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BIOCIDE LEACHING
A soil capacity model to indicate the hazard of groundwater contamination by biocides

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The Research Program on Sustainability in Agriculture (REPOSA) is a cooperation between Wageningen Agricultural University (WAU), the Center for Research and Education in Tropical Agriculture (CATIE), and the Costa Rican Ministry of Agriculture and Livestock (MAG). In addition, REPOSA has signed memoranda of understanding with numerous academic, governmental, international, and non-governmental organizations in Costa Rica.

The overall objective of REPOSA is the development of an interdisciplinary methodology for land use evaluation at various levels of aggregation. The methodology, based on a modular approach to the integration of different models and data bases, is denominated USTED (*Uso Sostenible de Tierras En el Desarrollo*; Sustainable Land Use in Development).

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REPOSA's research results are actively disseminated through scientific publications, internal reports, students' thesis, and presentations at national and international conferences and symposia. Demonstrations are conducted regularly to familiarize interested researchers and organizations from both within and outside Costa Rica with the *USTED* methodology.

REPOSA is financed entirely by WAU under its Sustainable Land Use in the Tropics program, sub-program Sustainable Land Use in Central America. It operates mainly out of Guápiles where it is located on the experimental station *Los Diamantes* of MAG.

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REPOSA es financiado por la UAW bajo su Programa del Uso Sostenible de la Tierra en los Areas Trópicos. La sede de REPOSA está ubicada en la Estación Experimental Los Diamantes del MAG en Guápiles.

Preface

This report presents a description of the investigation on the environmental aspects of biocide use in the Atlantic Zone of Costa Rica. Special emphasis was laid in the development of a biocide leaching model to indicate the hazard of groundwater contamination of biocides on different soil types.

The idea of this research came to me during my stay at the Atlantic Zone Programme in Guápiles, Costa Rica. I worked in a palm heart plantation and almost every day a little yellow plane flew over me on its way to a banana plantation. I saw the possibilities and even more the constraints of the use of biocides. I hope this report can contribute to the research needed for the planning of sustainable land use.

I would like to thank my supervisor Jetse Stoorvogel for his continuing support. His enthusiasm was very motivating. I would like to thank the staff of the PPUNA, especially, Louisa Castillo, Ineke Wesseling and Fabio Chaverri for the possibility of using their information and their hospitality.

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1 INTRODUCTION

Study area

Agriculture is one of Costa Rica's largest industries and has a high use of biocides (Hilje et al., 1987). Investigations are carried out to evaluate the environmental and health effects of this biocide use. In Costa Rica, research on the effects of agriculture biocide use is carried out by 'Programa de Plaguicidas de Univercidad Nacional' (PPUNA, Pesticide Program of the National University).

The Atlantic Zone Program (AZP) is the result of an agreement for technical cooperation between the 'Centro Agronómico Tropical Investicación y Enseñanza' (CATIE, Centre of investigation and education for tropical agriculture) and 'Ministerio de Agricultura y Ganaderia (MAG, Costa Rican ministry of agriculture and animal husbandry) and Wageningen Agriculture University (WAU). The program focuses amongst other on the development and testing of the methodology "Uso Sostenible para Tierras en El Desarollo" (USTED: Sustainable land use in development). This methodology aims at the analysis of land use and to support agricultural land use planning by integrating socio-economic with agronomic and edaphic factors.

The methodology developed by the Atlantic Zone Program permits incorporation of quantitative parameters to indicate sustainability of land use. During the analysis of alternative land use scenarios, the effect of incentives and policies on the indicator values will be studied, resulting in knowledge about the trade offs between environmental effects and changes in the socio-economic environment.
One of these sustainable parameters gives an indication of biocide use in the form of a biocide index (BI). This BI (Equation 1, Chapter 2) is calculated on the basis of the active ingredients, toxicity, persistency and quantities of the biocides used. All these chemical characteristics of the different biocides are added to get one index for the total use of biocides within one cultivation.

This study tries to contribute to the investigation of biocides and its external effects within the Atlantic Zone of Costa Rica.

Objectives

One of the aims of this study is to quantify the hazard of contamination by biocide leaching into the groundwater.

The crops included in the methodology of the AZP are maize, cassava, pineapple, palm heart, and plantain. For these crops and two additional crops (banana and ornamental plants) the biocide use will be analyzed and an index value, indicating the environmental effects will be described. The banana and ornamental plants are included, because they represent a large area of the Atlantic Zone and a lot of chemical are applied in these two crops.

To develop an index that describes the effects of biocide use, different aspects have to be taken into account. There is an effect on the air, soil and water environment with its flora, fauna and biodiversity. It is difficult to quantify these effects and to discover the source of the contamination, because it is difficult to take representative samples. There is also a direct risk for the worker who is applicating the biocide.
The present biocide index, as described above, will be subdivided into two new values; one is indicating the environmental effects (excluding the health effects) and another is indicating the effects on human health.

This study emphasizes the development of an indicator for the hazard of groundwater contamination. This will lead to an index value for the environmental effects of biocide use. The methodology developed is based on the limited database that is available, keeping in mind the need for an index value.

For a correct description of the effect of biocide use, the health effects also should be formulated. This however is not included in this study. Uytewaal (1995, in prep.) will calculate an index value indicating the effects of biocide use on human health (mainly the farmers and workers).

These two studies will result in two indices indicating respectively the health (HBI = human biocide index) and environmental (EBI = environmental biocide index) aspects.

The set up of this report is as follows. In Chapter 2 general information of the Atlantic Zone of Costa Rica and some background information on biocide use in Costa Rica is given. The methodology of the Atlantic Zone Program is described and the biocide index as it is determined and used until now. In Chapter 3 materials and methods of this study are described and the Biocide Leach model (B-Leach) is introduced. Chapter 4 describes how the results of the B-Leach model will be used as biocide index including the LD50 value (lethal doses for 50 % of the population). Chapter 5 shows the results of this study followed by conclusions and recommendations in Chapter 6.

2 BACKGROUND INFORMATION

2.1 The Atlantic Zone

The Atlantic Zone is situated in the north eastern part of Costa Rica between 10° and 11° northern latitude and 83° and 84° western longitude (figure 2.1). This zone is defined as the northern part of the province of Limon. It comprises an area of circa 450,000 ha. It is bordered by the central mountain ranges (including the volcano Turrialba (3329 m) and the volcano Irazu (3423 m)) in the south, the Caribbean sea in the east and the Cordillera de Talamanca in the south-east.

During the second phase of the Atlantic Zone Program (AZP) the USTED methodology has been developed and applied at the sub-regional level for the Neguev settlement located in the northern part of Limon province and the Guácimo canton (Stoorvogel et al., 1995 I). In the following sections a short description is given of climate, soils, vegetation and land use.

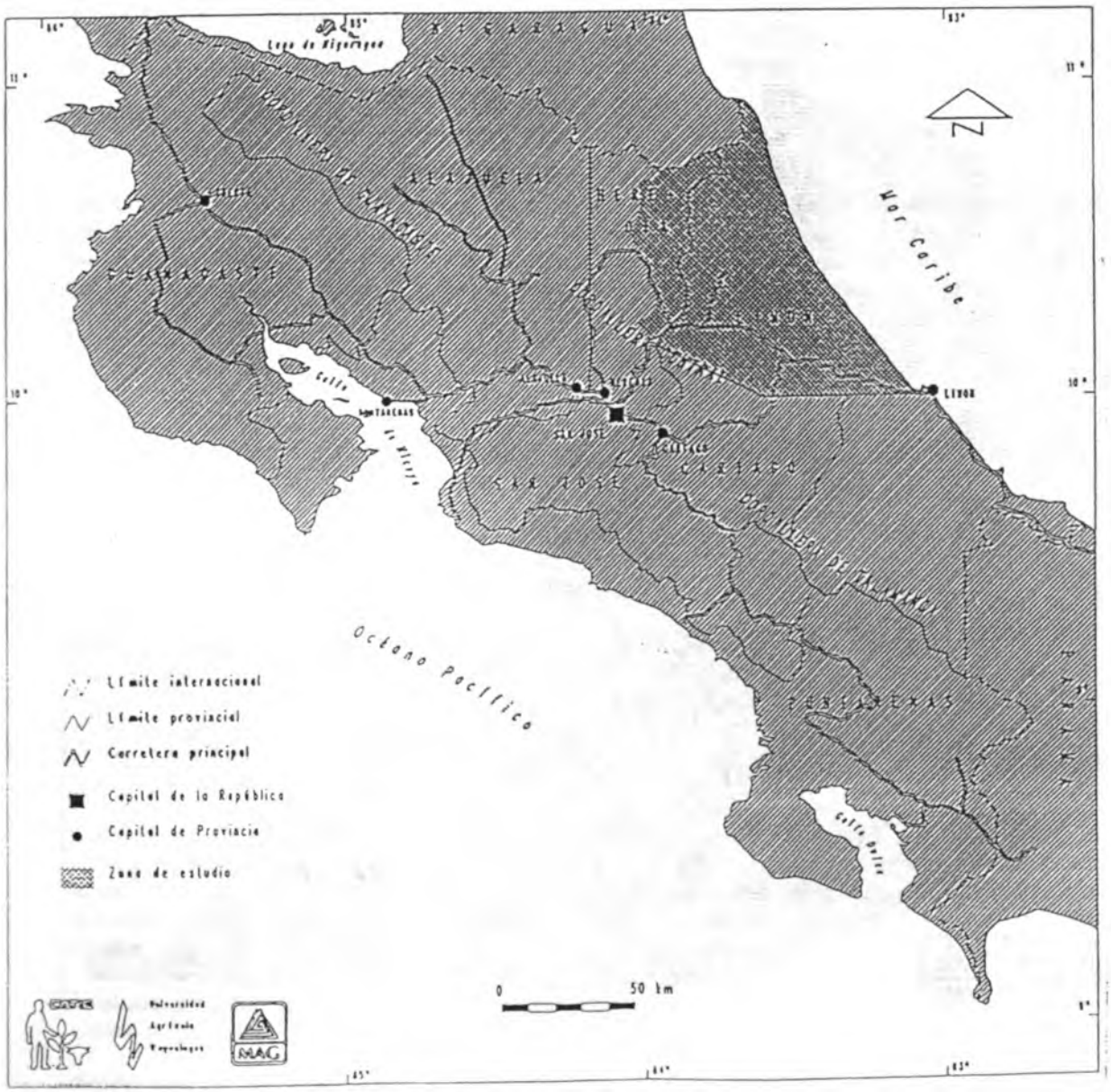


Figure 2.1 Location of the Atlantic Zone within Costa Rica

The climate in the Atlantic Zone is characterized as tropical humid (Herrera, 1985). Mean temperature varies from 18° to 24°C, mainly depending on altitude. Small temperature changes throughout the year occur. Annual variation of temperature is dominated by the monsoon with the highest temperatures before the onset of the summer-rains, around june (Portig, 1976). Total yearly rainfall is 3000 mm in the mid-east increasing to 4500 mm in the north and 6000 mm in the north-eastern part of the Atlantic Zone. Potential evapo-transpiration in the Atlantic Zone varies between 3 mm per day in June and 4.2 mm per day in March and April (Herrera, 1985).

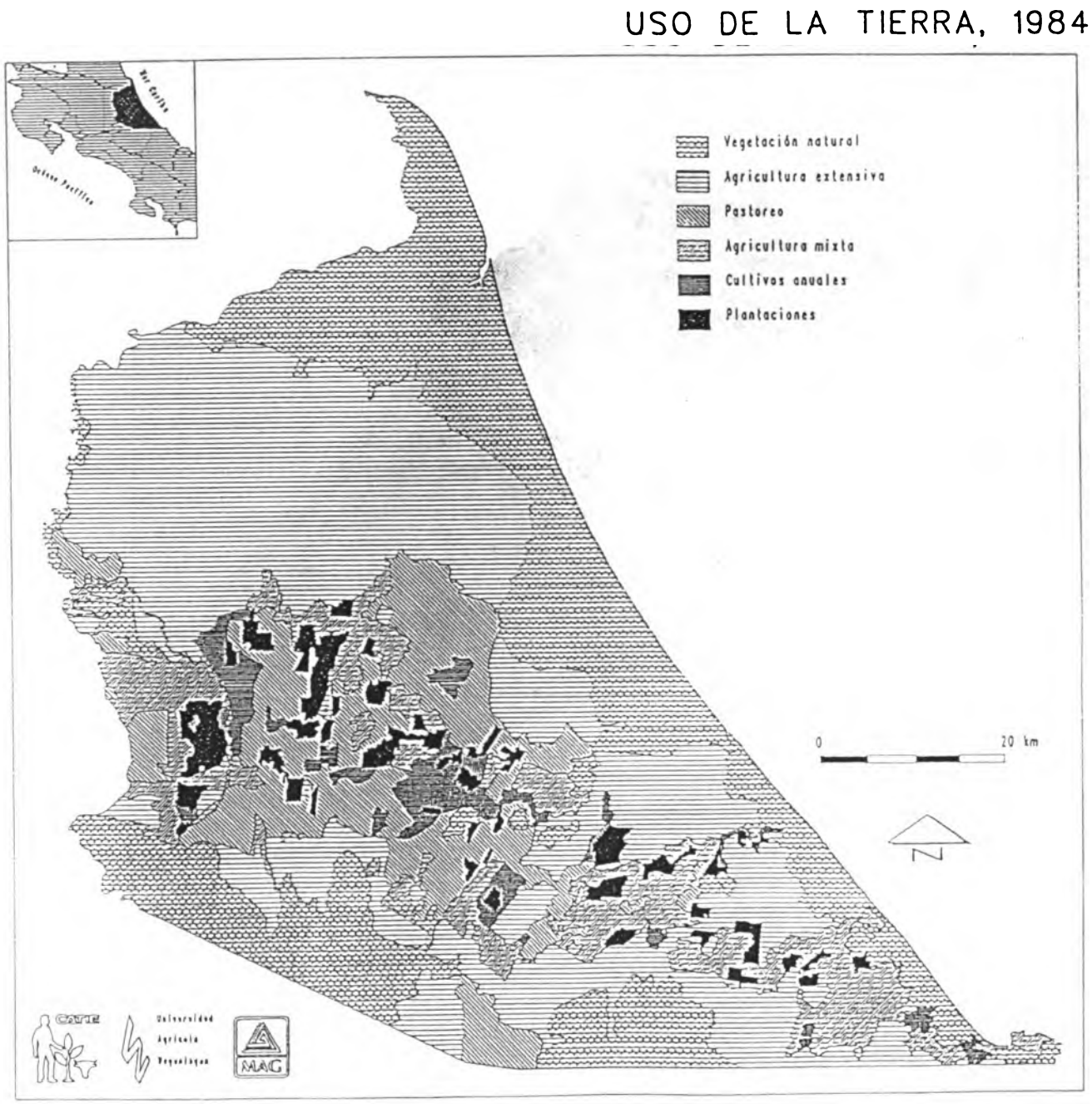


Figure 2.2 Land use in the Atlantic Zone of Costa Rica, 1984 (Stoorvogel and Eppink, 1995).

2.1.2 Soil classification

The Atlantic Caribbean lowland has been a sedimentation basin since early Tertiary. The coastline is made up by a narrow strip of succeeding beach ridges with parallel canals. Inland of these canals coastal swamps occur, gradually passing into a vast alluvial plain. At the foot of the volcano ranges the alluvium takes the form of alluvial fan deposits. At some places, the flat plain landscape is interrupted by remnants of basaltic tertiary volcanoes.

