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Population dynamics and treatment strategies of *Phytophthora infestans* (late blight) in the Mid-Hills of Nepal

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Abstract

The fungus *Phytophthora infestans* is a major ubiquitous pest in solanaceous crops and causes great damages in the agricultural systems in Nepal. This is especially true in the cash crop orientated areas of the Mid-Hills and the Terai region, where potato and tomato cropping is a prominent income source of the rural population. This fact in combination with cheap and readily available pesticides is responsible for the frequent and perceived over-use of chemical plant protection agents. Based on this background a series of agronomic field trials in the Jhikhu-Khola watershed aiming at the optimisation of *P. infestans* treatment strategy was conducted. Within the field trials three different treatment strategies comprising both conventional and an alternative IPM approach were tested. Additionally a mathematical model for the simulation of the population dynamics of *P. infestans* was established, which is based on a universal epidemiological model with further specification for the late blight. The parameter estimation for the model was accomplished with uncontrolled field data. Using this model different treatment strategies were tested by introducing pesticide treatment strategies into the model. Based on both field trials and population dynamics simulation recommendations for an optimised conventional treatment strategy were developed.

Introduction

This paper deals with the most prominent pest of solanaceous crops world-wide, the late *blight Phytophthora infestans* and its population dynamics. This fungal disease is able to destroy a crop completely and consequently causes serious economic damages or even famines where potatoes are the main staple crop. This is historically documented as the infamous famine in Ireland in the mid-1840s, which resulted in the large immigration wave to America. Since then, the control of *P. infestans* has been a major issue in agricultural research and production.

Nepal is no exception to that. Since the introduction of potato and tomato as valuable cash crops, the control of late blight is the major concern of Nepali farmers. To a large extend the control bases on chemicals, as documented in national pesticide consumption and import statistics as well as in the surveys conducted in the investigation area, the Jhikhu-Khola watershed (Kansakar, Khanal et al. 2001; Pujara and Khanal 2001), being one of the largest production areas of potatoes and tomatoes for the Kathmandu valley.

Based on this background a series of agronomic field trials were conducted in co-operation with the Plat Protection Division (PPD) of the Department of Agriculture (DOA). These trials intented to investigate the reduction potential of and possible alternatives to the usual chemical control measures.

In the trials the visible disease development of *P. infestans* as well as the control measures were recorded. The results were statistically evaluated in order to compare the different applied treatment strategies. Additionally a dynamic pest population model for *P. infestans* was developed for the simulation of the disease epidemic and the effect of fungicide treatment. This mathematical model was used to study the response of *P. infestans* epidemics under the given geographic and climatic circumstances to different treatment strategies. Based on these theoretical studies combined with the statistical evaluation of the field data recommendations for fungicide application strategies were eventually derived.

Experimental design

For the field trials a representative plot on irrigated (khet) land was selected on the DOA Horticulture Farm in Tamaghat. Three different treatment strategies were applied, namely the "usual treatment", "reduced treatment" and "IPM". The usual treatment is an adoption of the mean treatment strategy of the local farmers, which means that the protective fungicide Mancozeb was non-discriminatory applied weekly and the systemic fungicide Metalaxyl when necessary (cf. CEAPRED 2000). In the reduced treatment the same dose as in the usual treatment was applied but at half frequency only. The IPM treatment is an Integrated Pest Management strategy, using mainly biological and cultural pest management methods and chemical pesticides just as the last resort to save the crop. The biological alternatives to Mancozeb are the parasitic fungi *Trichoderma viridae* and *Trichoderma harzianum*, which thrive on the expenses of other fungi like *P. infestans*.

The selected site was separated into 12 sub-plot of approximately equal size (45-50 m^2). The plots with the same treatment strategy were arranged in clusters, with 4 repetitions for each strategy. Figure 1 shows the layout of the experimental plots. On this plot potatoes were grown during the typical season for irrigated land, i.e. from November 1999 to February 2000. During this period a weekly pest assessment was done on 10 selected plants per plot. The disease pressure was recorded as the visibly infected foliage area per plant in steps of 10 %. Besides this the dates and concentrations of treatment measures within the three treatment strategies were also logged.

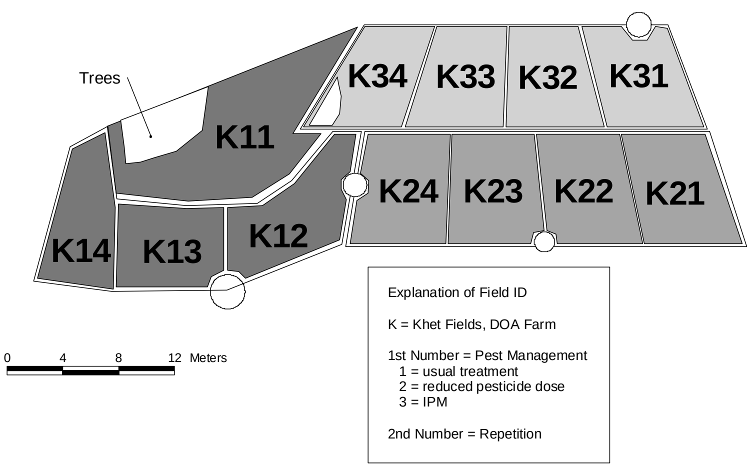

Fig. 1 Experimental fields on khet land (DOA Farm at Tamaghat)

Dynamic population model

The population dynamics model of *P. infestans* bases on the approaches of van der Plank (1963), who proposed that epidemics of plant diseases can be characterised by the three factors latent period p, infectious period i and infection rate R. The latent period is the time between the infection of plant tissue and the outbreak of lesions. The infectious period is the timespan, in which the lesion sporulate, before the plant tissue finally dies. The original model of van der Plank (1963) formulating the epidemic in terms of total infected plant tissue was extended by Hau (1988) to a model describing all relevant stages (Uninfected **U**, Latent **L**, Infected **I**, Dead **A**) as a set of Delay Differential Equations (DDEs):

$$\frac{dU}{dt} = -R \cdot U(t) \cdot I(t) \quad (1)$$

$$\frac{dL}{dt} = R \cdot U(t) \cdot I(t) - R \cdot U(t-p) \cdot I(t-p) \quad (2)$$

$$\frac{dI}{dt} = R \cdot U(t-p) \cdot I(t-p) - R \cdot U(t-p-i) \cdot I(t-p-i) \quad (3)$$

$$\frac{dA}{dt} = R \cdot U(t-p-i) \cdot I(t-p-i) \quad (4)$$

(1) – (4) are the base model used in this work, but for the description of the epidemic of *P. infestans* it has to be extended. According to Hau (1988) citing van der Plank (1963) the growth of infectious lesions is an important factor in Phytophthora epidemics. It is also known that only the newly set lesions sporulate, but with a comparatively high intensity. Hau (1988) introduced a linear lesion growth into the standard model, as well as sporulation functions in order to distinguish an age dependent sporulation of the infectious plant material, but not specifically for *P. infestans* epidemics. This has been done in this work by defining a sporulation function, which allows only newly set lesions to sporulate and with a sporulation intensity (sp_int) that is higher than the usual value of 1 used by Hau (1988). The sporulation function was formulated as g(s,t), describing the sporulation intensity of lesion set at the time s at runtime t. (5) shows the rectangular step function.

$$g(s,t)=\begin{cases} 0 & \text{if} \quad 0 \le t-s < p \\ sp\_int & \text{if} \quad p \le t-s < p+1 \\ 0 & \text{if} \quad p+1 \le t-s \end{cases} \tag{5}$$

The sporulation functions were introduced into the model by expressing the infectious part in integral form:

$$Y(t-p)-Y(t-p-i)=\int_{t-p-i}^{t-p}\frac{dY(s)}{ds}\,ds=\int_{0}^{t} g(s,t)\frac{dY(s)}{ds}\,ds \tag{6}$$

Finally the complete epidemiological model for *P. infestans* is written in a set of difference equations (7) – (11), replacing the DDEs in (1) – (4) with appropriate formulations in differences and writing the integrals in (6) as the equivalent sums (Hau 1988). This step enables an explicit straight-forward solution of the model with negligible differences to the numerical solution of the DDEs and, more important, it also enables the incorporation of fungicide effects, which causes numerical problems in the solution of the DDEs.

$$L(t+\Delta t)= L(t)+\Delta t\cdot FY(t)-\Delta t\cdot FY(t-p) \tag{7}$$

$$I(t+\Delta t)=I(t)+\Delta t\cdot FY(t-p)+\Delta t\cdot W\cdot U(t)\cdot\sum_{x=1}^{i/\Delta t-1} FY(t-x\Delta t-p)-\Delta t\cdot FY(t-i-p)\cdot\left(1+\Delta t\cdot W\cdot\sum_{x=1}^{i/\Delta t-1}U(t-x\Delta t)\right) \tag{8}$$

$$A(t+\Delta t)= A(t)+\Delta t\cdot FY(t-i-p)\cdot\left(1+\Delta t\cdot W\cdot\sum_{x=1}^{i/\Delta t-1}U(t-x\Delta t)\right) \tag{9}$$

$$U(t+\Delta t)= 1-L(t+\Delta t)-I(t+\Delta t)-A(t+\Delta t) \tag{10}$$

with

$$FY(t)=R\cdot U(t)\cdot\left(\sum_{x=1}^{i/\Delta t-1}\left(R\cdot U(t-x\Delta t-p)\cdot I(t-x\Delta t-p)\cdot\left(1+\Delta t\cdot W\cdot\sum_{u=1}^{x}U(t-u\Delta t)\right)\cdot g(t-x\Delta t-p,t)\right)\right) \tag{11}$$

Fungicide effects

Prior to a mathematical formulation of fungicide effects, the different modes of action have to be described and categorised. The different fungicide effects can be divided into three main classes (Gutsche 1988, Schepers and Bouma 1999):

- **protective action:** The spores are killed before germination/penetration.
- **curative action:** The fungicide is active during the post infection period (latent period), but before lesions become visible.
- **eradicant action:** *P. infestans* is killed within sporulating lesions and thus preventing further sporulation and lesion growth.

Figure 2 depicts these modes of action and their influence on the different stages of a late blight epidemic. While the protective and curative action are quantitatively studied for Mancozeb and Metalaxyl, the most prominent for this classes on the market (Gutsche, Burth et al. 1994), the eradicant action is only qualitatively stated for Metalaxyl.

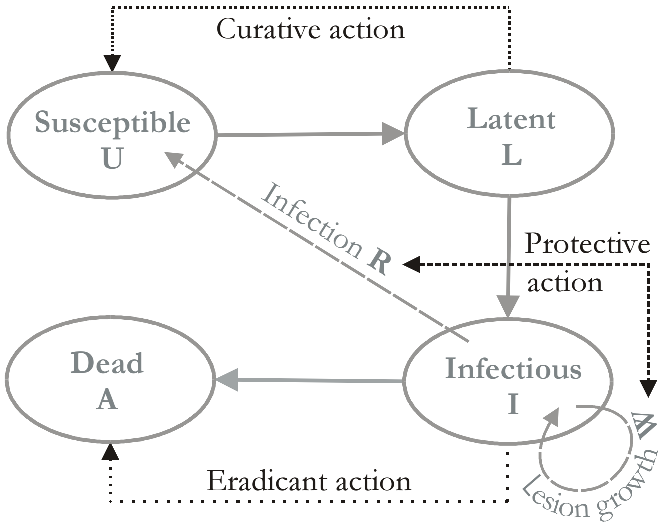

Fig. 2 Different modes of fungicide action

The protective action is defined as a reduction of the infection rate R and the lesion growth rate W. The curative action is considered as a reduction of latently infected to susceptible, uninfected plant tissue. Finally the eradicant action is expressed as an immediate transition of infectious lesions to dead plant material.

The time dependent fungicide effects are formulated according to Gutsche, Burth, et al. (1994) with a maximum efficacy of 1, i.e. 100 %. The incorporation of the fungicide effects into (7)–(11) was done according to the definitions above and are described in detail in Apel (2002).

Results

Field experiments

The results of the field experiments are illustrated by Figure 3 in terms of mean relative infection levels, whereas an infection level of 1 is equivalent to a real infestation of > 50 % infected leaf area. It can be seen that the usual and reduced approach are equally effective in controlling the disease. However, the IPM approach apparently failed. But this was caused by the non-availability of the required biological agents and not by the efficacy of *Trichoderma*. The agents were only available after the infestation reached a level at which a control, even with chemicals was no longer possible. In consequence this means that the IPM data can be regarded as a untreated control series, which was further used for the parameter estimation of the population dynamics models (4.2).

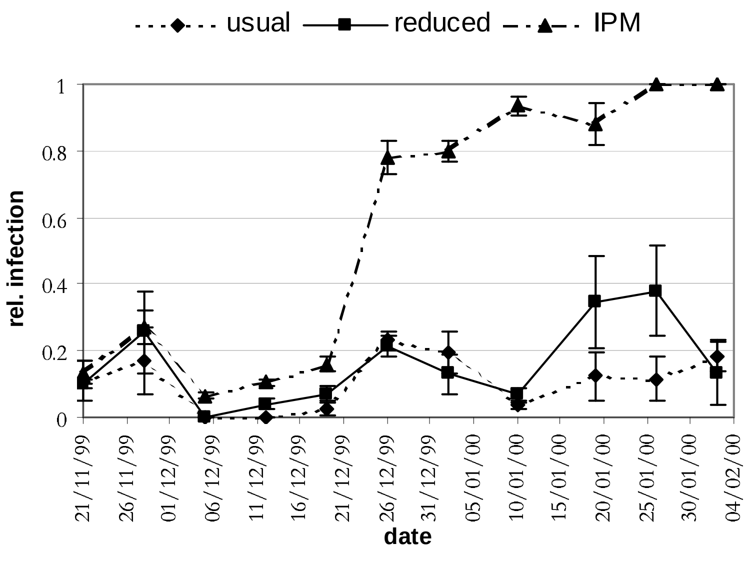

Fig. 3 Normalised mean infection of *P. infestans* on potato at the different treatment strategies, Nov. 1999 – Feb. 2000; error bars indicate one standard deviation

The statistical significance of the influence of the treatments on the disease development were tested with a Repeated Measures Analysis (Winer 1971). This showed that the treatments have a highly significant influence on both the trend and level of the disease development and hence corroborated the visual interpretation of the field results.

Population Dynamics

For the parameter estimation of the population dynamics model the "uncontrolled" IPM data were used. In a first step the basic parameters p, i, and R were estimated with (1) – (4) on the basis of the Least Squares criterion. In a second step the *P. infestans* specific parameters sporulation intensity sp_int and lesion growth rate W were additionally estimated using the same technique using equations (7) – (11) with a stepsize of $\Delta t = 1$. This procedure resulted in the parameter set listed in Table 1 with a good fit to the experimental data ($R^2 = 0.908744$). Figure 4 shows the model fit and the trajectories of all stages.

Table 1 Optimised parameter set for (7) – (11); initial infection y0 distributed equally to L and I

p	3	W	0.326488
i	11	sp_int	3
R	0.333	y0	0.0073

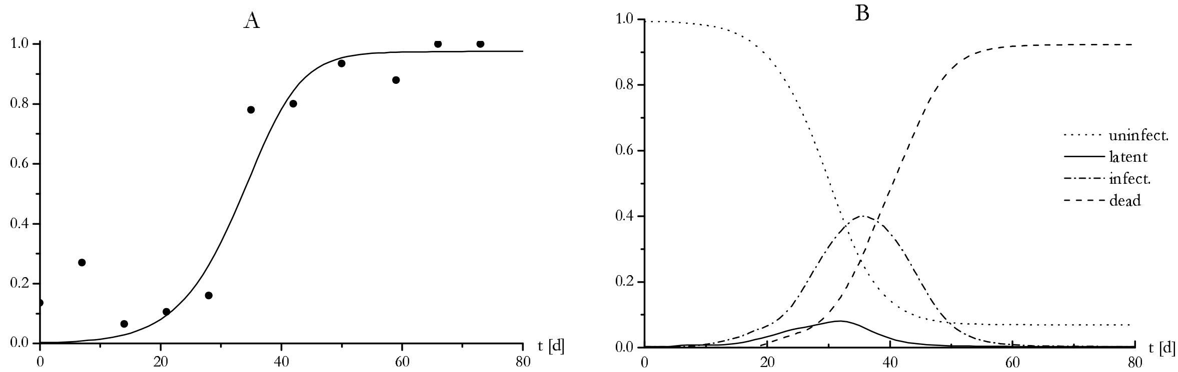

Fig. 4 Phytophthora model (7) -(11) with optimised parameters: A: visible infection (L + I) and data, B: all stages

Fungicide application scenarios

According to the experimental design and the different modes of fungicide action different treatment scenarios were calculated with the Phytophthora model (7) – (11) and the optimised parameter set. For all the three modes of fungicide action associated to frequently used fungicides on the market, scenarios were defined with two different application intervals, 7 and 14 days, and different application thresholds, depending on the infestation level. Figures 5 – 7 show the resulting calculated disease developments. t_a in the legend gives the application start in days equivalent to the defined thresholds of infestation levels of 0, 0.05, 0.1, 0.15 and 0.2 respectively.

Discussion and recommendation

The experimental comparison of different treatment strategies of *P. infestans* showed that a reduced approach applying fungicides only half as often as it is usually practised in the Jhikhu-Khola watershed is sufficient for the control of the disease. An assessment of the efficacy of the IPM approach cannot be given with the present data, because the biological control agents were not available on the Nepali market in time.

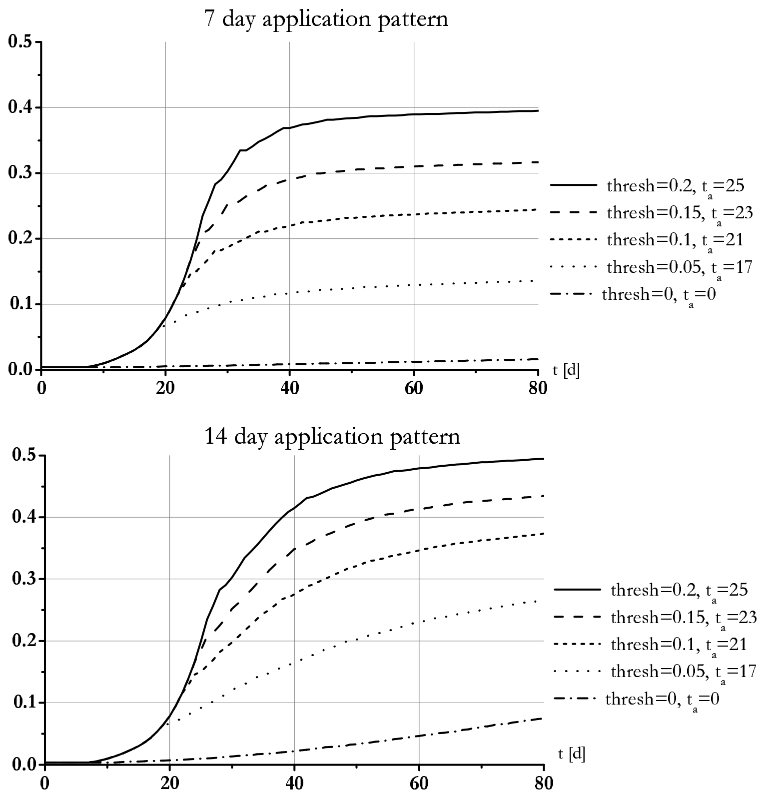

Fig. 5 Model response (visible infection) to the control of *P. infestans* with a protective fungicide (Mancozeb)

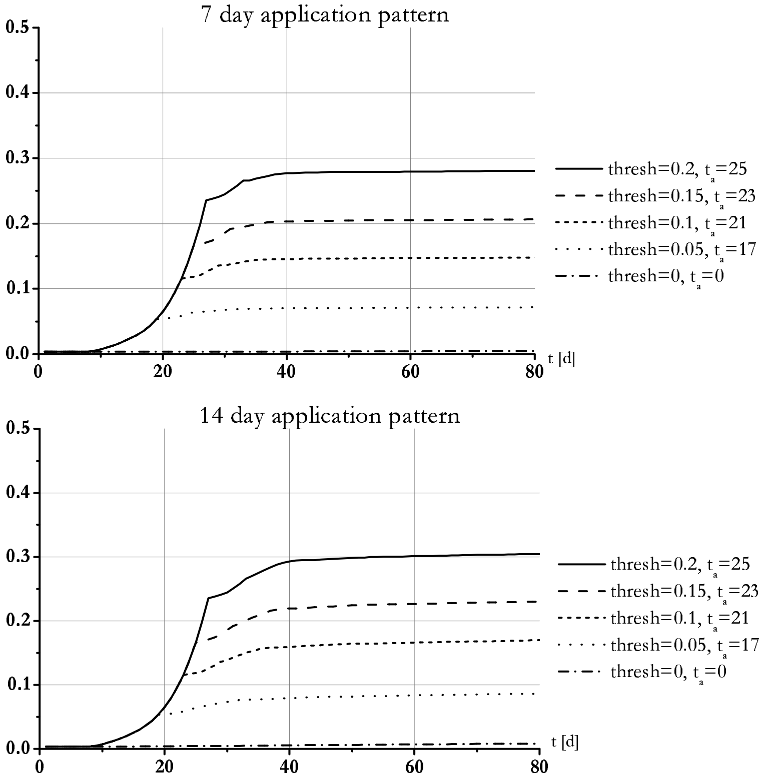

Fig. 6 Model response (visible infection) to the control of *P. infestans* with a fungicide with curative and protective action (Metalaxyl + Mancozeb)

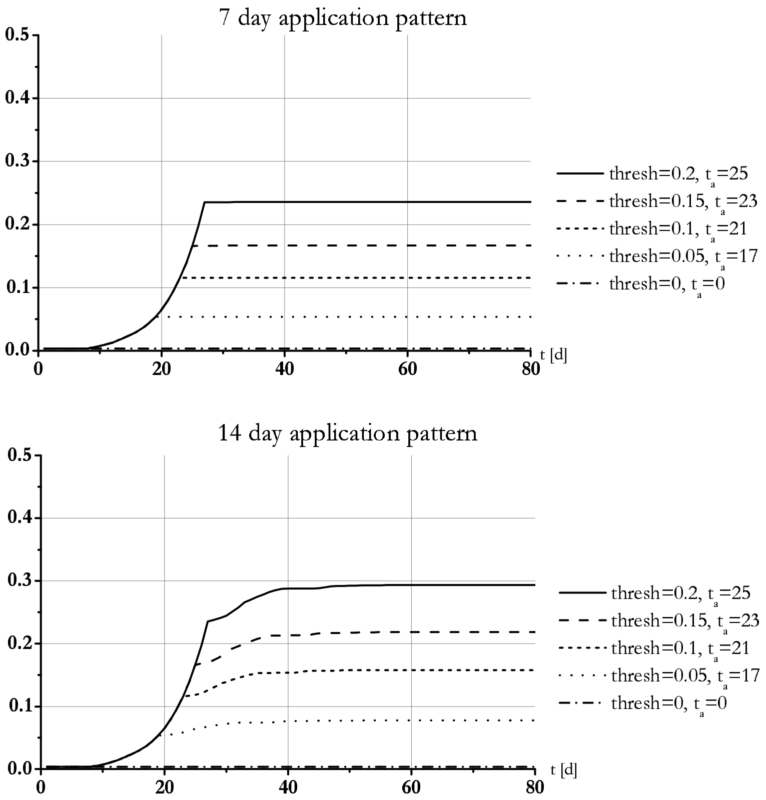

Fig. 7 Model response (visible infection) to the control of *P. infestans* with a fungicide with eradicant, curative and protective action (Metalaxyl + Mancozeb)

However, the consequently uncontrolled disease development served as a valuable data source for the parameter estimation of a population dynamics model for *P. infestans*. With these data site specific epidemiological parameters could be identified. The values stated in Table 1 indicate that the latent and infectious period of Nepali tribes of *P. infestans* are of comparable length to European tribes (Gutsche 1999).

The infection rate R however is almost three times higher under Nepali conditions indicating either a higher aggressiveness of the local tribes or favourable climatic conditions or both. However, while interpreting the parameter values it has to be kept in mind that these are effective parameters, summarising not only disease specific effects, but also external influences like climatic conditions and growth of the host plant. This has a significant consequence on the validity of the model, viz. the estimated parameters: It is only valid for *P. infestans* epidemics on potato under post-monsoon climate in the mid hills of Nepal. This is also the reason why a reduction of the disease level cannot be simulated with this model. In order to achieve this, the growth of the host plant, the recovery potential of the host plant in the different phenological stage and the climatic influence have to be modelled explicitly.

However, the model can of course be used for the assessment of fungicide treatment strategies under site specific conditions. The fungicide application scenarios corroborated the findings of the field trials: A 14-day application interval of a protective fungicide (Mancozeb) can be sufficient for the control of the late blight (cf. Figure 5).

But the model calculations revealed another important fact: the start of the applications. As shown in Figures 5 – 7, an early application start is necessary to control the disease effectively, even with a combined protective, curative and eradicant effect. Due to the aggressiveness of the disease an effective control is hardly possible if the disease exceeds an infestation levels above 0.2, equivalent to 10 % real infected leaf area, especially in the reproductive stage of the host plant. In other words this means that the economic threshold level for *P. infestans* treatments would be close to zero, especially under the low cost conditions of pesticides in Nepal in comparison to the high market value of the crops.

From these findings two basic recommendations for the conventional treatment of *P. infestans* in the Mid-Hills of Nepal can be derived:

1. For the control of *P. infestans* on potato in the winter season in the Mid-Hills of Nepal a regularly application of Mancozeb at the recommended dose in 14 days intervals is sufficient. The application should start within the first week after crop establishment.

2. In severe cases a Metalaxyl+Mancozeb fungicide formulation may be used to stop the epidemic. In this case a weekly application frequency is recommended.

With this recommendation it is most likely that *P. infestans* is controlled sufficiently (i.e. not completely eradicated) while keeping investments in chemical control low, improving the economic benefit and reducing the environmental contamination risk.

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Environmental risk assessment of pesticide use based on the modelling of the environmental fate of pesticides in soil

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Abstract

Based on laboratory and field experiments the environmental fate of four selected pesticides (Dimethoate, Fenvalerate, Malathion, and Metalaxyl) in the Jhikhu-Khola watershed, Nepal was investigated, both on soils representative for irrigated (khet) and rainfed (bari) conditions. The degradation, sorption, and transport behaviour were described with deterministic mathematical models. Based on these models a risk assessment of the accumulation of the pesticides in soil and groundwater was conducted. In order to achieve this standard, worst and best case scenarios were developed. The framework and conditions for the scenarios were set by the physical and socio-economic environment in the watershed, which was investigated by a socio-economic survey. With this method it was possible to assess the risk of groundwater contamination and residue formation in soil on a quantitative basis for parts of the watershed. According to this the risks of severe, actual residue formation are very low, but chances for long term residue accumulation are present. The likelihood of groundwater contamination is also low, but more uncertainties remain as compared to residue formation, because the transport mechanisms are not completely understood and because of insufficient data.

Introduction

The fate of pesticides in the environment knows many possible ways of degradation, transport and accumulation, as shown in Figure 1.

These numerous possibilities challenge every attempt of an environmental risk assessment of pesticide use in general, because it is virtually impossible to describe or even quantify every single dissemination pathway shown in Figure 1, even for a single pesticide. Nonetheless this is exactly the aim of this paper. Taking an agriculturally intensively used watershed in the Mid-Hills of Nepal, the Jhikhu-Khola watershed, as an example, a viable approach using deterministic mathematical models and statistics is presented in the following chapters.

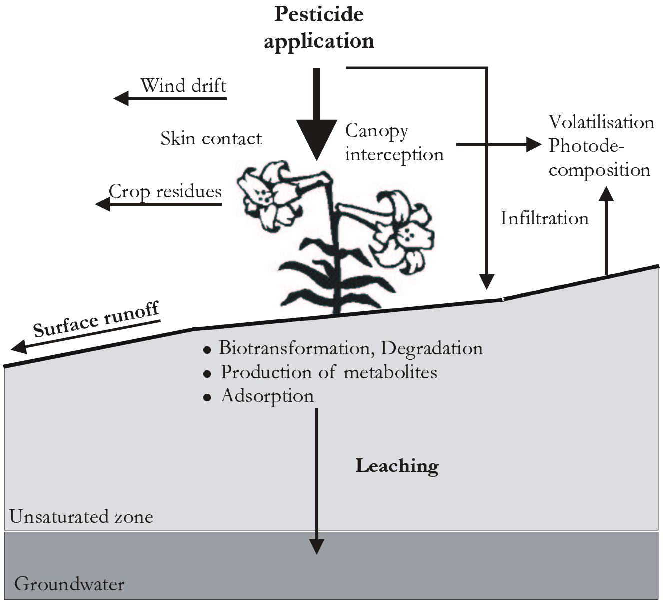

Fig. 1 Dissemination pathways of pesticides in the environment

Methodology

Step 1: Selection of target compounds

If pesticide use in general has to be assessed, a selection of the pesticides used in the investigation area has to be taken, which is representative for the whole range in use. The criteria for the representativeness are:

- frequency and amount used
- pesticide classes
- physicochemical properties

In our case four pesticides were selected according to this criteria:

- Dimethoate organo-phosphorous insecticide, systemic action
- Fenvalerate insecticide, synthetic pyrethroid, contact action
- Malathion organo-phosphorous insecticide, contact action
- Metalaxyl fungicide, systemic action

These four compounds cover the range of pesticide classes used in the watershed, as well as a wide range of physicochemical properties and consequently different assumed environmental fates (cf. Table 1). Only the vapour pressures are in a comparable low range indicating a very low tendency for volatilisation.

Table 1 Basic physicochemical properties and DT_{50}-values of the selected pesticides. source (Tomlin 1994), ‡ different sources: a) (Di & Aylmore 1997), b) (Tomlin 1994), c) (EXTOXNET 1999), d) (ARS-USDA 1999), e) (Hornsby et al. 1996)

	Dimethoate	**Fenvalerate**	**Malathion**	**Metalalxyl**
solubility [mg/l] †	238000	0.002 - 1	145	8400
vapour pressure [mPa] †	1.1	0.0192	5.3	0.75
$\mathbf{K_{ow}}$ [ ] †	506	$2.6*10^6$	560	56.2
$\mathbf{DT_{50}}$ [d] ‡	7[a,e], 4-20[c]	35[a], 75-80[b], 88-287[d]	1[a], 9 [d], 1-25[c]	70[a], 7-170[c]

Step 2: Problem definition

After the compound selection the actual environmental problem caused by the pesticides has to be defined in order to design the appropriate experimental setup. The problem definition is ruled by the environmental and agronomic setting. In our case the dominant land use types are small scale terraces with and without irrigation. The irrigated terraces termed “khet land” are level, bounded by earthen walls and irrigated by ponding water in the field with usually three crops per year. On the contrary the rainfed terraces (“bari land”) are sloping without any bounds with only two crops per year due to water shortage in the pre-monsoon season.

The climate is of monsoon type with rainfall concentrated on the months June – September, limiting the number of crops grown on bari land. On both khet and bari land the seasons of high pesticide input are before and after the monsoon, when vegetables are grown as cash crops. Taking these facts into consideration, the most probable dissemination pathways were identified leading to the following problem definition:

1. Probability of residue formation in soil on both khet and bari land.
2. Leaching to groundwater on khet land

Step 3: Laboratory experiments

The next step in the risk assessment comprises laboratory batch experiments for the detection of the degradation and sorption behaviour of the selected compounds in soil taken from the investigation area. In our case the experiments were conducted under varying temperatures during and at three different soil humidity levels ranging from almost dry soil to saturation. This experimental setup produced sufficient data for the detection of not only the degradation and sorption process and parameters, but also for a temperature and humidity dependent formulation of the degradation.

