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GIS as a tool for Classification Lake's acidification- and eutrophication degree

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Abstract GIS (Geographic information system) was used as a tool to classify 50 lakes according to acidification- and eutrophication degrees. Both water pH and alkalinity showed similar trends of distribution whether they were used alone or together as determining criteria for acidification degree. Where as variables that was used for the determination of eutrophication degree revealed more or less different patterns. Therefore, one must be careful in determining which variable or variables that could be used in classification of lakes according to their eutrophication degree. Moreover, GIS can be used in documentation, analyzing, and prediction the possible future changes in Iraqi aquatic ecosystems.

Introduction

Geographic information system (GIS) can be considered as a database management system that can be used for entering, storing, retrieving, transforming, measuring and combining spatial data. The system integrated with a series of routines that allow sophisticated spatial analysis and display. The data must have been digitized and registerd to common coordinate system (Burrough, 1986, Johnston, 1998).

The first step in the development and use of GIS was Harvard's laboratory for computer graphics in the early 1960's, whereas the first implementation of the system was carried out in 1964 for the analysis of the Canadian Land Inventory data (Tomlinson *et al.* 1976). In the mid-twentieth century, many mathematical indices and models were developed that prompted quantitative thinking about ecological patterns and to quantify community structure, e.g. Margalef (1958), and Pielou (1966). These mathematical advances have contributed to the spatial analysis capability of contemporary GIS. Ecologists have not adopted GIS until 1980's. Aseries of international conferences on integrating GIS and environmental modeling, organized under the support of U.S. National Center for Geographic Information and analysis, have been essential in the exchange of knowledge and ideas about the use of GIS in ecology (Goodchild *et al.* 1993).

GIS combines layers of information about a place to give a better understanding of that location. Which layer of information are combined would depends on the project theme (e.g. detecting relationship between environmental factors and aquatic ecosystem state, tracing a point source pollution event in a river, planning a buffer zone to protect wildlife etc.). In environmental planning, GIS has the ability to perform more complex analysis, to handle large amount of information and to illustrate patterns with map. Moreover, the use of scenario techniques in nature conservation has been improved with GIS (Haines-Young *et al.* 1993). Models can be created which describe the existing relationship between aquatic organisms and the environmental factors and through the use of geostatistical spatial interpolation one can predict the future distribution of organisms (Horssen *et al.* 1999, Lehman, 1998, Marguerite and Welch 1993, Tucker *et al.* 1997).

The output from GIS query or model can be used in the form of tables, graphs etc. Moreover, GIS has the ability to display results in the form of specialized map output, either in large screen or in hard copy. The basic components of GIS are the computer's central processing unit (CPU) used to run the software, and various peripherals for data entry, data storage, visual display, and hard copy output.

Inland water (lakes and rivers) are very important natural ecosystems. The watershed has a direct or indirect impact on these systems. Any change in the physical, chemical and biological factors in the surroundings would lead to alteration in water quality, which in turn negatively affects organisms that live in these waters. Recovering process of lakes is usually slow and restoration measures do not lead always to satisfactory results.

In Sweden, there are about 95000 lakes and 300 000 km running water. A large number of these bodies are affected to some degree by acidification or eutrophication. During the 1980's about 20% of the lakes and 30% of the running water in Sweden were considered to be acidified (SEPA, 1999a). During 1982, the Swedish Environment Protection Agency (SEPA) began a large scale activity of liming aquatic ecosystems (SEPA, 2002a). 90% of lakes and 11% of running waters have been limed either once or more, and each year spread about 200 000 tons of lime that cost about 160-170 million Swedish crown (SEPA, 1999b).

Eutrophication caused by the increase in nutrient concentrations is a well-documented phenomenon. Nutrients that are responsible for the outburst of phytoplankton in aquatic environments are usually phosphorus and nitrogen. Phosphorus is considered to be a limiting nutrient for phytoplankton in many Swedish lakes. When extra amounts of phosphorus enter lakes from the catchment area or through an inlet, a surplus in phosphorus concentration will be resulted. This process could lead to another nutrient limitation, usually nitrogen.