The following subdivision of soils is made for the Atlantic Zone (Stoorvogel et al, 1995 II):

1) young alluvial well drained volcanic soils with a relative high fertility (inceptisols and andisols).
2) relatively old well drained soils developed on fluvio- laharic sediments with a relatively low soil fertility (oxisols and inceptisols) and
3) young poorly drained volcanic soils with a relatively high soil fertility (entisols and inceptisols).

Soils of group 1 have a good structure and have a moderate to high organic matter content.
Soils of group 2 are strongly weathered (red-brown colour), have a low organic matter content and have more clay minerals. They appear on the higher parts of the Atlantic Zone and have a low infiltration. Superficial run off takes plays.
The soils of group 3 have a bad structure. They mainly appear in the lower parts of the Atlantic Zone. Because this soils have a bad water infiltration capacity, a lot of water accumulates in this lower part of the Zone.

2.1.3 Vegetation

About a hundred years ago, most of the area was covered by tropical moist and wet forest and pre-mountain wet forest. On the higher parts of the central and Talamancan mountain ranges, situated in the south of the Atlantic Zone lower-mountain and mountain rain-forest were found. Nowadays much of the forest has been cut for wood extraction and because of conversion into pasture and crop land (Jongschaap, 1993).

2.1.4 Land use

Land use in the Atlantic Zone is very variable in time and space (see figure 2.2) regarding the crops, management and field size. Farms produce maize, cassava, plantain and pineapple, papaya and also vegetables (sweet peppers and chili), citrus fruits, beans, courgette, pumpkin and roots (yam and chamol).

Plantations cultivate bananas, palm heart and ornamental plants for exportation. In addition, pastoral systems for beef production, some with silvo-pastoral systems and forestry for timber, are found. A considerable area is set aside as national park or forest reserve in which eco-tourism is being developed (Alfaro et al., 1994).

Land use is correlated with soil fertility and drainage. Most plantations are found on the fertile soils, naturally well drained, or drained by canals. Sections of the badly drained soils are not appropriate for other land use than forest if no drainage system is constructed. Most of the crops are restricted to the fertile, well drained soils, although some crops are found on the infertile soils (e.g. pineapple and palm heart). Pasture is found on all soil types. Banana plantations often have sufficient capital to get access to the more fertile soils or to construct a good drainage system (Belder, 1994).

Land use and farm size are interrelated. Bananas are cultivated on large plantations. For small farmers the cultivation of arable crops is in general the most important activity. This is especially the case in the settlements of the Instituto de Desarollo Agricola (IDA, the Institute for Agricultural Development), which buys large farms and redistributes it in parcels between 5 and 10 ha. Most annual crops are cultivated in these settlements (Belder, 1994).

Land use and infrastructure are related. In regions where the main activity is agriculture, infrastructure is created in intensively managed areas.

Besides farm size and infrastructure, economy is an important factor which influences land use. Before 1988, the cultivation of maize was promoted by a governmental subsidy on grain maize. After the abolition of this subsidy, maize is mostly cultivated for own consumption and occupies only limited areas of land. The protected areas consist of primary and secondary forest but some colonization takes place.

2.2 The Atlantic Zone Programme (AZP)

2.2.1 General description of the AZP.

In 1986 the AZP was established to analyze land use in the Atlantic Zone of Costa Rica, as a joint project between the Wageningen Agriculture University (WAU, the Netherlands), the Costa Rican Ministry of Agriculture (MAG, Ministerio de Agricultura y Ganaderia) and the Centre for Research and Education in Tropical Agriculture (CATIE, Centro Agronómico Tropical de Investigación y Enseñanza).

AZP has had different phases with different objectives. It started in April 1986 with a diagnosis of the agricultural problems in the zone. Phase one ('86-'90) aimed at an inventory of both land use and soils. In 1991 a critical evaluation of the project had been carried out. The research was good, but disciplinarity was contrasting the project objectives. The continuation of the project was secured by provisional finance for 3 years, based on a new research programme. The WAU policy now linked the funding of the outreach station (*steunpunt*) projects to the results of investigations.

Since 1991 the research plan of the second phase was focused on the development and testing of USTED. The study area has been limited to the northern part of the Limon province (Oostrom, 1993).

The USTED methodology incorporates a linear programming model, a Geographic Information System (GIS), and a customized data management tool. The options for land use are described at field level, but the methodology allows analyses for land use at the field, the farm and the regional level (Jansen et al., 1995)

In this methodology a farm is considered to comprise one or more Land Units (LUs), the natural resources. These are defined by their soil types with a number of pedological characteristics and their slope. Technical options for the use of each LU are given by Land Use Systems at a defined Technology (LUSTs). A LUST is a combination of Land Unit (LU), Land Utilization Type (LUT) and a specified technology.

The core of the LUST description is formed by a chronological description of a particular operation sequence, such as sowing, fertilizing, harvesting, in which all field operations are quantified in use of labour, traction, equipment and materials. Thereby it is permitting desorption of different technologies by varying the use of input and the resulting output. The LUSTs descriptions quantify all inputs and outputs, but do not contain all the information needed to calculate the coefficients for use in the optimization model. This information, called attributes, contains prices, nutrient contents, toxicity of biocides etc. and is stored separately from the LUSTs (Jansen and Schipper, 1995).

The sustainability of the LUST is evaluated on two criterias: the soil nutrient balance and the use of agro-chemicals in the form of a biocide index. Since the aim of the study is to indicate possible land use under changing conditions, not only the current occurring LUSTs are described, but alternatives are identified as well. Description of actual LUSTs, i.e. LUSTs that are present in the area, is based on research on farm level and on LUT level (Jongschaap, 1993 ; Tönjes, 1994). Alternative LUSTs are based on literature data, fertilizer experiments (Chin, 1994) and expert knowledge amongst others (a crop simulation model of maize and palm heart is in development). In the optimization model, various farm-types have been distinguished, differing in size of farm types and in soils. To each of these farm types all the LUSTs are offered in the optimization model to calculate optimal land use in relation to the goal and the constrictions (e.g. labour availability, limits to N, P, and K balances, limits to environmental contamination).

At the end of the second phase the USTED methodology is operational on the sub-regional level, with Neguev settlement as example (Jansen & Schipper, 1995).

In 1994 the third phase of the project started. In this phase the USTED methodology will be extended to incorporate the regional level and to improve the animal production system handling. In addition this methodology will be tested in another area of Costa Rica (Guanacaste), with different climate, land use and soil types.

2.2.2 Biocide index (BI) as a sustainability parameter

A large list of sustainability parameters can be developed, but for the operation of a methodology such a multitude of parameters is not feasible and a selection needs to be made. According to the criteria, which AZP selected, it should be possible to quantify the parameters and they should be a mayor possible cause of non-sustainability (Jansen et al., 1995).

Nowadays, the major part of the remaining forest occurs in forest reserves and national parks. In the remote rural areas of the Atlantic Zone, groundwater and (in the rainy seasons) surface water is used for drinking water. Possible environmental effects of agricultural activity are mainly caused by chances in water quality, in the form of nutrient enrichment and biocide pollution (Jansen et al., 1995).

For above described reasons the balances of nitrogen (N), phosphorus (P) and potassium (K) in the soil and an index for the biocide use were selected as sustainability parameters.

The BI, as it is described by the PZA, gives an indication for the total use of biocide on the basis of their active ingredient, toxicity and half life time (Jansen et al., 1995).

For each LUST the following biocide index is calculated.

$$BILU_l = -\frac{1}{y} \sum_{a=1}^{n} \sum_{b=1}^{m} A_{l,a,b} * AI_b * TOX_b * DUR_b \qquad \text{(EQ 1)}$$

BILU = biocide index of LUST 1
Y = duration of LUST 1 in years
n,a = total and a^{th} number of biocide applications in LUST 1
m,b = total and b^{th} number of biocide used at application a in LUST 1
A = amount of commercial formulation of biocide b at application a
AI = fraction active ingredient in the commercial formulation of the biocide b
TOX = indication of toxicity b, related to the World Health Organization (WHO) code. The WHO codes indicates the toxicity of a biocide and has a value : Ia = extremely hazardous, Ib = highly hazardous, II = moderately hazardous and III = slightly hazardous (WHO, 1992)
DUR = indication of duration of existence of toxin of biocide b in the system. Here taken as the squared root of the duration in days, to take into account the fact that the same absolute difference in duration is more important at short than at large duration.

Indications of the behaviour of biocides in the soil, which can be found in literature, vary with method of investigation, and conditions during determination (temperature, soil type, etc.) which are not adapted to the conditions of the Atlantic Zone. An other limitation of the BI is the fact that the hazard of a biocide is not related to the soil characteristic as clay content and organic matter content. In this study it is tried to build in these 'soil effects'. Summing the effects (characteristics) of each individual biocide, is like summing apples and pears this is also a limitation of the present BI.
The translation of the WHO code into a value is tentative, because the WHO code represents a abstract value as extreme, moderate and slightly, and has to be translated into a concrete value.

2.3 Biocides in Costa Rica

During the last three decades chemical control of pests, diseases and weeds, aimed at minimizing yield losses, has been introduced throughout the world. A wide range of biocides have become important in agriculture, mainly in developed countries, but also increasingly in developing countries. About 25 % of the current world consumption takes place in developing countries, mainly on cash crops. Because of the pressure on Third World agriculture to increase productivity to provide for its still increasing population (TOOL, 1988), the use of biocides in developing countries is expected to double in the period of 10 years from 1985 to 1995. About half of this increase will result from application to a larger proportion of the agricultural land (WHO, 1992).

The widely spread use of biocide is the result of the advantage they offer. Their use can prevent loss of yield and reduce risk for losses. Some can work quickly, which makes them suitable for use in emergency situations, and frequently they are the only remedy when crops are under immediate threat of infestation.

While biocides have contributed significantly to increase production and yields, they have also created a number of serious economic, ecological and public health problems. Economic losses have occurred as a result of biocide resistance and biocides generated secondary pest problems (Murray & Nathan, 1994). They have also occurred as a result of rejection of Central American exports upon arrival in the United States due to biocide residue contamination (Murray & Hoppin, 1992). Public health problems have emerged in the form of acute biocide poisoning as well as chronicle problems (Finkelman et al., 1993) and biocide use has caused environmental contamination and wildlife depletion (Castillo et al., 1993).

In response to this array of problems, alternative pest control technologies have been developed. Integrated Pest Management (IPM) was introduced in Central America at the end of the 1960's. But today IPM remains marginal in most farming systems in Central America (Murray & Nathan, 1994).

The use of agricultural chemicals (biocides and fertilizers) in Costa Rica began on a large scale after 1945. Nowadays, agriculture accounts for more than 19% of the gross national product and the export of these products, especially of coffee, banana, sugar cane and fresh meat, is one of the country's most important sources of foreign currency (Seitz, 1994) (Table 2.1). The use of biocides is also common in the non-export orientated agriculture (Hilje et al., 1987).

The crops of interest in this study are export orientated crops (banana, ornamental plants, pineapple and increasingly palm heart) and non-export orientated crops (maize, cassava, pineapple and platain).
Import export data give an indication of the amount of biocide used in agriculture in Costa Rica (Table 2.2). It is not the exact amount because part of the imported biocide may be used in industry to produce compound biocides which are exported.

Table 2.1 Costa Rican export of agricultural products, 1991 (MAG, 1992)

product	volume	value $
Agriculture total		951,650.4
Coffee	146,670.0	263,624.0
Banana	1,538,000.0	380,884.0
Plantain	11,121.6	3,009.9
Ornamental plants	44,937.7	58,675.6
Sugar	89,286.0	24,663.0
Fruits	196,906.8	101,861.6

Table 2.2 Import and export value of biocides in Costa rica 1980, 1990 and 1991 (PPUNA, 1992).

	1980	1990	1991
Biocide export	10,709	6,500	5,014
Biocide import	35,287	25,546	45,827
Import net	24,578	19,046	40,813

Three categories of users of biocides can be distinguished. First the international companies which cultivate products for the export. They use biocides in large quantities and normally with a more sophisticated technology than the other categories. The second category are coffee and sugar cane plantations. They also use biocides, but their application technology is less adequate. The last category are the small scale farmers. They are below the influence of publicity and technological advice. The big neighbouring farms have a negative demonstration function to the small scale farmers.
Environmental and health effects of biocide use take place in all groups, but they differ in quantity, technical criteria and method of application (Hilje et al., 1987).

The methods of application which are used the most in Costa Rica are; aerial, tractor, knapsack sprayer and manual. Aerial is only practised in big plantations farms of banana, ornamental plants, rice, tobacco, sugar cane, algodon and sorghum (Hilje et al., 1987). During this aerial application, neighbouring crops may 'benefit' from the application.

The backpack spray is the most common way of application, in banana as well as in coffee plantations as in

small scale agriculture. In plantations the worker is coping with strict regulations, such as good equipment and protecting clothes compared, with local farmers. The environmental effects are usually due to leakage of the backpack and washing the equipment after spraying (in the rivers).

Application of biocides by tractor is frequently used especially in tree plantation.

Nematicides and other systemic biocides (granulars) are applied by hand. Nowadays granulars are applied by a special kind of back pack spray. A risk of the use of granulars is run off with rain water to the rivers where the biocide is in direct contact with water flora and fauna (Hilje et al., 1987).

In general the effects which biocides have on the environment differ and are characterized by their chemical composition. But in many cases the effects are unknown. Hazards which can occur are; destruction of non-target organisms which may have a positive effect on the crop, development of resistant species, accumulation in soil, crop or animal, leaching to groundwater or run off to surface water with effects on water flora and fauna. All these effects result in a loss of ecological stability.

3 MATERIALS AND METHODS

3.1 Set up of the study

For the selected crops; palm heart, maize, cassava, pineapple, platain, banana and ornamental plants, the pests and diseases and the biocides used are described. For each biocide data on the amount of a biocide per ha per application and the total number of applications per year are collected. Hereford the database of PPUNA and the Atlantic Zone Programme, interviews with experts (CORBANA and CINDE) and literature (library of CORBANA, CATIE and PZA) are used.

For all relevant biocides the characteristics for the active element(s) (toxicity, persistency, mobility, solubility, etc.), are collected (database PPUNA, Environmental Fate One Liner Data Base and FactSheets).

As pointed out in the introduction, the emphasis of this study lies on the estimation of the hazard for groundwater contamination and to incorporate this hazard into a biocide index. The present BI is calculated by summing all the effects of each individual biocide. This is like summing apples with pears. In the 'new' biocide index (EBI) the maximum concentration of biocide, that will leach into the ground water, will be translated into a percentage of trout that will die at this concentration of a specific biocide. For this calculation the value for the LD50 value is used. LD50 indicates the concentration at which 50 % of the (trout) population will die. With this value an estimation can be made how many trout will die at a specific concentration. The total percentage of dead trout after using all biocides of one LUST is the indication value for the hazard of contamination by the use of biocides.

After the collection of relevant literature about the risk of biocide leaching towards ground water, a capacity type model for the calculation of biocide leaching is developed. In this model also soil characteristics are incorporated. The estimated amount of biocide leached forms the bases of the biocide index.

For each selected crop a biocide index will be calculated for the LUST with the highest biocide use for different soil types of the Atlantic Zone. The 14 soil types used (Stoorvogel, 1989) (Appendix II) were selected out of three areas; Neguev, Río Jiménez and Cocori. These soils are used, because of practical reasons. The soil data of interest were directly available. The determination of the texture might have been a problem, because you deal with Volcanic strongly weathered soils (allophanes). For this reason the clay % can have been estimated too low. These 14 soil types compromise two of the three main soil groups of the Atlantic Zone. These two soil types represent the area where most of the selected crops are cultivated.

Areas, defined on soil type, with a potential hazard for pesticide contamination of the groundwater, will be distinguished.