The mathematical model used for the description of the degradation and sorption was the one-site kinetic sorption model (Richter 1996) as shown in equ. (1) – (2)

$$\frac{d}{dt}(\theta c) = -\alpha\rho(K_D c - S) - \theta k(T,\theta)c \tag{1}$$

$$\frac{d}{dt}(\rho S) = \alpha\rho(K_D c - S) \tag{2}$$

with c = solute concentration, S = sorbed conc., α = sorption rate constant, ρ = soil bulk density, θ = volumetric soil water content, K_D = sorption equilibrium constant and $k(T, \theta)$ = temperature and water content dependent degradation rate. For the description of the temperature and humidity response of the degradation different functions were used depending on the data. The response functions are compiled in Richter (1996).

Step 4: Field experiments

Field experiments are necessary to verify the degradation and sorption rates identified in the laboratory experiments and to investigate the transport mechanism in soil. For this purpose Potassium Bromide KBr was used as a conservative tracer for the estimation of the transport parameters additionally to the selected pesticides.

The mathematical model for our problem with ponding irrigation on khet land are stationary convection-dispersion equations (CDEs) coupled with the degradation and sorption terms in two domains (fast and slow), i.e. a preferential flow system was identified. The exchange between the domains are formulated as 1^{st} order processes, analogously to the sorption. Detailed descriptions of the model can be found in van Genuchten & Wagenet (1989), Gerke and van Genuchten (1993) and Apel (2002).

Step 5: Scenario definition

The overall aim of the scenario calculation is the quantification of uncertainty associated with the transfer of the laboratory and local field experiments to a complete watershed. The quantification of the variance of the parameters involved is prerequisite for a realistic and comprehensible risk assessment. The number of parameters involved depends on the problem definition. In our case the risk of residue formation was assessed by the variation of application doses. The basis for the application variance was a representative survey of 200 households in the watershed (CEAPRED 2000). Additionally the annual variance of soil temperatures was considered by using temperature dependent degradation rates and a representative soil temperature variation for a complete year.

However, for the variance of the transport velocities necessary for the groundwater contamination assessment no qualified data source was available. This was mainly caused by the preferential flow regime identified in the field experiments, which cannot be estimated by available data like soil type or grain size distribution. This means in consequence that all the following scenarios and risk assessments apply for soils similar to the soils in the field trials only.

The scenarios for the residue formation are defined as mean, worst and best case scenarios under the following conditions and variations:

<u>conditions</u>:

- identified transport mechanism
- saturated water content, stationary flow
- representative soil temperature variation
- temperature/humidity response from batch experiments

<u>variation</u>:

- source: field survey (CEAPRED 2000)
- ***mean scenario***: mean of all recorded doses & frequency, 25% applied to soil surface
- ***worst case***: highest mean dose + 1.96 standard deviations, highest frequency, all to soil surface
- ***best case***: lowest mean dose - 1.96 standard deviations, lowest frequency, 10% to soil surface

The application statistics are taken from the survey, whereas the part applied directly to the soil surface are empirically assumed. The final risk assessment is consequently based on the results of the scenario calculations and the underlying statistics.

Results

In this chapter the results for only one selected pesticide, Dimethoate, are presented exemplarily for the complete assessment.

Laboratory batch experiments

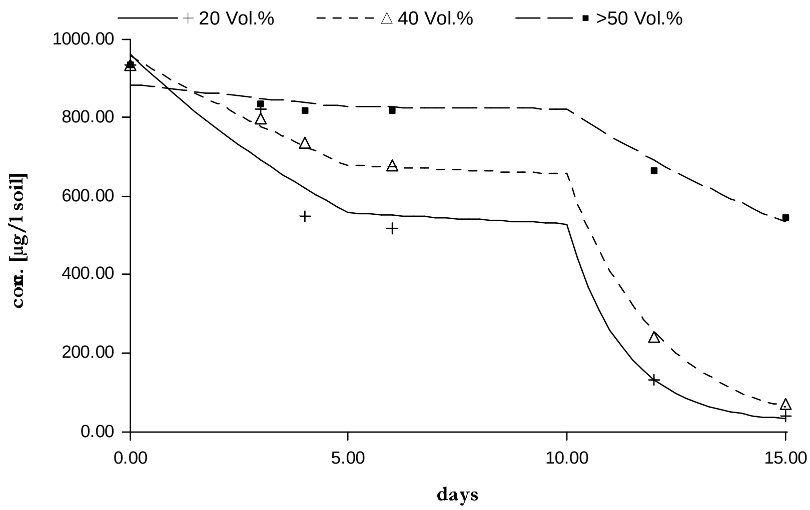

Fig. 2 Laboratory data and model fit of Dimethoate with varying temperatures and different soil water contents; temperature change: 20°C/10°C/30°C; total $R^2 = 0.97812$

Figure 2 shows the experimental laboratory data set and the model fit. The temperature as well as the humidity response are clearly visible and could be well explained by optimum functions (Apel 2002).

Field experiments

In a first step the parameters for the water transport model were estimated with two Bromide profiles five and seven days after application of the substance. Figure 3 shows the resulting fit. The preferential flow regime is clearly visible in the two peaks, one remaining close to the soil surface and the second, faster moving deeper in the profile.

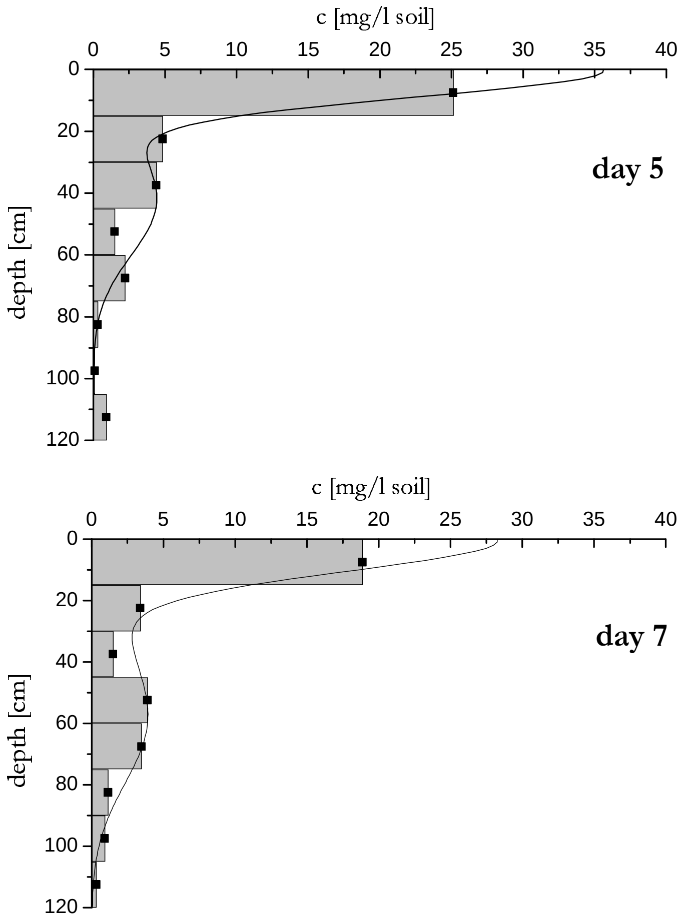

Fig. 3 Model fit to Bromide profiles of field trial, overall $R^2 = 0.9671$

The identified parameter values for the water transport were consequently used for the transport model of the pesticides along with the degradation and sorption parameters estimated in the laboratory experiments. In all cases this resulted in poor fits to the field profiles. Hence further estimations of field degradation rates were necessary, which were typically faster than the laboratory rates. Figure 4 shows the resulting model fit of this procedure to the Dimethoate profiles. This fit shows that the assumed models for the transport, degradation and sorption are able to sufficiently explain the fate of the substances in soil. This is the prerequisite for the next step, the scenario calculation and the following interpretation, the risk assessment.

Scenario calculations

The conditions and case variations for the scenarios are listed under Step 3 in chapter 2. The use of the slower laboratory degradation rates are justified by the consideration of the annual soil temperature variation and the conservative approach underlying the scenarios. The results of the mean and worst case scenarios for Dimethoate are shown in Figure 5 and 6 respectively.

The results of the standard scenario show several remarkable facts. The seasonal temperature variation is clearly visible in the degradation, respectively the residue formation within the different cropping periods. The graph in Figure 5 containing the total substance in the calculated profile of 1.2 m depth under 1 m^2 shows a slow degradation of Dimethoate during the winter (potato) season and consequently a comparatively large residue formation, while the degradation during the summer and monsoon season increases to such an extent that residues are reduced. Although there is a residue reduction during summer and monsoon, an apparently substantial amount of substance is left in the soil column after one year.

At a first glance this appears to be alarming, but a look at the concentration profile of the last day mitigates this impression. The concentration are comparatively low throughout the profile and hardly analytically quantifiable, depending on the quantification limit established. The dotted lines in the graphic indicate two different quantification limits. The higher limit is obtained by recovery experiments through the complete analytical process with all partners involved, the lower one taken from literature is derived by peak heights in the chromatograms. This means that with the experimental quantification limit it would be hard to detect the substance in quantifiable amounts after the three seasons and even with the lower limit the concentration in the deeper profile are unlikely to detect. The consequence is that the residue formation is probable, but in hardly detectable quantities.

There is also an amount of the substance leaving the profile, i.e. leaching to lower depths, as the lower boundary graph shows. But again, the concentrations there are in a range difficult to detect. An approximation of the substance outflow yields that about 5% of a single application assumed in the scenario leave the soil column, posing no risk to groundwater contamination due to dilution.

This situation is quite different in the worst case scenario. Here of course the residue formation reaches a worrying quantity as well as the substance leaving the profile (cf. Figure 6). The last day profile shows clearly detectable and quantifiable concentration up to the bottom of the profile and the amount leaving the profile is in the order of one standard application. This case would pose a serious threat to the environment, especially the residue formation. Fortunately this scenario is very unlikely as shown in the following chapter.

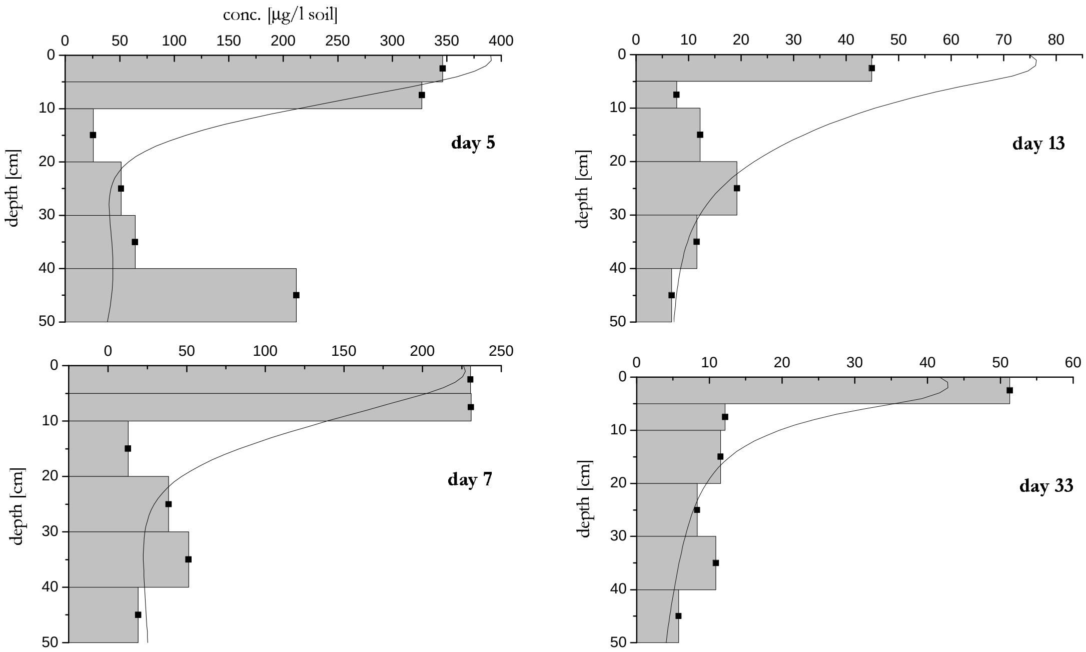

Fig. 4 Dimethoate profiles and model fit in field trial, total R^2 = 0.793

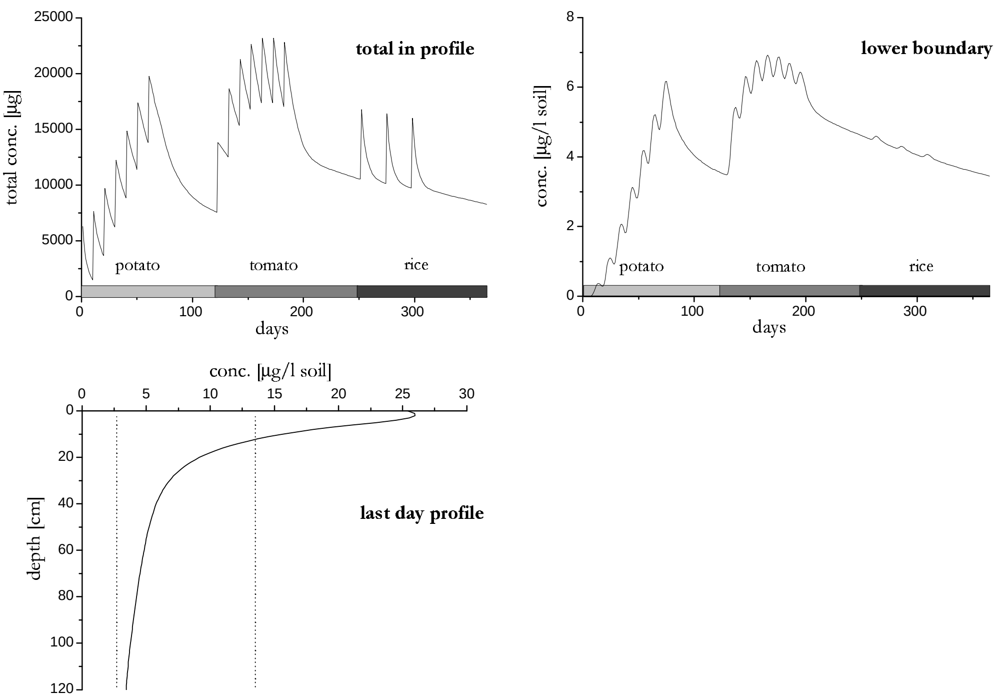

Fig. 5 Results of the mean scenario calculation for Dimethoate; reference area: 1 m^2, dotted lines in last day profile indicate quantification limits

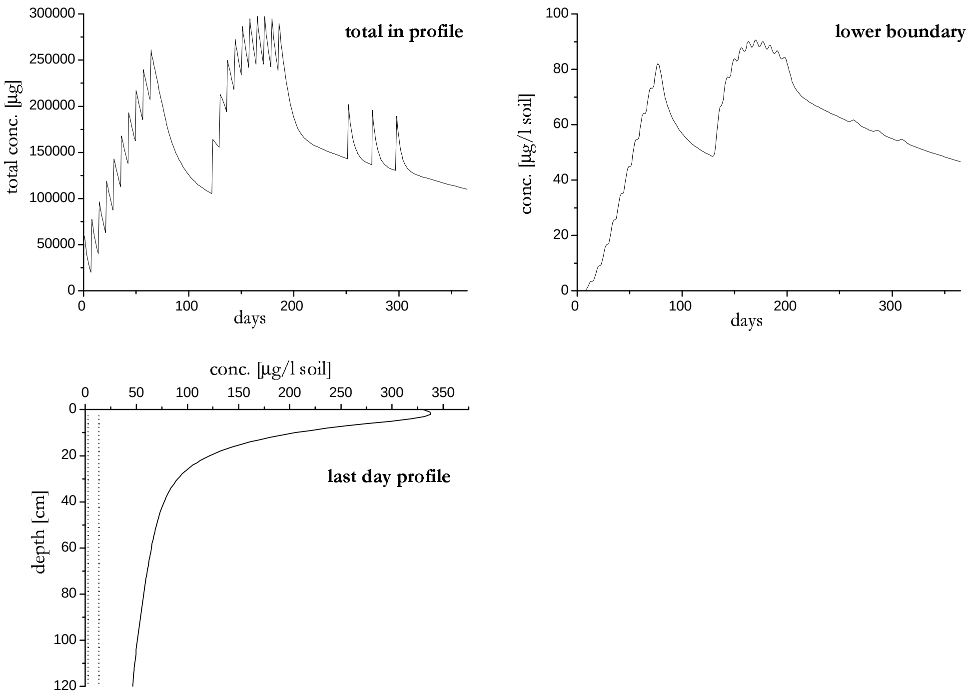

Fig. 6 Results of the worst case scenario calculation for Dimethoate; reference area: 1 m^2, dotted lines in last day profile indicate quantification limits

In contrast to this the best case scenario yields a non quantifiable residue situation, even with the low quantification limit. Also the leached amount is of such a low quantity that it can be neglected. However, the probability of this scenario is as low as the best case, since equivalent assumptions were made.

Risk assessment and discussion

Prior to the evaluation of the risks associated with the single pesticides the probabilities of the worst and best case scenarios have to be calculated. As mentioned before the definition of the application doses is based on statistics derived from a representative survey in the investigation area. For the worst case scenarios the highest mean application dose found on the selected crops plus 1.96 standard deviations are taken. Under the normal distribution assumption this means that the probability of a single application of a dose equal or higher as a worst case dose is 2.5 %. This has to be corrected by the probability of the highest mean dose used in the scenario. Under the assumption that all of the six recorded mean doses are equally likely, this evaluates to 1/6, i.e. 16.6 %, because in the survey report (CEAPRED 2000) six mean doses are given for the three crops in the scenarios in two different areas of the watershed. Consequently the final quantifiable probabilities of the worst and best cases are

0.416 % (Apel 2002).

The only unquantifiable factor remaining is the portion reaching the ground. For this only qualitative statements can be given. While the assumption for the mean and best case may be realistic for the mean and the cautious farmer, the “all to ground” assumption of the worst case is quite unlikely to be found at every application date. This means that the probability of the worst case is surely lower than the calculated 0.416 %, but to what extent cannot be quantified with the information present. Taking these probabilities into account the interpretation of all the scenarios for all four substances leads to the final risk assessment for the watershed, which can be summarised with the following two points:

1. There is no acute risk of residue formation or groundwater or open water contamination under the present situation.
2. There are chances of long term residue formation, especially with synthetic pyrethroids, albeit of low probability (< 1%).

But again it has to be kept in mind this assessment refers to soils similar to the soil in the field experiments only. This means that although this soil type is the most common, a complete risk assessment for the whole watershed was not possible.

Based on this risk assessment and the underlying assumption four general recommendations can be formulated in order to reduce the already low risks or to minimise the uncertainties still present:

1. Improvement of the application techniques.
2. Increased control of the application doses.
3. Cautious use of synthetic pyrethroids.
4. Further research on different soils.66

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Financing the disposal of unwanted pesticides

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Abstract

Significant quantities of unwanted pesticides are being retained by agricultural producers in barns and other out buildings throughout the United States. USA state governments have responded to the hazards posed by these pesticides by implementing programs to collect and dispose of them. This paper discusses state's experiences with different approaches to pesticide collection and disposal. Alternative methods of funding pesticide collection and disposal programs are presented, and efficiency and equity aspects of different funding methods are discussed. Suggested characteristics of an effective response to the unwanted pesticide problem include a permanent funding source, acceptance of pesticides from all small businesses, and coordination of pesticide collections with household hazardous waste programs.

Introduction

The problem of unwanted pesticides

Significant quantities of unwanted pesticides are being retained by agricultural producers in barns and other out buildings throughout the United States. Some of these unwanted pesticides are pesticides whose registrations were canceled or suspended by the Environmental Protection Agency (EPA). Other unwanted pesticides were not used because superior products replaced them. In some instances, producers changed crops or employed a pesticide contractor and did not consume existing stocks. The Great Lakes regional EPA office estimated that more than 13 million pounds of pesticides were stored in the six states of that region (Jones 1993).

Governments at all levels have expressed an interest in dealing with the potential problem posed by stocks of unused pesticides. The EPA enacted a Universal Waste Rule to ease the requirements for the safe disposal of unwanted pesticides and other common hazardous wastes (*Code of Federal Regulations*, title 40, part 273, 1996). Many states have developed a framework regulating the disposal of hazardous wastes through household and permanent hazardous waste programs at local and county levels. An additional development at the state level has been the creation of agricultural pesticide collection programs to provide a viable disposal option for unwanted pesticides. Nearly every state has initiated a special agricultural pesticide collection program to provide for the safe disposal of accumulated pesticides, and nearly 10 million pounds of unwanted pesticides have been collected.

One impediment to the disposal of pesticides is cost. The lawful disposal of unwanted pesticides pursuant to the Resource Conversation and Recovery Act (RCRA) is expensive (*U.S. Code* 1994). Many persons have stored unwanted pesticides due to their unwillingness to pay for their disposal. For governments, the funding of pesticide collection programs is a limiting factor for the efforts provided by many states. Reported costs show that significant amounts of money are needed to dispose of unwanted pesticides.

The high cost of unwanted pesticide disposal suggests that the availability of funding may be critical to the removal of this environmental hazard. This paper focuses on costs of pesticide collection and methods of funding collection programs. We begin by briefly discussing federal provisions for the disposal of hazardous waste, since any collection efforts must comply with these provisions. This is followed by a discussion of factors that affect the costs of disposal. The third section uses results from a survey we conducted as the basis of a discussion of state regulatory initiatives for pesticide disposal and approaches states have taken to funding collection programs. The funding methods used by the states are then compared and contrasted with respect to equity and efficiency considerations.

Federal provisions for the disposal of hazardous waste

The EPA delineates regulations that identify hazardous wastes and prescribes regulations that espouse human and environmental safety under Subtitle C of the Resource Conservation and Recovery Act (*U.S. Code* 1994). Detailed regulations for the disposal of hazardous wastes, including pesticides to be disposed of or abandoned, have been set forth in Parts 260 through

272 of the *Code of Federal Regulations* (1996). Persons collecting wastes need an EPA generator identification number. As hazardous waste generators, persons collecting wastes must maintain a contingency plan, conduct employee training, prepare a manifest for each shipment of collected materials, and use approved hazardous waste transporters to take the materials to a designated hazardous waste treatment, storage, and disposal facility. These provisions show a required infrastructure involving significant expenditures to deal with the disposal of pesticides.

Relaxed regulations for universal hazardous wastes were prescribed in Part 273 of the *Code of Federal Regulations* (1996) and the provisions are known as the Universal Waste Rule. Universal hazardous wastes including pesticides, batteries, and thermostats are small qualities of wastes held by many persons. Stocks of banned and unused pesticide products collected and managed as part of a waste pesticide collection program qualify to be treated as universal wastes. Under the relaxed rules of Part 273, persons managing agricultural pesticides with a collection program qualify as handlers of universal wastes and have fewer burdensome requirements than apply to generators under the Subtitle C requirements.

Costs of disposing of pesticides

When pesticides are abandoned or disposed of, rather than used for their intended purposes, they are hazardous wastes, and they must be handled under federal hazardous waste provisions. Besides costs of disposal, pesticide collection programs may incur special expenses due to the type or condition of material or container. Aggregate disposal costs raise questions concerning who should pay for the disposal of unwanted pesticides. Should owners of particularly dangerous pesticides such as dioxins pay more due to higher disposal costs? Who should pay the testing costs for an unknown pesticide? Should there be a fee for on-site pickups or pesticides in deteriorated containers?

Not all pesticides cost the same to dispose of safely, and the disposal of some banned pesticides has involved significant costs. Overall, states have not attempted to recapture these expenses through participant charges. Indeed, some states have targeted banned pesticides due to the greater threat they pose to the environment, though such pesticides often have greater disposal costs. Given the age and storage conditions of unwanted pesticides, some pesticide containers have lost their labels and their contents are unknown. A similar situation exists for the on-site pickup of deteriorated containers. While a fee could be assigned to safety inspections and on-site collections, states have absorbed the expenses of these measures as part of the cost of removing stored pesticides.

Regulatory initiatives and funding options

Our examination of state pesticide collection efforts is based primarily on data collected in 1996 by the Michigan Department of Agriculture (Cubbage 1996) and a survey we sent to the state lead agencies for pesticide regulation. The data compiled by the Michigan Department of Agriculture summarizes several aspects of state pesticide collection efforts. For our survey, each state was contacted and asked to supply additional information on their state pesticide collection efforts. Follow-up phone calls were employed for over one-half of the states to augment the reported information concerning safety features and the permanency of the state collection efforts.

Our survey revealed that nearly one-half of the states have passed special legislation or a designated state agency has enacted administrative regulations governing unwanted pesticides. Survey responses about funding indicated that several states had instituted programs to generate funds specifically for pesticide collection programs. Five different methods have been used to raise such funds: (1) grants, (2) user fees, (3) state pesticide registration fees, (4) taxing the sale of pesticides, and (5) surcharges or site taxes. Some states employ more than one of these methods, as the use of one of these funding sources does not preclude the use of another.

Grants

Some states have not assessed any charges against participants, relying on federal and state monies to cover program costs. Grants for pesticide collection programs have come from the EPA pursuant to programs under the Clean Water Act, the Federal Insecticide, Fungicide and Rodenticide Act, and the Resource Conservation and Recovery Act (Beaver 1996, Jones 1993, Karnatz 1991,l Panter 1996, Tolar 1996, Vogel 1994). The U.S. Department of Agriculture also has made monies available, and private companies have contributed funds in some states (Karnatz 1991). Private contributions have also been made by pesticide retail outlets through the provision of sites for the collections (Spitzmueller 1995). In other cases, states have made special appropriations from general funds for collection programs.

The funding of many initial pesticide collection programs through federal grants has enabled states to remove thousands of pounds of unwanted pesticides and dispose of them safely. However, these efforts do not provide a basis for a pragmatic long-term response to the issue of the safe disposal of unwanted pesticides due to the continued generation of such materials. Moreover, applying for funding is time consuming and the management of short-term individualized efforts may involve extra costs. Collection efforts dependent on largesse may cause a state to forego the development of a more meaningful long-term collection program. Therefore, while grants have been significant in addressing the environmental program of accumulated pesticides, many states have arranged for additional funding.

User fees

An objective of some states is to have persons who own unwanted pesticides help pay disposal costs through user fees. By adopting user fees, the pesticide disposal program does not foster dependence on governmental benevolence for an expense connected with private business activities. Conflicting concerns confront a user fee requirement. While user fees make participants assume some responsibility for their unwanted pesticides, persons owning unwanted pesticides may be less likely to participate when there is a fee. States intent on requiring persons to help pay for the disposal of unwanted pesticides may discourage participation so that significant quantities of unwanted pesticides remain in storage.

From an economic perspective, user fees may involve an inordinate amount of effort to raise insignificant sums. Since user fees often do not cover the costs of disposal, provisions for other sources of funds will be required. States organizing collection programs will need to decide from their own experiences, needs and funding sources whether a user fee would be appropriate.

State pesticide registration fees

A prevalent financing provision for states with established agricultural pesticide programs is to use pesticide registration monies for collection programs. Separate from federal pesticide registration fees under the Federal Insecticide, Fungicide, and Rodenticide Act, states are able to charge an annual fee for the registration of each pesticide used in the state. Some states specifically allocate part of the registration fee to cleanup and collection programs.

Regulatory provisions for minimum or maximum amounts that may be collected or used for collection programs may also be important. The Michigan law provides for the suspension of groundwater protection fees if the money in the fund exceeds $3,500,000 (*Michigan Compiled Laws Annotated* 1996). In this manner, fees are discontinued if monies are not needed for disposing of unwanted pesticides or funding environmental remedial projects. The Michigan groundwater protection fee would be reinstated when the fund contained less than $1,000,000 at the close of a succeeding fiscal year.

Pesticide and site taxes

Another funding possibility is a tax on pesticide products. Michigan has adopted a detailed funding program that involves both registration monies and a tax on pesticides sold (*Michigan Compiled Laws Annotated* 1996). There is a specialty pesticide groundwater protection fee of $100 per product, with products excluding agricultural pesticides. Groundwater protection fees for agricultural pesticides are 0.75% of wholesale value of the previous registration year's product sales or a minimum of $150. Monies are deposited into the freshwater protection fund to be used for numerous purposes, including "pesticide pickup programs for pesticides not currently registered for use".

Some household hazardous waste programs use alternative surcharges and site taxes as a means to help fund the collection of pesticides. Michigan has enacted provisions to allow qualifying counties to impose a surcharge on households for waste disposal including hazardous (*Michigan Compiled Laws Annotated* 1996). Households may be taxed $25 per year for this service. Colorado enacted legislation for a site tax under which property owners within the jurisdiction of the waste facility would be assessed a hazardous waste site tax (*Colorado Revised Statutes Annotated* 1989). The funds raised from a site tax would be used with other funds to pay for the cost of land, labor, equipment, and services needed for the operation of the hazardous waste facility.

Efficiency and equity characteristics of funding sources

Although the funding methods described above have been implemented differently across states, each funding approach is associated with certain characteristics with respect to its impact on collection incentives and cost distribution. These characteristics are summarized in table 1 which classifies equity and efficiency characteristics for each type of funding for two objectives: the disposal of existing pesticide stocks and the disposal of pesticide stocks that may be accumulated in the future. The equity rating is based on the "polluter-pays" principle which is an application of conventional economic prescriptions to internalize negative externalities by levying a fee or charge on firms or industries responsible for the pollution (Runge 1994, p.70, 132). The potential efficiency rating is concerned with the potential of a funding strategy to result in the "complete" disposal of stocks of unwanted stored pesticides.

Equity ratings in Table 1 range from lowest equity (1) to highest (3). An equity rating of 1 indicates that there is no linkage between the source of disposal funds and the ownership of unwanted stored pesticides. An equity rating of 2 indicates a partial linkage between ownership and disposal cost, and an equity ranking of 3 indicates that a high percentage of disposal cost is borne by the owner of unwanted stored pesticides.

Potential efficiency indices in table 1 range from lowest efficiency (1) to highest (3). A ranking of 1 indicates that the funding method provides a disincentive to pesticide disposal in a voluntary program. An efficiency index of 2 indicates the absence of a disposal disincentive associated with the funding method. An efficiency index of 3 indicates both the absence of funding related disposal disincentives and the existence of incentives to reduce pesticide use. Reducing pesticide use may lessen future disposal problems by reducing the quantities of pesticides purchased.

Because the ability of a program to effect the complete disposal of unwanted pesticides is influenced by more than the source of funding, Table 1 considers the *potential* efficiency of each funding method. The level of disposal that is attained will be affected by both the size of the pool of disposal funds and the specific characteristics of the disposal program. Additionally, if participation in a disposal program is voluntary, the degree of disposal attained by any program will depend on characteristics of owners of unwanted pesticides. Some pesticide owners may want to be rid of stored pesticides to the extent that they would be willing to pay some or all of the costs of disposal. Other owners may choose not to participate, even in a no-fee disposal program, simply to avoid transactions costs (e.g. time and paperwork) associated with the program.

Table 1 Efficiency and equity characteristics of funding methods

	Existing Stocks		Future Stocks		
Funding Method	Potential Efficiency	Equity	Potential Efficiency	Equity	Comments
Grants	2	1	2	1	uncertain sustainability
User fees	1	3	1	3	possible reduction in future accumulation
Registration fees	2	1	2	2	reduced pesticide use
Pesticide tax	2	1	3	2	reduced pesticide use
Site tax	2	1	2	1	

Efficiency ratings: 1 - disincentive for disposal, 2 - no disincentive for disposal, 3 - no disincentive for disposal plus incentive for reduced accumulation.

Equity ratings: 1 - no link between source of funds and ownership of unwanted pesticides, 2 - partial link between ownership and source of funds, 3 - strong link between ownership and source of funds.

The disposal of existing stocks of unwanted pesticides is distinguished from the disposal of future pesticide stocks in Table 1 due to possible effects of the disposal-funding source on pesticide accumulation. Since existing stocks are already in place, their accumulation cannot be affected by the funding method used for a disposal program. The method of funding may, however, affect future pesticide use, accumulation, and disposal costs. The highest efficiency rating for disposal of existing stocks is therefore 2, since the source of funding cannot affect accumulation of existing stocks. An efficiency rating of 3 is possible for the objective of eliminating future unwanted stocks, since the funding method may affect future accumulation as well as future disposal.

