Project in Natural Resources Management

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TARGETING CRITICAL AREAS FOR NON POINT SOURCES EUTROPHICATION

Introduction

Eutrophication of lakes and rivers, and even the sea, has grown into a major environmental problem (SNV, 1988; Ryding and Rast, 1989). It is widely accepted that eutrophication is dependent on the limiting nutrient concept with nitrogen and phosphorus primarily responsible. The source of those nutrients today is in most places non point leakage from agriculture, forestry and urban areas (as stormwater), and not point sources (e.g. Rekolainen, 1989; Beaulac and Reckhow, 1982; Baker, 1992; Högelin, 1994). In order to achieve the greatest improvement of impaired water resources, targeting critical areas for non-point source areas using Geographical Information Systems is increasingly used (e.g. Sivertun et al, 1988; Tim et al., 1992; Lilja and Suska, 1994, and references therein). Mitigation by ecotechnology, including wetland and riparian zone restoration can be used for a holistic restitution (e.g. Gumbricht et al, 1996[1]). Several recent studies have concluded such solutions to be economically feasible (Fleischer et al., 1991; Gren, 1993)

Objective

The objective of this project is to target critical source areas for non point leakage of nitrogen and phosphorus and suggest management mitigation. The targeting is based on an integrated landscape concept considering hydrological and hydrochemical processes, and is implemented using GIS and an expert system as tools. After completing the project you shall have acquired knowledge about factors determining non-point source pollution of nitrogen and phosphorus. You shall also have improved your skills in GIS analysis and learned about expert systems. You shall have become familiar with how to write a scientific report.

To improve your cognitive capacity, different unstructured problems are offered for optional study. Subjects to study include applying and evaluating an alternative GIS-method for targeting critical areas. Wetland and riparian zone restoration are popular means to mitigate non point source pollution, you can thus choose to dig deeper into this subject by a) literature studies, b) implementing a scenario of restoration in your study area, and compare its hypothetical effect with that of the original scenario. You can develop a GIS tool for finding good spots for wetland restoration, including consideration of hillslope feeding areas. A demanding, but interesting task is to evaluate the model performance based on field data (i.e. collected in Environmental Data). A more policy oriented problem is how society should act to manage surface water quality, either from a planning perspective, using EIA, or by economic and legal tools. The economic feasibility of ecotechnological solutions for mitigation of non-point sources is also a possible subject.

Background

Phosphorus is not very mobile in soil, it is readily immobilised by sorption and precipitation reactions with aluminium, iron, manganese, calcium and clay minerals (Lindsey, 1979; Pionke

[1] Can be found under G:\KURSER\AOM\1B1636\NRM\ARTICLES\Urbwien96.doc

and Urban, 1985; Gumbricht, 1993a). Thus many studies show that phosphorus losses correlate with erosion rates and surface runoff (Maas *et al*, 1985; Andersson, 1986; Pionke *et al*, 1988). Also plant washoff is suggested to be an important source for P-runoff (cf. Pionke *et al*, 1988).

Factors affecting P-loss rates through erosion thus include rainfall intensity, soil-type, vegetation (type and cover) and slope. When studying loads to aquatic environments also distance to the watercourse along the flow path is important (Wischmeier and Smith, 1978; Maas *et al*, 1985). Surface runoff generation in temperate climate mainly depend on precipitation and infiltration capacity and occur almost exclusively in the discharge area (Grip and Rodhe, 1985, Rodhe, 1987; Gumbricht, 1992[2]). In arid regions, hortonian runoff (rainfall intensity exceeding infiltration capacity) also contribute to surface runoff and thus erosion. Keeping a riparian vegetated strip adjacent to the water course is reported to eliminate phosphorus leakage to the water course by sedimentation and deposition (Peterjohn and Correll, 1984; Cooper and Gilliam, 1987; Smith, 1989; Baker, 1992).

