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Assessment of Nitrate Leaching Risk in Hazelnut Areas of the Eastern Black Sea Region

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Prediction of nitrate leaching from cropland is crucial for preventing the surface or groundwater degradation and the economical balance. Nitrate leaching index model used in this study evaluates both soil hydrological groups requiring some soil characteristics and climatologically data. This study was carried out to evaluate and predict potential nitrate leaching risk from hazelnut fields in Ünye-Tekkiraz district of the eastern Black sea region of Turkey. The results show that while more than half of the study area (54.1 %) has high and very high risk category, 45.9 % of it has moderate level. Low nitrate-leaching risk land was not found in the study area. In addition, many models include only quantitative estimates on the relationship between nitrate leaching and the environmental or management factors at the plot scale and do not allow to make evaluation for the regional or larger areas. Therefore, the main objectives of this study are (i) to determine seasonal trends of the potential nitrate leaching, (ii) to assess nitrate leaching risk and (iii) to classify the hazelnut areas associated with leaching risk and prepare risk map in Tekkiraz district of Ordu, Turkey.

Key Words: Nitrate leaching model, Hydrological soil group, Soil characteristics.

INTRODUCTION

Organic and inorganic fertilizers are important parts of modern agricultural practices. Due to modern agricultural practices they are strongly linked to manure and fertilizer application for maintaining optimum yields[1,2]. In spite of their valuable benefit, fertilizer may7 have adverse effect such as nitrate leaching leads resulting in water quality degradation. Many farm managers and policy makers, therefore, have focused on whole-farm nutrient management planning to maximize their benefit from fertilizer use.

Nitrate (NO_3^-) leaching from crop fields is directly controlled by water discharge flow. The soil-NO_3^- residual is defined as leaching risk that is affected by numerous factors such as climate conditions, soil properties and agricultural practices (*e.g.*, tillage, fertilization, irrigation, manure application, crop rotation, *etc.*)[3]. Many previous studies have examined the relationship between NO_3^- leaching and the environmental or management factors at plot scale[4-6]. However, with limited time and cost for field experiments, estimation of NO_3^- leaching, especially at regional or catchments scale has to rely on models such as MIKESHE[7] and MODFLOW[8], CENTURY and SOILN[9,10]. One of these simulation models is nitrate leaching index (NLI) that may be a more effective way to predict nitrate leaching processes in significantly large areas.

Turkey is one of the few countries in the world with a favourable climate for hazelnut production. Hazelnut is an important nut species for Turkish economy. Turkey is responsible for about 70 % of world hazelnut production and 75 % of the world hazelnut trade. The production area spread densely all along the Black Sea coast, where the hazelnut has been native for the last 2500 years. Ordu is one of the most important hazelnut production centers. It constitutes 28 % of Turkish hazelnut production. Although hazelnut has the long history in this region, there has been still low level of production in hazelnut farming. One of the main factors causing productivity loss in hazelnut orchards is the incorrect use of fertilizers (application kind, time, amount, *etc.*). Most of the traditional hazelnut producers use only nitrogen fertilizers such as ammonium nitrate, ammonium sulfate and calcium ammonium nitrate, *etc*. In addition, considerable loss of nitrogen may occur in the research area if heavy rains immediately flow a surface application of nitrogen fertilizer on moist soil surface, particularly if there is considerable slope. Since annual precipitation is more than 1000 mm, there has been considerable nitrate leaching risk in the study area. However, there has been no or less study focus on nitrate leaching especially at regional level. So, the main objectives of the study are (i) to determine seasonal trends of the potential nitrate leaching, (ii) to assess nitrate leaching risk and (iii) to classify the hazelnut areas associated with leaching risk and prepare risk map in Tekkiraz district of Ordu, Turkey.

EXPERIMENTAL

The study was conducted in the Ünye-Tekkiraz district and its near vicinity, located in between east of Samsun and west of Ordu provinces in Black Sea region. The coordinates of the research area are 342179-346386 N and 4538866-4535329 E (UTM). The study area covers *ca.* 15.3 km^2.

The study area has various topographic features (flat, hilly, rolling, *etc.*). Hilly and rolling physiographic units are particularly common in the study area. Elevation varies from 325 m to 850 m above sea level. Based on the meteorological data covering the period of 1998-2005, average annual precipitation and temperature are 1162.4 mm and 14.2 ºC, respectively[11] (Table-1).