The aim of this study was to classify some of the Swedish lakes according to,

1- Acidification degree using water pH and alkalinity.
2- Eutrophication degree using total phosphorus concentration, total nitrogen concentration, chlorophyll-a concentration, total volume of phytoplankton, and cyanbacterial total volume.

Material and Methods

In this study Arcview 8.2 program was used for the classification of lakes. A digitized map, obtained from the National Land Survey, that represents 21 administrative provinces of Sweden, was compiled together then all the Swedish lakes were superimposed on the map. Fifty lakes in different parts of Sweden were chosen in this study. The other remaining lakes were removed from the map (Fig. 1). Nine lakes, represent those lakes that were limed with calcium carbonate since 1982 either once or more, whereas the other lakes were not limed and they were not affected directly by gas emission and their watersheds were not used intensively. In general, these lakes have areas between 0.04 and 14 km², and depth between 2 and 10m.

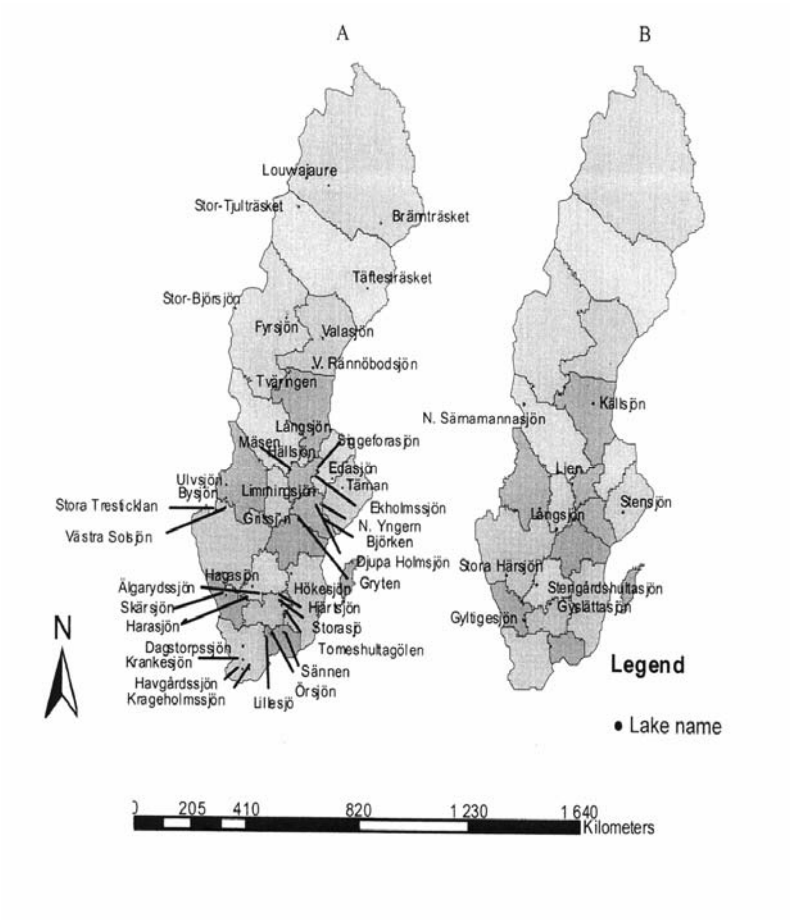

Fig. 1. Location of non-limed (A) and limed (B) lakes in Sweden.

In order to classify the lakes according to acidification- and eutrophication degrees, seven variables were taken from the Swedish agriculture university (SLU) database. Median values of water pH and alkalinity, for the period 1995-1998 (1990's) and 2000-2002 (2000's), were calculated for each variable that was used for the classification of acidification degree in order to demonstrate whether liming action help to improve lake's condition. The median values of five variables; total phosphorus concentration, total nitrogen concentration, chlorophyll-a concentration, total volume of phytoplankton, and cyanbacterial total volume for August during the period 2000-2002 (2002's), were calculated and then used for the determination of eutrophication degree. These variables were registered to a common coordinate. Moreover, the criteria of the Swedish Environmental protection Agency (SEPA, 1999 d and e) was used to classify the lakes (Table 1 A and B).

