential machinery work days (MWD) for field operation in the relevant period of autumn or spring
2. crop water supply – balance between atmospheric demands on the crop, incident rainfall and soil water reserves accessible by the crop

Input requirements

- droughtiness
- machinery workdays - spring
- series
- Accumulated temperature above 0 degrees

Results

The model was implanted for the Eden, Tern and Lossie catchments. Figures 3.1.5 to 3.1.19 illustrate the results for sugar beet, cereals, maize, potatoes and barley respectively. Missing crops indicate that they are not appropriate for a particular catchment.

Literature references

Beard, G.R. (1987), Suitability of Land for Selected Vegetable Crops, SSLRC report

Jones, R.J.A. and Thomasson, A.J. (1986), Land suitability classification for temperate arable crops, in Beek, K.J., Burrought, P.A. and McCormack, D.E. (eds), Proceedings of the International Workshop on Quantified Land Evaluation Procedures, Washington DC, 27 April – 2 May 1986, ITC Publication No. 6

Thomasson, A.J. and Jones, R.J.A. (1991), An empirical approach to crop modelling and the assessment of land productivity, *Agricultural Systems*, 37, pp.351-367

Thomasson, A.J. (1995), Assessment of soil water reserves available for plants (SWAP): a review. In: European land information systems for agro-environmental monitoring. King, D., Jones, R.J.A. and Thomasson, A.J. (Eds). Institute for Remote Sensing Applications. Joint Research Centre. Office for Official Publications of the European Community. Luxembourg.

Wright, P.S. (1986), Alternative Crops: Their soil and climatic requirements, SSLRC report

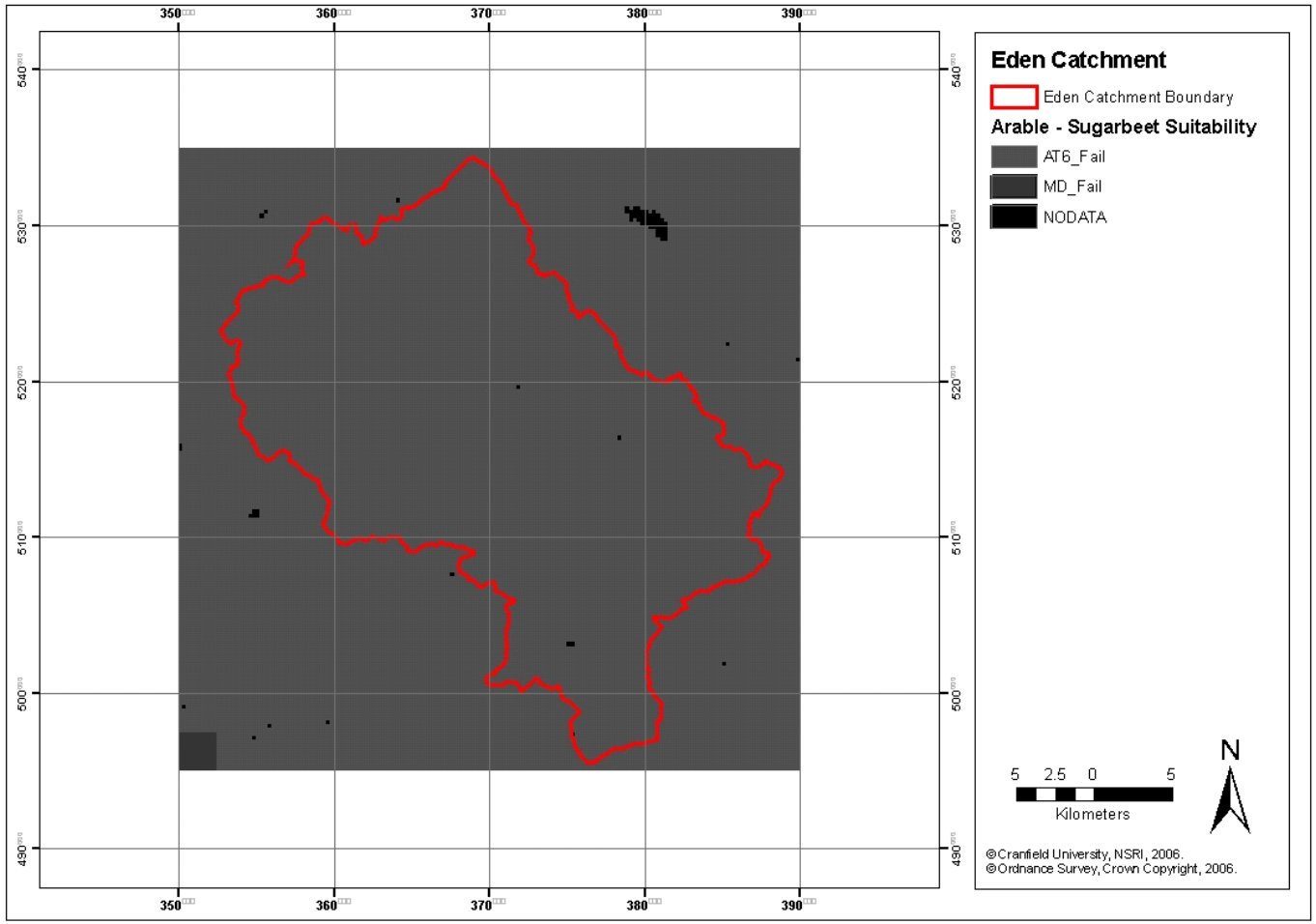

Figure 3.1.5: Agricultural Suitability (Sugar Beet) model for the Eden catchment

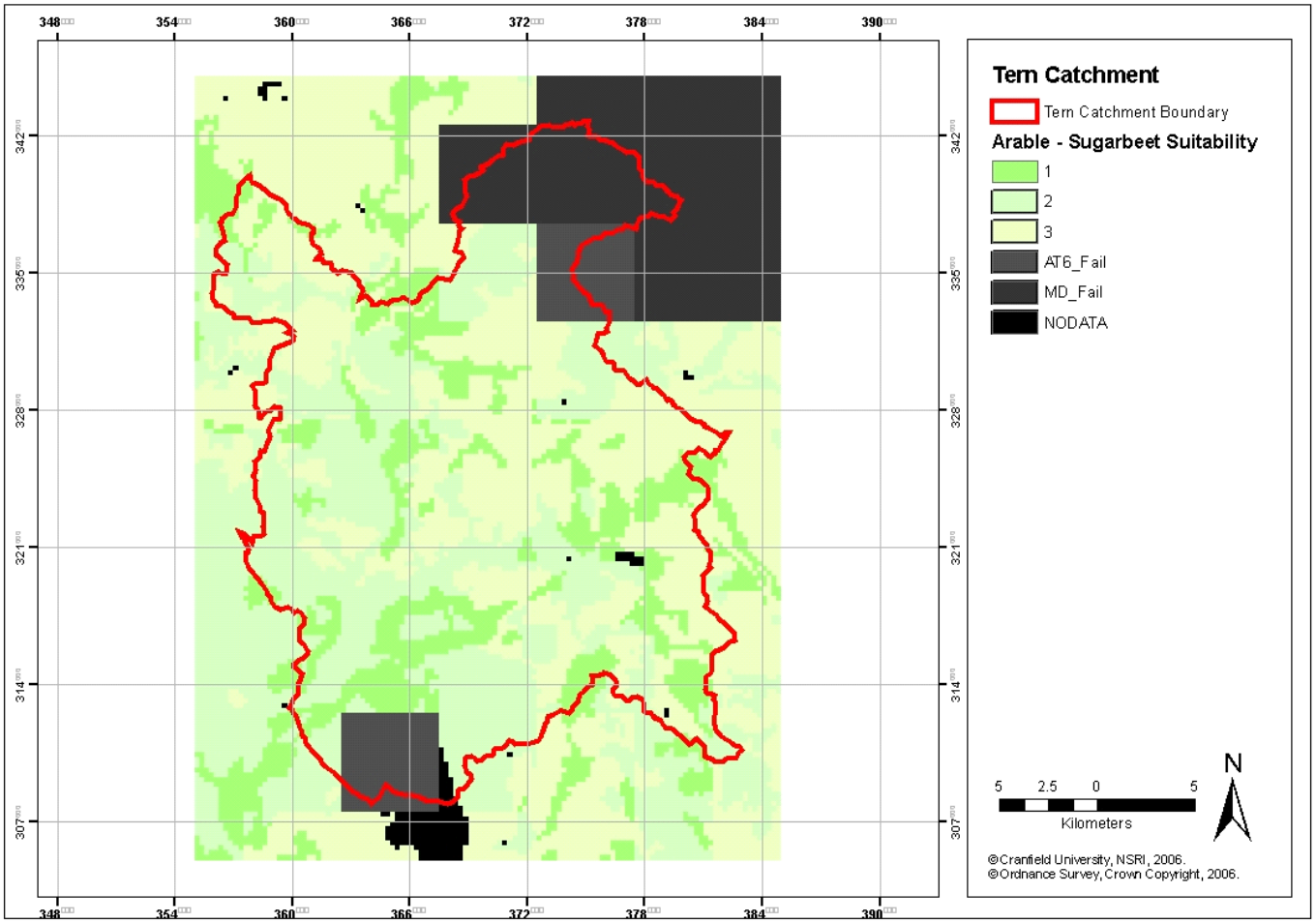

Figure 3.1.6: Agricultural Suitability (Sugar Beet) model for the Tern catchment

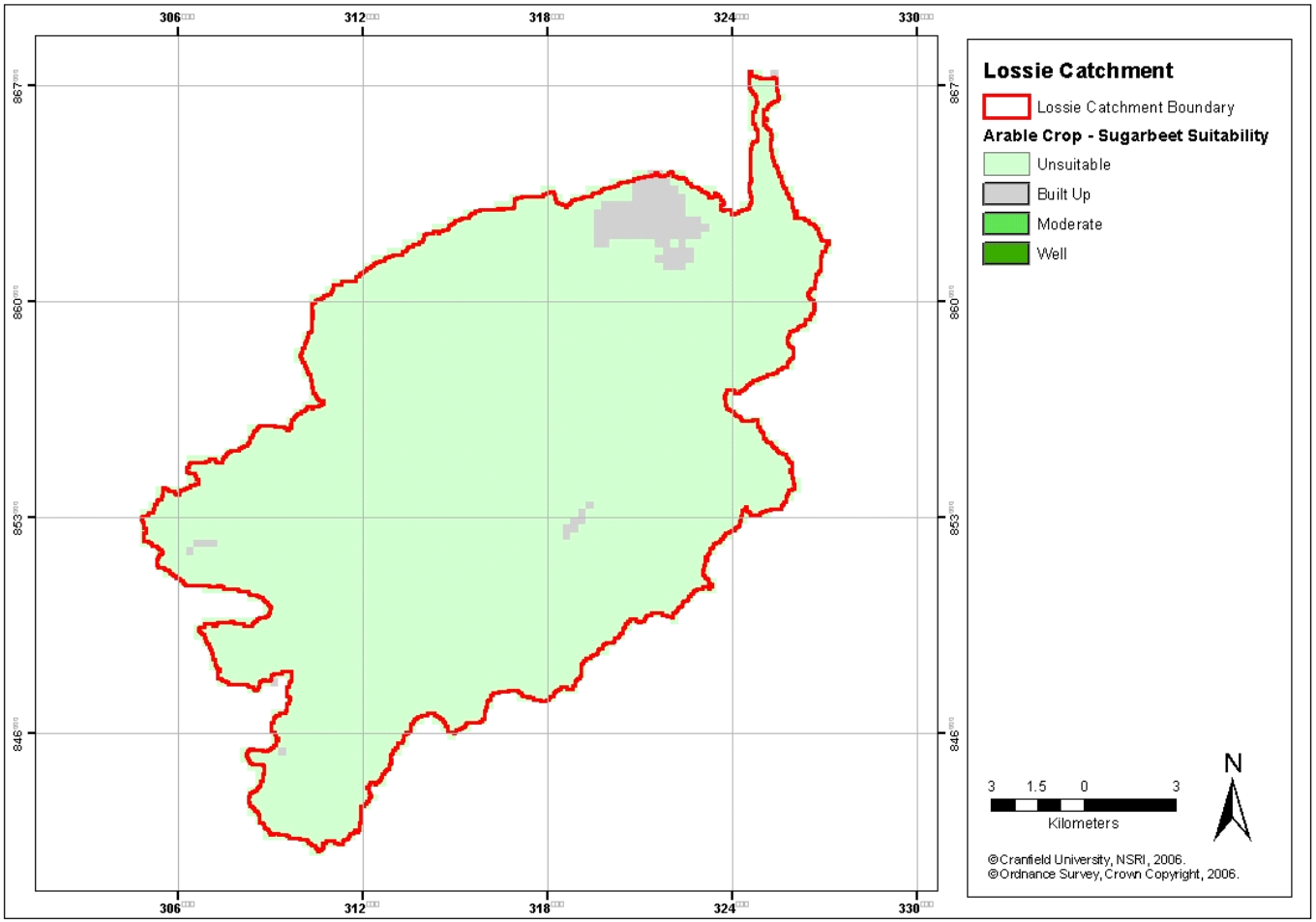

Figure 3.1.7: Agricultural Suitability (Sugar Beet) model for the Lossie catchment

