Appendix 3.2: Models – Environmental Interactions

Critical loads for Acidity Buffering

Organisation: NSRI

Date: 1991

Objectives

- To produce a map of England and Wales at 1km resolution for deriving critical loading total deposited sulphur and nitrogen
- To be based on the dominant soil type and it's classification according to a modified Skokloster scheme

Methodology

The Skokloster Classification was applied to each of the National Soil Map soil associations for England and Wales in turn, with modifications to the original classification to allow for organic soils (peats) and mineral soils. This methodology also takes into account land use, texture class and geology. 'Soil' was considered to be the upper 50cm of the surface material which is most likely to bear the brunt of acid inputs.

Map Unit	Soil Association	Geology	Mineraolgy	Initial Skokloster Class	Texture Class	Comment	Land Use	Final Skokloster Class	Extent km2 / %
311a	Revidge	Pal grt & sst	Mic/Q	5	S	Shallow/ v. acid	MRG	5	103 / 0.06
582a	Batcombe	Plateau drift/CwF	MS/Mic	4	FZ/C	Slow drainage	A/ST/W	3	1164 / 0.76

Table 3.2.1: Examples of Soil Associations of England and Wales and their Classification according to a modified Skokloster Scheme (taken from Loveland, 1991)

Input requirements

- Map unit

Results

The model was implemented for the Eden (Figure 3.2.1) and Tern (Figure 3.2.2) catchments. As the model relies entirely on map units, the model could not be implemented for the Lossie catchment.

Literature references

Loveland, P.J. (1991), The Classification of the Soils of England and Wales on the Basis on Mineralogy and Weathering – the Skokloster Approach, A Report to the Department of the Environment, Research Contract Reference PECD 7/12/44

Howard, J.A., Thompson, T.R.E., Hornung, M. and Beard, G.R. (Eds) (1989), An Assessment of the Principles of Soil Protection in the UK, Natural Environmental Research Council, Institute of Terrestrial Ecology/Soil Survey and Land Research Centre

Hornung, M. and Skeffington, R.A. (1993) Critical Loads: concept and applications. Natural Environment Research Council, Institute for Terrestrial Ecology. ITE Symposium No. 28, 12-14 February 1992, Grange-over-Sands.

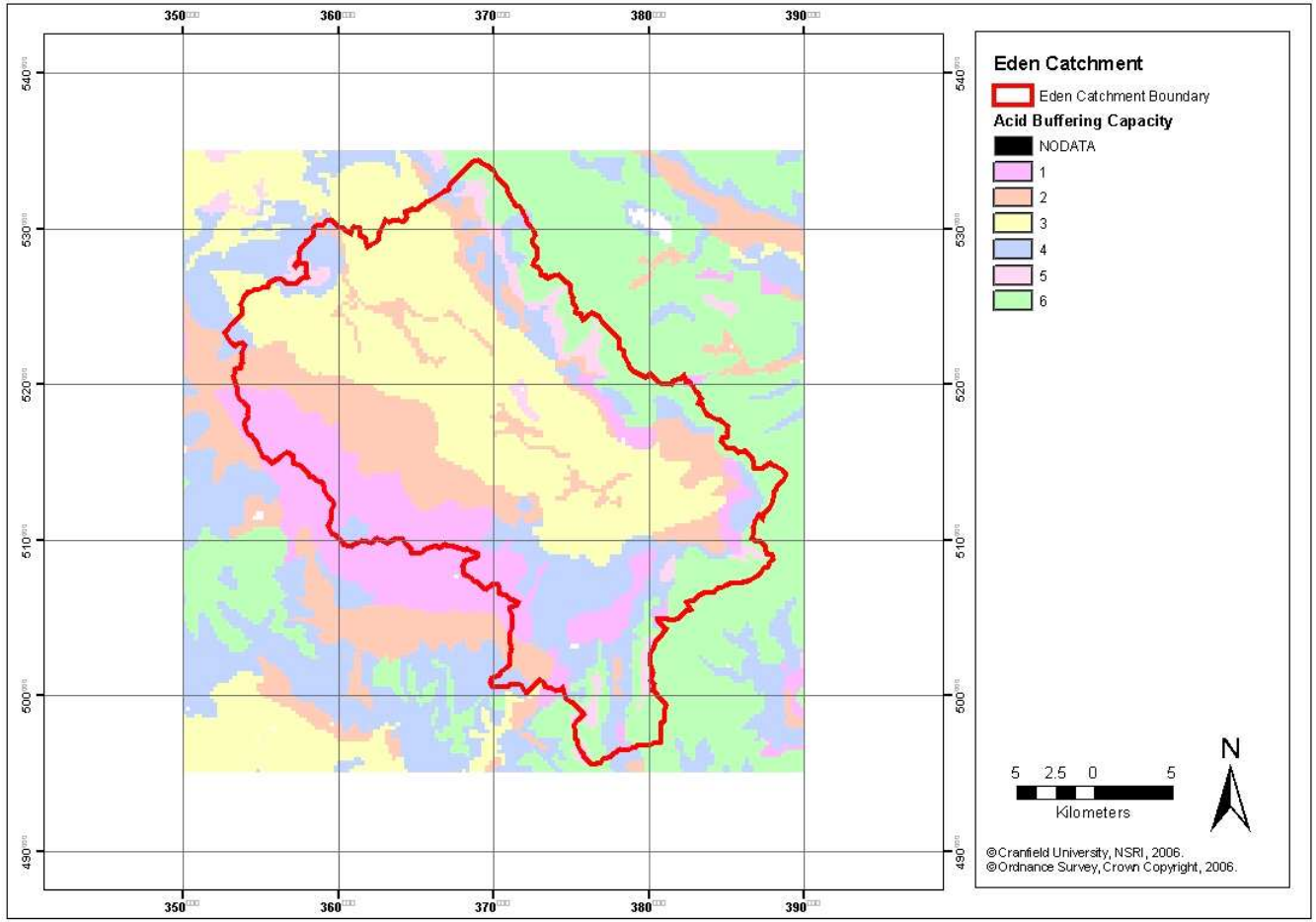

Figure 3.2.1: Acid Buffering Capacity for the Eden catchment

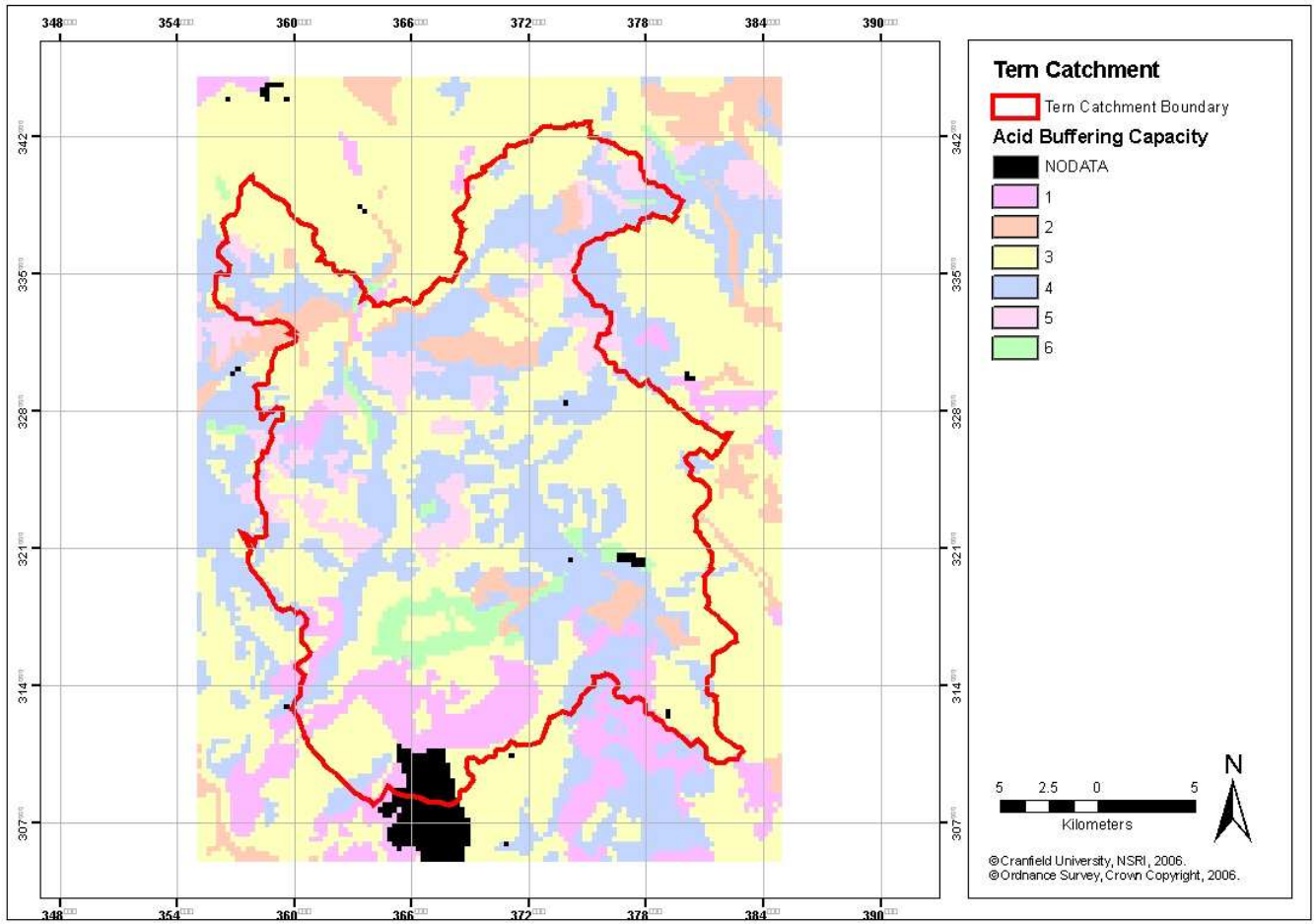

Figure 3.2.2: Acid Buffering Capacity for the Tern catchment

Critical loads of acidity

Organisation: Developed collaboratively by CEH, NSRI, Macaulay Institute, Aberdeen University

Date: Last revised 2003, original 1995.

Definition: A critical load is a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge (Nilsson and Grennfelt 1988).

Objectives:

- To predict the critical load for sulphur and acidity for soils based on the long term capacity of soils to buffer atmospheric inputs
- To provide a simple, empirical methodology to allow GB soils to be assigned to critical load classes as defined by Sverdrup and Warfvinge (1995) and the UNECE mapping programme
- To empirically assign critical loads to mapping units on GB soil maps, series or association level, using available national databases on soil morphology, mineralogy and chemistry.

Methodology:

In the UK, critical loads of acidity have been assigned to soils based primarily upon their mineralogy and chemistry (Hornung et al 1995). Five critical load classes were used. Soils were first assigned to a soil material class, on the basis of their mineralogy and in particular the dominant weatherable minerals, using a modified version of a system developed by Sverdrup and Warfvinge (1988). These soil material classes were used to assign the soils to an initial critical load class. This initial critical load class could then be modified using pH, particle size class, slope or drainage class to derive the final, mapped critical load (Hornung et al 1995). The critical load of soils which were likely to have been limed at intervals, to maintain arable or intensive grass production, were increased by one soil critical load material class. Each critical load class covers a range. A single critical load was not assigned to soils in the UK mapping programme as it was felt that the range of values within a class indicated the uncertainty within the assignments and variation within a mapping unit. However, if a single critical load value is required for a given soil, the mid point value of the relevant critical load class should be used.

Critical loads for peats were determined using a methodology developed by Smith et al (1993). The method set the critical load for ombrogenous peats as the input of hydrogen ions that not result in a change of the peat pH of more than 0.2 pH units. The method used a series of regressions, developed from experimental work, which related peat pH to calcium concentration for each of a series of rainfall pHs. The regressions were used to calculate a pristine pH and then the rainfall pH which would produce a 0.2 reduction in the peat pH. The rainfall was multiplied by runoff to calculate the acid flux, the critical load. Critical load values for mineralotrophic/eutrophic peats were assigned and modifiers used in a similar way as those for mineral soils.

Input requirements

Mineral soils:

- Base saturation
- pH
- Texture
- Dominant mineralogy
- Soil material – geological origin

Peat soils:

- Precipitation amount
- Run off amount
- Rainfall chemistry
- Current peat pH

Results

The model was implemented for the Eden (Figure 2.2.3), Tern (Figure 3.2.4) and Lossie (Figure 3.2.5) catchments.

Literature References

Federal Environment Agency. 1996. UNECE Manual on methodologies and criteria for mapping critical levels/loads and geographical areas where they are exceeded. Federal Environment Agency (Umweltbundesamt) Berlin.

Nilsson, J & Grennfelt, P.(ed). 1988. Critical loads for sulphur and nitrogen. (Report 1988:15). Nordic Council of Ministers, Copenhagen, Denmark.

Hornung, M, Bull, K.R., Cresser, M., Hall, J., Langan, S.J., Loveland, P, and Smith,C. 1995. An empirical load map of critical loads of acidity for soils in Great Britain. Environmental Pollution, 90,301-310.

Smith, C.M.S., Cresser,M.S. and Mitchell, R.D.J. 1993. Sensitivity to acid deposition of dystrophic peat in Great Britain. Ambio, 22, 22-26.

Sverdrup, H. & Warfvinge, P. 1988. Weathering of primary minerals in the natural soil environment in relation to a chemical weathering model.Water, Air and Soil Pollution, 38, 387-408.

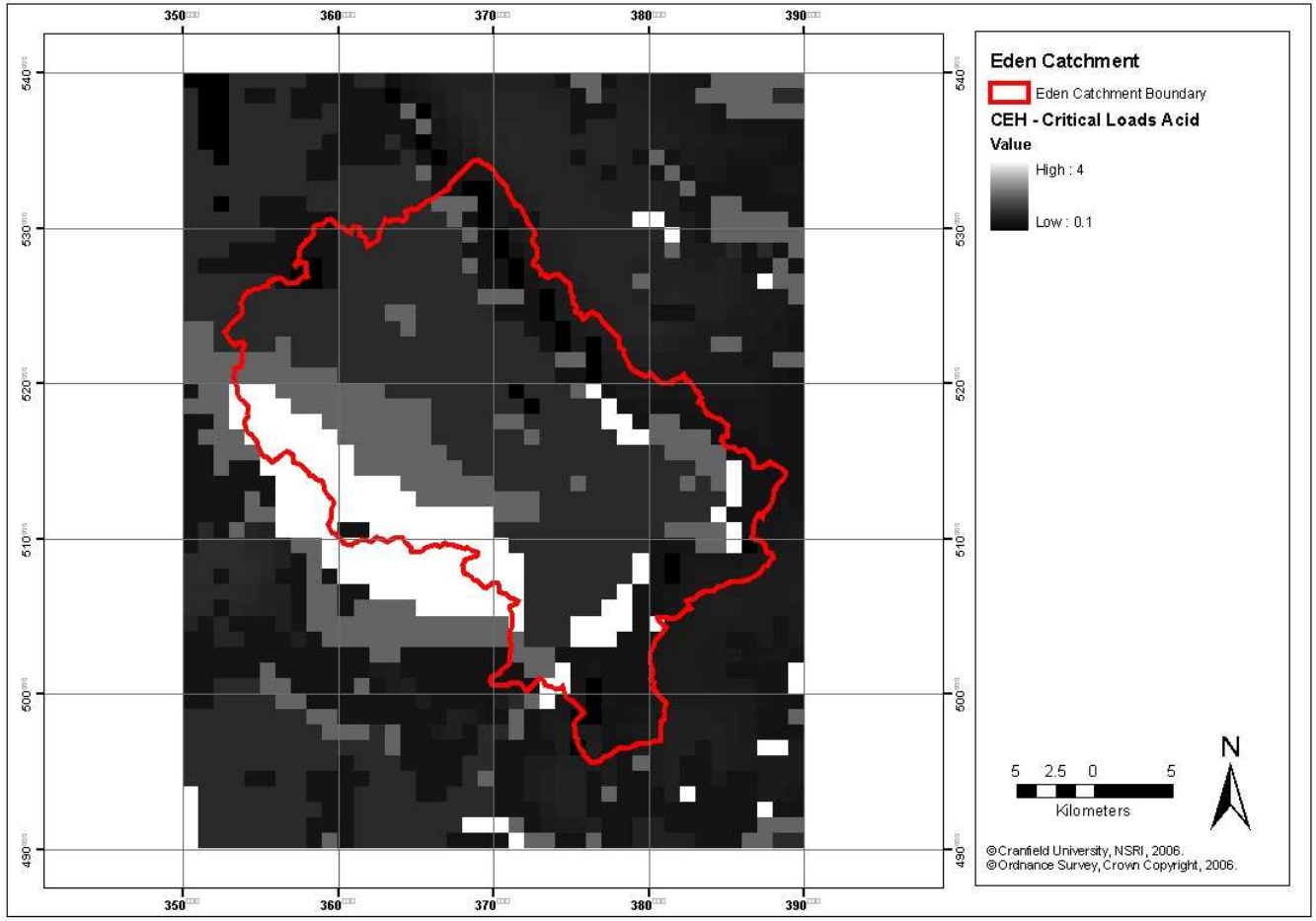

Figure 3.2.3: Critical Loads (Acid) for the Eden catchment

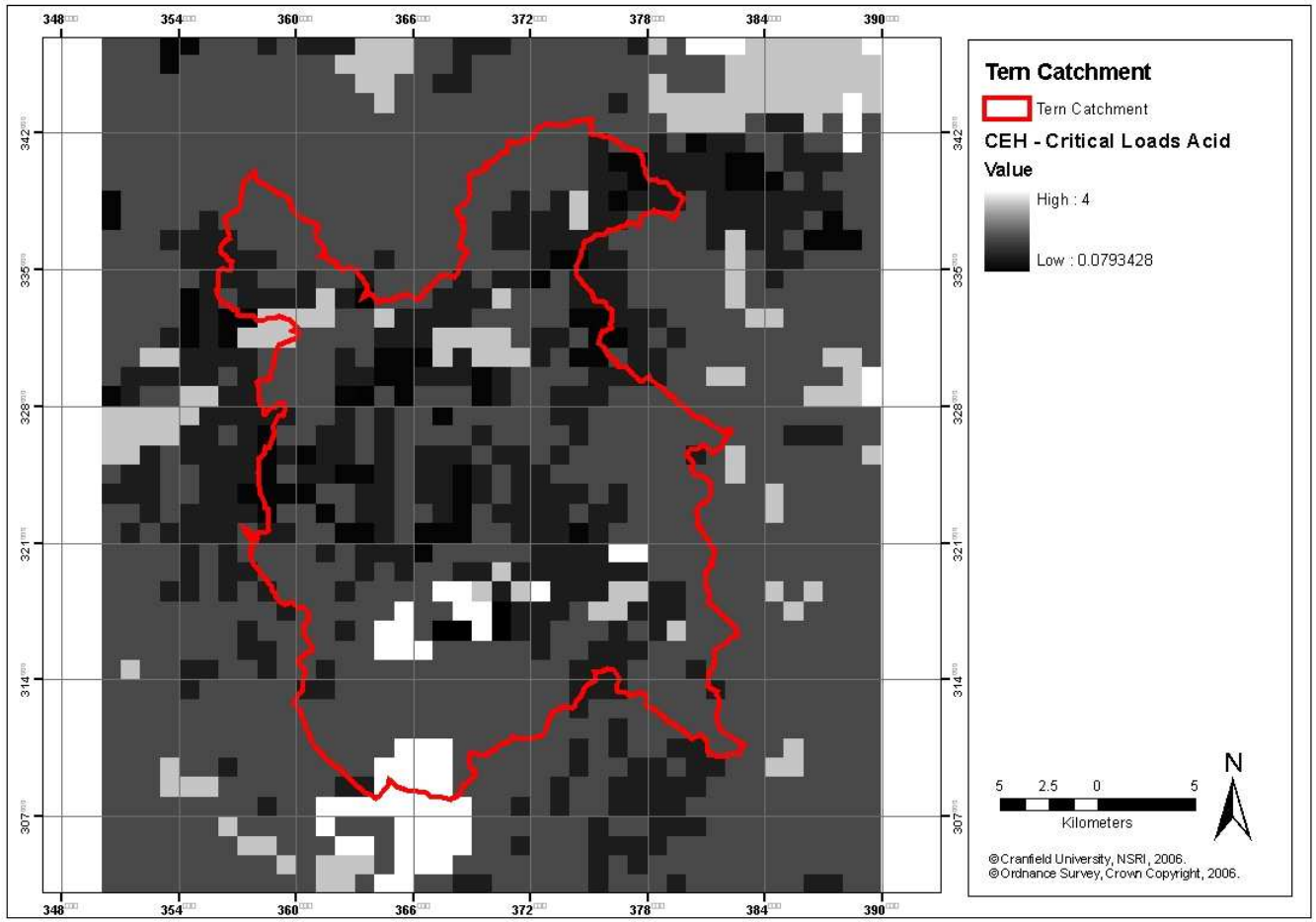

Figure3.2.4: Critical Loads (Acid) for the Tern catchment

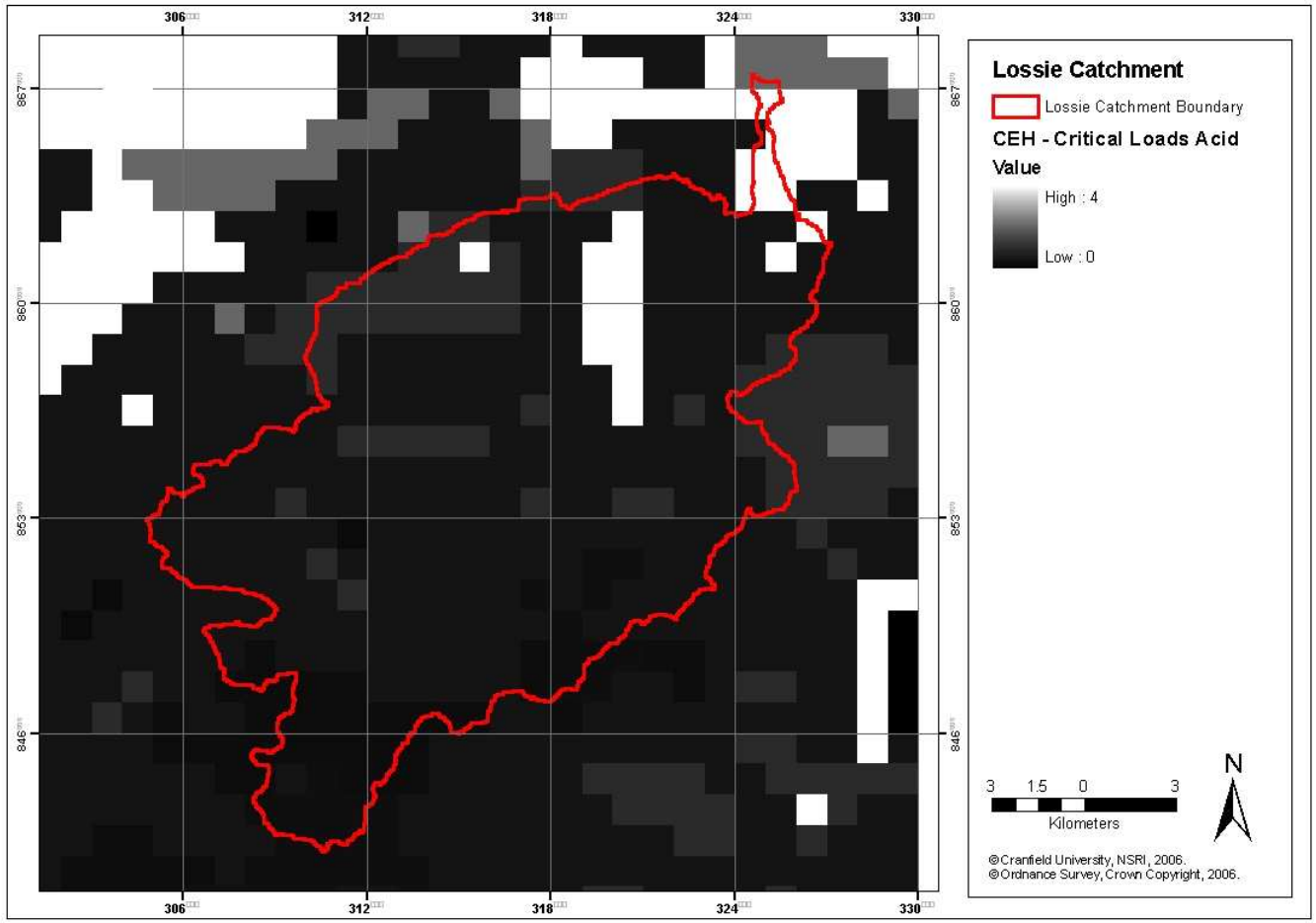

Figure 3.2.5: Critical Loads (Acid) for the Lossie catchment

Critical Loads of Nitrogen

Organisation: CEH - developed under the auspices of the UNECE (based on approaches initially developed at the University of Utrecht)

Date: 1996

Definition: A critical load is a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge (Nilsson and Grennfelt 1988).

