The open discussion version of this paper is available at: Sługocki Ł, Czerniawski R. (2017) Impact of the catchment land use on some factors of lakes trophic status: a GIS approach. PeerJ Preprints 5:e2203v2 https://doi.org/10.7287/peerj.preprints.2203v2

Impact of the catchment land use on some factors of lakes trophic status: a GIS approach

Łukasz Sługocki, Robert Czerniawski

University of Szczecin, Faculty of Biology, Szczecin, Poland

Corresponding author:
Łukasz Sługocki

Email address: lukasz.slugocki@usz.edu.pl

ABSTRACT

Background. Artificial enrichment of lakes has posed serious management problems for water supply. In results many European lakes had already undergone significant eutrophication. It seems that a good tool to determine the influence of catchment use on the trophic changes in lakes is Geographic Information System (GIS) and its databases.
Methods. The study covered 31 stratified lakes located in northwestern Poland. These lakes were chosen on account of their considerable recreation value and economic importance. The parameters chosen as dependent variables were Secchi depth and electrical conductivity. Local catchments and network catchment of studied lakes as independent variables were prepared using QGIS Wien (2.8.7). The land use variables were prepared with Corine Land Cover, 2006 (CLC2006).
Results. According to Carlson index the studied lakes ranged from mesotrophic to eutrophic. Both dependent variables Secchi depth and conductivity values were significantly correlated with independent land use variables ($P < 0.05$).
Discussion. Our survey revealed that percentage use of the catchment (developed in the Geographic Information System) can be a useful tool in the assessment of the lakes risks. With the GIS tools we also confirmed a significant impact of land use on changes transparency and conductivity values in North West lakes in Poland.

Keywords: Catchment area, Land use, QGIS, Corine Land Cover, Secchi depth, Conductivity, Eutrophication

Please cite this paper as: Łukasz Sługocki, Robert Czerniawski (2018) Impact of the catchment land use on some factors of lakes trophic status: a GIS approach. In Marchesini I. & Pierleoni A. (Eds.) Proceedings of the 4th Open Source Geospatial Research and Education Symposium (OGRS2016). Perugia, 12-14 October 2016.
https://doi.org/10.30437/ogrs2016_paper_10

INTRODUCTION

Artificial enrichment of lakes has posed serious management problems for water supply. Most researchers agree on the general effects of various land use on water quality. Agriculture and urban land use has been associated with nutrient enrichment (Soranno et al., 2015). In results many European lakes had already undergone significant eutrophication (Carpenter et al., 1999). Measurement depth of Secchi disc (SD) is common method of determining the transparency of water (Carlson, 1977). Water transparency is the sum total of all the final effects of trophic-state determining factors – understood as the lake productivity. In summer it is the transparency of the water that most fully satisfies the conditions required of an index that is expected to make possible comparative analysis of the trophic state (Karabin, 1985). Generally, with an increase of lake trophic status the changes of electrical conductivity values are also observed (Nürnberg 1996). Electrical conductivity is included to simulate the chemical properties of the habitat, which may have a direct or indirect effect on ecosystems. Lakes often have a conductivity gradient from the top to the bottom of drainage system (Alexander et al., 2008) therefore, the assumption that catchment area and land use affects concentration of dissolved ions in water bodies. Just in Poland there is approximately 7 000 lakes then is a need to develop simple models to assess the degree of exposure of individual water basins. It seems that a good tool to determine the influence of catchment use on the trophic changes in lakes is open source Geographic Information System (GIS) and its databases (Bocher & Steiniger, 2009). Extensive regional lake surveys becoming more accessible since GIS methods developed. In the last years many relevant open databases expanded which is useful in the water management and environmental studies. CORINE land cover 2006 (CLC2006) contributes to the knowledge of the land cover in 24 European countries. The basic aim of these studies is to determine land use impact on transparency and conductivity of waters.