This chapter is divided as follows. First the theory and the construction of the biocide leaching model is described in section 3.2. Then the data needed for the model and data collection are mentioned in section 3.3. In section 3.4 the restrictions of the use of B-Leach are set aside.

It should be said explicitly that the development of the model took place on the basis of a limited data set available.

3.2 Biocide Leaching model (B-Leach model)

3.2.1 Mobility of residues in the soil - a theory

The factors which govern the mobility of a biocide in the soil are related to the physical and chemical properties of the compound and the associated field conditions where it is applied. Of all the soil properties affecting the biocide movement, none is more important than the capacity of the soil to absorb molecules of the applied chemical and thereby protect them from leaching. Only limited absorption can occur due to a lack of sufficient organic matter and clay materials.

The potential of a chemical to move through the soil is determined by the following factors. Water solubility above 30 ppm can allow significant movement of the biocide through the soil (Gustafson, 1993), but when the absorption is high little will leach. Soil absorption is represented in the absorption proportionality factor Kd. Kd reflects the distribution of the organic chemical (biocide) over different soil phases (soil and water).

(1) $$Kd = \frac{\text{amount absorbed per unit weight of soil}}{\text{amount in solution per unit volume of liquid phase}}$$

$$Kd = \frac{\text{ug absorbed / g soil}}{\text{ug /equilibrium solution}}$$

Larger Kd's indicate a higher binding capacity. A Kd equal to or higher than 5 l/g means a potential adsorption of the pesticide.

Koc and Kom are the biocide soil sorption coefficients normalized by respectively organic carbon and organic matter.

(2) $Koc = Kd / OC$

OC = soil organic carbon content (dimensionless)

Koc often gives a better representation than Kd to the extent of adsorption of such chemicals in soil. Koc refers in general to the OC and not to one specific soil type with a specific OC content like Kd. Values of Kd may vary widely for different chemicals in accordance with their adsorption, e.g. from < 1 l/g for picloram to > 1 x 10E5 l/g for DDT. Since the organic matter plays a dominant role in the adsorption of organic chemicals in the soil, Kd referring to the soil as a whole can be for practical reasons substituted by Kom or Koc (Bolt & Bruggewert, 1978). This means that equation (2) and (3) are only valid when the clay content is not too high.

(3) $Kom = Kd / OM$

OM = soil organic matter content (dimensionless)

In cases where one is forced to convert between these two constructs and an assumption has to be made concerning the relationship between OM and OC a factor of 1.724 has been recommended (Gustafson, 1993).

$OC = OM / 1.724$

The water balance is probably the main factor in biocide leaching. Biocide leaching depends highly on the soil water balance. Within the B-Leach model the water balance is kept very simple. The daily flow is considered to be constant throughout the year and no capillary rise is build in. These assumptions are correct if you consider the tropical humic conditions of the Atlantic Zone of Costa Rica. The rainfall is a extremely high and well distributed throughout the year, which supports the assumption that no capillary rise will occur. Alternative runs will be done for the by pass flow by reducing the depth of the groundwater table (taking the half).

The data available about biocide behaviour in soil and water are scarce, especially for humid tropical conditions. When developing a more sophisticated model, also more soil and biocide characteristic data are necessary.

The soil infiltration capacity also influences the hazard for contamination. A low infiltration capacity of the soil results in run off (tropical rainfall) and direct contamination of surface water. As said before the water flow is considered constant.

The charge of the biocide molecule influences the transport of the biocide in the soil. Negative charged molecules are more likely to move freely. The persistence of a biocide also influences the hazard for groundwater contamination. Compounds which are very persistent to degradation stay in the soil and consequently have more opportunity for movement.

The amount applied, type of formulation and method of application used, can also influence the movement of the active ingredient. The parameters mentioned above, need to be satisfied before a chemical is judged to have a potential for leaching and contaminating ground water. Thus a chemical with for example a water solubility in excess of 30 ppm and a low Kd will not accumulate in groundwater if it is rapidly biodegraded. Certain field conditions are also necessary to be taken into account, such as texture, organic matter content, groundwater level and biological factors, such as activity of the soil organisms and nature of the crop plant.

When all the factors are conducive, it is still not certain that groundwater contamination will occur under practical conditions, but with these factors a potential hazard for groundwater contamination can be described (GIFAP & NEFYTO, 1987 and Bolt & Bruggewert, 1978).

Table 3.1 LIST of important parameters.

parameter	use in B-Leach
Kd clay % OM	Distribution of the biocide over soil and soil water phase. Depends on the soil characteristics: clay % and organic matter content, and biocide characteristics.
FC and BD	To calculate the water and soil quantities and biocide concentration in the soil water.
Yearly rainfall and evapotranspiration	To calculate the soil water flow (the assumption is made that the soil is saturated under humid tropical climate conditions).
	To calculate the decreasing (through metabolism) amount of biocide in the soil.
Total application of the biocide and the HLT of the biocide	To be able to distinguish liquid application and granular application. With granulars the biocide is released to the soil during some days (normally ten days). The total application is spread out over these days.
Application formula: liquid or granular	

3.2.2 The construction of the B-Leach model

To predict the hazard of ground water contamination, the B-Leach model is developed (see Figure 3.1). The soil is divided into successive 10 cm soil compartments (until the groundwater table) for which the Kd values are calculated on basis the texture and the organic matter content through the use of a pedo-transfer function.

The sorption of the biocide on the soil depends mainly on two soil characteristics; the soil organic matter content and the clay content of the soil. This simplified relation is the pedo-transfer function mentioned in the text above;

(4) Kd = a * clay + b * OM

The higher the Kd value, the greater the binding capacity of the soil.

An other important parameter is the HLT (half life time) of a biocide. This is the time taken for the concentration of the parent compound to be reduced to half of its original amount. It gives a measure for the persistence of the biocide in the soil. HLT depends on soil properties, environmental factors and physio-chemical characteristics of the pesticide. Although it is realised that the HLT for a biocide may vary widely for different ecological environments, data are not available to differentiate the value of the HLT and an average value for aerobic soil metabolism is used. In this model HLT for the aerobic soil metabolism is used. This is the most important in the aerobic metabolism in the soil.

Although it is difficult to find a value correlated to the tropical (climatic) conditions, it still remains a valuable tool in comparing rates of biocide degradation and thus for comparing the hazard of ground water contamination. But absolute values may be worthless.

In the B-Leach model there are two different types of inputs. Soil characteristics and inputs related to characteristics of the biocide, called 'crop' characteristics.

As said before, the soil is subdivided in compartments of 10 cm depth. For each layer the bulk density (g/cm^3), field capacity water content (%), clay content (%), and organic matter (%) are described (Appendix II). Climatic conditions are extinguish to the 'crop' characteristics and are evenly distributed over all days. To calculate daily water flow, the yearly rainfall and the daily evapotranspiration are estimated. For each biocide the number of applications per year, the day of application and the amount of each independent application (kg/ha) is described. A biocide can be applied in two different forms: liquid and granular. This model takes into consideration that granulars release biocides in steps spread out over a particular time, which from now on is called the 'time of breakdown granulars'.

By dividing the day into parts water transport can occur from layer i to i+1. The water flux from compartment i to i+1 may be larger than the soil matrix in the compartment i+1 can contain. The step size is given by time interval. The time of calculation of water/biocide transport is given in a number of steps (number of days divided by time interval).

Table 3.2 The needed inputs per biocide and per soil

crop data	dimension	
NrAppl		number of applications
daynr, gift B	(kg/ha)	day number and amount of application B
HLT	(days)	half life time biocide
Grantime	(days)	time of breakdown granulars
a		a constant for clay in Kd equation
Kom		b constant for OM in Kd equation
Rain	(mm/year)	rainfall
ET	(mm/day)	evapotranspiration
Time interval	(days)	duration of a time interval
step	(days)	number of steps
soil data		
depth	(cm)	depth
BD	(g/cm_3)	bulk density
FC	(%)	field capacity water content
clay		% clay
OM		% organic matter

Model runs start with the application of an amount of Q kg of a biocide B. Each subsequent day the soil water flow transports B to the next compartment. Additionally it is assumed that the equilibrium (Kd) between absorbed and dissolved forms of the biocide is reached instantaneous. For each day the model calculates the amount of biocide in soil, in water and the total amount (= soil + water).

The decomposition of the biocide (though e.g. aerobic microbiotic metabolism is considered and related to the half life time (HLT). In the data base of PPUNA the values for half life time (HLT) under conditions of aerobic microbiotic metabolism were found. The HLT is the time needed to breakdown half of the amount of B present in the soil. The higher the HLT the more persistent is B.

The model outcome comprises the concentration of B in the layer just above groundwater for each of the individual time steps. For the calculations of the index, the maximum concentration encountered is used. The end of the calculation is defined by the user and can be at the point when very little biocide is left in the soil or after a fixed number of time lags.

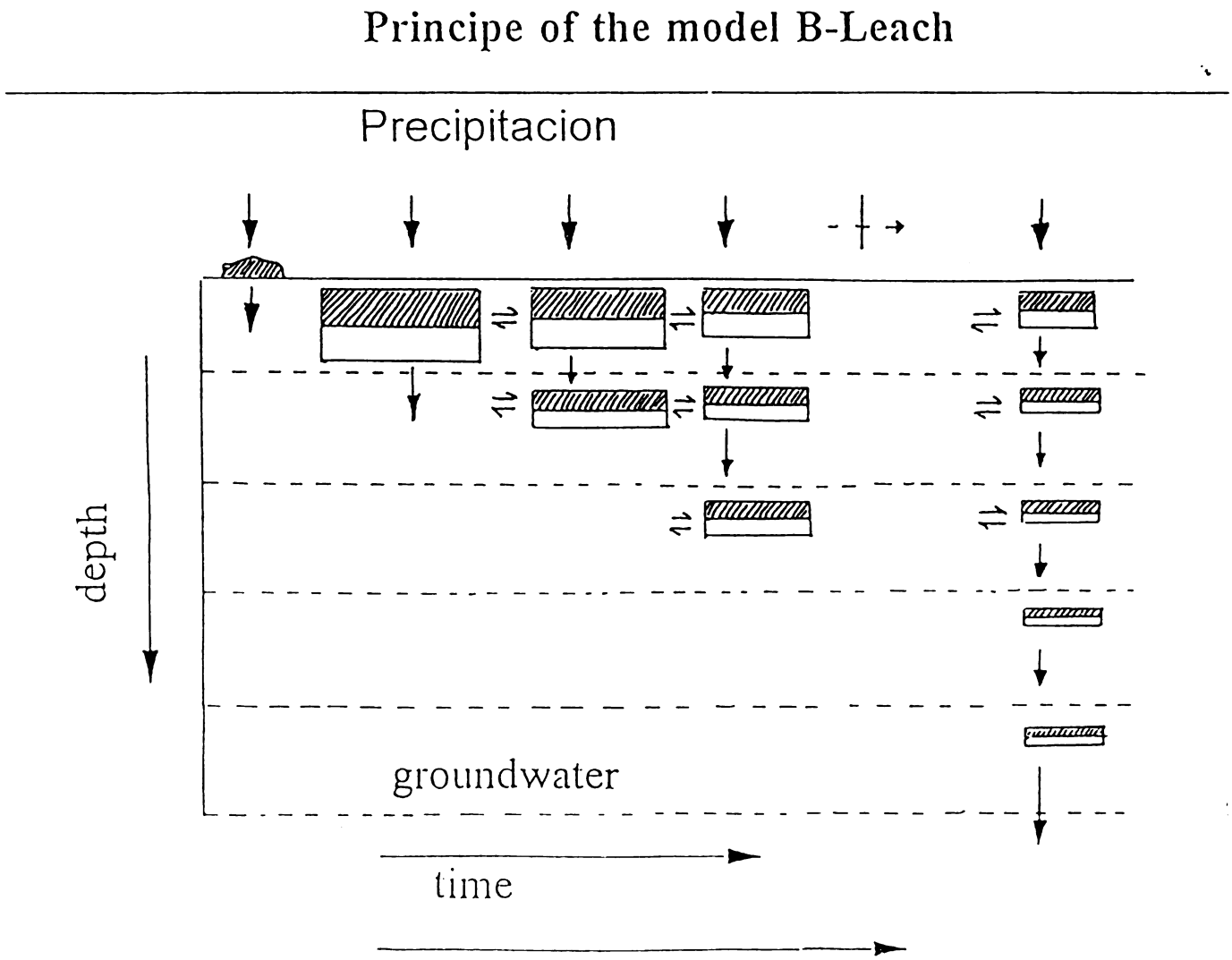


Figure 3.1 Structure of B-Leach

The following part discusses the equations and calculations used in the B-Leach model (Appendix V; listing of the program written in turbo pascal(TPC)).

The water flow within a step is calculated by the following equation:

(5) FLOW = Time interval * (Rain/365-ET) * 0.01

Rain is the yearly rainfall (mm/y) and ET is the daily evapotranspiration (mm/day).

For each compartment the Kd (l/g) and ratio are determined. The ratio (soil(i)/water(i)) reflects the distribution of B over the soil and water phase. It is composed by the division of the total amount of biocide in the soil of a compartment i and the total amount of biocide in the soil water of a compartment i. The soil layers are assumed to be always saturated.

(6) Kd = a * clay % + b * OM %

(7) Ratio = Kd * BD / (FC * 100)

BD is the dry bulk density (g/cm^3) and FC is the field capacity (dimensionless), often defined to be the water held by the soil when drained to a matric potential of 0 kP.

Before the biocide is applied the assumption is made that the soil and soil water do not contain biocide beforehand, but new applications can follow after the first day. After an application (gift) a new equilibrium is assumed to be established instantaneously.

The amount of biocide in the soil (kg/ha) of compartment 1 is for $t > 1$:

(8) $$soil(1) = \frac{ratio(1) * gift}{1 + ratio}$$

The amount of biocide in water (kg/ha) of compartment 1 is for $t > 1$:

(9) water(1) = gift - soil(1)

The concentration in each compartment is calculated by:

(10) concB(y) = water(y) / (FC(y) * 0.01)

The amount leached is the concentration of the biocide in the deepest compartment (y) multiplied by the flow out of the deepest compartment.

(11) leach = leach + (water(y)/FC * 0.01) * flow

The total amount of biocide in the compartment y is the amount in the soil plus the amount in the water plus the flow out of compartment (y-1) minus the flow out of compartment y including the degradation by using the HLT. This results in equation (12) for the top compartment and equation (13) for the other compartments.

(12) total(1) = (input + soil(1) + water(1) - flow * [water(1)/(FC * BD * 0.01)]) * (0.5 E (step/HLT)))

(13) total(y) = (soil(y) + water(y) + flow * [(water (y-1) / FC(y-1) * BD(y-1) * 0.01) - (water(y) / (FC(y) * BD(y) * 0.01))]) * (0.5 E (step/HLT))

The difference between compartment 1 and the rest of the compartments is that no B enters compartment 1 after application as opposed to the compartment where B enters from the compartment above where a new equilibrium is restored and B is desorbed and is transported by the water flow to the underlying soil compartment. The total amount of B in the soil and soil water is the sum of all the compartments.

Finally the adsorption and degradation of B are combined to result in the total amount of B in the soil compartment.

(14) soil(y) = ratio(y) * total(y) / (1+ratio(y))

(15) water(y) = total(y) - soil(y)

As said before, the final output of the model is given by the maximum concentration of a biocide leached into the groundwater. This number is an indication for the hazard of ground water contamination and is a basic part of the EBI.

3.3 Data collection

Collecting soil data

The soil characteristics are selected from the profile description (Appendix I). When data from a layer were missing, the mean of the two adjacent layers has been taken. In some soils the depth of ground water table was unknown or the groundwater was deeper than the soil profile. To determine the highest depth of the ground water, the profile description has been studied on gley an iron spots. When no signs of groundwater could be determined, the maximum concentration at 120 cm was calculated.