Objectives:

- To provide a simple method of assigning a critical load for nutrient nitrogen to widely occurring habitats or ecosystems
- To derive critical loads of nutrient nitrogen based on published material on vegetation responses to N inputs/additions and expert judgement

Methodology:

Empirical critical loads have been set for a number of grassland, heathland, wetland and forest ecosystems based on experimental results, field observations or 'expert judgement' (Bobbink et al 1996). Ranges of critical loads are given for each ecosystem or habitat to take account of uncertainties and a single value is recommended for use where required or appropriate. The current recommended values used in the UK are given in Hall et al 2005.

Input requirements:

- Vegetation or habitat type

Results
The model was implemented for the Eden (Figure 3.2.6), Tern (Figure 3.2.7) and Lossie (Figure 3.2.8) catchments.

References:

Bobbink, R., Hornung, M. & Roelofs, J G M. 1996. Empirical critical loads for natural and semi-natural ecosystems. In: UNECE Manual on methodologies and criteria for mapping critical levels/loads and geographical areas where they are exceeded. Federal Environment Agency (Umweltbundesamt) Berlin.

Nilsson, J & Grennfelt, P.(ed). 1988. Critical loads for sulphur and nitrogen. (Report 1988:15). Nordic Council of Ministers, Copenhagen, Denmark.

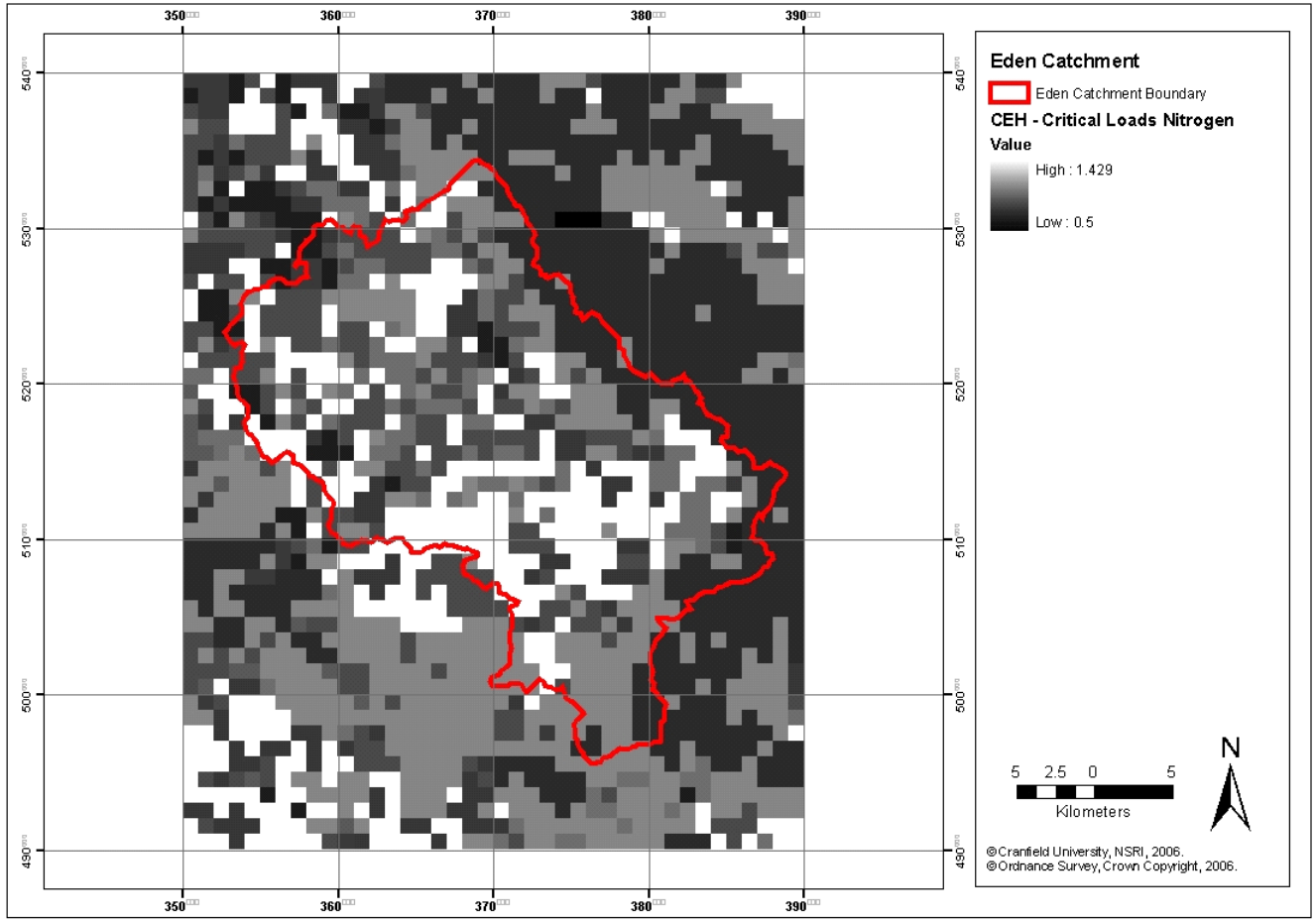

Figure 3.2.6: Critical Loads (Nitrogen) for the Eden catchment

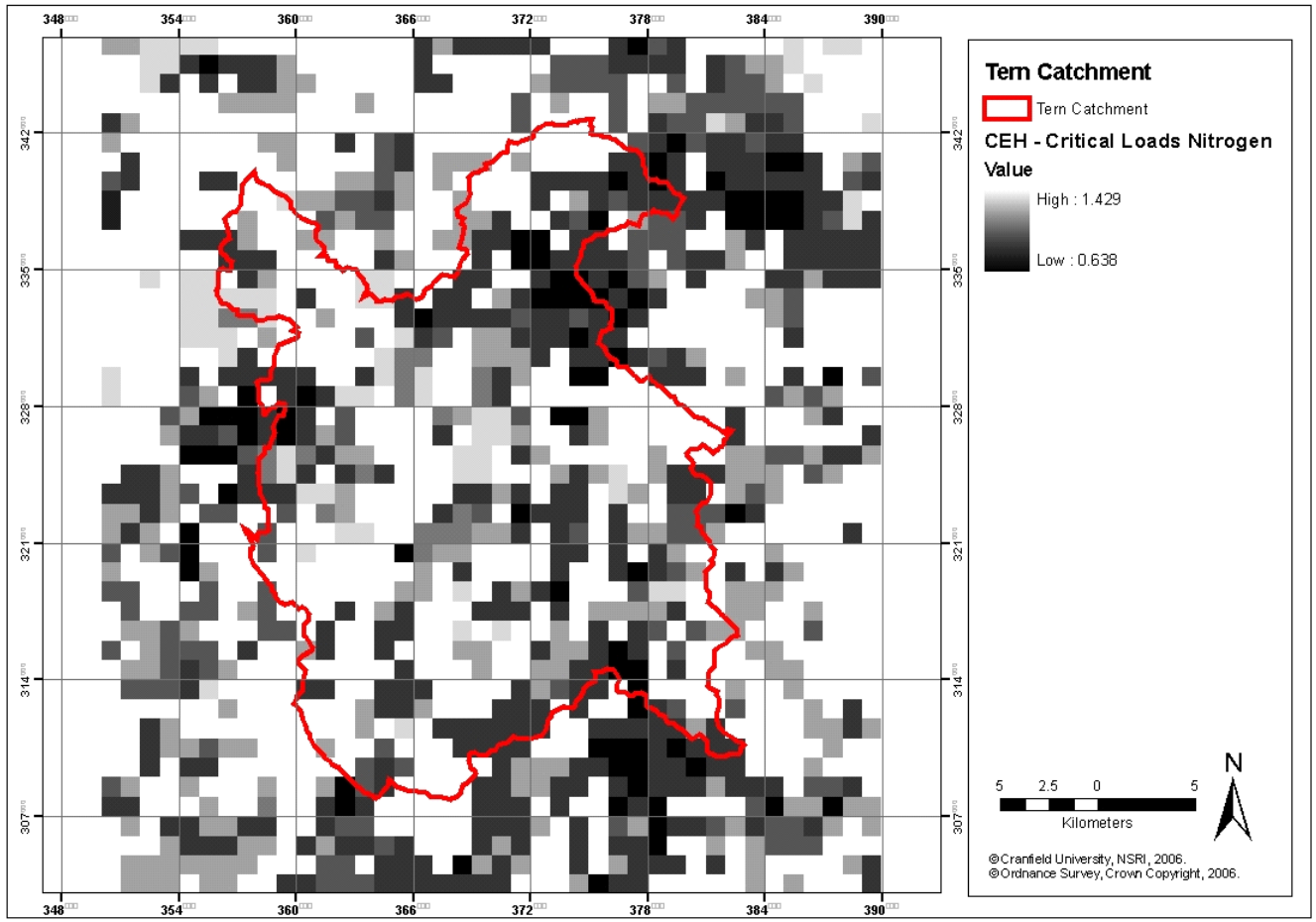

Figure 3.2.7: Critical Loads (Nitrogen) for the Tern catchment

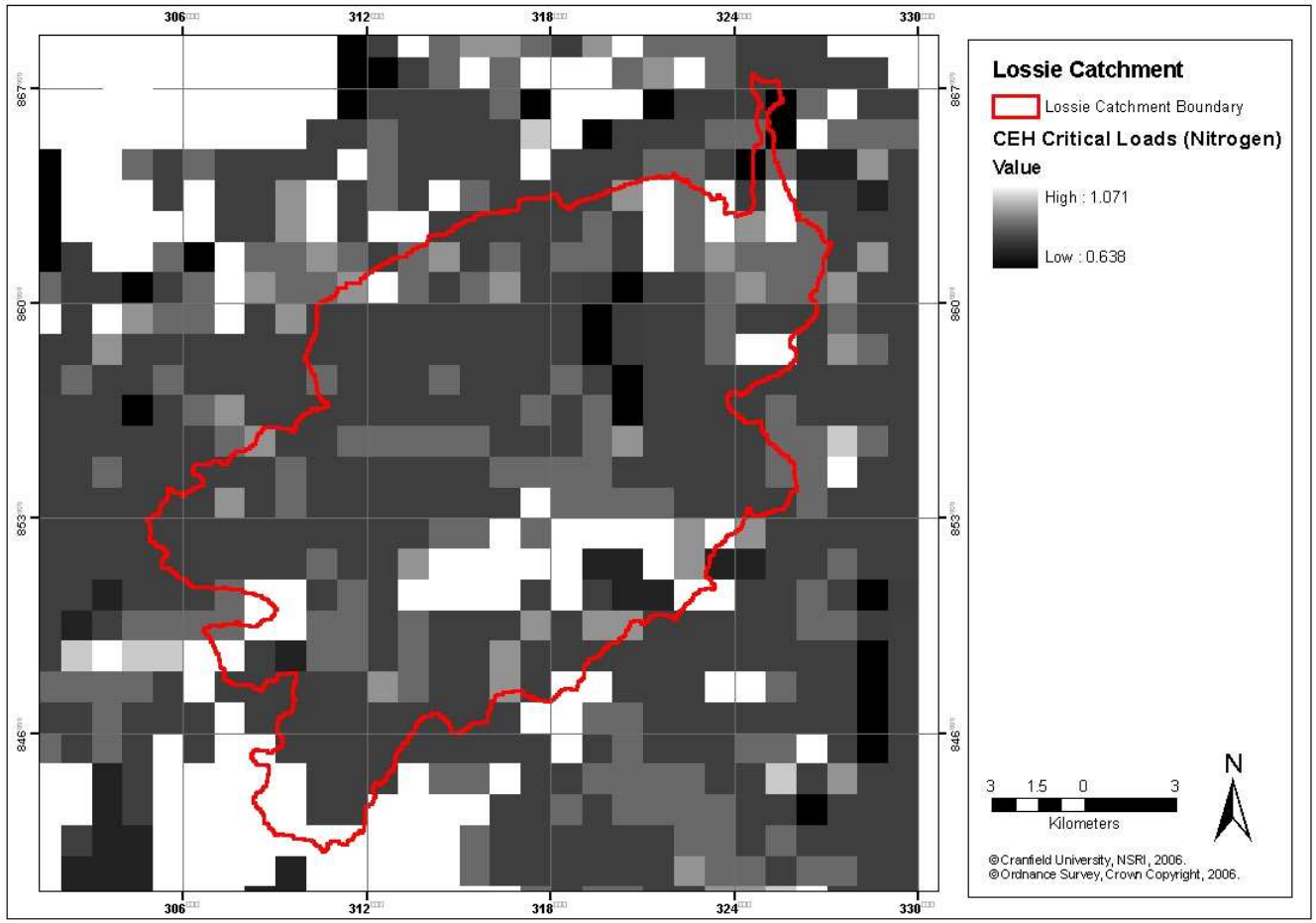

Figure 3.2.8: Critical Loads (Nitrogen) for the Lossie catchment

Soil Leaching - Nitrate

Organisation: NSRI

Date: 1989

Objectives

- To estimate potential nitrate losses from agricultural land

Methodology

The assessment of soil leaching potential is based upon the dominant soil type within each 5km x 5km National Grid square in SE UK (obtained from National Soil Map database). A number of environmental factors are required for predicting nitrate leaching loss – soil, agroclimatic (excess winter rainfall) and land use. Cells are then allocated into one of 4 nitrate leaching risk classes: from extreme to low (Table 3.2.2) based on permeability and parent material.

Class	Rating	Description
1	Extreme	Deep permeable sands; shallow soils over porous or well fissured rock; 1.0-2.5% org. C (typical organic carbon content under arable cropping)
2	High	Deep permeable light loams; 1.5-2.5% org. C
3	Moderate	Deep permeable medium loams; 2.0-4.0 % org. C
4	Low	Slowly permeable loams and clays

Table 3.2.2: Soil characteristics for assessing leaching risk (modified from Jones et al, 1989)

This methodology can be used to estimate potential nitrate losses to groundwater for land under different crops.

Input requirements

- series
- leaching class

Results
The model was implemented for the Eden (Figure 3.2.9), Tern (Figure 3.2.10) and Lossie (Figure 3.2.11) catchments.

Literature references

Jones, R.J.A., Thomasson, A.J., Robson, J.D. and Carter, A.D.. (1989). The distribution of potential nitrate leaching losses from agricultural land in the UK based on computerized soil and climatic data. In: Agriculture: Computerization of land use data. R.J.A. Jones and B.Biagi (eds), 85-95; EUR 11151 EN: Luxembourg