Nitrogen in the form of nitrate is a conservative tracer, and thus readily follow the path of the water (Wellings and Bell, 1980; Pionke and Urban, 1985). Nitrogen is removed from the soil-water sphere by biological and biochemical processes, i.e. ammonification, assimilation and denitrification (cf. Gumbricht, 1993). Under anaerobic conditions in fine textured soils, ammonification is almost complete (Andersson, 1986). The ammonia formed is largely adsorbed to soil particles and immobilised. Assimilation can also be significant in the root-zone and denitrification can be high in fine textured soils if readily mineralisable carbon is available (as energy source). Several studies report riparian zones and wetlands to be important ecotones for denitrification (Lowrance *et al*, 1984; Cooper *et al*., 1987; Cooke and Cooper, 1988; Pinay and Decamps, 1988; Cooper, 1990; Lowrance, 1992). Most studies indicate that a zone of 30 meters is able to reduce the substantial part of nitrate before reaching the open water. In coarse soils with high hydraulic conductivity (aquifers) denitrification mainly takes place in the seepage zone in the discharge area, and is of significance mainly under baseflow conditions (Slater and Capone, 1987; Cooke and Cooper, 1988). As convex slopes directs the water flow through the seepage zone, this slope type promotes denitrification. However, since surface runoff only contain small amounts of nitrogen, usually the concentration in baseflow is higher (Pionke *et al*, 1988). Nitrogen leakage is thus greater from coarse-textured soils than from clayey soils owing to their poorer water retention ability, higher infiltration capacity and less efficient nutrient uptake (Andersson, 1986).

More recent research have pointed at the importance of the landscape structural pattern (matrix of patches and corridors of different ecosystems and their boundaries - ecotones) for the degree of spatial closure of matter fluxes (Ripl, 1995; Gumbricht, 1995[3]; Gumbricht et al., 1996[4]). Landscape restitution should hence emphasise phase related management of biologically communicating interfaces. Potential spatial structures relating to communication processes include:

- vegetation cover, density and distribution,
- spatial use (including distance to open water) and fragmentation,
- hillslope profile and flow path (direction, velocity and system order),
- upstream area,

[2] Can be found under G:\KURSER\AOM\1B1636\NRM\ARTICLES\NHK92.doc

[3] Can be found under G:\KURSER\AOM\1B1636\NRM\ARTICLES\Cracow.doc

[4] Can be found under G:\KURSER\AOM\1B1636\NRM\ARTICLES\Urbwien.doc

- ecotone length and direction to hillslope.

This suggests that targeting critical leakage areas should consider contextual conditions, especially of vegetation cover. The high degree of complexity and non-linearity involved in evaluating such spatial patterns necessarily leads to conceptual modelling and heuristic pattern recognition (cf. Gumbricht, 1995 and Gumbricht et al., 1996). In this project, however, we will stick to a more traditional cause-effect model. By using a simple expert system knowledge of integrated effects of soil, slope, vegetation cover and distance to open water will be combined for an evaluation of leakage susceptibility. The expert program is described in appendix 6.

Simple cause-effect models for predicting nutrient leakage from arable land developed for a GIS environment can be found in Sivertun et al (1988) and Tim and Jolly (1994). Vieux and Needham (1993) discusses sensitivity to grid-cell size for such models. Xiang (1993) discusses a GIS method for riparian water quality buffer generation.

Stormwater runoff from exploited areas that is normally not treated before reaching the recipient contain large amounts of both nitrogen and phosphorus (Malmquist, 1983; Falk, 1986). As the exploited area generally is directly connected to the recipient through a pipe system, only the type of exploited area and precipitation matters, distance to watercourse and slope is irrelevant (Table 1).

Table 1 Direct runoff generation as storm flow from areas of different exploitation, and average concentration of total nitrogen and total phosphorus in stormflow runoff (modified after Falk, 1986).