Collecting crop data

For each crop the amount of biocide application per ha and the total number of applications per year was collected, by collecting all the biocide activities of the different LUST's used by the PZA (see chapter 2). For banana and ornamental plants the biocide application data were collected by literature and interviews with farmers and their advisors (ornamental plants).
To establish the Kd function for each biocide (equation (4)), estimation and calculations had to be done. For the majority of the biocides a Koc value is known (One Liner database of I.P.E) and some Kd values for different textures classes (Appendix III). When a Kd value was given for a texture class the clay % was estimated as followed (Klute, 1986):

Table 3.3 Texture class and estimated clay %

texture class	clay %
sand	4
silt	6
loamy sand	7
sandy loam	12
silt loam	16
loam	18
sandy clay loam	28
clay loam	33
silty clay loam	35
sandy clay	44
silty clay	47
clay	70

The Koc (related to the % organic carbon) was recalculated into Kom (related to the % organic matter) by dividing the Koc by 1.724.

With a known Kom and a Kd for a known clay percentage, the 'a' constant was calculated by linear regression. Resulting in a Kd equation, where 'a' is the constant for clay and 'b' is Kom/100 (Appendix IV).

3.4 Restrictions of the B-Leach model

The B-Leach model is a simple model. Factors like by-pass-flow and run off (vertical flow) are not taken into account. Also the water balance is kept very simple as indicated in 3.2.

Keeping these restrictions in mind, the B-Leach model can be classified as a deterministic functional model (Addiscott and Wagenet, 1985). Deterministic, because the preassumption is made that a system or process operates in such a way that the occurrence of a given set of events leads to a uniquely-definable outcome. The term functional is used for models which incorporate simplified treatments of solute and water flow and make no claim to fundamentality but do thereby require less input data and computer expertise for their use. This is exactly the case in the B-Leach model; the water flow is calculated by daily rainfall and evapotranspiration. Equations, such as Darcy's Law for water flow, are not included.

When by-pass-flow occurs the biocide concentration in groundwater would be higher. As said before this model is used to give an index value for the risk of ground water contamination by biocide leaching. When by-pass-flow occurs it is thought to be the same for all the biocides and the ratio will be equal. It will not influence the biocide index in a prohibitive way. The risk calculated is a minimum risk. If the result is leaching, the amount of biocide leached and the concentration can be much more in reality.

By pass flow can be incorporated in the model by taking the half of the depth of the soil in stead of the whole depth, because water takes the shortest way through the macro pores. For the soils eg2 and rjz22 this has been done.

The HLT for the biocides is found in the environmental fate on-liner data base (FPA). These values are not adapted to humid tropical conditions, as is the case in the Atlantic Zone of Costa Rica. By taking all the data out of the same data base and under the same conditions this effect is tried to be minimized.

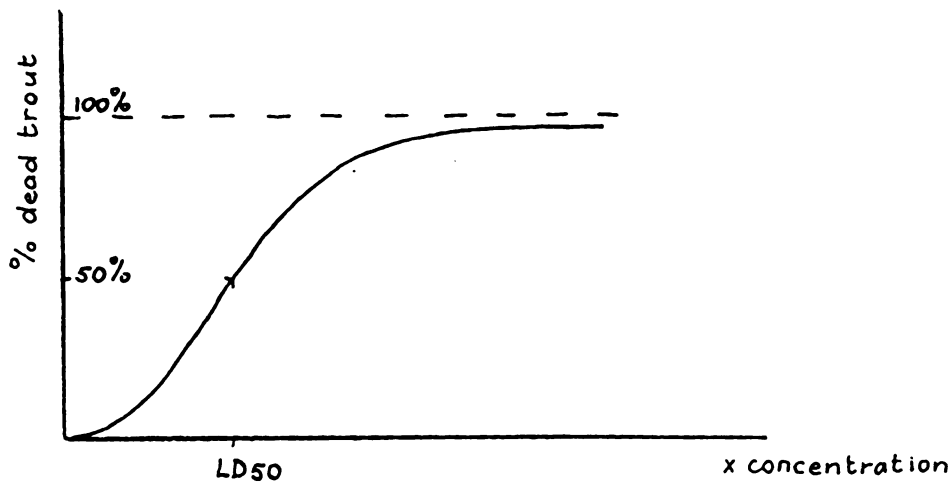
The calculation of Kd is fragile. The determination of the a and b constant is in some cases estimated due to a lack of data. But as it is said before the results of B-Leach are used as indication value and are worthless when taking them absolute.

3.5 From concentration to index value

To develop a biocide index, next to the concentration, the toxicity is needed to quantify the hazard of a specific biocide and it is necessary to have a common factor to be able to sum up the effects of all the different biocides. The toxicity is reflected as the concentration of a chemical at which 50 % of a population dies. For the biocide index developed the LD50 (lethal doses 50%) of Trucha arco iris (rainbow trout) is used. The reaction of trout on a chemical is representative for other water organisms and most of the available LD50 data were analyzed for trout. By using the maximum concentration, calculated by B-Leach, the percentage of trout that would die can be calculated.

It is thought that the relation between concentration and % trout that will die, is as follows:

(16) $\%\ \text{dead trout} = (1 - e^{-a * \text{concentration}}) * 100\%$



With the assumption that when no biocide leaches no trout will die and the use of the LD50 value (y = 0.5 and x = concentration in mg/l) the 'a' for each biocide can be determined (Appendix VIII).

(17) $a = -\frac{\ln(1 - y)}{x}$

With equation (16) the % of dead trout can be calculated.

The biocide index is then:

(18) 1- (fraction trout alive biocide 1 * fraction trout alive biocide 2 * fraction trout alive biocide 3 * fraction trout alive biocide 4 * etc)

The biocide index can have a value in between 0 and 1. A biocide index of 0 indicates that there is no hazard while using B. A biocide index of 1 indicates that all trout will die and the hazard of ground water contamination is the highest.

4 RESULTS

4.1 Crop description and biocide use

Maize, plantain, pineapple, cassava, palm heart and banana are the main crops in the study area and will be included in this study. An overview of each crop is given with the emphasis on its pests and diseases.

Maize - *Zea Mays*

Maize has been an important crop in the Atlantic Zone. After 1987 the cultivated area decreased, due to adverse economical measures taken by the government (freezing prices, purchases of less maize, less financial and technical assistance). At the moment maize is not an important crop (Chin, 1994).

Sowing takes plays in january/february and july/august. The yields of january sowed maize are usually higher, due to a better rainfall distribution and higher radiation levels. The soil is prepared mechanically (plough) or manually (weeding and herbicide use). The plant distance is very variable and varies between 30,000 and 80,000 plants/ha (Chin, 1994).

The yield is traditional about 1.75 and 2 ton/ha, which is low due to a bad weed, insect and disease control (Chin, 1994). Weeds are the main technical problem. Weed control is done by a combination of manual weeding and herbicide use (Paraquat, 2,4-D, Diuron, Parathion). Pests are also a serious problem in maize. The most common is 'Gusano cogollero' (*Spodoptera frugiperda*), a foliar pest. Other principal pests in the zone are 'gusano cortador' (*Agrostis sp.*, *Feltia sp.*) and the 'barrenador del tallo' (*Diatraea lineolata*). Furthermore the soil pests 'vaguita' (*Diabrotica sp.*) and gallina ciega (*Phyllophaga sp.*) are found. Control is done when damage occurs, principally with liquid insecticides.

'Cobrot' is the most important disease in the zone, usually caused by leaf disease and to a lesser extent by stem diseases. The nematodes present are *Pratylenchus* and *Helycothyllenchus*, their effect on maize has not been investigated until now (Chin, 1994).

Table 4.1 General biocide application for maize

biocide		application/ha (kg/ha)	number of applications per year	gift/y (kg/ha)
paraquat	H	0.552	3	1.66
triadimefon	F	0.5	1	0.50
carbofuran	NI	0.5	1	0.50
methylparathion	NI	0.48	1	0.48
methamidophos	NI	0.6	1	0.60

Palm heart - *Bactris gasipaes*

The Atlantic Zone has good conditions for the cultivation of palm heart, a perennial crop. The cultivation of palm heart is a recently started activity in the Atlantic Zone and the cultivated area is expanding (De Haan & Waayenberg, 1992).

Sowing takes place throughout the year, preferable on a cloudy day. The most important soil preparation is weed control. Plant densities vary between 2500 and 4000 plant/ha. The yield is 2,333-2,666 palms/ha (Chin, 1994), but can be much higher in plantations.

83% of the farmers use herbicides (Paraquat, Paraquat + Diuron, Paraquat + glyfosate) to control weeds. Only a small part control the weeds by manual weeding. Diseases are not common, but can occur. Examples are plantrot ('Pudrición del Cogollo'), black leave spot (*Mycosphaerella sp.*) and yellow leave spot (*Pestalotiopsis sp.*). There are no controlling activities for these diseases. A problem is 'Taltuza' (*Ortogeomys cherriei*) a

rodent which eats the fresh young roots and digs big holes. Poisoned palm heart stalks or traps are used to control this plague (Chin, 1994).

Table 4.2 General biocide application for palm heart

biocide		appl/ha	#/y	gift/y
paraquat	H	0.552	2	1.10

Cassava - *Manihot esculenta c*

Cassava is cultivated by small farmers in small quantities. Recently the cultivated area with cassava has expanded in the Atlantic Zone, due to a growing export market. It is a crop with low production costs, low risk for damage and diseases, and low fertilization requirements. Cassava is planted in january/february in mono culture or associated with maize and/or beans, or it is planted in september/october. When cultivated in association with maize, cassava is planted after the flowering of the maize. There is little or no soil preparation needed (Chin, 1994).

The plant density is 10,000-12,000 plants/ha (also in associations). Harvest takes place after 10 months. The yield varies between 4,600 and 16,500 kg/ ha (fresh weight). Hardly any weed control is carried out before sowing. Taltuza causes a lot of damage. An other plague is the trips (*Frankliniellea* and *Corynothrips*), usually controlled by using resistant varieties. No significant damage is caused by diseases according to MAG (1982a). 'Roña' (*Spaceloma manithoticola*) and *Erwinia sp.* are the most important diseases.

Table 4.3 General biocide application for cassava

biocide		appl/ha	#/y	gift/y
paraquat	H	0.552	3	1.66
dimetheoate	IN	0.4	4	1.60

Pineapple - *Ananas comusus (L) Merr.Syn.*

Pineapple is a monocotyledon crop, genus of the *Bromeliaceae*. It is cultivated for local consumption and export. Cultivars used in Central America are Cayenne, Spanish and Abacaxi. The best temperature for cultivation is between 24° and 26° C. Pineapple is tolerant to drought, due to its special water storage cells and its CA - metabolism. Pineapples are best suited to tropical lowlands and to areas which have more than 635 mm rainfall per year (den Daas, 1993).

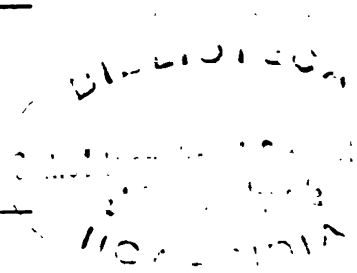
Pineapples are propagated vegetatively by planting the crown of leaves or from suckers. The plant density in the Atlantic Zone is about 35,000 plants/ha. In the Atlantic Zone often the plants are inserted in single rows, with 100 cm between the rows and 40-50 cm between the plants in the rows, because of the low fertility of the soils. The yield of fresh fruits per ha is 38-75 tons for the first crop. The ratoon is only half of this amount (den Daas, 1993).

Before planting, the propagules have to be cured to control mealy bug (*Pseudococcus brevipes*). If pineapples are grown continuously on the same plot, the soil has to be fumigated to kill nematodes. Fumigation and mulching (sugarcane bagasse) are only done by large commercial growers. Other pests are insects, fungi, rats and bacterias.

During the last five years the number of pineapple-farmers in the Atlantic Zone increased almost 9 times, in general because of the low fertility requirements (den Daas, 1993).

Table 4.4 General biocide application for pineapple

biocide		appl/ha	#/y	gift/ha/y
diuron	H	1.6	2	3.20
benomyl	F	0.5	3	1.50
deltamethrin	IN	0.025	1	0.03
diazinon	IN	0.6	3	1.80
carbofuran	IN	0.1	1	0.10



Plantain - *Musa spp*

About 3500 ha of plantain in Costa Rica is cultivated. The distribution and the characteristics of this crop are very similar to banana. 73% of the farmers have less then 5 ha. 84.2 % use biocides, the same used in banana (Wesseling, 1990).

Banana - *musa spp*

Banana has an extension of 28.817 ha in Costa Rica, the mayor part lies in the Atlantic Zone. The Atlantic Zone has good cropping conditions for banana.

Before planting the field is cleared by the application of herbicides. The density generally used in the Atlantic Zone is 1800-1850 plants/ha. The first harvest can be obtained after 8-9 months with good planting material. The average yield is 2461 boxes/ha/year (with a weight of 18.4 kg/box) (Bessembinder, unpublished).

The main disease in banana in the Atlantic Zone is black Sigatoka (*Mycosphaerella fijiensis*). Regularly fungicides have to be applied to keep the decease under control. Contact fungicides are best used in relatively dry periods. In wet periods cocktails with systemic fungicides can be used every 8-15 days. Systemic fungicides can be used every 14 - 21 days (Bessembinder, unpublished). Besides black Sigatoka, the most important problem is probably the presence of nematodes (*Radolphus similis, Heliotylenchus multicinctus, Meloidegyne sp., Pratylenchus sp.*) (Wielemaker, pers.com.).

Twice a year a systemic and contact nematicide is applied. At present insects are of minor importance in the Atlantic Zone. Only the blue bags which protect the fruits are impregnated with a insecticide (Wielemaker, pers. com.). Several weeds, especially grasses, are found as weeds in bananas. They are generally treated in a chemical way (paraquat, glyfosate, diuron and oxyfluorfen) (Bessembinder, unpublished).

Table 4.5 General biocide application for banana

biocide		appl/ha	#/y	gift/y
glyphosato	H	0.95	11	10.45
paraquat	H	0.552	11	6.05
fenamifos	N	5.55	2	11.10
terbufos	N	5.55	2	11.10
propiconazol	F	0.1	9	0.90
tridemorf	F	0.45	11	4.95
mancozeb	F	1.25	10	12.50
chlorothallonil	F	1.25	5	6.25

Ornamental plants

The presence of nurseries for the cultivation of ornamental plants has increased the last years, especially in the higher parts of the Central Valley of Costa Rica, but also in the Atlantic Zone. The use of pesticides is intensive. About twice a week pesticide is applied. The data collected below are a mean of 20 different plantations spread out over whole Costa Rica (keeping the pests and diseases of the Atlantic Zone in mind). Some information of crop management will be given for *Marginate cane*.

The plant density is 25.00 plants /ha. 95 % is produced for the export. The production is about 5 plants per mother plant/years (5*25.000= 125,000 plants/ha/year). The highest costs after labour are the biocide costs.

A pest is louse, which is managed by a granular insecticide/nematicide, resulting in no problems with nematodes. An other problem are thrips. For this reason herbicide has to be used. Snails do not have any effect, but are not allowed by export organisations. There is as in palm heart plantation a problem with Taltuza. A

nutrient deficiency of Bohr (B) result in a extreme sensitivity of the plant for Fusarium.