State or federal grants for the disposal of unwanted pesticide stocks were assigned efficiency and equity ratings of 2 and 1, respectively, for both existing and future stock disposal. The efficiency rating of 2 for existing stocks reflects the fact that grant funding imposes no disincentives for disposal. The efficiency rating for grants is also 2 for future disposal because grant funding provides no incentives to reduce future pesticide use. The equity rating of 1 for both existing and future disposal under grant funding reflects the fact that grant funding is supported by unspecified sources of state or federal dollars and is unrelated to ownership of unwanted pesticides. A reliance on grants to fund pesticide disposal also raises questions about sustainability of the disposal program over time, as this is not a continuous method of raising funds, but is subject to periodic funding decisions by state or federal governments.

The use of user fees to finance disposal merits a 3 rating for equity in the disposal of both existing and future pesticide stocks, because user fees are imposed directly on the owners of these stocks. The efficiency rating of user fee financing is 1 for both existing and future stocks, however, because the user fee creates a financial disincentive for owners of unwanted pesticides to participate in a disposal program. A user fee program for disposal of future stocks may reduce future pesticide use and accumulation, since the user knows he will pay for disposal, but an efficiency rating of 1 was still assigned to user fee programs for future stocks because, in a voluntary program, user fees still provide a disincentive for participation.

Registration fees, imposed on pesticide manufacturers, were assigned an efficiency rating of 2 for disposal of existing stocks because they do not create a barrier to participation. Registration fees were also assigned an efficiency rating of 2 for disposal of future stocks, because current fees on individual pesticides are too low to provide significant incentives for reductions in future pesticide usage. If annual state pesticide registration fees were raised sufficiently to increase the cost of purchasing pesticides, however, an efficiency rating of 3 for disposal of future stocks would be appropriate.

An equity rating of 1 was assigned to registration funding for disposal of existing stocks, since the funds will come from current and future purchasers of pesticides rather than current owners of unwanted pesticides. The equity rating increases to 2 for disposal of future stocks because future owners of unwanted stocks will be a subset of current and future pesticide purchasers. The equity rating is 2 rather than 3, however, because fees on purchasers who do not accumulate unwanted pesticides will be subsidizing the disposal costs of purchasers who do accumulate these stocks.

Pesticide tax funding for disposal was assigned an efficiency rating of 2 for disposal of existing stocks, due to the absence of participation disincentives, and 3 for disposal of future stocks. Pesticide taxes act to discourage future pesticide use as they reduce prices received by pesticide producers and increase cost for pesticide users in accordance with pesticide supply and demand elasticities (Gunter et. al. 1996). Pesticide taxes were assigned an equity rating of 1 for disposal of existing stocks, because costs are imposed on future pesticide users rather than on owners of existing unwanted stocks. This rating was increased to 2 for disposal of future stocks, because accumulators of future stocks would be subject to the tax when they purchased pesticides.

Site taxes provide funds for disposal by imposing a cost on individuals residing within a specific political boundary. Site taxes were assigned efficiency ratings of 2 for disposal of both existing and future stocks, since they do not create participation disincentives, but neither do they create disincentives for future accumulation. Site taxes were assigned equity ratings of 1 for disposal of both existing and future stocks, since they are based on location rather than on ownership of unwanted pesticides.

The five funding options discussed above represent options that have been used in the states, as indicated by our survey results. In terms of cleaning up existing stocks of unwanted pesticides, it should be noted that none of these options provides incentives for participating in a collection program. At best, existing programs avoid disincentives to participation by not charging owners of unwanted pesticide stocks for collection, and attract participants whose utility from being rid of such stocks outweighs the effort required to participate. Greater participation could likely be obtained by providing financial incentives for participation, perhaps through a bounty on pesticides, which are brought in. Although this approach might increase the collection of existing stocks, however, the problem of future accumulation of unwanted stocks might be exacerbated, if pesticide users expect this type of program to be available in the future. Additionally, the polluter-pays concept for assigning costs would be reversed under a program of financial incentives for unwanted pesticide owners, and funding requirements for collection programs would increase.

Concluding comments and implications

The continued storage of unwanted pesticides creates the risk of potential environmental contamination by a natural disaster; a tornado or a flood could cause a stored pesticide to be dispersed into the ground or water. Farm properties sold or inherited often mean that pesticides are passed to persons who have not had training or experience in using them. In many cases, persons possessing or inheriting pesticides lack knowledge of how to dispose of them safely. The hazards created by unwanted pesticides have led states to provide for the collection and proper disposal of unwanted pesticides as a precautionary measure that safeguards citizens and natural resources.

States have found that multiple collections over a number of years are necessary to attain the removal of most accumulated stocks of unwanted pesticides. Given differences in population, amounts of accumulated pesticides, dangers posed by unwanted pesticides, and other hazardous waste collection efforts, recommending a single strategy for all states is not possible. Costs are an important consideration in pesticide collection efforts. In view of the new Universal Waste Rule and its relaxed requirements concerning pesticide collections, achieving lower collection costs should be possible. Once states have removed large quantities of stored pesticides, they can probably forego participant registration and move to a relaxed program where costs would be about $1 per pound.

If pesticide collection programs are to remain voluntary, states may want to consider different programs for the disposal of existing and future unwanted pesticide stocks. It may be necessary to give greater weight to efficiency considerations in facilitating the cleanup of existing stocks, since a high rate of participation will be needed to accomplish a high level of disposal. "Polluter-pays" considerations, which attempt to internalize the externality associated with unwanted pesticides by charging pesticide producers and consumers for the cost of collection programs, may be given greater emphasis in designing programs to reduce future stocks of unwanted pesticides. Registration fees and pesticide taxes are attractive funding sources for disposal of future stocks since they impose disposal costs on pesticide manufacturers and users, may provide disincentives to future pesticide accumulation, and avoid disincentives to participation in collection programs. An annual registration fee/pesticide tax system also has the advantage of providing a continuing source of funds. States with other hazardous waste collection programs may find that these programs can be used with agricultural pesticide collections.

Descriptions of the approaches and experiences of the states in addressing the problem of unwanted pesticides are useful in understanding many of the practical difficulties and considerations associated with pesticide disposal. In some ways, the state efforts thus far can be viewed as independent pilot or demonstration programs for pesticide disposal. Although there are differences in the unwanted pesticide problem in each state, there are also many similarities, which may permit states to benefit from the experiences of others.

The ability of states to improve their collection efforts by learning from each other's experiences would be greatly enhanced by improvements in data collected on unwanted pesticide quantities and characteristics, pesticide collections, and on the characteristics of collection programs. With such data, anecdotal and theoretical analysis of collection programs may be supplemented with empirical studies of the effectiveness of different approaches.

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Collaborative project on environmental risks of pesticides and sustainable development of Integrated Pesticide Management System (IPMS) in Nepal considering socio-economic conditions

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Abstract

The paper informs about some major structural and organisational issues of a collaborative project on IPMS in Nepal, with the Kathmandu workshop on environmental risk assessment of pesticides and IPM as a specific project component. Its strictly informal character is thought to allow quick orientation about concept, organisation, partnerships, database, main results and appropriate references. Articles which are included in this proceedings volume will be directly referred to. Website indications of project partners may satisfy further information needs.

Starting point

Pesticide misuse is an increasing problem in developing countries and, therefore, also in Hindu Kush-Himalayan (HKH) region (Neupane 2002) and in Nepal (Baker & Gyawali 1994, Dahal 1995, Kansakar et al. 2002, Palikhe 2002, Shrestha & Neupane 2002, Upadhyaya 2002, Neupane 2002). It may causeyield reduction as a result of combined resistance, resurgence and secondary pest outbreaks, and damages of environmental resources like water and soils, and health problems which affect both farmers and consumers as well. To mitigate direct impacts of pesticides and through food chain on man and the environment again and again the same demands are being raised with respect to creating the political, scientific and educational fundamentals, and to regulations considering political, economic, agronomic and socio-economic aspects and practices.

To investigate risks of pesticides in subtropical environment a collaborative research project was started in 1999, and ends in 2002 (Herrmann 2001, Herrmann & Schumann 1999, Schumann & Herrmann 2000; www.tu-bs.de/institute/igg/physhyd/index.html). The project is funded by Volkswagen-Stiftung Foundation, Germany.

Research concept and project structure

The project aims at developing adequate, scientifically-based Integrated Pesticide Management System (IPMS) for Nepal which could be applicable to whole HKH region. As experimental example Jhikhu Khola catchment basin of 111.41 km² and 750-2100 m a.s.l. was chosen which is located in the mid-hills of central Nepal in a market-near position at Arniko highway at about 50 km east of Kathmandu (Fig. 1). The key tool of the project is data base containing relevant environmental and socio-economic data (Fig. 2).

Reliable data are above all necessary with respect to development of model scenarios by which alternative solutions of reduced pesticide applications can be developed and tested considering official regulations and economic constraints with regard to sustainable environmental protection. In this respect an appropriate concept will be elaborated for cultivation of vegetables and grains in Nepal in cooperation with geographic, geo-ecologic and agro-ecologic sciences in particular and with ecological chemistry, hydrology and economics on the one hand, and with local authorities and stakeholders on the other hand. The complex problem is met with a multilateral approach which consists of scientific (pesticidal [Apel 2002, Apel et al 2002, Apel & Richter 2002, Khanal & Pujara 2002, Kreuzig & Bahadir 2002, Vinke et al. 2002] and environmental [Herrmann et al. 2001, Schumann 2002, Schumann et al. 2001, 2002, Piepho 2002]) and socio-economic components (Herrmann et al. 2001, Wiebelt 2002, Shrestha & Neupane 2002, Ceapred 2000, 2001) (Fig. 2) to be worked at in cooperation with local governmental, consulting and research institutions. The organisational structure of the project of the project is shown in Fig. 3 together with main fields of activity. Project partners are listed in the Annex.

Experimental design

Field experiments refer to both *bari* (rainfed) and *khet* (irrigated) land with the latter much more affected by pesticide application. Flow paths, origin and age of surface and subsurface waters which control transport and storage of pesticides within and pesticide export from the agro-ecosystem are studied by using for instance environmental isotopes (Herrmann et al. 2001), and transport of water and pesticides is planned will be calculated for the study system as a whole, and especially for specific compartments such as unsaturated soil zone (Schumann 2002) and aquifers with the help of appropriate mathematical models. Altogether there is an urgent need for the evaluation of environmental hazards and risks of water-induced pesticide pollution to demonstrate possible damages of the environment including man for different pesticide application scenarios.

Fig. 1 Geographical situation of project's experimental sites

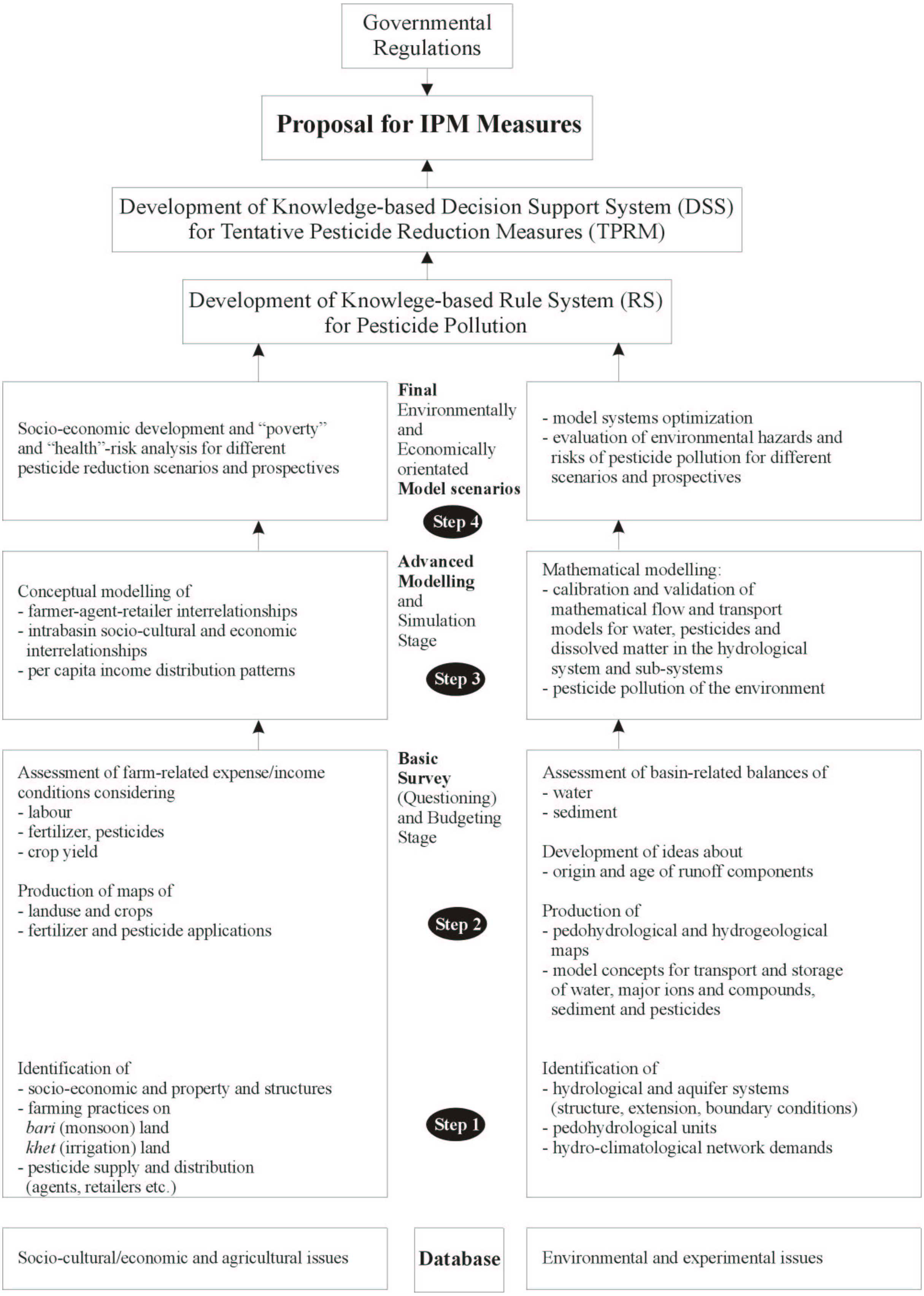

Fig. 2 Summary of concept and contents of the research programme

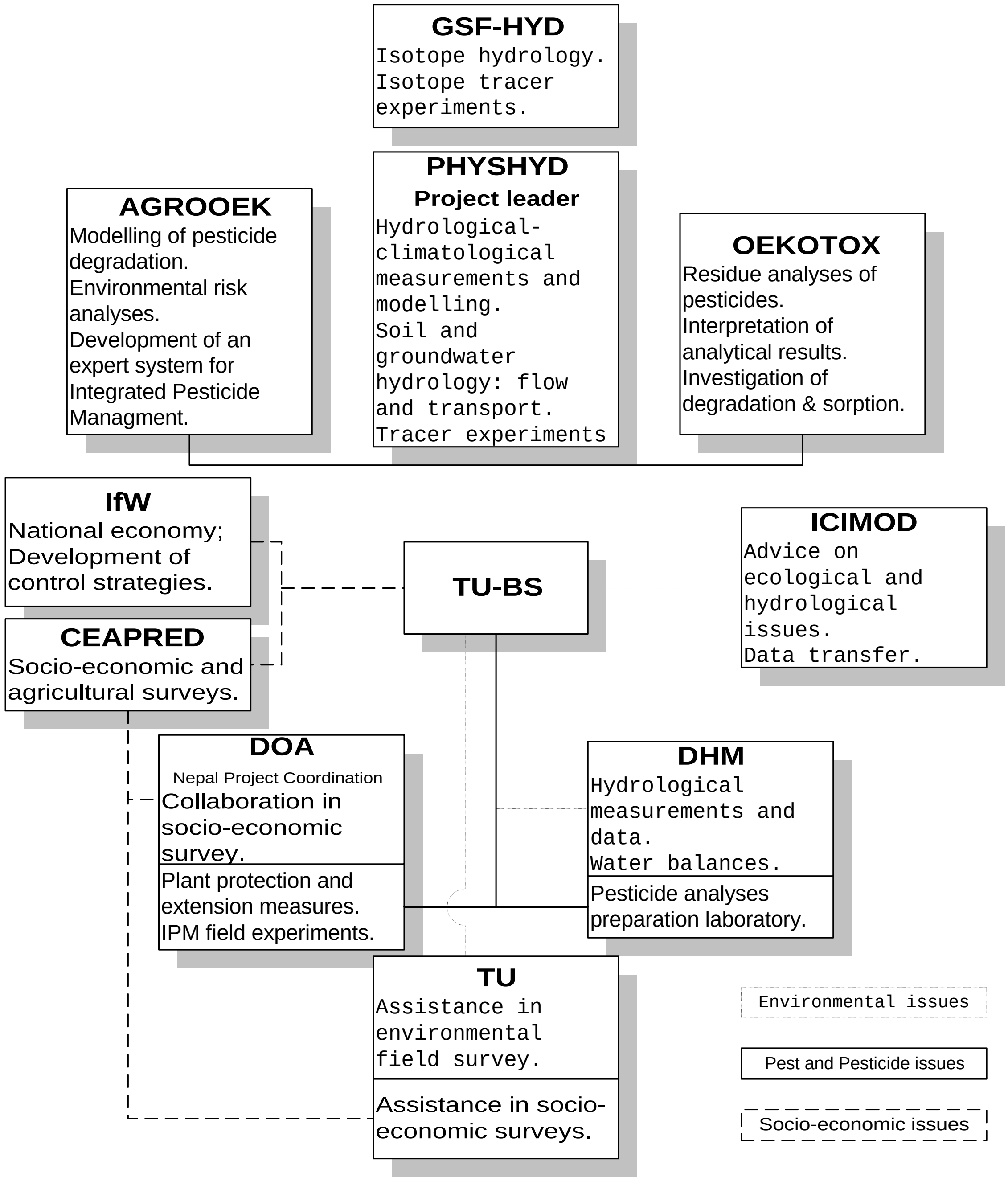

Fig. 3 Organisational and scientific project structure with

Selected results and conclusions

With respect to hydrology:

- For complex hydrological systems which are focussed as part of even more complex environmental systems (as e.g. agro-ecosystems) multilateral Integrated Catchment Approach (ICA) concepts seem to be indispensable and island solutions seem irrelevant.

- Under subtropical monsoon climate the input variations of stable isotopes can be big enough to use their tracing ability and herewith connected modelling tools similar as for the mid-latitudes.

- In irrigated environments, surface runoff processes dominate which are mainly controlled through monsoon, and are modified by irrigation schemes. Hence mixing isotopic effects of rain and irrigation water prevail hydrological *khet* systems thus limiting reliable flood hydrograph separations.

- A most crucial task is the quantification of hydrological and hydraulic conditions of water storage within the temporarily (at least partially) saturated upper soil zone and of the vertical and lateral transfer through this zone. The study of preferential flow pattern should be focussed in this context. However, this can be done with reasonable effort on plot scale only.

With respect to pesticides:

- Preliminary results show, that actual environmental pollution through pesticide storage in the top soil and their water-bound transport is less than expected from the observed pesticide application quantities due to soil properties and climatic conditions. Next, a concentration on pesticide transport within vadose zone and residue analysis in harvested crop is needed.

- Health risks might still be through pesticide accumulation in the food chain and unsafe application practices. For these the project could not account since these questions are not within it‘s work-scope. Lacking precautions also comprise too short waiting periods between pesticide application and crop consumption.

- Under field conditions target compounds compounds malathion, dimethoate, fenvalerate and metalaxyl disappear faster than in the lab. During flooding field plots, substance are transported to deeper soil layers up to 50 cm except malathion. Although concentrations found after 2-3 weeks are rather low, long term accumulation and leaching cannot be excluded if large amounts of pesticides are applied repeatedly. Especially for fenvalerate a quantitative risk assessment is hard to make because of complex sorption behaviour.

With respect to socio-economy:

- Feasibility of measures for environmental protection, hence of project results, is difficult due to lack of money, resources and control instances and the relative economic unimportance of pesticides.

- The regional infrastructure of the Nepali government on district scale serves as a good basis to educate farmers about hazards and risks of pesticide use, and on proper choice and use of pesticides.

Acknowledgement

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Use and handling practices of pesticide in hybrid vegetables and maize seed productions in Bangladesh: A case study of BRAC contract farmers

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Abstract

Composition of pesticides used for producing hybrid vegetables and maize seeds and farmers' awareness on effects of pesticide use are examined using survey data from randomly selected 65 'contract seed growers' in northwestern Bangladesh. Pesticide cost accounts for about 6% of the gross value of output. Eighty-eight percent of farmers used pesticides at least once. In most cases, actual application rate exceeded the recommended dose. Also, frequency of pesticide use was alarming. Mean number of application is 3.1 times (range 1–10 times) in a crop cycle. Although farmers seemed to be aware of health hazards associated with chemicals, they also used banned pesticides. Among the pesticide users, 35% reported use of organophosphates, ranked from extremely to highly hazardous by the World Health Organization. Perceived positive effects of pesticides outweigh the harmful effects that need to be properly evaluated. A major thrust for raising farmers' awareness on effects of pesticides use, expansion of the IPM practices, and undertaking policy advocacy to devise pesticides regulation and effective implementation were suggested.

Introduction

Emergence of pest resistance to pesticides is one of the major negative aspects of pesticide use and is compounded by a widespread assumption that chemicals are harmful to human health and the environment. There is widespread acceptance that the modern agricultural technologies are much more prone to insect, pest and disease infestations. Lichtenberg & Nguyen (2001) mentioned that although the benefits of the use of pesticides to prevent crop losses and increase foodgrain production is well recognized, its unwanted side effects on human health and environment have a major concern. Therefore, with the increased diffusion of ‘green revolution’ technology in regions of Asia, Latin America and Africa, and the present thrust in the promotion of ‘hybrid technology’, pesticides have become and will continue to be a major component of modern day agriculture.

Pesticide use in Bangladesh, negligible until the 1970s, has recorded a dramatic rise in recent years. Rahman & Thapa (1999) reported that the use levels of pesticide increased from 2,200 metric tons in 1980-1982 to 6,500 metric tons in 1992-1994 and modern rice cultivation increased from 29.3% of total rice area to 49.0% during the same period.

Motin (2000) found an alarming feature of pesticide use in Bangladesh where farmers are reported to use some pesticides which are already banned worldwide including Bangladesh Also, little is known about the knowledge and handling practices of pesticides of Bangladeshi farmers. In general, most of the Bangladeshi farmers do not have any ‘formal education’ and, therefore, are not in a position to read the instructions (if any) on the containers to safeguard from adverse health effects of pesticides, unless the existing agricultural extension network makeup the deficiency.

The present study examines the composition and levels of pesticides used, handling practices as well as assess the level of awareness on pesticide use by the farmers engaged in the production of ‘hybrid vegetable and maize seeds’ in Bangladesh supported by BRAC, a national non-government organization.

BRAC initiated a program to involve landless, marginal and small farmers by undertaking a comprehensive agricultural developmental program in 1996. Its Agriculture Extension Program aims to increase the nutritional and income status of the rural households by increasing agricultural production through technology transfer, quality input supply and sharing knowledge of better organizational and management practices with small and landless farmers. It promotes and diffuses an estimated 81 types of modern and/or hybrid varieties of field crops to its beneficiaries as well as marginal and small farmers. Between 1996 and 2000 approximately 100,000 women were trained as vegetable growers and at present BRAC produces about 90% of the maize seeds and 35% of the vegetable seeds in Bangladesh as mentioned in BRAC (2000).

Since ‘hybrid technologies’ are highly chemical input intensive, knowing the composition of these chemicals and the handling practices adopted by the farmers can provide information on its potential hazards and assist us in suggesting ways of improving the condition of these programs. The study is expected to contribute to limited knowledge on the chemical use aspects of BRAC’s agriculture development program. It is also expected that such study would help devise more environment friendly rural development interventions.

Sources of data

The research was based on a survey conducted among the BRAC supported ‘contract hybrid vegetable and maize seed producers’ including a survey of BRAC’s own ‘foundation seed’ production farm located in Dinajpur district. A pre-tested structured questionnaire was utilized. Although BRAC operates its various programs throughout Bangladesh, the hybrid vegetable and maize seed production program is concentrated in specific regions of the country where it is supported by its seed production farm in Dinajpur as well as its seed processing center in Bogra district. Therefore, information on chemical use and handling practices was collected at random from a total of 65 contract vegetable and maize seed growers from 29 villages of 6 upazilas (sub-districts) of Dinajpur and Bogra. The questionnaire was designed according to the level of the respondents’ understanding. Data collection was conducted for a period of two weeks during March 27–April 10, 2000.

Results

Composition of pesticides

Pesticides used for agriculture may be broadly classified in four categories: (a) organophosphate, (b) organochlorine, (c) carbamate, and (d) pyrothroid. According to WHO (1984), pesticides of organophosphate and organochlorine group are highly hazardous for human health.

Composition of pesticides used by BRAC contract farmers is presented in Table 1. A total of 27 brands of pesticides were used. Among these 27 brands, 11 are banned worldwide including Bangladesh as mentioned by Motin (2000). An alarming 65.4% of farmers used Darsban, a banned pesticide. Though no information on human health component was collected in this study, one can get an indication of potential human health hazard by observing the type and level of pesticides used. It is evident from Table 1 that organophosphates are used by 35.4% of farmers followed by organochlorines (32%) and pyrothroids (26.5%) that contains most of the banned pesticides. Carbamates are used by only 6.1% of farmers.

Table 1 Proportion of farmers using various pesticides for seed production

Pesticide group	WHO chemical hazard category	Number of brands used	Percent of farmers using pesticides
Organophosphate	IA, IB, II	11	35.4
Carbamate	IA, IB, II, III	5	6.1
Organochlorine	IB, II	5	32.0
Pyrothroid	II	6	26.5
Total		27	100.0

Note:
IA = extremely hazardous, likelihood to hospitalize or long term illness.
IB = highly hazardous, likelihood to hospitalize or long term illness.
II = moderately hazardous, likelihood for more than two days of sickness, need to see physicians
III = slightly hazardous, likelihood for dizziness or vomiting or blurred vision or skin rash.
Sources: WHO (1984); Field Survey (2000)

Use level of pesticides

As pesticides are used with greater frequency, that is, as and when required, even the minimal doses eventually add up to a large rate of application. Although the standard recommended rate by BRAC staff (in verbis) is 4 ml and/or g per decimal (1 decimal=40.4686 square metre) of land for each application, the average level of pesticide application by farmers seems alarming estimated at 2.8 kg of active ingredients per ha (Table 2). The application rate was highest for vegetables (3.4 kg of active ingredients per ha) followed by maize (3.1 kg of active ingredients per ha). In other words, the cumulative application rises to 14 ml or g/dec in vegetables and 13 ml or g/dec in maize seed production.

Cost of pesticide use is estimated at Tk. 1,331 per ha and the highest cost is in vegetables (Tk. 1,485 per ha) followed by maize (Tk. 1,223 per ha). The overall factor share of pesticides is estimated at 6% of gross value of output and is highest in vegetables (7.4% of gross value of output) (Table 2).

Table 2 Pesticide application rates and costs per hectare of vegetable and maize seed production

Crop name	Number of observa-tions	Pesticide use rate (ml or g/ha)		Pesticide cost (Tk./ha)		Pesticide cost as share of gross value of output (%)	
		Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
Vegetables	66	3444.6	8830.3	1484.8	1505.3	7.4	14.0
Leafy vegetables	32	1400.1	1345.0	1060.9	1266.8	4.7	7.2
Maize	14	3116.8	3640.4	1222.6	964.0	2.2	4.7
All crops	112	2819.5	6967.2	1330.9	1385.8	6.0	11.6

Note:
Considering the types of crops produced by these 65 farmers, the total number of observations stands at 112: leafy vegetables 32, vegetables 66, and maize 14, respectively.
1 US$=56.50 Tk as of November 15, 2001.
Source: Field Survey (2000)

The frequency of application varies widely ranging from 1 to 10 times in a single seed production cycle. Also, frequency of pesticide use is highest in vegetables and leafy vegetables (Table 3). Overall, 88% of all farmers used pesticides at least once in a crop season, while the remaining 12% did not use any pesticides. In the case of vegetables, 94% of farmers applied pesticides at least once and a substantial 14% of the farmers applied pesticides more than five times. In the case of maize, however, 71% of farmers applied pesticides only once in a crop season.

Table 3 Number of application of pesticides in a crop season

Number of applications of pesticides	Percentage of farmers			
	Leafy vegetables	Vegetables	Maize	All crops
Farmers applying pesticides	**78.1**	**93.9**	**85.6**	**88.4**
One time	6.3	10.6	71.4	17.0
Two times	18.8	22.7	7.1	19.6
Three times	31.3	18.2	0	19.6
Four times	12.5	21.2	0	16.1
Five times	6.3	7.6	0	6.3
More than five times	2.9	13.6	7.1	9.8
Farmers not applying pesticides	21.9	6.1	14.4	11.6
Total	100.0	100.0	100.0	100.0
Mean number of application	**2.50**	**3.79**	**1.29**	**3.10**
Standard deviation	2.05	3.52	1.44	3.08
Total number of observations	32	66	14	112

Source: Field Survey (2000)

The frequency and cumulative use of pesticides of various categories is alarmingly high in BRAC ‘foundation seed’ production farm at Dinajpur (Table 4). The net sown area of the seed farm is approximately 2 ha where ‘foundation seeds’ of a large variety of hybrid vegetables for both summer (*kharif*) and winter (*rabi*) seasons are produced. Consequently, the total amount of active ingredients of pesticides going to a limited soil area of only 2 ha reaches an alarming level. Table 4 clearly reveals that this small plot ultimately received an estimated total of 11.7 kg of organophosphates, 6.9 kg of carbamates, 6.8 kg of organochlorines, and 3.8 kg of pyrothroids in active ingredients in a one-year crop cycle. Among the individual crops, the highest amount of organophosphates and carbamates were applied to okra. Also, the maximum amount of organochlorines and pyrothroids were applied to tomato and bottle gourd respectively. Specifically, a total of 14 brands of pesticides were used in this seed farm of which 7 are banned pesticides.

Table 4 Amount of pesticides used in BRAC foundation seed production farm, Dinajpur

Crop name	Area (ha)	Total amount of pesticides (active ingredient) used (g or ml)			
		Organophosphate	Carbamate	Organochlorine	Pyrethroid
Bean	0.14	420	0	0	840
Yardlong bean	0.08	160	0	160	00
Mungbean	0.10	400	0	0	0
Bottle gourd	0.20	0	200	200	1,600
Bitter gourd	0.12	0	0	240	960
Ridge gourd	0.12	240	0	360	120
Pumpkin	0.08	160	160	80	80
Ash gourd	0.10	200	0	300	100
Cucumber	0.05	160	20	200	40
Kangkong	0.02	80	0	0	40
Vatishak	0.10	600	0	0	0
Red amaranth	0.16	0	640	640	0
Amaranth	0.06	0	240	300	0
Tomato	1.34	0	2,640	2,640	0
Radish	0.16	960	0	160	0
Eggplant	0.30	2,400	0	1,500	0
Okra	1.48	5,856	2,928	0	0
Cauliflower	0.02	80	80	20	0
All crops	2.00	11,716	6,908	6,800	3,780

Note:
The figures were obtained by calculating the actual application rate of 4 g/ml of active ingredient diluted in 1 litre of water per 1 decimal of land area times the frequency of application in individual crops over the total crop cycle.
Source: Field Survey (2000)

Assessing farmers' chemical handling practices

To assess farmers' chemical handling practices, a series of inter-related questions were asked. Multiple responses were recorded in cases with open-ended questions meant for eliciting reasons and sources of information. A test of association between responses and relevant outcomes are conducted wherever applicable to facilitate inferences.