Type of area	Hard surfaces (%)	Direct runoff (%)	Nitrogen (mg/l)	Phosphorus (mg/l)
Industrial commercial	90	80-100	2.0-3.0	0.4
Traffic areas	90	80-100	2.0-2.5	0.3
Dense block of flats	40	60-70	2.0	0.3-0.4
Sparse block of flats	30	60-70	2.0	0.3-0.4
Family houses with large gardens	20	50-60	1.75-2.0	0.3
Family houses with small gardens	10	50-60	1.75-2.0	0.3

Compulsory task

Your task is to produce two maps showing susceptibility to leakage of nitrogen and phosphorus for a selected area (watershed) in the map Stockholm 10 I SV. You shall use an integrated expert approach where combined landscape elements forms a base assessment map

(BAM) (appendices 1 and 2). Inference of element composition is done in an expert system (GUIDE - appendix 6; Chmiel and Gumbricht, 1996[5]). The BAM shall be graded into relative categories of susceptibility to leakage, and the absolute leakage roughly estimated based on empirical figures (appendix 5). The result shall be presented in an article where you should also discuss the problem of nutrient leakage and suggest mitigating measures for your watershed. Chosen method and assigned values have to be defended by some documented hypothesis (reference or your own ideas). In appendix 4 you find some help for how to go ahead in front of the computer.

Optional subtasks

An optional subtask is requested to receive a higher grade. There is no detailed help given for solving subtasks. The intention is that you should find the necessary information yourself. We suggest that you start by reading the instruction text, and seek for references that can help you. If you have any specific questions, please come and ask. You can choose from the following subtasks:

- Use a different methodology, e.g. the Universal Soil Loss Equation USLE (appendix 3), to find critical areas for phosphorus leakage. Compare and evaluate the outcome of the two methods.

- Dig deeper into the mitigation measures you have suggested by literature studies, and evaluate the different techniques for the climatic conditions in Sweden or your native country.

- Implement the mitigation strategies that you have considered into your study area by creating a new scenario in IDRISI (i.e. change landuse). Analyse and evaluate the non point source loading in this scenario compared to your original results (use appendix 5).

- Construct a GIS model that identifies the potentially best spots for wetland and/or riparian zone development, taking into consideration upslope feeding areas (i.e. the hillslope). It is also possible to analyse and evaluate the result of this scenario by applying your expert rules for classification on the managed landscape.

- Evaluate your model result(s) against the field data of conductivity that you sampled in the Environmental Data course. To do this you must work with sub basins 13 or 14 (in <subwshed>). For each sample point (found in <ed95ec>) a statistical evaluation of the upstream conditions are needed (several approaches possible - see above). Delineation of upstream areas can be done either manually, by the IDRISI program *watrshed* (which however is rather poor in performance) or using a separate (windows) program *updrain* (found under P:\DOS\IDRISI\UPDRAIN\). Compare upstream encoded pattern with the conductivity (e.g. by visual inspection or statistical analysis - cf. Gumbricht et al., 1996).

- A more policy oriented task is to study how different countries have chosen to tackle surface water quality problems (e.g. eutrophication). Sweden has adopted a planning perspective, now combined with evaluations of natural background levels compared to present situation (Gustafsson, 1992). In Germany static levels have been set according the use of water (categorised into 4 levels of quality needs), and financed via fees for discharge and water use (Gumbricht, 1991). In France they have democratic system based on water users, officials and politicians, who decide on desired goals and puts fees and taxes accordingly (Gustafsson, 1989).

[5] Can be found under G:\KURSER\AOM\1B1636\NRM\ARTICLES\guide.doc

You can chose to evaluate those systems, perhaps in relation to the Brundtland commission (WCED, 1987) or Agenda 21. Several articles on those subjects can be found in e.g. Stockholm Water Symposia proceedings. For instance Gumbricht (1993b) discusses barriers to be overcome for implementing a holistic management for preserved landscape sustainability and protection of water resources.

- Using Environmental Impact assessment (EIA) is commonly a way to avoid changes in a non-sustainable direction. Thus you can study the use of EIA combined with a drainage basin approach applied to nutrient leakage (Balfors, 1994). Evaluate the project applicability of the project approach for use in EIA.

- Evaluate the economic feasibility of applying ecotechnological solutions for non-point source mitigation.

You are welcome to discuss the topics. The optional subjects will be central topics of the final oral NRM-seminar.