TABLE-1
AVERAGE PRECIPITATION AND TEMPERATURE VALUES BETWEEN 1988 AND 2005

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	AV
P (mm)	100.1	96.5	92.3	73.8	66.9	69.6	54.9	101.9	94.0	162.3	130.8	119.3	1162.4
T (ºC)	6.8	6.4	7.8	11.1	15.0	19.8	23.3	23.7	20.0	16.3	11.9	8.8	14.2

AV = Annual average.

According to soil taxonomy[12], the soil temperature regime and moisture regime were classified as mesic and ustic, respectively. There are 9 different soil series in study area and they were classified as inceptisol (44.2 %), alfisol (36.1 %) and entisol (19.7 %). In most of the study areas hazelnut farming has been common, whereas southern part of the study area is generally covered with small forest and pasture lands. Distribution of geological pattern of the research area is palaeocene and eocene rocks consisting of sandstone, siltstone and marl including widely distributed and altered eocene aged volcano-clastics which are composed of basalt and andesite (Table-2).

Nitrate leaching model: The nitrate leaching index evaluates soil's leaching potential based on rainfall and soil characteristics. Since nitrate is water soluble, it moves downward as water percolates through the soil. Czymmek[13] stated that the extent of percolation depends on permeability, pore-size distribution, soil depth to a restrictive layer, artificial drainage and precipitation amount and its distribution over the year. The nitrate leaching index rates or nitrate leaching risk potential base on soil hydrologic group and 17 years average annual precipitation data taken from weather station. There are four hydrologic soil groups: A, B, C and D[14]. The definition of each hydrologic soil groups is given in Table-3.

The nitrate leaching index is the product of the percolation index and the seasonal index[15,16]. Percolation index estimates the average amount of rainfall in inches per year that percolate through the root zone based on rainfall data and soil hydrological groups. The equation for the percolation index is:

TABLE-2
DISTRIBUTION OF THE SOIL SERIES AND THEIR SLOPE, PARENT MATERIAL AND LAND USES

Soil series	Taxonomic classes	Area (ha)	Ratio (%)	Slope (%)	Parent material	Land use & Land cover
Çubuklu	Lithic Ustorthent	209.4	13.72	30-45	Alterated basalt	Hazelnut, forest, rangeland
Armut Tepe	Typic Ustorthent	92.9	6.10	15-30	Basalt	Hazelnut
Dizdar-I	Typic Haplustept	107.1	7.02	0-5	Basalt	Hazelnut
Dizdar-II	Typic Haplustept	89.9	5.59	5-15	Alterated basalt	Hazelnut, maize
Saraçli	Typic Dystustept	281.7	18.46	5-15	Andesite	Hazelnut
Umat	Typic Calciustept	201.7	13.21	15-30	Marl and lime stone	Hazelnut, maize
Kabadirek	Vertic Haploustalf	191.6	12.55	5-15	Andesite	Hazelnut
Yayci	Typic Haploustalf	115.6	7.58	5-15	Marl	Hazelnut
Küçük Göl	Typic Haploustalf	235.7	15.45	0-5	Andesite, basalt	Hazelnut

TABLE-3
HYDROLOGIC SOIL GROUPS

SHG	Definition of hydrologic soil groups
A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well to excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

SHG = Soil hydrological group.

$$PI = (P - 0.4s)^2 / (P + 0.6s) \text{ where } P > 0.4s$$

where: PI = Percolation index, P = Annual precipitation, s = parameter for the soil hydrological groups. Williams and Kissel[15] used Erosion-Productivity Impact Calculator (EPIC) to estimate s value for each of the four soil hydrological groups and suggested using s = 26 for group A, s = 38 for group B, s = 49 for group C and s = 57 for group D.

The seasonal index (SI) is the second component of the nitrate leaching index and calculated by means of the annual precipitation (P) and the sum of the fall and winter precipitation (PW, from October through March). The equation for the seasonal index is:

$$SI = [(2PW) / P]^{1/3}$$

where: SI = Seasonal index, P = Annual precipitation and PW = the sum of precipitation from October to March. Finally, to calculate nitrate leaching index (NLI), the PI is multiplied by SI. Then, NLI can be classified as indicated in Table-4[13-17].

