Water contamination by nitrate and pesticide in a small watershed under tobacco cultivation

Douglas Rodrigo Kaiser, Elena Blume, Danilo Rheinheimer dos Santos, Dalvan José Reinert, José Miguel Reichert

Center for Rural Sciences, Federal University of Santa Maria, Brazil. Email eblume@smail.ufsm.br

Abstract
Tobacco is usually seen as a "dirty crop" due to its risk to human health, both for producers and for smokers. Nevertheless, in many countries the crop has important social and economical impacts. Watershed is the unit where conservation strategies should be planned to favour soil and water conservation and amelioration. Thus, herein we present results on nitrate and pesticide contamination of surface and shallow well waters, in a small watershed under tobacco production. In the watershed with shallow soil and steep slopes, high potential for water resources contamination cropped to tobacco and rapid decline in soil productive capacity and in water quality were observed. The following elements lead to soil and water degradation: improper agricultural practices, utilization of high doses of fertilizers and pesticides, absence of riparian forest, and intense soil use. A shift in agricultural practices is needed in the short term, by including soil, water and wildlife conservation strategies; whereas a change in cash crop, in the long term, is necessary to replace tobacco cultivation.

Key Words
Rural catchment; watershed hydrology; environmental contamination; steep lands.

Introduction
Tobacco cultivation is an activity with a high potential for contamination of water resources in watersheds and it leads to a rapid decline in the productive capacity of the soil and water quality in these locations. This is largely due to the improper agricultural practices of these lands and the utilization of high doses of fertilizers and pesticides.

Runoff and leaching are the two main ways pesticides may reach surface and ground water. Runoff is the physical transport of pollutants over the soil surface by overland flow, whereas by leaching the pollutants are transported through the soil with infiltrating, ascending or laterally draining water.

The hydrologic cycle of water influences the complex partitioning of molecules and ions within and between the environmental components soil, water and air. Pesticides and other agrichemicals are applied at field scale and react in the soil at molecular scale, but the impact might be at watershed (sum of soil-water interactions). The amount of pesticide runoff depends on slope, soil texture, moisture content, rainfall characteristics, and pesticide characteristics. In watershed scale, the cropped areas distribution in the landscape affects sediment and pesticides concentration. The natural buffer zones (such as riparian zones) may act as pesticide trap along agricultural fields.

Leaching is increased for water-soluble pesticide, sandy texture, rainfall right after pesticide application, low-adsorbing pesticide, and existence of preferential flow through macropores and other large voids. Groundwater contamination is favoured by weakly-sorbed but persistent pesticides, since they are readily leached through the soil. Several pesticides commonly used in tobacco crops, such as chlorpyriphos, imidacloprid, flumetralin, and clomazone, are applied in southern Brazil, as well as non-recommended pesticides for tobacco crops as iprodione, atrazine and simazine. These chemicals pose risk to humans and wildlife.

Intensive farming significantly changes the natural ecosystem and the impacts may be assessed by analysis of surface water. The sediment and runoff leaving crop fields may transport several environmental pollutants used for crop protection against pests and diseases. Thus, water becomes unfit for human consumption bringing negative impact of major significance to rural communities, with repercussions also in urban communities. Surveys demonstrated that sediment discharge in the watershed is high and that phosphate ions are released to solution, on average, twice as rapidly as sediments collected from sub-watersheds with low anthropic activity than those from sub-watersheds with high anthropic activity.

Although tobacco might be seen as a “dirty crop” due its risk to human health, both for producers and for smokers, the crop an important social and economical impact in many countries. Brazil is the second largest producer of tobacco, where thousand families make their living. About 50% of those families live in the state of Rio Grande do Sul (RS), located in southern Brazil, where the studies presented herein were done.

Watershed is the unit where conservation strategies should be planned to favour soil and water conservation and amelioration. Thus, herein we present results on nitrate and pesticide contamination of surface and shallow well waters, in a small watershed under tobacco production.

Methods

A small watershed in Agudo-RS, southern Brazil, with an area of 480ha was studied (Figure 1). Lino Creek and its tributaries constitute the drainage system of the watershed located in a basaltic mountain side, between the Central Depression and Mid Plateau. The region is characterized by the presence of native forest and also of tobacco crop, which uses pesticides without proper control. The watershed is characterized by (i) a low anthropic activity site with steep slopes and stream borders protected with permanent vegetation (riparian zone) and few agricultural fields and (ii) a high anthropic activity site also with steep slopes, but there are agricultural fields close to the stream and less riparian vegetation.

Figure 1. Lino Creek watershed, Agudo-RS, Brazil.