Table 4.6 Biocide use in ornamental plants; an overview (emphasised on the Atlantic Zone)

herbicides

product	doses (commercial formulation)	frequency
Paraquat	2.5 l/ha	
Liphosate	1.5 l/ha	in total
Oxyfluorfen	1.9 l/ha	5 application/year
Simazina	2.5 l/ha	
Diuron	1.7 l/ha	

Combinations: Paraquat and Oxyfluorfen
Paraquat and Simazina

nematicides

product	doses	frequency
Aldicarb- syst	35-50 kg/ha	nematodes are not a
Ethoprophos-cont	9 l/ha	serious problem
Terbufos-cont	10 kg/ha	1-2 times/year
Fenaminophos-cont	60-70 kg/ha	

Aldicarb is good, but very expensive.
Marginates and *Caña indra* have very little problems with nematodes.

insecticides

product	doses	frequency
Endosulfan	1.2 l/ha	very variable
Metamidophos	1.2 l/ha	in general
Diazinon	1.2 l/ha	20 application
Metomyl	0.6 l/ha	per year.
Asephate	1.2 l/ha	
Phorato	35 kg/ha	

They change biocide to avoid resistance. On plantations with many insects each 15-22 days insecticides are applicated.

fungicides

product	doses	frequency
Mancozeb	0.75 kg/ha	aerial 20
Chlorotalonil	1.0 l/ha	applications /year
Carbendazine	0.3 l/ha	
Methylthiophonato	0.6 l/ha	by hand 27
Benomyl	0.5 l/ha	applications /year
FosetylAl	2.5 kg/ha	
Captan	2.5 kg/ha	
Hygroxy Cu	1.5 kg/ha	

acaracidas

product	doses	frequency

Bromopro-pilato	1.5 l/ha	33
Fenbutanin	0.2 kg/ha	applications /year
Propargite	2.0 kg/ha	
Aceite agricola	2.0 l/ha	
Vertimec	0.3 l/ha	
Tendion	1.5 l/ha	
Acarofin	0.25 l/ha	

4.2 Biocide Leaching and biocide index per crop management

The run of the B-Leach model for combinations of soil and crop data (Appendix II) resulted in a maximum concentration of biocide leach, within a given time. Table 5.7 shows the results for two soil types Negev 2 and Rio Jimenez 22 (results for the other soil types Appendix VII).

For some biocides it was not possible to calculate the time from application until completely break down of the biocide. For example, paraquat is very persistent in the soil, but is strongly absorbed. In B-leach's theory, it is possible that under continues water flow (tropical conditions) and a very slow metabolism (10 E6 years) paraquat would leach into the groundwater after a long time.

Table 4.7 Results B-Leach model and calculated % dead trout

crop	biocide	eg2	rjz22	% dead trout eg 2	rjz22
palm heart	paraquat	0	0	0	0
platain	paraquat	0	0	0	0
	mancozeb	0	0.02	0	2.97
	maneb	0	0.03	0	1.03
	propiconazole	0	0	0	0
	fenamiphos	0	0.01	0	6.1
cassava	paraquat	0	0	0	0
	dimetheoate	0	0	0	0
maize	paraquat	0	0	0	0
	triadimefon	0	0.01	0	0
	carbofuran	0	0.1	0	22
	methylparathion	0	0	0	0
	methamidophos	0	0.01	0	0
pineapple	diuron	0	0.16	0	1.85
	benomyl	0	0.03	0	11.6
	diazinon	0	0.01	0	7.41
	carbofuran	0	0.02	0	4.84
banana 1	glyphosato	0	0	0	0
	paraquat	0	0	0	0
	fenamiphos	0	0.26	0	80.6
	terbifos	0	0	0	0
	propiconazole	0	0	0	0
	tridemorf	0	0	0	0
	mancozeb	0	0.01	0	1.5
	chlorothallonil	0	0.01	0	2.73

banana 2	glyphosato	0	0	0	0
	paraquat	0	0	0	0
	diuron	0.02	0.6	0.2	6.78
	benomyl	0	0.02	0	7.87
	tridemorf	0	0	0	0
	propiconazole	0	0	0	0
	mancozeb	0	0.01	0	1.5
	chlorothalonil	0	0.01	0	2.73
	fenamiphos	0	0.26	0	80.6
	terbufos	0	0	0	0

The biocide index is calculated with the use of the percentage dead trout.

Table 4.8 Biocide index per crop (LUST)

crop	biocide index	
	eg2	rjz22
palm heart	0	0
platain	0	0.10
cassava	0	0
maize	0	0.22
pineapple	0	0.24
banana 1	0	0.81
banana 2	0.002	0.84

Figure 4.1 and 4.2 show the show the different indices on the different soils in the Atlantic Zone in Costa Rica

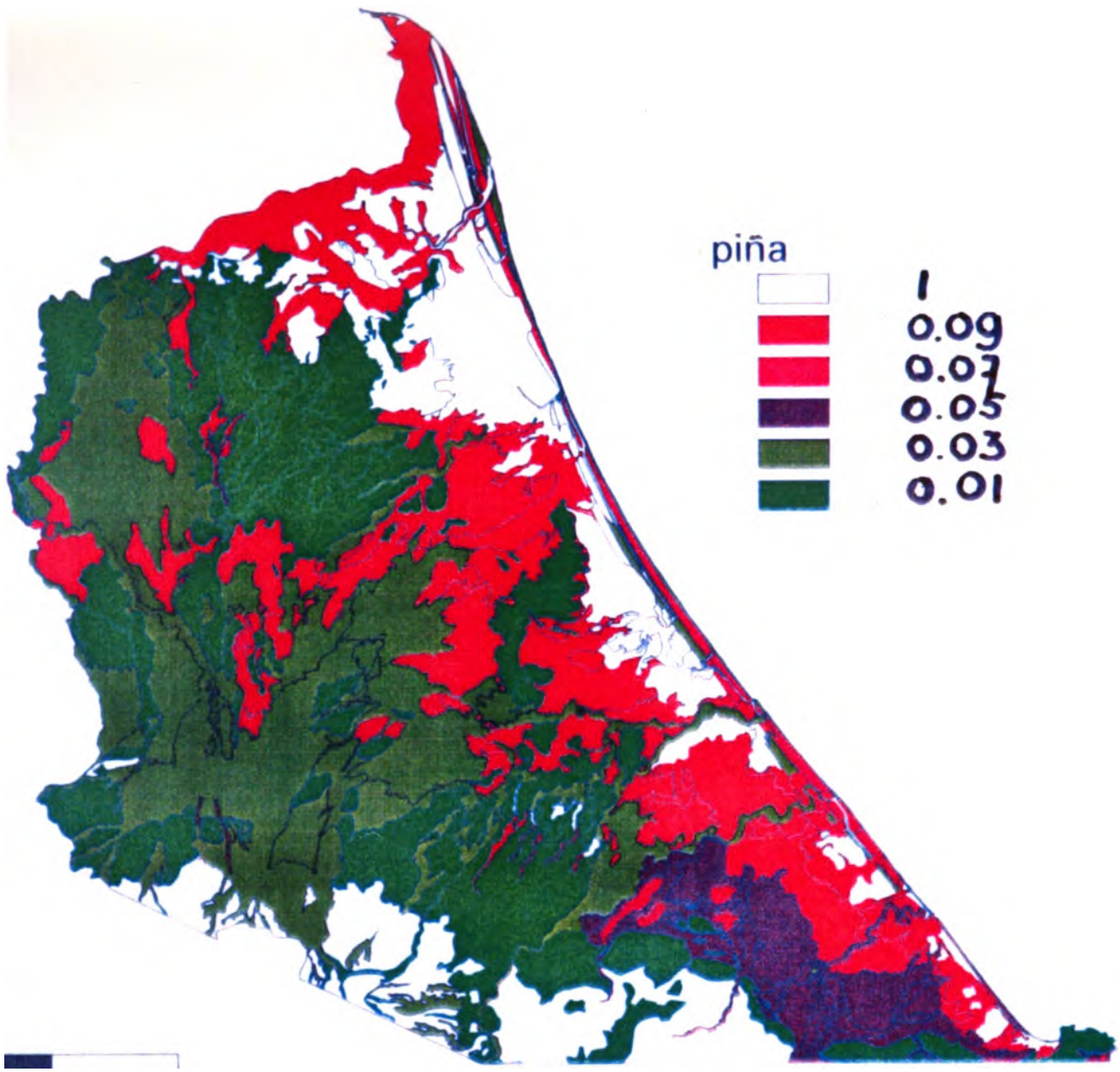


Figure 4.1 Biocide index for pineapple on different soil types in the Atlantic Zone of Costa Rica.

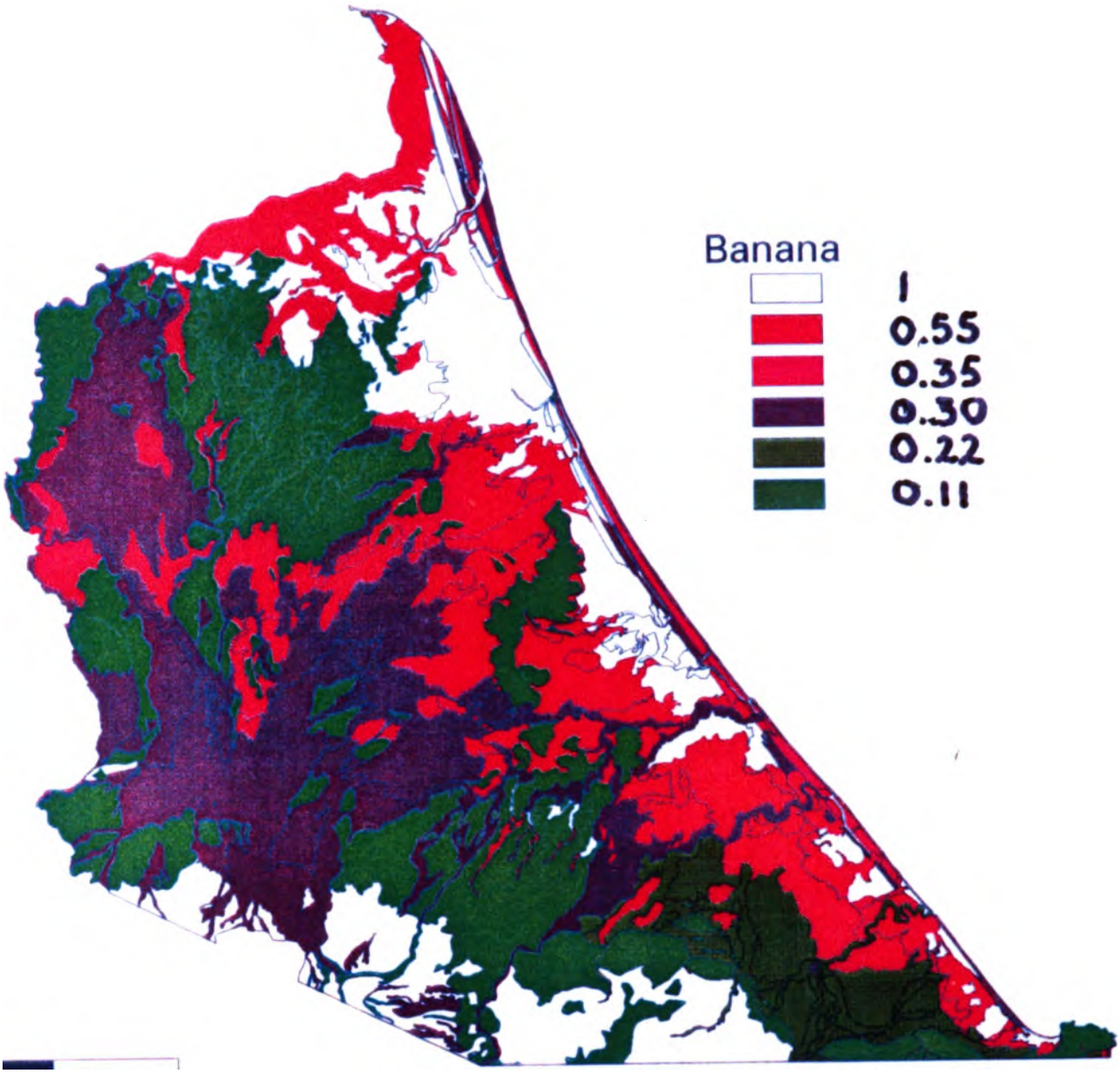


Figure 4.2 Biocide index for banana on different soil types in the Atlantic Zone of Costa Rica.

The results of B-leach for by pass flow in relation to the normal situation are shown in Table 4.9.

Table 4.9 Results B-Leach model for normal and by pass flow situation

crop	biocide	normal		by pass flow	
		eg2	rjz22	eg 2	rjz22
palm heart	paraquat	0	0	0	0
platain	paraquat	0	0	0	0
	mancozeb	0	0.02	0	0.06
	maneb	0	0.03	0	0.04
	propiconazole	0	0	0	0
	fenamiphos	0	0.01	0	0.02
cassava	paraquat	0	0	0	0.01
	dimetheoate	0	0	0	0
maize	paraquat	0	0	0	0
	triadimefon	0	0.01	0	0.01
	carbofuran	0	0.1	0	0.11
	methylparathion	0	0	0	0
	methamidophos	0	0.01	0	0.03
pineapple	diuron	0	0.16	0.01	0.16
	benomyl	0	0.03	0	0.03
	diazinon	0	0.01	0	0.02
	carbofuran	0	0.02	0	0.02
banana 1	glyphosato	0	0	0	0
	paraquat	0	0	0	0
	fenamiphos	0	0.26	0.01	0.43
	terbifos	0	0	0	0.02
	propiconazole	0	0	0	0
	tridemorf	0	0	0	0
	mancozeb	0	0.01	0	0.03
	chlorothallonil	0	0.01	0	0.02
banana 2	glyphosato	0	0	0	0
	paraquat	0	0	0	0
	diuron	0.02	0.6	0.09	0.53
	benomyl		0.02	0	7.87
	tridemorf	0	0	0	0.02
	propiconazole	0	0	0	0
	mancozeb	0	0.01	0	0.03
	chlorothalonil	0	0.01	0	0.02
	fenamiphos	0	0.26	0.01	0.43
	terbufos	0	0	0	0.02

5 DISCUSSION AND CONCLUSIONS

Models are always a simplification of the reality and some models are more complex than others. The B-leach model can be used to analyze biocide leaching and uses a data base that is available for the majority of the soils, crops and biocides and is appropriate in many different situations. A capacity model, like the B-Leach model, is adequate in these situations. The disadvantage of this model is that the use of biocide characteristics are, in many cases, related to temperate zones.
The used Kd-values are related to the Kom-values and percentage clay. No experiments have been done to check these Kd values under local conditions and the outcome of B-leach is not compared by measured values in groundwater.

As the results show, the biocide index is related to the biocides used in different LUSTs and to soil types (organic matter and clay content, depth of groundwater etc). The LUST of banana 2 is the most contaminating LUST, due to the use of Fenamiphos (a high toxic nematicide). The soil Rio Jimenez22 has a higher potential to leach biocide than Neguev2. More care should be taken with these soils while using biocides.

Conclusions

* In general it can be said that B-Leach yields appropriate data in many situations but the results have to be seen as an indication. For this reason the use of B-leach as a description of an index value for the hazard of groundwater contamination by biocides is good.
* More investigation is needed to guarantee the outcome of B-leach.
* Biocides react differently in different soils. That is why the soil characteristic have to be taken into account by planning crop protection management.