Twentyfour percent of farmers responded that they felt sick after handling chemicals, displaying some common symptoms (Table 5). Of the total farmers, 17% reported that they felt tired and weak after spraying pesticide in the crop field. A vomiting tendency and/or headache as well as burning sensation in the eyes, chest, and lower knee were also reported.

Table 5 Symptoms of illness after handling pesticides as responded by farmers

Symptoms of illness after handling pesticides as responded by farmers	Responses (%)
Feeling sick	**23.5**
Tired/ feel weak	17.2
Vomiting tendency/ headache/ bodyache	4.9
Burning sensation in eyes/chest/lower knee	4.9
Loss of appetite	2.5
Did not feel sick	75.3
Non-response	1.2

Note: Multiple response meaning total will be more than 100.
Source: Field Survey (2000)

When asked about what precautions were taken during pesticide application, 87% of farmers reported that they covered their faces with a cloth or mask while a few (13%) mentioned the use of caps or helmet and fewer still (5%) the use of hand-gloves made of polythene packets (Table 6).

An expected negative association between farmers who reported to feel sick and the use of mask and/or gloves was observed although the association was not significant. Correlation coefficient between incidence of feeling sick and use of mask is estimated at $r=-0.14$ and with use of gloves at $r=-0.16$. Another significant positive association was observed between use of mask and gloves ($r=0.22$, $p<0.05$). It seems that farmers are increasingly realizing that some precautions are necessary while applying pesticides.

Table 6 Precautions taken during pesticide application by contract seed farmers

Precautions taken during pesticide application	Responses (%)
Examples	
Cover the face with cloth/mask/eye-glasses etc.	86.7
Using cap/plastic helmet	12.5
Spraying in the direction of wind flow	6.2
Wearing polythene packets as hand-gloves	4.7
Wearing shirts	3.1
Spray pesticide during evening so as not to harm useful insects	3.1
Spray pesticide before meals	2.3
No precautions taken	13.3

Note: Multiple responses meaning total may exceed hundred.
Source: Field Survey (2000)

Washing hands with soap and/or ashes after using chemicals is common as reported by 98% of farmers. Also, a total of 88% of farmers reported that they are aware of the need to take precautionary measures while handling pesticides. A significant positive association between receiving information on precautionary measures in handling pesticides and use of mask was observed ($r=0.34$, $p<0.01$) indicating that awareness raising campaign did have an influence in the decision making process of the farmers.

BRAC staff was the main source of disseminating knowledge on handling chemicals reported by 43% of farmers (Table 7). Further, written instruction in the bottle or leaflet served as an important source (27%). Neighbors also served as a significant source (16%). Contribution of government agricultural officials was not cited as having a role in disseminating information on safety measures in handling chemicals.

Table 7 Sources of precautionary measures learned

Sources of precautionary measures learned	Responses (%)
BRAC staff	43.2
Written instruction in bottles/leaflet	27.1
From neighbours	16.0
Agricultural extension office	3.7
Chemical dealer	3.7
Block supervisor	2.4
Media (radio, TV)	1.2
Physicians	1.2

Note: Multiple response meaning total will be more than 100; Source: Field Survey (2000)

On the question of the timing of pesticide application, 68% of farmers responded that they applied pesticides mainly in the afternoon, followed by late morning after breakfast (51%), and before breakfast (21%). Only a few (6%) applied pesticide in the evening. A significant positive association between applying pesticides in the morning, afternoon, and late evening and incidence of sickness was observed for unknown reason. The estimated correlation coefficient between sickness and application time during morning is $r=0.28$ ($p<0.05$), afternoon is $r=0.38$ ($p<0.01$) and evening is $r=0.34$ ($p<0.01$), respectively. On the other hand negative association was observed between incidence of sickness and application time in the before breakfast and after breakfast applications although the values are not significant.

It was noted that most of the farmers (93%) stored the chemicals with some degree of caution (Table 8). About 49% of farmers reported that they kept it in a safe place or specific location at home. However, no clarification on what was meant by the term 'safe place' was given. Only 25% of farmers emphasized that they kept pesticides out of the reach of children, which indicates that the farmers are at least aware of the need to safeguard their children from contact with harmful chemicals. Only 7% of farmers stated that they were not aware of the need to take precaution in storing pesticides.

Table 8 Examples of storing chemicals as responded by farmers

Examples of storing chemicals as responded by farmers	Responses (%)
Examples	**92.6**
Keep in safe place at home/locked place/a specific place	49.4
Keep outside reach of children	24.7
Keep in secret place at home/in toilet	7.4
Keep in dry place at home	7.4
Keep anywhere in the home	3.7
Keep in polythene wrap	2.4
Non-response	7.4

Source: Field Survey (2000)

When asked about what to do with empty chemical containers, about 53% of farmers reported that they buried the empty chemical cans/bottles after use (Table 9). Eleven percent of the farmers stated that they cleaned it and 're-used' it for domestic purposes. The incidence of 're-use' raises an alarming issue of safety and also indicates the presence of unawareness among farmers on the potential hazards of pesticide contamination. Also, another 11% of farmers responded that they kept it anywhere at home indicating a total lack of caution in a strict sense adding more doubt on their level of awareness of the chemical hazards that can be caused by the indiscriminate storage of pesticides as well as empty containers. Few responded that they threw their used cans/bottles in the river and/or any other body of water (5% of farmers) and also in the woods (5% of farmers).

Table 9 Examples of disposing empty chemical cans as responded by farmers

Examples of disposing empty chemical cans as responded by farmers	Responses (%)
Examples	**90.2**
Bury in soil	53.1
Clean and re-use for other purpose	11.1
Keep anywhere at home	9.8
Throw in the woods	4.9
Throw in river/body of water	4.9
Wash and kids sell them	4.9
Keep in specific place	3.7
Non-response	9.8

Source: Field Survey (2000)

In response to the question, “what do they do with the crop residue left in the fields?” multiple responses were received. About 70% of farmers mentioned that they used it as fuel, 15% responded that they left it in the field, 18% used it to feed animals, and only 13% of farmers used it as compost. This response pattern revealed that the dominant tendency was to utilize the crop residue as fuel as well as animal feed. Crop residue that could not be used for fuel and animal feed, was ultimately left in the field and was made compost to some extent as explained by the farmers. In other words, the need for replenishing soil fertility by recycling crop residue did not seem to be very strong. Also, a significant positive association between the frequency of pesticide use and the utilization of crop residue as fuel was observed ($r=0.21$, $p<0.10$). Furthermore, significant negative association among the competing uses of crop residue was observed as expected. For example, correlation between use of crop residue as compost and as fuel is estimated at $r=-0.31$ ($p<0.01$) and for feeding animals at $r=-0.20$ ($p<0.10$). This indicates that crop residue once used for fuel and/or feeding animals precludes its availability to prepare compost that can ultimately help replenish the soil.

On the question of the existing pesticide use rate, about 77% of the farmers responded that they use enough pesticides. Among the remaining 23%, 5% felt that they should use more (up to 50% more than the existing rate) while 18% did not respond.

The perception of the farmers on the effect of pesticides (whether good or bad) was elicited separately. First, farmers were asked to opine on any advantages of pesticide use. Once completed, they were asked to opine on any disadvantages of pesticide use. Almost all of the farmers (95%) considered that pesticide use has advantages. The range of such advantages is elaborated in Table 10. The majority (85%) of the farmers opined that pesticide use increase production. About one-third (31%) thought that it prevented insect and pest attack. Another 15% responded that pesticide use increased the quality of output. Only 3% of farmers opined that there are no positive effects of pesticide use.

Table 10 Advantages of pesticide use as opined by farmers

Advantages of pesticide use in crops as opined by farmers	Responses
Advantages of pesticide use	**92.7**
Increases production	85.2
Inset and pests cannot do any harm	31.2
Improve quality of crop/seed	14.8
Reduces rot in crops	2.4
Non-use of pesticides damages production	2.4
Prevents dropping of flowers during crop growth stage	1.2
Prevents damage in leaf	1.2
No advantages	2.4
Non-response	4.9

Source: Field Survey (2000)

When farmers were asked next to opine on the disadvantages of pesticides use, 37% of them provided a long list, which is elaborated on Table 11. Of the farmers, 49% considered that there were no disadvantages of pesticide use. About 9% did not give any comment on whether or not pesticides had disadvantages, implying 58% being naive about any disadvantages of pesticides. Among the disadvantages, 10% of farmers thought that pesticides kill useful insects and animals, such as, earthworm, honeybees and frogs that are good for crop production. Adverse effect on human health (9%) emerged as the second important harmful effect of pesticide use. Damages to crop (8%) as well as the reduction of soil fertility (7%) also appeared among the adverse effects. About 5% opined that pesticides also kill birds that come into contact with the crops.

A significant negative association was observed between responding farmers who mentioned advantages and those who mentioned disadvantages of pesticides. The correlation coefficient is estimated at r=-0.23 ($p<0.05$). Also, a weak but positive association was observed between farmers reporting disadvantages of pesticides and the incidences of feeling sick after pesticide application (r = 0.14, not significant).

When asked "how many days after using chemicals did you harvest your crops?", only 5% of farmers responded that they had harvested them within 5 days while the majority (95%) harvested their crops from 7 days onward. The modal value of the number of days allowed to consume vegetables and fruit after spraying pesticides came out to be 7 days (noted by 28% of farmers) followed by 10 days (17%) and 15 days (9%), respectively. The implication is that farmers are at least aware that they should not consume products immediately that were sprayed with pesticides. A gestation period of 7 days or more allowed from time of pesticide application to consumption of products seems reasonably safe.

Table 11 Disadvantages of pesticide use as opined by the farmers

Disadvantages of pesticides used as opined by the farmers	Responses (%)
Disadvantages of pesticide use	**37.3**
Useful insects and animals (honey-bee, frog, earthworm) die	9.9
Effects human health	8.6
Damages crop and flowering due to excessive use	7.8
Damages soil fertility/leads to increase in fertilizer doses	7.4
Birds die	4.9
Effects the environment/damages environmental balance	3.7
Poisons food	1.2
Reduces fish	1.2
Increases crop pests	1.2
If inhaled causes stomach pain	1.2
No disadvantages	49.4
Did not examine whether have any disadvantages	8.6
Non-response	3.7

Source: Field Survey (2000)

Conclusion

The present study revealed that 'contract seed growers' used substantial amount of pesticides for boosting their vegetable and maize seed production. In most cases, the actual application rate of these chemicals exceeded the recommended dose. Also, frequency of pesticide use, in particular, was alarming in both the BRAC 'foundation seed' production farm as well as in the fields of 'contract seed growers'. On the other hand, although farmers seemed to be aware of health hazards associated with chemicals, they used banned pesticides as these are the only ones available in the market and are probably cheaper and show visible results. The belief that pesticides have more positive effects than harmful effects needs to be properly evaluated as this perception will boost pesticide application whenever their crops are infested with insect/pest and/or disease.

Also the introduction of more environment friendly techniques for pest control such as IPM (integrated pest management) technologies were virtually absent in BRAC's agricultural extension system. Results further revealed that even if BRAC wishes to introduce IPM, the current set-up would not be able to provide this service, as there is no capacity for such venture.

Based on these findings, the following recommendations deserve consideration: (i) promotion of IPM technologies by building staff capacity as well as that of its beneficiaries, (ii) introduce an intensive environmental awareness campaign among beneficiaries by first building its own capacity in this regard, and (iii) promote policy advocacy to ensure effective implementation of pesticide regulations by utilizing BRAC's own human resources and influencing other relevant agencies.

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The impact of Integrated Pest Management program on pesticide demand for soybean farming in Yogyakarta, Indonesia

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Abstract

Externality impact of pesticide use on environment and human health has been well proved by many researchers. In reducing such externality, the government of Indonesia waived subsidy for pesticide and introduced Integrated Pest Management (IPM) technology in 1989. One of the expected impacts of this policy is the reduction of pesticide demand. To see the impacts, *input demand model* for pesticide in soybean farming is employed. The objectives are (1) to estimate the demand of pesticide in soybean farming and (2) to analyze the impact of IPM program on pesticide demand. For this purpose, secondary cross-section time series data from 1990 up to 1998 taken from respective offices in Yogyakarta province, Indonesia are used. By using simultaneous and recursive equation models the impact of IPM program on the demand for pesticide is estimated. The study found that the IPM program has been reduced significantly the use of pesticides in soybean farming.

Introduction

Since early 1970s government of Indonesia has been inspired by green revolution "movement" to increase agricultural production through intensification program. Intensive agricultural technology characterized by the use of high-yielding variety with high use of inputs including pesticides has been promoted. For this purpose government has spent 725 million USD to subsidize agricultural inputs for the farmers (Conway & Barbier 1990). Around 40 percent out of 725 million dollars of the subsidy were used for pesticides (Table 1). As the Table shows, starting from 1975 the subsidy increased substantially up to 1985 and then gradually decreased afterwards until no subsidy was given in 1989. Distinctive negative externalities caused by heavy use of pesticide particularly for the environment (Bond, 1996) and human health (Kishi et al. 1995) is one of the important factors behind the reason why the Indonesian government waived subsidy for pesticides and at the same time IPM program was introduced (Rölling & Fliert 1994). One of the expected impacts of this policy is the reduction of pesticide demand (World Bank 1993).

Table 1 Use of pesticides and pesticides subsidy

Year	N-Fertilizer Use (100.000 ton)	Insecticide Use (1000 ton)	Insecticide Subsidy (million US $)	Year	N-Fertilizer Use (100.000 ton)	Insecticide Use (1000 ton)	Insecticide Subsidy (million US $)
1970	1.62	1.08	0	1980	7.87	6.37	37.6
1971	2.19	1.56	0	1981	9.46	8.94	101.5
1972	2.62	1.41	0	1982	10.60	11.25	162.4
1973	3.12	1.50	0	1983	9.86	14.26	135.9
1974	2.90	1.64	0	1984	11.37	14.12	127.5
1975	3.11	2.45	5.8	1985	11.17	15.19	147.0
1976	3.13	3.43	54.8	1986	11.48	17.65	146.8
1977	4.42	4.42	25.8	1987	12.39	17.94	117.8
1978	4.79	4.17	67.4	1988	12.52	16.36	97.2
1979	5.51	4.19	71.5	1989	13.01	12.44	0

Source: Useem *et al.* (1992).

Mass introduction of pesticides in the country at the beginning of the intensification program was mainly because of strong and optimistic belief that using pesticides was considered the most appropriate way to save the production from pest and disease attack. Therefore, training on the application of pesticides to the farmers was done very intensively during the early stage accompanied by large amount of input subsidy. However, the introduction of subsidy and mass use of pesticides for a long period of time has led to a number of negative consequences. One of the distinct behavioral consequences is that the farmers become too heavily dependent on pesticides in protecting their crops (Barbier 1989). Continuous dependency on pesticides has brought about adverse effects towards agricultural production. Firstly, it was found that only 1% of the inputs was absorbed by the plants, while the rest was left to environment as poisonous waste (Pimentel 1993). Secondly, it is not easy to change the farmers' behavior in using pesticide within a short period of time as has been experienced while introducing Integrated Pest Management (IPM) program.

Having a strong claim about the superiority of the IPM technology it is assumed that if the number of farmers who apply IPM technology increase, it is expected that in the long run the use of pesticides will decrease without sacrificing the level of production (Useem et al. 1992). Off course, the application of IPM technology is not the only factor causing a declining tendency of pesticide use in Indonesia. Increase of the price of pesticide may also contribute in such reduction. Theoretically, the effect of the price and IPM technology on pesticide use (demand) and on soybean production will work simultaneously. The change in pesticide demand and soybean production can be observed from the shift of pesticide demand curve. Meanwhile, by introducing IPM program the change in pesticide demand is expected to shift the supply curve of soybean rightward or at least the supply curve is unchanged due to the effect of the IPM technology.

The objectives of the study are (1) to estimate demand of pesticide in soybean farming, (2) to analyze the impact of IPM program on pesticide demand. For this purpose, secondary data taken from provincial agricultural office, Yogyakarta statistical bureau, pest and diseases monitoring office are used.

Regression analysis by using OLS (ordinary least squares) method is used to analyze the factors affecting the demand for pesticides (e.g. pest attack) within the scope area studied. The idea of the analysis is based on the fact that the nature of relationship between pesticide demand and level of pest attack could be in two forms. One form is that pesticide demand will increase when pest attack increase. This is mainly based on the pest control principle that pesticide is used whenever pest attack exists (Rola & Pingali 1983). Second form could be that the level of pest attack depends on the use of pesticide. This is also due to the fact that the level of pest attack declines when the application of pesticide increases.

Pesticide demand has unique characteristics compared to that of other common agricultural inputs such as labor, fertilizers, seeds, etc. First, pesticide is an input, which indirectly affect the production. The direct impact of pesticide is to minimize the crop loss because of the pest attack. Second, the effect of pesticide is uncertain because it depends on the nature of the pest infestation (Horowitz & Lichtenberg 1994). An effective effect will be observed whenever pest infestation exists. In other words, the use of pesticide will be ineffective whenever no infestation exists. Based on the above argument, pesticide demand function should be estimated in order to find the optimum level of potential production. Therefore, models need to be developed in order to find the most appropriate demand function for soybean. Two models are employed, namely simultaneous model and recursive model. By using simultaneous and recursive equation models the impact of IPM program on the demand for pesticide was analysed.

Study area

The study was conducted in Yogyakarta Province covering four districts namely Bantul district, Gunung Kidul district, Kulon Progo district and Sleman district. Those four districts are areas for the development of IPM program. Farmers Field School (FFS) training on IPM experiment plots for pest monitoring, and application of IPM technology have been disseminated in these areas.

Data

Secondary cross-section time series data are employed in this study. The data comprise four districts and covers ten years period (from 1989 to 1998). The data were taken from a number of sources such as Annual Report of Pest and Disease Monitoring and Forecasting of Yogyakarta province, Annual Report of Provincial Agricultural Office, and statistical data published by Provincial and District Statistical Offices. Types of data to be analyzed are soybean production (ton), pesticide use in one year (l/ha), area planted of soybean (ha), number of famers' field school unit that has been implemented (IPM), average price of soybean in one year (Rp/kg), average price of rice in one year (Rp/kg), average price of pesticides in one year (Rp/l), and percentage of area affected by pest attack (%).

Method of analysis

Simultaneous demand function model

Simultaneous demand function is constructed based on the assumption that IPM technology does not influence the production process so that the marginal product of pesticide is not changed. Hence, IPM technology is only one of the alternatives of plant protection beside pesticide application. In this case the use of pesticide (Xp) will be influenced by level of pest attack (PA), price of pesticide (Pp), price of soybean (Ps), and planted area of soybean (As).

By using this assumption, it is expected that the level of pest attack (PA) will be affected not only by use of pesticide (Xp) but also by IPM technology (IPM).

It is worth noting that price of fertilizers are not included in the model relied on the assumption that fertilizers and pesticides are not substitutable inputs in protecting the plant. Moreover, fertilizers and pesticide are also not complementary each other in the production process. Based on the above idea two equation models are formulated as follow:

$$Xp = b_{20} + b_{21}PA + b_{22}Pp + b_{23}Ps + b_{24}As + u_2 \quad (1)$$

$$PA = a_{10} + a_{11}Xp + a_{12} IPM + u_1 \quad (2)$$

By substituting equation (1) into (2) *reduced form* equation will be obtained. However, the reduced form could not be used for the estimation since exogenous variable still exists. To solve this problem two-step estimation is used. First step is to estimate the *reduced form* equation as expressed in the following equation:

$$PA\wedge = \phi_{10} + \phi_{10}IPM + \phi_{11}Pp + \phi_{12}Ps + \phi_{13}As \quad (3)$$

$$Xp\wedge = \phi_{20} + \phi_{20}IPM + \phi_{21}Pp + \phi_{22}Ps + \phi_{23}As \quad (4)$$

Using the above equations, estimated value of (PA^) and (Xp^) that are independent each other can be obtained. The next step is to estimate the 'independent' demand function by using the following equation:

$$Xp = d_{20} + d_{21}PA\hat{} + d_{22}Pp + d_{23}Ps + d_{24}As + v_2 \quad (5)$$

$$PA = c_{10} + c_{11}Xp\hat{} + c_{12}IPM + v_1 \quad (6)$$

The above equations indicate that IPM will reduce the pesticide use if the IPM technology significantly reduces the pest attack level ($c_{12} < 0$), while the use of pesticide is determined by pest attack ($d_{21} > 0$).

Recursive demand function model

Recursive demand model is based on the assumption that IPM technology is not only able to control the pest but also affect the production process so that the marginal product of pesticide is changed. In this case the use of pesticide (Xp) will be influenced by the level of pest attack (PA), price of pesticide (Pp), price of soybean (Ps), and planted area of soybean (As). By using this assumption, it is expected that IPM technology (IPM) determine both the level of pest attack (PA) and the level of pesticide use (Xp). Then the following equations are formulated:

$$PA = a_{10} + b_{11}\,IPM + u_1 \quad (7)$$

$$Xp = a_{20} + b_{21}PA + c_{21}IPM + c_{22}Pp + c_{23}Ps + c_{24}As + u_2 \quad (8)$$

so that u_1 and u_2 are uncorrelated. By using recursive model the demand function (8) can be directly estimated by using *OLS* (Gujarati, 1995).

Study results

Simultaneous pesticide demand function

Given the results of regression analysis as depicted in Table 2, the estimated value of pest attack (PA^) and pesticide use (Xp^) for a given period of analysis and different district can be obtained. Those estimated values, which has been free from endogenous effect, are then used to estimate the relationship between pesticide use and pest attack. Such relationship is indeed a demand function for pesticide since there are both pesticide price and rice price variables.

The results of the estimation (Table 3) indicate that pest attack is significantly reduced by pesticide application. Interestingly, IPM technology also has a significant effect in reducing pest attack. It explains that IPM principle is implemented so that pest infestation could be maintained at the low level and that the use of pesticide become considerably low as the farmer delay the application of pesticide as they become the last alternative for crop protection. The regression coefficient of pest attack that shows a considerably low value is mainly because the pest attack itself is very low.

Table 2 Regression results of simultaneous demand function (first step)

Independent Variables	Dependent Variables			
	Pest Attack		Pesticide Use	
	Coefficient	t-value	Coefficient	t-value
IPM (number of FFS)	-0.013^{ns}	-1.360	-2.895***	-5.001
Ratio of pesticide price to soybean price	-0.416^{ns}	-0.287	-149.155*	-1.767
Soybean area (ha)	-8.629 E-05*	-1.635	0.012***	3.925
Intercept	11.732***	1.259	1,607.06***	2.960
R^2	0.160		0.564	
F-value	2.032*		13.780***	
D-W	1.609		2.485	

Note: *** significant at 1% ** significant at 5% * significant at 10%

Table 3 Regression results of pest attack vs. simultaneous demand

Variables	Coefficient	t-value
Pesticide Use^ (kg)	-0.007*	-1.432
IPM (number of FFS)	-0.027**	-2.097
Intercept	13.508***	3.193
R^2	0.165	
F-value	3.270**	
D-W	1.879	

Note: *** significant at 1% ** significant at 5% *significant at 10%

Table 4 Regression results of pesticide use function (second step)

Variables	Coefficient	t-value
Pest attack^ (%)	207.60***	11.139
Price of pesticide (ratio)	-47.343***	-5.091
Soybean area (ha)	0.026***	10.244
Intercept	-901.81***	-10.970
R^2	0.537	
F-value	10.477***	
D-W	2.276	

Note: *** significant at 1% ** significant at 5% *significant at 10%

Table 4 shows that the increase of pesticide use is significantly caused by the increase in pest attack. This is understandable because farmers will apply pesticide only when severe pest infestation exists as in contrast to the “old notion” of the farmers that the application of pesticide becomes a primary measure for crop protection regardless the level of pest infestation.

From the relationship between pesticide use and pest attack (Table 3 and 4) it is fair to say that the demand for pesticide in soybean farming could be explained by using simultaneous demand function as the assumption that IPM technology is able to reduce pesticide use is fulfilled. Table 3 tells that all variables included in the model can explain 53% of pesticide demand variation. For IPM variable in particular, the regression result shows that the increase in the number of IPM farmer’s field school in one unit will reduce the percentage of pest attack. In turn, the reduction of pest attack will then reduce the amount of pesticide use. So, by using simultaneous demand equation it is found that the IPM technology tends to indirectly reduce the application of pesticide, as this technology is able to reduce the intensity of pest attack. Price of pesticide significantly reduces the amount of pesticide use in soybean farming as expected. However, the application of pesticide will increase as the planted area of soybean increase.

Recursive pesticide demand function

Table 5 presents the results of pesticide demand estimation by using recursive demand function. According to the model about 74% of pesticide demand can be explained by all variables included in the model, which is considerably good. Each variable (price of pesticide, level of pest attack, IPM technology, or planted area of soybean) significantly influence the demand for pesticides.

Table 5 Regression results of recursive demand function

Variables	Coefficient	t-value
Ratio of pesticide price to soybean price	- 220.43***	-3.706
Pest attack (%)	27.130***	3.874
IPM (number of FFS)	-2.599***	-6.161
Soybean area (ha)	0.040***	8.513
Intercept	1,754.2***	4.519
R^2	0.739	
F-value	23.010***	
D-W	1.922	

Note: *** significant at 1% ** significant at 5% * significant at 10%

Under *ceteris paribus* condition, the price of pesticide has a significant effect in reducing the demand for pesticide. Since a ratio of price of pesticide to price of soybean is used in the model, this result is theoretically justified. Assuming that the farmers are rational, as marginal product of pesticide decline if the price of pesticide goes up it will be responded by reducing the amount of pesticide used in farming when the marginal product of pesticide equals the new value of the ratio between pesticide price and soybean price.

The level of pest attack shows a significant effect on the increase of pesticide demand. This is still consistent with the IPM concept that pesticide will be applied when serious pest attacks exist. The analysis by using recursive demand model has a consistent result with that of using simultaneous demand model in term of the effect IPM on soybean demand. Dissemination of IPM technology has significantly reduced the amount of pesticide use. It implies that the introduction of IPM has a positive impact on pesticide use reduction in soybean farming. This is interesting because although IPM Farmer's Field School (FFS) for soybean cover only small portion of the area, however FFS for rice has been widely adopted by most of the farmers in this study area. In addition, rice farmers who joined FFS grow soybean too in their land.

Conclusion

By using simultaneous demand equation it is found that the IPM technology indirectly reduce the application of pesticide, as this technology is able to reduce the intensity of pest attack. Price of pesticide significantly reduces the amount of pesticide use in soybean farming as expected. However, the application of pesticide will increase as the planted area of soybean increase.

The analysis by using recursive demand model has a consistent result with that of using simultaneous demand model in term of the effect IPM on soybean demand. Dissemination of IPM technology has significantly reduced the amount of pesticide use, which implies that the introduction of IPM has a positive impact on pesticide use reduction in soybean farming. Although IPM Farmer's Field School (FFS) for soybean cover only small portion of the area, however IPM FFS for rice has been widely adopted by most of the farmers in this study area let alone rice farmers who joined FFS grow soybean too in their land.

The price of pesticide (a ratio of price of pesticide to price of soybean) has a significant effect in reducing the demand for pesticide, which is theoretically justified. This means that as marginal product of pesticide declines if the price of pesticide goes up it will be responded by reducing the amount of pesticide used in farming when the marginal product of pesticide equals the new value of the ratio between pesticide price and soybean price.

The study found that the IPM program has reduced significantly the use of pesticides in soybean farming in Yogyakarta from 1990 up to 1998. The positive impact of IPM program in reducing the pesticide demand is due to two important aspect of the program, namely the elimination of pesticide subsidy and the introduction of IPM technology.

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Integrated Pest Management program, pesticide use and rice productivity: A case study in Yogyakarta, Indonesia

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Abstract

IPM has been regarded as soft and friendly technology that provides not only financial benefits received by the farmers but more importantly environmental benefits for the whole society. Therefore, in view of sustainable development IPM program was introduced in 1989 as one of the important agricultural development strategy in Indonesia. The objectives of the study are (a) to analyze the relationship between pest attack, pesticide use and crop loss, (b) to study the impact of the IPM program on the use of pesticide, (c) to see the impact of the IPM program on the rice productivity. Farm survey data of the consecutive seasons of the year 2000/2001 were collected through field survey conducted in two villages of Moyudan sub-district in Yogyakarta province. For this purpose sixty rice farmers were interviewed. The study noted three important findings. First, the farmers in Yogyakarta still apply pesticide as an important measure of the crop protection. Second, the IPM program has successfully reduced the application of pesticides. Third, the rice yield of the IPM-trained farmers is higher than that of non IPM-trained farmers although statistically not significant.

Introduction

One of the key successes of the intensification program in Indonesia is the substantial increase of rice production because of the increase in crop yield through intensive use of inputs including chemical pesticides. The role of pesticides is to reduce the crop loss due to the pest and disease attacks. For this purpose, mass introduction program of pesticides was done intensively following the Green Revolution movement in Asia. Therefore, it is not surprising that the application of pesticide during the period of 1970s and 1980s has increased substantially contributed by incredible amount of subsidy (Irham & Mariyono 2002) which leads to the fact that the farmers in Indonesia have been accustomed in using chemical pesticides.

The green revolution has changed the notion of the farmers in such a way that the application of chemical pesticides in rice farming has been regarded as the best way to cope with the risk of crop loss caused by pest and disease attacks. The existence of production risks in rice has influenced the behavior of the farmers in deciding the inputs to be used and regarded pesticide as a guarantee in securing their crop production. However, most of the researchers believe that with indiscriminate use of pesticides and increasing application leads to a number of consequences such as elimination of natural predators, resistance of pests on the pesticides, frequent pest outbreaks, etc. so that crop losses increase (Saha et al. 1997; Harper & Zilberman 1989; Zilberman & Castillo 1994).

Due to the serious problems caused by pesticides application, , IPM program was introduced in order not only to reduce the amount of money spent for pesticides but also to save the agricultural environment due to considerable negative effects (see Harper and Zilberman 1992; Crissman et al. 1994; Antle & Pingali 1994; Rola & Pingali 1993). In this case IPM has been regarded as soft and environmentally friendly technology that derives other secondary benefits ranging from financial benefits received by the farmers to important environmental benefits for the society (Lazarus & Swanson 1983). Therefore, for the sake of sustainable development IPM becomes one of the components of agricultural development strategy in Indonesia that has been introduced in 1989.

Two questions can be raised regarding the role of the IPM program. First is whether the IPM program has successfully reduced the use of chemical pesticides considering the disadvantages of their application in agriculture. The study of Irham (2001) in Yogyakarta indicated that the farmers still rely on pesticide in protecting their crops from pest attack no matter if they are IPM-trained farmers or not. There is no significant difference in terms of pesticide application per ha between IPM-trained and non IPM-trained farmers although the dosage applied by both groups is much lower than the recommended one. It seems that the principle of IPM has been widely adopted among the farmers in the study area even though they are not formerly trained in IPM.

The second question is whether the farmers get incentives in adopting the IPM technology in coping with the risk of crop loss. One of the incentives of using pesticide as the last choice in protecting their crops is the guarantee of not loosing their crop yield. At least, the farmers can maintain the current yield with lower costs for pesticide. Studies about the relationship between IPM program and crop yield have been done by International Rice Research Institute (IRRI) taking the case of the Philippines (Rola & Pingali 1993) and by SEARCA (1999) for the case of Indonesia. One of the results was that the IPM-trained farmers produce higher yields compared to those of non IPM-trained farmers. Beside the statistical weakness of both studies, however, experience shows that it seems to be uneasy to change the attitude of the farmers immediately after getting accustomed for more than twenty years of their dependence on pesticides unless there is some incentive to change their habits as mentioned earlier. The result of the study done by Irham (2001) has showed this tendency. Therefore, more studies are needed to provide a better understanding on the impacts of the IPM program. This paper aims at: (a) analyzing the relationship between pest attack, pesticide use and crop loss, (b) the impact of the IPM program on the use of pesticide, (c) finding the impact of the IPM program on the rice productivity.