In the pesticide study, water samples were collected in five water sources used for human consumption and in the Lino Creek. Besides tobacco grown as main cash crop, other crops are cultivated after tobacco harvesting, while cultivated forest is used for wood production for tobacco drying after harvest. The water samplings were taken at three times during and after the cultivation of tobacco, namely: after the transplantation of the seedlings, during trimming, and after harvesting the tobacco. The quantification of the active ingredients chlorpyrifos, iprodione and flumetralin was made by gas chromatography with electron-capture detection, whereas imidalcloprid, atrazine, simazine and clomazone were quantified by high performance liquid chromatography with ultraviolet detection.

We also evaluated the nitrate concentration in soil solution in tobacco crop fields, native forest, grasslands and in water from two wells used for domestic supply, and monitored the concentrations of nitrate and ammonium in the soil solution in the region of the root system and below it in a shallow soil planted to tobacco under conventional tillage (CT), minimum tillage (MT) and no-till planting (NT), in a small, hilly watershed in southern Brazil. Monitoring of nitrate concentration in the soil solution was performed in and below the root zone (Kaiser *et al*. 2006), using tension lysimeters with porous ceramic cup for solution collection, and distillation and titration for nitrate analysis.

Results and discussion

In the tobacco production system in South Brazilian many types of pesticides are used. Some properties of these pesticides are: imidacloprid is a systemic insecticide that presents a high residual effect and mobility in the soil and has a half-life in soil from 48 to 190 days. Atrazine is a highly persistent herbicide in the soil, has a high potential for groundwater contamination despite its moderate solubility in water and has a half-life from 60 to more than 100 days. Clomazone is a highly effective herbicide but causes groundwater contamination due to its water solubility (1100 mg/L) and long half-life that averages from 28 to 84 days. Chlorpyrifos is an organophosphate insecticide that is classified as moderately hazardous. In soil,

chlorpyrifos is degraded at a moderate rate; due to the low solubility (1.4 mg/L) and hydrophobic nature (log K_{ow} 3.31–5.27); chlorpyrifos rapidly partitions from the water and adsorbs to sediment particles. Simazine is a persistent herbicide and does not adsorb strongly to soil particles. As it has a high half-life (36–234 days) in soil and low solubility (6.2 mg/mL) in water, it is likely to contaminate groundwater (Becker *et al*. 2009).

Six pesticides (imidacloprid, atrazine, clomazone, iprodione and chlorpyrifos) of the seven active ingredients tested were found both in the water from the creek and from wells used for human consumption. Only flumetralin was not detected in any of the water samples. In samples taken after transplantation of the tobacco, chlorpyrifos was detected in water in all nine collecting points in the watershed and showed to be persistent over time. The water could be consumed if the Brazilian standards would be considered, but could not when considering the European standards of water quality, since the standards are higher and thus more restrictive to human consumption. This poses both a scientific and a political issue.

The indiscriminate use of prophylactic treatments for the cultivation of tobacco along with the lack of landscape planning and environmental protection explain the widespread occurrence of pesticides in water from the creek and from wells for human consumption. This result called for immediate and intensive effort to reduce pesticide use in crop production, protection of wells for human consumption, and integrated watershed planning.

Results from the nitrate study show that nitrate reached depths below the tobacco root zone and represents a source of water contamination. The levels of nitrate were higher in crops fields compared to the grassland and native forest, reaching 80 mg/L in areas with tobacco. The well located below the tobacco crops had higher concentrations of nitrate, surpassing the critical limit of 10 mg/L in some periods.

Ranging from 8 to 226 mg/L, the nitrate content was greater after initial fertilization and decreased throughout the cycle. The average nitrate content in the rooting zone was 75 in the NT, 95 in the MT and 49 mg/L in the CT. Below the rooting zone, the average nitrate content was 58 in the NT, 108 in the MT and 36 mg/L in the CT. Minimum tillage presented the greatest nitrate concentration in the soil solution during the tobacco cycle, but was not statistically significant in relation to conventional tillage and no-till planting. The reduction in the nitrate concentration in the soil solution over time may be attributed to uptake of the nitrogen from the soil solution by the growing crop, microbial immobilization and also to the losses through runoff, denitrification and leaching.

A potential risk for contamination of groundwater sources of the watershed by nitrate is evident. In spite of the great variation in the nitrate concentration observed both among treatments through time and in space, the concentrations of nitrate found below the tobacco rooting zone were high when compared with other results in the literature.

Conclusions

High potential for water resources contamination in watersheds cropped to tobacco and rapid decline in soil productive capacity and in water quality were observed in the watershed with shallow soil and steep slopes. Improper agricultural practices, utilization of high doses of fertilizers and pesticides, absence of riparian forest, and intense soil use are elements leading to soil and water degradation. A shift in agricultural practices is needed in the short term, by including soil, water and wildlife conservation strategies, whereas a change in cash crop, in the long term, is necessary to move away from cultivating tobacco.

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Literature

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