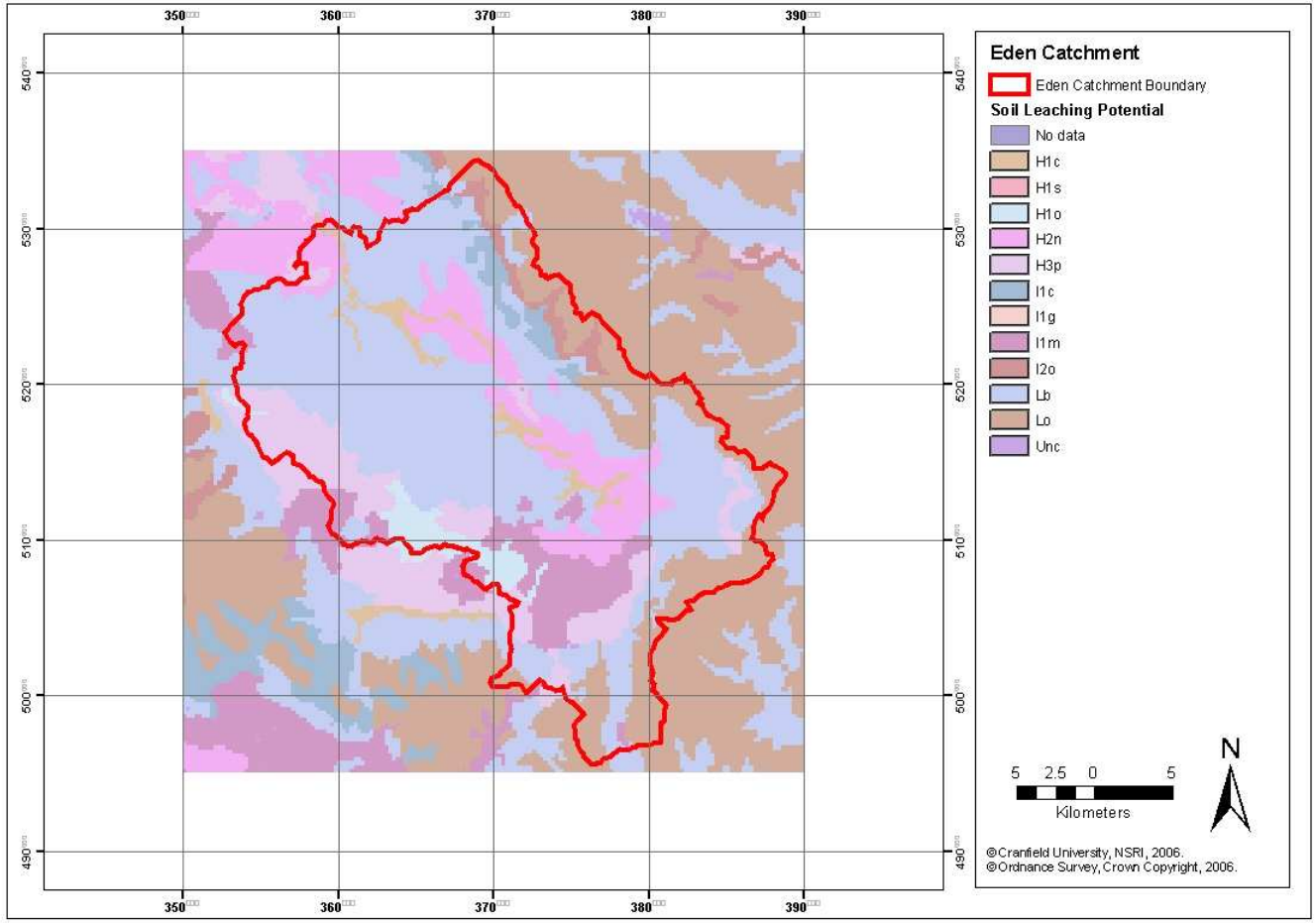

Figure 3.2.9: Soil Leaching Potential for the Eden catchment

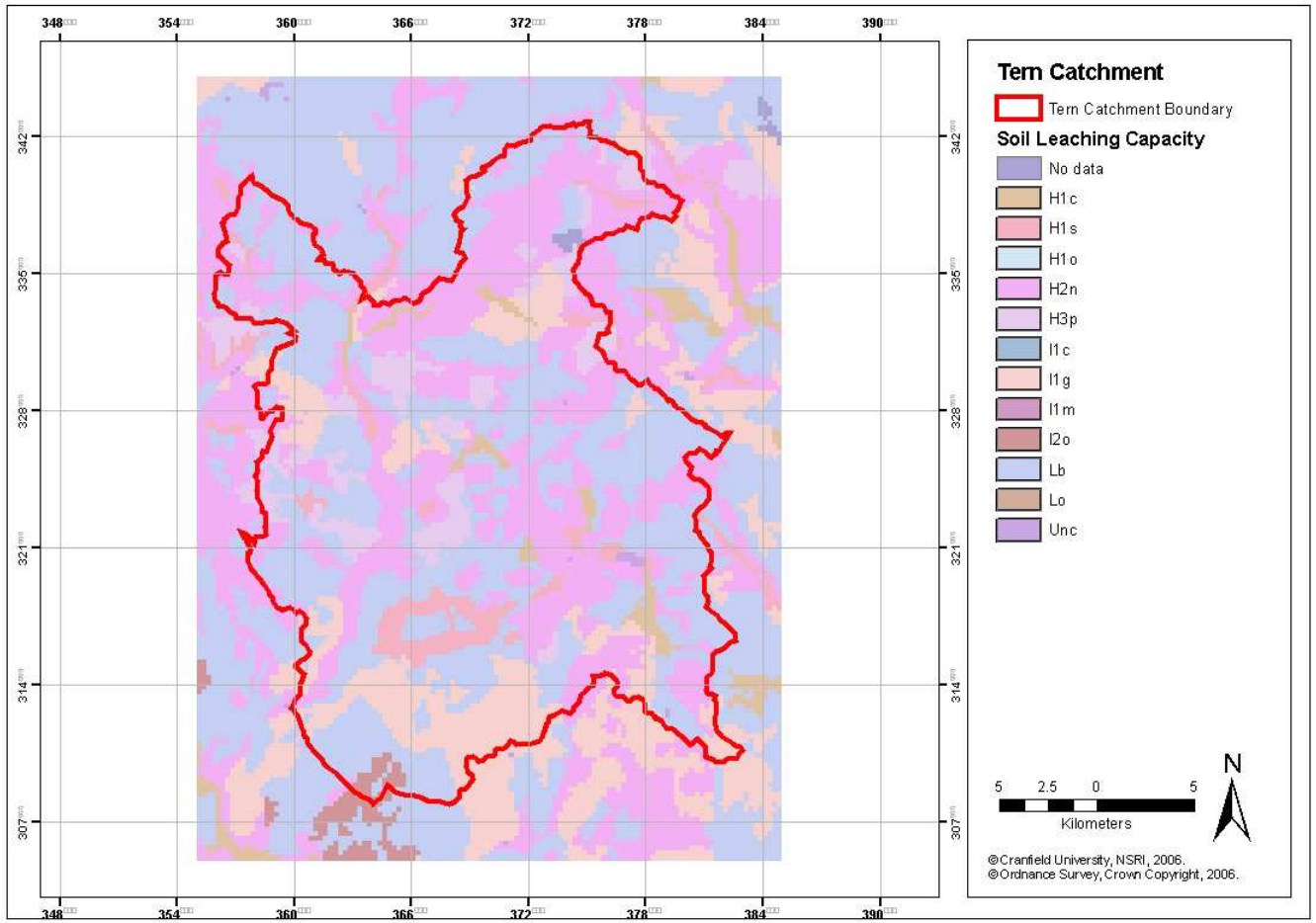

Figure 3.2.10: Soil Leaching Potential for the Tern catchment

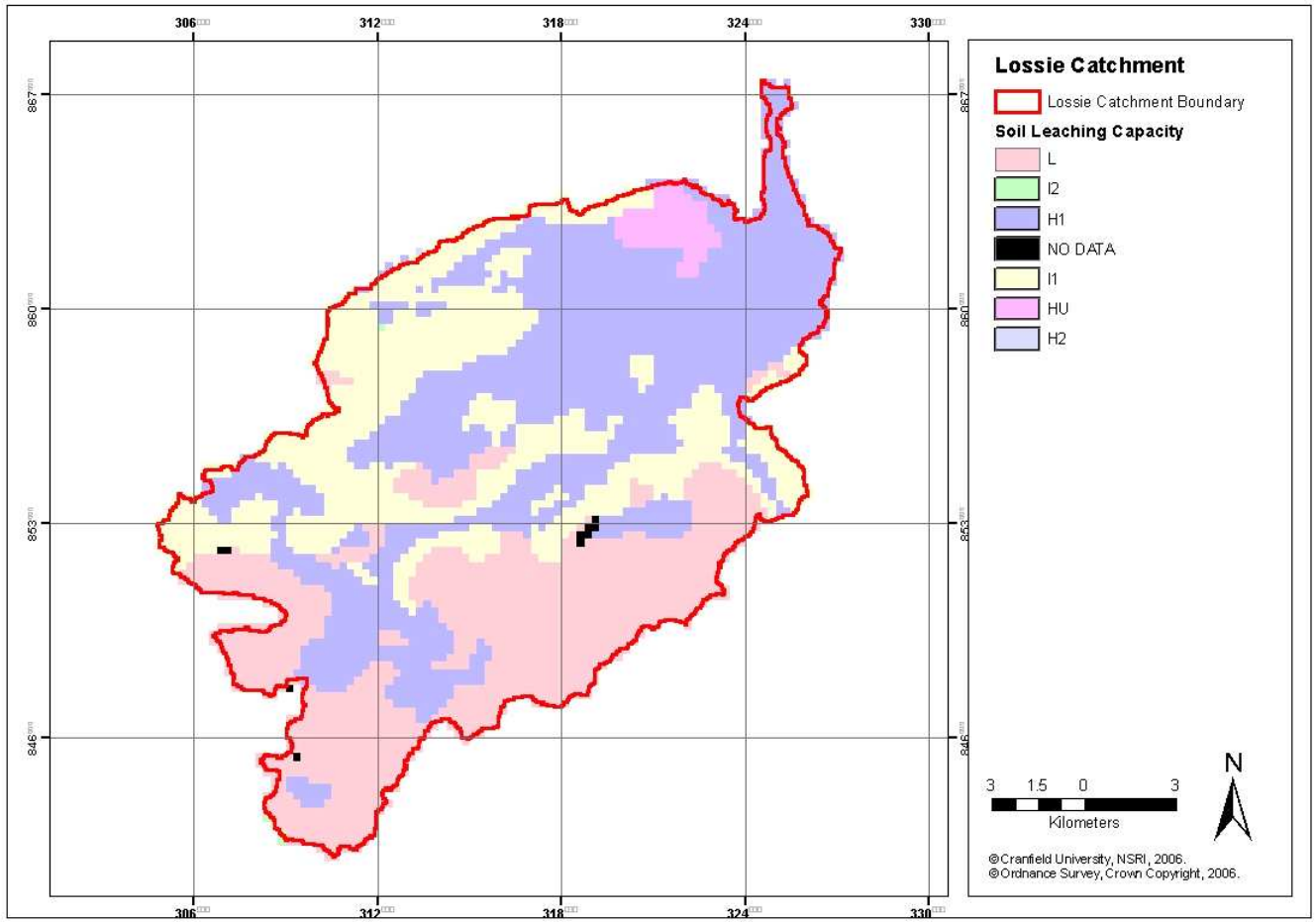

Figure 3.2.11: Soil Leaching Potential for the Lossie catchment

Sludge Disposal

Organisation: NSRI

Date: unknown

Objectives
This functional model is an example of the contaminant buffering capacity function of soil. The 'capacity' is represented by concentration limits for heavy metals in soil following the application of sewage sludge that are identified in a Government code of practice (Department of Environment, 1993).

Methodology and input requirements
At the heart of the Code of Practice is a set of maximum permissible concentrations for potentially toxic elements in soil after the application of sewage sludge. These should be measured from aggregate samples taken from the soil at 0 - 15 cm or 0 - 25 cm depth. For grassland, sampling is to 7.5 cm and a different set of limits is applied.

For this exercise, total metal and pH data from the National Soil Inventory (5 grid of sample points, 0 - 15 cm aggregate samples) were used in conjunction with the limit values relating to arable soils only.

PTE	Maximum permissible concentration (mg/kg dry solids)			
	pH 5.0<5.5	pH 5.5<6.0	pH 6.0<7.0	pH >7.0
Zinc	200	250	300	450
Lead		300		
Copper	80	100	135	200
Nickel	50	60	75	110

Table 3.2.3: Limits for heavy metals as a function of PH

Sludge should not be spread if the pH is below 5.0 or if one or more of the identified metals exceeds the permitted maximum concentrations for the stated pH ranges in Table 3.2.3.

Input requirements

- ph
- copper
- nickel
- zinc
- lead

Results
The model was implemented for the Eden (Figure 3.2.12) and Tern (Figure 3.2.13) catchments. The model was not implemented for the Lossie catchment as there is a more sophisticated model available from the Macaulay Institute.

Literature references

Department of the Environment (1993) Code of Practice for Agricultural Use of Sewage Sludge. HMSO, London.

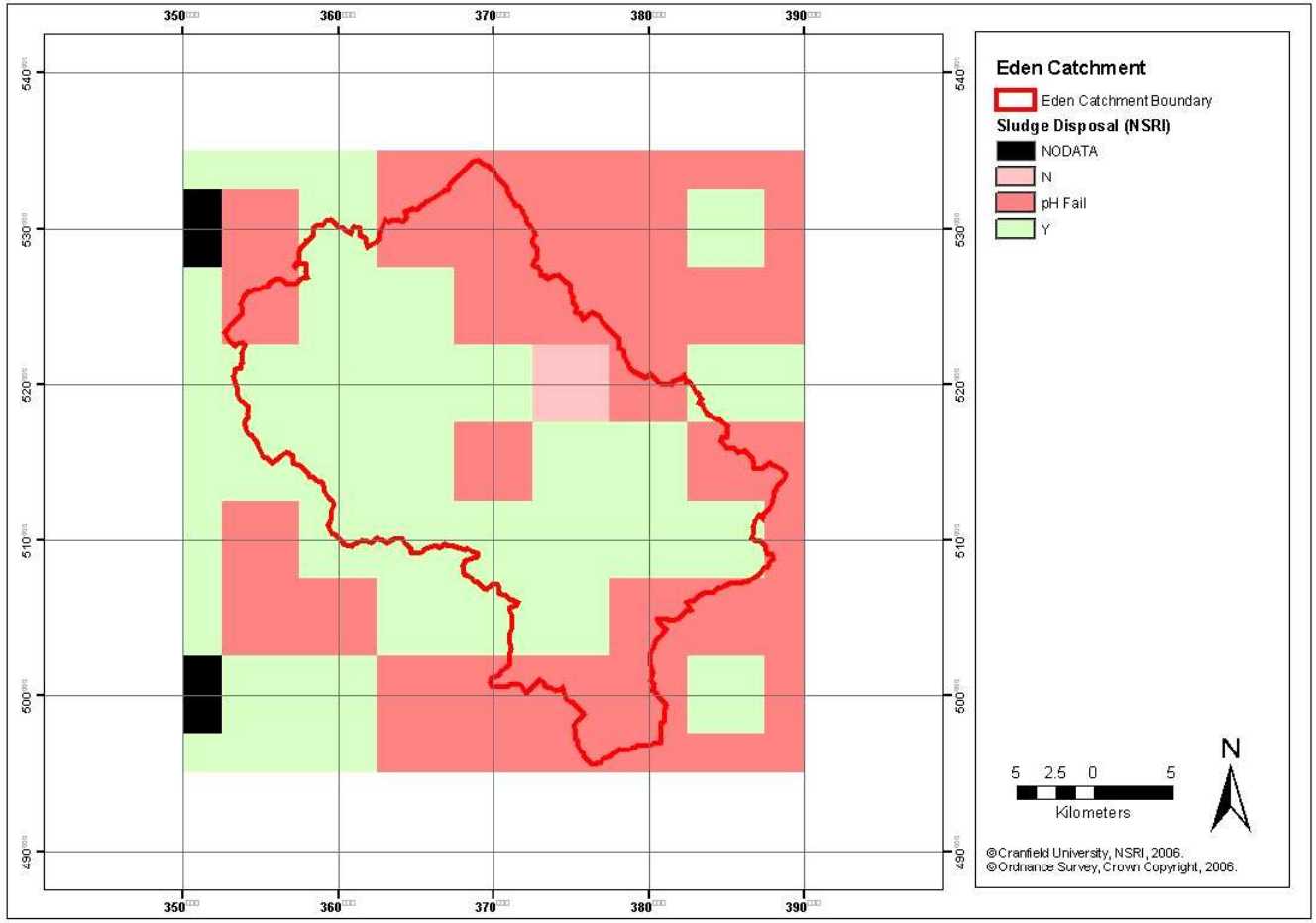

Figure 3.2.12: Sludge Disposal Acceptance model for the Eden catchment

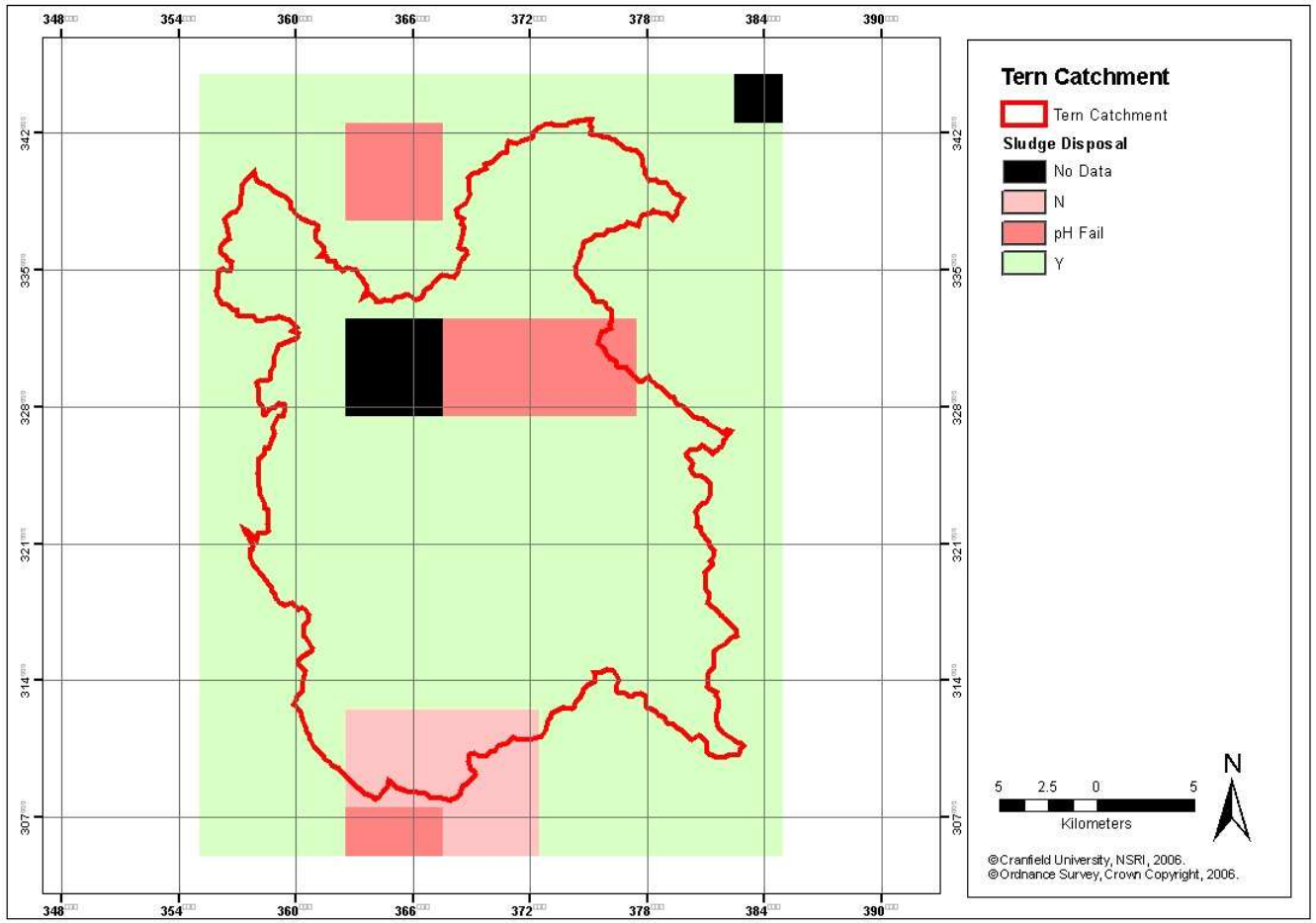

Figure 3.2.13: Sludge Disposal Acceptance model for the Tern catchment

Land suitability for sewage sludge application

Organisation: Macaulay Institute

Date: 1994

Objectives

- To provide an objective basis for the identification of land for sewage sludge application

Methodology

The model is a binary rule-based model in which the rules are applied in a step-wise manner. The categories identified are suitable and unsuitable.

```
Does soil have an organic or humose surface ——  YES  ——→  Unsuitable
horizon
          (derive from HOST class)?
                        |
                       NO
                        ↓
Is the soil a groundwater gley?             ——  YES  ——→  Unsuitable

                        |
                       NO
                        ↓
Is the slope >=15 degrees?                  ——  YES  ——→  Unsuitable
                        |
                       NO
                        ↓
Are the rock outcrops < 35 metres apart?    ——  YES  ——→  Unsuitable
                        |
                       NO
                        ↓
Is the land cover/use arable crops or improved ——  NO  ——→  Unsuitable
pasture?
                        |
                      YES
                        ↓
SUITABLE FOR SLUDGE RECYCLING
```

Figure 3.2.14: Methodology for identifying land for sewage sludge application

Input requirements

- Major soil subgroup (differentiated on HOST type)
    - Presence of an organic surface horizon
    - Presence of a groundwater table
- Slope
- Rockiness
- Land use

Results

The model was implemented for the Lossie (Figure 3.2.15) catchment. It was not implemented for the Eden and Tern catchments as there is a separate model by NSRI (see below).

Literature references

Towers, W. 1994 Towards a strategic approach to sewage sludge utilization on agricultural land in Scotland. Journal of Environmental Planning and Management, 37, 447-460.

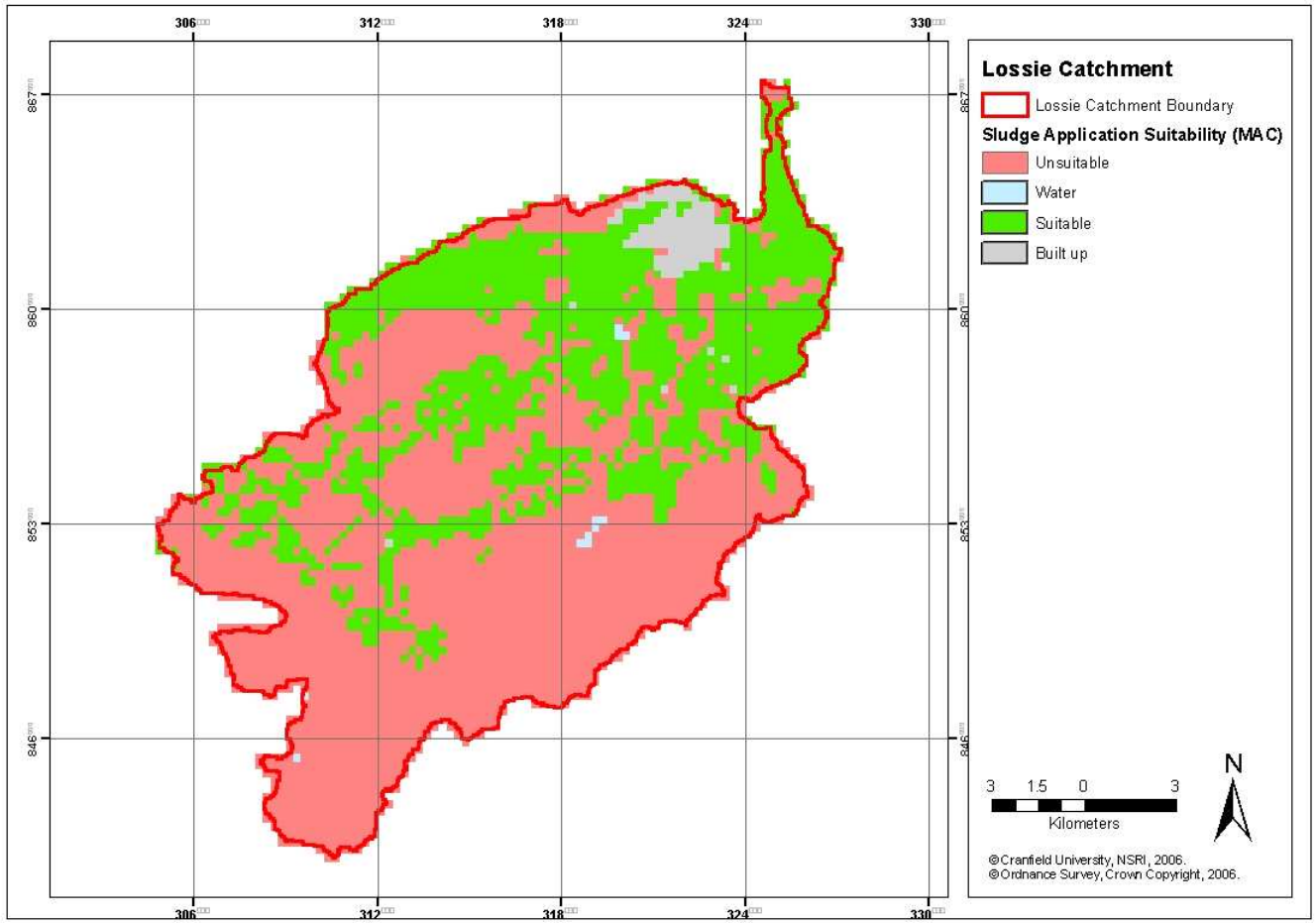

Figure 3.2.15: Sludge Application Suitability for the Lossie catchment

Slurry Acceptance Suitability Model

Organisation: NSRI

Date: 1979 (Lea), 1992 (Clarke et al)

Objectives

- To assess the relative suitability of soils for slurry acceptance
- To identify soils most capable of accepting slurry without causing pollution or later management difficulties

Methodology

The Sludge Acceptance Suitability Model uses the following seven components to establish a three category system in which the overall suitability rating of soils for slurry acceptance is determined by the component in the category of greatest risk.

- Rockiness (very large surface stones or bedrock outcrops)
- Stoniness of profile
- Flood hazard
- Moisture deficit
- Winter rain acceptance potential (WRAP)
- Porosity class of upper 10cm
- Poaching risk class (trafficability)

The resulting classes of slurry acceptance are defined as: I – Slight, II – Moderate, III – Severe (Table 3.2.4). Note that Lea (1979) states that frozen ground or fields with porous fill over drains should be avoided.

Class of slurry acceptance	**I**	**II**	**III**
Degree of risk	**Slight**	**Moderate**	**Severe**
Rockiness (% surface area)	Slightly rocky (<2)	Rocky (2-10)	Very or extremely rocky (>10)
Stoniness (% vol.)	Slightly stony or less (0-15)	Moderately stony (16-35)	Very or extremely stony (>35)
Flood hazard	No flooding	1 in 5 years	> 1 in 5 years
Moisture deficit (mm)	>100	100-15	<15
WRAP [1]	Very high and high	Moderate	Low and very low
Porosity class [2]	VP and EP	MP and SP	VSP
Poaching risk class [3]	Very low and low	Moderate	High and very high

[1] Farquharson et al. (1978)
[2] Hodgson (1976)
[3] Harrod (1979)

Table 3.2.4: Slurry acceptance (taken from Lea, 1979)

Clarke et al (1992) developed the model further by incorporating it into GIS (using SPANS software) to produce a map of slurry acceptance potential (SAP) for the South-West UK (Figure 3.2.16).

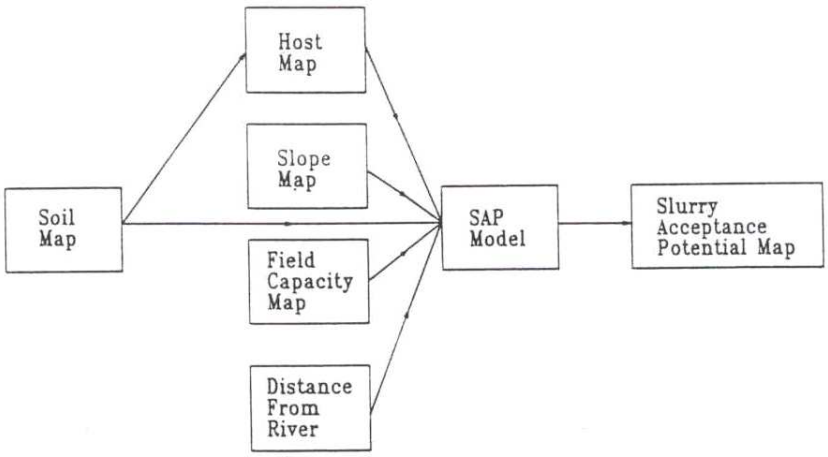

Figure 3.2.16: Model for mapping slurry acceptance potential (taken from Clarke, 1992)

Input requirements

- HOST
- Series
- Field capacity days
- Gradient

Results

The model was implemented for the Eden (Figure 3.2.17) and Tern (Figure 3.2.18) catchments. The model was not implemented for the Lossie as there is a separate model available from the Macaulay Institute (see above).