MATERIALS & METHODS

The study covered 31 stratified lakes located in northwestern Poland (Figure 1). These lakes were chosen on account of their considerable recreation value and economic importance. Lakes surface area range from 25ha to1871ha. The values of lakes depth range from 12m to 83m. Measurement of the lakes water was performed in the summer period (from 15 July to 15 August) 2011-2014 once for each lake. In case a lake has separate basins each basin was investigated. The parameters chosen as dependent variables were Secchi depth (m) and electrical conductivity ($\mu S\ cm^{-2}$). Carlson (1977) trophic state index was based on Secchi disc depth (SD(m)). Local catchments and network catchment of studied lakes as independent variables were prepared using QGIS Wien (2.8.7). The land use variables were prepared with Corine Land Cover, 2006 (CLC2006) (Büttner & Kosztra, 2007). Land use of studied drainage basins is largely dominated by forested land, which covers 52% of the watershed. Agricultural areas cover 37% of the basin. Water bodies cover 10% of the total area. Artificial surface (1%) is relatively low. Wetlands cover less than 1%. The correlations between the percentage of land use vs. Secchi depth and electrical conductivity were analyzed with Pearson coefficient correlation ($P < 0.05$) (Statistica 10).

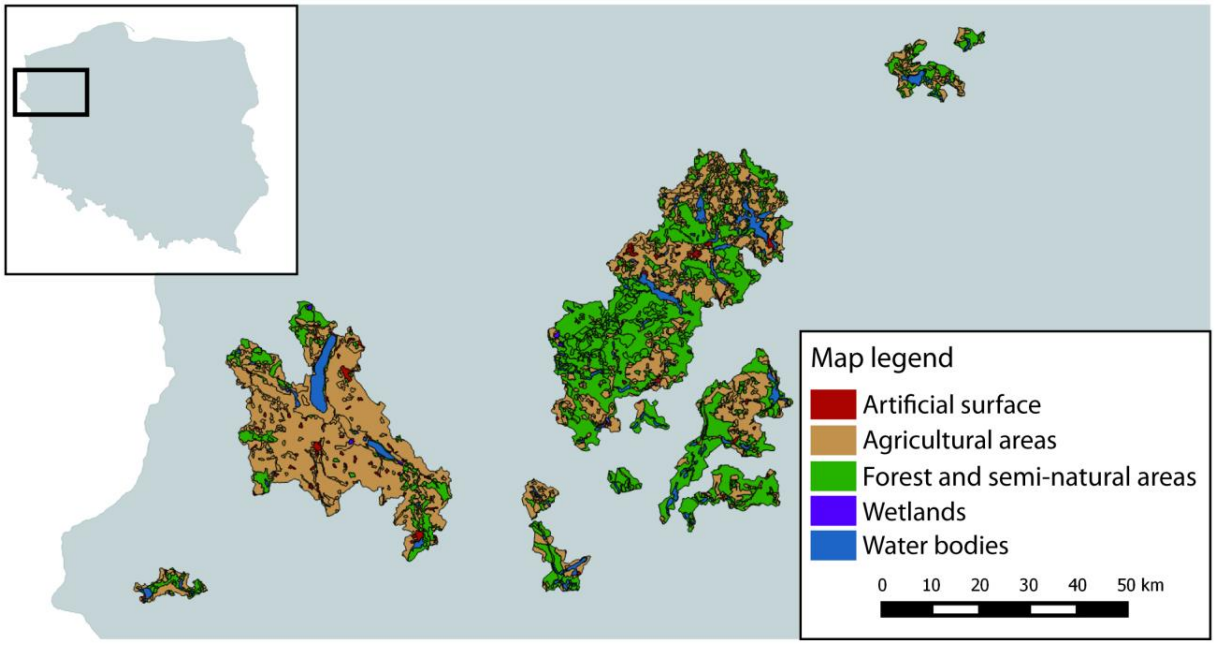

Figure 1. Map of studied catchment basins in Poland.