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APPENDIX I + II soil and crop data used in B-Leach

Crop / Biocide			
Palm heart			
Paraquat	2		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	100	0.55	Daynumber and Application 2 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	580		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Plantain			
Paraquat	2		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	100	0.55	Daynumber and Application 2 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	580		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Mancozeb	7		Number of applications
	1	3.2	Daynumber and Application 1 (kg/ha)
	50	3.2	Daynumber and Application 2 (kg/ha)
	100	3.2	Daynumber and Application 3 (kg/ha)
	150	3.2	Daynumber and Application 4 (kg/ha)
	200	3.2	Daynumber and Application 5 (kg/ha)
	250	3.2	Daynumber and Application 6 (kg/ha)
	300	3.2	Daynumber and Application 7 (kg/ha)
	70		T 0.5 days
	1		Time of breakdown granulars
	0.5		a in Kd function
	11.6		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Maneb	1		Number of applications
	1	1.6	Daynumber and Application 1 (kg/ha)
	70		T 0.5 days
	1		Time of breakdown granulars
	0.02		a in Kd function
	5.8		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Propiconazole	7		Number of applications
	1	0.1	Daynumber and Application 1 (kg/ha)
	50	0.1	Daynumber and Application 2 (kg/ha)
	100	0.1	Daynumber and Application 3 (kg/ha)
	150	0.1	Daynumber and Application 4 (kg/ha)
	200	0.1	Daynumber and Application 5 (kg/ha)
	250	0.1	Daynumber and Application 6 (kg/ha)
	300	0.1	Daynumber and Application 7 (kg/ha)
	80		T 0.5 days
	1		Time of breakdown granulars
	1.924		a in Kd function
	0.058		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Fenamiphos	1		Number of applications
	1	0.3	Daynumber and Application 1 kg/ha)
	30		T 0.5 days
	10		Time of breakdown granulars
	0.05		a in Kd function
	1.16		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps

Cassave			
Paraquat	3		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	60	0.55	Daynumber and Application 2 (kg/ha)
	120	0.55	Daynumber and Application 3 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	580		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Dimethoate	4		Number of applications
	1	0.4	Daynumber and Application 1 (kg/ha)
	50	0.4	Daynumber and Application 2 (kg/ha)
	100	0.4	Daynumber and Application 3 (kg/ha)
	150	0.55	Daynumber and Application 4 (kg/ha)
	4		T 0.5 days
	1		Time of breakdown granulars
	0.015		a in Kd function
	0.0116		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Maize			
Paraquat	3		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	60	0.55	Daynumber and Application 2 (kg/ha)
	120	0.55	Daynumber and Application 3 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	580		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Triadimefon	1		Number of applications
	1	0.5	Daynumber and Application 1 (kg/ha)
	18		T 0.5 days
	1		Time of breakdown granulars
	0.01		a in Kd function
	1.74		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Carbofuran	1		Number of applications
	1	0.5	Daynumber and Application 1 (kg/ha)
	90		T 0.5 days
	1		Time of breakdown granulars
	0.1		a in Kd function
	0.168		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Methylparathion	1		Number of applications
	1	0.48	Daynumber and Application 1 (kg/ha)
	5		T 0.5 days
	1		Time of breakdown granulars
	0.01		a in Kd function
	29.6		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Methamidophos	1		Number of applications
	1	0.6	Daynumber and Application 1 (kg/ha)
	6		T 0.5 days
	1		Time of breakdown granulars
	0.0311		a in Kd function
	0.0174		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Pineapple			

Diuron	2		Number of applications
	1	1.6	Daynumber and Application 1 (kg/ha)
	100	1.6	Daynumber and Application 2 (kg/ha)
	120		T 0.5 days
	1		Time of breakdown granulars
	0.082		a in Kd function
	2.32		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	300		number of steps
Benomyl	3		Number of applications
	1	0.5	Daynumber and Application 1 (kg/ha)
	80	0.5	Daynumber and Application 2 (kg/ha)
	180	0.5	Daynumber and Application 3 (kg/ha)
	320		T 0.5 days
	1		Time of breakdown granulars
	0.05		a in Kd function
	12.2		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Diazinon	3		Number of applications
	1	0.6	Daynumber and Application 1 (kg/ha)
	60	0.6	Daynumber and Application 2 (kg/ha)
	120	0.6	Daynumber and Application 3 (kg/ha)
	28		T 0.5 days
	1		Time of breakdown granulars
	0.0821		a in Kd function
	2.9		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Carbofuran	1		Number of applications
	1	0.1	Daynumber and Application 1 (kg/ha)
	90		T 0.5 days
	1		Time of breakdown granulars
	0.1		a in Kd function
	0.168		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Banana 1			
Glyphosate	11		Number of applications
	1	0.95	Daynumber and Application 1 (kg/ha)
	30	0.95	Daynumber and Application 2 (kg/ha)
	60	0.95	Daynumber and Application 3 (kg/ha)
	90	0.95	Daynumber and Application 4 (kg/ha)
	120	0.95	Daynumber and Application 5 (kg/ha)
	150	0.95	Daynumber and Application 6 (kg/ha)
	180	0.95	Daynumber and Application 7 (kg/ha)
	210	0.95	Daynumber and Application 8 (kg/ha)
	240	0.95	Daynumber and Application 9 (kg/ha)
	270	0.95	Daynumber and Application 10 (kg/ha)
	300	0.95	Daynumber and Application 11 (kg/ha)
	1		T 0.5 days
	1		Time of breakdown granulars
	1.8		a in Kd function
	5		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Paraquat	11		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	30	0.55	Daynumber and Application 2 (kg/ha)
	60	0.55	Daynumber and Application 3 (kg/ha)
	90	0.55	Daynumber and Application 4 (kg/ha)
	120	0.55	Daynumber and Application 5 (kg/ha)
	150	0.55	Daynumber and Application 6 (kg/ha)
	180	0.55	Daynumber and Application 7 (kg/ha)
	210	0.55	Daynumber and Application 8 (kg/ha)
	240	0.55	Daynumber and Application 9 (kg/ha)
	270	0.55	Daynumber and Application 10 (kg/ha)
	300	0.55	Daynumber and Application 11 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	580		Koc to be used in Kd fuction

Cassava			
Paraquat	3		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	60	0.55	Daynumber and Application 2 (kg/ha)
	120	0.55	Daynumber and Application 3 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	580		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Dimetheoate	4		Number of applications
	1	0.4	Daynumber and Application 1 (kg/ha)
	50	0.4	Daynumber and Application 2 (kg/ha)
	100	0.4	Daynumber and Application 3 (kg/ha)
	150	0.55	Daynumber and Application 4 (kg/ha)
	4		T 0.5 days
	1		Time of breakdown granulars
	0.015		a in Kd function
	0.0116		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Maize			
Paraquat	3		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	60	0.55	Daynumber and Application 2 (kg/ha)
	120	0.55	Daynumber and Application 3 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	580		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Triadimefon	1		Number of applications
	1	0.5	Daynumber and Application 1 (kg/ha)
	18		T 0.5 days
	1		Time of breakdown granulars
	0.01		a in Kd function
	1.74		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Carbofuran	1		Number of applications
	1	0.5	Daynumber and Application 1 (kg/ha)
	90		T 0.5 days
	1		Time of breakdown granulars
	0.1		a in Kd function
	0.168		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Methylparathion	1		Number of applications
	1	0.48	Daynumber and Application 1 (kg/ha)
	5		T 0.5 days
	1		Time of breakdown granulars
	0.01		a in Kd function
	29.6		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Methamidophos	1		Number of applications
	1	0.6	Daynumber and Application 1 (kg/ha)
	6		T 0.5 days
	1		Time of breakdown granulars
	0.0311		a in Kd function
	0.0174		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Pineapple			

Diuron	2		Number of applications
	1	1.6	Daynumber and Application 1 (kg/ha)
	100	1.6	Daynumber and Application 2 (kg/ha)
	120		T 0.5 days
	1		Time of breakdown granules
	0.082		a in Kd function
	2.32		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	300		number of steps
Benomyl	3		Number of applications
	1	0.5	Daynumber and Application 1 (kg/ha)
	80	0.5	Daynumber and Application 2 (kg/ha)
	180	0.5	Daynumber and Application 3 (kg/ha)
	320		T 0.5 days
	1		Time of breakdown granules
	0.05		a in Kd function
	12.2		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Diazinon	3		Number of applications
	1	0.6	Daynumber and Application 1 (kg/ha)
	60	0.6	Daynumber and Application 2 (kg/ha)
	120	0.6	Daynumber and Application 3 (kg/ha)
	28		T 0.5 days
	1		Time of breakdown granules
	0.0821		a in Kd function
	2.9		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Carbofuran	1		Number of applications
	1	0.1	Daynumber and Application 1 (kg/ha)
	90		T 0.5 days
	1		Time of breakdown granules
	0.1		a in Kd function
	0.168		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	250		number of steps
Banana 1			
Glyphosate	11		Number of applications
	1	0.95	Daynumber and Application 1 (kg/ha)
	30	0.95	Daynumber and Application 2 (kg/ha)
	60	0.95	Daynumber and Application 3 (kg/ha)
	90	0.95	Daynumber and Application 4 (kg/ha)
	120	0.95	Daynumber and Application 5 (kg/ha)
	150	0.95	Daynumber and Application 6 (kg/ha)
	180	0.95	Daynumber and Application 7 (kg/ha)
	210	0.95	Daynumber and Application 8 (kg/ha)
	240	0.95	Daynumber and Application 9 (kg/ha)
	270	0.95	Daynumber and Application 10 (kg/ha)
	300	0.95	Daynumber and Application 11 (kg/ha)
	1		T 0.5 days
	1		Time of breakdown granules
	1.8		a in Kd function
	5		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Paraquat	11		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	30	0.55	Daynumber and Application 2 (kg/ha)
	60	0.55	Daynumber and Application 3 (kg/ha)
	90	0.55	Daynumber and Application 4 (kg/ha)
	120	0.55	Daynumber and Application 5 (kg/ha)
	150	0.55	Daynumber and Application 6 (kg/ha)
	180	0.55	Daynumber and Application 7 (kg/ha)
	210	0.55	Daynumber and Application 8 (kg/ha)
	240	0.55	Daynumber and Application 9 (kg/ha)
	270	0.55	Daynumber and Application 10 (kg/ha)
	300	0.55	Daynumber and Application 11 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granules
	1		a in Kd function
	580		Koc to be used in Kd fuction

	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Fenamiphos	2		Number of applications
	1	5.55	Daynumber and Application 1 (kg/ha)
	150	5.55	Daynumber and Application 2 (kg/ha)
	30		T 0.5 days
	1		Time of breakdown granules
	0.05		a in Kd function
	1.16		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Terbufos	2		Number of applications
	1	5.55	Daynumber and Application 1 (kg/ha)
	150	5.55	Daynumber and Application 2 (kg/ha)
	27		T 0.5 days
	1		Time of breakdown granules
	0.6		a in Kd function
	4.1		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Propicanazole	9		Number of applications
	1	0.1	Daynumber and Application 1 (kg/ha)
	40	0.1	Daynumber and Application 2 (kg/ha)
	80	0.1	Daynumber and Application 3 (kg/ha)
	120	0.1	Daynumber and Application 4 (kg/ha)
	160	0.1	Daynumber and Application 5 (kg/ha)
	200	0.1	Daynumber and Application 6 (kg/ha)
	240	0.1	Daynumber and Application 7 (kg/ha)
	280	0.1	Daynumber and Application 8 (kg/ha)
	320	0.1	Daynumber and Application 9 (kg/ha)
	80		T 0.5 days
	1		Time of breakdown granules
	1.92		a in Kd function
	0.058		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Tridemorf	11		Number of applications
	1	0.45	Daynumber and Application 1 (kg/ha)
	30	0.45	Daynumber and Application 2 (kg/ha)
	60	0.45	Daynumber and Application 3 (kg/ha)
	90	0.45	Daynumber and Application 4 (kg/ha)
	120	0.45	Daynumber and Application 5 (kg/ha)
	150	0.45	Daynumber and Application 6 (kg/ha)
	180	0.45	Daynumber and Application 7 (kg/ha)
	210	0.45	Daynumber and Application 8 (kg/ha)
	240	0.45	Daynumber and Application 9 (kg/ha)
	270	0.45	Daynumber and Application 10 (kg/ha)
	300	0.45	Daynumber and Application 11 (kg/ha)
	50		T 0.5 days
	1		Time of breakdown granules
	1		a in Kd function
	11.6		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Mancozeb	10		Number of applications
	1	1.25	Daynumber and Application 1 (kg/ha)
	35	1.25	Daynumber and Application 2 (kg/ha)
	70	1.25	Daynumber and Application 3 (kg/ha)
	105	1.25	Daynumber and Application 4 (kg/ha)
	140	1.25	Daynumber and Application 5 (kg/ha)
	175	1.25	Daynumber and Application 6 (kg/ha)
	210	1.25	Daynumber and Application 7 (kg/ha)
	245	1.25	Daynumber and Application 8 (kg/ha)
	280	1.25	Daynumber and Application 9 (kg/ha)
	315	1.25	Daynumber and Application 10 (kg/ha)
	70		T 0.5 days
	1		Time of breakdown granules
	0.5		a in Kd function
	11.6		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval

	700		number of steps
Chlorothalonil	5		Number of applications
	1	1.25	Daynumber and Application 1 (kg/ha)
	50	1.25	Daynumber and Application 2 (kg/ha)
	100	1.25	Daynumber and Application 3 (kg/ha)
	150	1.25	Daynumber and Application 4 (kg/ha)
	200	1.25	Daynumber and Application 5 (kg/ha)
	37		T 0.5 days
	1		Time of breakdown granules
	0.021		a in Kd function
	8		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Banana 2			
Glyphosate 11			Number of applications
	1	0.95	Daynumber and Application 1 (kg/ha)
	30	0.95	Daynumber and Application 2 (kg/ha)
	60	0.95	Daynumber and Application 3 (kg/ha)
	90	0.95	Daynumber and Application 4 (kg/ha)
	120	0.95	Daynumber and Application 5 (kg/ha)
	150	0.95	Daynumber and Application 6 (kg/ha)
	180	0.95	Daynumber and Application 7 (kg/ha)
	210	0.95	Daynumber and Application 8 (kg/ha)
	240	0.95	Daynumber and Application 9 (kg/ha)
	270	0.95	Daynumber and Application 10 (kg/ha)
	300	0.95	Daynumber and Application 11 (kg/ha)
	1		T 0.5 days
	1		Time of breakdown granules
	1.8		a in Kd function
	5		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	500		number of steps
Paraquat	11		Number of applications
	1	0.55	Daynumber and Application 1 (kg/ha)
	30	0.55	Daynumber and Application 2 (kg/ha)
	60	0.55	Daynumber and Application 3 (kg/ha)
	90	0.55	Daynumber and Application 4 (kg/ha)
	120	0.55	Daynumber and Application 5 (kg/ha)
	150	0.55	Daynumber and Application 6 (kg/ha)
	180	0.55	Daynumber and Application 7 (kg/ha)
	210	0.55	Daynumber and Application 8 (kg/ha)
	240	0.55	Daynumber and Application 9 (kg/ha)
	270	0.55	Daynumber and Application 10 (kg/ha)
	300	0.55	Daynumber and Application 11 (kg/ha)
	100000		T 0.5 days
	1		Time of breakdown granules
	1		a in Kd function
	580		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Diuron	7		Number of applications
	1	2.8	Daynumber and Application 1 (kg/ha)
	40	2.8	Daynumber and Application 2 (kg/ha)
	80	2.8	Daynumber and Application 3 (kg/ha)
	120	2.8	Daynumber and Application 4 (kg/ha)
	160	2.8	Daynumber and Application 5 (kg/ha)
	200	2.8	Daynumber and Application 6 (kg/ha)
	240	2.8	Daynumber and Application 7 (kg/ha)
	120		0.5 days
	1		Time of breakdown granules
	0.082		a in Kd function
	2.32		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	1500		number of steps
Benomyl	7		Number of applications
	1	0.14	Daynumber and Application 1 (kg/ha)
	40	0.14	Daynumber and Application 2 (kg/ha)
	80	0.14	Daynumber and Application 3 (kg/ha)
	120	0.14	Daynumber and Application 4 (kg/ha)
	160	0.14	Daynumber and Application 5 (kg/ha)
	200	0.14	Daynumber and Application 6 (kg/ha)
	240	0.14	Daynumber and Application 7 (kg/ha)
	320		T 0.5 days
	1		Time of breakdown granules