Literature references

Clarke, S.R., Jones, R.J.A., Thompson, T.R.E. and Palmer, R.C. (1992), The use of a raster-based geographic information system for modelling environmental data as an aid to land management, Geologisches Jahrbuch. A122, 443-456

Farquharson, F.A.K., Mackney, D., Newson, M.D. and Thomasson, A.J. (1978). Estimation of run-off potential of river catchments from soil surveys. Soil Survey Special Survey, No.11

Lea, J.W. (1979). Slurry Acceptance. p. 83-99. In M.G. Jarvis and D. Mackney (ed.). Soil Survey Applications. Technical Monograph No.13, Harpenden, UK

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

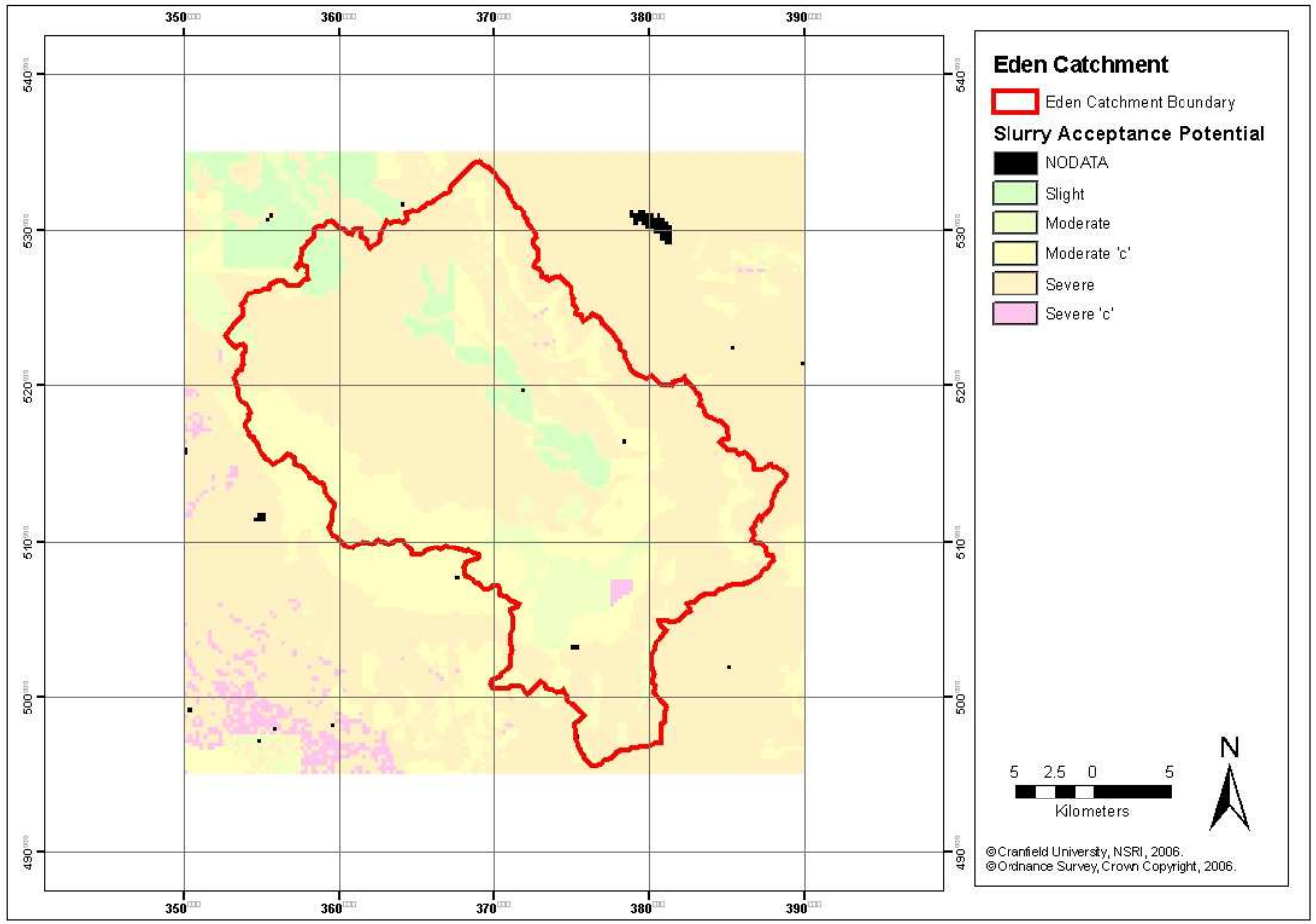

Figure 3.2.17: Sludge Acceptance Potential for the Eden catchment

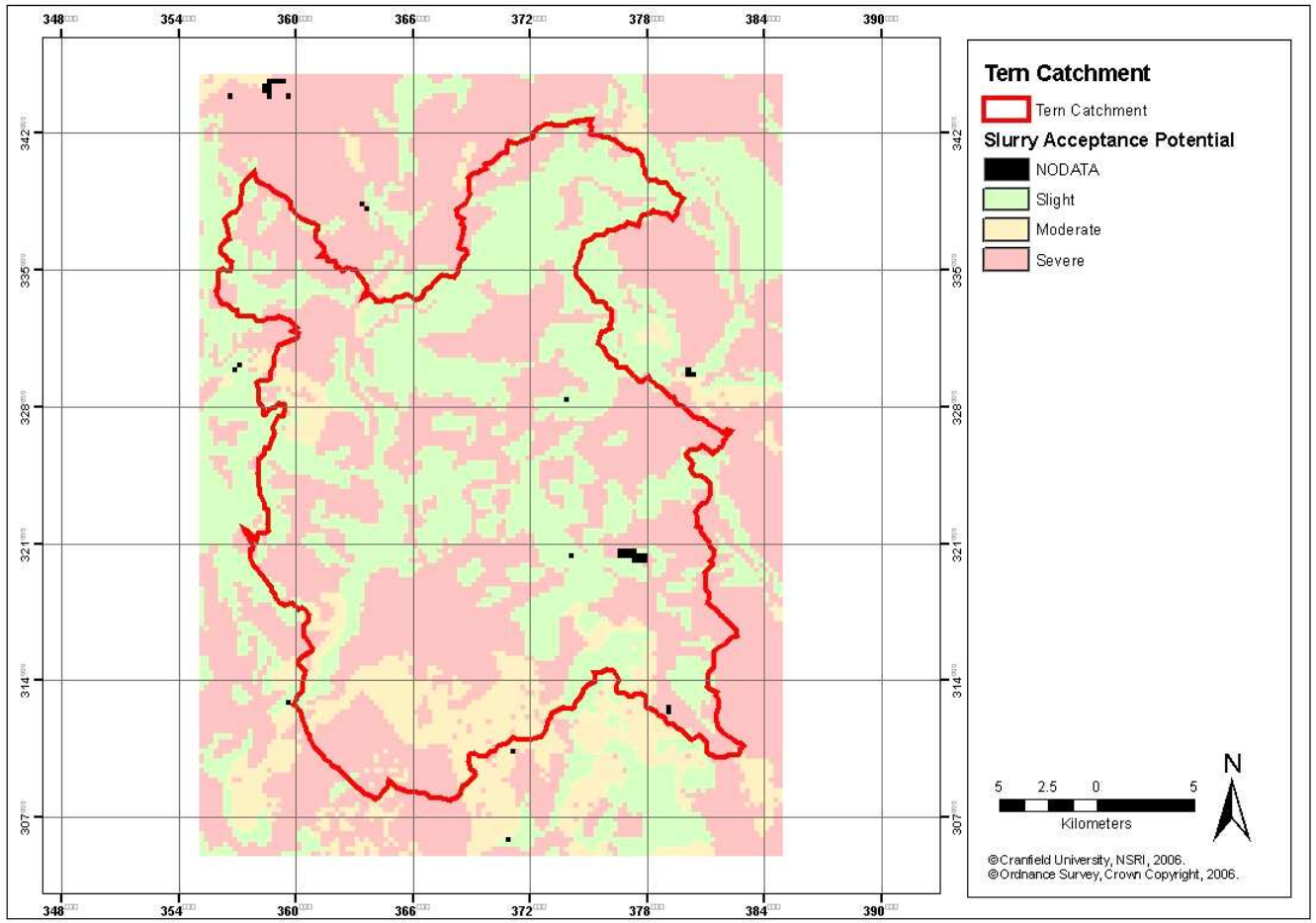

Figure 3.2.18: Sludge Acceptance Potential for the Tern catchment

Groundwater Vulnerability Mapping

Organisation: NSRI

Date: 1995

Objectives

- To identify the vulnerability of groundwater to contamination
- To allow planners, developers and regulatory bodies to make informed judgments on the location of new developments
- To prevent potentially polluting activities being proposed in highly vulnerable areas
- To allow owners of multiple sites to prioritise their investigative and subsequent remedial actions where historical practice may have given rise to land and groundwater contamination
- To increase general public awareness of the location of the groundwater resources at risk

Methodology

The method for mapping the groundwater vulnerability incorporates a soil classification which is based upon the physical and chemical properties of undisturbed soil to assess the likelihood of pollutants moving down through the soil column. Three datasets are required (Figure 3.2.19) and these combine to produce 27 different vulnerability combinations.

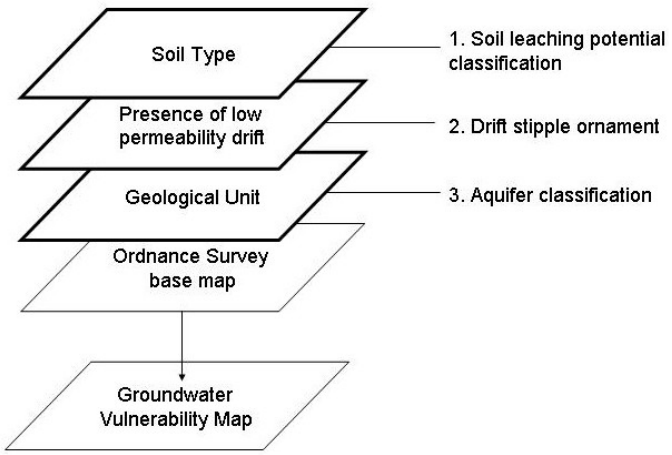

Figure 3.2.19: Datasets required for Groundwater Vulnerability Mapping (modified from Palmer et al, 1995)

Input requirements

- series
- pesticide leaching class

Results

The model was implemented for the Eden (Figure 3.2.20), Tern (Figure 3.2.21) and Lossie (Figure 3.2.22) catchments.

Literature references

Palmer, R.C., Holman, I.P., Robins, N.S. and Lewis, M.A. (1995), Guide to Groundwater Vulnerability Mapping in England and Wales, NRA R&D Note 578/1/ST

NRA (1992), Policy and Practice for the Protection of Groundwater, National Rivers Authority, Bristol

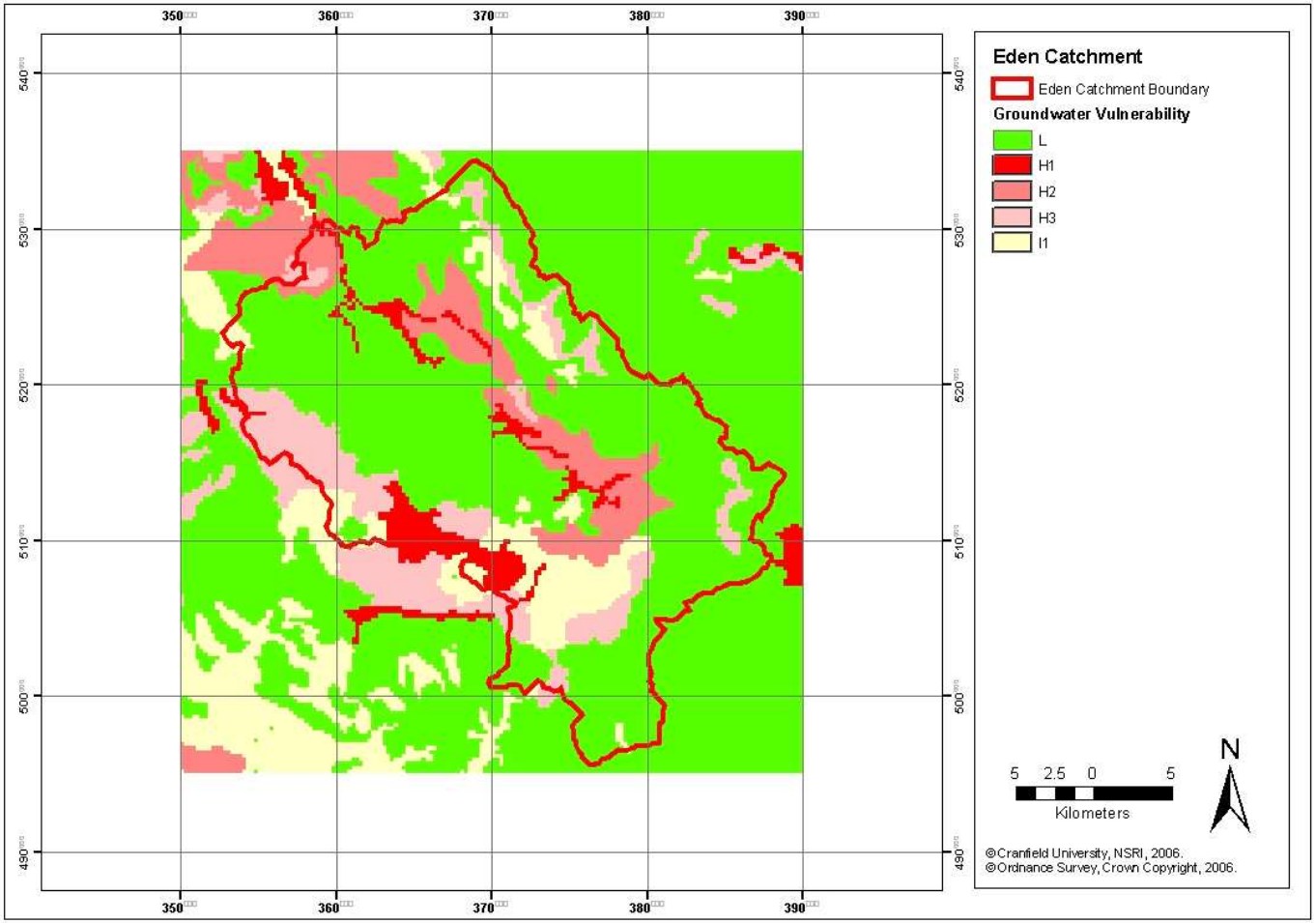

Figure 3.2.20: Groundwater vulnerability for the Eden catchment

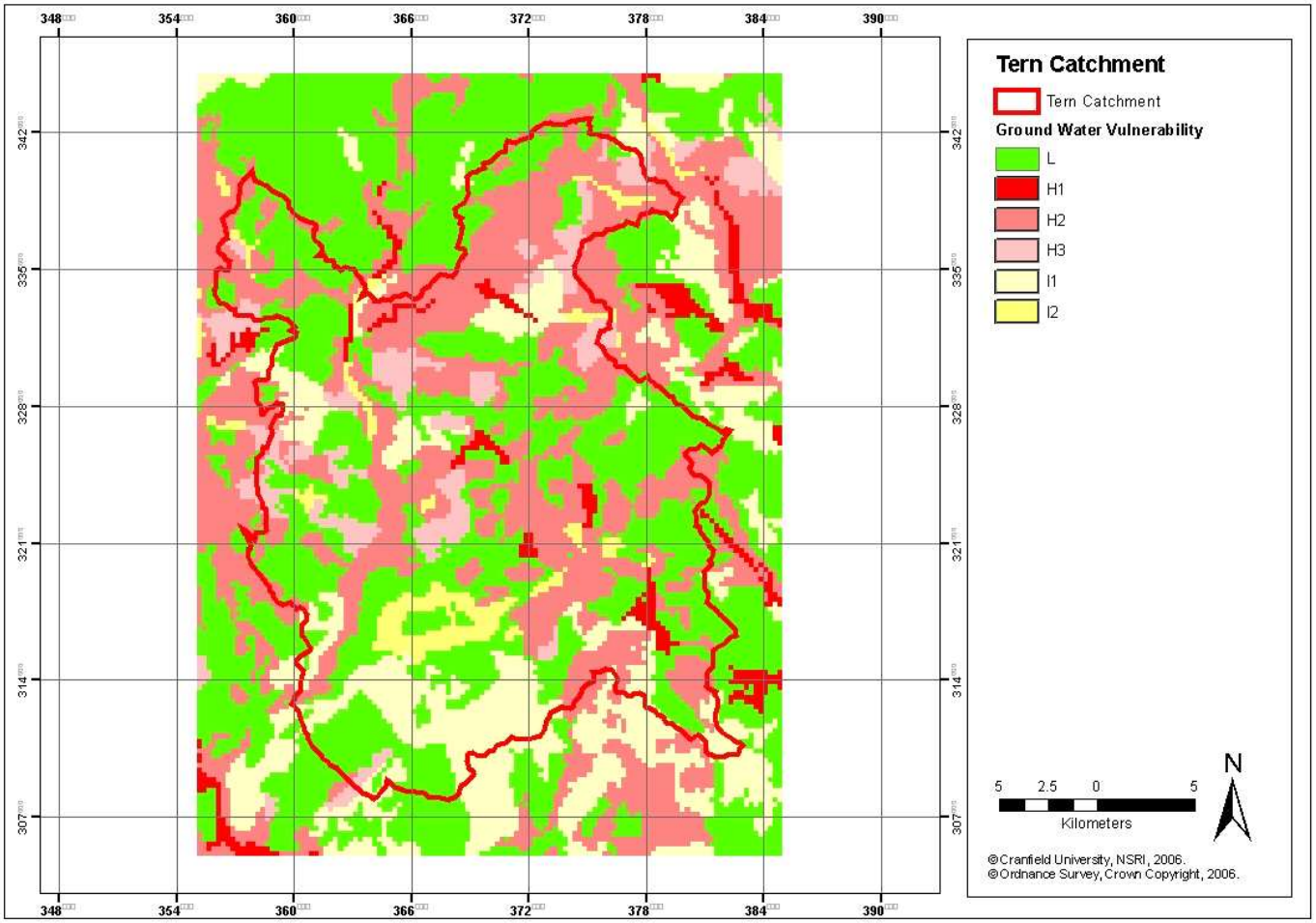

Figure 3.2.21: Groundwater vulnerability for the Eden catchment

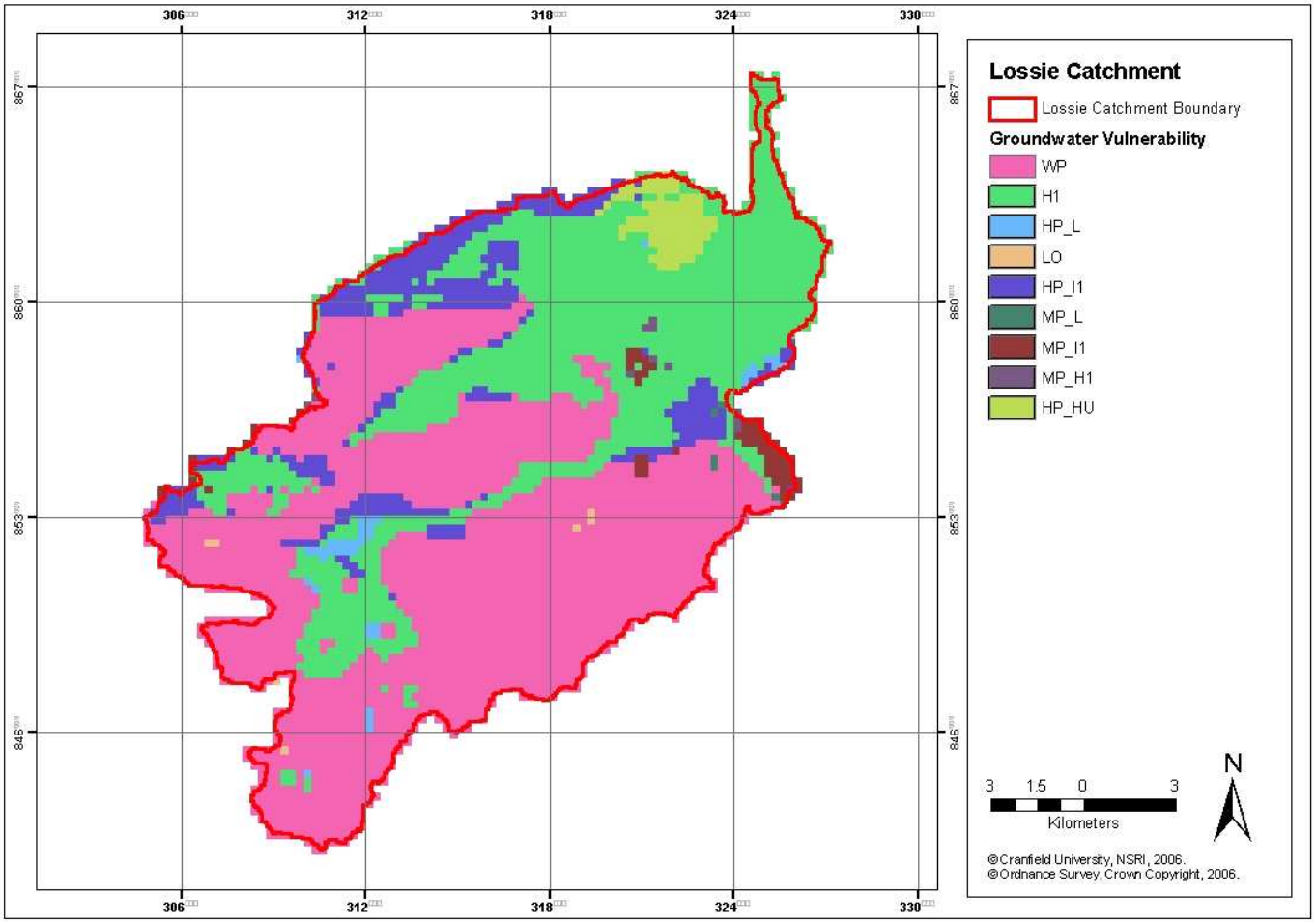

Figure 3.2.22: Groundwater vulnerability for the Eden catchment

SWATNAT Model

Organisation: NSRI

Date: 1996

Objectives

- To predict, for a nationally representative set of soil types, the average pesticide concentration entering streams in the peak drainage from fields following the first rainfall event to initiate drainage after pesticide application
- Based on an adaptation of the SWAT model (Brown & Hollis, 1996)

Methodology

The SWAT model is based upon an empirically derived hydrological link between soil type stream response to rainfall established during development of the Hydrology of Soil Types (HOST) system (Boorman *et al*, 1995).

The model predicts the average pesticide concentration entering streams in the peak drainage from fields following the first rainfall event to initiate drainage after pesticide application. This concentration is calculated by assuming that, during the rainfall event, all rainwater interacts with the upper part of the topsoil by displacing and mixing with the mobile water fraction. It is this displaced and diluted soil water fraction that moves rapidly to streams, either via surface flow or through the soil fissure/macropore systems and field drains, if present. During this process, some additional attenuation of pesticide is likely to occur as a result of sorption onto soil aggregate surfaces. The predicted drain concentration is thus calculated from the predicted solute concentration within the upper l mm of soil at the time of the rainfall event adjusted using a dilution factor to account for displacement and mixing by rain and a partition factor to account for pesticide sorption during transport to drains.