TABLE-4
RANKING OF THE LEACHING INDEX CLASS

Nitrate leaching index class	Definition
Low	0-2
Moderate	2.1-10
High	10.1-15
Very high	> 15

An LI below 2 indicates that the potential for nitrate leaching below the root zone is low. An LI greater than 10 indicates that the potential for soluble nutrient leaching below the root zone is high and very high. In addition, LI's value between 2 and 10 are considered as moderate.

Finally, all soil data were obtained from digital soil database prepared by Kurt[18] to generate hydrologic soil group map and then all data were analyzed using TNT Mips 6.4 GIS software[19]. In addition, Thornwaite method was used to determine soil water balance and evapotranspration (ET)[20].

RESULTS AND DISCUSSION

Investigated soil area was digitized and database was prepared. Totally 34 different polygons or land mapping units (LMU) were determined for the detailed soil map of the study area to form a hydrological soil group map by using GIS (Fig. 1). According to results, while about half of the study area (46.7 %) was classified as D hydrological soil group, characteristics of the B hydrological soil group were found in 42.6 % of the study area's soil. Only 10.7 % was classified as A hydrological soil group. C hydrological soil group was not determined in the study area according to Table-3.

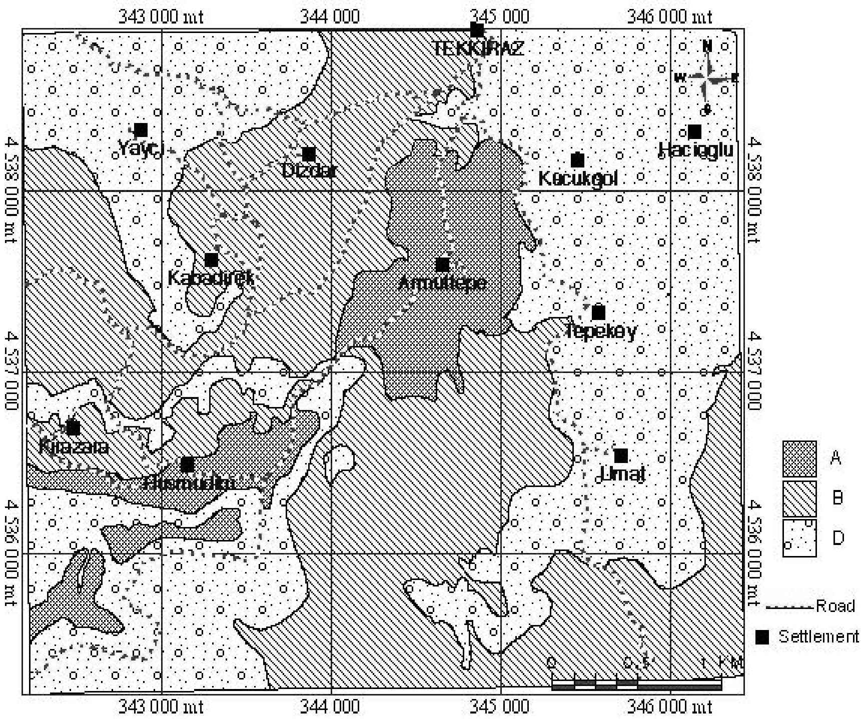

Fig. 1. Distribution of hydrological soil groups of the study area

Similarly, Olsen and Kristensen[21] explored nitrate leaching risks areas using a GIS system in Denmark. In order to assess nitrate leaching risk status, digital information on soil types, climates, slopes and land use-land cover data were used to create nitrate leaching risk map of Denmark. According to their results, counties in the western parts of Denmark had a higher risk of nitrate leaching due to differences in soil types. In the western parts sandy soils are dominant whereas in the eastern parts clay soils prevail.

Nitrate leaching index model was applied to the study area based on the soil hydrological group and 17 years average annual and winter (October-March) precipitation data. In all nitrate-leaching models, precipitation plays an important role in determining the risk for a specific area. In summer, evapotranspration has exceeded precipitation such that no leaching occurs where fields were covered by vegetation in the study area (Fig. 2). Fig. 2 also shows that from October to March, precipitation has exceeded ET so, nitrate leaching occurs, but in warmer climates, in late fall and early spring, ET are more significant and should be removed from the winter precipitation.