The project must be reported in a written paper. Your subtask should be presented as an interwoven part in the paper. Use times roman, size 12, with double spacing and margins on all sides of 2.5 cm. The paper should contain the following:

Title	
Abstract	
Key words	
Introduction	Why did you start?
Material and methods	How did you do it?
Results	What answer did you get?
Discussion	What does it mean?
References	Written as in this instruction!

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Appendix 1

A suggestion for classification of combined landscape elements according to susceptibility to P-leakage. Table headings indicate vegetation cover and distance to watercourse.

Table 1:1 P-susceptibility, exploited areas[1]

Exploitation	Low and sparsely	middle	High and traffic
Landuse category	8	7	6
Class	intermed.	high	very high

Table 1:2 P-susceptibility, uncovered (category 1)[2] *, distance < 100 meter (category 1)*[3]

slope	flat	modest	steep
soil category	0-2°	3-5°	>5°
1 clay/silt	high	very high	very high
2 sand	intermed.	high	high
3 gravel	intermed.	high	high
4 till	high	high	very high
5 organic	low	high	high
6 rock	low	low	low

Table 1:3 P-susceptibility, partly covered, distance < 100 meter

soils\slope	flat	modest	steep
1 clay/silt	intermed	high	very high
2 sand	low	intermed.	high
3 gravel	low	low	intermed.
4 till	intermed.	intermed.	high
5 organic	very low	low	low
6 rock	low	low	low

Table 1:4 P-susceptibility, covered, distance < 100 meter

soils\slope	flat	modest	steep
1 clay/silt	low	intermed.	high
2 sand	low	intermed.	high
3 gravel	low	low	intermed.
4 till	low	intermed.	high
5 organic	very low	low	low
6 rock	low	low	low

Table 1:5 P-susceptibility, uncovered, distance 100-400 meter

soils\slope	flat	modest	steep
1 clay/silt	intermed.	high	very high
2 sand	low	intermed	high
3 gravel	low	low	high
4 till	intermed.	intermed	high
5 organic	very low	low	low
6 rock	very low	very low	very low

Table 1:6 P-susceptibility, partly covered and covered, distance 100-400 meter

1 Reclassified from <landuse>

2 Partly covered = landuse category 2, covered = landuse cat.3

3 100-400m = distance cat.2, > 400m = cat.3

soils\slope	flat	modest	steep
1 clay/silt	intermed	high	high
2 sand	low	low	intermed
3 gravel	very low	very low	low
4 till	low	?	?
5 organic	very low	?	?
6 rock	very low	very low	very low

Table 1:7 P-susceptibility, partly covered and uncovered, distance > 400 meter

soils\slope	flat	modest	steep
1 clay/silt	low	?	?
2 sand	very low	very low	very low
3 gravel	very low	?	very low
4 till	very low	?	very low
5 organic	?	very low	very low
6 rock	?	very low	very low

Table 1:8 P-susceptibility, covered, distance > 400 meter

soils\slope	flat	modest	steep
1 clay/silt	?	?	?
2 sand	?	?	?
3 gravel	very low	very low	very low
4 till	very low	very low	very low
5 organic	very low	very low	very low
6 rock	very low	very low	very low

Appendix 2

Classification of landscape elements according to susceptibility to N-leakage. The table headings indicate vegetation cover and distance to watercourse.

Table 2:1 N-susceptibility, exploited areas

Exploitation	Low and sparsely	middle	High and traffic
Landuse category	8	7	6
Class	intermed.	high	very high

Table 2:2 N-susceptibility, uncovered (category 1)[1] , distance < 100 meter (category 1)[2]

soils\slope	flat	modest	steep
1 clay/silt	intermed.	intermed.	high
2,3 sand,gravel	high	very high	very high
4 till	intermed	intermed	high
5 organic	intermed	intermed	intermed
6 rock	very high	very high	very high

Table 2:3 N-susceptibility, partly covered, distance < 100 meter

soils\slope	flat	modest	steep
1 clay/silt	low	low	intermed
2,3 sand,gravel	intermed	high	high
4 till	low	low	intermed
5 organic	intermed	intermed	intermed
6 rock	high	high	high