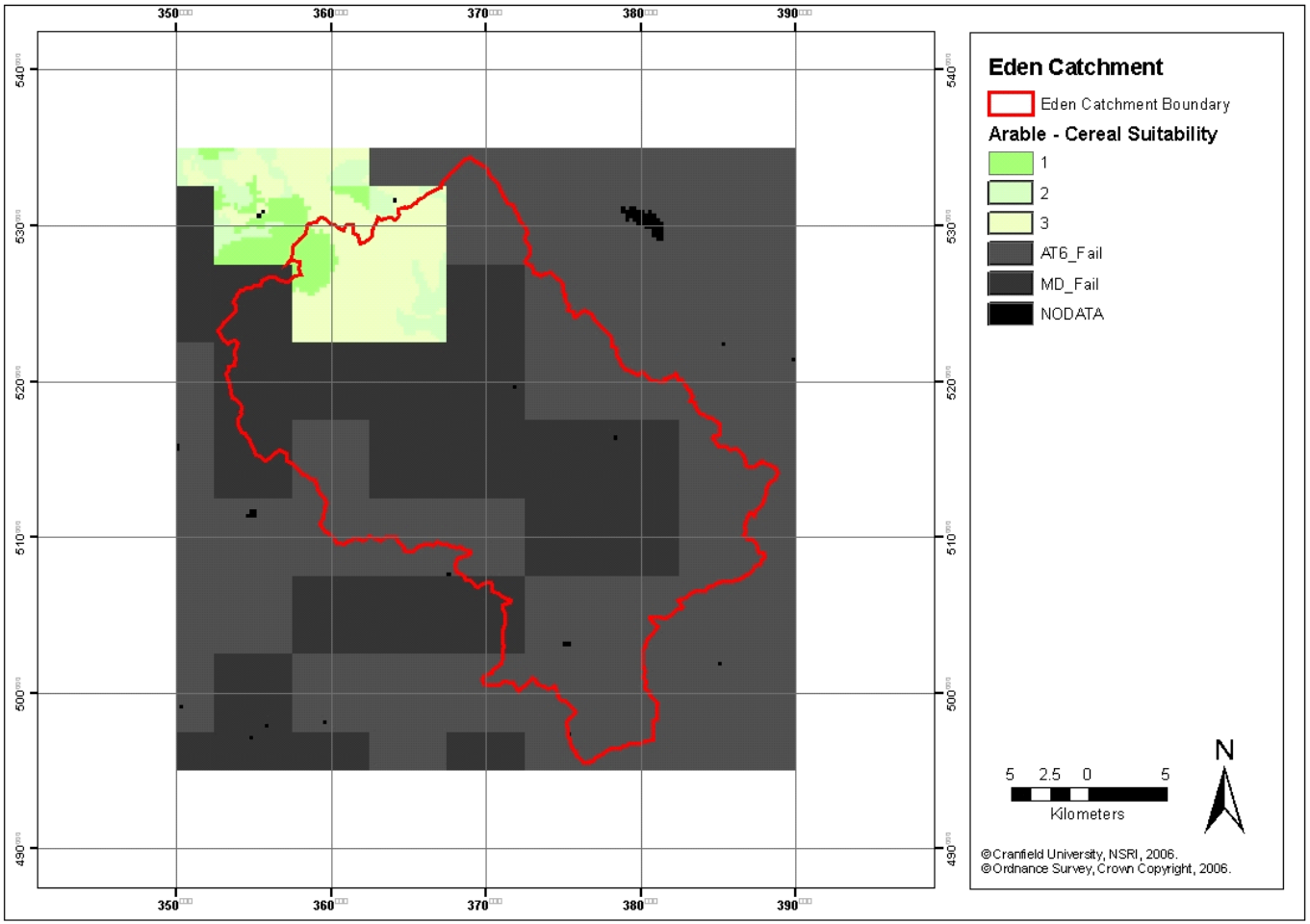

Figure 3.1.8: Agricultural Suitability (Cereals) model for the Eden catchment

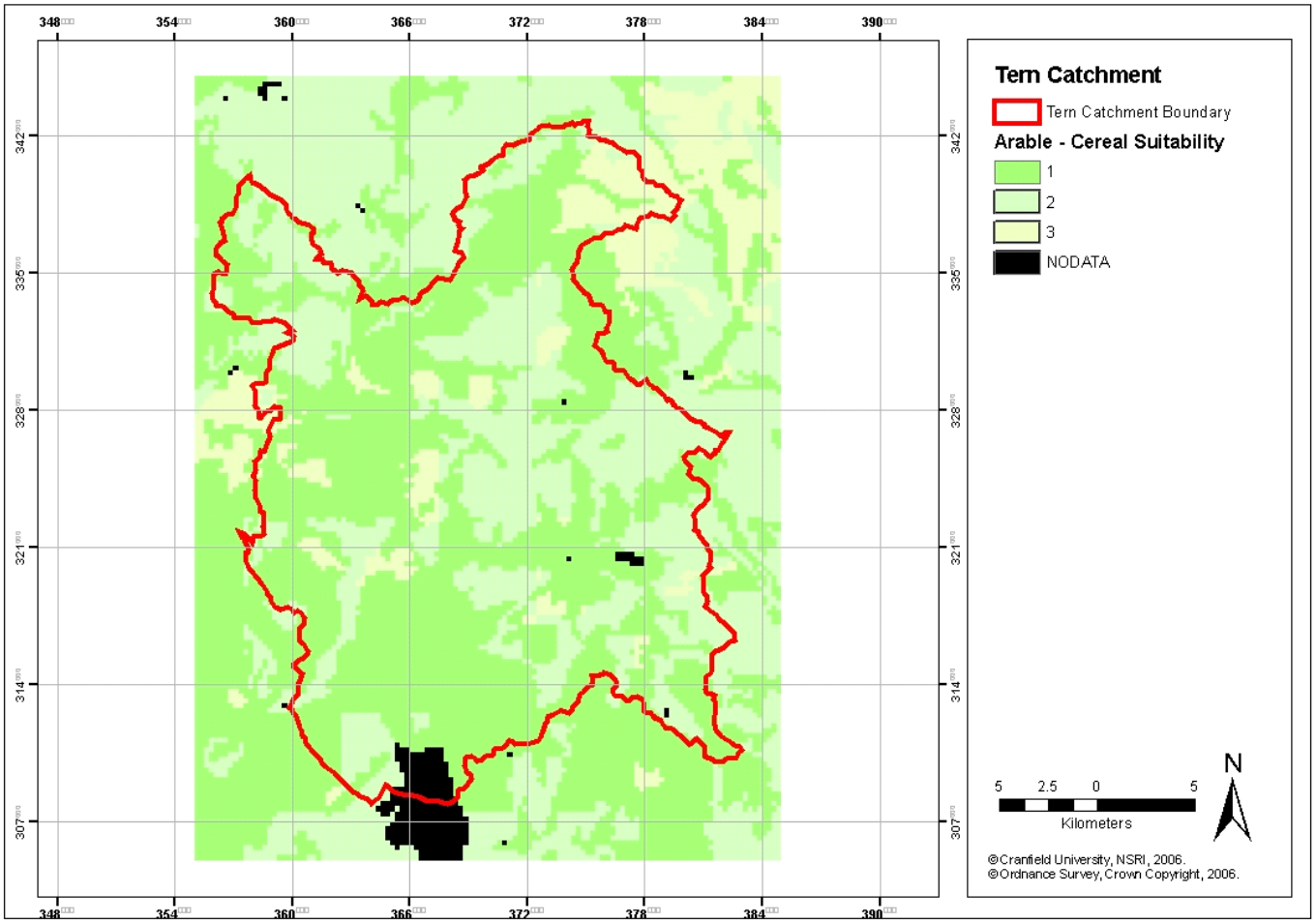

Figure 3.1.9: Agricultural Suitability (Cereals) model for the Tern catchment

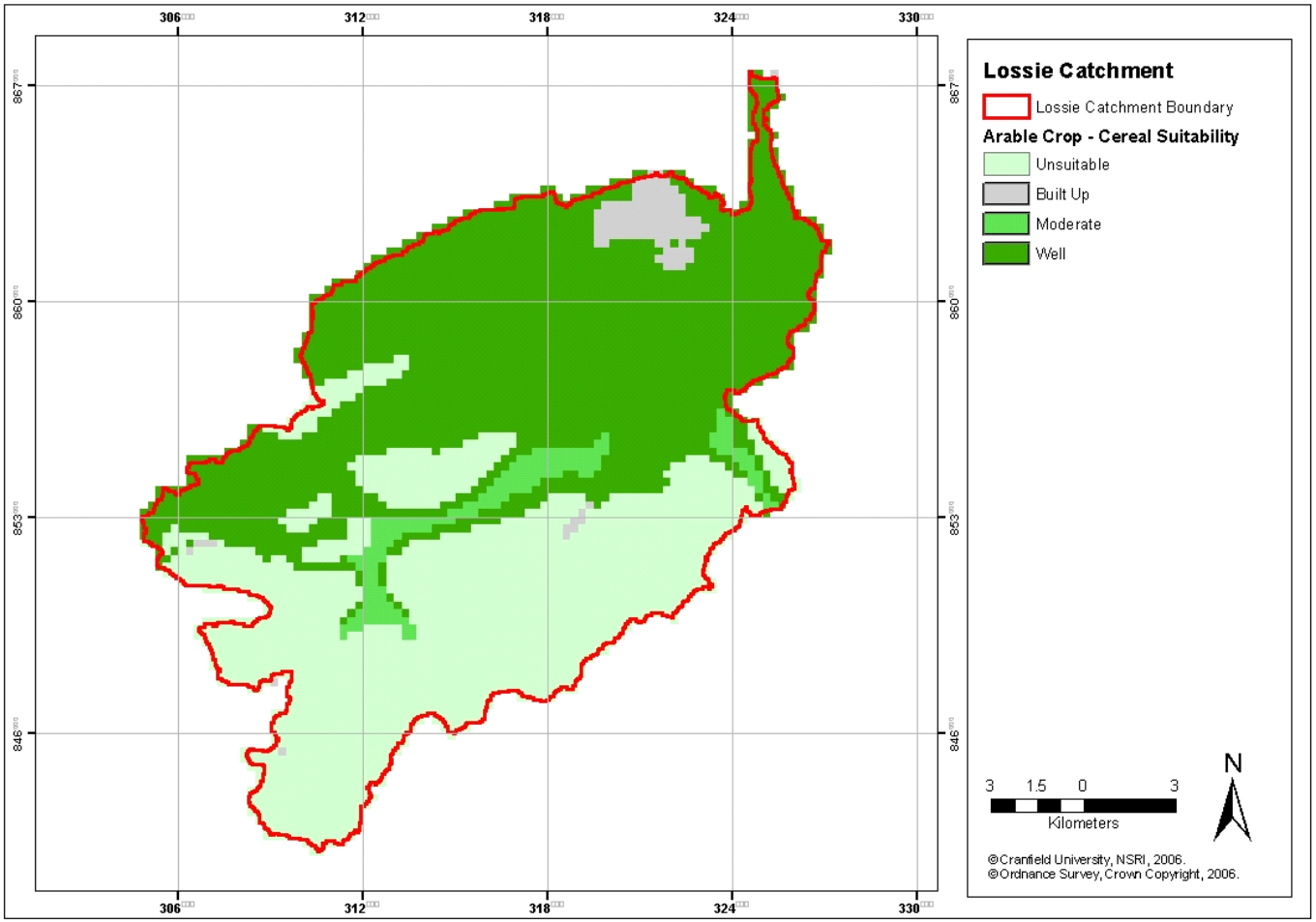

Figure 3.1.10: Agricultural Suitability (Cereals) model for the Lossie catchment

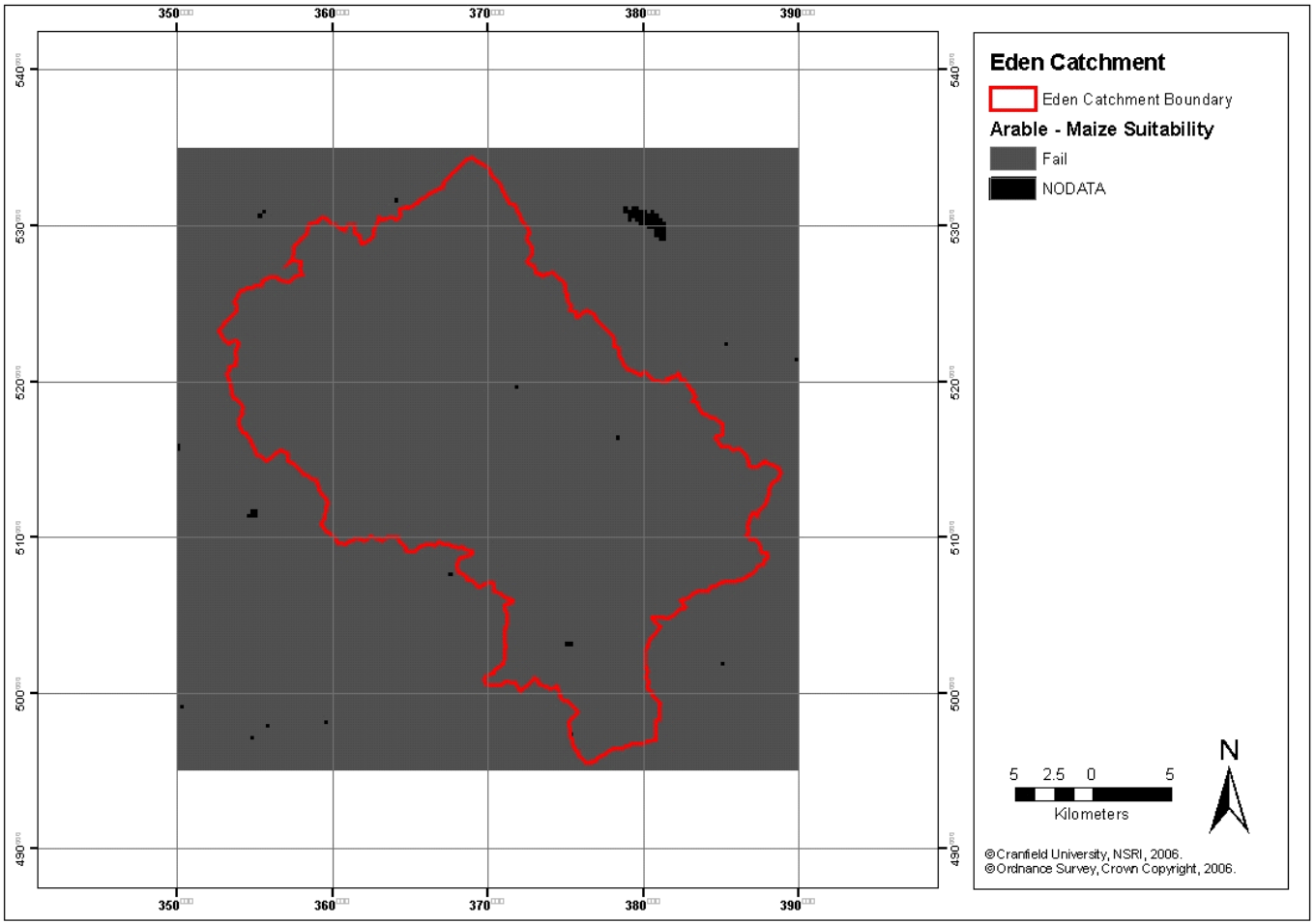

Figure 3.1.11: Agricultural Suitability (Maize) model for the Eden catchment

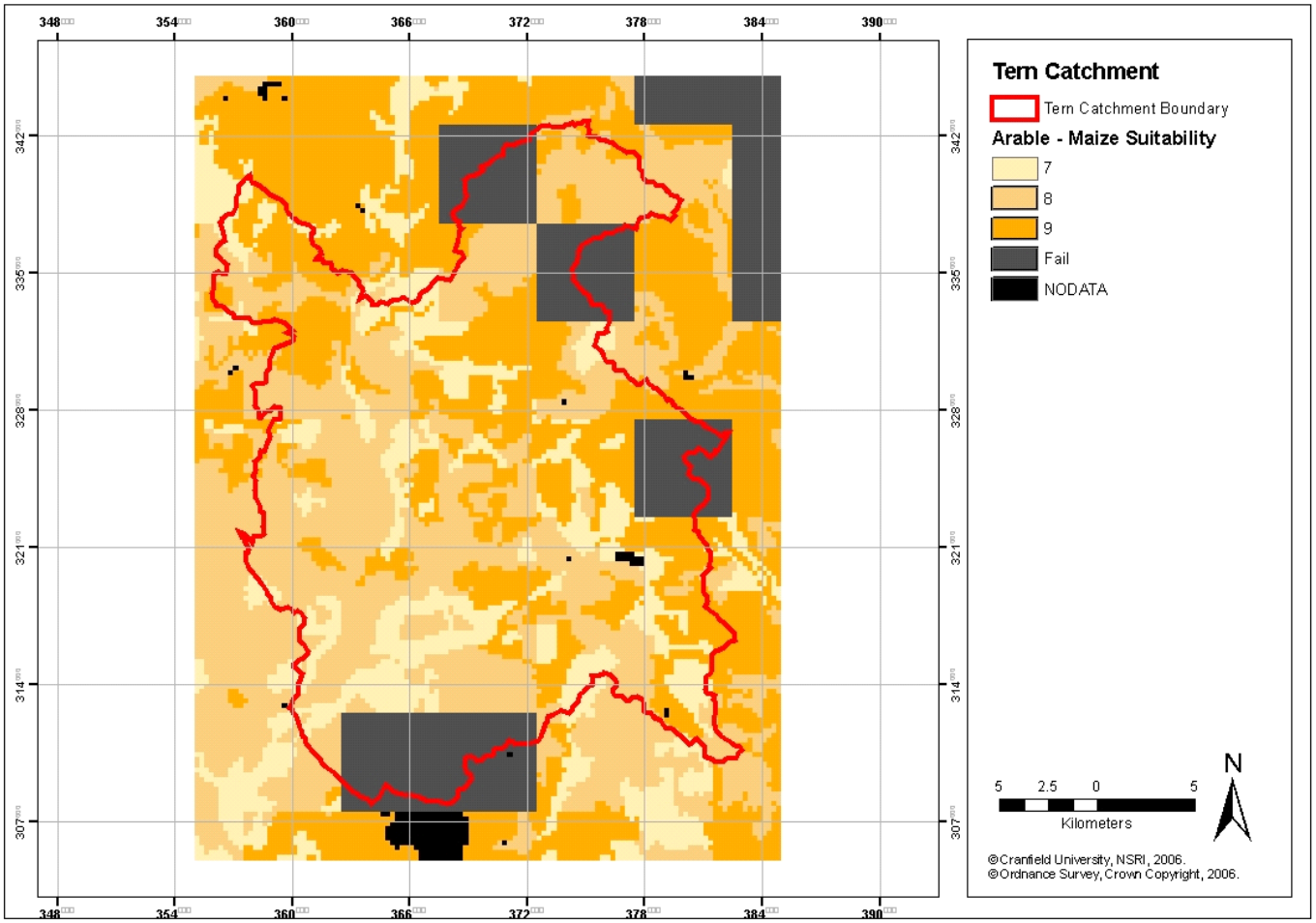