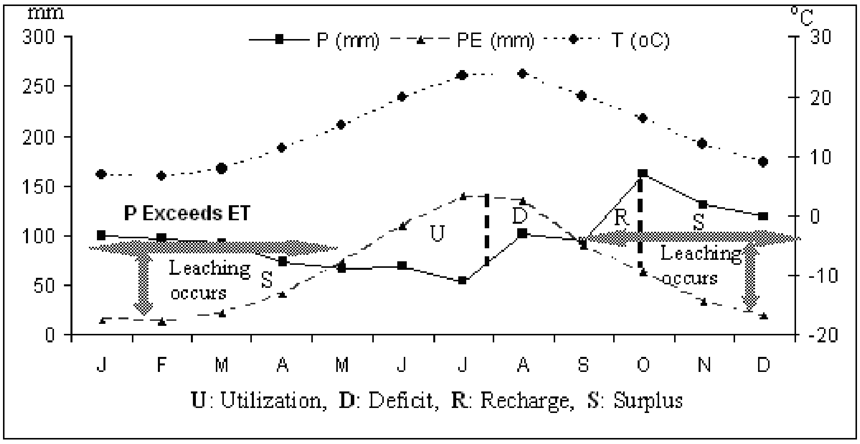

Fig. 2. Seasonal trends of the potential nitrate leaching

The comparison of areas within each nitrate-leaching risk categories (low, moderate, high and very high) was completed for several soil series in the study area. There was no area having low nitrate-leaching risk in the study area (Fig. 3). While 702.7 ha of land was classified as moderate risky category especially located on Küçükgöl, Yayci and some part of Umat and Çubuklu soil series, 576.5 ha of land take place in high risk category, especially found on Dizdar-I and Saraçli soil series. Only 250.9 ha of the total area was classified as very high nitrate-leaching risk in the study area due to coarse texture and shallow depth. This category was determined mostly

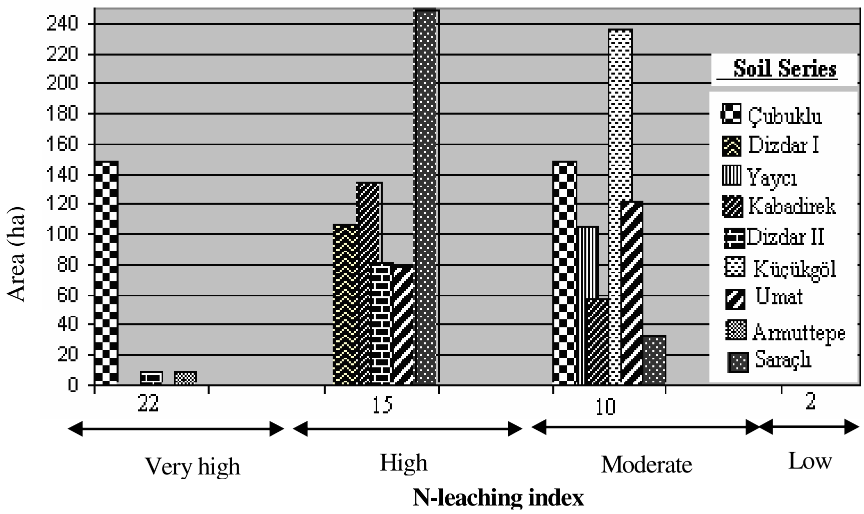

Fig. 3. Graph of the study area by existing nitrate leaching index assignment within several soil series

in Çubuklu soil series and in small part of the Armuttepe and Dizdar-II soil series. Silva[22] reported that nitrate leaching is usually less from fine textured rather than coarse soils due to slower drainage and a greater potential for denitrification process. Elements of the soil structure such as depth, cracks and root channels also contribute to the level of leaching.

Excessive nitrate leaching into ground and surface water from hazelnut agricultural regions have an increasing concern in the Eastern Black Sea region. Therefore, producers should take into account the some nitrogen conservation practices such as avoiding large amounts of fertilizer or manure use before heavy rainfall, disturbing soil cracks *via* tillage before or during the fertilizer application period, determining nitrogen requirement where nitrate leaching is high or very high based on soil test. In addition, designing N fertilizer management strategies increases the efficiency of N uptake by crops resulting in reduction of N leaching.