Table 1. Criteria used in the classification of acidification- (A) and eutrophication (B) degree.

A

Class	Designation	Alkalinity meq l^{-1}	pH
1	very good buffering capacity	> 0.2	>6.8
2	good buffering capacity	0.1-0.2	6.5-6.8
3	low buffering capacity	0.05-0.1	6.2-6.5
4	very low buffering capacity	0.02-0.05	5.6-6.2
5	no buffering capacity	≤0.02	≤5.6

B

Class	Eutrophication degree	Designation	TP µg l^{-1}	TN µg l^{-1}	Chl-a Conc. µg l^{-1}	Algal Total volume mm^3 l^{-1}	Cyanobakterial total volume mm^3 l^{-1}
1	Oligotrofic	Low conc.or very low biomass	12.5	≤300	<2.5	<0.5	<0.5
2	Mesotrofic	Moderately high conc. or low biomass	12.5-23	300-625	2.5-10	0.5-2	0.5-1
3	Eutrophic-1	High conc.or moderately big biomass	23-45	625-1250	10-20	2-4	1-2.5
4	Eutrophic-2	Very high conc. or big biomass	45-96	1250-5000	20-40	4-8	2.5-5
5	Hypertophic	Extremely high conc. or very big biomass	>100	>5000	>40	>8	>5

Results

Figure (2) reflects an increase in the number of non-limed lakes with no buffering capacity between 1990's and 2000's. Limed lakes did not show positive response to liming measure and the number of lakes that had a very good buffering capacity decrease from three to one between 1990's and 2000's (Fig. 3). Using the values of both variables, i.e. pH and alkalinity, for the period 2000-2002 revealed the same picture as that shown for the values of alkalinity alone (Fig. 4). This would means that it is better to use both variables for the classification of lakes according to their acidification degree.

Variables that were used to classify lake's eutrophication degree showed different trends. For non-limed lakes, 92% of the cyanobacterial biomass was found in lakes with low to moderately high concentration of total phosphorus and total nitrogen (Fig. 5, 6 and 8). There was more or less similar trends reflected by the total nitrogen concentration, total volume of phytoplankton, and chlorophyll-a concentration (Fig. 5, 7 and 9).

The number of oligotrophic lakes was the highest and the lowest according to cyanobacterial total volume and chlorophyll-a concentration respectively (Fig 8 and 9). All variables, except total nitrogen concentration, showed that there were a number of non-limed lakes that were either eutrophic-2 or hypertrophic.

The results of limed lakes showed that 100% of cyanobacterial biomass lived only in oligotrophic lakes. Total phosphorus concentration, total volume of phytoplankton, and cyanobacterial total volume (Fig. 6, 7 and 8) gave more or less similar patterns on one hand, and all the variables revealed the absence of eutrophic-2 and hypertrophic lakes among limed lakes, on the other hand.

Discussion

The most dominant cause of water acidification is the deposition of acidifying pollutant, i.e. sulfur oxides, nitrogen oxides and ammonia as well as the harvesting of biomass. Acidification of aquatic ecosystems has a great impact on organisms as well as on the structure and functions of ecosystems.

According to figures 2 and 4 it is quite obvious that the lakes with high- and with low buffering capacity are distributed in the north parts and south parts of Sweden respectively. The increase in number of lakes with no buffering capacity between 1990's and 2000's in spite of the reduction in the emission of sulfur by 80% in Sweden raise a question, why?

The reason might be that the emission of sulfur in other European countries are still high and part of this emission reach different regions of Sweden (EMEP,2000). The natural buffering system of aquatic ecosystem is provided by the bicarbonate ions that reach the water from the surrounding areas. These ions are released by the weathering of minerals in the surrounding lands and from the decomposition of organic matter. Lakes that are surrounded by easily weathered soil get a plenty of bicarbonate ions and therefore have generally a good buffering capacity. Swedish bedrocks and upper layers of soil consist predominantly of relatively difficult weathered soil. These soils have generally a bad neutralizing ability in comparison with the soil of other European countries. The calcareous bedrocks in Sweden are