Figure 3.1.12: Agricultural Suitability (Maize) model for the Tern catchment

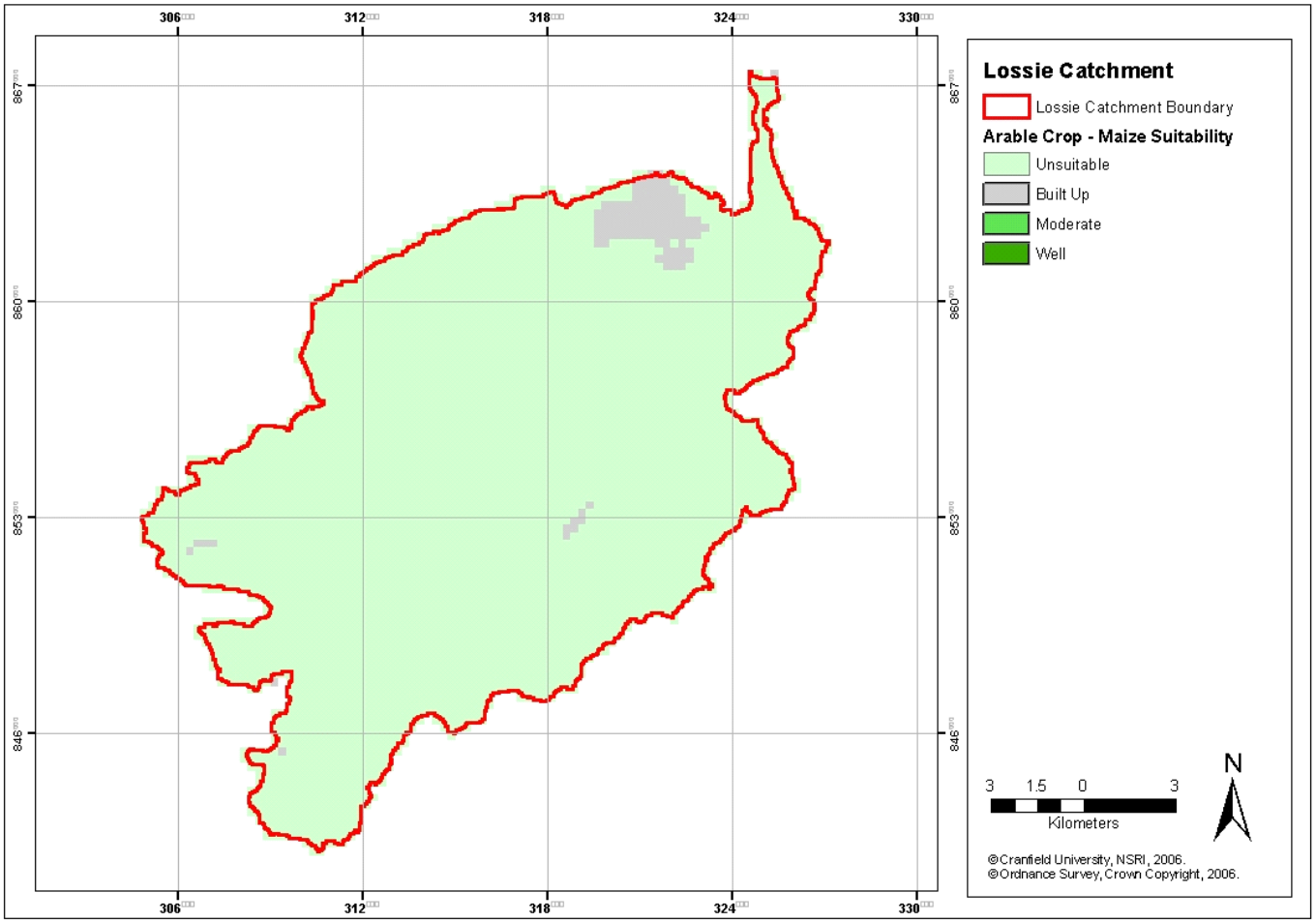

Figure 3.1.13: Agricultural Suitability (Maize) model for the Lossie catchment

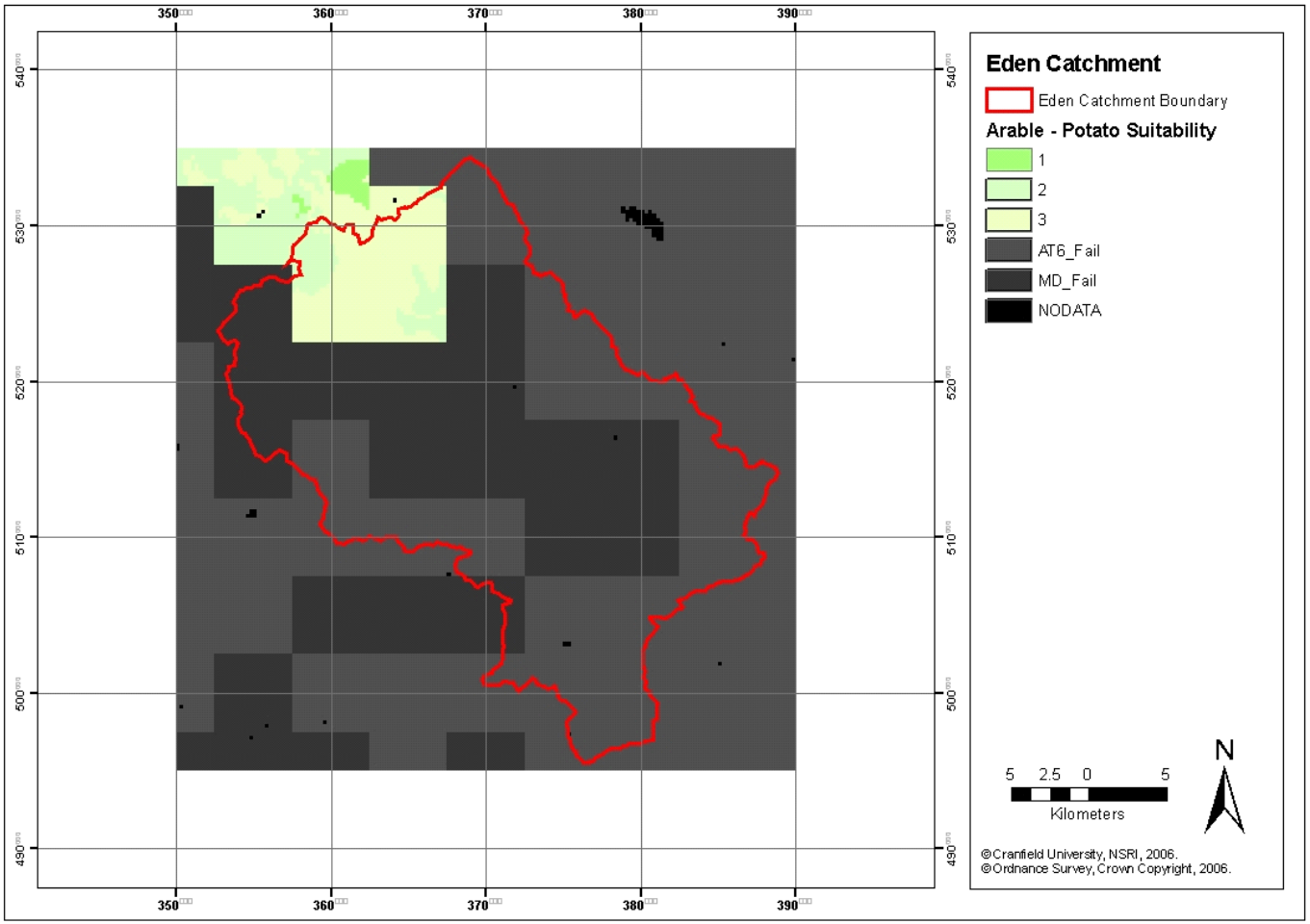

Figure 3.1.14: Agricultural Suitability (Potatoes) model for the Eden catchment

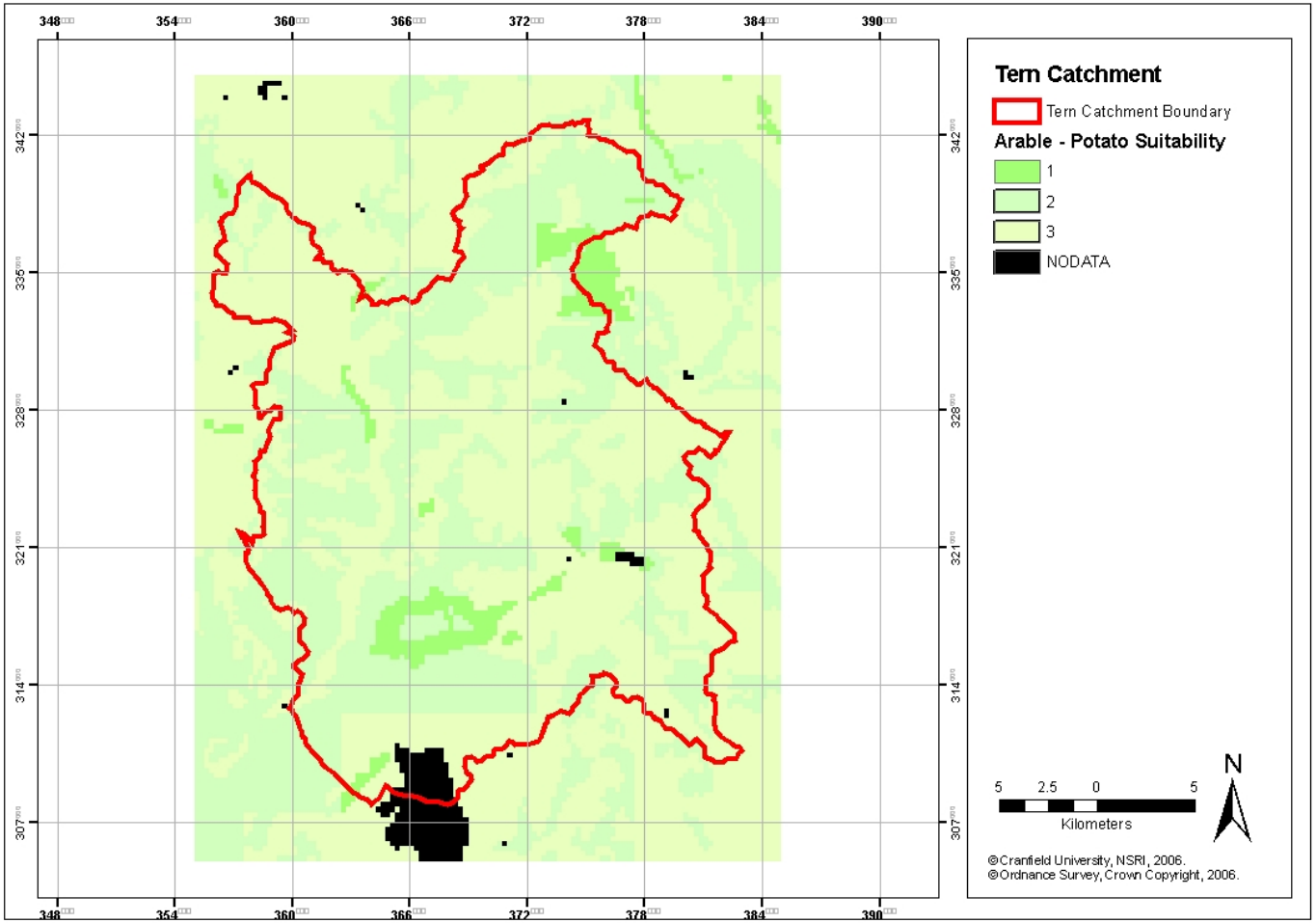

Figure 3.1.15: Agricultural Suitability (Potatoes) model for the Tern catchment

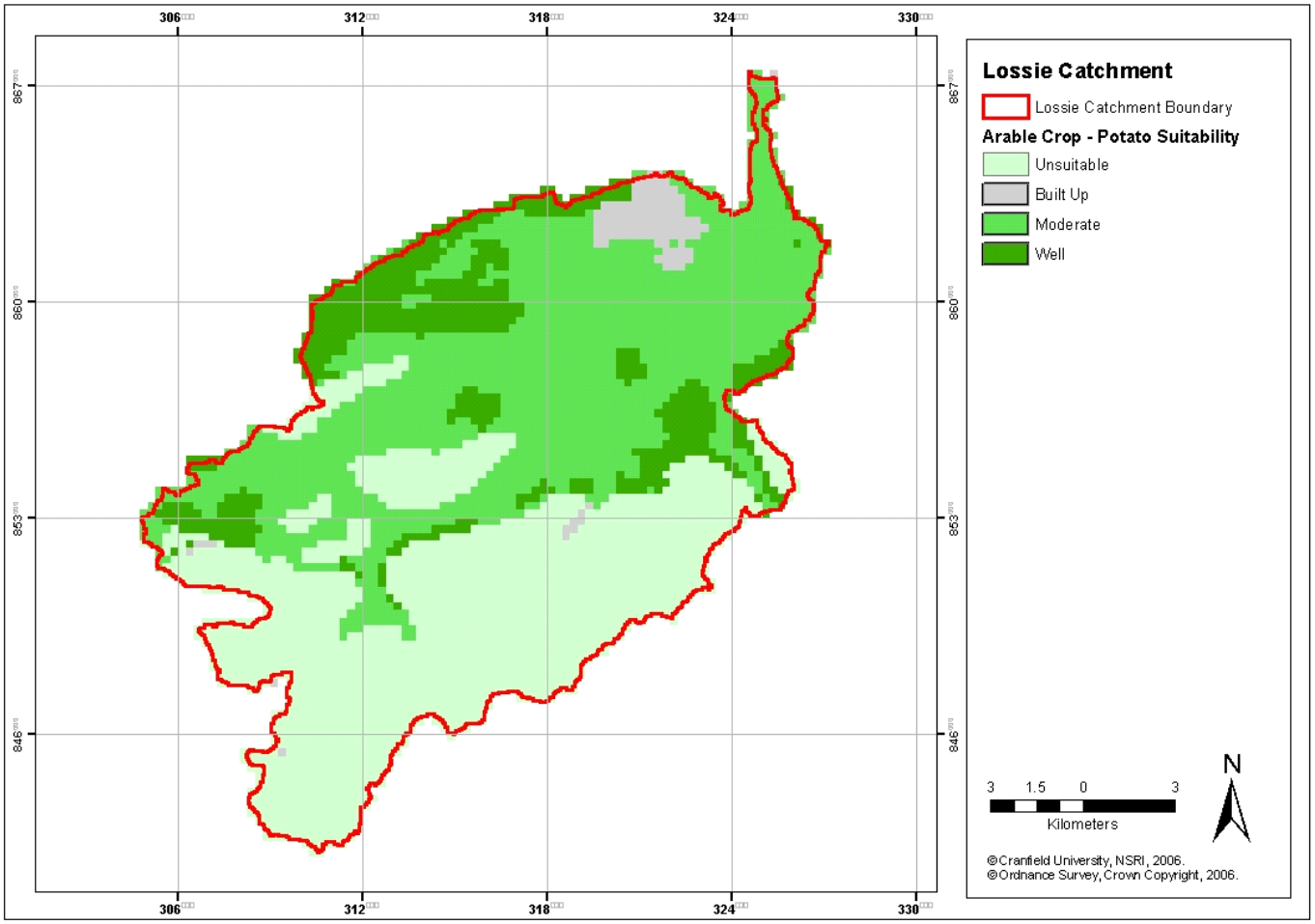

Figure 3.1.16: Agricultural Suitability (Potatoes) model for the Lossie catchment