Conclusion

On average current nitrogen use efficiencies are being reported to be about 50 % and economic worldwide average nitrogen losses are equivalent to millions of U.S Dollars[23]. Current assessment of nitrogen leaching is also an important environmental concern for the Black Sea region of Turkey. However, the approach of field sampling in significantly large and heterogenic areas is too expensive and time-consuming when dealing with the identification of areas posing a potential risk to the environment concerning[21-24]. Therefore, an assessment system that can combine the results of mathematical models with the information on soil characteristics and agricultural management within the existing geographical database could provide decision makers with sufficient information in a more expedient manner. This paper represents a model applied to a large hazelnut agricultural land in Ünye-Tekkiraz district of Black Sea region, based on common software tools and able to provide a quick evaluation of its fragility and sustainable natural resource management through the use of proper indicators.

REFERENCES

1. D.L. Karlen, L.A. Kramer and S.D. Logsdon, *Agron. J.*, **90**, 644 (1998).
2. D. Tilman, J. Fragione, B. Wolff, C. D'Antonio, A. Dobson, R. Howarth, D. Schindler, W.H. Schelsinger, D. Simerloff and D. Swakhamer, *Science*, **292**, 281 (2001).
3. C. Li, N. Farahbakhshazad, D.B. Jaynes, D.L. Dinnes, W. Salas and D. McLaughlin, *Ecol. Model.*, **196**, 116 (2006).
4. D. Barraclough, S.C. Jarvis, G.P. Davies and J. Williams, *Soil Use Manage.*, **8**, 51 (1992).
5. A. Bakhsh, R.S. Kanwar, D.B. Jaynes, T.S. Colvin and L.R. Ahuja, *Trans. ASAE*, **44**, 269 (2001).
6. M.R. Karaman, K. Saltali, S. Ersahin, H. Güleç and M.R. Derici, *Environ. Monit. Assess.*, **101**, 249 (2005).
7. Danish Hydraulic Institute (DHI), MIKE SHE Water Movement User Manual, Danish Hydraulic Institute (1999).

8. A.W. Harbaugh, E.R. Banta, M.C. Hill and M.G. McDonald, MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model - User Guide to Modularization Concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92, p. 121 (2000).
9. S. Liu, W.A. Reiners and M. Keller, *Environ. Modell. Softw.*, **15**, 727 (2000).
10. H. Johnsson, L. Bergström, P.E. Jansson and K. Paustian, *Agric. Ecosyst. Environ.*, **18**, 333 (1987).
11. Anonymous, Turkish State Meteorological Service (2005).
12. Soil Survey Staff, Soil Survey Manual, USDA Handbook Washington DC, USA (1999).
13. K. Czymmek, Q. Ketterings, H. van Es and S. DeGloria, The New York Nitrate Leaching Index, Cornell University, Department of Crop and Soil Sciences Extension Publication E: 03, pp. 1-34 (2003).
14. NSH, National Soil Survey Interpretations Handbook, 430, VI, Draft, USA (1992).
15. J.R. Williams and D.E. Kissel, in eds.: R.F. Follet, D.R. Keeney and R.M. Cruse, Water Percolation: An Indicator of Nitrogen-Leaching Potential, Soil Science Society of America, Inc. Madison, Wisconsin, pp. 59-83 (1991).
16. R.L. Kellogg, Potential Priority Watersheds for Protection of Water Quality from Contamination by Manure Nutrients, Page 20 in Animal Residual Management Conference, Kansas City, Missouri (http://www.nrcs.usda.gov/technical/land/pubs/) (2000).
17. P. Donovan and W.L. Daniels, Proceedings of the 25th International ESRI User Conference, pp. 1-7 (2005).
18. S. Kurt, Detailed Soil Survey and Mapping of Unye-Dizdar Village, M.Sc. Thesis, Natural Science Institute, Ondokuz Mayis University, p. 93 (2007) (unpublished).
19. TNT, TNT (The New Thing) MIPS (MicroImage Processing System), Getting Started Geospatial Analysis, MicroImages, USA (1999).
20. C.W. Thornwaite and J.R. Mather, Publications in Climatology, Laboratory of Climatology, Vol. X, No. 3 (1957).
21. P. Olsen and P.R. Kristensen, *Nutr. Cycl. Agroecosys.*, **50**, 307 (1998).
22. R.G. Silva, K.C. Cameron, H.J. Di, N.P. Smith and G.D. Buchan, *Aust. J. Soil Res.*, **38**, 13 (2000).
23. V.E. Harold and J. Delgado, Encyclopedia of Soil Science, pp. 1-3. (2003).
24. O. Dengiz and S. Akgül, *Turk. J. Agric. For.*, **29**, 439 (2005).

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