The model is run for each of a set of soil types representative of the range of different pesticide run-off potential in England & Wales. Soils with the highest runoff potential require only small volumes of rain to initiate run-off/drainage whereas those with the lowest runoff potential require large volumes of rain. Rainfall volumes required to initiate runoff/drainage from each soil type are termed minimum standard rainfall volumes and the average return periods for each of these rainfall volumes has been calculated within each of four climatic areas defined by the duration of their field capacity period. These are used to define the period between pesticide application and rainfall causing runoff/drainage for each soil type / climate combination

In order to take into account the uncertainty related to the pesticide-specific characteristics of soil sorption and degradation, the models are run for ‘worst case’ environmental conditions (those with the longest half-life and least sorption) and for ‘best case’ conditions (those with the shortest half-life and greatest sorption). These results are then compared to the appropriate Drinking Water Directive’s Maximum Acceptable Concentration (MAC) and a vulnerability assessment made (Table 3.2.5).

Vulnerability Assessment	Description
Low	The pesticide is not likely to contaminate the water resource unless it is misapplied
Low/Mod	Contamination of the water resource is unlikely but could occur under conditions where the pesticide is most mobile and persistent
Moderate	Occasional contamination of the water resource is possible, particularly under conditions where the pesticide is more mobile and/or persistent
Mod/High	Occasional contamination of the water resource is likely to occur except under conditions where the pesticide is least mobile and/or persistent
High	Frequent contamination of the water resource is likely

Table 3.2.5: Vulnerability Assessment Classes used in SWATNAT

Input requirements

- landuse
- series
- pesticide run-off class

Results

The model was implemented for the Eden and Tern catchments. Figures 3.2.23 to 3.2.26 show the predicted pesticide concentrations and vulnerability assessments for the Eden and Tern respectively. Due to data incomparability, the model could not be implemented for the Lossie catchment.

Literature references

Brown, C.D. & Hollis, J.M. (1996). SWAT - A semi-empirical model to predict concentrations of pesticides entering surface waters from agricultural land. *Pesticide Science* **47**, 41-50.

Boorman, D.B., Hollis, J.M. & Lilly, A. (1995). *Hydrology of Soil Types: A hydrologically-based classification of the soils or the United Kingdom*. Institute of Hydrology Report No. 126, Wallingford, UK. 137 pp.

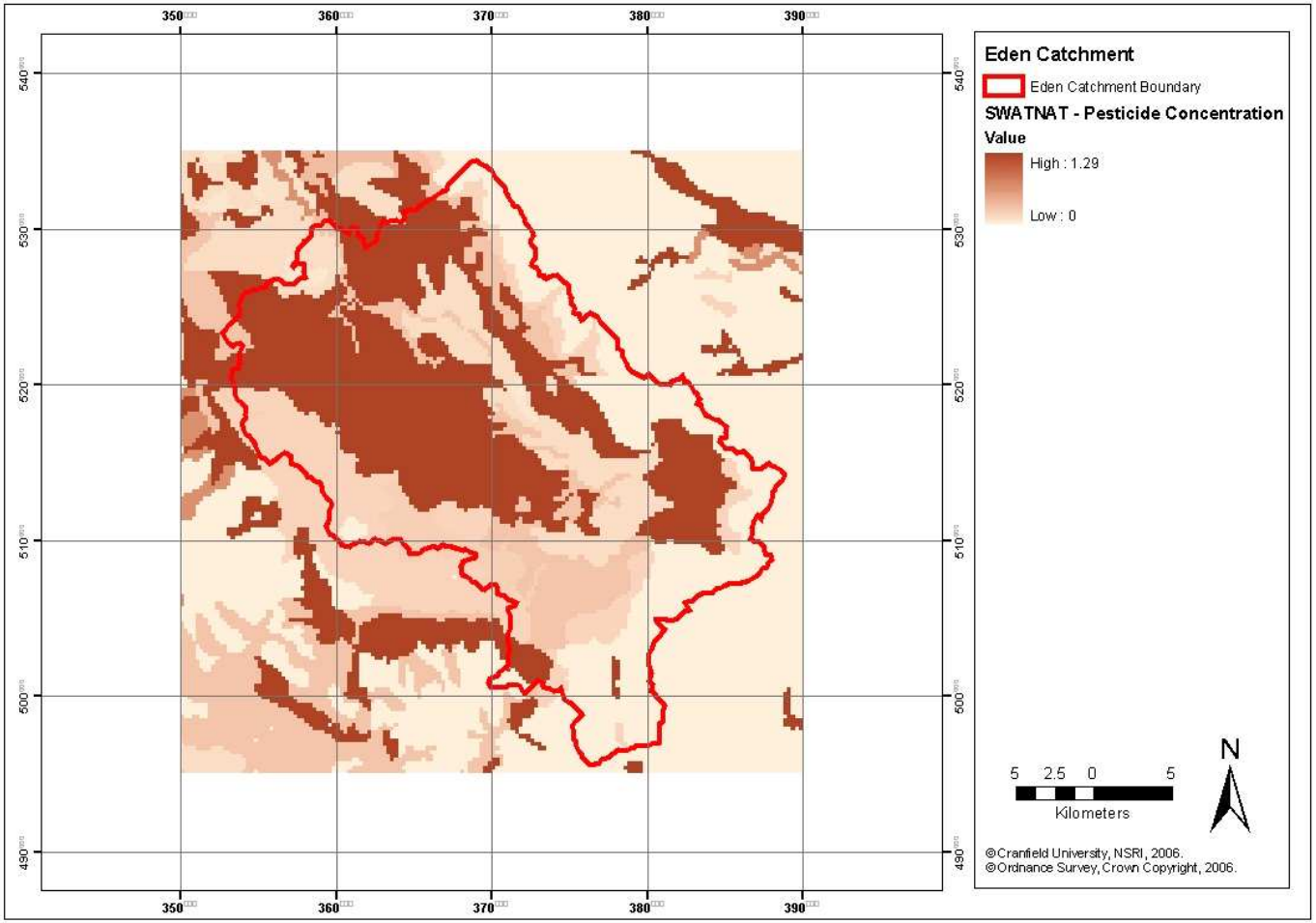

Figure 3.2.23: SWATNAT (Pesticide Concentration) for the Eden catchment

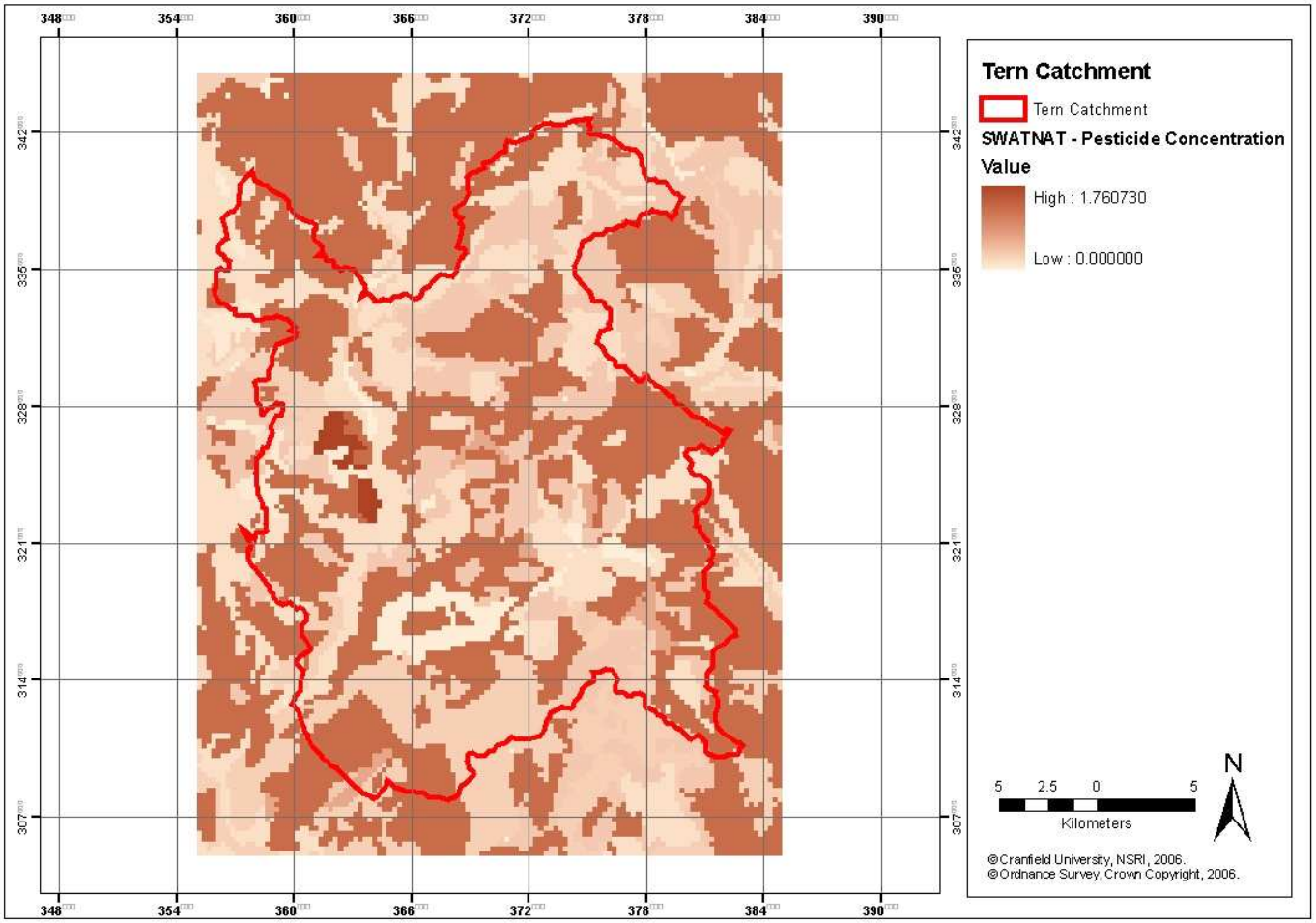

Figure 3.2.24: SWATNAT (Pesticide Concentration) for the Tern catchment

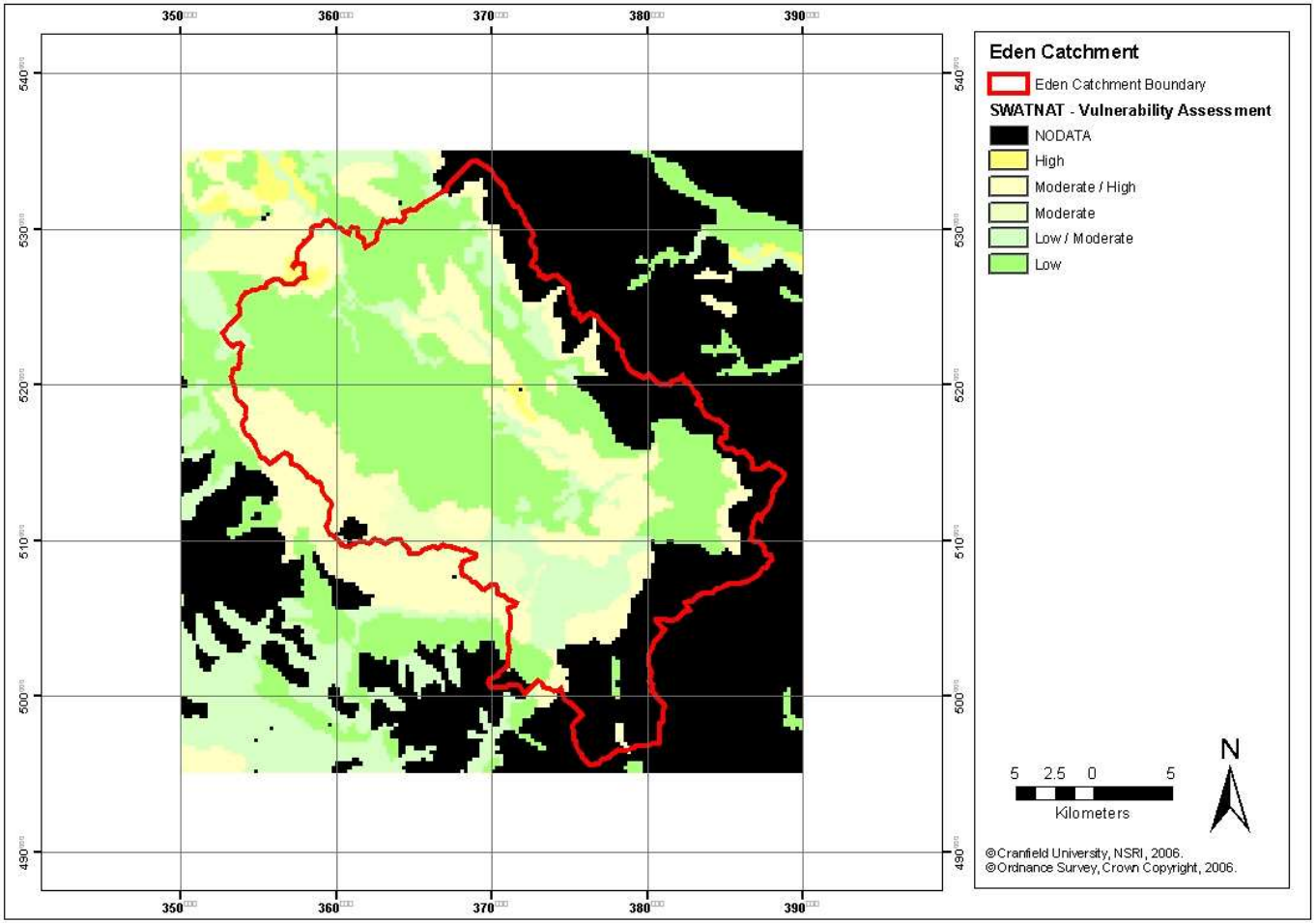

Figure 3.2.25: SWATNAT (Vulnerability Assessment) for the Eden catchment

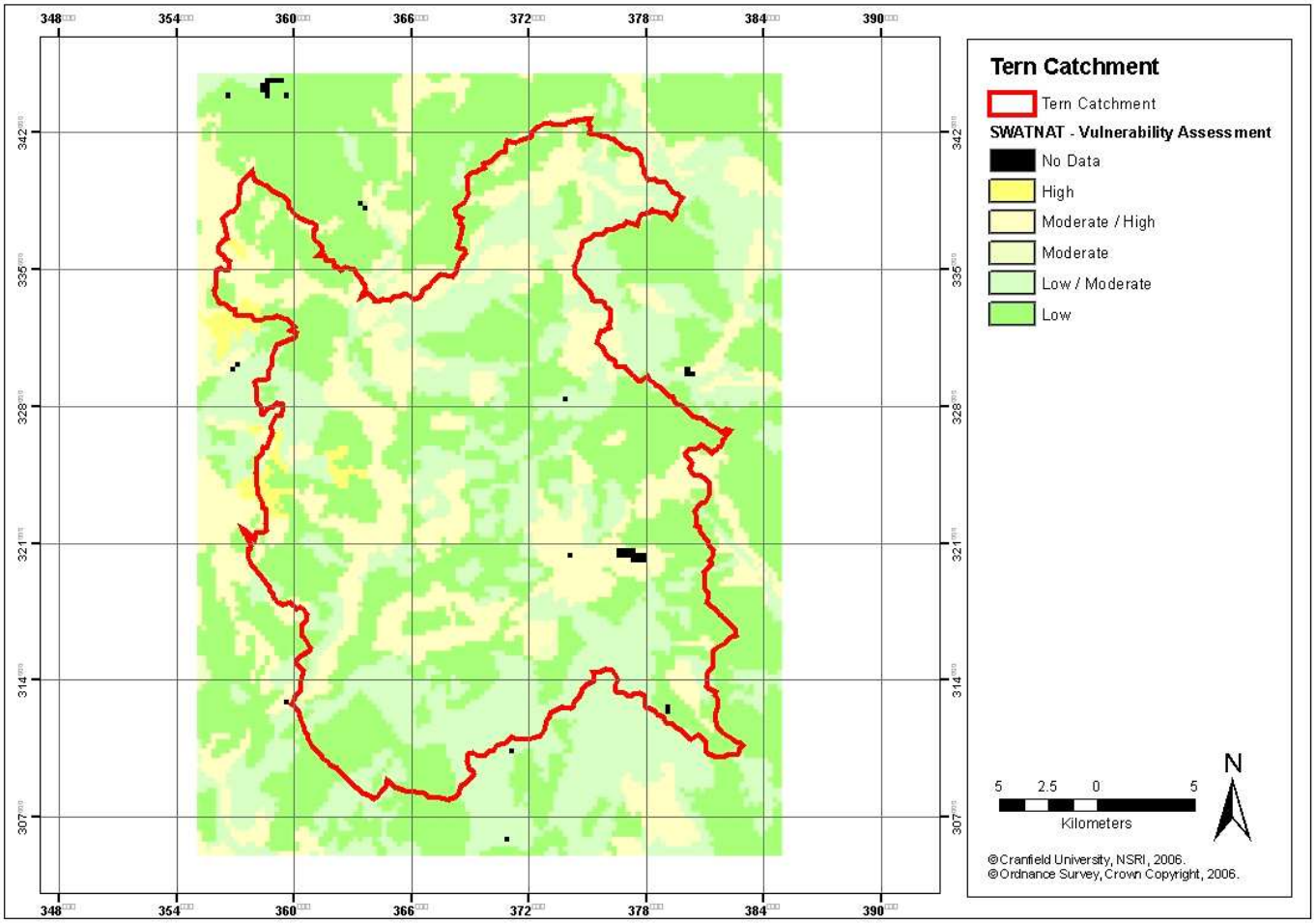

Figure 3.2.26: SWATNAT (Vulnerability Assessment) for the Tern catchment

Radiocaesium soil to plant transfer (Absalom) Model

Organisation: CEH (implemented). Developed by the University of Nottingham

Date: 2001 (revised), 1999 (original)

Objectives

- To make dynamic predictions of the transfer of radiocaesium from soil to vegetation
- To use readily available soil properties as model input parameters

Methodology

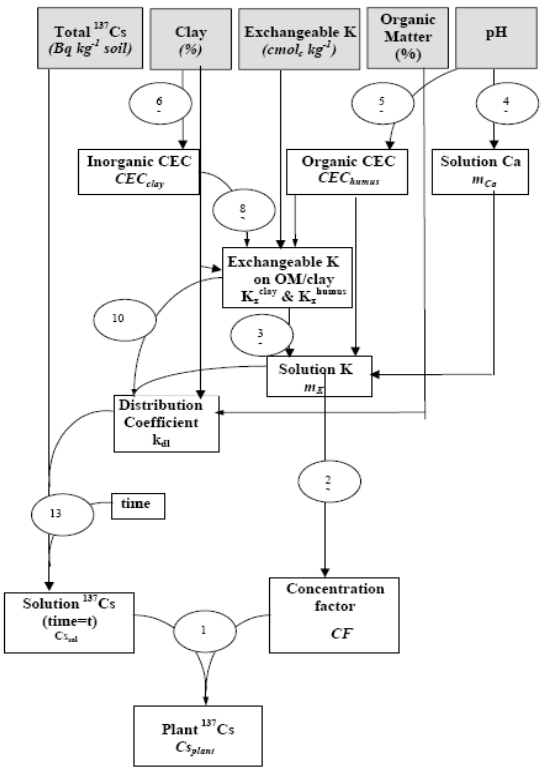

Figure 3.2.27: Flow diagram for the radiocaesium soil to plant transfer model (Source: Absalom et al. 2001). Input properties shown as shaded boxes.

The Absalom model dynamically estimates the activity of radiocaesium (deposited following atmospheric nuclear weapons tests or routine or accidental releases from nuclear sites) in grass from readily available soil properties. The model was initially developed for mineral soils (Absalom et al. 1999) using measurements of radiocaesium uptake for a pot experiment where ryegrass was grown on mineral soils from agricultural areas of Belgium. Soil clay content and exchangeable potassium status are used to estimate three key properties influencing the bioavailability of radiocaesium in soils: (1) the labile radiocaesium coefficient; (2) the solution potassium concentration; and (3) the radiocaesium soil solution to plant concentration factor. The effect of time upon the fixation of radiocaesium is modelled using two first-order decay equations. Predictions of radiocaesium activity concentrations in other crops are made using ratios to radiocaesium activity concentrations in grass. The model was successfully validated using a wide range of soil and crop combinations covering contamination time periods of 0.5-11 years collated from published and unpublished sources. A second pot experiment was used to quantify the uptake of radiocaesium to ryegrass grown on organic soils collected from northern England. The Absalom model was modified (Absalom et al. 2001) so dynamic predictions of radiocaesium uptake to grass could be made for all soil types (mineral and organic) from soil clay content, exchangeable K status, pH,

ammonia concentration and organic matter content. The modified model was successfully validated for a range of crops against published and unpublished data covering contamination time periods of 1-10 years.

Input requirements

- Radiocaesium deposition
- Soil clay
- Soil exchangeable potassium
- Soil organic matter
- Soil pH
- Time after deposition (days)

Results

The model was implemented for the Eden, Tern and Lossie catchments. Figures 3.2.28 to 3.2.33 illustrate the radiocaesium concentration and critical load values for lamb 100 days after fallout.

Literature references

Absalom, J.P, Young, S.D., Crout, N.M.J., Nisbet, A.F., Woodman, R.F.M, Smolders, E. & Gillett, A.G. (1999) Predicting soil to plant transfer of radiocaesium using soil characteristics. *Environmental Science and Technology*, 33, 1218-1223.

Absalom, J.P., Young, S.D., Crout, N.M.J., Snchez, A., Wright, S.M., Smolders, E., Nisbet, A.F. & Gillett, A.G. (2001) Predicting the transfer of radiocaesium from organic soils to plants using soil characteristics. *Journal of Environmental Radioactivity*, 52, 31-43.