Table 2:4 N-susceptibility, covered, distance < 100 meter

soils\slope	flat	modest	steep
1 clay/silt	very low	very low	low
2,3 sand,gravel	low	intermed	intermed
4 till	very low	very low	low
5 organic	intermed	intermed	intermed
6 rock	low	low	low

Table 2:5 N-susceptibility, uncovered, distance 100-400 meter

soils\slope	flat	modest	steep
1 clay/silt	low	low	intermed
2,3 sand,gravel	intermed	high	high
4 till	low	low	intermed
5 organic	intermed	intermed	intermed
6 rock	high	high	high

[1] Partly covered = category 2, covered = cat. 3
[2] 100-200m = cat. 2, > 400m = cat 3

Table 2:6 N-susceptibility, partly covered and covered, distance 100-400 meter

soils\slope	flat	modest	steep
1 clay/silt	very low	very low	very low
2,3 sand,gravel	?	low	low
4 till	very low	very low	very low
5 organic	intermed	?	intermed
6 rock	low	?	?

Table 2:7 N-susceptibility, uncovered, distance > 400 meter

soils\slope	flat	modest	steep
1 clay/silt	very low	very low	?
2,3 sand,gravel	very low	low	low
4 till	?	very low	very low
5 organic	intermed	?	intermed
6 rock	low	low	low

Table 2:8 N-susceptibility, partly covered and covered, distance > 400 meter

soils\slope	flat	modest	steep
1 clay/silt	very low	very low	very low
2,3 sand,gravel	very low	very low	very low
4 till	?	?	?
5 organic	?	?	?
6 rock	?	?	?

Appendix 3

The universal soil loss equation (USLE) model (Wischmeier and Smith, 1978; Sivertun et al, 1988). Under p:\DOS\IDRISI\UPDRAIN you will find a windows program (USLE2D) that will improve the USLE calculation of the slope factor. You are very welcome to try it.

Map	Class	USLE	GIS value
Soils (K)	Clay	0.45	5
	Silt	0.38	4
	Sands	0.33	3
	Organic matter	0.30	3
	Gravel/rock	0.20	2
Slope (%) (S)	>7	1.20	12
	5-7	0.78	8
	3-4	0.40	4
	1-2	0.19	2
	0	0.00	1
Landuse (L)	Agric (harvested)	0.10	20
	Agric (covered)	0.05	10
	Urban areas	0.03	6
	Grasslands	0.01	2
	Forests	0.005	1
	Water	0.00	0
Water course (m) (W)	Zone 1 (0-60)	1.00	10
	Zone 2 (60-200)	0.69	6
	Zone 3 (200-1000)	0.30	3
	Zone 4 (>1000)		

USLE value = (K*S*L*W)/4

Appendix 4

Some help in front of the computer

Login to the L server, select DOS and type *eutro_p*. A batch is run that creates the directory h:\eutro under your user containing all the starting files.

Start by selecting a watershed as study area. You find some defined watersheds in the image file <subwshed>. Display this image using *color* and zoom an area covering the watershed that you have selected. In order to save time and computer capacity, create a dataset by using *subset*. Delete all full size images before continuing (or the server might become overloaded - so far it has every year!).

The next step is to create the necessary map-layers for your analysis. If you follow the approaches suggested in appendixes 1 and 2, you must create four new map-layers: one for distance to nearest watercourse, one for slope, one for soil type and one for vegetation cover and exploited areas. The 4 map-layers are summarised in table 4:1. The creation of the new map layers shall be done by a batch programme, using command line syntax for IDRISI. EUTRO.BAT is a batch file that can be used for a start. It is not complete and you have to make changes in it yourself to be able to run it. The batch file can be edited with any editor, for instance edit under IDRISI (must be opened via IDRISI menu system). Choose 8 in the edit menu for creating or editing the batch file. Save the file using F2 when editing.