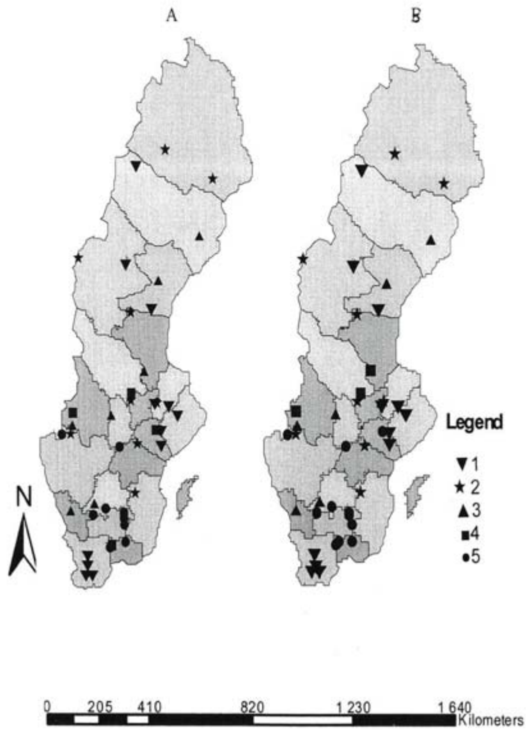

Fig.2. Classification of non-limed lakes according to water alkalinity. A-1990's, B-2000's
1=very good buffering capacity 2=good buffering capacity 3=low buffering capacity
4=very low buffering capacity 5=no buffering capacity.

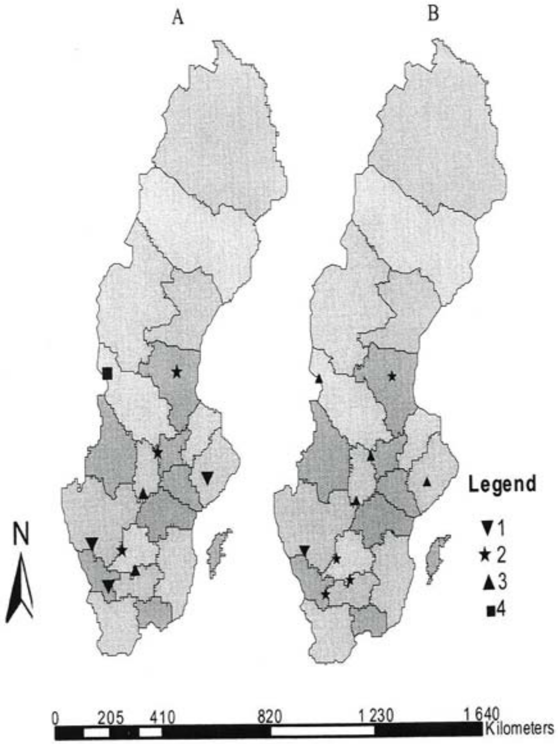

Fig.3. Classification of limed lakes according to water alkalinity. A:1990's, B:2000's
Legend: as in fig.2.

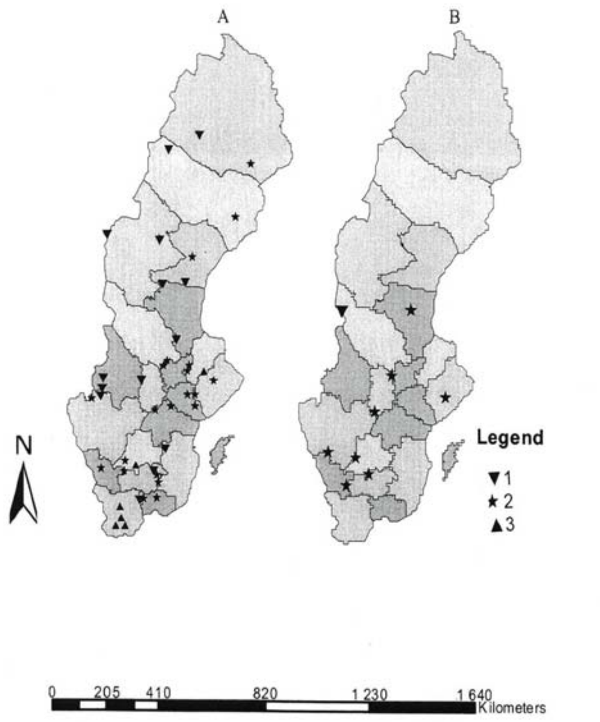

Fig.5. Classification of non-limed (A) and limed (B) lakes using total nitrogen concentration during 2000's.
Legend: 1=low concentration 2=moderately low concentration 3=high concentration 4=very high concentration 5=extremely high concentration.