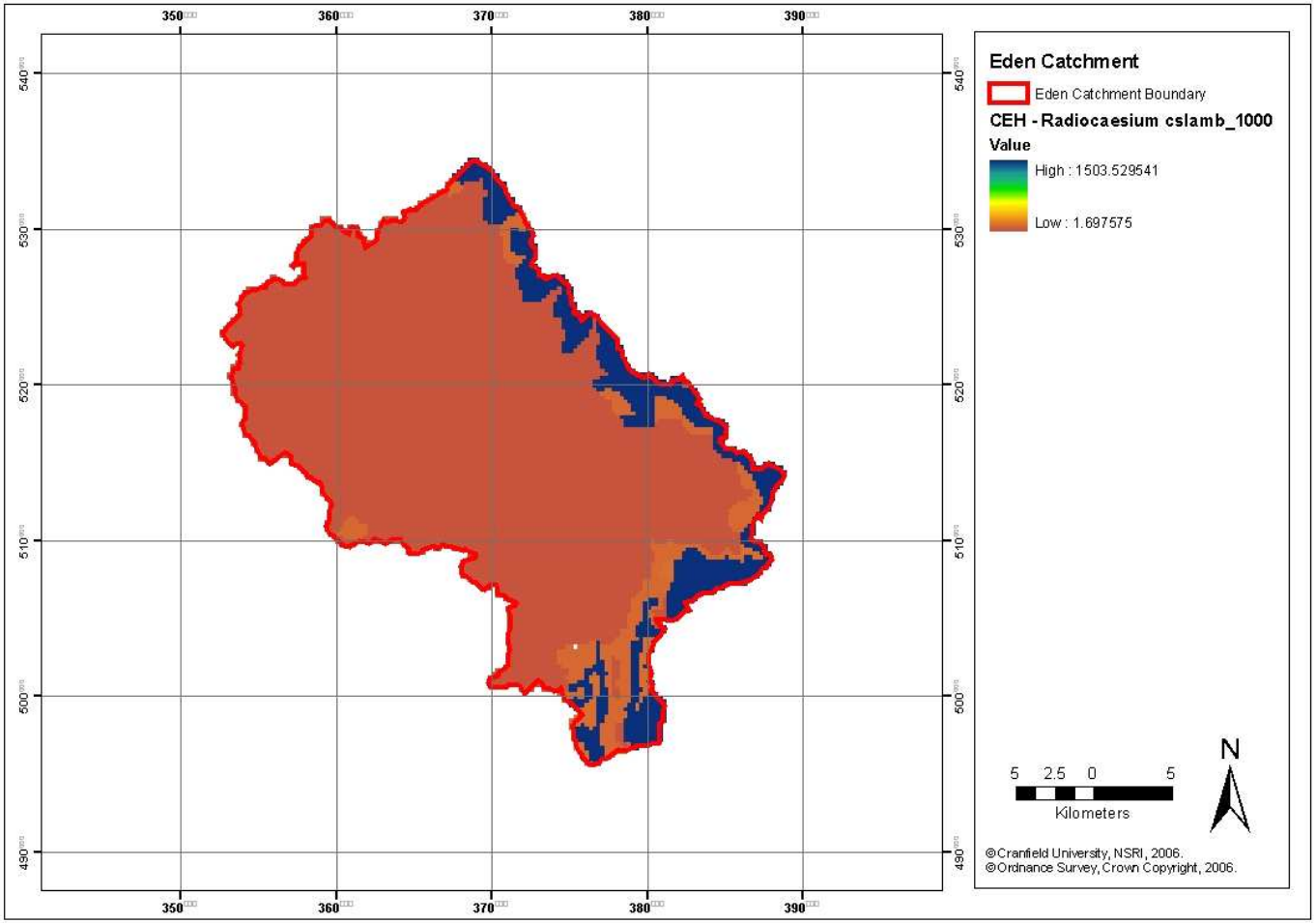

Figure 3.2.28: Predictive Radiocaesium concentration (Bq kg^{-1}) in lamb 1000 days after fallout for the Eden catchment

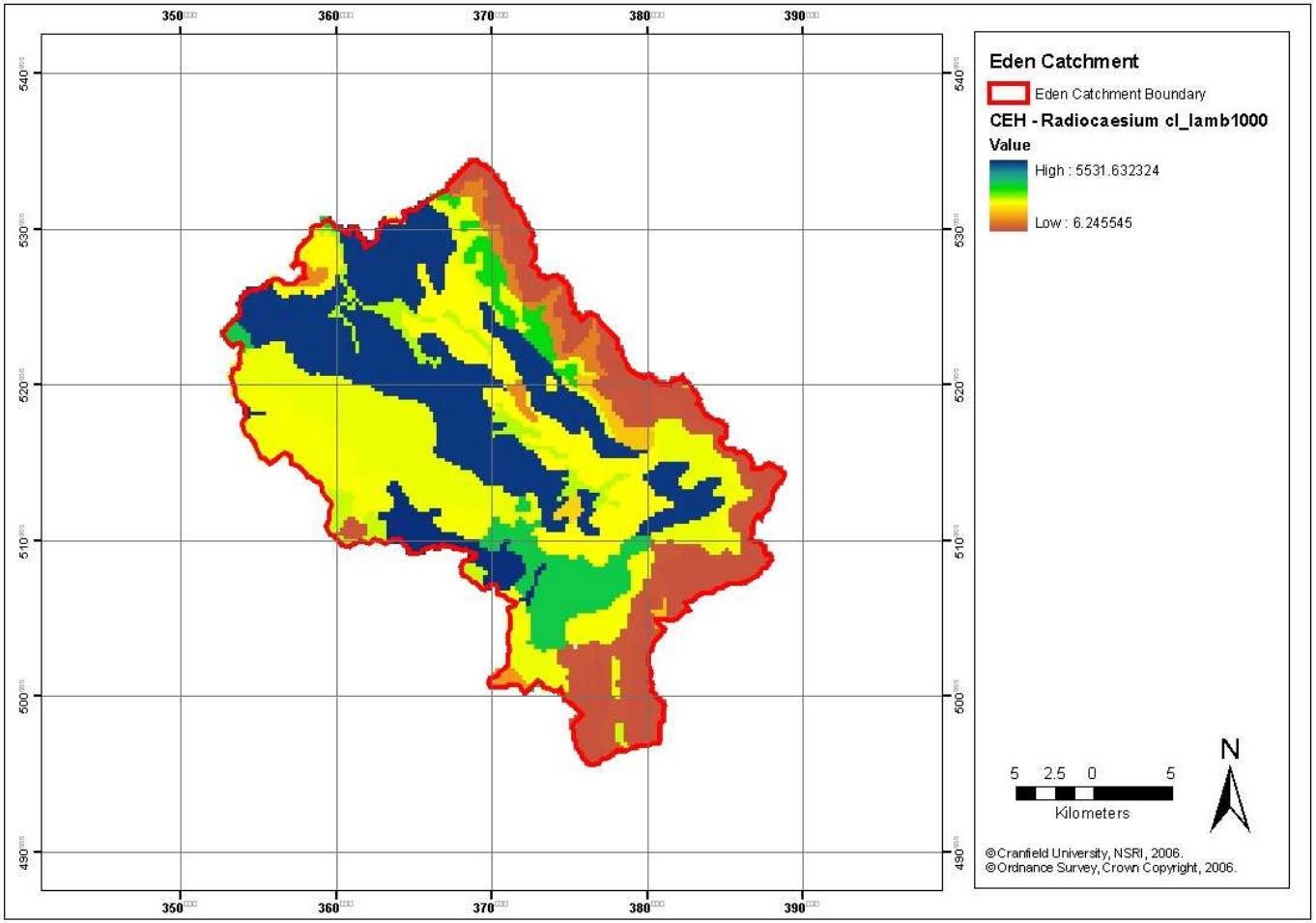

Figure 3.2.29: Critical Load (Bq m^{-2}) of radiocaesium for lamb 1000 days after fallout for the Eden catchment

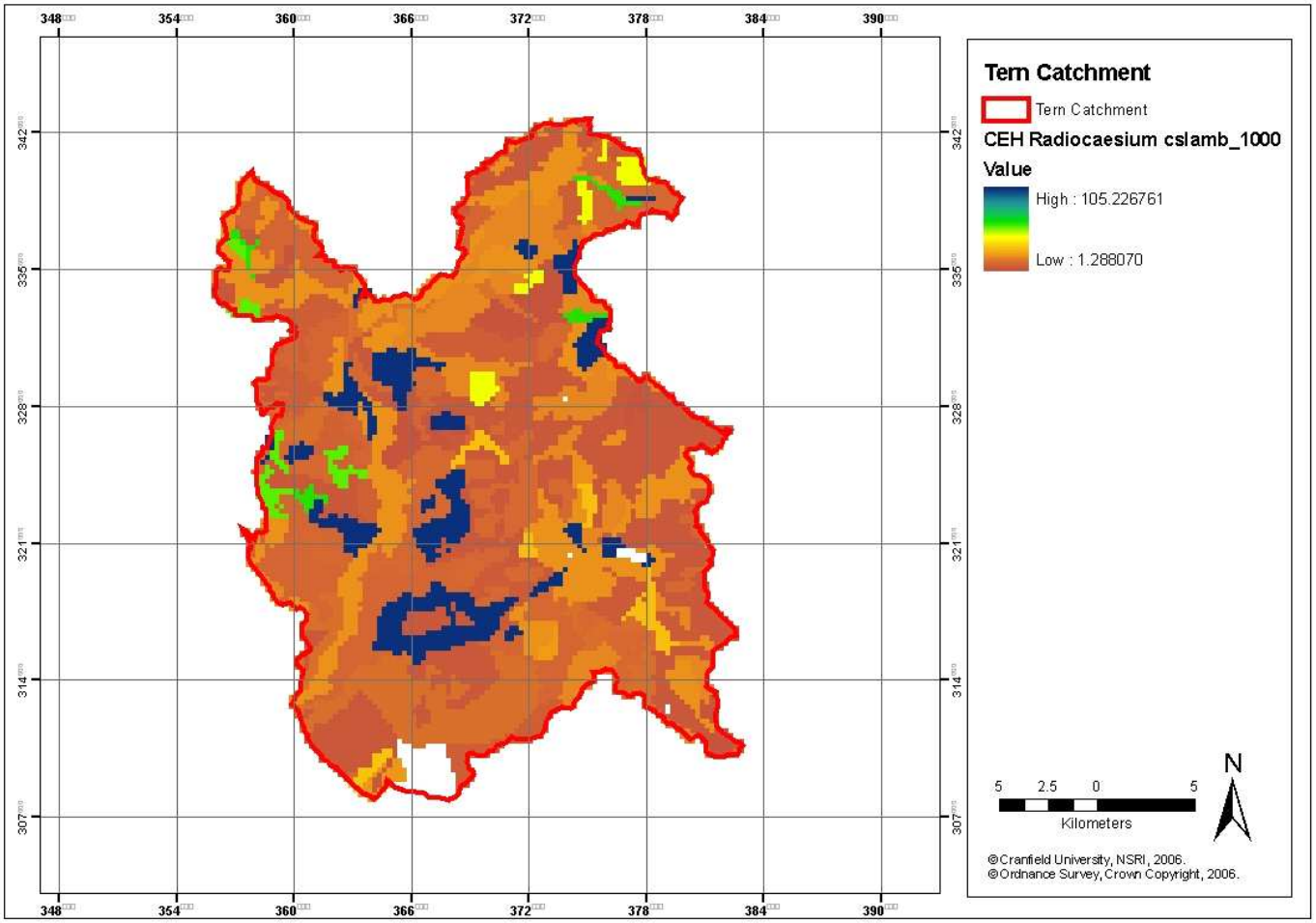

Figure 3.2.30: Predictive Radiocaesium concentration (Bq kg^{-1}) in lamb 1000 days after fallout for the Tern catchment

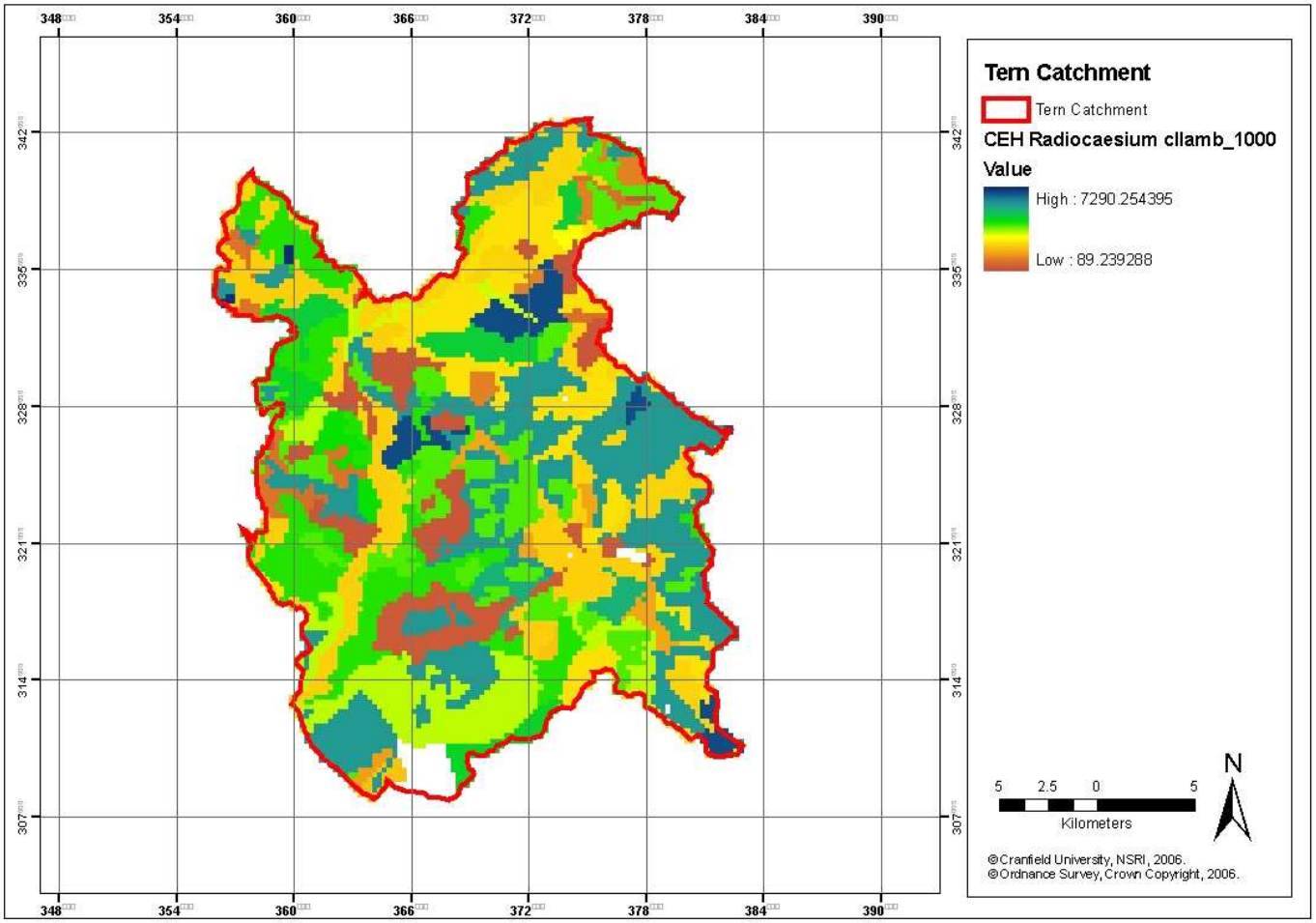

Figure 3.2.31: Critical Load (Bq m^{-2}) of radiocaesium for lamb 1000 days after fallout for the Tern catchment

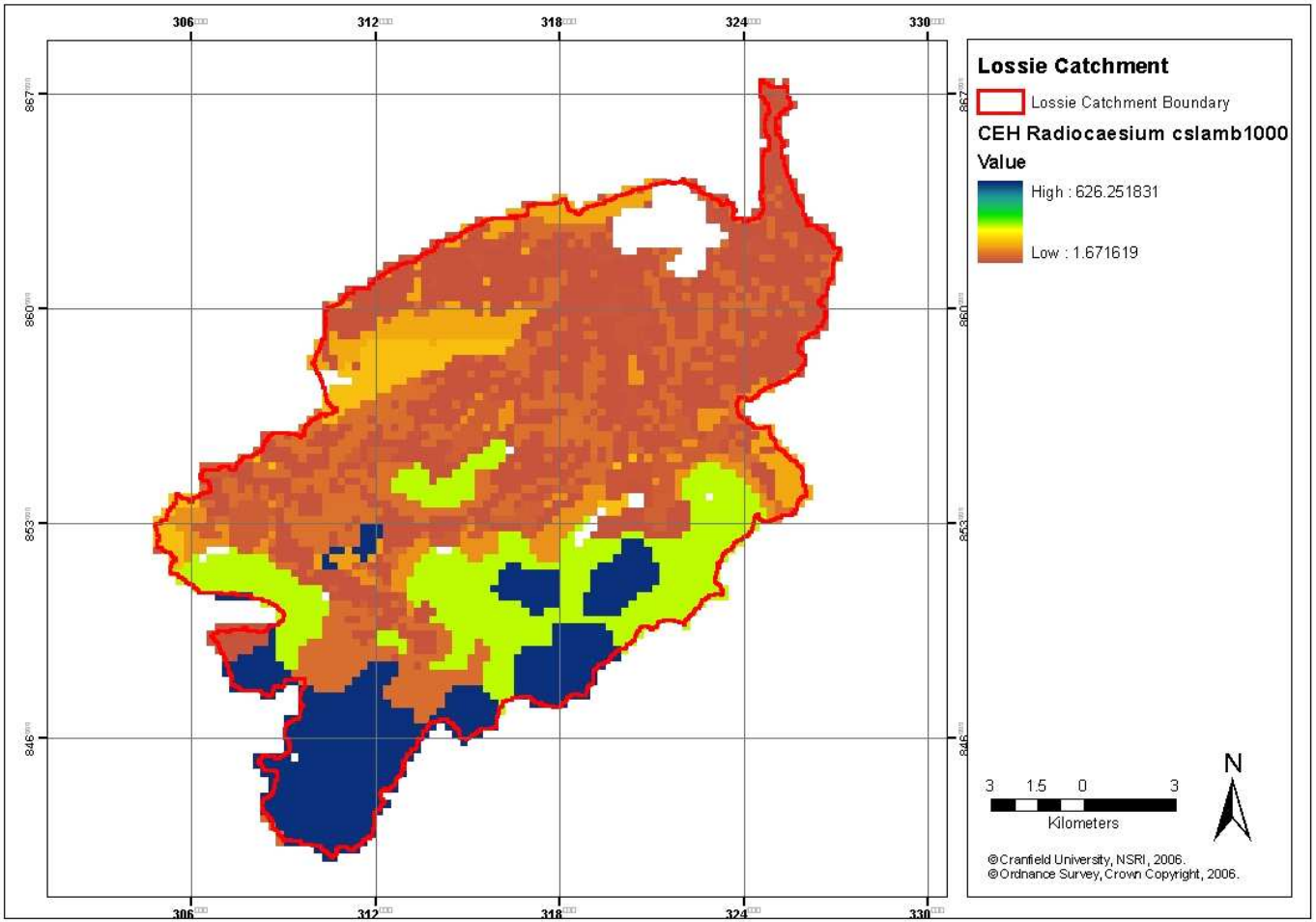

Figure 3.2.32: Radiocaesium concentration (Bq kg^{-1}) in lamb 1000 days after fallout for the Lossie catchment

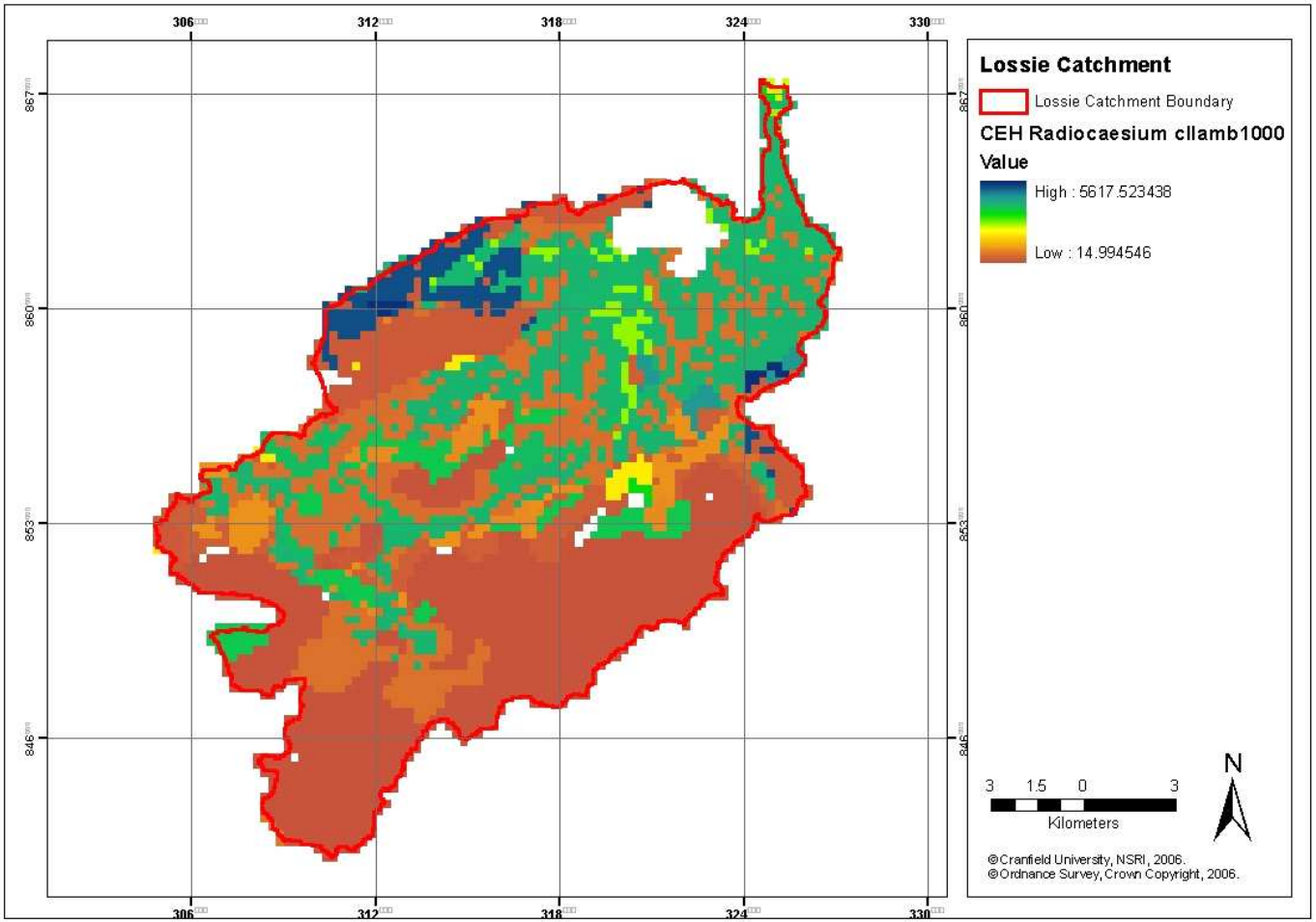

Figure 3.2.33: Critical Load (Bq m^{-2}) of radiocaesium for lamb 1000 days after fallout for the Lossie catchment

Metal binding capacity

Organisation: Macaulay Institute (modified from Blume and Brummer 1991)

Date: 1991 (original), 1997 (modification)

Objectives

- To assess the metal binding capacity of different soils for different metals

Methodology

The model is a weighted parametric classification and consists of a series of look-up tables that allows the user to 'score' a number of soil attributes and to ultimately arrive at a total score. This total score is then translated into a textual description of relative binding class; six classes have been identified ranging from very strong to no binding capacity. The table below illustrates two worked examples.

	Soil A	Soil B
pH ($CaCl_2$) of topsoil	6.1	4.9
Binding strength score	*4.5*	*2.0*
Organic matter content (%)	9	6
Binding strength score	*0.5*	*0*
Topsoil texture	Sandy clay loam	Loamy sand
Binding strength score	*0.5*	*0*
Topsoil colour (surrogate for iron oxide conc)	7.5YR3/3	10YR3/2
Binding strength score	*0.5*	*0*
Total score	***6.0***	***2***
Binding strength	**Very strong**	**Weak**

Table 3.2.6: Assessment of zinc binding capacity for two contrasting soils

Input requirements

- Soil pH (in CaCl)
- Soil organic matter content
- Soil texture
- Soil clay content
- Soil colour

Results

The model was implemented for the Eden, Tern and Lossie catchments. Figures 3.2.34 to 3.2.45 illustrate the model results for Zinc, Copper, Nickel and Cadmium respectively.

Literature references

Blume, H.P. and Brümmer, G. (1991) Prediction of heavy metal behaviour in soil by means of simple field tests, Ecotoxicology and Environmental Safety, 22, pp. 164-174.

