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A Pesticide Residue Risk Assessment from Agricultural Land Using GIS

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Abstract

Water quality contamination issues are of critical concern to human health, whilst pesticide release generated from irrigated land should be considered for protecting natural habitats and human health. This paper suggests new method for evaluation and analysis using the GIS technique based on integrated spatial modeling framework. The pesticide use on irrigated land is a subset of the larger spectrum of industrial chemicals used in modern society. The behavior of a pesticide is affected by the natural affinity of the chemical for one of four environmental compartments; solid matter, liquid, gaseous form, and biota. However, the major movements are a physical transport over the ground surface by rainfall-runoff and irrigation-runoff. The irrigated water carries out with the transporting sediments and makes contaminated water by pesticide. This paper focuses on risk impact identification and assessment using GIS technique. Also, generated data on pesticide residues on farmland and surface water through GIS simulation will be reflected to environmental research programs. Finally, this study indicates that GIS application is a beneficial tool for spatial pesticide impact analysis as well as environmental risk assessment.

Keywords: GIS, Pesticide

1. Introduction

The term of pesticide is a composite term which includes all chemicals to control weeds, insects, fungi, nematodes, and vertebrate poisons. Recently, pesticides have been detected in streams with agricultural area throughout the Nation. Pesticides in streams and farmland areas are of concern to toxicologists and water resource managers because pesticides can adversely affect such as disorder of immune systems. Pesticide concentrations in farmlands are measured and studied for carcinogenic impact assessment. The concern about the special vulnerability of humans to pesticides exposures makes the proposed USEPA guidelines for carcinogenic risk assessment of particular pesticides. They address cancer risks for humans.

For potential cancer risks, they would depend on the extent to which humans might be exposed how much and to what quantity of the pesticides. In farm land, it is potentially considered as point source. Pesticides in runoff water of the irrigated farm areas can deteriorate and adversely affect the health of humans and aquatic biota. However, it is impossible to completely assess pesticide risks as only collecting and monitoring at sites in farm areas.

Hence, the advantage that a GIS can provide is the capability of representing spatial data such as contaminated areas in order to assess carcinogenic risks. Before GIS simulation, all data are collected, stored, retrieved and statistically manipulated.[1)] Results of GIS simulation are used to display geographical relationships among contaminated areas, resident areas and natural habitats.

A trifluraline is considered to be a possible human carcinogen.[2)] A chemical structure of trifluraline is shown in Fig. 1. According to toxicity information for trifluralin, it is chemical that is one or more of the following highly acutely toxic, cholinesterase inhibitor, known potable carcinogen, known groundwater pollutant or known reproductive or development toxicant (http://www.pesticideinfo.org).

OHS Inc.[3)] and U.S.EPA[4)] report that, in 2-year study of rats fed 325mg/kg/day, the highest dose tested, malignant tumors developed in the kidneys, bladder and thyroid. Because there is probably increasing in the risk of human cancer. In animal studies, consumption of the trifluralin for drinking water(5 μg/L) has been shown to cause liver and kidney damage.[2)] Also, advisory level for drinking water is 2.0 μg/L.[5)] In the farm land, the trifluralin is strongly absorbed on soils including organic

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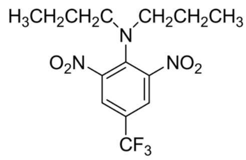


Fig. 1. Chemical Structure of Trifluralin.[6)]

matter and clay content (Koc=7,000 g/mL) and nearly insoluble in water.[7,8)]

Therefore, the farmers have strongly potential exposure possibility from their environment. Human exposure pathways are considered to be composed of several factors such as source, transport media, exposure point, route of exposure, and receptor population. Table 1 shows physical properties of trifluralin.

2. Materials and Methods

2.1. Description of Study Area

The Lower Rio Grande Valley region of Texas is located in South Texas. It is comprised of 4 counties such as Starr, Hidalgo, Cameron, and Willacy and extends along the Rio Grande from Falcon Dam to the Gulf of Mexico. Especially, Hidalgo, Starr, and Cameron have the region's 740,000 irrigated acres. 98% of all the water used in the border region is from Rio Grande River as seen Fig. 2. Also, in population map (Fig. 3), citizens including farmers are living near farmlands or downstream of river. The region of cotton and sorghum occupied in the most acreage, and other crops as citrus and sugar cane occupied in the other region. Also, in this LRGV region, farmers are using many pesticides and nutrients because they are important to the yield and quality of crops. However, toxicologists suggest that the discovered *anencephaly* and cancers in this region may be

Table 1. Pesticide use data (LBS) and properties[9)]

(a)