Table 4:1 Map-layers to be created according to appendixes 1 and 2

Original map-layer (windows from:)	Created map-layer	Classification according to	Classes	Programs used
wcourse + landuse	dist	distance to nearest watercourse	continuous	reclass distance overlay
dtm	slope	slope	continuous	surface
geology	geo	geology	1= clay/silt 2= sand 3= gravel 4= till 5= organic 6= rock	assign (idrsign when in command line)
landuse	cover	vegetation cover and exploitation	1= uncovered 2= partly covered 3= totally covered 4= low and sparsely exploited 5= middle exploited 6= high exploited and traffic	assign (idrsign)

Take a look at the batch file (appendix 7) in order to understand how it works, read the manual or type the command followed by "?" to get information about command line syntax. As you see there are some question marks at certain places in the batch file, you have to replace them with proper syntax. Edit the bat file line by line and look at the created images every now and then, e.g. by typing in the command line syntax for *color* and run the batch program. To run the program just type the name of the batch file at the command line. The

"REM" in front of the syntax must be deleted, otherwise the program on that line will not be run.

The first step in the batch file considers calculation of distance to nearest water course. The proximity analysis tool *distance* must be used on two different map layers, <wcourse> and a *reclass* of <landuse> only containing water. These layers are merged together by *overlay*. To create the raster file containing slopes *surface* is run. The reclassifications of <geology> and <landuse> are done by *assign* (*idrsign* in command line). The different categories of landuse and geology can be viewed in *describe,* or use *edit* on the document (.doc) files. Use *edit* to create two integer values files, one for landuse and one for geology, according to the classes stated in table 4:1.

Now you should have four map-layers corresponding to the classification in appendixes 1 and 2 (and thus table 4.1). It is time to think the final analysis through. We suggest that you create two files with rules that can be used with the programme *guide*. The advantage with *guide* is that you can easily change or correct your algorithm.

Given that your 4 map-layers are constructed as stated in table 4:1, the files with rules could look like the files P-GUIDE and N-GUIDE respectively. Those files will run the analysis as it is stated in tables 1 to 5 in appendix 1 and 2 respectively (i.e. you have to construct the algorithm and fill the empty cells for tables 6 to 8). Beware that the file names and categories in the two files are set according to table 4:1 (appendixes 1 and 2). Include only the parts of the guide files you have written yourself in the report.

Read about *guide* in appendix 6 and complete p-guide and n-guide. Run *guide* outside the batch program to make sure that it works. Command line syntax for *guide* is described in appendix 6. Then it is time to mask out everything except your watershed, and to put water into your images. Reclass <subwshed> to category one for your selected area, and zero for remaining areas. Then mask out the chosen watershed using overlay. Use similar steps to put water into your image. Run histo to get statistical information for your report.

When you are satisfied with your images, export them as bitmaps by using *img2bmp* or *hijack* them. Start by creating a good grey scale image (5 to 6 tones can be distinguished in the printout), and save the palette. Export your images with that palette. If you want to create a legend using *img2bmp*, use *legend.* The images can now be imported and edited in word. Alternatively, use IDRISI for Windows.

Appendix 5

Quantitative interpretation of the classes in appendixes 1 and 2

Class	P-leakage kg*ha-1yr-1	N-leakage kg*ha-1yr-1
1 Very low	<0.1	<5
2 Low	0.1-0.25	5-10
3 Intermediate	0.25-0.5	10-25
4 High	0.5-1	25-50
5 Very high	1-2	50-100
6 High exploited	1-2	25-50
7 Middle exploited	0.5-1	10-25
8 Low exploited	0.25-1	5-10

The table is valid only in South Eastern Sweden where rainfall is approximately 500-700 mm yr.-1 and deposition of nitrogen is approximately 15 - 30 kg ha-1 yr.-1.

Appendix 6

Guide

The program "GUIDE" is an inference tool which can be used for knowledge based classification of raster images. *Guide* outputs a raster map layer where the category values represent the application of user specified criteria (statements). *Guide* can also produce map layers showing likelihood of correct classification based on fuzzy statements. *Guide* is supported by MS-DOS and is adapted to IDRISI format.

Guide requires as input a file with knowledge based statements where the different input map layers are combined. A new raster map is created as output, and the category values of this map reflect the ability of each pixel in the named input layers to satisfy the user-given conditions.