	0.05		a in Kd function
	12.2		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	1500		number of steps
Tridemorf	7		Number of applications
	1	0.45	Daynumber and Application 1 (kg/ha)
	40	0.45	Daynumber and Application 2 (kg/ha)
	80	0.45	Daynumber and Application 3 (kg/ha)
	120	0.45	Daynumber and Application 4 (kg/ha)
	160	0.45	Daynumber and Application 5 (kg/ha)
	200	0.45	Daynumber and Application 6 (kg/ha)
	240	0.45	Daynumber and Application 7 (kg/ha)
	50		T 0.5 days
	1		Time of breakdown granulars
	1		a in Kd function
	11.6		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Propicanazole	7		Number of applications
	1	0.1	Daynumber and Application 1 (kg/ha)
	40	0.1	Daynumber and Application 2 (kg/ha)
	80	0.1	Daynumber and Application 3 (kg/ha)
	120	0.1	Daynumber and Application 4 (kg/ha)
	160	0.1	Daynumber and Application 5 (kg/ha)
	200	0.1	Daynumber and Application 6 (kg/ha)
	240	0.1	Daynumber and Application 7 (kg/ha)
	80		T 0.5 days
	1		Time of breakdown granulars
	1.92		a in Kd function
	0.058		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	1000		number of steps
Mancozeb	10		Number of applications
	1	1.25	Daynumber and Application 1 (kg/ha)
	35	1.25	Daynumber and Application 2 (kg/ha)
	70	1.25	Daynumber and Application 3 (kg/ha)
	105	1.25	Daynumber and Application 4 (kg/ha)
	140	1.25	Daynumber and Application 5 (kg/ha)
	175	1.25	Daynumber and Application 6 (kg/ha)
	210	1.25	Daynumber and Application 7 (kg/ha)
	245	1.25	Daynumber and Application 8 (kg/ha)
	280	1.25	Daynumber and Application 9 (kg/ha)
	315	1.25	Daynumber and Application 10 (kg/ha)
	70		T 0.5 days
	1		Time of breakdown granulars
	0.5		a in Kd function
	11.6		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	700		number of steps
Chlorothalonil	5		Number of applications
	1	1.25	Daynumber and Application 1 (kg/ha)
	50	1.25	Daynumber and Application 2 (kg/ha)
	100	1.25	Daynumber and Application 3 (kg/ha)
	150	1.25	Daynumber and Application 4 kg/ha)
	200	1.25	Daynumber and Application 5 (kg/ha)
	37		T 0.5 days
	1		Time of breakdown granulars
	0.021		a in Kd function
	8		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps
Fenamiphos	2		Number of applications
	1	5.55	Daynumber and Application 1 (kg/ha)
	150	5.55	Daynumber and Application 2 (kg/ha)
	30		T 0.5 days
	1		Time of breakdown granulars
	0.05		a in Kd function
	1.16		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps

Terbufos	2		Number of applications
	1	5.55	Daynumber and Application 1 (kg/ha)
	150	5.55	Daynumber and Application 2 kg/ha)
	27		0.5 days
	1		Time of breakdown granules
	0.6		a in Kd function
	4.1		Koc to be used in Kd fuction
	4000		Rain (mm)
	4		Et (mm/day)
	0.5		Time interval
	600		number of steps

soil data of B-Leach

soil

RJ222	3		Number of horizons			
		Depth	BD	FC	Clay	OM
		20	0.86	44	10	3.9
		64	0.71	61	8	0.3
		90	1.3	12	6	10.2
RJ224	5		Number of horizons			
		Depth	BD	FC	Clay	OM
		15	0.56	88	8	2.14
		50	0.67	76	8	0.13
		85	1.06	43	18	0.26
		110	1	43	14	0.56
		130	1	43	16	6.3
RJ225	3		Number of horizons			
		Depth	BD	FC	Clay	OM
		25	0.62	81	8	5.6
		56	0.51	101	10	0.9
		77	0.81	73	8	0.5
GP16		3	Number of horizons			
		Depth	BD	FC	Clay	OM
		7	0.64	81	9	19
		72	0.68	56	7	8.6
		124	1.11	11	11	0.56
GP26		4	Number of horizons			
		Depth	BD	FC	Clay	OM
		7	0.59	86	7	13.4
		89	0.72	67	9	5.51
		135	1.11	43	17	0.26
		150	1.02	46	11	0.56
NEG308	3		Number of horizons			
		Depth	BD	FC	Clay	OM
		5	0.93	46	7	3.6
		60	0.9	46	7	3.4
		120	1.31	8	5	0.75
COC5		6	Number of horizons			
		Depth	BD	FC	Clay	OM
		5	0.68	88	15	8.7
		15	0.7	87	15	4.5
		32	0.65	100	17	4.7
		48	0.77	78	17	1.8
		63	0.91	57	11	0.8
		100	1.1	43	7	0.8
COC6		3	Number of horizons			
		Depth	BD	FC	Clay	OM
		5	0.72	75	13	8.9
		30	1.02	45	9	1.6
		90	1.13	43	7	1.6
COC8		4	Number of horizons			
		Depth	BD	FC	Clay	OM
		12	0.68	89	10	9.7
		30	0.81	70	12	4.3
		55	0.99	57	6	2.1
		77	1.2	45	8	0.25
COC24	5		Number of horizons			
		Depth	BD	FC	Clay	OM
		5	0.74	71	22	12.9
		40	0.87	46	18	3.5
		50	0.97	36	10	1.1
		70	0.86	57	14	0.8
		150	0.82	61	18	1.1
COC25	5		Number of horizons			

	Depth	BD	FC	Clay	OM
	10	0.96	56	6	1.6
	17	0.88	69	6	1.1
	23	0.83	76	6	1.1
	30	0.82	80	8	0.8
	120	0.82	61	8	0.8
EG2	3	Number of horizons			
	Depth	BD	FC	Clay	OM
	10	0.9	56	58	8.8
	34	0.75	60	72	2.7
	120	0.8	60	72	1.1
EG3	4	Number of horizons			
	Depth	BD	FC	Clay	OM
	4	0.85	46	34	8.8
	30	0.96	55	26	3.1
	54	0.86	54	32	1.5
	70	0.96	55	32	0.8
EG4	4	Number of horizons			
	Depth	BD	FC	Clay	OM
	10	0.85	46	36	10.4
	30	0.97	53	42	5.7
	65	0.96	48	38	2.3
	120	0.96	55	38	2.3

APPENDIX III: Kd and Koc values per biocide

pesticide	half live time HLT	clay a	Koc	OM b	sorce	Kd values	situation	% clay	% OM
paraquat	stable	1	100000	580	estimation paraquat is immobile				
mancozeb	70 days	0.5	2000	11.6	estimation	94.5	riversediment		
						14	loamy sand		
maneb	70 days	0.02	1000	5.8	estimation				
fenamiphos	30 days	0.05	200	1.16	estimation	1.95	sandy loam		
						4.25	clay loam		
dimethoate	4 days	0.015	20	0.116	estimation	0.06	sand		
						0.3	sandy loam		
						0.57	silt loam		
						0.74	clay loam		
triadimefon	18 days	0.01	300	1.74	estimation	1.85	sandy loam		
						2.4	sand		
						2.6	clay loam		
						6.9	silt loam		
carbofuran	90 days	0.1	29	0.168	estimation	0.16	?		0.1
						30.3	?		79.5
methyl parathion	5 days	0.01	5100	29.6	estimation				
propiconazol	80 days	1.924	100	0.058	calculation	8.48	loamy sand		2.2
						1.96	sand		1.2
						26.2	silt loam		3.6
						59.03	sandy clay loam		5.6
methamidofos	6.1 days	0.0311	3	0.0174	calculation	0.97		7	0.8
						0.97		13	2.8
						0.98		23	0.6
						0.95		25	5.1
						0.91		43	2.1
diuron	120 days	0.062	400	2.32	estimation	2 - 25			
benomyl	320 days	0.05	2100	12.2	estimation	6.1 - 90			
diazinon	28 days	0.0821	500	2.9	calculation	5.6		3	2.2
						11.7		12	3.6
						3.7		3	1
						4.5		4	1.6

APPENDIX IV: a and b of the Kd equation per biocide

	a and b	Kd est.		Kd real	
propiconalzol	a=	1.7	10.4	10.04	8.48
	b=	0.7	17.84	17.84	1.96
			26.32	26.32	26.2
			51.52	51.52	59.03
methamidopho	a=	0.015	0.345	0.345	0.97
	b=	0.3	1.035	1.035	0.97
			0.525	0.525	0.98
			1.905	1.905	0.95
			1.275	1.275	0.91
diazinon	a=	0.85	4.97	4.97	5.6
	b=	1.1	14.16	14.16	11.7
			3.65	3.65	3.7
			5.16	5.16	4.5
terbefos	a=	0.6	5.499	5.4994117647	4.2
	b=	4.1	8.59	8.5988235294	13
			14.15	14.152352941	14.6
			11.54	11.541176471	11.4
chlorothallonil	a=	0.4	19.5	19.5	20
	b=	4.2	4.52	4.52	3
			5.76	5.76	29
			27.04	27.04	26
metribuzine	a=	0.023	1.139	1.139	1.32
	b=	0.3	2.075	2.075	1.9
			1.507	1.507	1.53

atrazine	a=	0.05	2.58	2.58	2.46	
	b=	0.1	0.19	0.19	0.2	
			1.04	1.04	0.79	
			0.53	0.53	0.73	
ametrina	a=	0.05	3.9529	3.9529411765	4.8	
	b=	1.9	3.9412	3.9411764706	3.8	
			7.9885	7.9882352941	5	
			3.2706	3.2705882353	2.8	
			1.256	1.2558823529	0.6	
simazina	a=	0.07	4.14	4.14	4.31	
	b=	0.25	0.37	0.365	0.65	
			1.67	1.665	1.27	
			0.83	0.83	0.48	
oxyfluorfen	a=	0.17	15.86	15.86	15.49	no leachi
	b=	9	9.4	9.4	9.95	
oxamyl	a=	0.002	0.216	0.216	0.08	
	b=	0.1	0.218	0.218	0.05	
			0.628	0.628	0.52	
			0.136	0.136	0.05	
			0.55	0.55	0.41	
ethoprop	a=	0.05	1.11	1.1058823529	1.08	
	b=	0.35	1.29	1.2911764706	1.24	
			1.17	1.1735294118	2.1	
			3.24	3.2441176471	3.78	

glyfosato	1 day	1.8	?	5	estimation	62	silty clay loam		
						90	silt		
						70	sandy loam		
						22	sandy loam		
									%OC
terbufos	27 days	0.6	4.1		estimation	2.8	loamy sand		0.29
						1.59	sandy loam		0.58
						1.95	loam		1.39
						2.15	silt loam		1.8
chlorothallonil	37 days	0.0209	1380	8	calculation	20	sandy loam		3.5
						3	sand		0.6
						29	silt		0.8
						26	silty clay		3.2
metribuzine	40 days	0.0256	41	0.238	calculation	1.32		13	2.8
						1.9		25	5
						1.53		59	0.5
atrazine	146 days	0.05		0.1	calculation	2.46		42	4.8
						0.2		2	0.9
						0.79		17	1.9
						0.73		9	0.8
simazina	234 days	0.02952		0.6	calculation	4.31		42	4.8
						0.65		2	0.9
						1.27		17	1.9
						0.48		9	0.8
									% OC
ametrina	84 days	0.05		1.9	calculation	4.8	sandy loam		3
						3.8	silt loam		2.9
						5	silty clay		5
						2.8	silt loam		2.3
						0.6	sand		0.9
oxyfluorfen	930 days	0.17	100000	8.6	estimation	15.49	clay		0.95
						9.95	sand		0.44
dalapon	800 days estimation	0	0	0	all P leaches rapidly				
oxamyl	28 days	0.008903	6	0.035	calculation	0.08	loamy sand		
						0.05	silt loam		
						0.52	silt loam		
						0.05	sandy loam		
						0.41	loam		
									%OC
ethoprop	112 days	0.025	120	0.7	calculation	1.08	sandy loam		1
						1.24	sandy loam		1.9
						2.1	silt loam		2.3
						3.78	silty clay		4.1

pesticide	Kd real		%clay	%OM	%OC	Koc soil	contante Om	Kd-Omcontst	x coef	Kd=a*OM%+b*clay%	Koctyp	opmerkingen	HLT	
pesticide	Kd real		%clay	%OM	%OC	Koc soil	contante Om	Kd-Omcontst	x coef	Kd=a*OM%+b*clay%	Koctyp	opmerkingen	HLT	
paraquat						100000		1000	0				stable	
mancozeb	94.5	riversediment	70			2000	1.1601E+01	11.6	0.5			mean clay %		
	14	loamy sand	7				1.1601E+01							
maneb						1000	5.8005E+00	5.8	0.02			chlorothalionil data	70 days	Aersoilmet
fenamiphos	1.95	sandyloam	12			200	1.1601E+00	1.16	0.05			mean clay %	30 days	maxAersoilmet
	4.25	clayloam	33				1.1601E+00					estimated		
dimetheoate	0.06	sand	4			20	1.1601E-01	0.16	0.015			mean clay %	4 days	maxAersoilmet
	0.3	sandyloam	12				1.1601E-01					estimated		
	0.57	siltloam	16				1.1601E-01							
	0.74	clayloam	33				1.1601E-01							
triadimefon	1.85	sandyloam	12			300	1.7401E+00	1.74	0.01			mean clay %	18days	maxAersoilmet
	2.4	sand	4				1.7401E+00							
	2.6	clayloam	33				1.7401E+00							
	6.9	siltloam	16				1.7401E+00							
carbofuran	0.16	?		0.1		29	1.6821E-01	0.1682	0.1				90 days	maxAersoilmet
	30.3	?		79.5			1.6821E-01							
methylparathio	?					5100	2.9582E+01	29.6	0.01				5 days	maxAersoilmet
propiconalzol	8.48	loamysand	7	2.2		100	5.8005E-02	0.058	1.92365			mean clay %	80 days	maxAersoilmet
	1.96	sand	4	1.2			5.8005E-02							
	26.2	siltloam	16	3.6			5.8005E-02							
	59.03	sandyclayloam	28	5.6			5.8005E-02							