		Sulfer	Trifluralin	Pendimethalin	Chlorothalonil	Dissulfoton
Pound Uses (LBS)	LRGV	32,000	820,000	360,000	126,000	98,000
	Texas	107,000	2,869,000	1,286,000	434,900	160,000
Cancer class		N/A	C	N/A	N/A	N/A
Vapor pressure (mPa)		N/A	14.6	4	14.1	7.2
Water solubility (ppm)		N/A	0.3	0.275	0.6	25
Soil absorption coefficient		N/A	8,000	5,000	1,380	600
Flux rate		-	0.00608	0.00291	0.00009	0.00048
Field half life (days)		5	60	90	30	30
Final rank		0.001	0.225	0.02	0.01	0.01

(b)

Trifluralin Properties	
CAS # [3)]	1582-09-8
Specific Gravity [3)]	1.294@ 25 degree
Boil Point [7)]	139-140 degrees
Melting Point [3)]	46-47 degrees
pH [10)]	7.0 (50% suspension)
ADI [6)]	0.1mg/kg/day

Fig. 2. The 8 irrigation districts in the Lower Rio Grande Valley in using GIS based.[12)]

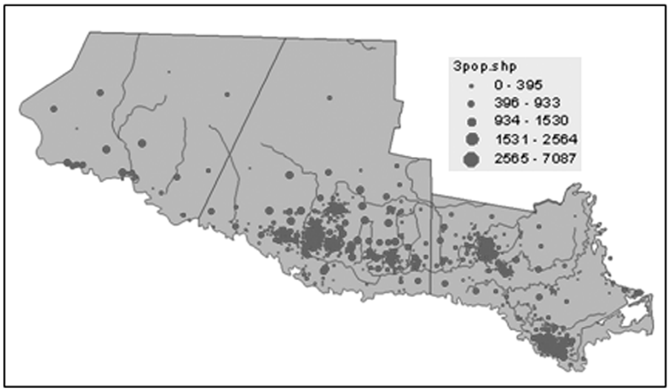


Fig. 3. Population distribution in Lower Rio Grande Valley (LRGV).

related to contamination originating from pesticides in agricultural runoff.[11] In field, the pesticide compounds most frequently are detected in runoff samples from farmland areas within three counties. In statistical reference, cropland treated with pesticides has increased by 52.5% from the 1969 to 1997 (U.S. Dept of Commerce, 1969-1997).

2.2. Pesticides Data Collection and Manipulation

In the study, pesticide use data in 2005 and land survey data are obtained from National Center for Food and Agricultural Policy, National Pesticide Use Database and U.S. Geological Survey. The 15 pesticides were used in Lower Rio Grande Valley region in 2005. However, only five pesticides are mentioned in Table 1(a). The other data source is shown in Table 1(b).

Cancer class, cancer potency, volatilization flux, and field half life are developed to prioritize and rank the pesticide in Table 2. As defined in equation 1 and 2, cancer hazard factor and hazard-adjusted pesticide use are to calculate pesticide density.

Cancer Hazard Factor =
Cancer class × cancer potency × flux × persistence/500 (1)

Hazard-Adjusted Pesticide Use
=Cancer hazard factor × pounds of use (2)

2.3. Population Data Collection and Manipulation

The population data in 2005 are collected from two sources: the U.S. Geological Survey and U.S. Census Bureau. First, population values are obtained from the Census Demographic Online Data and cartographic boundary files are downloaded from USGS website.

At the end of the data collection activity, a population data are converted point data to grid data (persons per m^2) using GIS manipulation process.

2.4. Computation of Carcinogenic Risk Impact Index (CRII)

The carcinogenic risk impact index (CRII) is obtained by the grid (30m by 30m) calculation of the information stored in GIS database such as population, area and pesticide information.

CRII(Carcinogenic Risk Impact Index) is calculated by following equation (3).[13]

$$CRII_j = W_a \sum_{i=1}^{n} Q_i \frac{I_{a,i,j} - I_{a,i,0}}{IT_a} + W_p \sum_{i=1}^{n} Q_i \frac{I_{p,i,j} - I_{p,i,0}}{IT_p} \tag{3}$$

Where $W_a + W_p = 1$ and W_a and W_p are the weights given to area and population. In general, W_a and W_p are 0.35 and 0.65, respectively; Q_i is the value of pesticide ranking i (1-5) in the scale or grid, for pesticide j ; $I_{a,i,j}$ is the are affected by pesticide ranking value i for pesticide j; $I_{p,i,j}$ is the population in areas affected. IT_a and TI_p are the total area and population of study. If more carcinogenic pesticides are considered, CRII can be obtained using the equation 4. However, it will refer to results and discussion in next paper:

$$CRII_j = \sum_{k=1}^{m} \left[W_k \left(\sum_{i=1}^{n} Q_{i,k} \frac{I_{k,i,j} - I_{k,j,0}}{IT_k} \right) \right] \tag{4}$$

where k is impact indicator that considered a carcinogenic risk component.