Paterson, E, Towers, W, Lumsdon, DG and Meeussen, JC (1997) Responses of Scottish soils to heavy metal inputs. Scottish Natural Heritage Review No 61, SNH Edinburgh.

Towers, W. and Paterson, E. (1997) Sewage sludge application to land - a preliminary assessment of the sensitivity of Scottish soils to heavy metal inputs. Soil Use and Management, 13(3), 149-155.

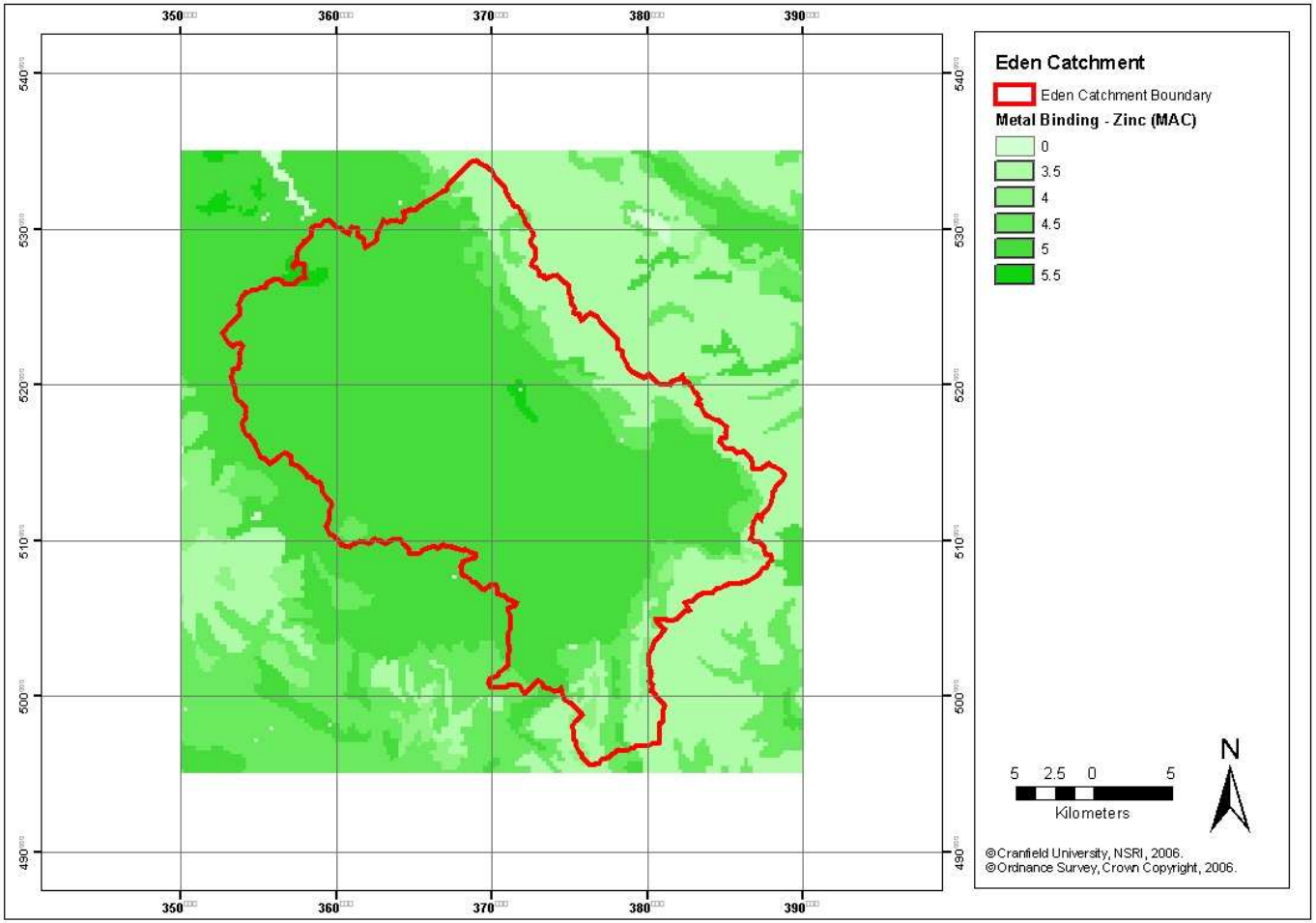

Figure 3.2.34: Metal binding capacity (Zinc) for the Eden catchment

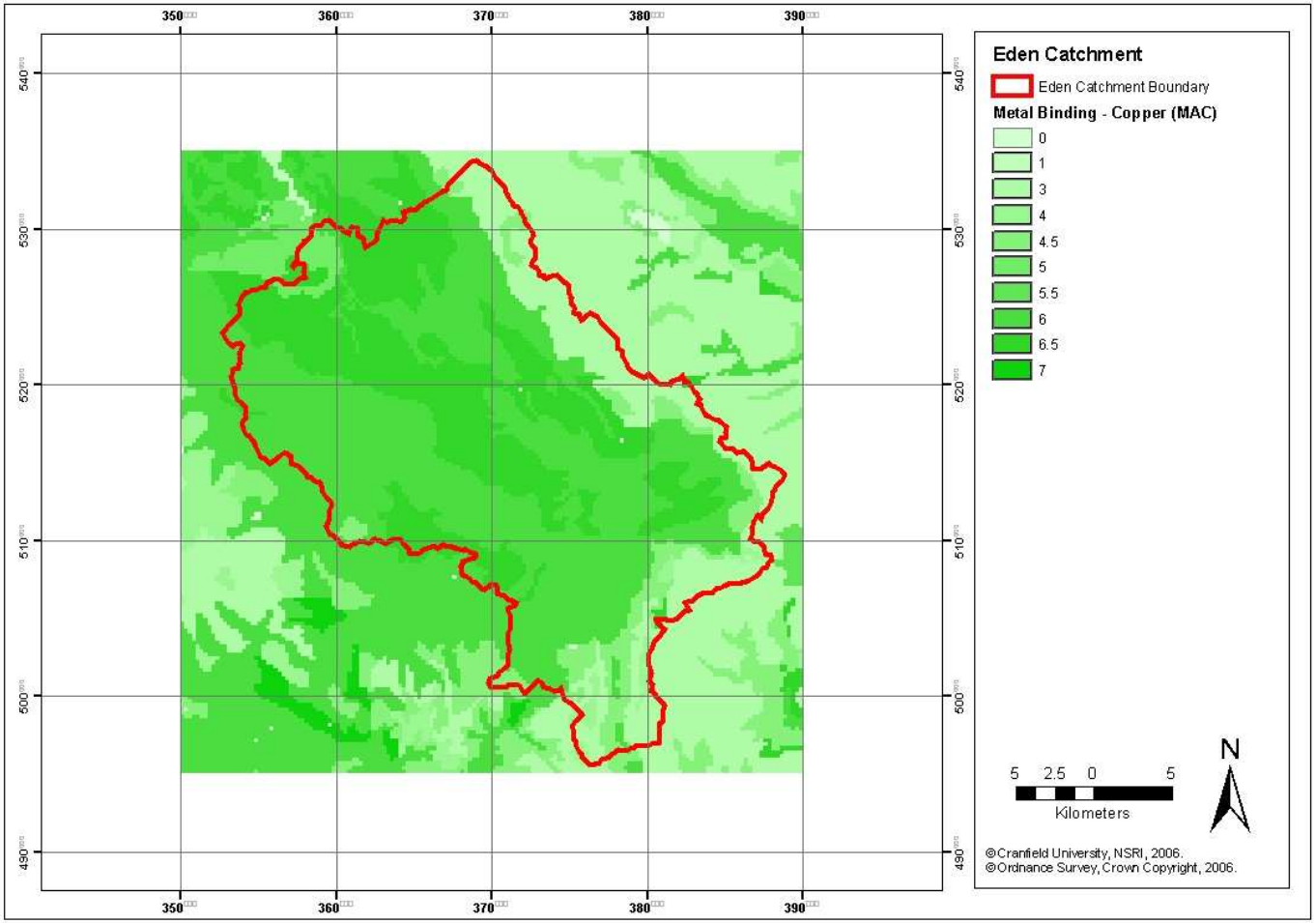

Figure 3.2.35: Metal binding capacity (Copper) for the Eden catchment

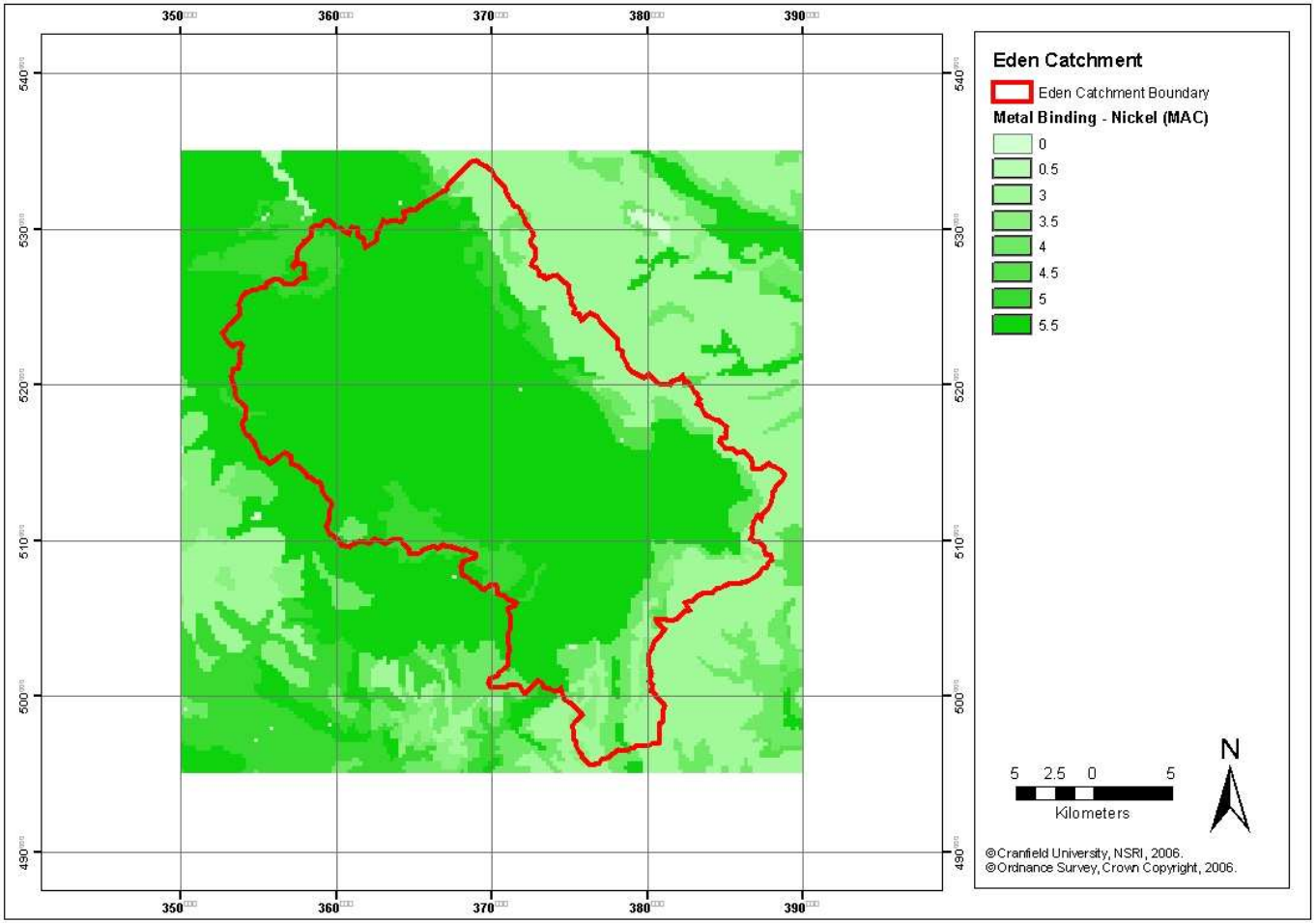

Figure 3.2.36: Metal binding capacity (Nickel) for the Eden catchment

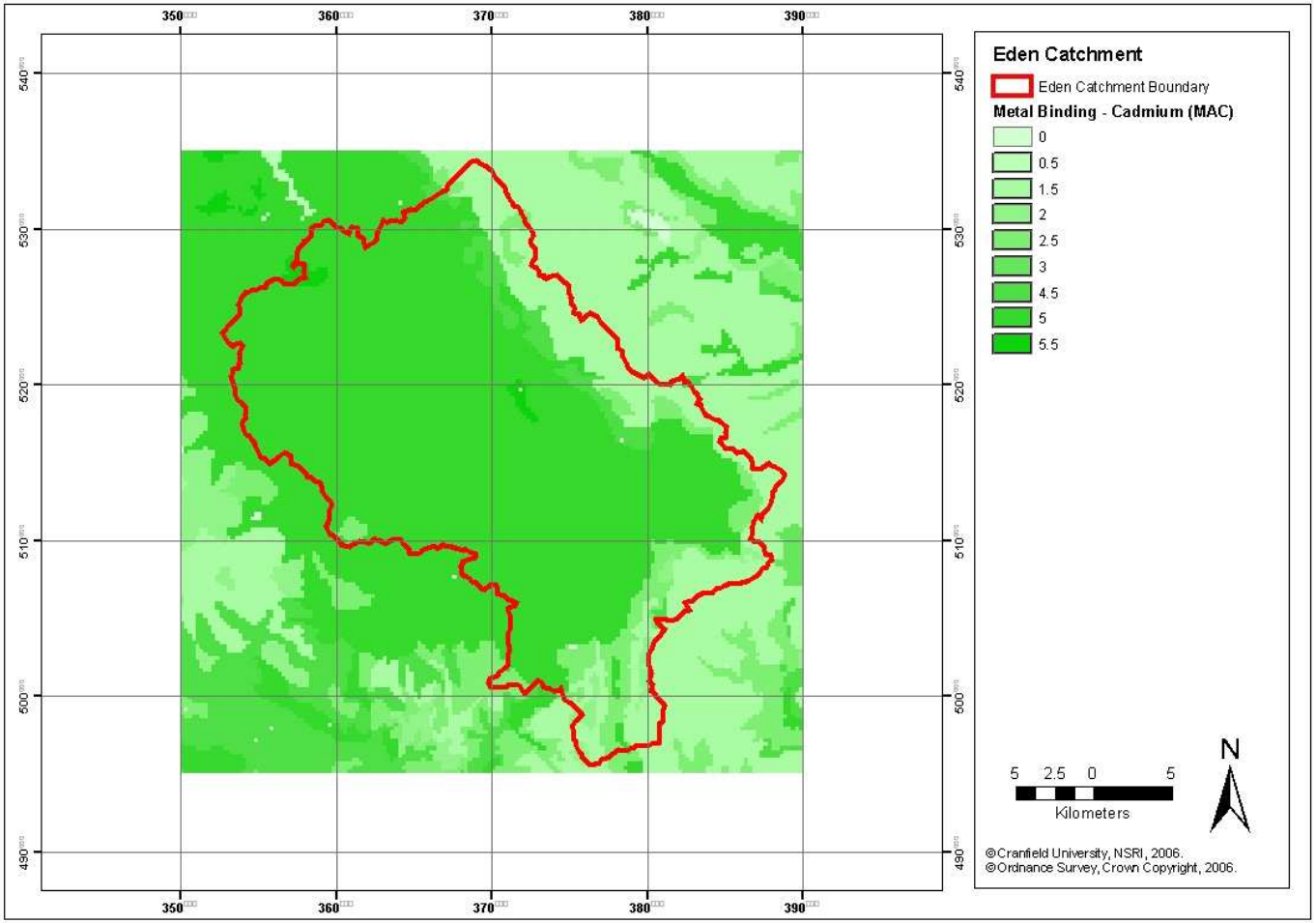

Figure 3.2.37: Metal binding capacity (Cadmium) for the Eden catchment

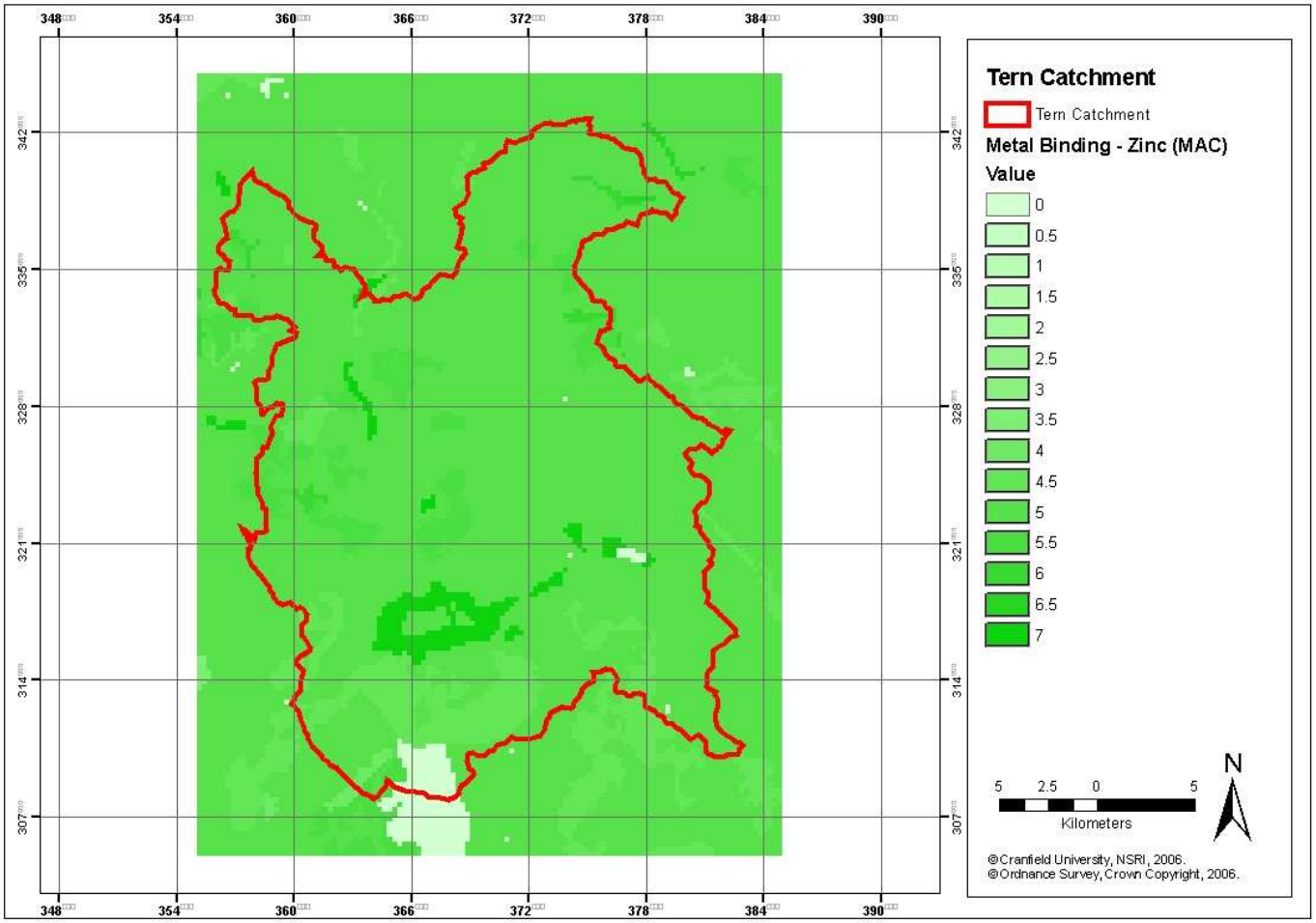