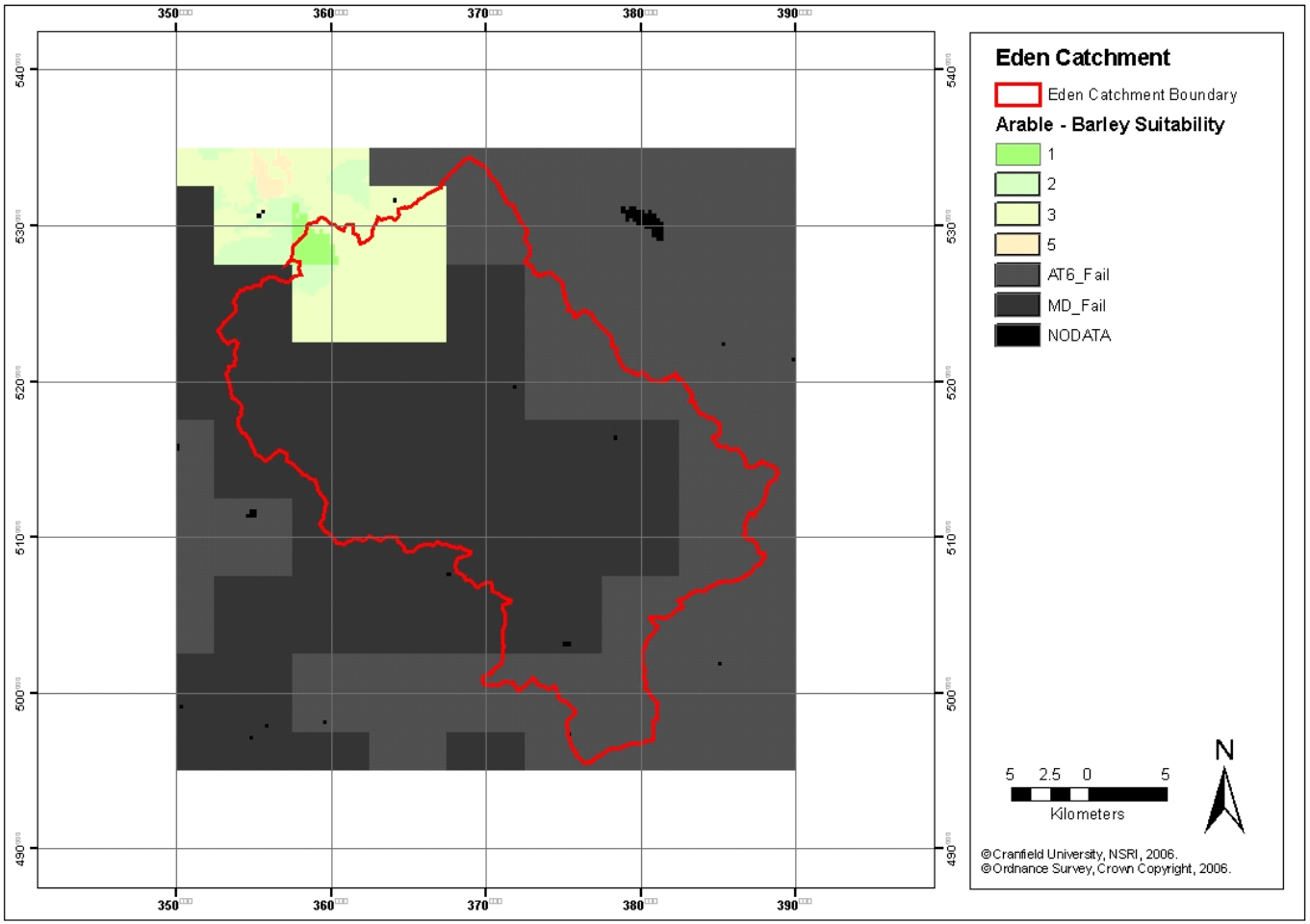

Figure 3.1.17: Agricultural Suitability (Barley) model for the Eden catchment

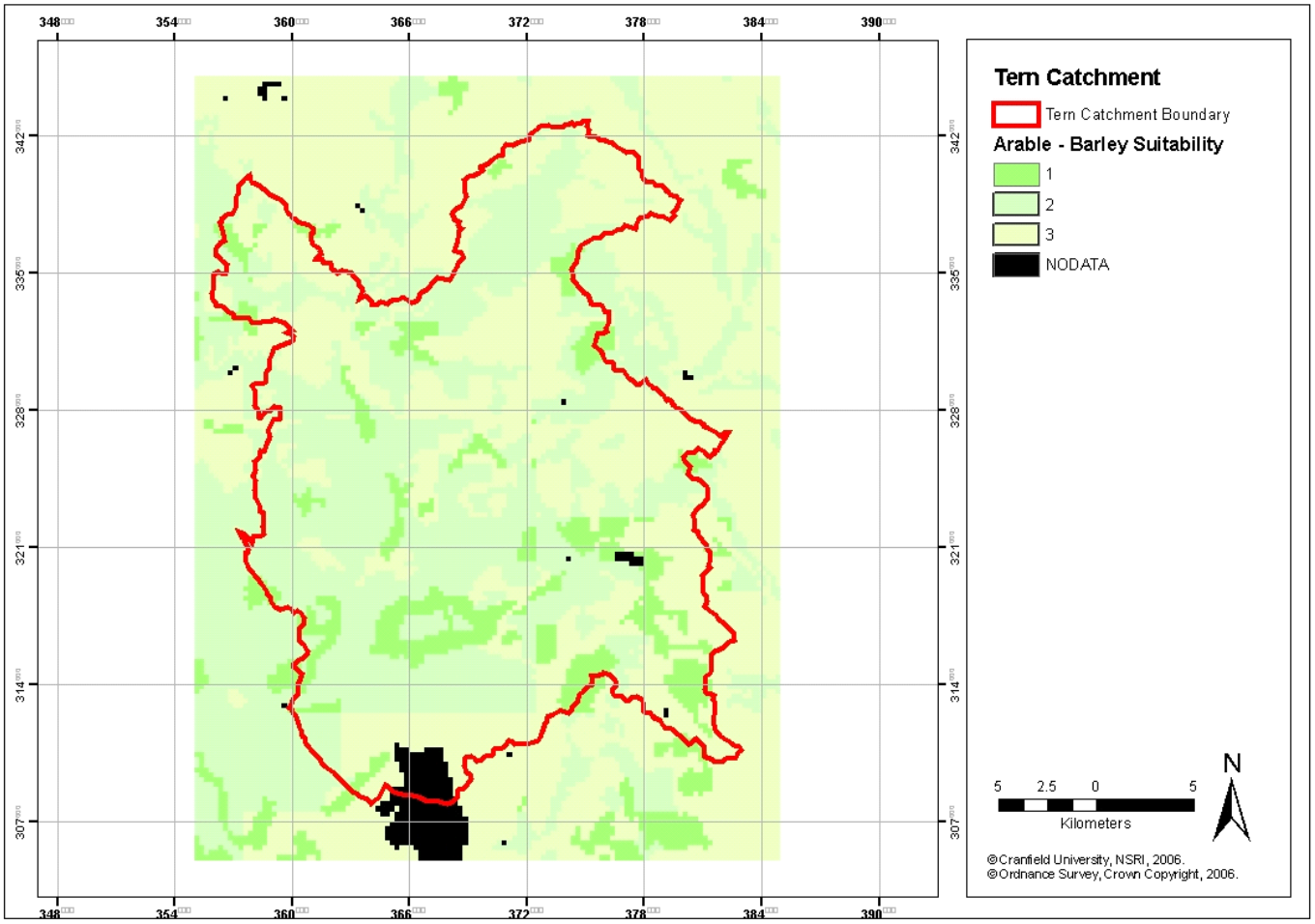

Figure 3.1.18: Agricultural Suitability (Barley) model for the Tern catchment

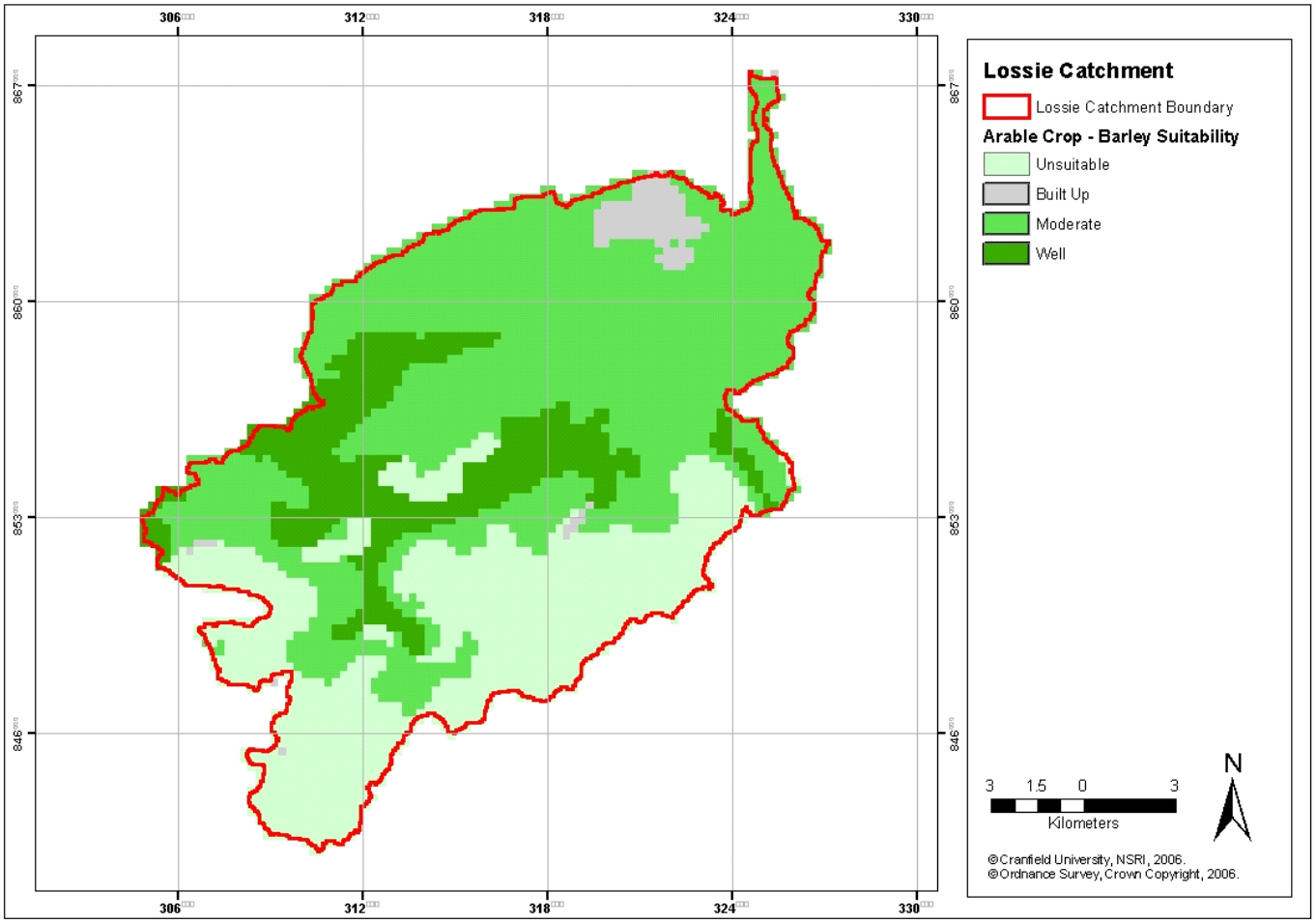

Figure 3.1.19: Agricultural Suitability (Barley) model for the Lossie catchment

Grassland Suitability Model

Organisation: NSRI

Date: 1979

Objectives

- To provide guidelines for assessing soil suitability for grass crops in England and Wales
- To assess the balance between potential production and utilization and husbandry of future growth of grass crops
- To use information obtained by normal soil survey, supplemented with climatic data where necessary
- To consider needs of the plant and restraints on farmer's use and management of crop

Methodology

Grassland suitability categories are derived from two subclasses: **yield and trafficability**. The yield categories intended to indicate relative suitability for grass production and are based on dryness subclasses identified by Hodgson (1976) which take into account balance between total soil available water and average maximum potential cumulative soil water deficit. For example dry lowland grass yield categories correspond with soil dryness subclasses. The trafficability categories indicate the ease with which grass can be used or managed without physical damage to the soil or the sward, by either animal hooves or vehicle wheels. This also depends on the effects of climate, slope and the surface bearing strength of the soil, which is dependent on density and water content. As with the yield categories, the soils are subdivided by climate into dry and moist environments.

By combining the yield and trafficability classes outlined above, the final grassland suitability classes fall into the following four categories:

A. Soils well suited to pasture
B. Soils suited to pasture, with only minor limitations
C. Soils suited to seasonal pasture
D. Soils ill-suited to pasture

Input requirements

- droughtiness
- moisture deficit
- length of growing season
- field capacity days
- moisture zone
- field capacity zone
- grass trafficability
- grass yield
- series
- depth to slowly permeable layer
- wetness class
- retained water (grass)

Results

The model was implanted for the Eden (Figure 3.1.20), Tern (Figure 3.1.21) and Lossie (Figure 3.1.22) catchments.

Literature references

Harrod, T.R. (1979). Soil suitability for grassland. p. 51-70. In M.G. Jarvis and D. Mackney (ed.). Soil Survey Applications. Technical Monograph No.13, Harpenden, UK

Hodgson, J.M. (1976). Soil Survey Field Handbook. Soil Survey Technical Monograph. No.5, pp99. Harpenden, UK