The conditions are either typed into an ascii file by the user using an editor, or by using training data and the program "PINGUIDE" (see below). The file with the conditions (the guide-file) has to have a very precise form in order to work. *Guide* either works after a best fit or hierarchical classification. The best fit way is used in the fuzzy mode, where the statement with highest likelihood assigns the cell. In Boolean mode a pixel that has been given a value will keep this value, it can not be changed by a condition further down in the guide-file.

In the fuzzy mode each cell is given a membership function (degree of belonging) associated with each output category (i.e. condition). The category with the highest membership assigns the cell in the final output. In fuzzy mode *guide* also produces an image showing the membership function related to the assigned category for each cell. The user can optionally choose to produce images of membership functions for any (or all) of the output categories. Only linear membership functions are supported (Fig. 6:1).

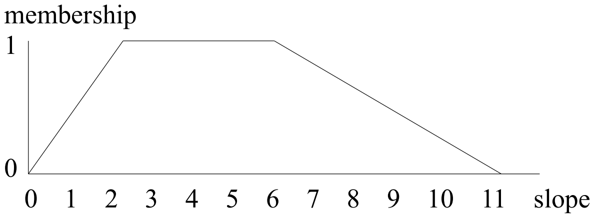

Fig 6:1 Example of fuzzy membership function. Between slopes 2 and 6 the membership is 1, whereas it changes gradually from 0 to 1 between slope 0 and 2 and 11 and 6 respectively. In guide the above fuzzy membership function is written "Whenimg @ 0 2 TO 6 11 Slope", the Boolean logic is written "Whenimg @ 2 TO 6 Slope" (see below).

Guide can handle images of different resolution if they are multiples.

Commands

The following commands are available in *guide*:

command	Followed by	Example - Boolean logic	Example - fuzzy logic
WHENIMG	= category # map	= 3 landuse	= 3 landuse
ALSOIMG	< category # map	< 7 geology	< 7 7 geology
	> category # map	> 30 slope	> 30 40 slope
	@ category# TO category# map	@ 10 TO 40 distance	@ 0 10 TO 40 50 distance
	+ row nr TO row nr	+ 0 TO 150	+ 0 0 TO 150 300
	* column nr TO column nr	* 100 TO 500	* 50 100 TO 500 600
SAVEIMG	# category # category name	# 5 Place with high risk	# 5 Place with high risk

These commands may be used to formulate conditions and statements ranging from simple classification to a more complex expert system type application. Statements are composed of one or more conditions followed by one or more hypothesis and/or conclusions.

WHENIMG-map condition

Map conditions are questions to each cell about the presence of specified map layers' category values. WHENIMG questions each cell in the named map layer about its contents. Cells which satisfy the named condition stated by WHENIMG will be assigned the subsequently stated map conclusion or hypothesis in the new map layer. In the Boolean mode cells which fail to satisfy named map conditions will still be open for assignment and thus questioned for the following condition in the guidefile. If a cell does not satisfy any of the stated conditions the cell will remain unclassified. If images are of different resolution, the first whenimg command must refer to an image with highest resolution. Following whenimg (and alsoimg) commands can be applied to any image.

ALSOIMG -map condition

Works as WHENIMG but must follow after a WHENIMG command or one or more ALSOIMG commands. The first ALSOIMG command in a statement must follow after a WHENIMG command.

SAVEIMG -map conclusion

Finishes each statement and gives each cell a specified category value in the new map layer based on the cell's ability or failure to meet conditions stated above this command in the guide file.

Example - Boolean logic

WHENIMG = 1 6 9 landuse
ALSOIMG < 100 150 200 distance
ALSOIMG < 3 5 8 geology
ALSOIMG @ 2 TO 3 5 TO 8 8 TO 10 slope
SAVEIMG # 4 HIGH RISK

Example - Fuzzy logic

> **WHENIMG = 1 6 9 landuse**
> **ALSOIMG < 100 150 TO 200 250 distance**
> **ALSOIMG < 3 4 5 6 8 9 geology**
> **ALSOIMG @ 1 2 TO 4 5 4 5 TO 8 9 7 8 TO 10 11 slope**
> **SAVEIMG # 4 HIGH RISK**

In the example above each rule contain a vector of 3 values (e.g. = 1 6 9 landuse). *Guide* can use the vectors in a combined mode - any value being true makes the rule true. Or sequential - for the whole statement to become true all values in the same sequential position must become true. The latter approach can be used when there are several subcategories to be classified (e.g. two different kind of agricultural areas). *Pinguide* (see below) creates rules applicable for sequential mode when there are several training areas defined for a single category.