Study area

Moyudan sub-district was selected as the study area. The sub-district constitutes one of the rice production centers in Yogyakarta province where IPM program has been promoted intensively by the distrct government of Sleman. The area is located in the north west of the city of Yogyakarta. Farmers Field Schools (FFS) have been set up following the introduction of the IPM program.

Data

Farm survey data of the consecutive seasons of the year 2000/2001 were collected through field survey conducted in two villages of Moyudan sub-district. Sixty rice farmers were interviewed during the survey. From the sixty interviewed farmers, thirty of them are IPM-trained farmers while the rest of the samples are Non-IPM trained farmers.

Method of analysis

Cross-table analysis is primarily used to analyze the relationship between pest attack, pesticide use, crop loss and yield of rice. In certain case, a simple statistical test is performed. Using the farm survey data, a similar way of analysis is also carried out to see the impact of IPM program on rice yield. To estimate the level and magnitude of relationship between inputs and yield of rice a regression method is applied.

Yield function is developed in estimating the functional relationship. Pesticide input is used as independent variable to know the effect of pesticide on rice yield. To detect the impact of the IPM program on rice yield a dummy IPM is introduced into the model. The following is the estimated model developed in this study.

$$\ln Y = \ln \alpha + \sum \beta_i \ln X_i + d_1 D\text{-}season_1 + d_2 D\text{-}season_2 + d_3 D_{\text{IPM}} + \varepsilon$$

where Y is yield of rice (kg/ha); X is rice input for $i = 1, 2, ... 8$; $D\text{-}season_1$ and $D\text{-}season_2$ are dummy variables for rainy season and first dry season, respectively; D_{IPM} is dummy IPM (1 for IPM-trained farmers, 0 for non IPM-trained farmers), α and β are coefficients of regressions; and ε are error terms.

Study results

Application of the IPM technology

Before analyzing the impacts of IPM program on pesticide use and yield of rice, understanding the implementation of the IPM technology by the farmers becomes necessary. Table 1 shows that resistant varieties have been adopted either by IPM-trained farmers or non IPM-trained farmers. Both groups of farmers have applied recommended technical culture except for fertilizer application particularly KCl fertilizer. The IPM trained-farmers used much more KCl compared to those of non IPM-trained farmers, which is statistically significant (Table 2). Only few of non IPM-trained farmers use this fertilizer although it has a significant effect in increasing rice productivity (Table 5). One of the possible reasons is that the non IPM-trained farmers still think the necessity of using this fertilizer while its price is a little bit higher compared to other type of fertilizers.

It is important to note that none of the farmers belong to both groups apply crop rotation (Table 1). This becomes the main reason for the high possibility of pest and disease attacks to exist in this area. The study found that during the last 5 years the farmers experienced serious crop damage particularly from rat attack, which now becomes the top dangerous pest in Yogyakarta province.

Table 1 Percentage of farmers who applied IPM technology

Types of Control Application	IPM-trained farmer	Non IPM-trained farmer
	%	%
1. Resistant variety	100	100
2. Technical culture		
a. Land preparation	100	00
b. Sanitation	100	66.7
c. Land idling	100	100
d. Crop rotation	0	0
e. Planting period	100	100
f. Crop distance	100	100
g. Recommended fertilizing	83.3	10
3. Mechanical control (for Rat)		
a. Collective killing ("gropyokan")	100	100
b. Trapping (net)	56.7	20
c. Smoking	66.7	23.3
4. Chemical control		
a. Pesticide	100	100
b. Non pesticide	53.3	0
5. Observation		
a. Every 1-3 days	80	53.3
b. Every 4-7 days	20	33.3
c. Every > 7 days	0	13.3
Grand Average	72	53

Source: Farm Survey, 2001

Table 2 Level of pesticide application and use of other chemical inputs

Types of Inputs	Rainy		Dry 1		Dry 2		One Year		Statistical t-value
	IPM-trained farmer	Non IPM-trained farmer	IPM-trained farmer	Non IPM-trained farmer	IPM-trained farmer	Non IPM-trained farmer	IPM-trained farmer	Non IPM-trained farmer	
Granular pesticide (kg/ha)	0.9	5.6	2.2	3.1	1.0	5.3	1.4	4.6	4.42***
Liquid pesticide (ml/ha)	187.7	335.7	368.0	526.4	164.6	292.5	240.1	384.9	21.65***
Urea (kg/ha)	180.8	170.0	177.6	170.6	174.9	172.4	177.8	171.0	1.29ns
TSP (kg/ha)	100.2	111.2	111.3	113.3	109.3	112.2	106.9	112.2	1.13ns
KCL (kg/ha)	41.0	0.0	41.9	5.5	43.6	0.0	42.2	5.5	5.54***
Seeds (kg/ha)	41.2	43.0	51.0	45.3	48.9	46.7	47.0	45.0	1.30ns

Source: Farm Survey, 2001 Note: *** = significant at 1% level

The study also found that IPM-trained farmers applied more mechanical pest control compared to that of non IPM-trained farmers particularly for rat control by using trap (net) and sulphur smoke. IPM-trained farmers also apply non-pesticide material such as salt and ashes although the effectiveness of such measures is still questionable.
One of the distinct different between both groups is that the IPM-trained farmers have better observation on their crops condition compared to that of non IPM-trained farmers. This is one of the successful achievements of the IPM Farmers Field School program in this study area.

The impact of IPM on pesticide use and rice yield

The study observed that the farmers in the study area still apply pesticide as an important measure in protecting their crops. However, the success of IPM program in reducing the application of pesticide is obvious. Table 2 proves that IPM-trained farmers apply pesticide (both granular and liquid pesticides) much lower compared to that of non IPM-trained farmers, and statistically significant.

Although both groups apply pesticide for their crop protection, their philosophy of using them is different. Most of IPM-trained farmers use pesticides only when pest attack exists, and only few of them use pesticide for preventive motive. This is understandable as they received the IPM principle in the training school. On the other hand, most of the non IPM-trained farmers regarded pesticide as a preventive measure regardless the level of pest attack although some of them apply pesticides only when severe pest attack exist.

Table 3 Farmers reasons of using pesticides (%)

Types Reason	IPM-trained farmer	Non IPM-trained farmer
Pest attack exist	66.7	40.0
Preventive motive	16.7	50.0
High yield motive	10.0	16.7
Neighbors' influence	6.7	10.0

Source: Farm Survey, 2001

Table 4 Rice yield, pest attack and crop loss

Items	Rainy		Dry 1		Dry 2		One year	
	IPM-trained farmer	Non IPM-trained farmer	IPM-trained farmer	Non IPM-trained farmer	IPM-trained farmer	Non IPM-trained farmer	IPM-trained farmer	Non IPM-trained farmer
Rice yield (kg/ha)	3611	3258	3673	3306	3865	3532	3717	3365
Pest attack (%)	21.5	29.6	25.6	26.1	20.5	25.5	23.0	27.0
Crop loss (kg/ha)	1848	2276	1749	2228	1469	2002	1688	2169

Source: Farm Survey, 2000

The study found that pest attack experienced by IPM-trained farmers is lower than that of non IPM-trained farmers. Although statistically insignificant, it proves that with a significant difference in terms of pesticide used by the two groups, it is fair to say that higher application of pesticide does not guarantee a lower pest attack (Table 4). It seems that the higher rate of pesticide application tends to increase the level of pest attack instead. Although the crops loss and rice yield between the IPM-trained and non IPM-trained farmers are not statistically different, this study found that the rice yield of the IPM-trained farmers is still higher compared with those of non IPM-trained farmers (Table 5). This finding suggest that IPM program shows its superiority in reducing the application of pesticides with out sacrificing the level of production in fact increase the production although statistically insignificant.

Table 5 Regression results of productivity function

Variables	Estimated results

	Coefficients	t-value
Intercept	7.6131***	14.732
LnUrea	0.0158	0.212
LnTSP	-0.0046	-0.071
LnKCL	0.0037*	1.507
LnSeed	0.0411	0.599
LnGranpest	-0.0042*	-1.371
LnLiqpest	0.0203	0.925
LnLabor	0.1001**	2.112
LnPestattack	-0.0683***	-2.429
Dummy IPM	0.0253	0.785
Dummy Season1	0.0154	0.461
Dummy Season2	0.0497*	1.447
R^2	0.1518	
F-value	2.732***	

Note : *** = Significant at 1 % ** = Significant at 5 % * = Significant at 10 %

Conclusion

By using the farm survey data the study found that during the last 5 years the farmers experienced severe crop damages mainly from rats attack as now become the most dangerous pest in Yogyakarta province. The study also noted that more IPM-trained farmers have tried to apply traditional non-pesticide pest control such as salt and ashes. One of the successful achievements of the IPM program in the study area is that the IPM-trained farmers have better observation on their crops condition compared to those of non IPM-trained farmers.

The study found that the farmers in the study area still apply pesticide as an important way of crop protection. The IPM program has successfully reduced the application of pesticide in Yogyakarta province. This result is consistent with the previous study conducted by Irham (2000). Although the rice yield between the IPM-trained and non IPM-trained farmers are not statistically different, the rice yield of the former farmers is higher than those of the latter farmers.

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Hydrological and meteorological components in the integrated pesticide management project at Jaisidhi Khola, Tinpiple

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Abstract

Study on hydrological and meteorological aspects of the research catchment at Jaishidi, Tinpiple in Kabhre district is one of the major activities of the Integrated Pesticide Management (IPM) project in Nepal. Pesticides used on crops and vegetables are washed by rain. Part of the rainfall directly flows to rivers and part infiltrates into the soil to replenish the soil moisture reservoir and some part may percolate the ground water also. In this way the surface runoff and the groundwater is polluted by use of pesticides on crops and vegetables. Hydrological and meteorological parameters of the study area are, therefore, collected extensively to evaluate the level of pollution of topsoil, surface water and groundwater.

The primary aim of this paper is to characterize the climatological and hydrological parameters of the Jaishidi catchment. The surface and groundwater of the Jaishidi catchment having 111 ha are polluted in Bari land and Khet land. Stream flows are collected from Jaishidi Khola and Khet stream at Tinpiple for comparing the surface water pollution from Bari and Khet land respectively. Stream water and well water samples are collected from the catchment at 5 and 16 sites respectively. Likewise, two full-fledged climatological stations, one at Bari land and another at the Khet land are installed.

Farmers are using irrigated water diverted from the Danfe Khola, which flows in the adjacent catchment, to fulfil the water for winter crops. Diverted flow from Danfe Khola to the Jaishidi catchment is gauged and of considerable volume, which is contributing in pollution of topsoil and subsurface water of the catchment. Farmers from the Jaishidi catchment and the neighbouring area are using springs for drinking water and the local wells for domestic purpose.

Introduction

Integrated pesticide management in Nepal is implemented in two sub watersheds of Jhikhu khola. Khet land and Bari land are two sub-watersheds, which cover 111 ha in total. It is a research project primarily focused on study of effect of pesticides in the environment and formulation of decision support system for pesticide reduction measures. The Department of Hydrology and Meteorology (DHM) of His Majesty's Government of Nepal is responsible for installation, observation, supervision and processing of hydro-meteorological data of the two watersheds.

Objective

The main objective of the hydrological and meteorological component is to provide adequate hydrological and climatological data for assessment of pesticides in surface and subsurface, and provide the hydrological and climatological information of the study area to the users.

Hydrological and meteorological activities in the project

Dilution process of the surplus amount of excessively applied pesticide on agriculture during winter occurs mainly during the monsoon (June-September). In dilution process, a part of excessive pesticide is diluted with the surface runoff and a part percolates into shallow and deep water tables. Therefore, for the study of surface and subsurface flow, which control transport and storage of pesticides, field measurements and detailed study of hydrology and meteorology of the study area are important.

Observation Network

Two hydrometric stations, one at Bari land (rainfed) sub-watershed and another at Khet land (irrigated) sub-watershed were established to collect the hydrometric data. Each station contains V- notch weir for flow measurement and staff gauges and pressure transducer for water level recording. Khet land station has also a floater as an additional water level recorder. A gauging station with weir and staff gauges was also established at an irrigation channel, which diverts flow from the other watershed, the Danfe Khola. This channel is intensively used for irrigation when the flow in the study watershed becomes almost nil. Flow measurements have been carried out at Bari land and Khet land gauging sites during the monsoon period of 1999 and 2000. Some flood events could not be measured as the floods occurred during the nighttime. Mostly the big events occur during nighttime.

Two full-fledged climatological stations, one at the Bari land and another at the Khet land are operated. It includes the parameters like air temperature at 2m height from ground level, manual and automatic rain gauge, incoming solar radiation and net radiation, wind speed and wind direction at 3 m from ground level, soil temperature at 5cm, 10cm, 20cm and 50 cm depth and evaporation from class A pan. The frequency of visit to the climatic stations is once a week in order to maintain the data logger smoothly and accurately running. Replacement of Silica Gel, Batteries for data logger and EPROMS is usually done once a month.

Stream water at 5 locations and well water samples at 16 locations are collected from the catchment at Tinpiple to monitor the inter connection of water quality between the surface and groundwater as well as degradation of water quality due to pesticide applied in crop lands. Likewise 2 streams (Jhikhu Khola and Kubinde Khola) and 21 observation wells at Tamaghat were monitored to find out quantity of pesticide infiltrated to ground water. The frequency of observation in these sites is at least once a week. The volume of sampling is normally 60ml or 125ml for weekly and 500ml in each quarter a year.

Data processing

High flow measurements and establishment of stage discharge relationship and calibration of weirs are completed for the year 2000. Staff gauge data and water level chart have been completely processed. Weekly weather reports from two climatic stations, Bari land and Khet land, have also been processed. Similarly, details of information from the observation wells have been prepared.

Insufficient data caused problem in establishing rating curves. Some peak flow measurement could not be done as the flood event occurred during nighttime.
The rating curves are established with measured data and some theoretical coefficients.

Findings

The following are the findings of the hydro-meteorological activities:

- The streams are non-perennial and flashy in nature.
- Because of the availability of less data statistical analysis was not possible. Limited analysis could be done from the available data.
- Precipitation: The annual precipitation in Bari land is 1107 mm for the year 2000, having a maximum intensity of 25.2 mm/hr on July 24 (Figure 1a.). Likewise annual precipitation received in Khet land is 1170 mm with a maximum Intensity of 18.5 mm/hr July 21 (Figure 1b). The long-term average (1976 to 2000) precipitation at

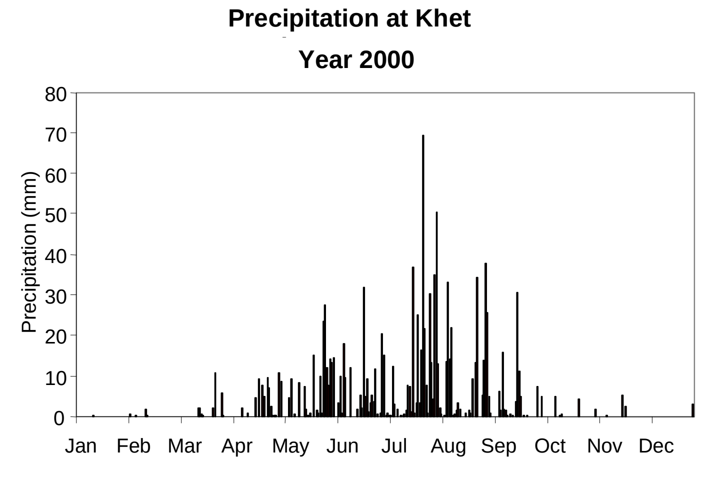


Fig. 1(a)

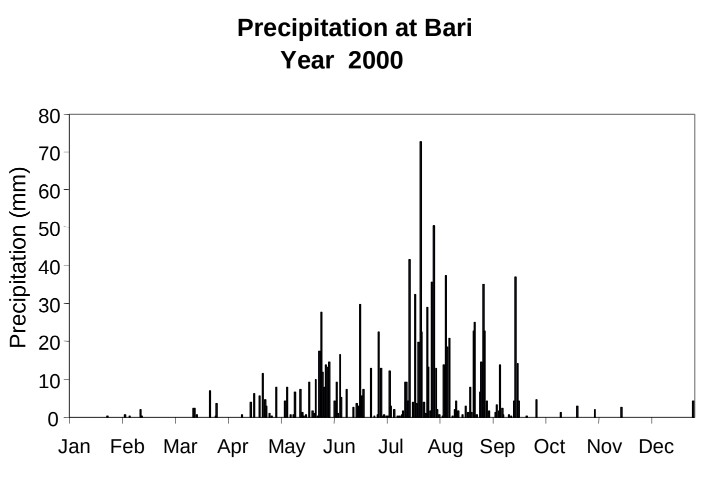


Fig. 1(b)

Fig. 1 (a) Monthly precipitation of Khet land and **(b)** Bari land in 2000

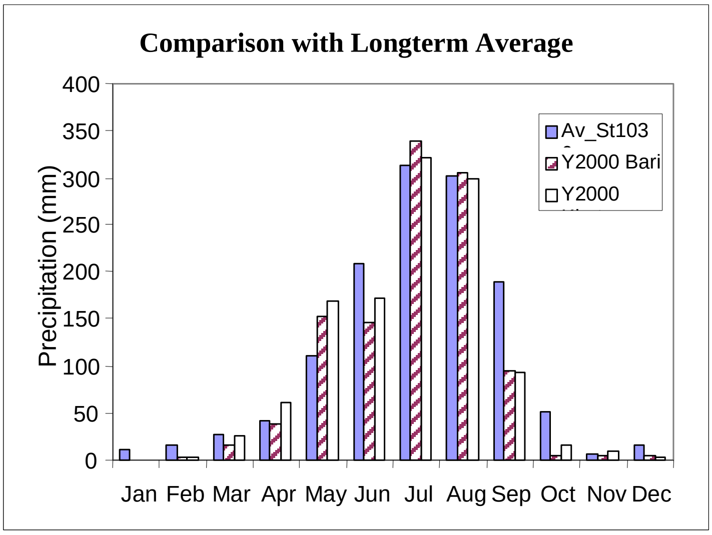


Fig. 2 Comparison of monthly precipitation in 2000 with longterm precipitation

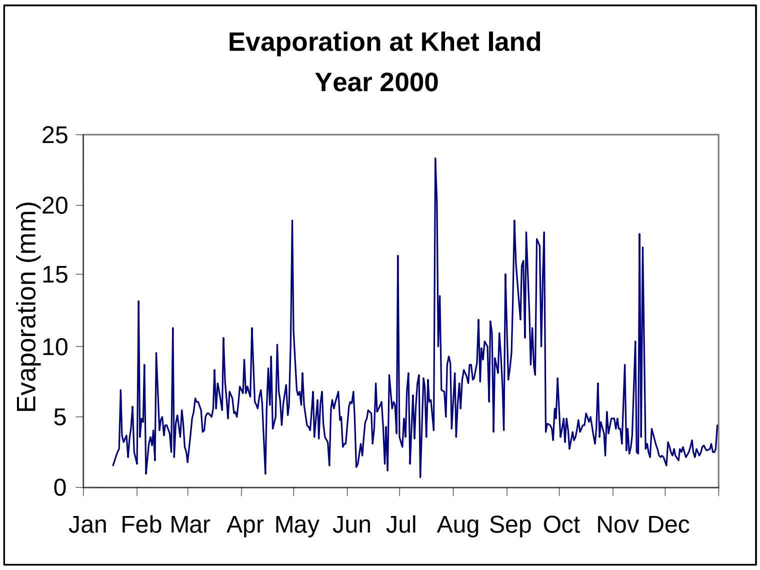


Fig. 3 Evaporation at Khet land in 2000

Tamaghat Horticulture farm is 1276 mm (Figure 2) (DHM, 1982; 1984; 1986; 1988; 1992; 1997 and 1999).

- Evaporation: Total pan evaporation is 2120 mm in year 2000. (Fig.3)
- Air temperature: The year 2000 is less warm than the long-term average temperature (Figure 4 (a) and 4 (b)).

  The extreme temperatures in 2000 were:

  Maximum = 35.3 ^{o}C (2 April)

  Minimum = 2.2 ^{o}C (17 January)

  The study area is warmer and dryer than the Kathmandu valley.

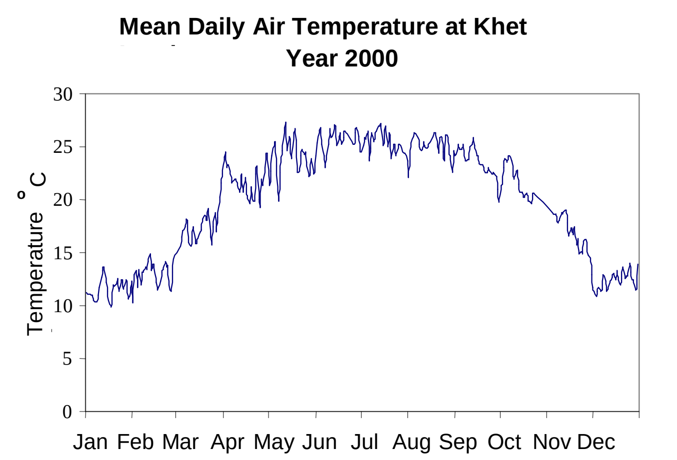


Fig. 4 (a)

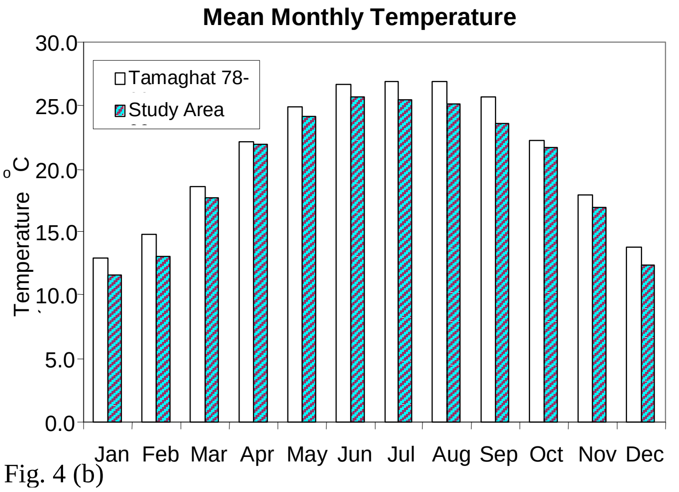
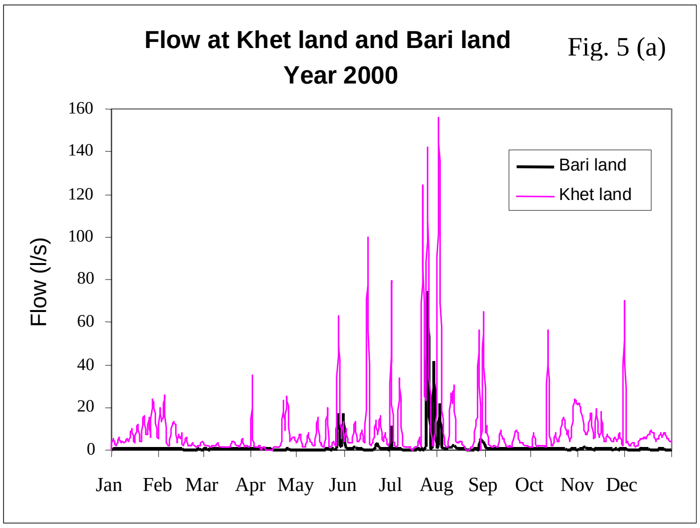


Fig. 4 (b)

Fig. 4 (a) Air temperature in 2000 and **(b)** Comparison of monthly air temperature in 2000 with longterm temperature at Tamaghat.



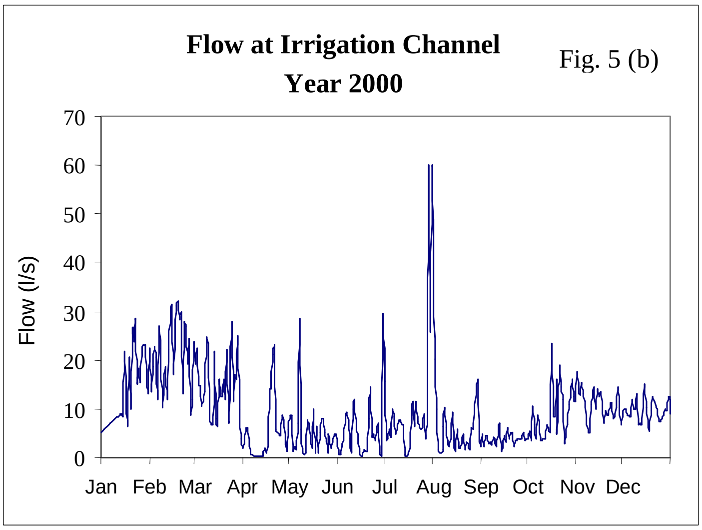


Fig. 5 (a) Flow at Khet land and Bari land in 2000 **(b)** Flow at irrigation channel in 2000

- Runoff at Khet land, Bari land and irrigation channel is presented in figure 5 (a) and 5 (b).
- The result shows that slow the dilution process last long the contaminants. Sampling the surface runoff and gauging the flow in streams and irrigation channel help to find water balance and periodic changes in water qualities.

Conclusions

The year 2000 is found to be climatologically representative.

The Rating Curve of the gauging sites should be improved in case of continuation of post project monitoring activities.

Some hydrological event model can be run with the hydrological and climatological data collected during research period.

Hydrological and climatological data are adequate for preliminary assessments of pesticides.

The findings of this paper can be used as supplementary information of hydrological and meteorological phenomena for the farming purpose.

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Use of insecticides in Nepal

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Abstract

The use of insecticides has been increasing in Nepal. Present paper aims to assess the spatial dimensions of the use pattern of insecticides in the country. This paper is based on available secondary information. The results show that the use of insecticides varies with types of crop grown, biophysical condition and access to service infrastructures such as roads and market towns. The use of insecticides in terms of number of holdings is comparatively higher in sugarcane, paddy and potato, in Tarai districts located in subtropical zone and the hills with better access to market and other service infrastructures.

Introduction

Modern chemical pesticides were first introduced in Nepal in 1955. Though present use of pesticides in Nepal is not so high as compared to other countries in Asia, it has been increasing in recent decades (Dahal 1995). Chemical pesticides are used in Nepal for agricultural crops to control vector diseases and also for domestic use to control household pests. Sometimes, it is also used for fishing.

The use of pesticides in the country is likely to grow in the future. In order to meet increasing food demand in the country, it is necessary to increase present level of production of agricultural crops. To some extent, it is possible through the protection of plant and crops from diseases and pests by using pesticides. But inappropriate use and handling of pesticides without appropriate knowledge results in several human health and environmental problems. Such problems have already been noticed in different parts of Nepal. Ignorance on selection, storage and handling of pesticides among many of the farm families on the one hand and tendency to use highly toxic pesticides for immediate effect on the other have exacerbated such problems (Klarman 1987, Dahal 1995). Moreover, inaccessibility and unavailability of adequate service infrastructures such as health have caused poor response among affected families to cope with the impacts of pesticides use. Proper understanding of the use of pesticides at different spatial scale and planning and administrative units is necessary so that immediate actions could be taken in problematic areas. It is in this context, present paper aims to assess the use pattern of insecticides in Nepal.

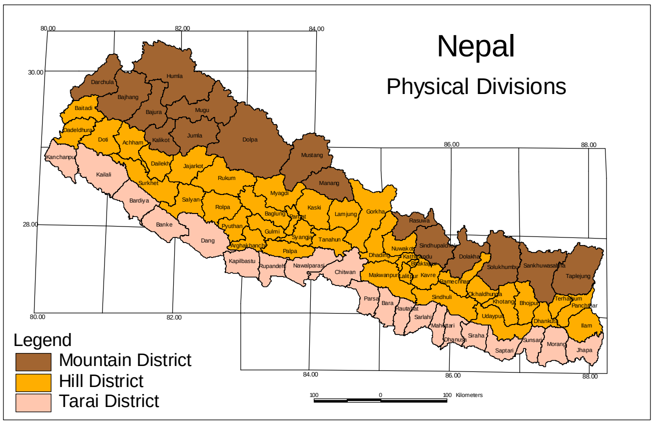
Methods and materials

This paper is based on available secondary information on the use of insecticides in the country. Central Bureau of Statistics (CBS), National Planning Commission, His Majesty Government of Nepal has published data on National Sample Census of Agriculture carried out in 1991/92. It contains district wise information on the number of holdings using different types of agricultural inputs including insecticides. Number of household using insecticides has been reported for major crops grown in the country. These include paddy, maize, wheat, potato, vegetables and sugarcane. Based upon this information, spatial dimensions of the use of insecticides in the country have been assessed and analysed.

Results and discussions

Nepal is divided into 75 administrative districts and three major ecological zones - Tarai, hills and mountains. Tarai is the northern extension of the Indo-Gangetic plain, which is very fertile and accessible as compared to the hills and mountains. Large areas in the hills and mountains are still inaccessible and it takes more than nine days walk to reach from road heads and major market centres. Though district boundary does not exactly match with the ecological boundary, the government has divided these districts into these three zones. Government's definition has been followed in this paper. Fig. 1 shows the location of districts

Fig. 1 Districts of Nepal by ecological zones



by ecological zones.

Table 1 shows total number of reported holdings growing paddy and the number of holdings using insecticides. Out of total holdings growing paddy, only 13.3 percent holdings use insecticides in paddy crop. Percentage of holdings using insecticides decreases from Tarai in the south to the hills and mountains in the north. It is 20.9 percent in the Tarai, 7.3 percent in the hills and 1.4 percent in the mountains. District wise percentage of holdings using insecticides in paddy is shown in Fig. 2. It shows that the percentage of holdings using insecticides in paddy is comparatively very high in districts located in central Tarai and Kathmandu valley, which are highly accessible to major market centres.

Table 1 Number and percentage of holdings using insecticides in paddy crop

Ecological regions	Total number of holding	Holdings reported		Holding using insecticides	
		Number	Percent	Number	Percent
Mountain	211391	143165	67.7	2056	1.4
Hill	1407077	928529	66.0	68062	7.3
Tarai	1117618	953330	85.3	199302	20.9
Total	2736086	2025024	74.0	269420	13.3

Source: CBS (1994)

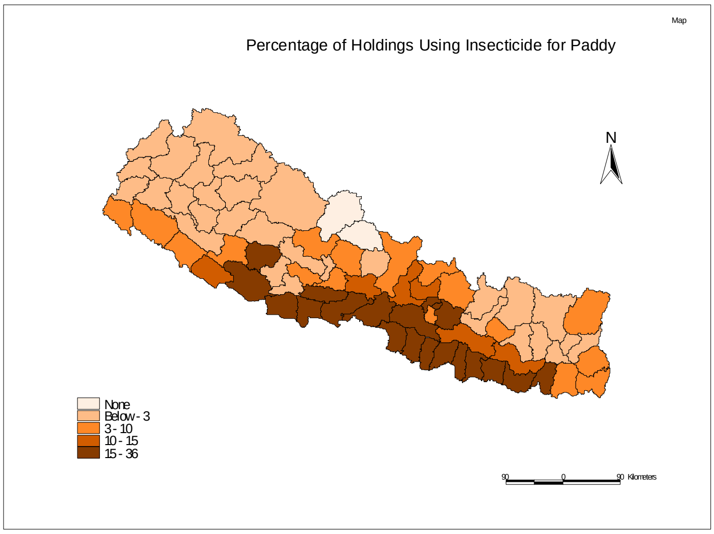


Fig. 2 Percentage of holdings using insecticides for growing paddy

Table 2 shows total number of reported holdings growing maize and the number of holdings using insecticides. Percentage of holdings using insecticides in maize is very low. Only 2.5 percent of the total maize growing holdings use insecticides. This percentage is comparatively very high in the Tarai (5.5 percent) as compared to hill (2.1 percent) and mountain (0.5 percent) districts. District wise percentage of holdings using insecticides is shown in Fig. 3. It shows that the Tarai and hill districts located in central part of the country have comparatively higher percentage of holdings using pesticides in maize.