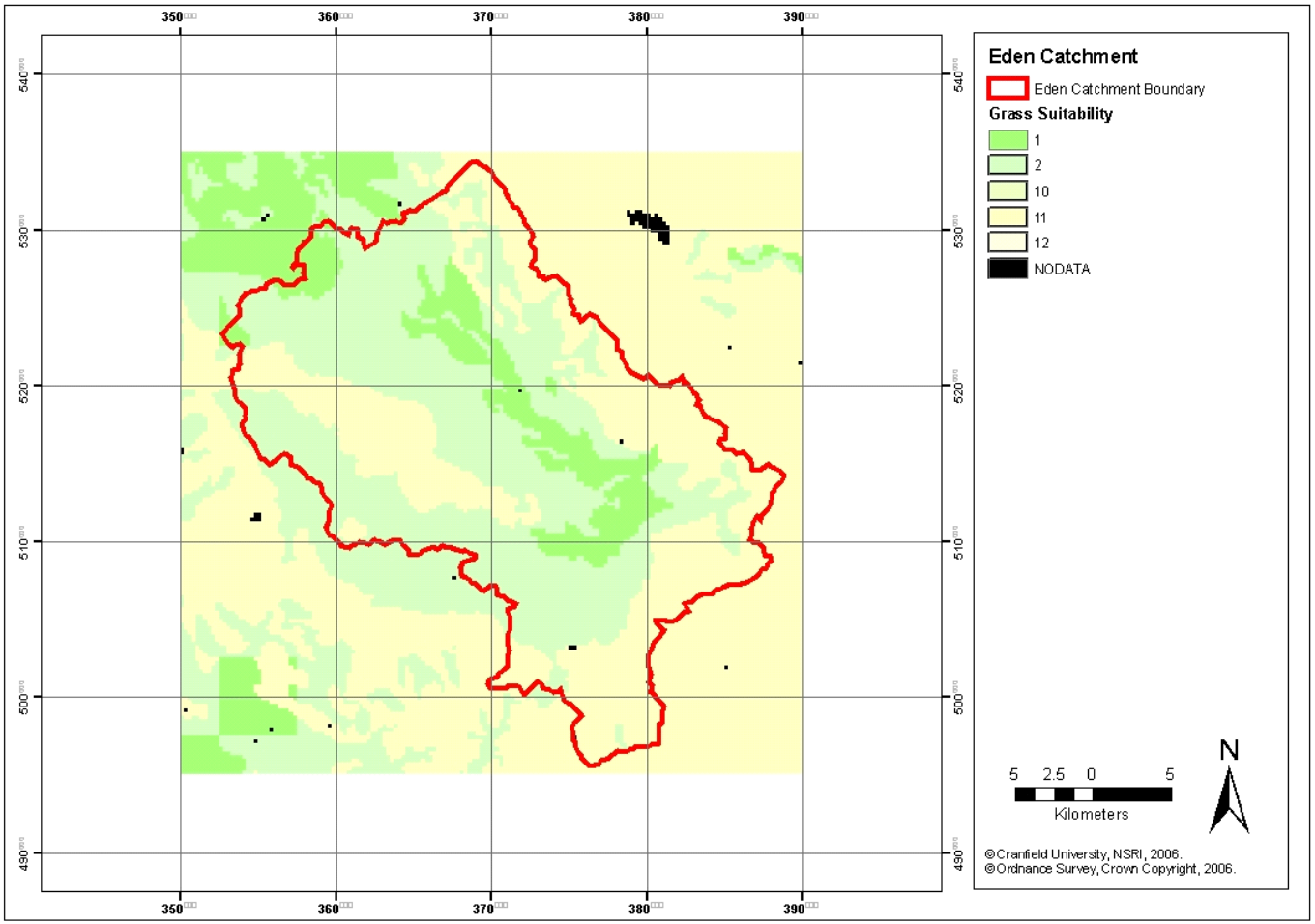

Figure 3.1.20: Grass Suitability for the Eden catchment

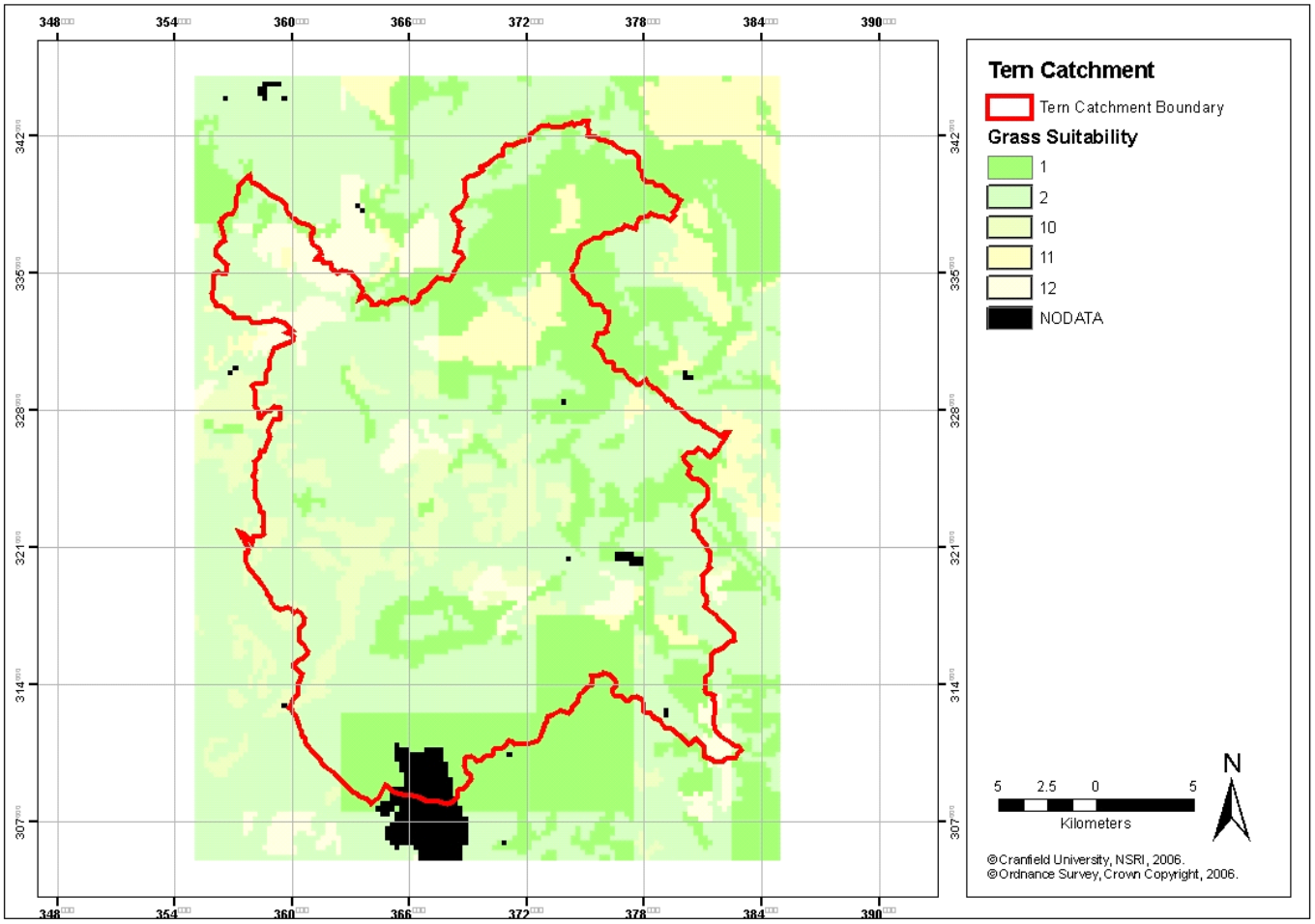

Figure 3.1.21: Grass Suitability for the Tern catchment

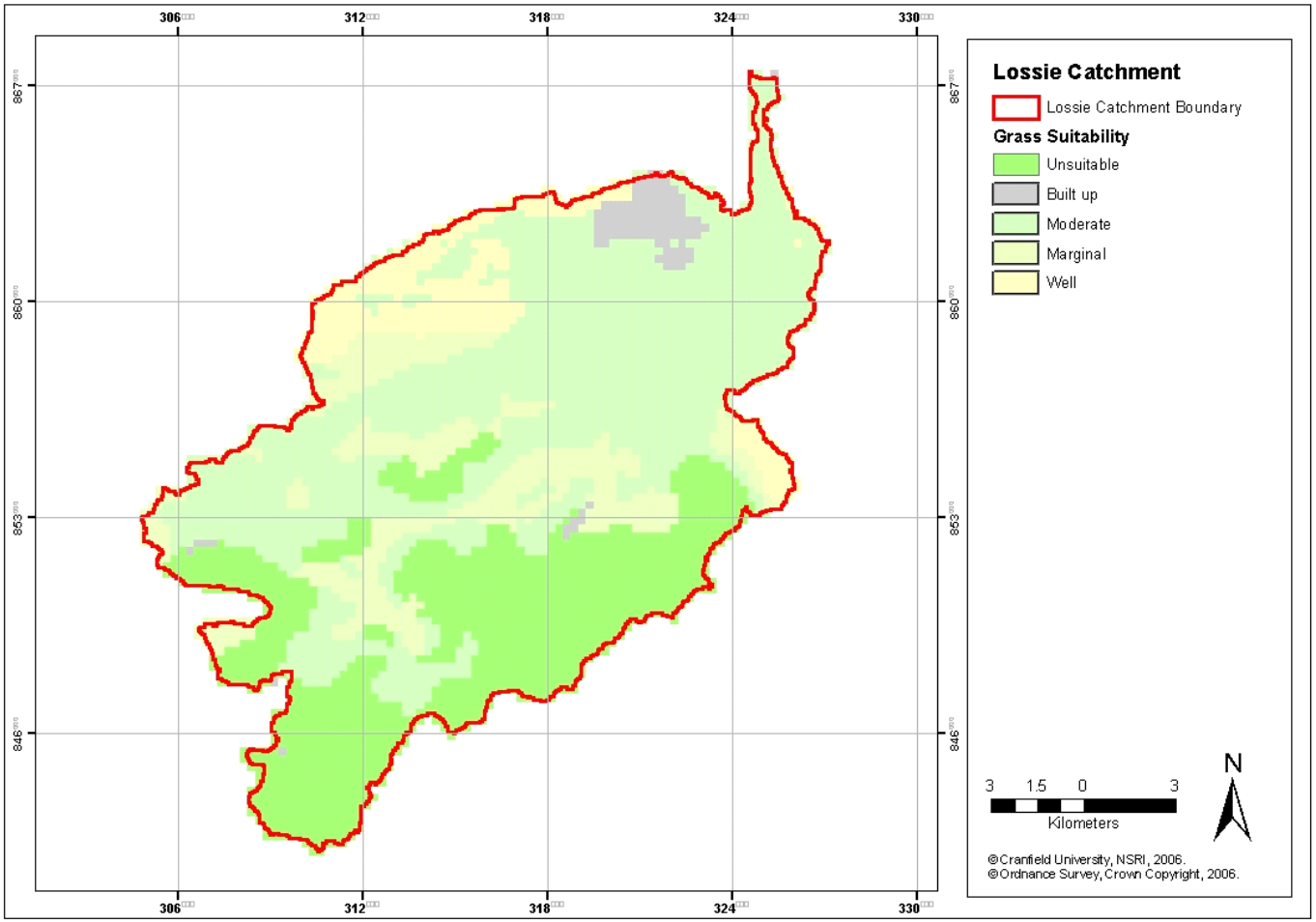

Figure 3.1.22: Grass Suitability for the Lossie catchment

Energy Crops Suitability Models

Organisation: NSRI

Date: unknown

Objectives

- To assess suitability of land for energy crops
    - Sunflowers
    - Lupins
    - Willow

Methodology

The suitability of land for growing energy crops such as lupins and sunflowers is described in Siddons et al (1993). Thresholds are defined for unsuited, marginally suited, moderately suited and well suited land, based on a number of parameters. For example, to assess the suitability of land for lupins across England and Wales, the dominant soil series for each 5km x 5km grid square was used to classify the pH range and the model is based on the interaction of crop climate requirements with land qualities such as droughtiness, ease of workability at optimum sowing time and soil reaction or fertility. The potential yield for willow is calculated using potential soil moisture deficit and available water to 1 metre for a specified soil series. This data is extracted from relevant LandIS databases.

Input requirements

- Map unit
- Sunflowers
    - Accumulated temperature
    - Spring machinery work days
    - Crop specific droughtiness
- Lupins
    - Accumulated temperature
    - Soil pH range
    - Autumn machinery work days
- Willow
    - Droughtiness

Results

Two energy crops were implemented for this project, namely willow and sunflower. The willow model was implemented for the Eden (Figure 3.1.23) and Tern (Figure 3.1.24) catchments, whereas the sunflower model was implemented for all three catchments (Figures 3.1.25 to 3.1.27). The willow model was implemented for the Lossie catchments as the Macaulay Institute has a separate model (see below).

Literature references

Wright, P.S. (1986), Alternative Crops: Their soil and climatic requirements, SSLRC report

Siddons, P.A., Jones, R.J.A., Hollis, J.M. and Hallett, S.H. (1993), Land Suitability for Lupins and Sunflowers, SSLRC report