In Fig. 4, there are several steps involved in this process to create the necessary CRII output from the required input such as collected and manipulated data. To illustrate carcinogenic risk impact map), cokriging is used. It uses information on seve-

Table 2. Pesticide cancer hazard weights by attribute

Weight number	Cancer class	Cancer potency[a] (mg·kg^{-1} · day^{-1})	Volatilization flux[b,c]	Field-half life[c] (days)
10	A	>1	>10^{-1}	-
8	B1	>0.1-1	>10^{-8}-10^{-1}	-
7	B2	-	-	-
5	C	>0.01-0.1	>10^{-8}-10^{-2}	>100
4	-	-	-	76-100
3	G or D.R.[d]	>0.001-0.01	>10^{-7}-10^{-5}	51-75
2	-	-	-	26-50
1	NA	<0.001 or NA	>10^{-7} or NA	<25 or NA

[a]USEPA.[2)]
[b]Flux rate = vapor pressure / (water solubility×soil adsorption coefficient).[14)]
[c]Vapor pressure, water solubility, soil adsorption coefficient, and field half-life is acquired from USDA.[10)]
[d]Genotoxic or developmetal / reproductive toxicant.

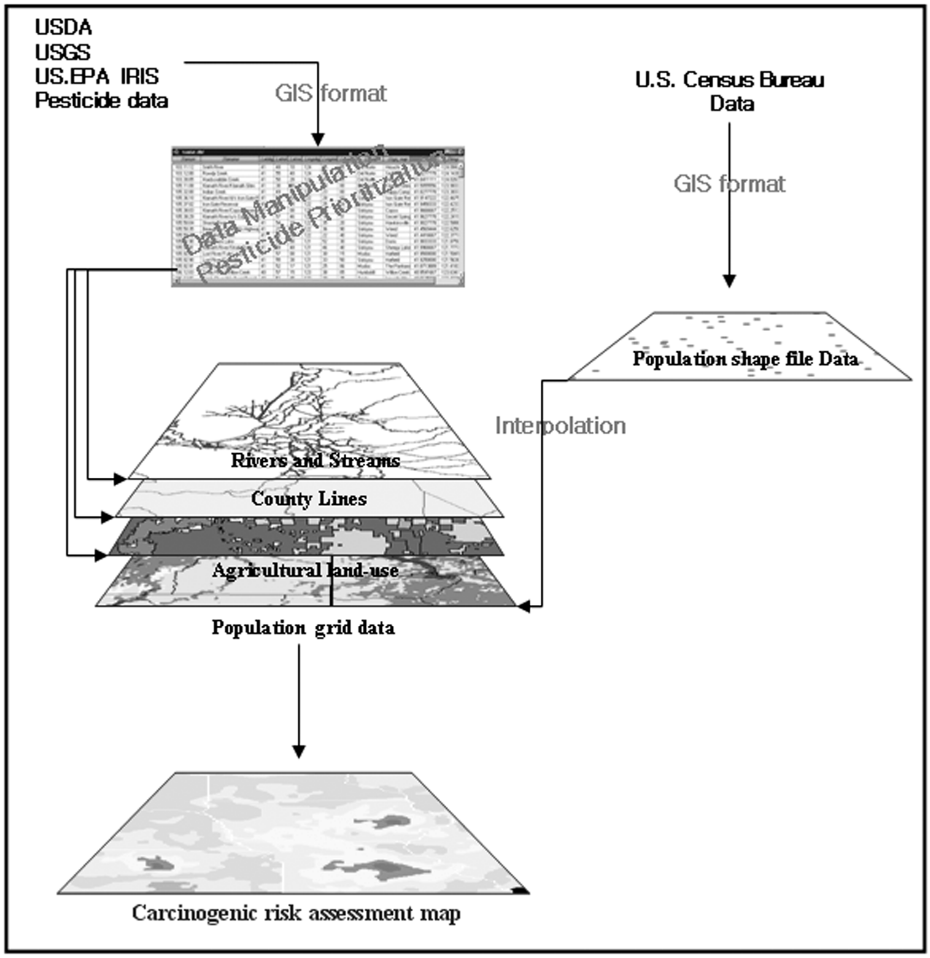


Fig. 4. The specific procedure for CRII (Carcinogenic Risk Impact Index).

ral variable types such as population grid data, agricultural land and topographic map. Cokriging estimates the autocorrelation for each variable as well as all cross-correlations. Both autocorrelation and cross correlation are used to make better CRII assessment. Here, correlation is the tendency for variables of population data, location data of source of trifluralin in farm land areas and trifluralin use data with cancer hazard factor to be related. In geostatistics, the information on spatial locations including variables allows to simulate CRII map.