Table 2 Number and percentage of holdings using insecticides in maize crop

Ecological regions	Total number of holding	Holdings reported		Holding using insecticides	
		Number	Percent	Number	Percent
Mountain	211391	177391	83.9	875	0.5
Hill	1407077	1407077	100.0	32113	2.1
Tarai	1117618	355244	31.8	19374	5.5
Total	2736086	2081375	76.1	52362	2.5

Source: CBS (1994)

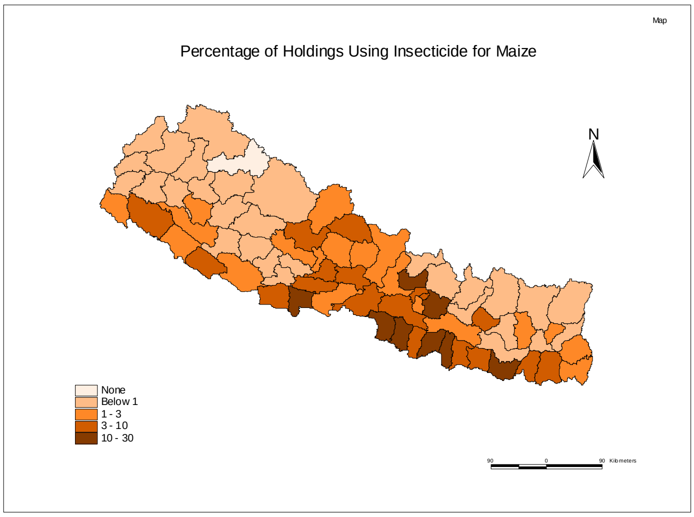


Fig. 3 Percentage of households using insecticides for growing maize

Table 3 shows total number of reported holdings growing wheat and the number of holdings using insecticides. About 5 percent holdings growing wheat use insecticides in the country. It is higher in Tarai as compared to the hills and mountains. Fig. 4 shows the percentage of holdings using insecticides in districts. Again the percentage of holdings using insecticides is higher in the central part of the country.

Table 3 Number and percentage of holdings using insecticides in wheat crop

Ecological regions	Total number of holding	Holdings reported		Holding using insecticides	
		Number	Percent	Number	Percent
Mountain	211391	155257	73.5	1152	0.7
Hill	1407077	784803	55.8	26899	3.4
Tarai	1117618	696426	62.3	55909	8.0
Total	2736086	1636486	59.8	83960	5.1

Source: CBS (1994)

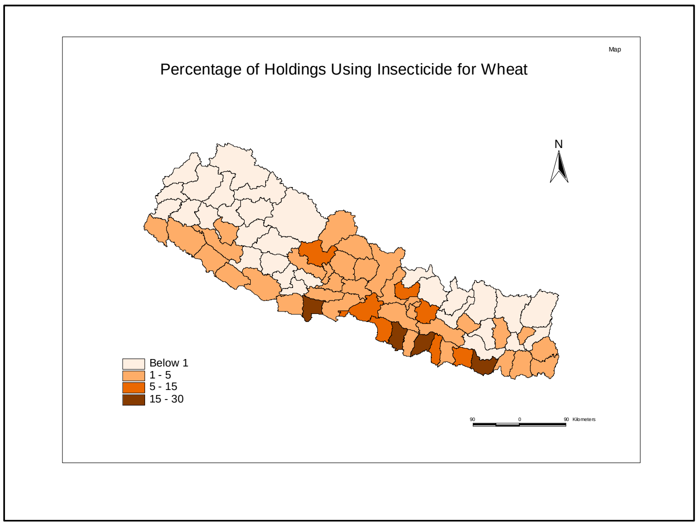


Fig. 4 Percentage of households using pesticides fro growing wheat

Table 4 shows total number of reported holdings growing potato and the number of holdings using insecticides. About 11 percent of the total holdings growing potato use insecticides and its percentage is comparatively very high in the Tarai as compared to hill and mountain districts.

Fig. 5 shows the percentage of holdings using insecticides in potato in different districts of Nepal. It shows that the Tarai and the hill districts located in the central part of the country have comparatively higher percentage of holdings using insecticides.

Table 4 Number and percentage of holdings using insecticides in potato crop

Ecological regions	Total number of holding	Holdings reported		Holding using insecticides	
		Number	Percent	Number	Percent
Mountain	211391	91902	43.5	463	0.5
Hill	1407077	317406	22.6	24185	7.6
Tarai	1117618	326746	29.2	55214	16.9
Total	2736086	736054	26.9	79862	10.9

Source: CBS (1994)

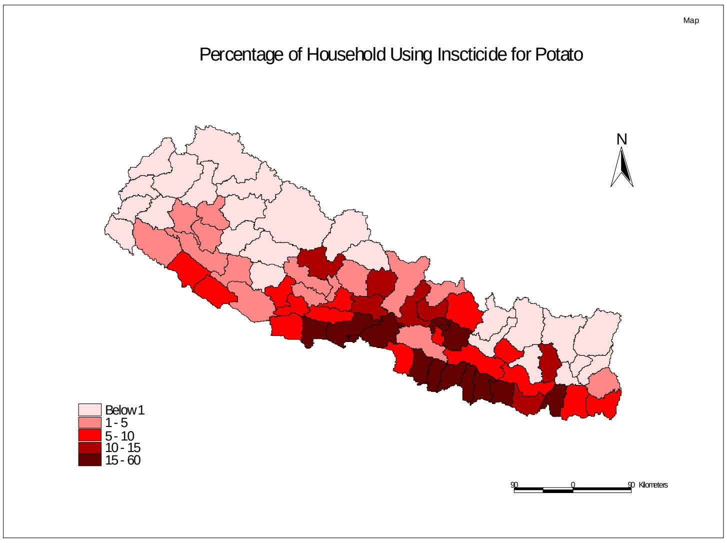


Fig. 5 Percentage of households using pesticides for growing potato

Table 5 shows total number of reported holdings growing vegetables and the number of holdings using insecticides. About 7 percent of the total holdings growing vegetables use insecticides and its percentage is comparatively very high in the Tarai as compared to hill and mountain districts. Fig. 6 shows the percentage of holdings using insecticides in vegetables in the districts of Nepal. It shows that the Tarai and the hill districts located in the central part of the country have comparatively higher percentage of holdings using insecticides.

Table 5 Number and percentage of holdings using insecticides in vegetables

Ecological regions	Total number of holding	Holdings reported		Holding using insecticides	
		Number	Percent	Number	Percent
Mountain	211391	68578	32.4	416	0.6
Hill	1407077	377501	26.8	15740	4.2
Tarai	1117618	319976	28.6	38043	11.9
Total	2736086	766055	28.0	54199	7.1

Source: CBS (1994)

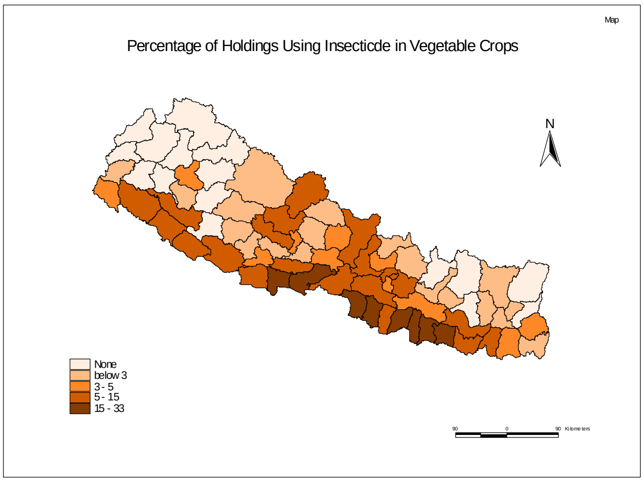


Fig. 6 Percentage of households using pesticides for growing crops

Table 6 shows total number of reported holdings growing sugarcane and the number of holdings using insecticides. About 24 percent of the total holdings growing sugarcane use insecticides. The percentage of holdings using insecticides is relatively high in Tarai in comparison to hill and mountain districts. District wise percentage of holdings using insecticides is given in Fig. 7. Again, the percentage of holdings using insecticides is higher in the Tarai and hill districts in the central part of the country.

Table 6 Number and percentage of holdings using insecticides in sugarcane

Ecological regions	Total number of holding	Holdings reported		Holding using insecticides	
		Number	Percent	Number	Percent
Mountain	211391	2000	1.0	65	3.3
Hill	1407077	13178	0.9	216	1.6
Tarai	1117618	67411	6.0	19167	28.4
Total	2736086	82589	3.0	19448	23.6

Source: CBS (1994)

Figure 7

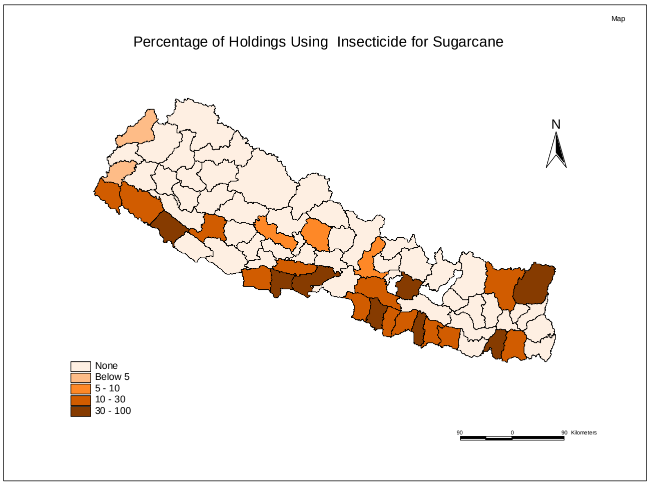


Fig. 7 Percentage of households using pesticides for growing sugarcane

Conclusion

This study shows that the use of insecticides in terms of the number of holdings is comparatively high in crops like sugarcane (23.6 percent) followed by paddy (13.3 percent), potato (10.9 percent) and vegetables (7.1 percent) in the country. The use of insecticides seems to be more in the cash crops such as sugarcane, paddy, potato and vegetables. The percentage of holdings using insecticides is comparatively high in central part of the country including Kathmandu valley where access to road and market towns is easy. Very few holdings are using insecticides in mountain districts. It is mainly due to the fact that these districts are inaccessible and the occurrence of pests and diseases in high altitude area is comparatively low. In the absence of information, it is not possible to discuss use intensity and handling of insecticides and its impact in the country as a whole, and this is very essential for the sustained economic and environmental development. However, studies carried out in many parts of the country shows that many environment and health related problems have already been noticed due to misuse of chemical insecticides in the country. Further works on impact assessment are needed.

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Pesticides in soils - Experimental design of laboratory, lysimeter and field studies

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Abstract

The application of plant protection products is inevitably accompanied by a temporary soil contamination (Fig. 1). This impact on soil quality is only acceptable when pesticide residues are subsequently eliminated by microbial and chemical degradation processes. Before pesticides are frequently applied in agricultural production, their environmental fate and behaviour have to be assessed in the frame of the registration procedure in Germany. Considering the state of scientific knowledge, a risk/benefit analysis has to be performed focused on a multistep control concept with sequential laboratory, lysimeter and field studies. Furthermore, the same experimental approaches are consequently applied in post-registration monitoring programmes to study long-term effects of pesticides´ applications.

Sorption

Sorption and degradation are the main concentration determining processes for pesticides in soils (Kreuzig 1998). On the one hand, chemical and microbial degradation and mineralisation lead to the elimination of parent compounds applied and corresponding metabolites formed (BBA 1986a). On the other hand, sorption processes determine the availability of these xenobiotics in the soil solution. Subsequently, pesticide residues occurring in the soil solution may underly leaching and transport into deeper soil horizons and into aquifers by saturated and unsaturated water flow, respectively. A relevant mobility of pesticides could be given when the soil/water coefficients are K_d<5, K_{OC}<300, the solubility is >30 mg/L and the disappearance time of 50 % of the amount initially applied is DT_{50}> 14 days (Fichter & Holden 1992).

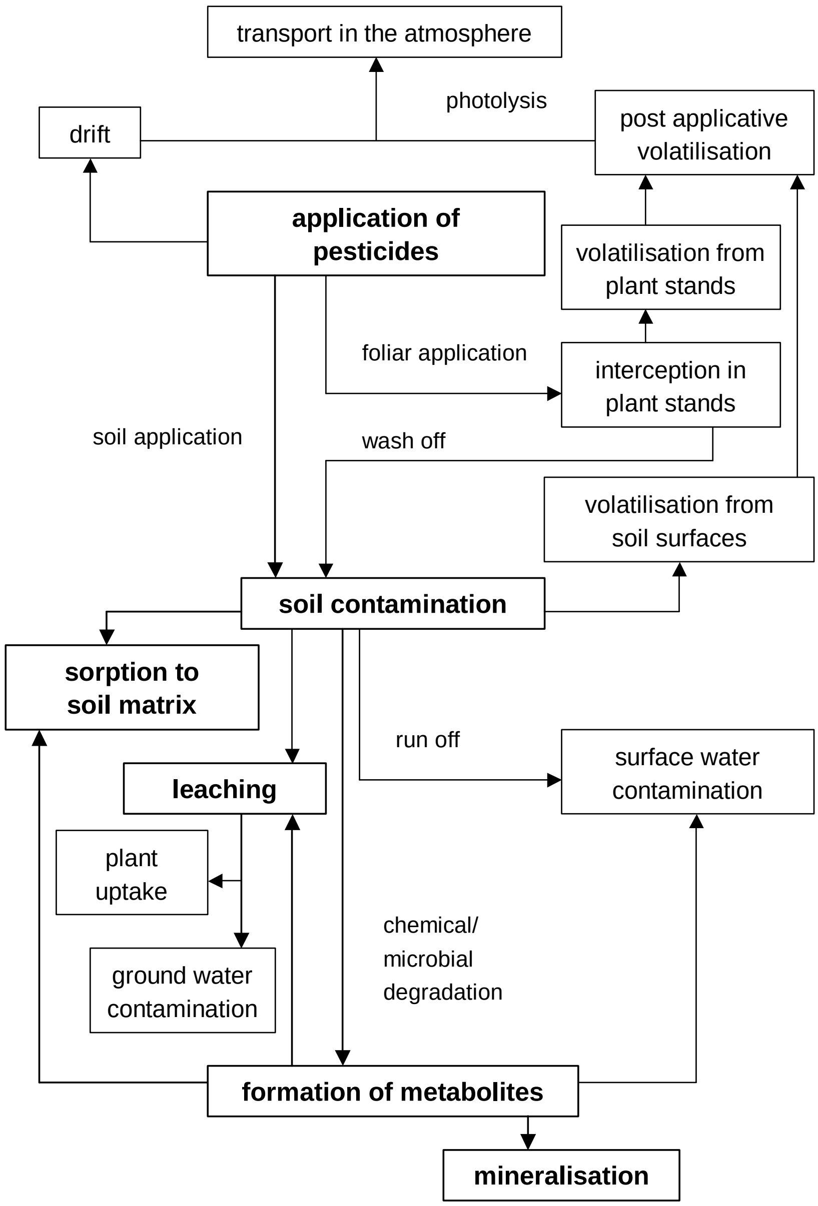
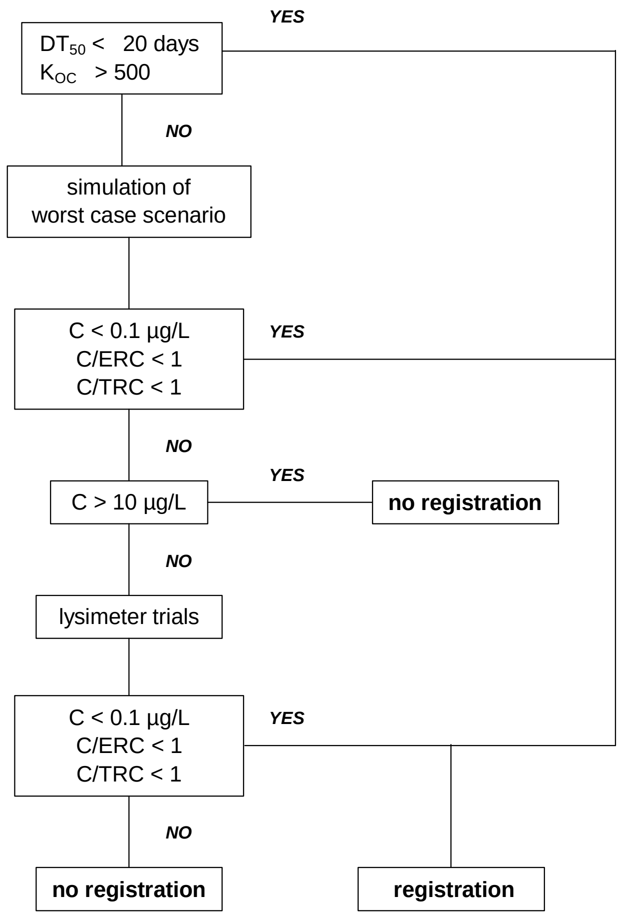


Fig. 1 Fate and behaviour of pesticides in agro-ecosystems (Kreuzig 1998)

K_d and K_{OC} values

Therefore, mobility and leaching of pesticides have to be assessed defining threshold values for YES/NO decisions (Fig. 2). The basis of testing concept I is defined as DT_{50}<20 days and K_{OC}>500 (Kloskowski et al. 1992a). This means that only compounds with high disappearance rates and slight to high sorption tendencies can be directly registrated without the performance of additional leaching tests. Particularly considering that high sorption tendencies are attended by low pesticides´ concentrations in the soil solution, high K_{OC} values should exclude low DT_{50} values. According to this, both threshold values are closely correlated to each other and nearly every pesiticide has to be tested.

Following the NO decision, pesticide concentration, environmentally and toxicologically relevant concentrations, the latter ones are approximately matching PEC/PNEC approaches (BBA 1998, Kratz et al. 2000), has to be assessed by the simulation of worst case scenario. In principle, the pesticides concentration in the soil solution has to fall below the environmentally and toxicologically relevant concentrations to impede adverse effects on algae, bacteria, daphnia, fishes and higher plants as well as on man and domestic animals, respectively. If a concentration of C>10 µg/L would be exceeded, lysimeter trails have subsequently to be performed with special respect to ground water contamination (BBA 1990).



C = concentration (~ PEC: predicted environmental concentration)
ERC = environmentally relevant concentration (~ PNEC: predicted no effect concentration)
TRC = toxicologically relevant concentration (~ PNEC)

Fig. 2 Testing concept I on mobility and leaching of pesticides (Kloskowski et al. 1992a)

The experimental determination of K_d values according to the OECD guideline 106 "adsorption/desorption" shows substance and soil specific differences (OECD, 1981). For the morpholine fungicides fenpropimorph and aldimorph and their primary metabolites fenpropimorphic acid and aldimorph-C_{12}-alcohol, K_d values illustrate higher sorption tendencies for the alkyl substituted morpholine than for the phenyl substituted one and for both metabolites in contrast to the parent compounds reflecting differences in polarity. Particularly the K_d values of 0.5 and 1 for fenpropimorphic acid in silty sand and clayey silt soil reveal high mobility and leaching potential (Stockmaier et al. 1996, Stockmaier et al. 1997).

Soil column experiments

As shown in Fig. 3, testing concept II is targeted on pesticides of higher persistence and focused on soil column experiments under worst case conditions, i.e. disturbed soil sample and saturated water flow (BBA 1986b). If the threshold value of DT_{90} > 100 days is exceeded or not, amounts of 5 % or 10 % of the parent compound or corresponding metabolites, respectively, are allowed to occur in the percolate. If these limits are exceeded, column tests with "aged" residues have to be incorporated into this test scheme in order to control the availibility reducing impact of sorption. If aged residues occur in the percolate in amounts of >2 %, lysimeter trials have to be subsequently performed following testing concept I.

As examplified in the soil column experiment applying fenpropimorphic acid, the K_d value of 0.5 do not correspond to a significant percolate contamination. The application rate was 500 µg and 393 mL demineralised water were infiltrated simulating the precipitation of 200 mm. Nevertheless, only 0.1 % of the amount applied was determined in the percolate (Stockmaier et al., 1996). The same result was given for fenpropimorph which was fortified in a parallel experiment. Significant differences were found when the soil samples of the columns were separated into 5-cm soil layers. While the parent compound was remained in the superficial soil layer, the metabolite was distributed within the soil column with maximum concentrations in the 15-20-cm layer. Despite of its high polarity and its low K_d value, the infiltration rates were not high enough for its passage through the soil column and for the percolate contamination.

Lysimeter and field studies

The same tendency was found when lysimeter trials were performed applying a ^{14}C-labelled fenpropimorph formulation (Ebing et al., 1994). Within a period of 56 days, the results of the formation of metabolites and non-extractable residues under laboratory conditions could be confirmed. However, no radioactivity was detected in the percolate although the lysimeters were additionally sprinkled over a period of 4 years.

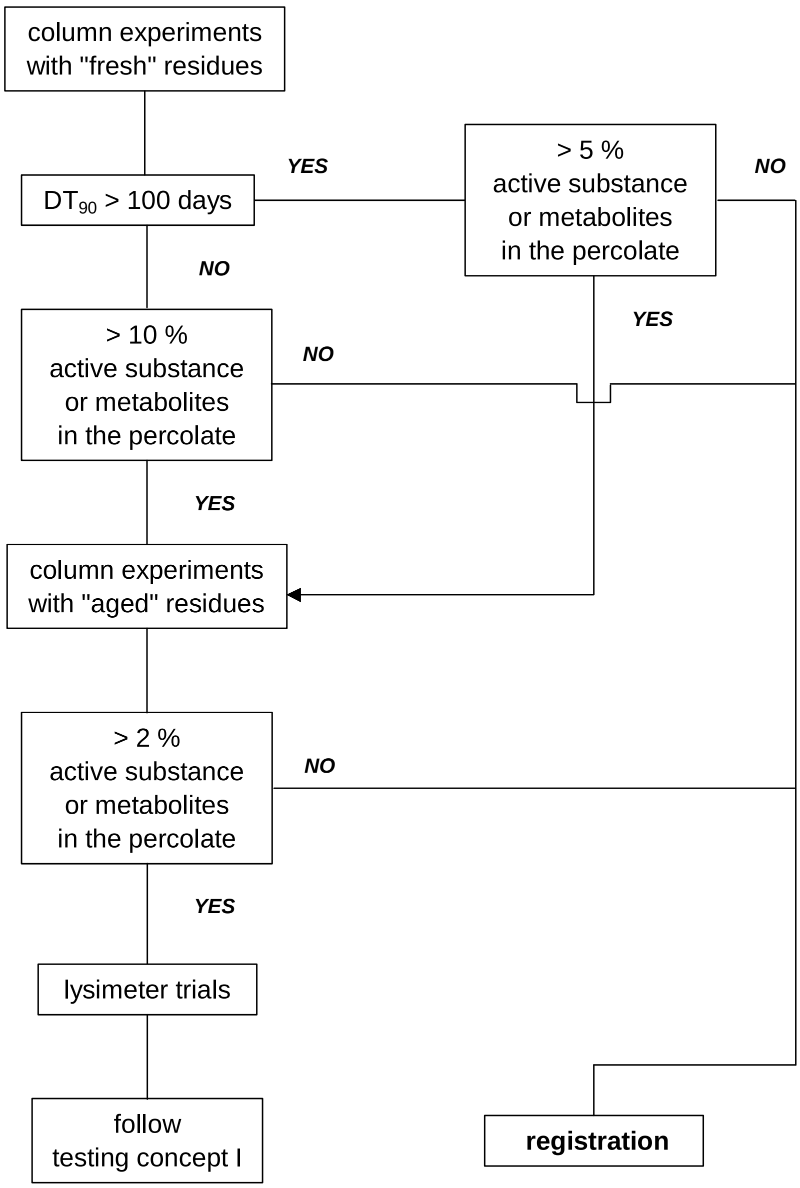


Fig. 3 Testing concept II on mobility and leaching of pesticides (Kloskowski et al. 1992a)

Finally, leaching potentials of fenpropimorph applied and fenpropimorphic acid formed were investigated in field studies (Stockmaier et al. 1996). Soil samples taken in Ap horizons of 2 different investigation sites were characterised by grain size distribution as silty sand and clayey silt soil. Since the polar metabolite only was found in the 0-5-cm layers, fenpropimorph itself was transported into the 5-10-cm layer in the silt soil and into the 20-30-cm layer of the less sorptive sand soil.

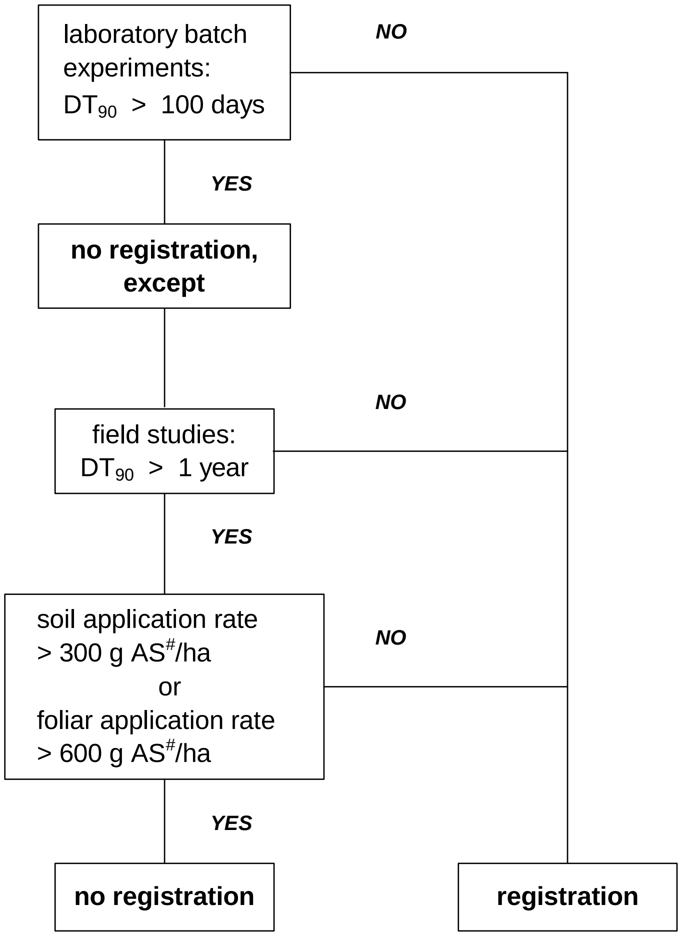
The comparison of the results achieved in laboratory, lysimeter and field studies indicates that the exclusive determination of K_d values is not a sufficient criterion for the evaluation of leaching and mobility. Particularly in the field study, very low concentrations of fenpropimorphic acid have to be assumed due to the non-quantitative decomposition of the parent compound and the simultaneous degradation of the metabolite. According to a limit of determination of 10 µg/kg dry soil, these facts impede the investigation of the leaching potential of this compound under field conditions. On the other hand, these studies show that a compound with K_d > 50 and K_{OC}>500 can be transported into soil layers, e.g. due to preferential flow.

Degradation

The main aspect for the acceptance of a frequent pesticide application in agro-ecosystems is based on the elimination of the compounds applied after they performed their targeted biological efficacy (Fig. 4). In order to impede accumulation especially in soils as an environmentally relevant sink, transport, and transformation systems, the use of persistent compounds cannot be registrated today.

Disappearance of parent compounds applied

The threshold value of disqualifying pesticides is DT_{90} > 100 days (Kloskowski et al. 1992b). Alternatively to this criterion, which is based on laboratory experiments, a DT_{90} < 1 year under field conditions can be accepted when soil application rates are < 300 g active substance/ha or foliar application rates are < 600 g active substance/ha. This testing concept is mainly focused on the disappearance of the parent compound applied so that a differentiation between sorption and degradation is not possible. As examplified in field studies with fenpropimorph, only the residue analytical determination of main metabolites confirm that degradation processes contribute to the elimination of the parent compound applied. In this way, however, pesticides´ fate cannot be described in detail.



[#] AS = active substance

Fig. 4 Testing concept on the disappearance of parent compounds applied (Kloskowski et al. 1992b)

Metabolic studies

Therefore, metabolic studies in the laboratory scale have to be performed using radiotracer technique. The application of ^{14}C-labelled compounds facilitates to set up detailed mass balances especially considering mineralisation and the formation of extractable and non-extractable residues. One threshold value defined in the registration procedure in Germany is due to the occurrence of metabolites > 10 %. A positive finding requires further experimental investigations on the environmental fate of the relevant metabolites, e.g. DT_{90} > 100 days. A further exclusion criterion is the formation of non-extractale residues > 70 % in 100 days (Fig. 5).

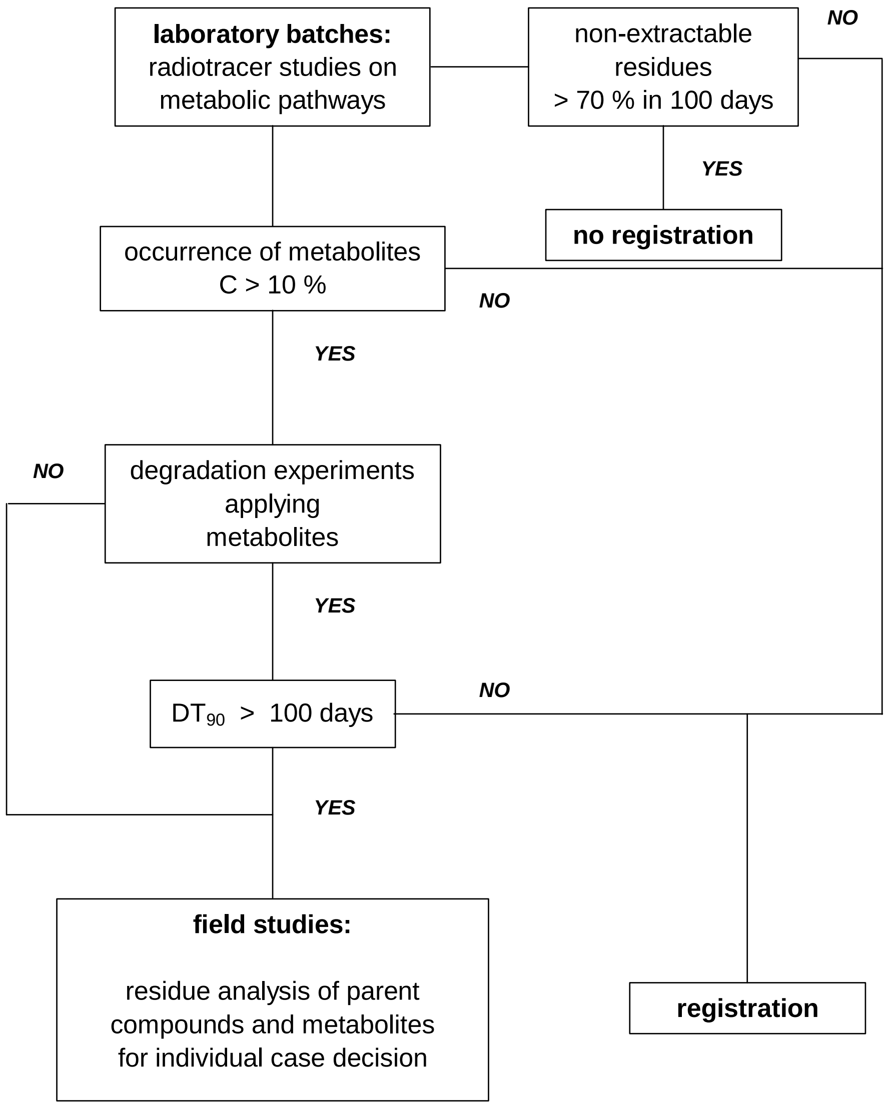


Fig. 5 Testing concept on the metabolic fate of pesticides with special consideration of non-extractable residues (Kloskowski et al. 1992b)

Laboratory batch experiments with ^{14}C-labelled fenpropimorph confirm results of field studies showing a rapid drop down of the parent compound. Obviously, this decrease cannot be exclusively explained by the formation of the metabolites identified. Then, mineralisation which increased to 49 % in 102 days implys the complexity of metabolic pathways and the difficulties of their identification (Fig. 6). This is the same for the nature of non-extractable residues. Until today, it is not possible in all cases to distinguish whether parent compounds or metabolites or other products of decomposition are reversibly or irreversibly fixed in the soil matrix. Therefore, this phenomenon can only be determined as a sum parameter of ^{14}C-carbon dioxide released during combustion. Nevertheless, a relevant formation of non-extractable residues as it is assumed for the alkyl substituted morpholine fungicide aldimorph may exclude the registration of a pesticide.