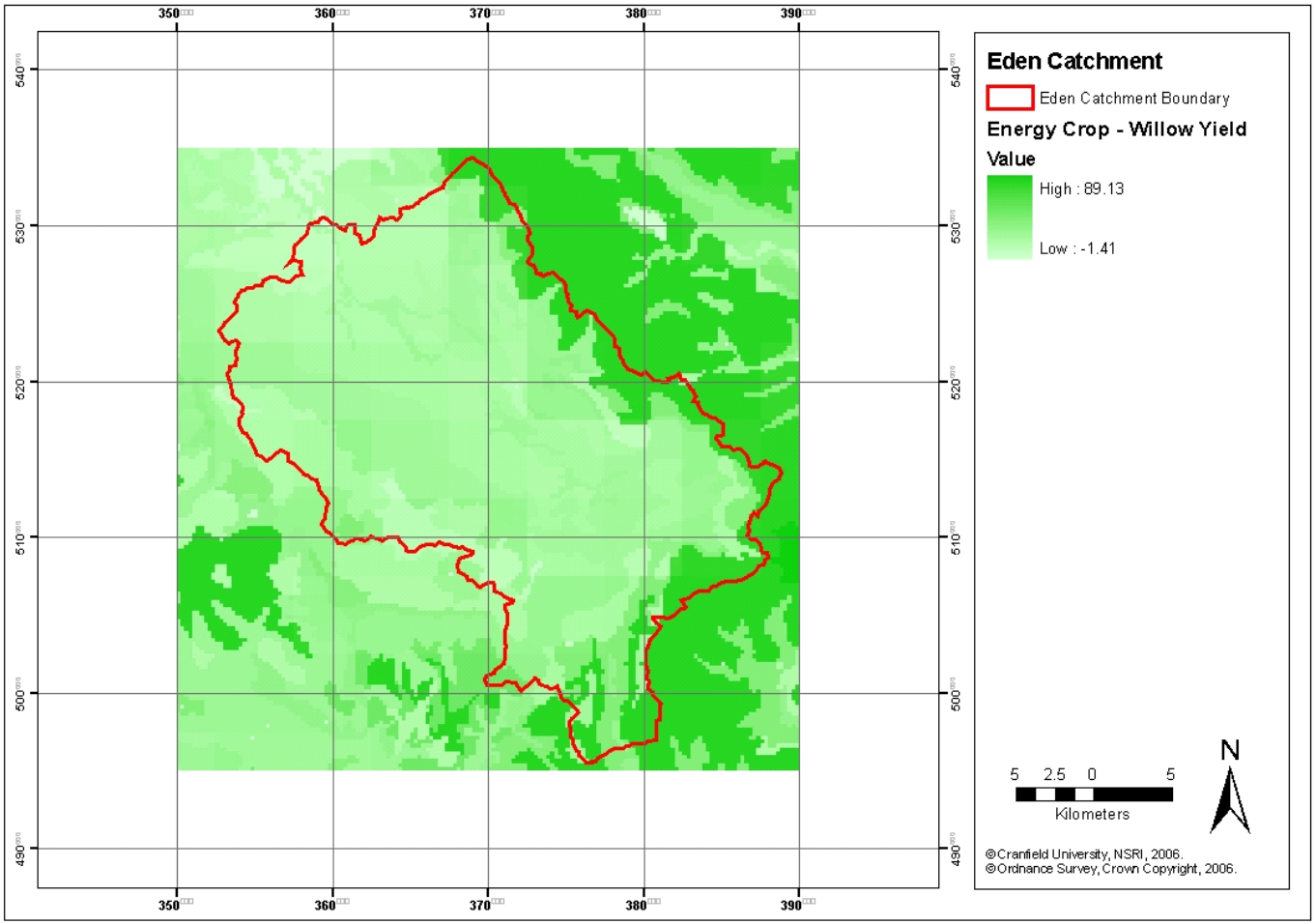

Figure 3.1.23: Energy crop suitability (Willow) for the Eden catchment

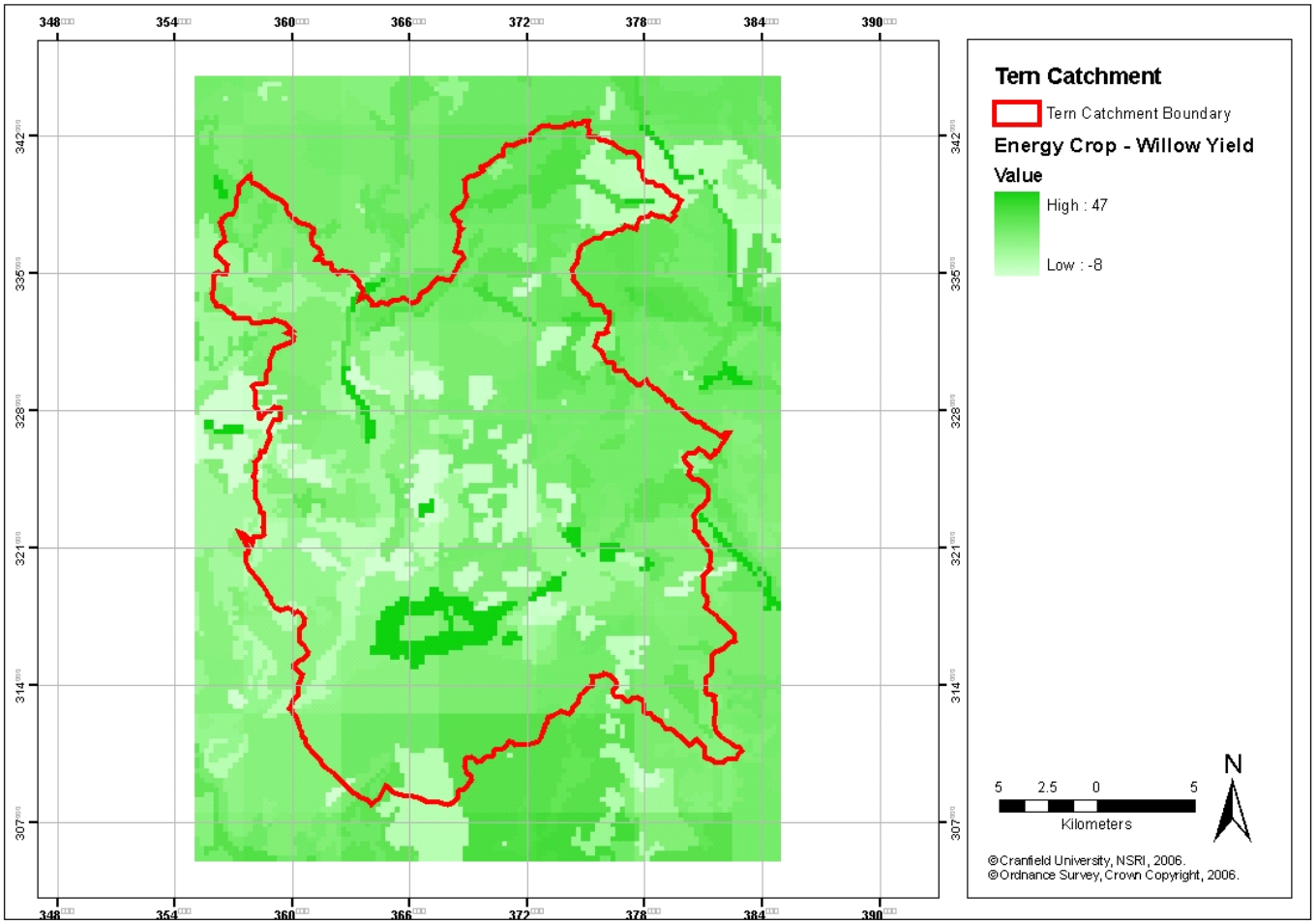

Figure 3.1.24: Energy crop suitability (Willow) for the Tern catchment

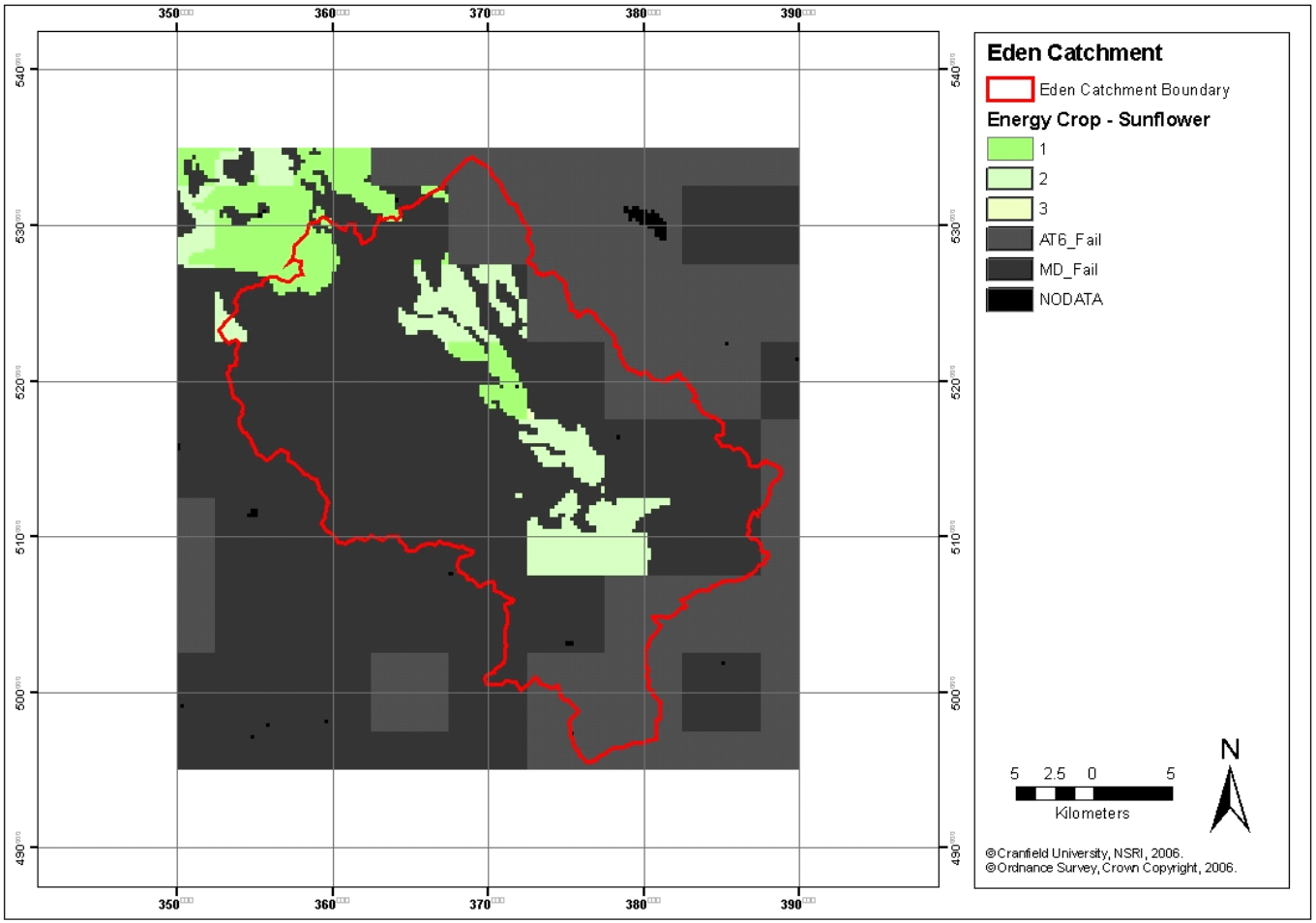

Figure 3.1.25: Energy crops (Sunflower) for the Eden catchment

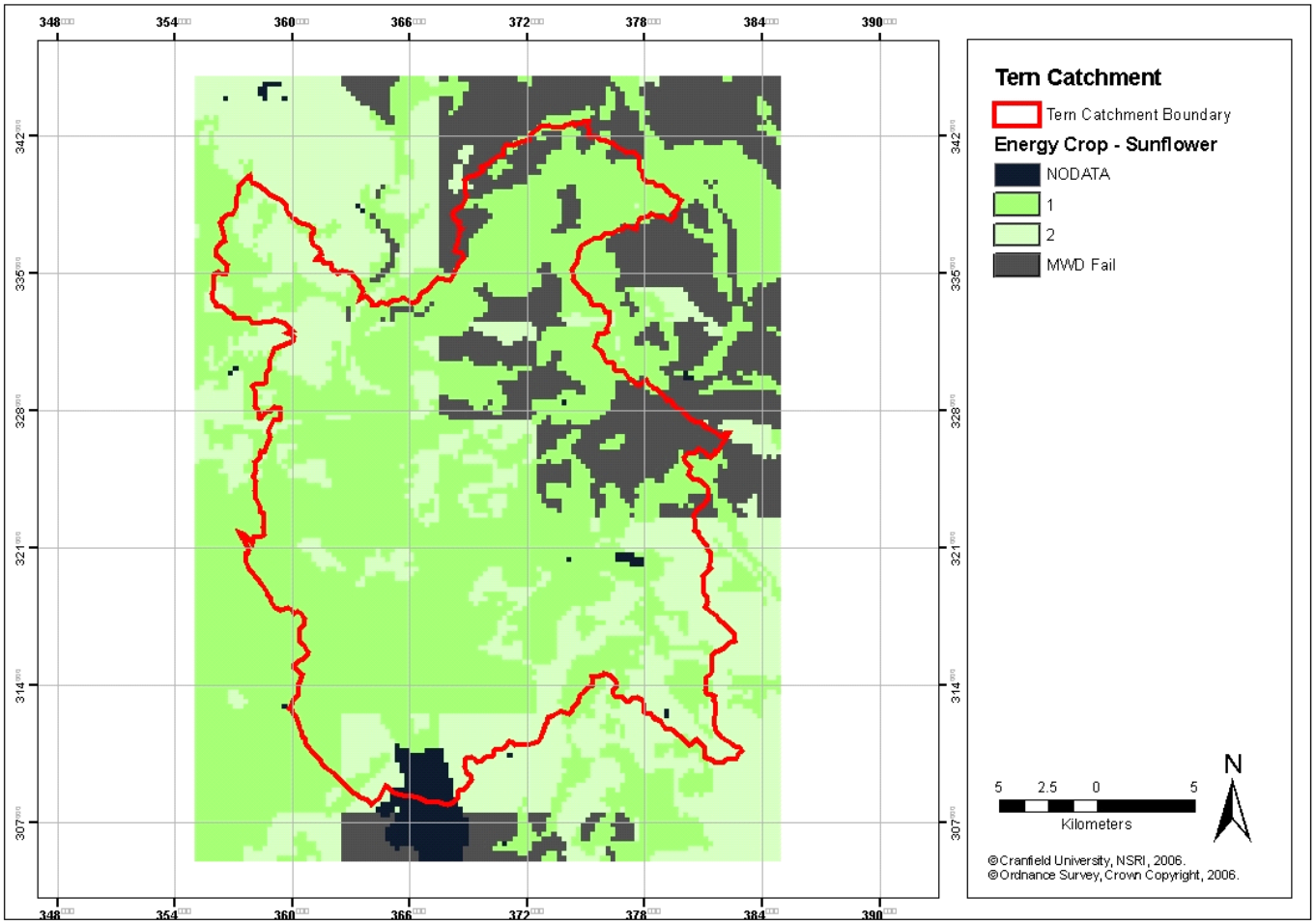

Figure 3.1.26: Energy crops (Sunflower) for the Tern catchment

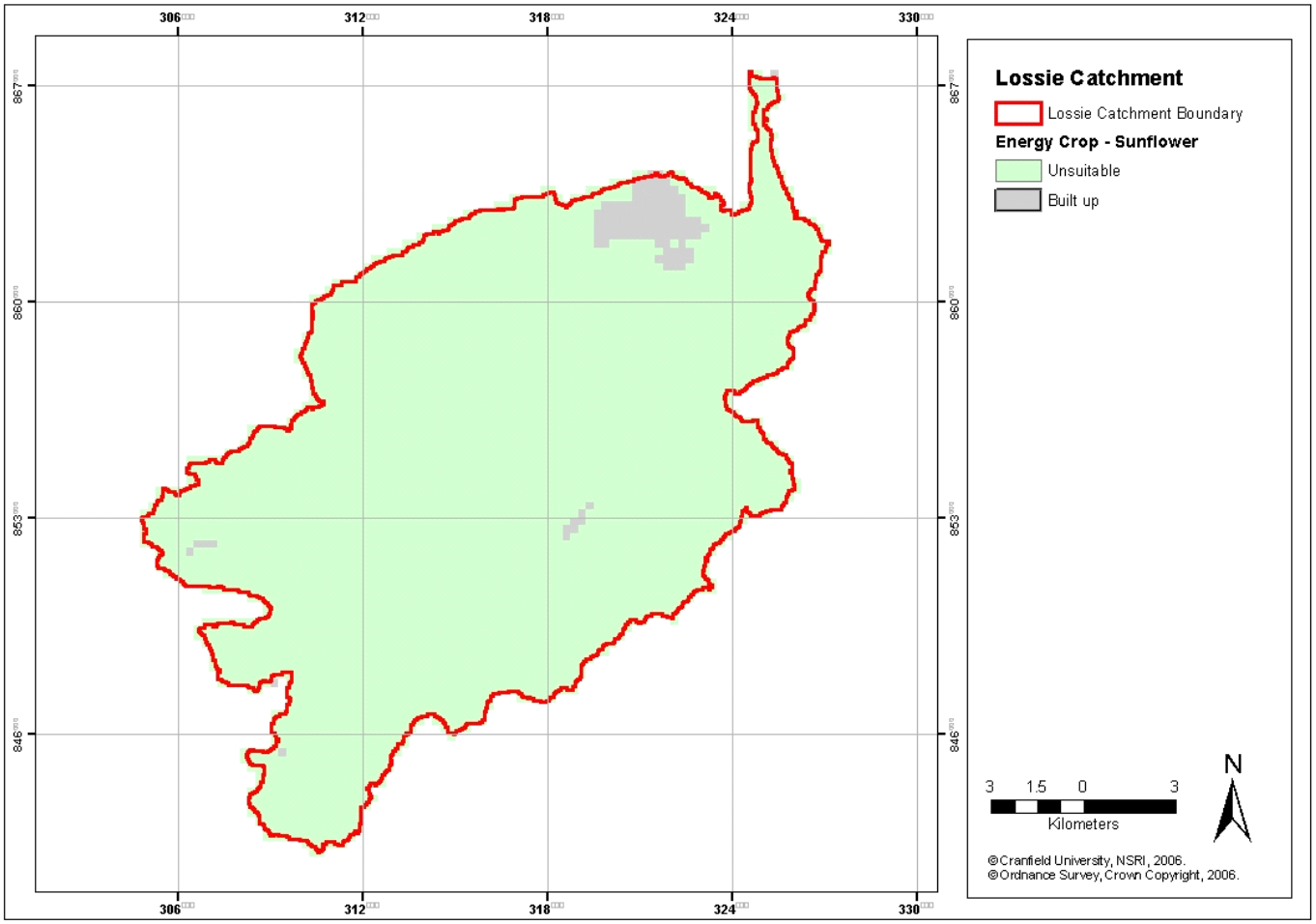

Figure 3.1.27: Energy crops (Sunflower) for the Lossie catchment

Title: Potential for Short Rotation Coppice

Organisation: Macaulay Institute

Date: 1997

Objectives

- to assess the potential for short rotation willow

Methodology

The methodology relies on a series of decision rules that initially differentiates between suitable and unsuitable land (Table 3.1.3) and subsequently classifies the suitable land into three classes (Table 3.1.4).

Table 3.1.3: Criteria used to determine land suitable for short rotation coppice

	Willow	Poplar
Soils	Brown earths, brown calcareous or podzolic soils, humus-iron, humus or iron podzols, mineral gleys, mineral alluvial soils[1]	As for willow
Slope	<= 12 degrees	As for willow
Topography	non or slightly rocky	As for willow
Land cover	arable and improved pasture, rough grasslands	arable and improved pasture
Accumulated temperature (day degrees above 5.6°C)	> 875	>1100

Table 3.1.4: Criteria and thresholds for site assessment for short rotation willow production.

	Slope (degree)	Exposure[2]	Droughtiness[3]	Land cover	Accumulated temperature[3]	Predicted Yield (oven-dry tonnes/ha)
Marginally suited	9-12	Exposed	<= 0mm	scrub or maritime pasture	876-1100 day-degrees above 5.6°C	1-7
Suited	6-8	exposed or moderately exposed	1-49 mm	mainly rough grass	1101-1375 day degrees above 5.6°C	5-11
Highly suited	<=5	moderately exposed or sheltered	>= 50 mm	arable or improved pasture	1375 day degrees above 5.6°C	9-15

[1] based on Scottish soil classification (MISR 1984)
[2] based on Birse and Robertson (1970)
[3] based on MacDonald *et al* (1994)

Input requirements

- Major soil subgroup
- Gradient
- Rockiness
- Land cover (current vegetation)
- Exposure
- Droughtiness

Results

The model was implemented for a previous project and was not reproduced for this project. The model was not implemented for the Eden and Tern catchments as NSRI has a separate model (see above).