If a line begins with a !-character *guide* will not take that row under consideration when executing the input file.

To start *guide* just type "guide" at the command line, the program then asks for the name of the guide-file and a name for the output image before the classification starts. It should be noted that *guide* requires input files in byte or integer format, and that each map layer only can be used once in each statement.

Command line syntax for *guide:*
1 : x
2 : name of guidefile
3 : output file name
4 : 1=cross fitting mode, 2=position fitting mode
5 : 1=Boolean mode, 2=Fuzzy mode

> e.g. ”guide x n-guide nitrogen 1 1”

PINGUIDE

Pinguide is a tool for pinning down an expert rule ready to be used by *guide*. As input *pinguide* requires digitised vector files identifying training areas to be used for extracting information from the input images. And a textfile identifying training areas and input map layers: *Pinguide* can be used for extracting both Boolean and Fuzzy logic. For both alternatives *pinguide* extracts rules either based on min-max values or mean and standard deviation

3 4
water
agricult
forest
TM3 1 1.0
NDVI 1 1.0
PCA1 1 1.0
Geology 1 1.0

The first line state number of training areas and input maps respectively. The numbers following the input maps indicate type of rule (1 = max-min, 2 = mean-sd) and fractions of span (real number) to be used in setting the fuzziness. Example, if the training area mean value is 6 and its SD = 2, type of rule = 1, and fraction set to 1.0, the fuzzy rule will be Alsoimg 2 4 TO 8 10 (derived as: -2sd+m -1sd+m TO 1sd+m 2sd+m).

The derived rules can be changed by using any text editor.

If the training files contain more than one polygon id, *pinguide* will create rules with multiple values. When running guide the different values can be used in combination or separately.

Appendix 7

REM EUTRO.BAT

REM Removal of the original files (to save memory). Make sure that you have
REM a subset from the original files before you delete the original files!
REM MAINT X 1 1 WCOURSE
REM MAINT X 1 1 LANDUSE
REM MAINT X 1 1 DTM
REM MAINT X 1 1 GEOLOGY
REM MAINT X 1 1 SUBWSHED

REM If your files not are named as in this batch file you
REM may either rename them (using <maint> e.g.) to "wndland","wndwcour","
REM "wndgeo" and "wnddtm" or change the file names in the batch.

REM Reclassification of landuse to mask out everything except water. You have
REM to complete the command by typing in the proper numbers:
REM RECLASS X I WNDLAND WATRLAND 2 1 1 ? 0 ? 64 -9999

REM Calculation of distance to water:
REM DISTANCE X WATRLAND DISTWL
REM DISTANCE X WNDWCOUR DISTCOUR

REM We want only one map showing distance to water, use <overlay> to make
REM a new maplayer
REM OVERLAY X ? ?

REM Guide requires files in byte- or integer format, conversion is necessary:
REM CONVERT X ? ? I 1 2 2

REM Delete files that will not be used anymore:
REM MAINT X 1 1 DISTWL
REM MAINT X 1 1 DISTCOUR
REM Calculation of slope in degrees
REM SURFACE X 1 WNDDTM SLOPE ? ? 1

REM Convert slope into byte-binary format
REM CONVERT X ? ?

REM Reclassification of geology and landcover by the use of values files.
REM You have to make the valuesfiles (geo.val and land.val) yourself. Use
REM <edit> in IDRISI e.g..

REM IDRSIGN X WNDGEO GEO GEO 3
REM IDRSIGN X WNDLAND COVER LAND 3

REM You have to write the rest of the batchfile yourself!