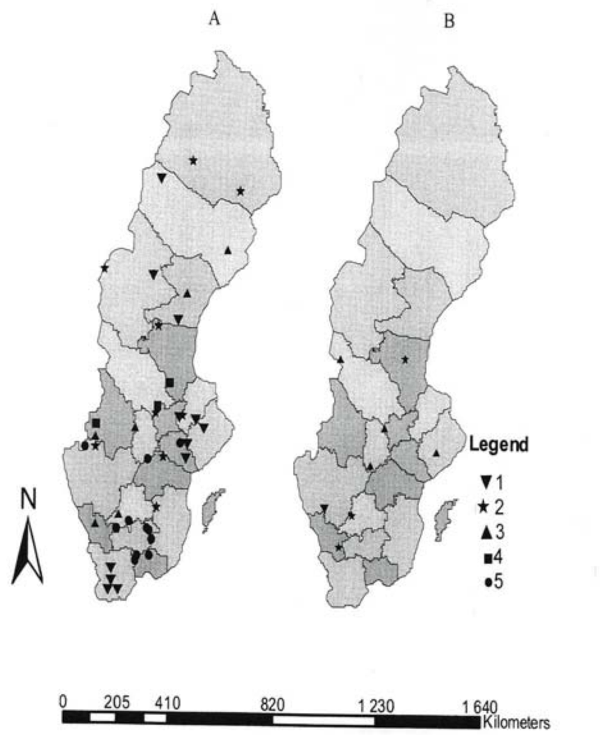

Fig.4. Classification of non-limed (A) and limed (B) lakes using water pH and alkalinity during 2000's.
Legend: as in Fig.2

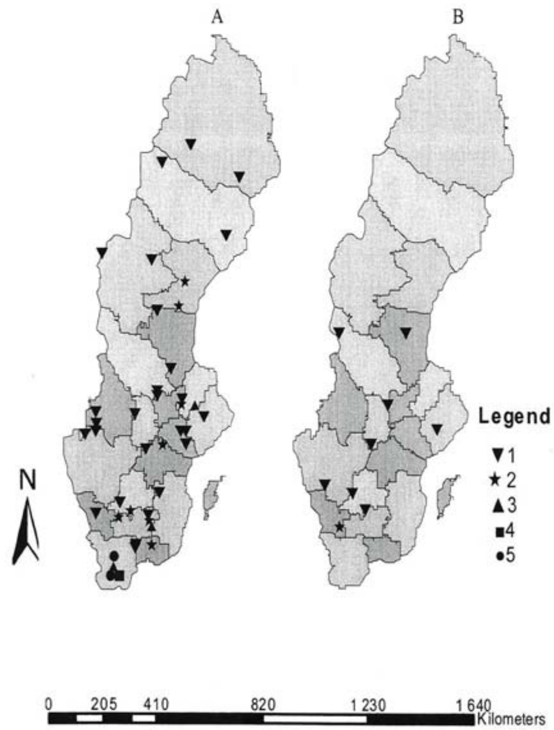

Fig.6. Classification of non-limed (A) and limed (B) lakes using total phosphorus concentration during 2000's.
Legend: as in Fig.5