3. Results and Discussion

The result of the detection for trifluralin in study area is given in Fig. 5. It is detected highly on the cropland with irrigation. The used trifluralin levels should be a concern for people who live near croplands with irrigation. Actually, there are several possible exposure scenarios that must be considered. Specially, the most important scenario indicates that trifluralin in surface water and groundwater is important cause. Actually, in LRGV, its levels exceed drinking water quality criteria.

Fig. 6(a) shows that CRII (Carcinogenic Risk Impact Index) map is created when calculating in using equation 3. The CRII map consists of the GIS grid formats (30m × 30m) which include in carcinogenic impact values.

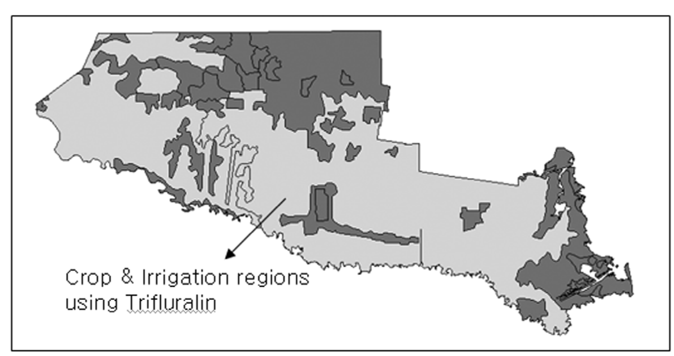
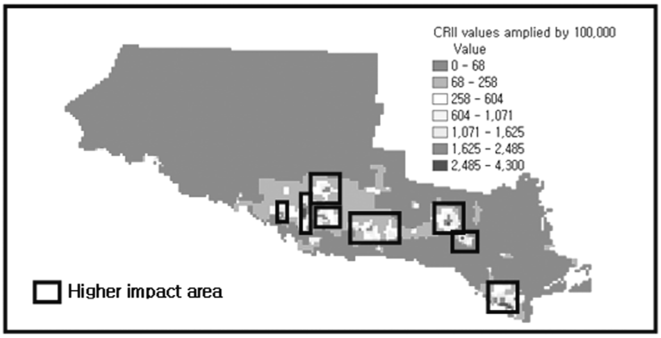
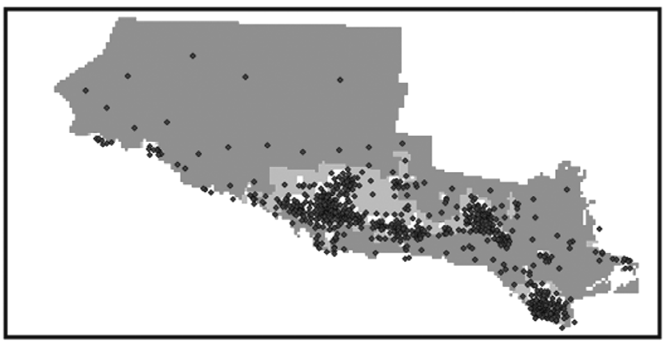


Fig. 5. The trifluralin usage map in crop and irrigation land within LRGV.

Of course, they have different value according to locations. The legend of Fig. 6(a) shows that impact values are amplified to see variation because the carcinogenic impact effects are too low in GIS map. Also, rectangle area with high population density and high trifluralin usage should be the biggest exposure sites. Also, Carcinogenic Risk Impact Index (CRII) value is mostly high in rectangular sites. The resident areas having high population density within irrigated farmland are potential exposure points. They can show that the defined carcinogenic impact extent becomes a very influential factor on the degree of accu-



(a) CRII value



(b) Joining the map using population layer and CRII layer

Fig. 6. The CRII distribution map.

racy with which the points can be predicted. The average values with amplified by 100,000 range from 2,485 to 4,300.

4. Conclusion and Summary

Carcinogenic risk assessment using GIS aims at studying the correlation of environmental hazards such as emission of a pollutant with irrigation work or any possible combination of this and estimating the associated possibility and probability of occurrence of agricultural and climatic events. The procedure for developing GIS application for carcinogenic risk assessment is described in this paper, along with several specific input data such as population density, trifluralin data and cropland areas. However, this paper is not undertaken to compare calculated data with measured data because CRII shows the potential possibility. Thus, it is in difficulty for comparison in real.

The advantage of using GIS application is very effectively for this purpose. Specially, a huge number of spatial data with non spatial environmental hazard data are displaying and analyzing in a fast and accurate ways. In present, GIS work based on this application is undertaking in high land area, Gangwon province. In future, it will be introduced in EER.

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