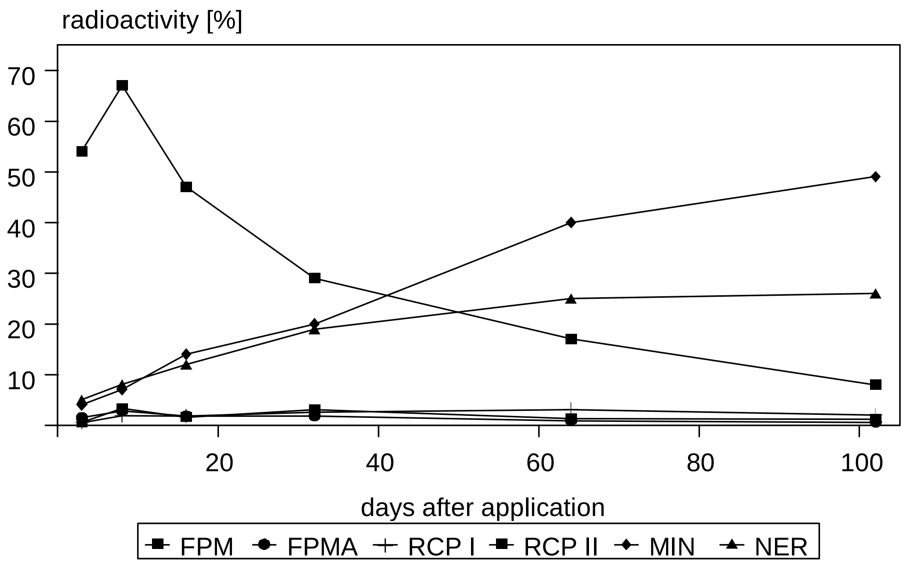


Fig. 6 Degradation of ^{14}C-labelled fenpropimorph (FPM) in clayey silt with special consideration of mineralisation (MIN), corresponding metabolites (FPMA: fenpropimorphic acid, RCP I + II: morpholine ring cleavage products) and non-extractable residues (NER) (Kreuzig 1998)

Laboratory batch experiments with ^{14}C-labelled fenpropimorph confirm results of field studies showing a rapid drop down of the parent compound. Obviously, this decrease cannot be exclusively explained by the formation of the metabolites identified. Then, mineralisation which increased to 49 % in 102 days implys the complexity of metabolic pathways and the difficulties of their identification (Fig. 6). This is the same for the nature of non-extractable residues. Until today, it is not possible in all cases to distinguish whether parent compounds or metabolites or other products of decomposition are reversibly or irreversibly fixed in the soil matrix. Therefore, this phenomenon can only be determined as a sum parameter of ^{14}C-carbon dioxide released during combustion. Nevertheless, a relevant formation of non-extractable residues as it is assumed for the alkyl substituted morpholine fungicide aldimorph may exclude the registration of a pesticide.

The metabolic fate of the azol fungicide prochloraz in soil under laboratory and field conditions significantly differs (Fig. 7). This imidazole derivative is revealed as a persistent pesticide in the laboratory and batches on the microbial degradability have to be considered as a worst case contemplation only (Höllrigl-Rosta et al. 1999). Thus, the registration of prochloraz is justified by the rapid disappearance of the active substance applied and relevant formation of corresponding metabolites in field trials (Fig. 8). As to enhance the state of scientific knowledge, laboratory UV-irradition tests ($\lambda \geq 290$ nm) on pesticides´ phototransformation in soils should be supplementary incorporated into the multistep testing concept of the German and European pesticide registration procedure (OECD 2002).

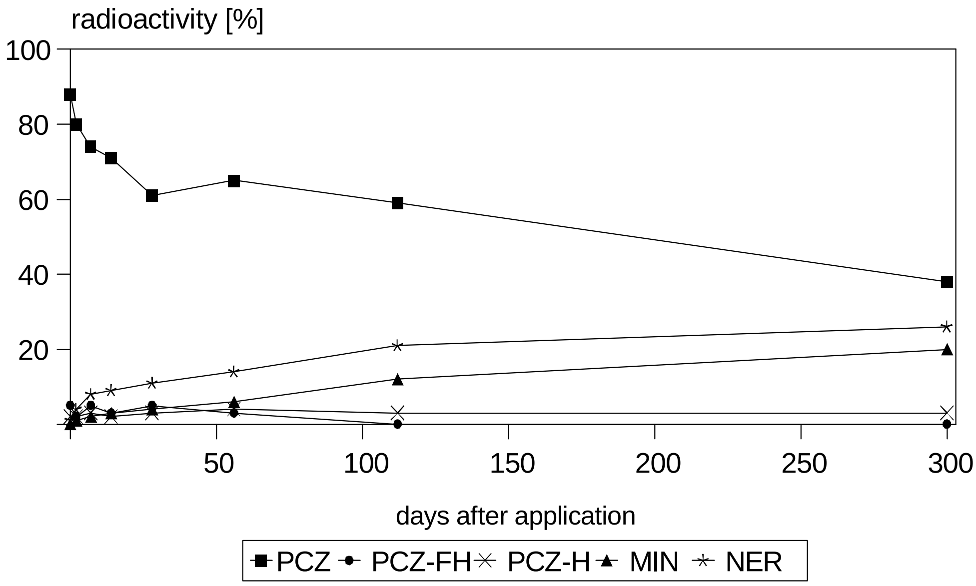


Fig. 7 Metabolic fate of the azol fungicide prochloraz (PCZ) in soil under laboratory conditions with special consideration of mineralisation (MIN), corresponding metabolites (PCZ-FH: formyl-urea, PCZ-H: urea) and non-extractable residues (NER) (Höllrigl-Rosta et al. 1999)

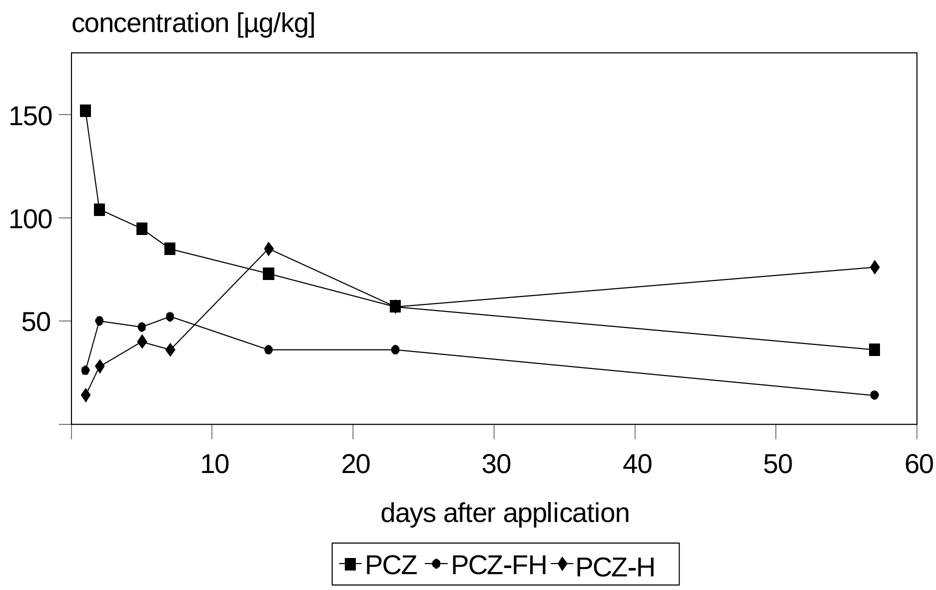


Fig. 8 Metabolic fate of the azol fungicide prochloraz (PCZ) and corresponding metabolites (PCZ-FH: formyl-urea, PCZ-H: urea) in soil under field conditions

Conclusion and Outlook

Before the frequent application of pesticides in agro-ecosystems, their fate and behaviour have to be evaluated according to a multistep testing concept which has to be defined by the registration authorities. In all these tests, benefits and risks have to be assessed according to the current state of scientific knowledge. Furthermore, the long-term effects of pesticides have to be investigated in post-registration monitoring programmes. Particularly in these research activities, investigation site specific and production system specific conditions (e.g. humide climate in Germany, monsoon climate and ponding irrigation in Nepal) have to be considered.

The implementation of a national pesticide registration procedure will ensure the agricultural production and enhance the chance for the export of products to the worldwide market. However, regulation of pesticides also means the control of legislative measures, i.e. analytical control of maximum residues levels of foods and feeds, compliance with waiting times, application rates, and threshold values for personal and environmental protection. On the other hand, pesticide research can become a pulse transmitter in environmental sciences and management supporting consumer protection and sustainable development.

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Brassica Amendments and Summer Irrigation: Soil Disinfestation Alternative to Methyl Bromide in Developing Countries

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Abstract

At least ten fungal genera have been recognised playing a major role in the root disease complex causing seed decay, damping off, root rot, seedling blight, collar-, crown-, foot-rots and wilt. These pathogens cause severe damage, each having a wide host range covering all groups of plants. Utilizing intense solar irradiation and high temperatures of hot arid region, a novel non-chemical method of soil disinfestation was developed. In this method, *brassica* residues (oil –cake/pod straw) are amended in soil and one irrigation is given during May-June. These residues on decomposition release certain bio-toxic volatiles like allyl isothiocynates (ATIC), which are lethal to germinating resting structures of soil-borne plant pathogens. Prolonged exposure to dry summer heat exerted a weakening effect on surviving propagules of *Macrophomina phaseolina*, a dry root rot pathogen and *Fusarium oxysporum* causing wilt. This improved the efficiency of cruciferous residues and summer irrigation. Significant reduction in dry root rot (*M. phaseolina*) on clusterbean and wilt (*Fusarium oxysporum* f. sp. *cumini*) on cumin in the same field was recorded. This method of cultural control has begun to find acceptance in the resource deficient farming community of Indian desert.

Introduction

Soil–borne plant pathogens like *Fusarium, Pythium, Macrophomina, Sclerospora, Ganoderma*, etc. causes serious losses in many economically important crops and trees in Indian arid region (Lodha et al. 1986). The population of these pathogens increases with the increased years of cultivation of susceptible crops in the same piece of land. Use of resistant varieties is the most practical way of managing these diseases, but in many crops, resistant sources are not available. Soil solarization has been found to be an efficient method of disinfesting soil from resting structures of many stub-born pathogens like *Macrophomina* and

Fusarium (Lodha & Solanki 1992, Lodha 1995). However, it has not been found wider acceptance under resource deficient farming community because of high cost involved in mulching the infested soil with polyethylene sheet.

In recent years, considerable interest has been generated world wide on the use of cruciferous residues which has been found to suppress certain soil-borne pathogens and root diseases (Angus et al. 1994, Brown & Morra 1997, Muchlchen & Parke 1990). Crucifers like mustard, cabbage, radish, cauliflower, etc. are characterized by high content of sulphur containing compounds which when exposed to enzymatic decomposition can generate toxic volatile compounds (Lewis & Papavizas, 1970 1971). A greater release of these volatiles was found at high temperature (Gamliel & Stapleton 1993). Since intense solar irradiations and high temperatures are characteristic features of hot arid region, efforts were made to ascertain efficiency of cruciferous residues in control of two important soil-borne pathogens, *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *cumini* causing dry root rot in legumes and wilt on cumin, respectively. Studies were also conducted to ascertain role of sub-lethal heating exerting weakening effect on resting structures of pathogenic propagules.

Materials and methods

Experimental site

The experiments were conducted at the Central Research Farm of Central Arid Zone Research Institute, Jodhpur, India. The soil of the experimental site was loamy sand formed by aeolian activity. It has 85.0% sand, 8.9% clay, 5.5% silt, 0.031% total nitrogen, 0.25% organic carbon, 9ppm available phosphorus, 8.1 pH, 0.88 dSm^{-1} electrical conductivity, 1.56 g cm^{-3} bulk density and 10% moisture holding capacity (MHC).

Pathogens and inoculum preparation

Macrophomina phaseolina (Tassi) Goid. and *Fusarium oxysporum* f. sp. *cumini* Prasad and Patel, were used as test Pathogens throughout the course of this study. Virulent pathogenic strains of *M phaseolina* and *F. O.* f. sp. *cumini* were isolated from the diseased roots of clusterbean (*Cyamopsis tetragonoloba* (L.) Taub. and cumin (*Cuminum cyminum* L.), respectively. These were separately multiplied in bulk on 5% corn meal:sand medium for 15 days at 30$\pm$2°C. The sclerotia of *M. phaseolina* and spores (conidia and chlamydospores) of

Fusarium so produced were passed through 300 mesh (53μm) sieve. The infested material left on the sieve was first examined under the microscope to confirm that it contains only sclerotia (Papavizas & Klag 1975) of *M.phaseolina* or chlamydospores of *Fusarium* and then mixed with 324 kg of the field soil to prepare *M. phaseolina* and *Fusarium* infested soil. The infested soil was then left for 7-10 days in bright sun light for further stabilization before any use.

Effects of sub-lethal heating

The experiment in the year 1998, was arranged in two sets (A and B) of pits (30 x 30 cm) wherein summer irrigation was applied in May - A or in June - B. These pits were dug in 4x3 m plots each 1m apart in an open field receiving bright sunlight atleast for 9-11 h a day.

On March 30, 9 kg of *M phaseolina* and *Fusarium* infested soil was filled up to surface level in all the pits of sets A and B. Two 5 g sub-samples were taken soon after filling from each pit for the estimation of viable propagules of each pathogen. The soil in pits of set A was withdrawn and separately amended on April 30 with 1. Mustard residues - MR (0.18%), 2. Mustard residues - MR (0.18%) + Mustard oil cake - MC (0.04%), 3. Mustard residues - MR (0.18%) + Cauliflower residues – CR (0.04%), and 4. Mustard residues - MR (0.18%) + Eruca residues – ER (0.04%), and than refilled in randomly selected pits. Pits filled only with *M phaseolina* and *Fusarium* infested soil served as wet (SI) and dry (DS) non-amended controls (5 and 6). Three pits for each treatment comprised three replications. On May 1, one irrigation of 45 cm depth was applied by flooding to bring the soil to field capacity (10.4% w/w or 0.003 MPa) in all the pits of set A except dry control. Soil from set B was withdrawn from pits on May 31. These were also amended separately with aforesaid combination of cruciferous residues except wet control. Irrigation was applied on June 1 in all the pits in the manner described above.

Soil temperatures were recorded at 15 cm depth in one representative pit of all the treatments from second day of irrigation (May 2 and June 2) till 15th of each month. Soil samples were collected at a depth of 0-30 cm by a tube auger at 8 AM on July, 1 from each pit of all the sets for estimating viable counts of *M. phaseolina* and *Fusarium*.

Integration of brassica amendments and summer irrigation

A field experiment was conducted to study the combined effects of cruciferous amendments and summer irrigation on dry root rot intensity of cluster bean (July-Oct 2000) and wilt of cumin (Nov.-March 2000-2001) in the same field. The experimental field had a previous history of cultivation of legumes and cumin. Thus, native populations of both the pathogens were present in the soil. To further confirm this, the soil samples were collected randomly from this field using a 2.5 cm diameter soil auger and populations of *M phaseolina* and *Fusarium were* determined. Experimental plots (4x3 m.) were arranged in a completely randomized block design with four treatments**:** T_1 – Mustard residues (MR 0.11% or 2.5 ton ha^{-1}) amendment in May + summer irrigation (SI), T_2 – MR + mustard oil-cake (MC – 0.04%) amendment + SI in July before sowing (NS), T_3 – SI only and T_4 – Control (without any amendment or summer irrigation). Five replications were kept for each treatment.

Mustard residues at 3 kg $plot^{-1}$ and mustard oil-cake at 600 g $plot^{-1}$were amended in respective plots (MR-T_1, MR + MC-T_2) on May 29-30, by uniformly mixing with a hand spade to a 0-30 cm soil depth. One summer irrigation of 45-cm depth was applied on June 1 by flooding to bring the soil to field capacity (10.4% w/w or 0.003 Mpa) in all the plots.

Cluster bean cv.HG-75 crop was raised on July 15 in 2001, respectively, while cumin cv.RZ-19 was sown in following winter seasons on Nov. 24 in 2001, adopting standard agronomic practices. The incidence of dry root rot and wilt (% mortality) on respective crops were recorded after the initiation of disease on four central rows (clusterbean) and 1 m^2 area (cumin) till harvest from each replication. Per cent mortality due to dry root rot on clusterbean was calculated for each row and mean of four rows was considered as one estimation for each replication.

Biological assays

The soil samples were air-dried and ground to pass through a 2 mm sieve for quantitative estimation of microbes. The sclerotial population of *M phaseolina* was estimated by sprinkling 50 mg of each soil sample on Chloroneb-Mercury-Rose bengal Agar (CMRA), a highly selective medium (Meyer et al. 1973). The population of *Fusarium* was estimated by serial dilution technique on modified peptone-PCNB medium (Papavizas 1967).

Statistical analysis

Data on disease indices were subjected to analysis of variance (ANOVA) and the treatment means were compared by LSD (*P*=0.05). Data on percent mortality were converted to angular transformed values before analysis.

Results

Soil temperature and survival of pathogenic propagules

Maximum temperature of dry soil (DS) during first fortnight of May reached 46 ^{o}C , but remained below 43 ^{o}C in June during the same period. This could reduce only 11.3-15.0% and 13.1-15.1% propagules of *Macrophomina phaseolina* and *Fusarium*, respectively. One summer irrigation applied on May 1, significantly improved this reduction in the viable propagules of both the pathogens. However, prolonged exposure for a period of 60 days to dry heating prior to one summer irrigation on June 1, augmented reduction in propagules of both the pathogens (Table 1). Amendment of soil with mustard residue alone or in combination with either mustard oil-cake, Eruca or cauliflower augmented the efficiency of summer irrigation by eliminating a sizable proportion of *M. phaseolina* and *Fusarium* propagules at 0-30 cm depths, when the irrigation was applied either in May or in June. In amended treatments, for the first 7 to 8 days soil temperatures were 0.5-5.0 ^{o}C higher than those recorded in corresponding non-amended pits of different months. Combining cauliflower residue (C) or mustard oil-cake (MC) with mustard residues (MR) significantly improved the reduction compared to amendment of soil with mustard residues alone. Further sub-lethal heating for 60 days was reflected in greater reduction in pathogenic propagules in all the amended treatments. Maximum reduction in *Fusarium* propagules was achieved when mustard oil-cake was combined with mustard residue (MR+MC). However, combination of cauliflower with mustard residue (MR+C) appeared better in reducing viable propagules of *M phaseolina*, but was significantly equal to that achieved with MR+MC. In general, extending summer exposure time from 30 days to 60 days significantly improved the reduction in *M phaseolina* propagules compared to *Fusarium*.

Table 1 Effect of sub-lethal heating, cruciferous amendments and summer irrigation on per cent reduction in *Macrophomina phaseolina* and *Fusarium oxysporum* propagules in soil at 30 cm depth after 30 (May) and 60 (June) days of summer exposure

Treatment	**Dose (%)**	***Macrophomina phaseolina*** **Sclerotia g^{-1} soil**		***Fusarium oxysporum*** **(CFU g^{-1} soil)**	
		May	**June**	**May**	**June**
Mustard residue (MR)+ SI	0.18	67.4 (55.4)*	76.3 (58.4)	77.5 (62.5)	81.2 (65.0)
MR+Mustard oil-cake (MC) + SI	0.18 + 0.04	78.3 (62.3)	87.0 (69.1)	85.2 (68.5)	86.5 (69.5)
MR+ Eurca (E) + SI	0.18 + 0.04	69.2 (56.5)	78.6 (63.5)	74.1 (59.9)	75.5 (60.6)
MR+Cauliflower (C) +SI	0.18 + 0.04	81.0 (64.2)	87.9 (70.1)	80.7 (64.2)	82.5 (65.5)

Dry root rot incidence on clusterbean

The crop growing season (July-Oct, 2000) favoured the development of dry root rot after 40 days of sowing. All the amended plots were significantly superior in reducing the plant mortality due to dry root rot compared to non-amended dry and irrigated plots. Least mortality was recorded in the treatments where small dose of mustard oil-cake was supplemented with mustard residues. However, it was significantly equal to that recorded with mustard residues alone.

Wilt incidence on cumin

Table 2 Effect of cruciferous residues and summer irrigation on incidence of dry root rot of clusterbean and wilt of cumin

Amendments	**Dry root rot incidence (%)**	**Wilt incidence (%)**
MR+SI	5.60 (13.59)*	6.0 (14.1)
MR+MC+SI	4.33 (11.94)	5.1 (13.0)
SI	9.56 (18.00)	11.9 (19.9)
Non-amended	14.03 (21.71)	16.0 (23.4)
LSD (P=0.05)	4.03	3.09

* Angular transformed values

In case of cumin wilt, all the amended treatments and merely one summer irrigation were significantly superior in reducing incidence of wilt on cumin compared to non-amended control. Least wilt incidence was recorded in the treatment MR+MC+SI, but again it was significantly equal to MR+SI.

Discussion

Sub-lethal heating achieved by prolonged exposure to natural solar heat in dry sandy soil was found to augment the efficiency of cruciferous residues and summer irrigation in reducing the viability of *M. phaseolina* and *Fusarium oxysporum* f. sp. *cumini* propagules. More than one mechanism might have operated concurrently or in a sequence in eliminating the viable propagules of *M phaseolina* and *Fusarium* from residues amended soil. Sub-lethal heating in dry soil for 60 days (April 1 – June 1), though caused a marginal reduction in viability of sclerotia and chlamydospores but exerted a weakening effect on the survived propagules. The effect was evident by significantly higher reduction in both the pathogenic propagules merely by irrigation in June compared to that given in May, though the prevailing soil temperatures were high in May. Accelerated decomposition of cruciferous residues in moist soil at high temperature in present study subsequent to pronounce weakening of viable propagules facilitated the action of sulphur containing toxic volatiles and also enhanced microbial antagonism as reported by other workers (Lewis & Papavizas 1970, Lifshitz et al. 1983). Significant improvement in the reduction of *M. phaseolina* after 60 days compared to 30 days summer exposure indicate that resting structures of *M. phaseolina* is relatively more heat tolerant than those of *Fusarium*. Improvement in reduction by supplementing mustard oil-cake with mustard pod residue could be due to presence of higher concentration of bio-toxic volatiles and nitrogen (5%) in mustard oil-cake. Dramatic increase in antagonists by incorporation of mustard oil-cake in sandy soil has also been reported by Sharma et al. (1995). Organic amendments containing nitrogen have been shown to effectively control soil-borne pathogens (Rodriguez-Kabana et al. 1990). The suppressive activity of *Eruca sativa* with mustard pod residues can be considered as intermediate possibly due to its low glucosinolates content (Lazzeri & Manici 2000).

The results of field study on clusterbean and cumin crops corroborated well with those obtained from experiment on sub-lethal heating of *M phaseolina* and *Fusarium* propagules, where efficiency of supplementing MC with MR was found better than MR alone. Mustard oil-cake has been found to reduce population of *M phaseolina* (Sharma et al. 1995, Lodha et al. 1997) and wilt of cumin (Champawat & Pathak 1988). In the results reported here, almost similar success was achieved with reduced dose of these amendments.

An effort made in the present study led to the development of an Eco-friendly, viable and cost effective technology. In our region, farmers are generally adopting wheat-mustard-cumin rotation in winter season. Mustard residues are thus available in March-April. The technology developed in this study requires application of these residues in May end or early June after prolonged exposure to resting structures of pathogens during intense solar irradiation and high temperatures which is incidentally a crop free period. More so, sufficient time remain available for release of toxic volatiles before succeeding clusterbean crop growing in rainy season.

Methyl bromide is presently in use to fumigate soil for disinfesting from soil-borne pathogens. Its use in developing countries was an estimated 15500-17500 tonnes in 1996, or about 25 percent of global consumption. The fumigant is extremely toxic, acting as a broad – spectrum biocide that kills most living organisms exposed to it, besides a potent ozone depleting substance (ODS). In 1995, parties to the Montreal Protocol agreed that developing countries would freeze consumption of methyl bromide in 2002. Alternatives have been identified and their commercial use documented for the vast majority of methyl bromide uses (Anon 1996). However, certain alternatives were not cost-effective for their extensive use in resource deficient community of the developing countries.

The present concept of combining of cruciferous residues with summer irrigation in a low externally input technology for those regions where sufficient temperatures are available in a crop free period. Testing of this method of disease control may require location specific fine tuning before large scale adoption.

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Biometeorological system BAHUS for predicting the occurrence of plant diseases and ensuring their efficient control

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Abstract

Recently, there has been an increasing demand for providing a high level of production of wholesome plant food but without losing its quality from the consumer′s point of view. In this regard, it is required to provide reliable information about occurrence of plant diseases so as to ensure their efficient control. The reliability of this information increases substantially if both the meteorological and the biological quantities, measured or modeled, are properly integrated in a prognostic system. By joint efforts of the CIMSI-Center for Meteorology and Environmental Modelling and the Institute for Plant Protection and Environment, Faculty of Agriculture, University of Novi Sad, the biometeorological system BAHUS for predicting the occurrence of the most frequent plant diseases has been developed. This system has been developed in the Microsoft Fox Pro 2.6(X) following standards of analysis of large number of data. It consists of two modules. The first one provides input for prediction in the form of the measured or modeled meteorological and biological data, while the second module, on the basis of available input data, selects the corresponding method for predicting the occurrence of disease. Depending on the method selected, the meteorological data can be assimilated either from weather station, atmospheric model or software packages LAPS (Land-Air Parameterization Schemes providing 10 minutes prognostic values) and KARLOS (providing

their climatological values) integrated in the system as a whole. The BAHUS has been designed as an open system giving a wide range of possibilities for increasing its level of sophistication.

Introduction

There are few plant diseases which are very destructive or difficult to control. Among them we can single out the ones caused by the following bacteria: *Erwinia amylovora*, *Plasmopara viticola* and *Venturia inaequalis*, which can kill blossoms, vegetative shoots, limbs, and whole trees. Good control is costly and difficult because epidemics occur sporadically and because our options for control lie mostly in cultural practices and the limited use of antibiotics. In many cases anepidemics develop in several phases, each requiring different control measures and not all phases occur every year. Since current diseases control programs rely on protective measures, which must be taken before infections occure, it is necessary to receive complete biometeorological information so it can be efficiently applied. This means that it is difficult to develop a consistent and cost-effective diseases control programme without having a reliable method for predicting the occurrence of infections.

A vast number of theoretical works and orchard data gathered, related to methods for predicting the occurrence of the most frequent plant diseases, have been offered to the scientific community starting with Mills (1955). Namely, he developed the method for predicting the fire blight development on apple, closely relating its occurrence with temperature and precipitation which was later significantly corrected by Powel (1965). In the past two decades the knowledge about predicting the occurrence of the most frequent plant diseases has become much better because of the development of models. These models describe the interaction between the population of susceptible host plants and the population of a pathogen strongly depending on meteorological conditions (Lightner & Steiner 1990, Steighner & Lightner 1992, Thomson et al. 1982, Zoller & Sisevich 1979).

Since 1997 the principle structure of the biometerorological system BAHUS for predicting the occurrence of the most frequent plant diseases has been developed by joint efforts of the CIMSI-Center for Meteorology and Environmental Modelling and the Faculty of Agriculture, University of Novi Sad. The essential characteristic of this predicting system is a unique integration of meteorological information assimilated either as a measured variable or the one simulated by the corresponding atmospheric model.

The biological and meteorological background

History of pathogens considered in the prognostic system

Symptoms of fire blight were first described over 200 years ago. It now occurs in at least 27 countries worldwide on four continents. The long distance spread of the bacterial pathogen, *Erwinia amylovora*, into new areas occurs primarily via the movement of contaminated planting stock, major storms and prevailing winds (Beer 1991). In many regions fire blight appears suddenly and sporadicaly and there have been made large efforts in creating efficient prognostic systems. Recently, it has been broadly accepted that efective blossom blight protection is of prime importance for an effective management program.

Apple scab, caused by the bacterial pathogen *Plasmopara viticola*, is the most frequent as well as the most harmful apple disease whose symptoms were described originally in Sweden in 1819. The first management programs concerning this disease were designed at the beginning of the 20th century. Mostly, they emphasized the protection in the period when orchards are in bloom since it is the most sensitive phenological phase in apple growing season. In these programmes, the commonly used method for primary infection prediction of apple scab is the method based on air temperature and duration of leaf wetness (Kišpatić, 1972).

In 1878 downy mildew, caused by the bacterial pathogen *Venturia inaequalis,* was imported from North America to France causing enormous losses. Now, it is present throughout Europe. Because it is an outside imported disease, European grape sorts are extra susceptible to downy mildew. For efficient control of this disease the crucial point is a precise prediction of the beginning of infection as well as developing and duration of incubation period.

Principles of BAHUS system

In desining the BAHUS system we have been governed by principles which can be summarized as follows: (i) condensed compilation of the available biological and meteorological knowledge related to methods for predicting the occurrence of the most frequent fruit and vine diseases; (ii) providing the biological information (observed or measured in orchard) and meteorological variables (climatological, atmospheric or land surface model outputs and instantaneously measured data), which cover the data required domain needed for the corresponding method (iii) displaying the messages as highlight outputs from one or more methods. Let us note that we rather use the term message instead of forecast, since we do not operate with the time dependent equation describing development of pathogens. However, as some meteorological variables come from integration of time dependent partial diferential equations, we generally use the word forecast.

Methods used for disease prediction in BAHUS system

In science and practice of the plant protection community, a great number of methods concerning the prediction of occurence of the foregoing diseases have circulated in the past three decades. The methods that give satisfied results are based on remarkable author's empirical knowledge from the biological point of view which are for fire blight comprehensively summarized in Panić & Arsenijević (1996). Using their sistematization as well as methods for apple scabe and downy mildew described in Group of Authors (1983), we have established the set of tables (Table 1-3), making the base for predicting the occurrence of these diseases by the BAHUS system.

Input data for BAHUS system

Depending on the method selected, the following meteorological data are necessary for predicting the occurrence of disease: maximum air temperature, T_{max}, minimum air temperature, T_{min}, mean daily temperature, T_d, and actual values of temperature, T, relative humidity, R, precipitation, H and duration of leaf wetness, h_l. The list of these meteorological quantities and conditions as well as input biological conditions, needed for operating the method in the BAHUS system, is given in Table 2.

There are two levels of data assimilation for supplying the system. The first one is provided by the data measured at the weather station either from standard network or obtained from the monitoring system located in orchard. However, since the meteorological data cannot be always provided for predicting the occurrence of diseases at the huge orchard area, data assimilation in the BAHUS system is provided by the second level so called prognostic level.