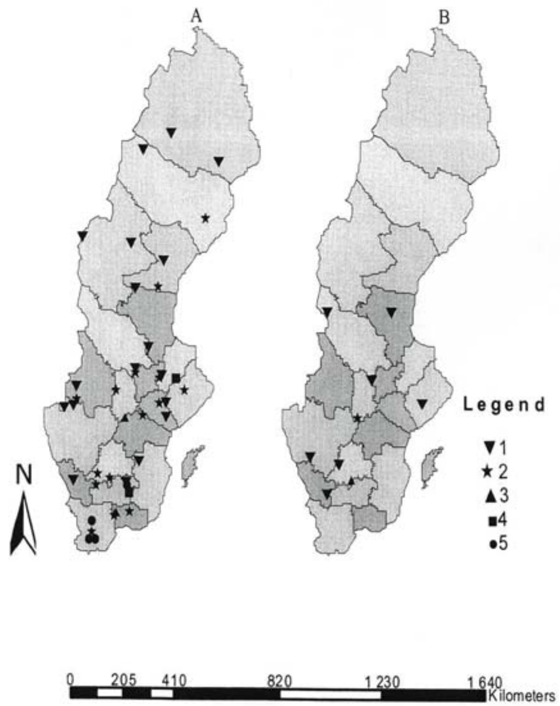

Fig.7. Eutrophication degree of non-limed (A) and limed (B) lakes according to phytoplankton total volume during 2000's.
Legend:1=oligotrophic 2=mesotrophic 3=eutrophic-1 4=eutrophic-2 5=hypertrophic

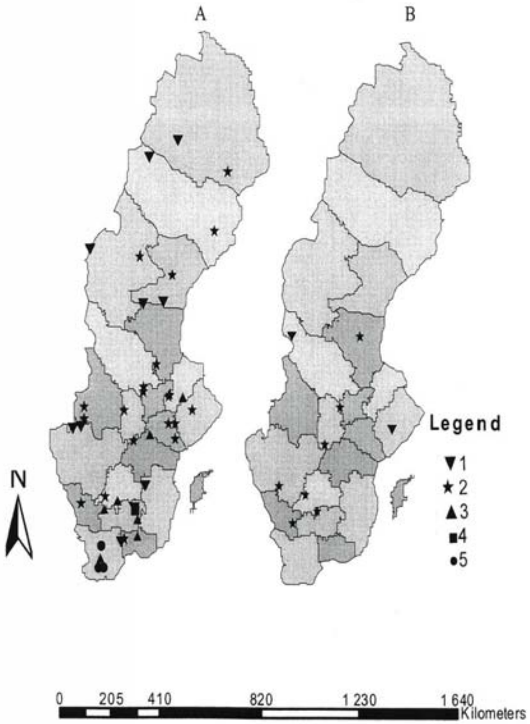

Fig.9. Eutrophication degree of non-limed (A) and limed (B) lakes according to chlorophyll-a concentration during 2000's.
Legend: as in Fig.7

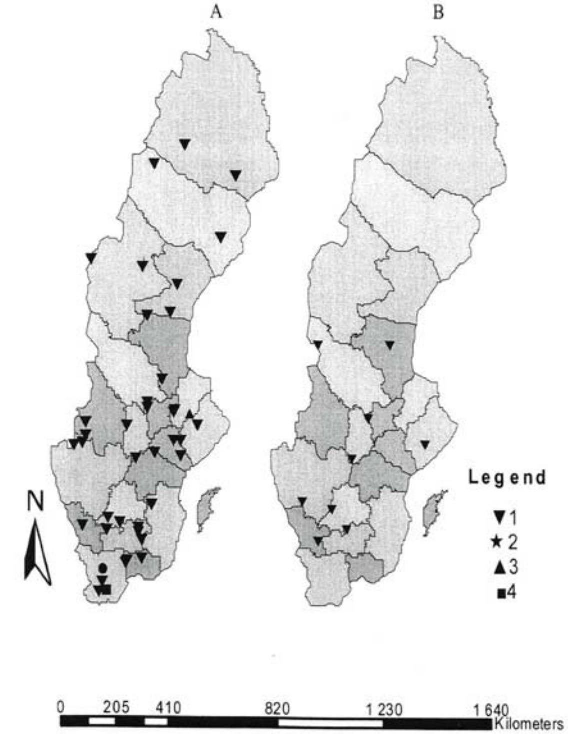

Fig.8. Eutrophication degree of non-limed (A) and limed (B) lakes according to cyanobacterial total volume during 2000's.
Legend: as in Fig.7

restricted to certain areas, as in north parts, there the fallout of acidifying pollutants are relatively low (SEPA, 1999b).