RESULTS

According to Carlson index the studied lakes ranged from mesotrophic to eutrophic. Both dependent variables Secchi depth and conductivity values were significantly correlated with independent land use variables ($P < 0.05$) (Figure 2). Significant correlation for Secchi depth values covers only network catchment area ($P < 0.05$). Secchi depth values was significantly positively correlated with percentage of forest and water in catchment and significantly negatively with agricultural areas ($P < 0.05$). Value of conductivity was significantly positively correlated with percentage of forest in local and network catchment, wetlands in network catchment ($P < 0.05$). Values of conductivity were significantly negatively correlated with percentage of forest in local and total catchment ($P < 0.05$).

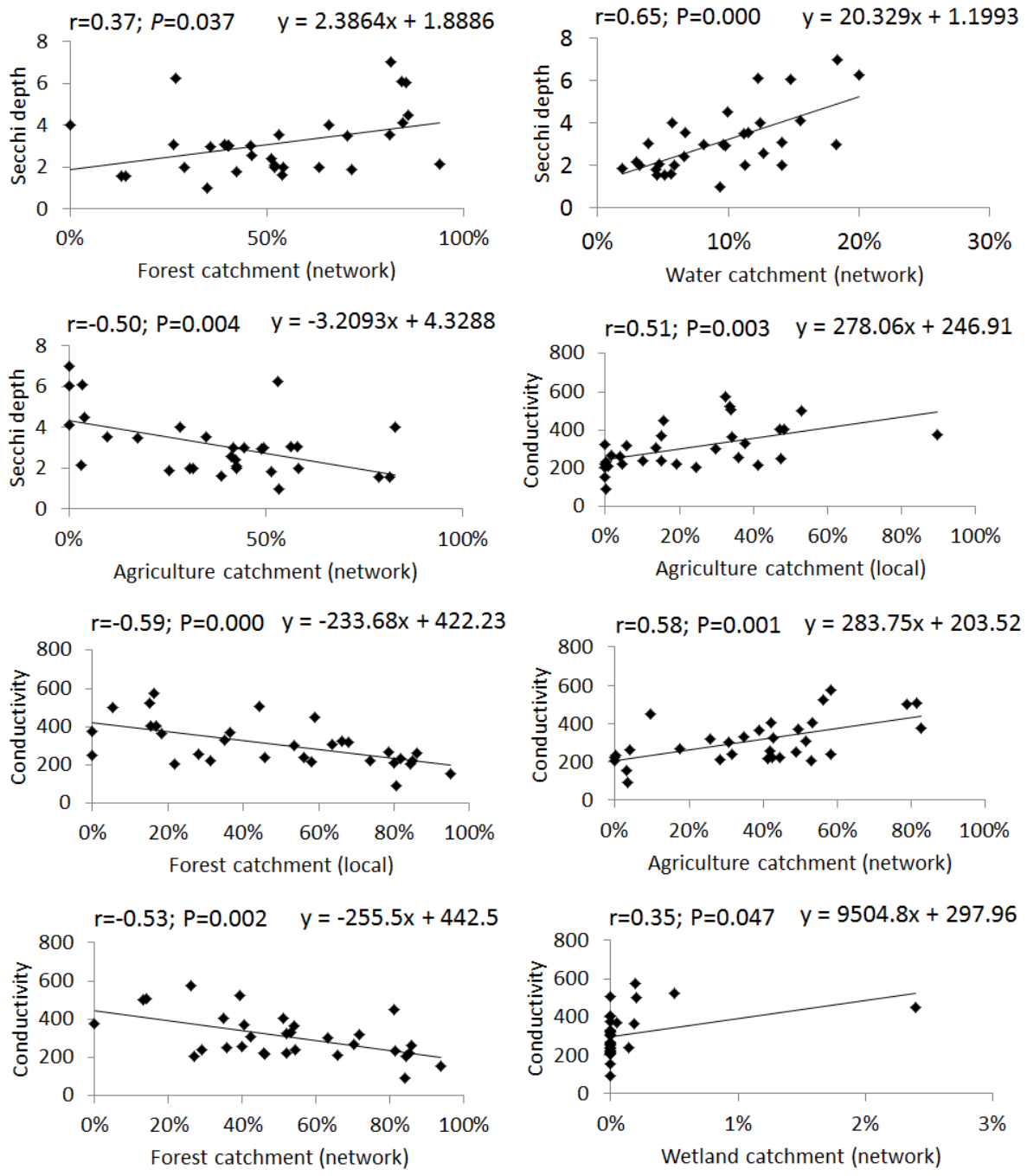

Figure 2. Significant correlations ($P<0.05$) between percentage of catchment land use vs. values of Secchi depth (m) and conductivity (µS cm^{-2}).