Literature references

Birse, E. L. and Robertson, L. (1970) Assessment of Climatic Conditions in Scotland. 2. Based on exposure and accumulated frost. The Macaulay Institute for Soil Research, Craigiebuckler, Aberdeen.

Macaulay Institute for Soil Research (1984) Soil and Land Capability for Agriculture 1: 250 000 Survey. Organization and Methods. The Macaulay Land Use Research Institute, Aberdeen.

MacDonald, A.M., Matthews, K.B., Paterson, E. and Aspinall, R.J. (1994) The impact of climate change on the soil/moisture regime of Scottish mineral soils. *Environmental Pollution*, 83, 245-50.

Towers, W., Morrice, J., Birnie, R.V., Dagnall, S. and Aspinall, R.J. (1997) Assessing the potential for short rotation coppice in Scotland. Report to SOAEFD.

Andersen, R. S., Towers, W. and Smith, P. (2005) Assessing the potential for biomass energy to contribute to Scotland's renewable energy needs. Biomass and Bioenergy, 29, 73-82.

Woodland Suitability Model (Treefit)

Organisation: NSRI

Date: 1992

Objectives

- To aid the selection of tree species for a site for various purposes

Methodology

'Treefit' is a database of information around 60 tree species which was developed to find the suitability of particular tree species to particular sites. This database was used to develop an empirical model, using data on tree growth from Forestry Commission experimental sites and general yield class plotted against a number of parameters. The Treefit database interacts with LandIS to produce suitability maps of each tree species according to the input requirements specified below. A two-class system of 'suited' and 'unsuited' is mapped using GIS (Table 3.1.5), and data is then interpolated between the 5km x 5km NSI points.

	pH	**Soil Depth (cm)**	**Altitude (m)**	**AT>5.6^{o}C (days)**	**Droughtiness (mm)**	**Field Capacity Days**
Suited	2.5–6.5	>40	>550	>500	<50	>100
Unsuited	<2.5 >6.5	<40	<550	<500	>50	<100

Table 3.1.5: Model Criteria (taken from Christie, 1992)

An example of the use of Treefit for predicting the spatial variation in Sitka Spruce suitability can be found in Christie (2002). Each parameter was mapped separately, the maps overlaid and a modelling equation applied to produce a single map of 'suitability for Sitka Spruce'. Field capacity days and droughtiness data are manipulated to show the potential change in spatial distribution of 'suitable' sites with changing rainfall and evapotranspiration. This study helped to illustrate the climatic sensitivity of Sitka Spruce suitability and therefore demonstrate the potential impact of climate change.

Input requirements

- series
- wetness class
- ph
- accumulated temperature above 6 degrees
- minimum soil depth
- droughtiness
- landuse

Results

The model was implanted for the Eden and Tern catchments. Results for Norway Spruce and Noble Fir are illustrated in Figures 3.1.28 to 3.1.31 respectively. As there is a separate model developed by the Macaulay Institute, the model was not applied to the Lossie catchment.

Literature references

Christie, S. (1992), “Climatic sensitivity of land suitability for Sitka spruce in England and Wales”, MSc thesis, Silsoe College

Hartnup, R. (1991) ‘Treefit’ – an Aid to Forestry and Silviculture, Agricultural Engineer, Autumn 1991, 88-91