The results of this study revealed that the lakes with no buffering capacity occur in the southern parts of Sweden. Nitrogen deposition has increased during the last few decades, and therefore many parts of Sweden and other European countries have been impacted.

In these parts, the soils are saturated with nitrogen and the vegetation cover can no more absorb the whole amount of inorganic nitrogen that is available (Swedish Forestry, 2001). Accordingly, nitrates would leaches from the soil and reach lakes and water ways, and this could mean that nitrogen deposits are taken part in the acidification process of aquatic ecosystems.

As said before, the soil acidification could be the results of tree logging. These soils in the catchment areas affect aquatic ecosystems. Vegetation's uptake of basic ions is counteracted by the supply of acidic ions that cause a permanent soil acidification in case trees felled and taken away. According to the Swedish Forestry, about 40% of tree logging is carried out in nine of the administrative provinces, which represent 22% of the total area of Sweden, there acidified lakes are distributed.

The aim of lakes- and watercourses liming was to counteract the acidification impact on water and organisms, to reduce the future deterioration of the water quality, to preserve the biological diversity, and to facilitate persistent use of the natural resources. About 200 000 tones of lime were spread during 1990 only to counteract the effects of continuous supply of acidifying pollutant. About 6000 lakes and few hundreds rivers and streams were included in this program and were spread at least once. Water bodies in the south and the south west of Sweden were the most frequently spreads (SEPA, 2000). In spite of this, many lakes and water ways remain acidified and do not respond positively to the liming measure. Aquatic ecosystems might need longer time or/and frequent lime spreading in order to recover from acidification problem.

Eutrophication of inland waters in Sweden is caused primarily by discharge of phosphorus from municipality- and private sewers, agriculture, as well as industry (SEPA, 1999c). The supply of nutrients has been relatively continued for reasonably long time, and hence the recovery of these systems is slow. Although the direct discharge of nutrients has been reduced, however the internal loading from sediment is long lasting. The concentration of nitrogen in forest soils has increased successively, and in the long run there is a risk for soil to be saturated with nitrogen and hence a possibility for nitrogen to leach from the soil into lakes and water ways (Swedish Forestry, 2001).

The phosphorus concentration in agricultural soil in Sweden is relatively low but the use of fertilizers increase the risk of phosphorus leaching from soil. According to Figures 6,7, and 9, there are three lakes that are hypertrophic and situated in skane district in the southern part of Sweden. Moreover, lake Stora that is situated in kronoberg district (southern part of Sweden) is also hypertrophic (fig. 7). The SCB (Swedish Central bureau for Statistic) estimated a surplus of phosphorus (2.7 kg ha^{-1}) in the agricultural soil of kronoberg.

The use of total nitrogen concentration in this study revealed that none of the limed and non-limed lakes are eutrophic-2 or hypertrophic. Lakes that are not limed which are classified eutrophic-1 are generally located in skane district. During 1999, the average concentration of nitrogen that was leached from the soil in this district was 47 kg ha^{-1} which represents the highest level of nutrients that leached from soil in Sweden (SEPA, 2000b).

Although three of the non-limed lakes (lake Sannen, lake Or, and lake Tomeshultagolen in Kalmar, southern part of Sweden) have no buffering capacity (Fig. 2), however, they are classified as eutrophic-1 according to chlorophyll-a and total phytoplankton volume. It is well known that acidified lakes are oligotrophic (Wetzel, 2001). The phytoplankton species that live in these lakes might have been adapted to grow in such ecosystem.

This study showed that 92% and 100% of cynabacterial community grow in oligotrophic water in both non-limed and limed lakes respectively. Many investigations have indicated that Cyanobacteria are the dominating phytoplankton in eutrophic lakes (Wetzel, 2001). It is therefore one must be careful in choosing one factor or factors for the classification of lakes using GIS. The factors that might be taken in consideration when using GIS for the classification of lakes could be limiting factors to the phytoplankton, impact of watershed, as well as factors within the aquatic ecosystem it self.