Figure 3.2.38: Metal binding capacity (Zinc) for the Tern catchment

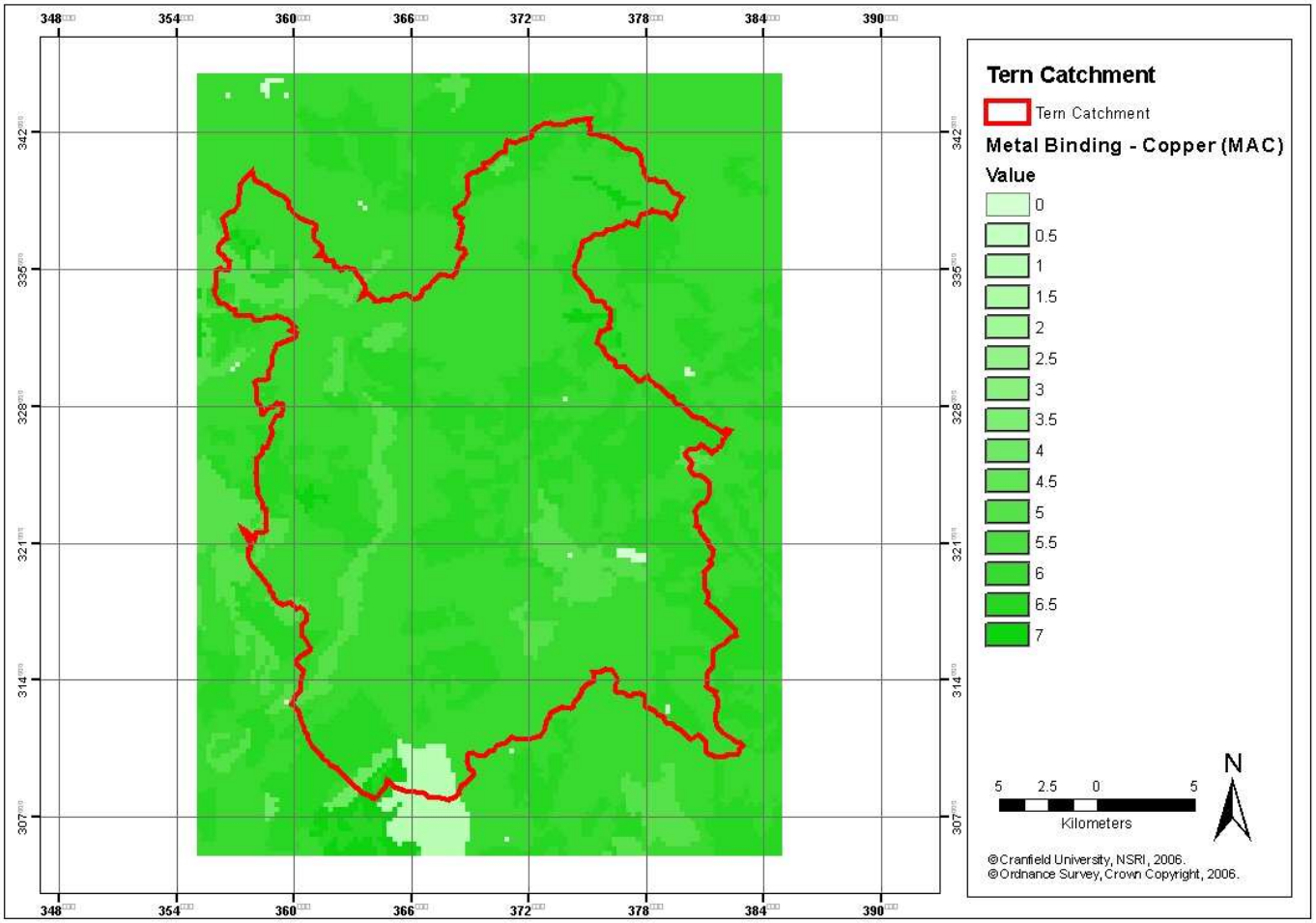

Figure 3.2.39: Metal binding capacity (Copper) for the Tern catchment

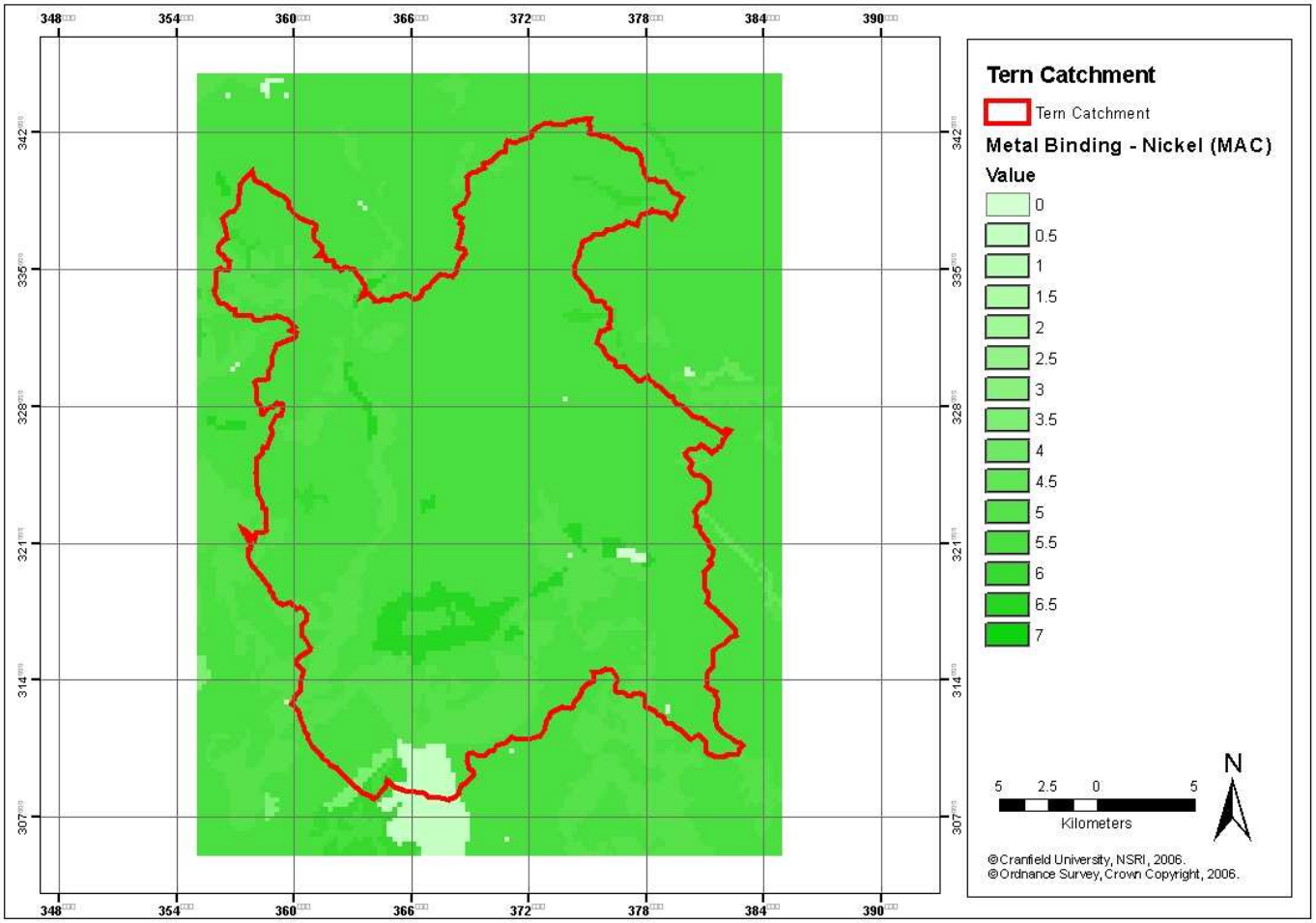

Figure 3.2.40: Metal binding capacity (Nickel) for the Tern catchment

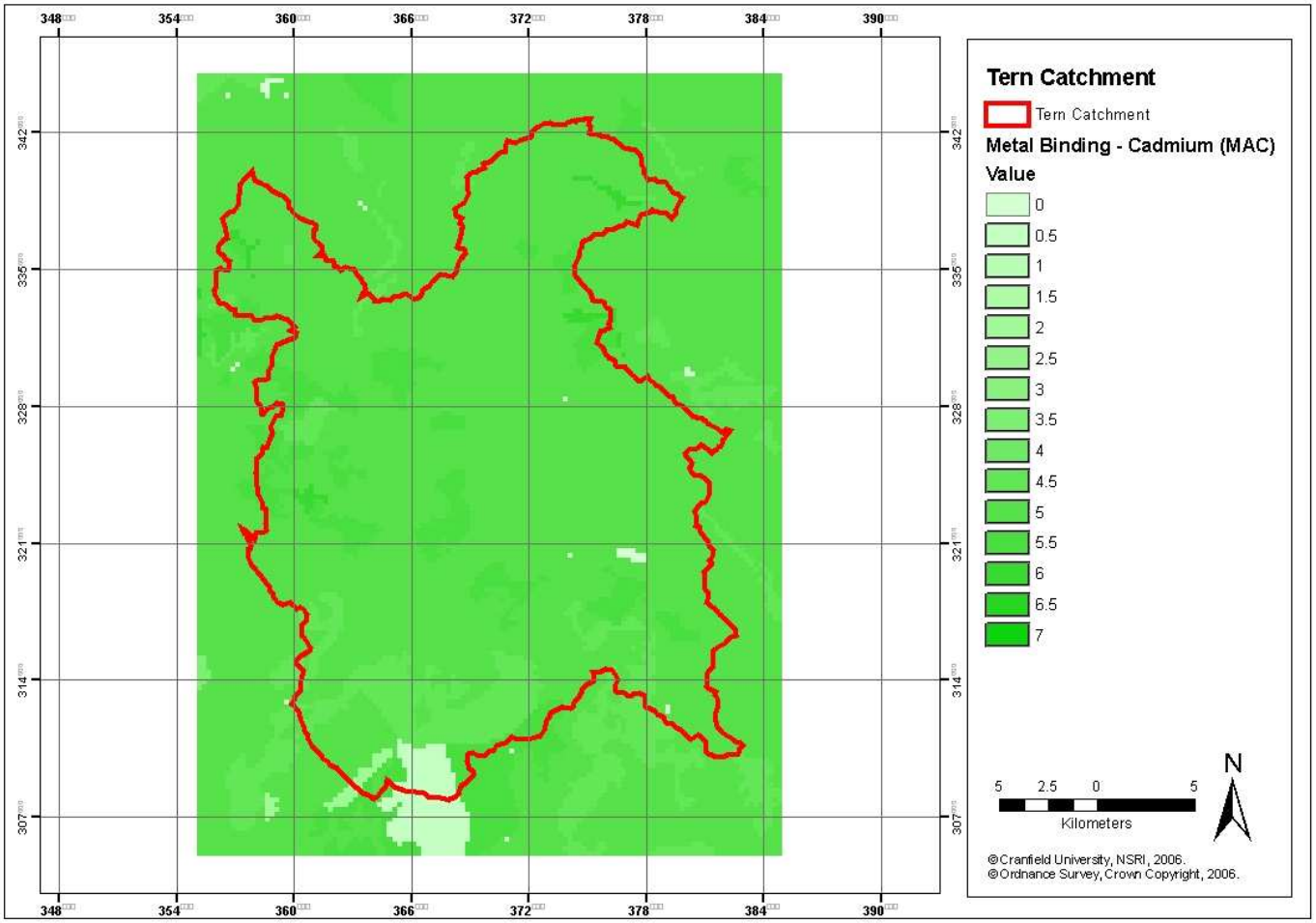

Figure 3.2.41: Metal binding capacity (Cadmium) for the Tern catchment

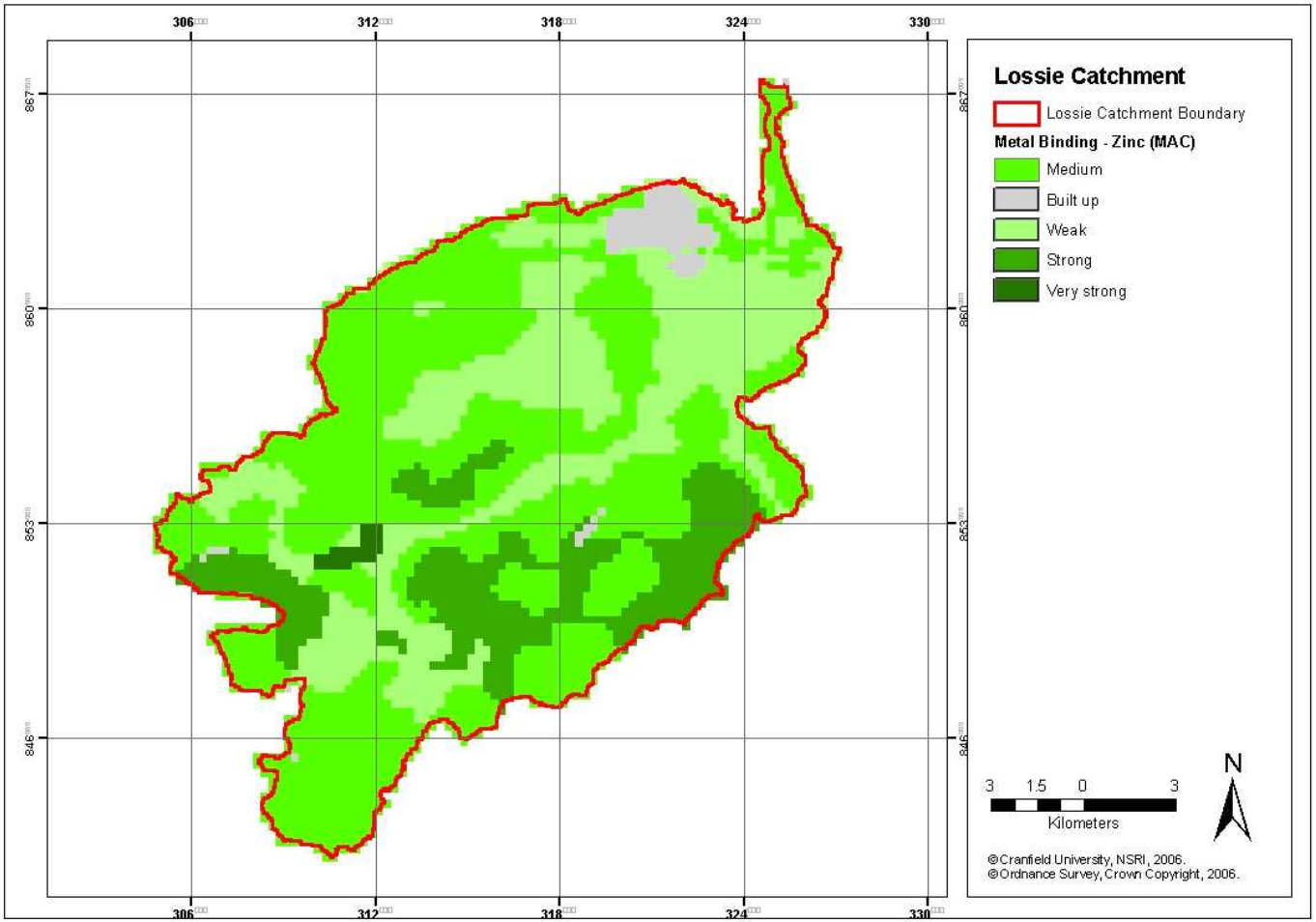

Figure 3.2.42: Metal binding capacity (Zinc) for the Lossie catchment

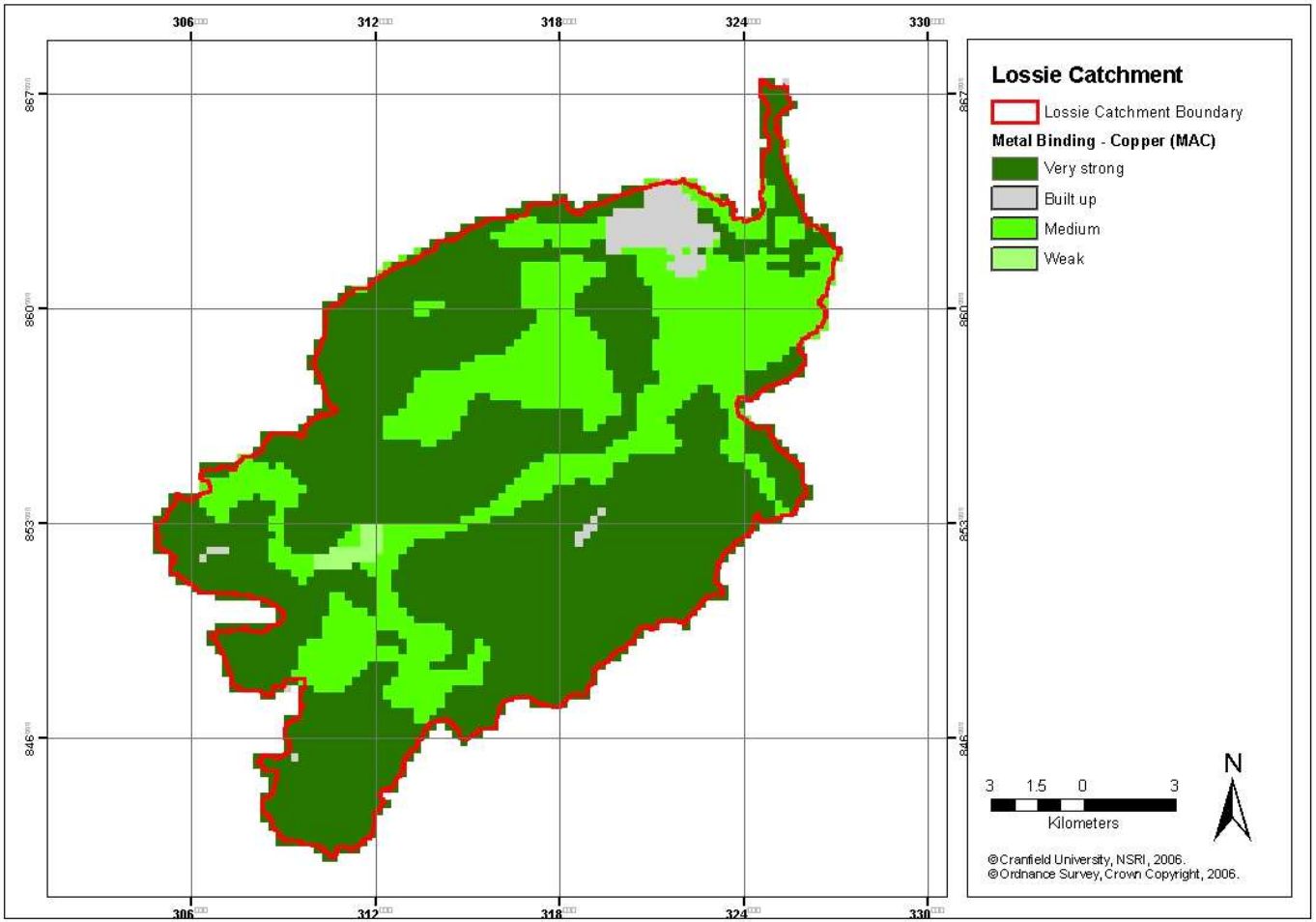

Figure 3.2.43: Metal binding capacity (Copper) for the Lossie catchment

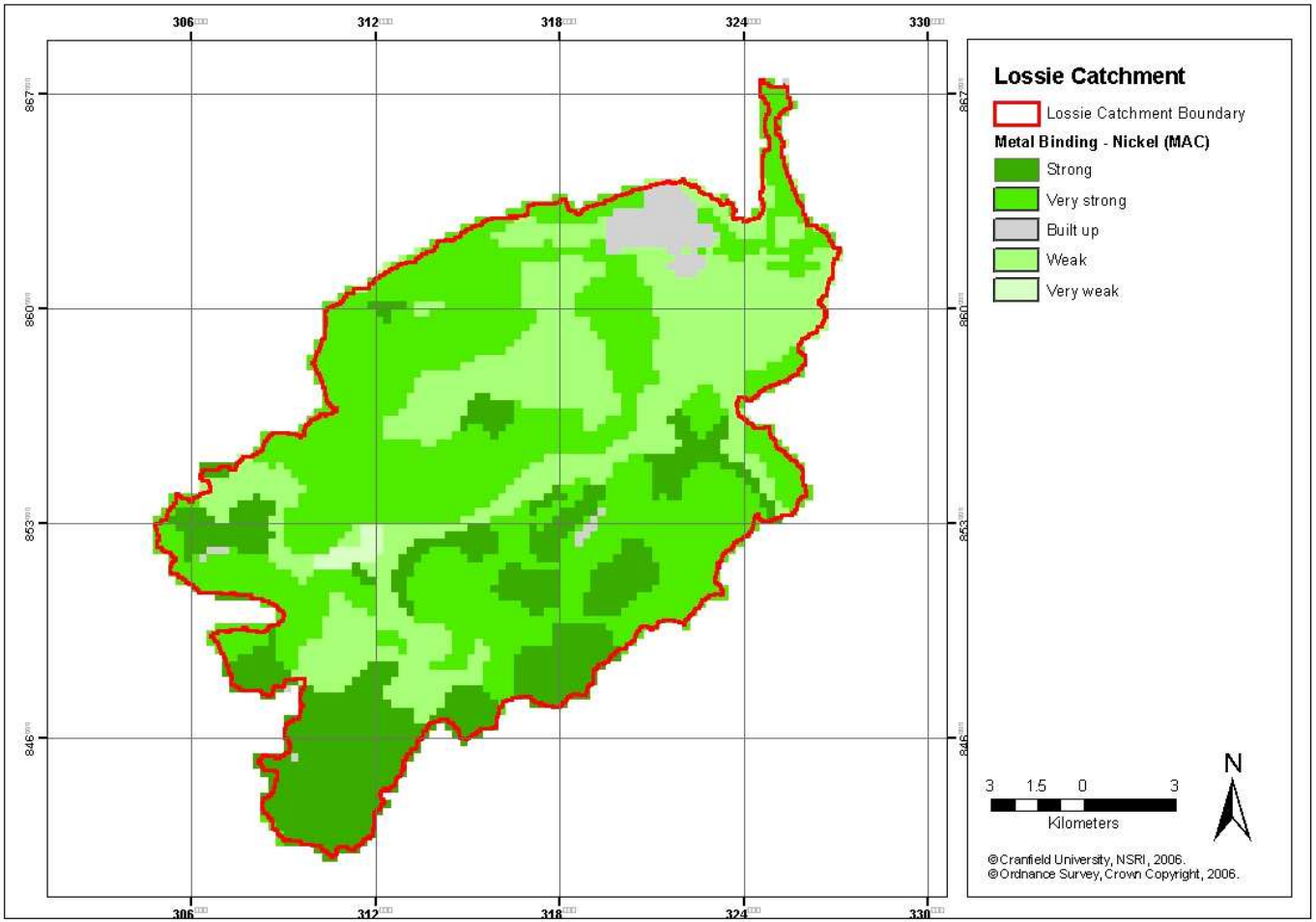

Figure 3.2.44: Metal binding capacity (Nickel) for the Eden catchment

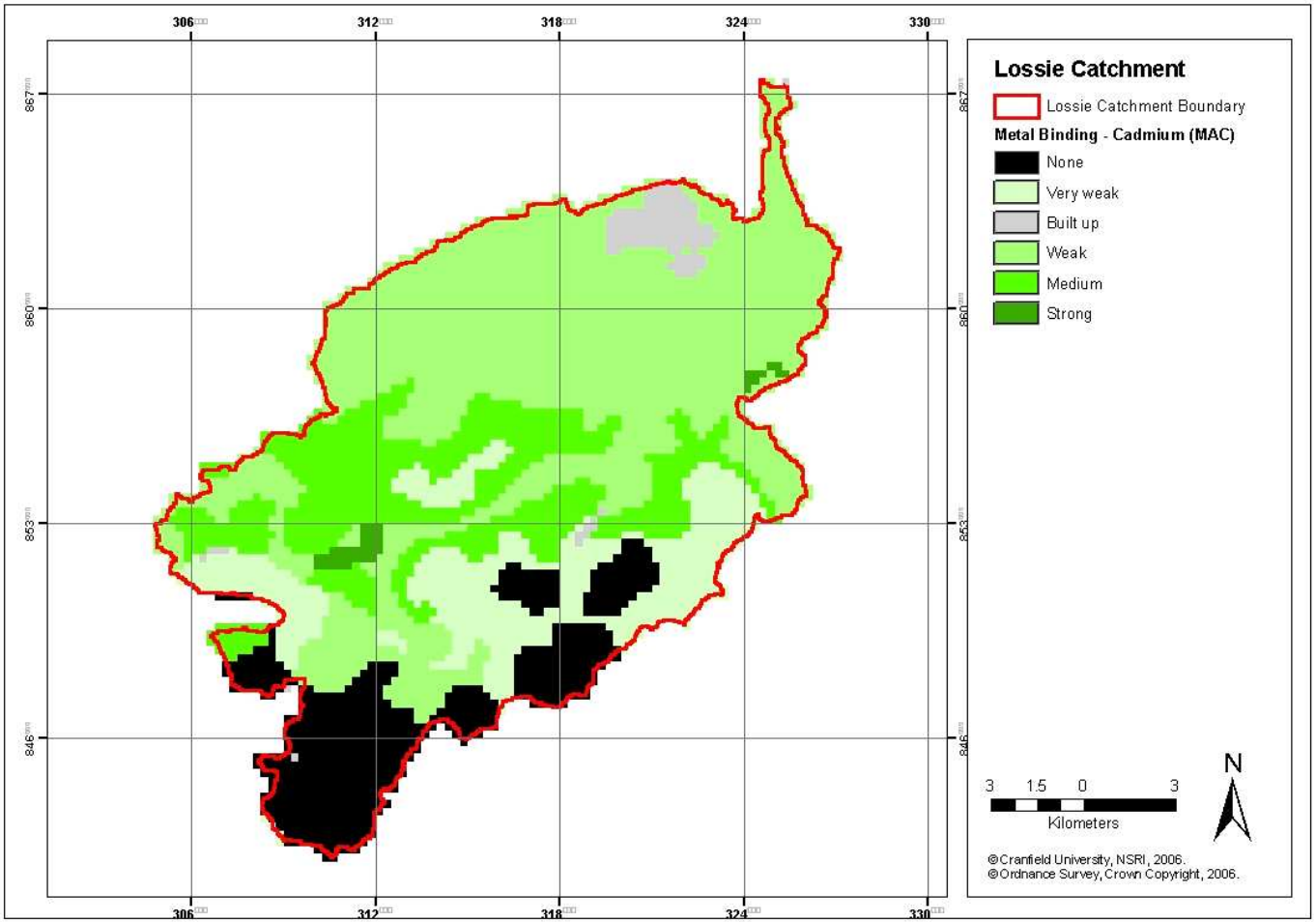

Figure 3.2.45: Metal binding capacity (Cadmium) for the Eden catchment