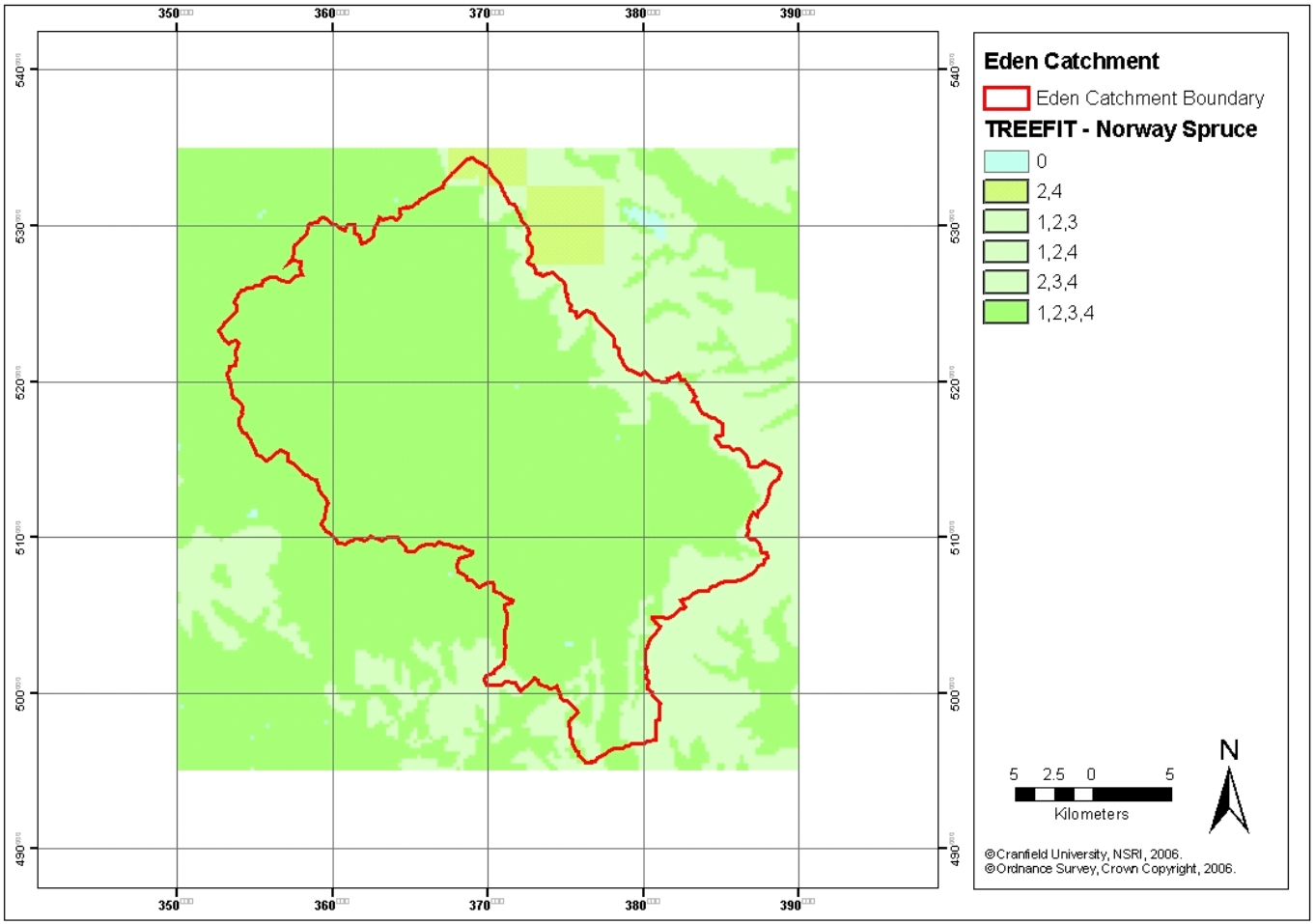

Figure 3.1.28: Forestry Suitability (Norway Spruce) for the Eden catchment

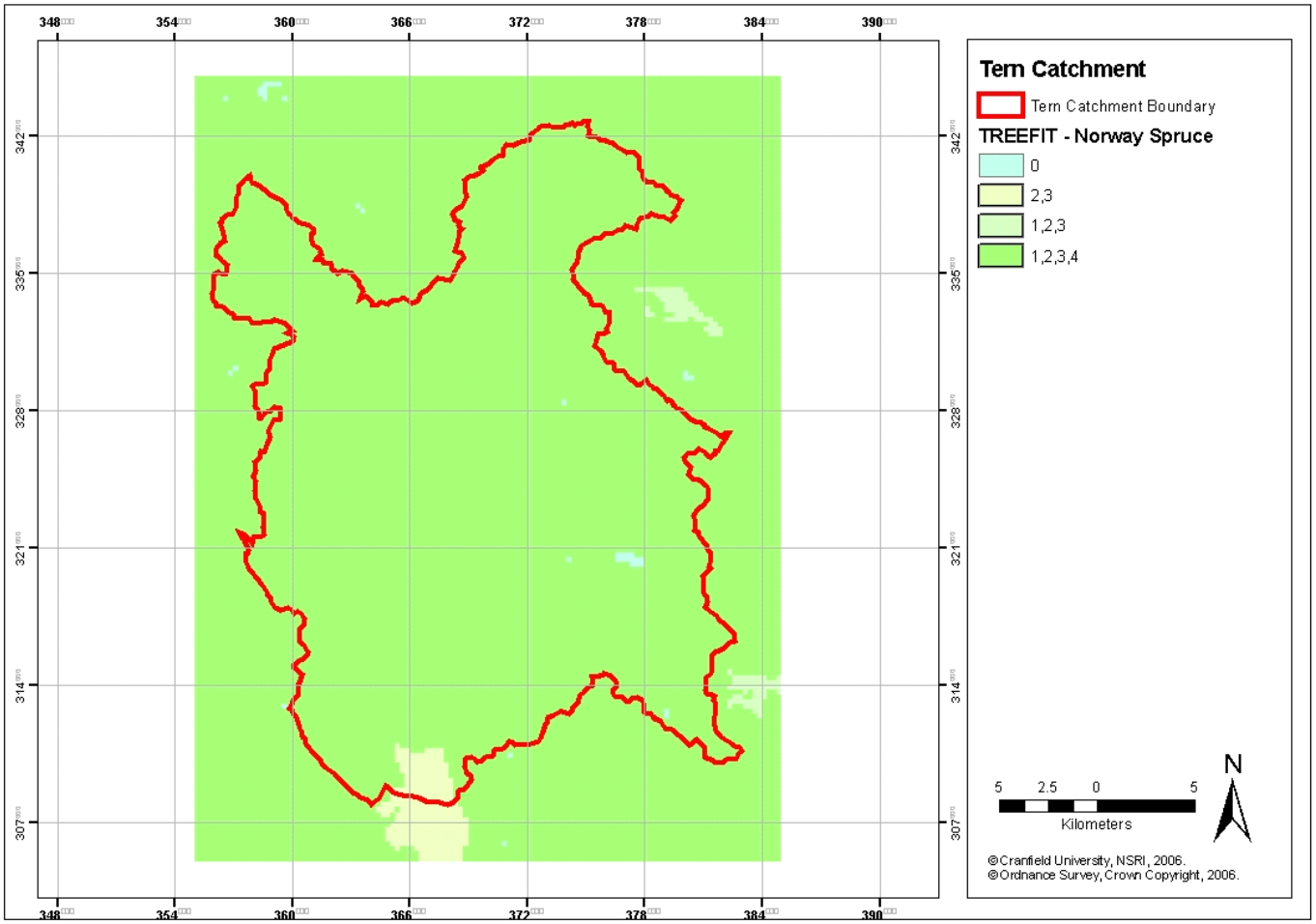

Figure 3.1.29: Forestry Suitability (Norway Spruce) for the Tern catchment

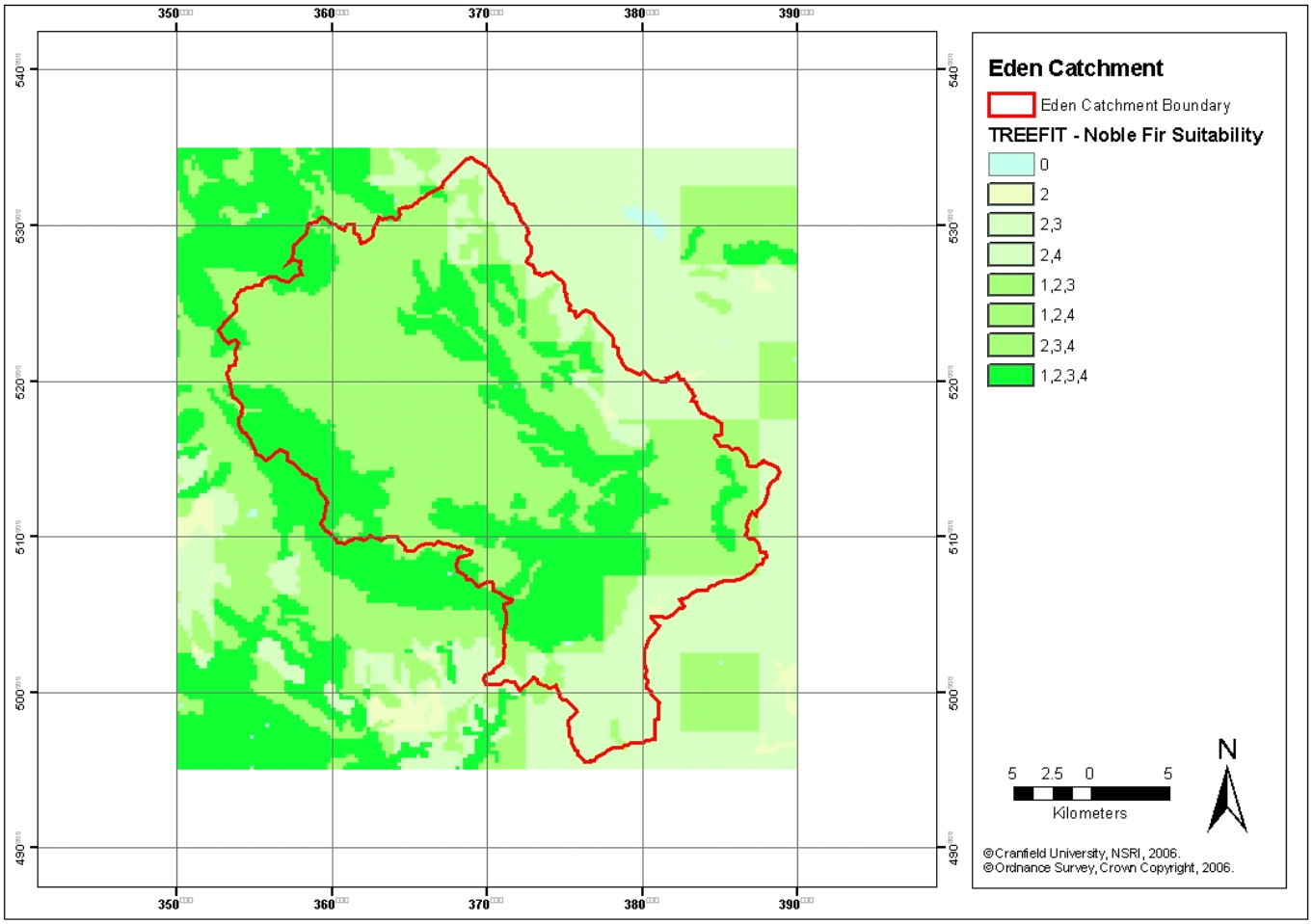

Figure 3.1.30: Forestry Suitability (Noble Fir) for the Eden catchment

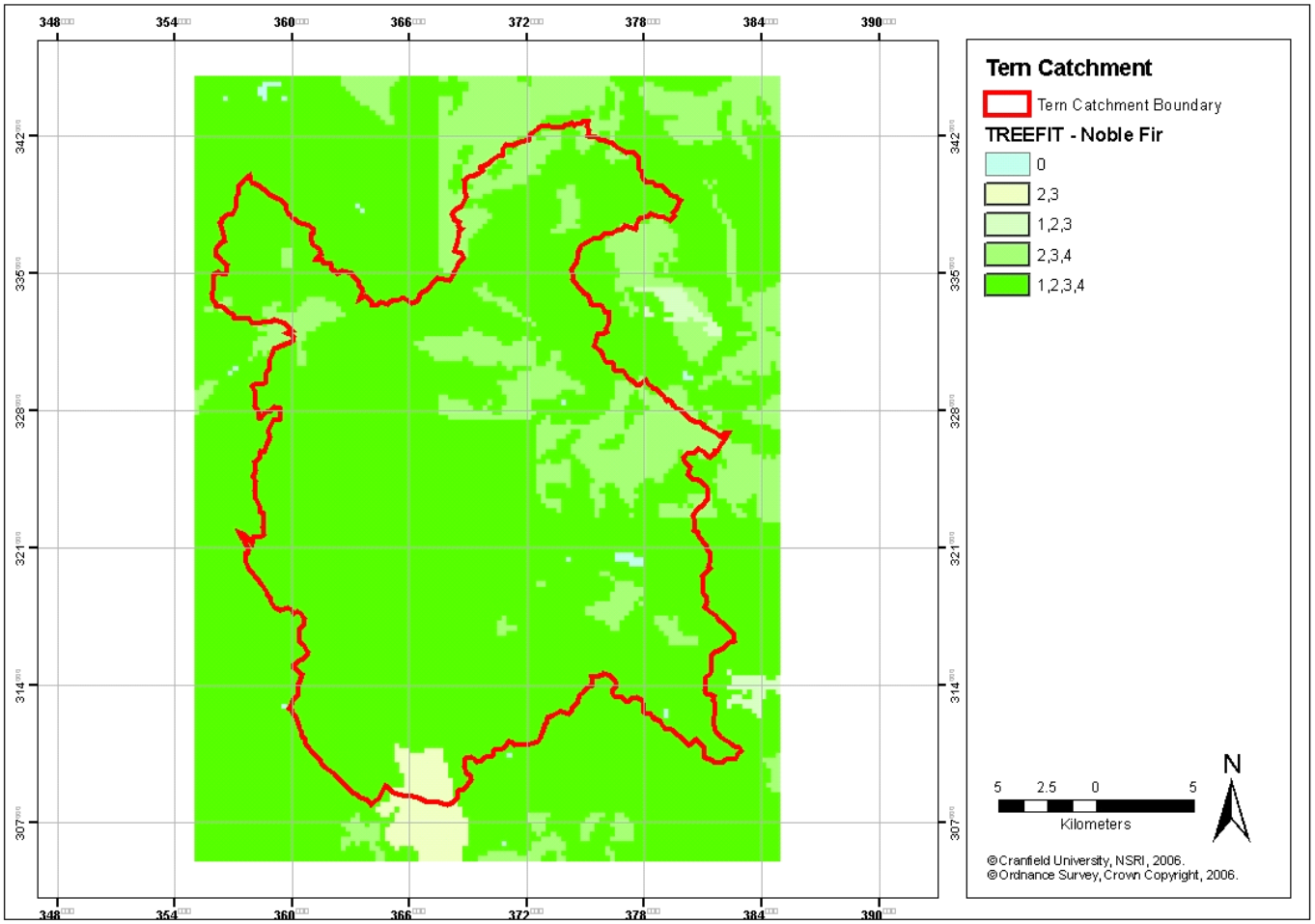

Figure 3.1.31: Forestry Suitability (Noble Fir) for the Tern catchment

Land Capability for Forestry

Organisation: Macaulay Institute/NSRI/Forestry Commission

Date: 1988

Objectives

- to assess the potential of land for forestry based on an assessment of the increasing degree of limitation imposed by the physical factors of soil, topography and climate on the growth of trees and on silvicultural practices.

Methodology

The methodology comprises a series of published guidelines (Bibby *et al* 1988) that allows land to be classified into seven classes based on the limitations imposed by soil, climate, topography and interactions between them. It is similar in approach to the LCA classification and there are a number of assumptions that underpin the classification that must be borne in mind. The final classification depends on the most limiting factor rather than on an average of all the factors.

Class	Classification
F1	Land with excellent flexibility for the growth and management of tree crops
F2	Land with very good flexibility for the growth and management of tree crops
F3	Land with good flexibility for the growth and management of tree crops
F4	Land with moderate flexibility for the growth and management of tree crops
F5	Land with limited flexibility for the growth and management of tree crops
F6	Land with very limited flexibility for the growth and management of tree crops
F7	Land unsuitable for producing tree crops

Table 3.1.6: LCF classes

Input requirements

A range of soil, climatic and topographic data and assessments are required including:

- Annual accumulated temperature above 5.6 degrees C
- Exposure
- Windthrow hazard
- Soil nutrient status
- Topography
- Soil droughtiness – interaction between soil and climate parameters
- Soil Wetness - interaction between soil and climate parameters
- Soil depth

Results

The model was implanted for the Eden (Figure 3.1.32), Tern (Figure 3.1.33) and Lossie (Figure 3.1.34) catchments.

Literature references

Bibby J S, Heslop R E F and Hartnup R (1988). Land Capability Classification for Forestry in Britain. Macaulay Land Use Research Institute, Aberdeen.

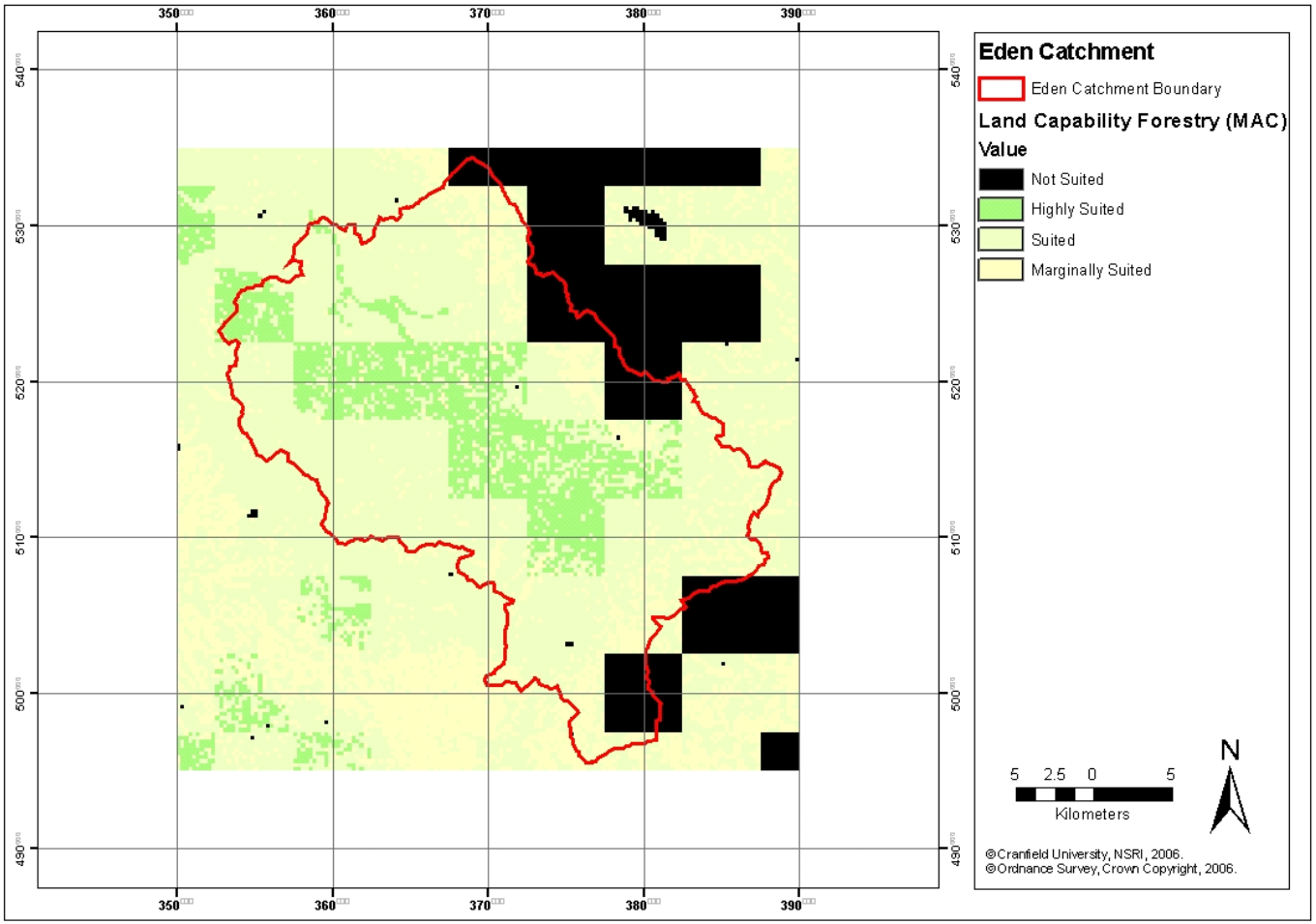

Figure 3.1.32: Land Capability for Forestry for the Eden catchment

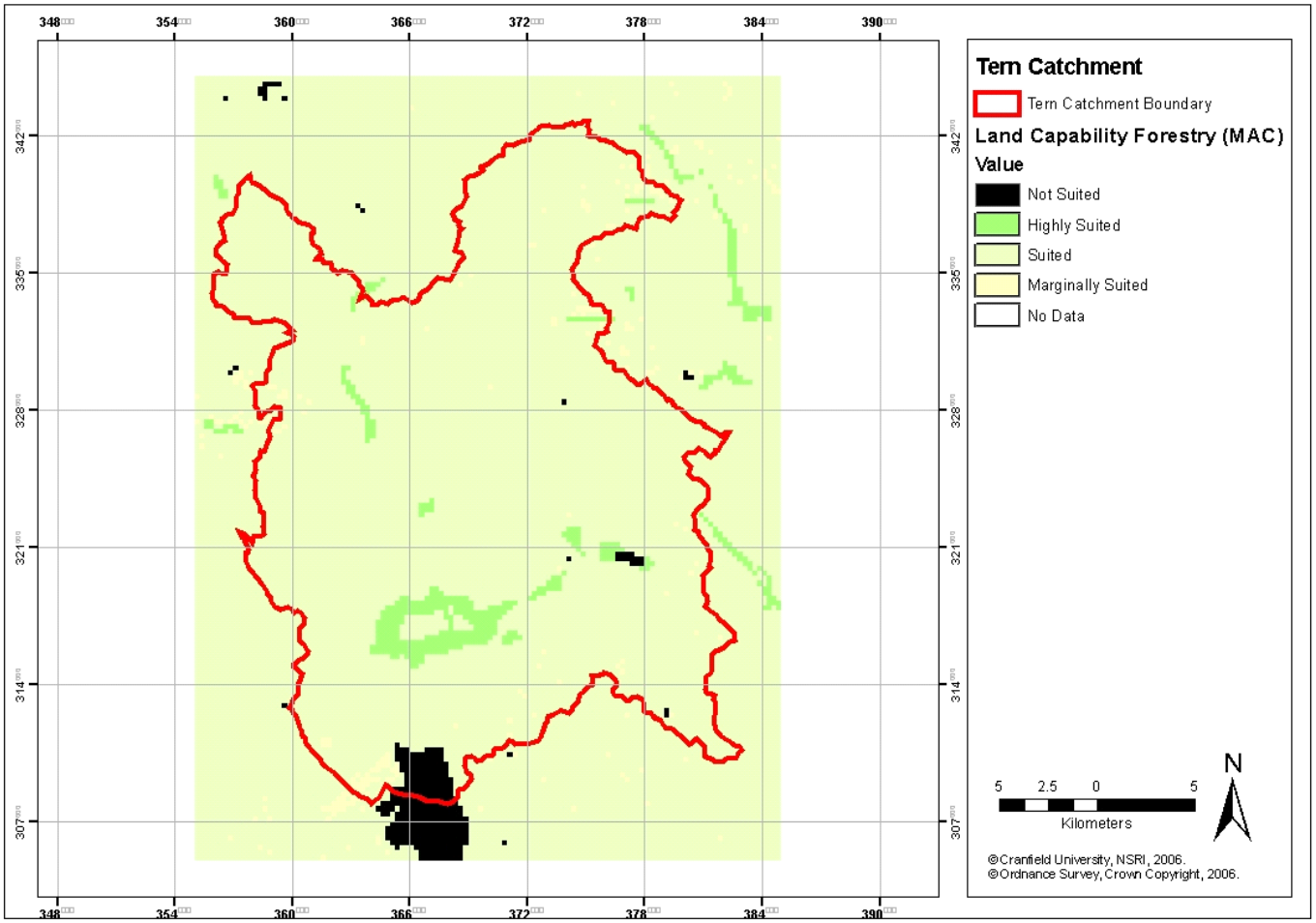

Figure 3.1.33: Land Capability for Forestry for the Tern catchment

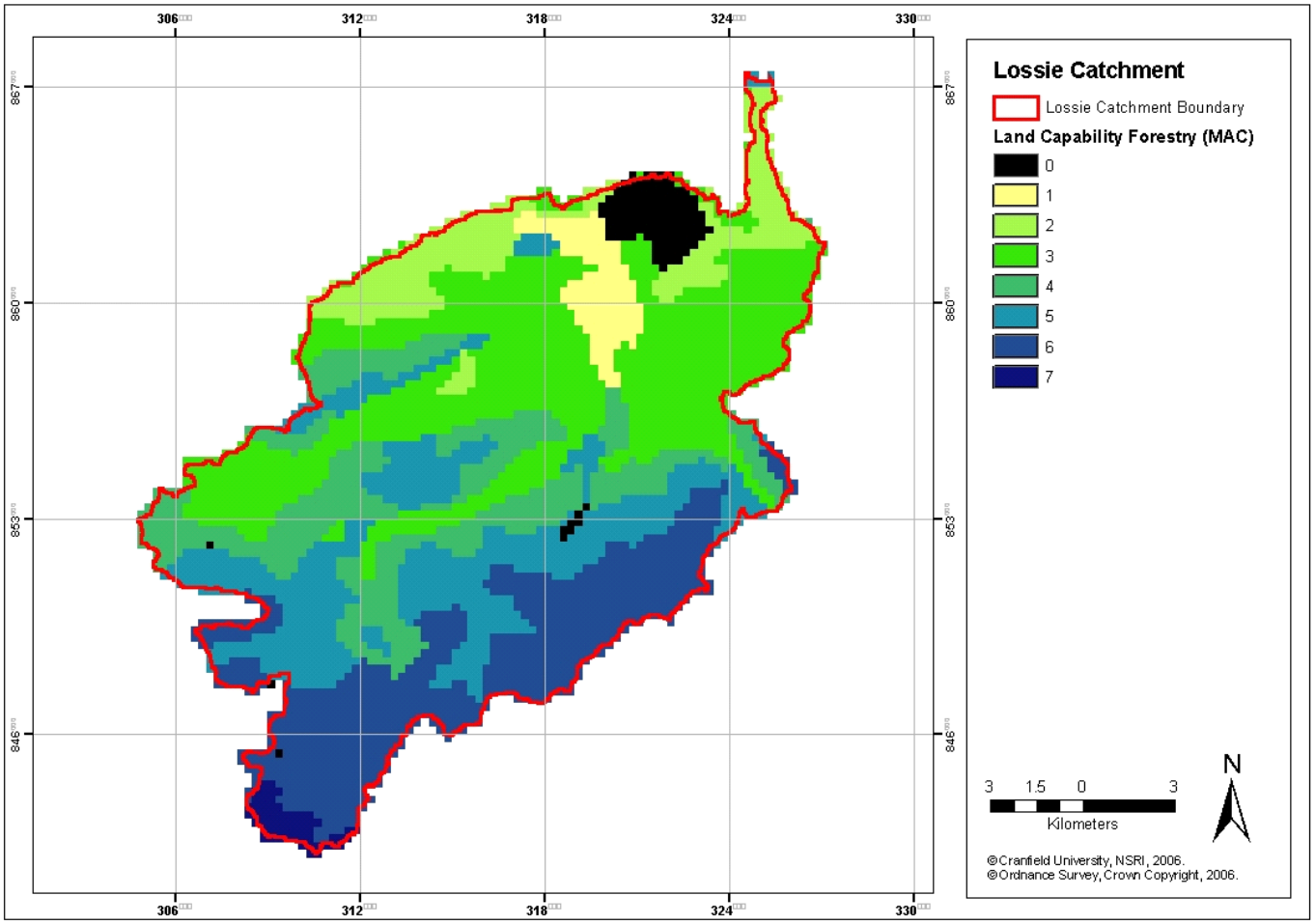

Figure 3.1.34: Land Capability for Forestry for the Lossie catchment