Many Scientific studies have been conducted in Iraq. However, there is no database documentation of the results of these investigations. It is necessary to implement GIS in the environmental studies that are conducted in Iraq in order to help ecologists and politicians to take the right decision in environmental planning and conservation.

References

Burrough, P.A. 1986. Principles of Geographic Information Systems. Oxford University Press, Oxford. UK.

European Monitoring and Evaluation Program (EMEP).2000. Transboundary acidification and eutrophication in Europe. EMEP report 1, 74pp.

Goodchild, M.F., Steyaert, L.T. and Parks, B.O.(eds.). 1993. Geographic information system and environmental modeling. Oxford University Press, New York.

Haines-Young, R., Green, D.R. and Cousins, S.(eds.). 1993. Landscape ecology and geographic information system. Taylor and Francis, London.

Horssen, P.W., Schot, P.P. and Baredregt. 1999. A GIS-based plant prediction model for wetland ecosystems. Landscape Ecology, 14: 253–265.

Johnston, C.A. 1998. Geographic information system in ecology. Blackwell science, London. UK.

Lehman, A. 1998. GIS modelling of submerged macrophyte distribution using Generalized Additive Models. Plant Ecology, 139: 113–124.

Margalef, D.R. 1958. Information theory in ecology. General system bulletin, 3:36-71.

Marguerite, M. R. and Welch, R.A. 1993. GIS technologies for aquatic macrophyte studies: Modelling applications. Landscape Ecology, 8:163-175.

Pielou, E.C. 1966. The measurement of diversion different types of biological collections. Journal of theoretical biology, 13:131-144.

Swedish Environmental Protection Agency (SEPA). 1999a. Only natural acidification. Report 5000.
SEPA. 1999b. Acidification and liming of Swedish water. Monitor 12.
SEPA. 1999c. No eutrophication. Report 4999.
SEPA. 1999d. Criteria for environmental quality. Chemical and physical factor for lakes and water ways. Report 4920.
SEPA. 1999e. Criteria for environmental quality. Biological factors for lakes and water ways. Report 4921.
SEPA. 2000. Liming during 2000's. Report 5086.
SEPA. 2002a. Liming of lakes and watercourse. Handbook 1.
SEPA. 2002b. Leaching of nitrogen from Swedish farm land. Calculation of leaching during 1995 and 1999. Report 5248.
Swedish Forestry. 2001. Effects of land acidification on biological diversity and counter actions. Report 11c.
Tomlinson, R.F., Calkins, H.W., and Marble, D.F. 1976. Computer handling of geography. Unesco Press, France.
Tucker, K, Rushton, S.T., Sanderson, R.A., Martin, E.L., and Blaiklock, J. 1997. Modelling bird distributions - a combined GIS and Bayesian rule-based approach. Landscape Ecology, 12:77-93.
Wetzel, R.G. 2001. Limnology. Lakes and river ecosystems. Third edition. Academic Press, London.

استخدام نظام المعلومات الجغرافي كأداة لتصنيف البحيرات اعتمادا على درجة الحامضية ودرجة الإثراء الغذائي

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المستخلص تم تصنيف 50 بحيرة اعتمادا على درجة الحامضية ودرجة الإثراء الغذائي باستخدام نظام المعلومات الجغرافي. أعطت كل من درجة الأس الهيدروجيني وقاعدية الماء أنماط متشابهة في توزيع البحيرات عند استخدام هذين العاملين معا أو بصورة منفردة كمعايير محددة في تصنيف البحيرات حسب درجة الحامضية. في حين حددت العوامل التي استعملت في تقدير درجة الإثراء الغذائي للبحيرات نماذج مختلفة على الأعم. لهذا يجب توخي الدقة في اختيار المتغيرات التي تستعمل في تصنيف البحيرات حسب درجة الإثراء الغذائي. لا بد من التأكيد على أهمية استخدام هدا النظام في دراسات البيئية المائية العراقية من اجل توثيق وتحليل والتنبؤ بالتغير المحتمل حدوثه في الأنظمة المائية العراقية.