DISCUSSION

Our survey revealed that percentage use of the catchment (developed in the GIS) can be a useful tool in the assessment of the lakes risks. With the GIS tools we also confirmed a significant impact of land use on changes transparency and conductivity values in North West lakes in Poland. For the value of Secchi depth for the examined lakes, the greatest impact was the percentage of water basins in the network catchment. A large catchment area and high total surface of lakes in this catchment could cause the spatial retention of nutrients in the catchment. The retention of nutrient has been reported to increase with catchment size, resulting in a spatial "scale effect" of observed nutrient losses per unit area (Ekholm et al., 2000). However, in the case of our research there was no significant correlation between the surface of catchment vs. the values of Secchi depth and conductivity. Lakes characterized by larger catchment forests showed a statistically significant higher visibility and lower values of conductivity. In lakes where the catchment was characterized by a high percentage of agricultural area and artificial surface we found significantly lower values of Secchi depth and the higher conductivity values. The specific nutrient load from agricultural land is approximately 10 times the load from forested land in southern Finland (Rekolainen et al., 1995). Agricultural nutrient losses have been demonstrated to accelerate eutrophication of aquatic systems in many countries.

CONCLUSIONS

The results demonstrate that land use in catchment area of lakes affects transparency and conductivity that are variables determining trophic changes. Hence land use also can certainly affect the other factors that directly influencing the rates of primary production. So, this work showed that further research should be conducted to address issues such as the impact of land use on water bodies. Results of the present study can be important in water management and environmental studies of lakes and their catchment area. The study also point to the usefulness of GIS tools and its databases for evaluation of land use influence on increase of lakes trophic status.

REFERENCES

Alexander ML, Woodford MP, Hotchkiss SC. 2008. Freshwater macrophyte communities in lakes of variable landscape position and development in northern Wisconsin, USA. *Aquatic Botany* 88:77-86.

Büttner G, Kosztra B. 2007. CLC2006 Technical guidelines. Technical Report No. 17 / 2007. EEA. Available from http://www.eea.europa.eu/publications/technical_report_2007_17

Bocher E, Steiniger S. 2009. An overview on current free and open source desktop GIS developments. *International Journal of Geographical Information Science* 23(10):1345–1370.

Carlson RE. 1977. A trophic state index for lakes. *Limnology and oceanography* 22(2):361-369.

Carpenter SR, Ludwig D, & Brock WA. 1999. Management of eutrophication for lakes subject to potentially irreversible change. *Ecological applications* 9(3):751-771.

Ekholm P, Kallio K, Salo S, Pietiläinen OP, Rekolainen S, Laine Y, & Joukola M. 2000. Relationship between catchment characteristics and nutrient concentrations in an agricultural river system. *Water Research* 34(15):3709-3716.

Karabin A. 1985. Pelagic zooplankton (Rotatoria + Crustacea) variation in the process of lake eutrophication. II. Modifying effect of biotic agents. *Ekologia Polska* 33:617–644.

Nürnberg GK. 1996. Trophic state of clear and colored, soft-and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. *Lake and Reservoir Management* 12(4):432-447.

Rekolainen S, Pitkänen H, Bleeker A, & Felix S. 1995. Nitrogen and phosphorus fluxes from Finnish agricultural areas to the Baltic Sea. *Hydrology Research 26*(1):55-72.

Soranno PA, Cheruvelil KS, Wagner T, Webster KE, & Bremigan MT. 2015. Effects of Land Use on Lake Nutrients: The Importance of Scale, Hydrologic Connectivity, and Region. *PloS one* 10(8):e0135454.