pesticide	Kd real		%clay	%OM	% OC	Koc soil	contante0m	Kd- mcontst	x coef	Kd_a*OM%+b*clay%	Koctyp	opmerkingen	HLT	
methamidopho	0.97		7	0.8		3	1.7401E-02	0.0174	0.03106				6.1 days	maxAersoilmet
	0.97		13	2.8			1.7401E-02							
	0.98		23	0.6			1.7401E-02							
	0.95		25	5.1			1.7401E-02							
	0.91		43	2.1			1.7401E-02							
diuron	2to25					400	2.3202E+00	2.32	0.082			estimated	120 days	maxAersoilmet
benomyl	6.1		?			2100	1.2181E+01	12.2	0.05			estimated	320 days	maxAersoilmet
	90													
diazinon	5.6		3	2.2		500	2.9002E+00	2.9	0.08206		255	calculated	28 days	maxAersoilmet
	11.7		12	3.6			2.9002E+00				325			
	3.7		3	1			2.9002E+00				370			
	4.5		4	1.6			2.9002E+00				281			
glyfosato	62	siltyclayloam	35			?		5	1.8			mean clay %	1 day	maxAersoilmet
	90	silt	6									estimated		
	70	sandyloam	12											
	22	sandyloam	12											
terbufos	2.8	loamysand	7		0.29	?		4.1	0.6		517	mean clay %	27 days	maxAersoilmet
	1.59	sandyloam	12		0.58						1414			
	1.95	loam	18		1.39						540			
	2.15	siltloam	16		1.8						297			
chlorothallonil	20	sandyloam	12	3.5		1380	8.0046E+00	8	0.0209			mean clay %	37 days	maxAersoilmet
	3	sand	4	0.6			8.0046E+00							
	29	silt	6	0.8			8.0046E+00							
	26	siltyclay	47	3.2			8.0046E+00							
metribuzine	1.32		13	2.8		41	2.3782E-01	0.238	0.02562				40 days	maxAersoilmet
	1.9		25	5			2.3782E-01							
	1.53		59	0.5			2.3782E-01							

```
ses Graph;

ar
 GrMode,GrDriver,NrComp,NrStep,NrAppl,
 i1,i2,StepNr,GranTime,NrHor            : Integer;
 TotAppl,ConcMax,
 HLT,Rain,ET,a,b,Flow,Leach,Input,Step  : Real;
 Title,Path                             : String;
 Infile,Outfile                         : Text;
 GraphCheck                             : Boolean;
 Depth,FC0,Clay0,FC1,Clay1              : Array[1..30] of Integer;
 BD0,BD1,Kd,Ratio,OM0,OM1               : Array[1..30] of Real;
 Soil,Water,Total                       : Array[0..30] of Real;
 Gift                                   : Array[1..20] of Real;
 TimeAppl                               : Array[1..20] of Integer;

rocedure GetInFile;
 Begin
 If ParamCount<3 then
     Begin
     writeln('USAGE: PLEACH <CROPFILE> <SOILFILE> <OUTFILE> <GraphCheck>');
     HALT
     End;
 {$I-}
 Assign(Infile,ParamStr(1));
 Reset(Infile);
 {$I+}
 If IOresult>0 then
     Begin
     writeln('Crop file does not exist');
     HALT
     End;
 Readln(Infile,Title);
 Readln(Infile,NrAppl);
 TotAppl:=0;
 For i1:=1 to NrAppl do
   Begin
   Readln(Infile,TimeAppl[i1],Gift[i1]);
   TotAppl:=TotAppl+Gift[i1];
   End;
 Readln(Infile,HLT);
 Readln(Infile,GranTime);
 Readln(Infile,a);
 Readln(Infile,b);
 Readln(Infile,Rain);
 Readln(Infile,ET);
 Readln(Infile,Step);
 Readln(Infile,NrStep);
 For i1:=1 to NrAppl do
    TimeAppl[i1]:=Round(TimeAppl[i1]/Step);
 GranTime:=Round(Grantime/step);
 Close(Infile);
 {$I-}
 Assign(Infile,ParamStr(2));
 Reset(Infile);
 {$I+}
 If IOresult>0 then
     Begin
     writeln('Soil file does not exist');
     HALT
     End;
 Readln(Infile,NrHor);
 Readln(Infile);
 Flow:=(Rain/365-ET)*Step*0.01;
```

pesticide	Kd real		%clay	%OM	%OC	Koc soil	contante0m	Kdomcontst	x coef	Kd = a * %+ *clay%	Koctyp	opmerkingen	HLT	
atrazine	2.46		42	4.8		?		0.1	0.05		87	calculted	146 days	maxAersolimet
	0.2		2	0.9							39			
	0.79		17	1.9							70			
	0.73		9	0.8							155			
ametrina	4.8	sandyloam	12		3	?		1.9	0.05			mean clay %	84 days	maxAersolimet
	3.8	siltloam	16		2.9									
	5	siltyclay	47		5									
	2.8	siltloam	16		2.3									
	0.6	sand	4		0.9									
simazina	4.31		42	4.8		103	5.9745E-01	0.6	0.02952				234 days	maxAersolimet
	0.65		2	0.9			5.9745E-01							
	1.27		17	1.9			5.9745E-01							
	0.48		9	0.8			5.9745E-01							
oxyfluorfen	15.49	clay	70	0.44		100000	5.8005E+02	580	0			mean clay %	930 days	maxAersolimet
	9.95	sand	4	0.95			5.8005E+02							
dalapon	0					geen		0	0				?	
oxamyl	0.08	loamysand	7	2		6	3.4803E-02	0.035	0.0089			mean clay %	28 days	maxAersolimet
	0.05	siltloam	16	1.9			3.4803E-02							
	0.52	siltloam	16	6			3.4803E-02							
	0.05	sandyloam	12	1			3.4803E-02							
	0.41	loam	18	5.1			3.4803E-02							
ethoprop	1.08	sandyloam	12		1	120	6.9606E-01	0.7	0.025			mean clay %	112 days	maxAersolimet
	1.24	sandyloam	12		1.9		6.9606E-01							
	2.1	siltloam	16		2.3		6.9606E-01							
	3.78	siltyclay	47		4.1		6.9606E-01							

```
or i1:=1 to NrHor do
   Begin
   Readln(Infile,Depth[i1],BD0[i1],FC0[i1],Clay0[i1],OM0[i1]);
   If BD0[i1]*FC0[i1]*0.01<Flow then
      Begin
      writeln('Waterflow is larger than soil storage !!!!');
      Close(Infile);
      HALT
      End;
   End;
Close(Infile);
If ParamStr(4) = '0' then GraphCheck:=False else GraphCheck:=True;
End;

ocedure SoilDat;

gin
Comp:=Round(Depth[NrHor]/10);
r i1:=1 to NrComp do
 Begin
 i2:=1;
 While Depth[i2]<i1*10 do Inc(i2);
 BD1[i1]:=BD0[i2];
 FC1[i1]:=FC0[i2];
 OM1[i1]:=OM0[i2];
 Clay1[i1]:=Clay0[i2];
 End;
d;

rocedure DrawBar(i:Integer;Gift,Twater,Tsoil:Real);

egin
etFillStyle(0,0);
ar(40,20+i*20,440,40+i*20);
etFillStyle(1,15);
ar(40,20+i*20,40+400*Round(Tsoil/Gift),30+i*20);
etFillStyle(1,15);
ar(40,30+i*20,40+800*Round(Twater/Gift),40+i*20);
nd;

unction Pwr(GT:Real;Ex:Real):Real;

egin
wr:=Exp(Ex*ln(GT));
nd;

rocedure PestInput;

egin
nput:=0;
or i1:=1 to NrAppl do
  Begin
  If (StepNr>=TimeAppl[i1]) and (StepNr<(TimeAppl[i1]+GranTime)) then
     Input:=Input+Gift[i1]/GranTime;
  End;
nd;

egin
etInFile;
oilDat;
etDir(0,Path);
f GraphCheck=True then
  Begin
  grDriver := Detect;
  InitGraph(GrDriver,GrMode,Path);
  SetGraphMode(GrMode);
```

```
   End;
 or i1:=1 to NrComp do
   Begin
   Kd[i1]:=a*Clay1[i1]+b*OM1[i1];
   Ratio[i1]:=Kd[i1]*FC1[i1]/(BD1[i1]*100);
   Soil[i1]:=0;
   Water[i1]:=0;
   End;
:oncMax:=0;
.each:=0;
.ssign(Outfile,ParamStr(3));
.ewrite(Outfile);
/riteln(Outfile,Title);
/riteln(Outfile,'StepNr   Leach    Conc    Totals in different compartments');
'or StepNr:=1 to NrStep do
   Begin
   Total[0]:=0;
   Leach:=Leach+(Water[NrComp]/(FC1[NrComp]*0.01))*Flow;
   If ConcMax<Water[NrComp]/(FC1[NrComp]*0.01) then
      ConcMax:=Water[NrComp]/(FC1[NrComp]*0.01);
   PestInput;
   Write(Outfile,StepNr:6,Leach:8:1,Water[NrComp]/(FC1[NrComp]*0.01):8:2);
   For i1:=1 to NrComp do
      Begin
      If i1=1 then
         Total[1]:=(Input+Soil[1]+Water[1]-Flow*Water[1]/(FC1[1]*BD1[1]*0.01))*
.r(0.5,Step/HLT)
      Else
         Total[i1]:=(Soil[i1]+Water[i1]
                    +Flow*(Water[i1-1]/(FC1[i1-1]*BD1[i1-1]*0.01)
                    -Water[i1]/(FC1[i1]*BD1[i1]*0.01)))
                    *Pwr(0.5,Step/HLT);
      Total[0]:=Total[0]+Total[i1];
      Soil[i1]:=Ratio[i1]*Total[i1]/(1+Ratio[i1]);
      Water[i1]:=Total[i1]-Soil[i1];
      Write(Outfile,Total[i1]:8:2);
      End;
   If GraphCheck=True then
      For i1:=1 to NrComp do
         Begin
         SetFillStyle(0,0);
         Bar(40,20+i1*20,440,40+i1*20);
         SetFillStyle(1,15);
         Bar(40,20+i1*20,Round(40+400*(Soil[i1]/TotAppl)),30+i1*20);
         SetFillStyle(1,3);
         Bar(40,30+i1*20,Round(40+400*(Water[i1]/TotAppl)),40+i1*20);
         SetFillStyle(0,0);
         Bar(600,400,620,100);
         SetFillStyle(1,15);
         Bar(600,400,620,400-Round(300*(Total[0]/TotAppl)))
         End;
   Writeln(Outfile);
   End;
Close(Outfile);
If GraphCheck=True then
   Begin
   Readln;
   RestoreCrtMode;
   CloseGraph;
   End;
Writeln('The maximum concentration observed was : ',ConcMax:8:2);
Readln;
End.
```

APPENDIX VI: Amount of biocide application per crop

crop	H/I/N/F	syst or contact	pesticide comercial name	pesticide name a i.	a.i	appl rate	unit	applai	# appl/y	gift/y
palm heart	H	contact	gramoxone	paraquat	0.28	2	l/ha	0.552	2	1.10
platain	H	contact	gramoxone	paraquat	0.28	2	l/ha	0.552	2	1.10
	F	protect	dithane-m-45	mancozeb	0.8	4	l/ha	3.2	7	22.40
	F	contact	maneb BO	maneb	0 8	2	kg/ha	1.6	1	1.60
	F	systemic	tilt-25%	propiconazol	0 25	0.4	l/ha	0.1	7	0.70
	I/N	systemic	nemacur	fenamiphos	0.1	3	kg/ha	0.3	1	0.30
cassave	H	contact	gramoxone	paraquat	0.28	2	l/ha	0.552	3	1.66
	I/N	systemic	perfection	dimetheoate	0.5	0.8	kg/ha	0.4	4	1 60
maise	H	contact	gramoxone	paraquat	0.28	2	l/ha	0.552	3	1.66
	F	systemic	bayleton-2500EC	triadimefon	0.25	2	kg/ha	0.5	1	0.50
	N/I	systemic	furadan-25kg	carbofuran	0.1	5	kg/ha	0.5	1	0.50
	N/I	contact	methylparathion	methylparathion	0.48	1	l/ha	0.48	1	0.48
	N/I	systemic	tamaron-60%	methamidophos	0 6	1	l/ha	0.6	1	0.60
pineapple	H	systemic	diuron	diuron	0.8	2	kg/ha	1.6	2	3.20
	F	systemic	benlate(1kg)	benomyl	0.5	1	kg/ha	0.5	3	1.50
	I/N	contact	decis(1lt)	deltamethrin	0.03	1	l/ha	0.025	1	0.03
	I/N	contact	diazinon	diazinon	0.6	1	l/ha	0.6	3	1.80
	I/N	systemic	furadan-25kg	carbofuran	0.1	1	kg/ha	0.1	1	0.10
banana 1	H	systemic	roundup	glyphosato	0.48	1.98	l pc/ha	0.9504	11	10.45
	H	contact	gramoxone	paraquat	0.28	2	l/ha	0.552	11	6.07
	N	systemic	nemacur	fenamifos	0.1	55.5	kg/ha	5.55	2	11.10
	N	contact	counter	terbufos	0.1	55.5	kg/ha	5.55	2	11.10
	F	systemic	tilt	propiconazol	1	0.1	kg ai/ha	0.1	9	0.90
	F	systemic	calixin	tridemorf	1	0.45	kg ai/ha	0.45	11	4.95
	F	protect	dithane-M-45	mancozeb	1	1.25	kg ai/ha	1.25	10	12.50
	F	protect	bravo	chlorothalonil	1	1.25	kg ai/ha	1.25	5	6.25
banana 2	H	systemic	diuron	diuron	0.8	3.5	l/ha	2.8	7	19.60
	H	systemic	roundup	glyphosato	0.48	1.98	l pc/ha	0.9504	4	3.80
	H	contact	gramoxone	paraquat	0.28	2	l/ha	0.552	11	6.07
	F	systemic	calixin	tridemorf	1	0.45	kg ai/ha	0.45	7	3.15
	F	systemic	benlate	benomyl	0.5	0.25	kg/ha	0.125	7	0.88
	F	systemic	tilt	propiconazol	1	0.1	kg ai/ha	0.1	7	0.70
	F	protect	dithane-M-45	mancozeb	1	1.25	kg ai/ha	1.25	10	12.50
	F	protect	bravo	chlorothalonil	1	1.25	kg ai/ha	1.25	5	6.25

APPENDIX VII: Results of B-Leach per crop and 14 soil types

crop (LUST)	soil type / biocide		rjz25	rjz24	rjz22	gp26	gp16	neg308	coc25	coc24	coc8	coc5	coc6	eg4	eg3	eg2
palm heart	paraquat	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
plaitain	paraquat	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	mancozeb	F	0	0	0.02	0	0	0	0	0	0	0	0.01	0	0	0
	maneb	F	0	0	0.03	0	0	0.01	0	0	0	0	0.01	0	0	0
	propiconazole	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	fenamiphos	N	0	0	0.01	0	0	0.01	0	0	0	0	0.01	0	0	0
cassave	paraquat	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	dimetheoate	I/N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
maise	paraquat	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	triadimefon	F	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
	carbofuran	N/I	0.01	0.02	0.1	0.01	0.04	0.11	0.02	0.01	0.02	0.01	0.07	0.01	0.02	0
	methylparathion	N/I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	methamidophos	N/I	0	0	0.01	0	0	0.01	0	0	0	0	0	0	0	0
pineapple	diuron	H	0.01	0.04	0.16	0	0.01	0.1	0.04	0.01	0.01	0.01	0.11	0.01	0.05	0
	benomyl	F	0	0.01	0.03	0	0	0.01	0.01	0	0	0	0.02	0	0	0
	deltamethrin	N/I														
	diazinon	N/I	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
	carbofuran	N/I	0	0	0.02	0	0.01	0.02	0	0	0	0	0.01	0	0	0
banana 1	glyphosate	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	paraquat	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	fenamiphos	N	0.01	0.02	0.25	0	0	0.12	0.02	0	0.01	0	0.12	0	0.04	0
	terbufos	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	propiconazole	F	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
	tridemorf	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	mancozeb	F	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
	chlorothalonil	F	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
banana 2	glyphosate	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	paraquat	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	diuron	H	0.05	0.19	0.6	0.01	0.03	0.44	0.17	0.08	0.05	0.04	0.45	0.03	0.23	0.02
	benomyl	F	0	0	0.02	0	0	0.01	0	0	0	0	0.01	0	0	0
	tridemorf	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	propiconazole	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	mancozeb	F	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
	chlorothalonil	F	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0