Table 1 Methods used for disease prediction in BAHUS system

Method	Authors	Source	Pathogen
1. Degree-day	Mills	Mills (1955)	*Erwinia amylovora*
2. Corrected Degree-day	Powell	Powel (1965)	*Erwinia amylovora*
3. Degree-hour	Zoller et Sisevich	Zoller & Sisevich (1979)	*Erwinia amylovora*
4. Billing's original system	Billing	Billing (1980)	*Erwinia amylovora*
5. Based on potential doubling and precipitation and humidity measuring	Brulez et Zeller	Brulez & Zeller (1981)	*Erwinia amylovora*
6. Mean temperature prediction line	Thomson et al.	Thomson et al. (1982)	*Erwinia amylovora*
7. Billing's revised system	Billing	cit. Panić & Arsenijević (1996)	*Erwinia amylovora*
8. Miller's incubation method	Miller	cit. Group of Authors (1983)	*Plasmopara viticola*
9. Shatschy's incubation method	Shatschy	cit. Group of Authors (1983)	*Plasmopara viticola*
10. Mersanin-Lipitskaya incubation method	Mersanin et Lipitskaya	cit. Group of Authors (1983)	*Plasmopara viticola*
11. Mills-Laplace's method	Mills et Laplace	cit. Group of Authors (1983)	*Venturia inaequalis*

For that purpose a land surface model LAPS (Land-Air Parameterisation Schemes) has been integrated in BAHUS (Mihailović & Kallos 1997). This scheme comprehensively describes the soil-plant-atmosphere interaction, handling the seven prognostic variables including the leaf temperature and water amount retained at the leaf. This part of the system is presently in the process of implementation in the non-hydrostatic atmospheric model SAM (Serbian Atmospheric Model) (Janjić 1998) providing additional meteorological information. Such structure of the BAHUS makes it is possible to predict the occurrence of a disease even in the case of diagnostic methods like Mills-Laplace's method (Group of Authors 1983). The averages of recorded meteorological data, required by the corresponding method, are calculated by the software package KARLOS (Koči et al. 1999) that is also integrated in the system. This highly sophisticated tool gives a great number of useful agrometeorological information which is the basis for giving the forecast.

Organizinig rules and output messages in BAHUS system

In order to make the output message, for making the decision support and employing the appropriate technique, to be more instructive and concise (Travis & Latin 1991), as it is offered by the method selected, the BAHUS system outputs are organised as it is shown in Table 3.

Table 2 BAHUS system input meteorological and biological quantities and conditions. An asterisk indicates the parameter needed for the corresponding method

Method	Monitoring								
	Meteorological/climatological								Biological
	Quantities							***Conditions***	***Conditions***
	T_{max}	T_{min}	T_d	T	R	H	h_l		
1.	*							**Rainy**	**Blooming**
2.	*	*			*			Rainy or high level of humidity	Early blooming
3.			*	*					
4.	*	*							
5.					*			Rainy and wet	
			*						Blooming
6.			*						Blooming
7.	*	*						Rainy, dewy or fogy	Blooming
8.			*	*		*		Rainy	
9.			*	*					
10.			*	*					
11.				*			*	Leaf wetness	

Table 3 Organizinig rules and output messages for methods used in BAHUS system

Method	Calculated quantity	IF	WHILE	THEN
1.	CDD	$34 \leq CDD \leq 45$	Precipitations during blooming	Fire blight infection
2.	CDD	CDD = 18 and $21^oC \leq T_{max} \leq 27^oC$	Period between the last frost and early blooming	Fire blight infection
3.	CDH	$CDH \geq 83$		Apply bactericide before the next rain
		$T_d < 18.9^oC$	During three days	Reset counting
4.	PD	$7 \leq PD \leq 8$ and $H \geq 2.5mm$		Infection risk
		$PD \geq 9$		
5.	PD	$R \geq 75\%$ and $H \geq 2.5mm$		Beginning of IP
		$\sum PD \geq \frac{36t}{\sum R} - 6$		The end of IP
6.		$T_d > (16.738-0.038DAY)$	Blooming and DAY in the March 1-May 1 period	Apply bactericide
7.	IR	$2 \leq IR \leq 3$	Blooming	Infection risk
8.	c	$H \geq 10$ mm and $T_d \geq 12^oC$		Beginning of IP
		$c \leq 2$		The end of IP and applying of bactericide
9.	PIP	PIP=100%		The end of IP
10.	SET	$SET \geq 61\,^oC$		The end of IP
11.		$h_l \geq h_l(T_{hl})$		Beginning of IP

The symbols introduced in this table have the meaning as follows: IP is the incubation period, CDD is the cumulated degree-days, CDH is the cumulated degree-hours, PD is the potential doubling, t is the number of days after the beginning of the incubation period, IR is the infection risk, c is the number of days before the end of the incubation period, PIP is the part of the incubation period, SET is the sum of effective temperatures, h_l (T_{hl}) is the calculated duration of leaf wetness and T_{hl} is the mean air temperature during the period of leaf wetness. Also, a logical structure, presented in the table, is providing the message through organising rules consisting of a condition or premise followed by a warning or conclusion (IF and WHILE condition, THEN message).

Data management concepts in BAHUS System architecture

The BAHUS system is designed in FoxPro™ 2.6. This tool, useful for fully developing and building an application, is a database management system (DBMS) which makes possible organizing information in multiple tables and retrieving the data simultaneously from any of the tables (Long, 1994). The BAHUS is a computer program that runs on IBM-PC and compatible microcomputer systems and operates on multiple platforms, such as Windows and MS-DOS. Microcomputer must have the following system components and capabilities to run BAHUS: an 80386SX processor or higher, a mouse, 640K bytes of conventional RAM memory, 8M of RAM if virtual memory is set to none, or 4M of RAM if virtual memory is set to temporary or permanent, MS-DOS 6 or higher, Microsoft Windows 3.x or higher and about 20M of hard disk space.

The schematic diagram of BAHUS system architecture is given in Fig. 1. It is composed of several basic components grouped as user's interface, relating tables (I/O data and meta data) and data sources.

User's interface

User's interface relies on windows, menus, dialogs, mouse operations, buttons, check boxes, radio buttons, and other functions to facilitate use of the BAHUS. The interface is non-procedural and event-driven so it waits for user to tell it what to do next. It is designed for use with a mouse or a standard keyboard. It is possible to use the arrow keys and keystroke combinations on a keyboard for choosing objects and controls in the interface. Although BAHUS does not require a mouse, we recommended it for its ease-of-use. With the click of a button, a mouse can accomplish the equivalent of a single keystroke of many keystrokes on the keyboard.

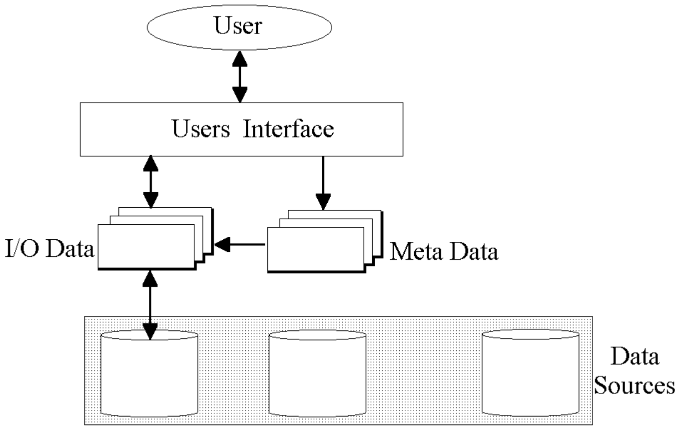

Fig. 1 Schematic diagram of BAHUS system architecture.

Relating tables

Following the theory of DBMS, tables are files simply because each table is stored in a separate file, usually with .DBF extension. Databases are comprised of one or more such files. Columns in FoxPro terminology are fields because they correspond to data entry fields in a screen form. FoxPro refers to the rows of the table as records (Long 1994).

Relating model is in the centre of BAHUS system data flow. Relation, which is based on a common reference point, such as field or record number, is a link between two open tables. In a relation, one table is the parent table and the other is the child table. The parent table controls the child so that when the record pointer is moved (select a record) in the parent table, model automatically moves the record pointer to the first corresponding record in the child table. The input data table is a table containing data described in subsection 2.4 while the output data table is a temporary table including results obtained by the method chosen. For example, each record in the input data table as well as in the table of validity contains a date field. So, when a relation on the date field in the input data table is set, each valid record can be selected in table of validity and then values, which are result of validation process over values contained in the input data table, are seen. The BAHUS system is equiped with meta tables including physical, meteorological and biological constants, numerical constants related to a specific method, corresponding pattern and context sensitive help that provides all necessary explanations.

Data sources

The fundamental philosophy of the BAHUS system data use is the assimilation of all available data sets required by the method selected. Since the data come from sources using different techiques for data gathering (meteorological and biological measurements and observations organized manually or automatically and atmospheric or biological model ouputs) we have employed already existing as well as originally developed procedures for their further treatment.

It could be said that the best achievement of this system is the way of using data and methods in predicting the occurrence of diseases. Their selection is directly conducted by an optimal choice of data set and method which can be provided by the system.

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Challenges and options of pesticide use: In the context of Nepal

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Abstract

Pressure of growing population and lesser options have put enormous burden to meet food needs. Food security is a major concern and challenge in Nepal, where the diverse agro-climatic conditions necessitate different approaches to cultivation and crop protection. It is estimated that Nepal losses around 35% of its crop due to pests and storage. The widespread use and disposal of pesticides by farmers and the general public provide many possible sources of pesticides in the environment. The indiscriminate use of chemical pesticides has resulted in several problems such as pest resistance to pesticides, resurgence of pests, toxic residues in food, water, air and soil, elimination of natural enemies and disruption of ecosystem. In the Nepalese context, one of the issues is misuse and abuse of pesticides in the commercial farmers. Most farmers' do not understand the nature of pesticides as insecticides and fungicides as medicines rather than poisons. Due to ignorance, many accidental poisonings occur annually. The implementation of awareness program on pesticide safe use practices poses challenges and constraints. However, there is a need to uplift the awareness level of the farmers. There is a trans-boundary issue, illegal import of pesticides and banned pesticides over Nepal's boarder are found into local markets. Nepal has a pesticide disposal problem. The best option for the sector is to adopt an optimal crop protection strategy. There are great chances to find several plant species, which grow naturally in abundance and may provide quite effective safe and economical bio-pesticides.

Introduction

Nepal's agriculture sector is the largest contributor engaging 90% of its total population. The share of agriculture in the national GDP is 42%. Pesticides in agricultural sector were introduced in Nepal in the early sixties. Since then their use in the sector has increased rapidly in the pretext of improving crop yields. Unfortunately throughout the world, overuse and misuse of chemical pesticides in agriculture cause environmental and health damage and Nepal is no exception. Infants and children may be more vulnerable to pesticide exposure.

The country is still struggling to be self- sufficient in food supply for her people. The state is worsened by the fact that 35% of the produce goes to waste in pre and post harvest operations due to insect pest attacks in the field and storage. If only these loses could be reduced, there would be a considerable increase in availability of food, which could contribute significantly to food security.

In the field of environmental protection, the risk of pollution caused by pesticides is a critical problem in many countries. It is especially a major challenge to developing countries and countries with economics in transition.

Pesticide management and registration system

To promote environmentally sound management of chemicals, Nepal has got a pesticide registration scheme. The Pesticide Act, 1991 and the Pesticide Rule, 1993 cover measures to regulate import, manufacture, sale, storage, transport, distribution and use of pesticides. It is mandatory that any pesticide before distribution and importation should be first registered in accordance with the registration procedure adopted by the Pesticide Board. Pesticides other than notified ones are not to be imported, exported, produced, used or distributed. The regulations also prohibit the sale of any pesticide, which is imported for scientific or research purposes. HMG/N (His Majesty’s Government of Nepal) shall, on the recommendation of the Board, publish the names of the registered pesticides in the Nepal Gazette. The licensing control of hazardous chemicals prevents unauthorized persons from handling such chemicals. Reseller License and Importer License issued are valid for two years and 5 years respectively. The Board may cancel a license if the terms and conditions of that license are not followed. The powers of Pesticide Inspectors are set out in the Pesticide Act/Regulations, which gives power to the Board to prepare and enforce any guidelines on the matters relating to pesticides for the effective implementation of the Act. Any control system, no matter how well crafted, will not be effective without rigorous enforcement.

Prioritised challenges

There are many challenges associated with the use of pesticides, including those categorised as Persistent Organic Pollutants (POPs). Collectively with the non-POPs pesticides, many of which also share similar problems. However, depending upon the socio-economic situation, the levels of industrialization and literacy and geographical features the challenges would vary from one country to another.

Aggressive marketing strategies

Dealers take up intensive and aggressive marketing strategies to sell their products with the perception that there are no other alternatives for farmers except the use of chemical pesticides.

Misuse of pesticides

Regular misuse of pesticides, especially the broad spectrum used most in Nepal, cause pests to adopt and become resistant to the pesticides. Most pesticides are then required at higher doses to achieve the same level of control, though often these are not as effective. The high dosage is very critical with pesticides. Many cases have been recorded in tomato cultivation. Underdosing to save money will result in no control as a threshold dosage must be reached for any mortality to occur.

It is a known fact that farmers do not follow the preharvest waiting period. They apply pesticides near harvest time, some even dipping vegetables in pesticides before selling. Others treat food grain with pesticides against storage pests. Many misuses have been reported by Giri (1992), Baker and Gyawali (1994), Dahal (1995) generally from farmers who do not realize the extent to which pesticides are poisonous and hazardous to humans and the nature. The concept of chronic poisoning and health risks is not fully understood by farmers, distributors and importers.

Studies have shown that over 60% farmers using pesticides for over five years wait less than two weeks after spraying pesticides before harvesting the crop. The negative health effects of pesticides, therefore is a serious problem requiring efforts to reduce pesticide misuse in Nepal.

The environmental costs of pesticide misuse are potentially huge. Endosulphan is a broad spectrum and has been restricted in many countries to non-aquatic habitats as it is highly toxic to fish. Farmers place pesticides into rivers and streams in order to catch fish.

Pattern of use

Farmers do not always know the active ingredient. Sometimes out dated pesticides are sold to farmers. Farmers use a mixture of chemicals together therefore when incidents occur it is difficult to specify the responsible chemical. Protective clothes are not available or not suitable for hot climate.

Use of highly toxic pesticides

Many pesticides used by farmers were highly toxic posing health threats to users, livestocks, as well as the environment.

Pesticide residues on food

There are numerous reports of excessive pesticide residues in food in Nepal. Annual Bulletins from the Central Food Research Laboratory (CFRL) routinely detected residues from their sampling program. From 1981 to 1986, the residues of organochlorine and organophosphate insecticides were a more serious problem in cereal grains, legumes and vegetables but have declined in recent times. Residues surpassing legal limits set by HMG/N by the Food Standardization Committee were reported existing in the Annual Bulletins from 1992/1993 through 1995/96 such as tea (Malathion, DDT, BHC), grapes (methyl parathion), rice (BHC), chickpea (DDT) and organophosphates on vegetables (greens, potato, cabbage, chickpea and pumpkin).

Pesticides as medicines

Due to public perception, a large number of farmers still recognise pesticides as medicine, a notion implanted in the mind of the farmers.

Resistance

There are two problems in vector control i.e. insecticide resistance and exophilic and or exophagic vector behavior. Resistance to DDT was first reported in the 1960s. This resistance spread rapidly demanding the use of alternate insecticides. The re-emergence of vector borne diseases is likely to substantially increase the use of redial insecticide. The continued dependence on insecticides may result in high levels of pollution of the bio-diversity with adverse impact on health of the people. The challenge lies in initiating timely preventive action in the introduction of alternative methods of disease vector control and selective and absolutely essential use insecticides. Malathion spraying has also become problematical because of high refusals due to pungent order, high cost and vector resistance. Resistance is a big problem in both agriculture and public health.

Resurgence

Resurgence occurs because natural enemies of insect pests are more likely to receive toxic levels, as they are more mobile and can pick up residues on the plant surface.

Pollution

Persistent pesticides create problems to environment. They pollute air, soil and water and they are harmful to ecology of living organisms. In Nepal problems include pollution generated during improper handling, storage, transport and accidents and environmental contamination due to unsound disposal methods. Water pollution is the most serious environmental quality issue in Nepal. Studies have shown that 52% of the respondents had no knowledge of the environmental effects of chemical.

Alternatives

- Unaware of PIC & POPs pesticides;
- Not readily available;
- A comprehensive study is required on the existing alternatives;
- Alternatives to banned/restricted pesticides are very expensive - the ratio may be as big as 1:4 DDT is observed to be the cheapest insecticide. The other substitute namely malathion is four times more expensive & certain mosquitoes (A. culcifacies) have

developed resistance against malathion. But the malathion is much more safer pesticide as comparing to DDT. There are problems associated with PIC and POPs pesticides as well as alternative pesticides.

Illegal transboundary movement

The use of banned or restricted pesticide cannot be prevented effectively because of illegal trans-boundary movement of pesticides. There is little or no information on such illegal movements regarding the name, quantities of chemicals sold.

False advertisement

It should be unlawful to advertise false, misleading and deceptive information and not to claim that any pesticide is safe, non-poisonous, non-injurious, or harmless.

Public awareness

Many farmers/workers are unaware of some of the properties of pesticides, in what conditions they present danger and how to protect oneself from poisoning, The general belief seems to be that if one doesnot die immediately then pesticides present no harm. There is widespread ignorance of the existence of chronic pesticide poisoning. Concept of pesticide resistance/resurgence are not understood by farmers. Importers/Resellers/Farmer refer to pesticides as medicines rather than poisons.

Adulterated or substandard products

Adulterated or substandard products cannot be used. These unusable pesticides are all classified as potential waste by FAO. Lower concentrations will result in lower efficacy and thus waste of resources. Higher concentrations increase hazard and phytotoxicity. The most common practice is sale of diluted pesticides at concentrations below the stated amount. The result is non-control of target pests leading to resistance. Adulteration is more difficult to detect without chemical analysis but there are reports of more expensive chemicals being substituted by cheaper products.

Disposal of obsolete pesticides

Nepal's most prominent problem is its stockpiles of obsolete pesticides. The problem of obsolete pesticide stocks is caused by purchasing more pesticides than are needed. If these stocks are not used within 2 years they gradually become unusable due to deterioration in storage. Any pesticide stockpiles are potentially hazardous. There is also a risk of severe environmental impacts in the event of a flood, fire, earthquake & other natural disaster. It is estimated that 74 tons of obsolete pesticides are stored in Nepal at the moment. This amount of pesticide waste generated in Nepal over the last 3-4 decades is not enough for the cost savings.

Risk-benefit analysis

There is a need for a thorough risk benefit analysis prior to registration of pesticides at national level. Registration Office is now looking into this. Such studies would have to take into consideration in both agriculture and health field. Lack of capacity is the serious problem in this regard.

Local data

Local data are not available simply because not much research works have been done on toxic chemical pesticides.

Experts

Nepal does not have competence and sufficient experts in the field of pesticides toxicology/research.

IPM products

Very few IPM products such as pheromone traps and other bio-environmental safe alternatives are available in the country at higher rates as these products are not classified as agricultural products.

Post registration

Without a strong post registration surveillance, the legislation process would be rendered inconsequential. The registrar's office is slowly looking into all this due to manpower problem.

Product stewardship principles

The government needs to pledge "from cradle – to – grave product stewardship". Chemical manufacturers and importers should be made responsible for cradle to grave cycle of their products especially toxic chemical pesticides.

Cooperation

General lack of adequate co-operation among stakeholders in chemical management including PIC procedure.

Infrastructural challenges

Lack of laboratory facilities to

- Pesticide quality residue analysis
- Toxicological analysis

Inadequate institutional development to handle all matters of pesticides like toxicological aspects. Laboratory facilities are required to accomplish such tasks.

Challenges to implement the PIC

The implementation of PIC poses challenges and constraints in Nepal.

- Decision Guidance Document (DGDs) which is very technical.
- Local Data not available because not much research has been done on PIC chemicals
- Lack of adequate knowledge on Risk Assessment.
- Low awareness among stakeholders on chemical management issues and PIC procedure.

In the Asian region agriculture is an important part of the economy. Where nations are not separated by natural boundaries, there has traditionally been a free trade of various commodities including pesticides and other agro-chemicals. It may be possible that there are cases where chemicals covered under PIC which have been banned or severely restricted are being exported to the country without complying with PIC procedures.

International agreements

International agreements related to the management of hazardous chemicals include

- The Stockholm Convention, 2001
- Rotterdam Convention on PIC, 1998
- FAO Code of Conduct on Distribution and Use of Pesticides, 1985
- London Guidelines for the Exchange of Information on Chemicals in International Trade, 1987.

Implementation of these international agreements is hampered by factors such as expertise & inadequate infrastructure.

Options

The possible options on alternatives to eliminate or reduce their use or dependence are suggested as follows.

The IPM option (IPM already on the ground)

United Nations Conference on Environment and Development (UNCED) Agenda 21 emphasises IPM as the best tool for 21st century Plant Protection Services. It states that IPM should be the guiding principle for pest control and that it is the best option for the future as it guarantees yield, reduces costs, is environmental friendly and contributes to the sustainability of agriculture.

Because of the serious and adverse effects of pesticides, various efforts have been made to develop alternative approach aiming at eliminating or reducing their use or dependence. In practice, several models exists and have been advocated:

- Integrated Pest Management
- Integrated Crop Management (ICM) Which emphasise "Judicious" as opposed to "Indiscriminate" use of pesticides

- Low external Input Sustainable Agriculture (LEISA)
- Organic Agriculture (OA)
- Use of environmental friendly safer pesticides with low toxicity

Realizing its potentiality, HMG/Nepal has already given priority to create public mass awareness and implemented effective IPM program through IPM Farmer Field School (FFS) for proper, sound and judicious management of pesticides. Today, IPM is considered as "National Pest Control Strategies" in Nepal. Presently, IPM provides the best option for rice and vegetables (Tomato, cauliflower, potato) and is more widely adopted. IPM has been widely accepted as the alternative to pesticide application, although IPM doesnot exclude the use of pesticides. It advocates the judicious and prudent use of such chemicals. A novel approach to meet this challenge, FFS had emerged in southeast Asia.

The IVM option

Vector control interventions that can be incorporated in an integrated approach include :

Environmental Management

- Environmental Modification (Irrigation schemes, Drainage Management & Road Construction of housing development)
- Environmental Manipulation (recurrent activities to reduce environmental receptivity often linked to operation and maintenance work)
- Zooprophylaxis (the use of cattle to divert zoophilic vector species away from biting humans)
- Personal Protection (Mosquito nets, use of repellents)

Biological Control

- Use of predators/parasites (the use of larvivorous fish is the most common approach and can be linked to fish culture for income generation.
- Use of bacterial toxins (Bacillus thuringiensis)
- The aim of the application of biological and environmental management methods is to eliminate mosquito breeding. IVM strategies that use no insecticide at all can be cheaper than spraying houses with DDT.

Chemical Control

Latest development is use of bed nets treated with synthetic pyrethroid, which is non-toxic and biodegradable and does not accumulate in nature as DDT.

Citizen Awareness

An increasing number of farmers producing organic vegetables is an indication of the expanding scope for IPM and citizen support.

Botanical Insecticides

Nepal is very rich in flora and there is a great scope for the development and use of botanical pesticides. In recent years, neem (Azadirachta indica) is getting popularity as a source of botanical pesticides which is highly eco-friendly. A number of world companies are engaged in processing neem seeds for extracting azadirachtin, a lamanoid, which is valued as an antifeedent chemical against a variety of insect pests.

There is also a variety of natural botanical pesticides available to farmers. In the past, Nepalese farmers used these traditional methods of pest control and are still using them in hilly areas. Botanical pesticides are easy to grow and use and their costs are often minimal or free. Most botanical plants have low toxicity as compared to chemicals and their residues do not pollute the environment. The most common pesticidal value of Nepal's indigenous plants include Allium sativum (insect repellent), a leaf extract of Artemisia vulgaris (for caterpillars & stored grain pests), Urtica dioica (stems and leaves for red ants and cutworms), Zanthoxylum armatum's fruit (insect repellent for : stored grain pests), Acorus calamus (insect repellent & contact poison) & Chenopodium botrys (insect repellent).

Prior Informed Consent

The PIC procedure provides important support to countries that do not have adequate legislation to regulate and control import of chemicals. The procedure is also very useful in that it provides for information exchange on specified chemicals which will assist the government in making decisions. Chemicals should not be exported without the explicit consent of the importing country.

Basel Convention

Products, the use of which is no longer permitted (banned, deregistered), are candidates for disposal. Banned or deregistered products may be still usable in other countries where use is still permitted. But due to the Basel Convention guidelines, the exporting country has to receive permission from the importing country.

HMG/N has already ratified the Basel Convention on the control of the transboundary movements of hazardous wastes and their control.

Conclusion and Recommendations

Farmers need to know what is the information printed on a pesticide label. Instructions written on the label or an accompanying leaflet need to be followed to obtain the recommended dosage. Farmers need to be reminded that pesticides are not the only control measures for pest problems. The strengths of both Government and NGOs entities should be utilized in this large endeavor. The government should foster IPM and remove taxes from IPM products. This recommendation is in line with recent changes in government policy where IPM methods are to be preferred over pesticide usage. There is a need for co-ordination and cooperation among and between countries within the same region. UNEP and FAO could play the role as a facilitator.

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Evaluation of the hydrological behaviour in a small catchment by using the model WaSim. A case study within the IPMS-Project in Nepal

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Abstract

This study presents a modular modelling system for simulating the hydrological behaviour of a small catchment in the middle mountains of Nepal, right in the investigation area of a close sub-unit of Jhikhu Khola catchment, 50 km east of Kathmandu. The model used is WaSim (Water balance Simulation Model) which is a physically-based distributed hydrological catchment simulation model with the ability to interface with GIS / ArcView. Within this different complex modelling system it is possible to combine the different model configurations in order to achieve an effective modelling structure with the best adaptation to the treated problem and the actual data base. Aspects about surface runoff and water flow as well as evaporation and soil water balance are described and finally be transformed into thematic maps. This GIS maps will be used as a visual tool which facilitate the interpretation of the regional physical conditions and gives a quantitative representation of short or long term processes in the hydrological cycle.Data preparation and/or data pre-processing is an imperative. Therefore some problems of data capture and parameter estimation are briefly touched, which incorporates on the one hand the development of digital elevation model (DEM) or the geo-referenced aerial photographs up to the derived land use map, and on the other hand the importance of parameter determination with respect to soil properties and plant physiology (LAI).

First results and validation calculations are also presented here. The range of precision and the extent of different data bases for calculating the water balance of agricultural site depends on actual boundary conditions in the project scale concepts. If data availability and data requirements are all clarified, this type of hydrological catchment simulation model seems to be a effective and practical tool in planning and decision making.

Introduction

An attempt was made to apply a hydrological catchment simulation model to a small watershed in Nepal. The chosen investigation area is a sub-unit within the Jhikhu Khola catchment, 50 km east of Kathmandu. The catchment covers an area of ca 12.5 ha, the elevation ranges from 750-2.100 m a.s.l.. The whole task is embedded in the integrated pesticide management Project IPM (HERRMANN & SCHUMANN 1999), where the main goal is to strive for a tenable make up environmental risk assessment relating to pesticides and integrated pesticide management in developing countries.

This paper addresses one approach of the hydrologic component of the IPM project. The study demonstrates a strategy to examine the hydrological behaviour of a representative catchment with all relevant water fluxes within the studied system. Based on project information main interest was to apply a physical-based distributed model built up by variable modular structure. It provides an applicable conceptual framework with respect to the physically based description and measurable dimensions. The model should have the ability to interface with an Geographic Information System (GIS). The use of GIS facilitates visual interpretation of prediction and subsequent recommendation. Recent progress and difficulties concerning the input data uncertainties and their solving approaches will be discussed.

Scope and hypothesis setting

During the pre-project phase all kinds of considerations and investigations were made, and following GTZ's goal-oriented project planning matrix (ZOPP) a strategy was drawn up which suited to the hydrologic interests, and denotes the course of examination. The synopsis of the internal project design is illustrated in Table 1.

In section "*Strategy*" in Table 1, the method of working is sketched step by step. Reflections are made in the following issue, how each activity steps take place.

The hypotheses is drawing up, that a well suited model will be required to be a practical tool to simulate the behaviour of the target catchment. The assumption is made that on the basis of a hydrological catchment simulation model it is possible to describe the major physical processes in the individual parts of hydrological cycle.

Table 1 Synopsis of internal project design "Hydrology"

Why ?	To strive for environmental risk assessment of pesticides and integrated pesticide management in developing countries	***Primary aim***
What ?	To produce a knowledge-based rule and expert system available for tentative pesticide reduction measures (considering the national control mechanisms of local agronomic, socio-economic and environmental boundary conditions)	***Project over goal***
Who ?	Hydrology is able to achieve contribution to that issue	***internal project***
What ?	**Realization of describing the major physical processes in the individual parts of hydrological cycle**	***project purpose***
Which ?	Importance of following external factors and boundaries: Security, logistic, facilities, collaboration, representative experiment field, suitable research methods, application of PC –tools is realistic, extremely packed time frame	***Important assumption***
How ?	*Strategy:* *Hypothesis development* **Stock-taking and evaluation of mandatory basis data (physical feature resources / basin characteristics) and model choice** **Implementation of new In situ tests** **Pre-processing of grid maps and data sets** **Process studies through the application of integrated components (GIS & Water Simulation Program)** Post-processing **Application of Case study** **Visualisation** Consequences	***objectively verifiable indicators***
Where ?	Identification and Evaluation: **Allocation of experiment fields** Topographic -, geologic - and soil maps Literature survey Assessment of existing environmental data Regular recording of meteorological data from climate station as well as from the recording gauges, piezometers and other physical measurement equipment Scientific studies and pure research (experiments and field tests)	***means / sources of verification***
To whom ?	**Uses and Effects:** **Investigation could be a contribution to promote the ecological awareness to all person affected** To point out the relevant consequences and /or effects of ecological system (network) on local and regional scale and assess the influence of human intervention **Measures integrated environmental compatibility and sustainability in the developed guide-lines**	***expected results / output***

Choice of model

In order to assess the suitability of a certain model structure to solve the particular problem, a decision support system in form of a status–feasibility matrix was drafted. The objectives, indicators and furthermore aspects were taken from the "*Zopp*" mentioned above. Table 2 shows the objectives (*supposed be*) and the targets with the actual conditions in the project area. It serves as auxiliary line to delimit the formulation of question and likewise helps to chose a suitable model configuration. Further it allows an evaluation of the final success. For this project intention the preconditions were evaluated with the help of a suited questionnaire from where the pertinent aspects were sketched and finally assembled. Each header of categories in the table clip of actual conditions are composed, but actually they hide several further reaching and/or important aspects. For example landscape complexity includes the following aspects: geomorphologic feature, biotic complex and natural or human disturbance; for hydrologic system: bucket system, linearity or non-linearity, homogeneity or heterogeneity and open or closed;...and so on).

Table 2 Status-feasibility matrix

Supposed to be
Objective *(1)* • To describe the major physical processes in the individual parts of hydrological cycle
Process *(2)* • Water balance • Rainfall-runoff relationship
Model set-up *(3)* • Temporal and spatial resolution (events and seasonal, grid scale not to small)
Model approach *(5)* • Physical based • Conceptual, modular and semi-distributed • Incorporated uncertainties

Actual conditions
Landscape complexity • high
Hydrologic system • non-linear, heterogen
Signature • Regime curve (discharge), specific parameter, ...
Driving forces (availability of rules, variables and arguments..) • temperature, precipitation, humidity, wind, ...
Boundaries *(6)* • High uncertainties (time frame, acts of God...)
Feasibility's *(4)* • medium to limited (data capture)
Means and facilities • high (logistic, measurement devices, lab,...)

Judgement
High constraints Parameterization and validation becomes tricky High uncertainties have to be taken into account Challenge

Nos.: 1 purpose, 2 process, 3 spatial and temporal frame , 4 data availability, 5 requirements and 6 expenditure of energy]

At the beginning the operator defines the process that has to be described, and also assesses the temporal and spatial scales which might be relevant.

The decision for a specific model set-up is therefore depending on the assessment which can be seen in the status-feasibility matrix. The decision for a suitable simulation model is consequently based on the principle selection criteria just stressed in Table 2 [see nos.(1)-(6)].

On this basis the target area is clearly seen, however, high general constraints cause significant uncertainties that have to be considered during the model performance. The interactions (causes and effects) between categories are assessed as not stable**.** Observations in other studies show close interaction of non-linearities in a system and parameters variances. Therefore parameter estimations and model validations are expected to be difficult. To summarise, without additional disturbance due to the general constraints, it will be a challenge to realise the task in time. The focus is the description of the run-off relationship within the small catchment. The objective and inherent processes are consequently described.

In this study the parsimonious approach is pursued that model configuration must only be as complex as needed to capture the appropriate signature that is given, because the scale frames and actual boundary conditions emphasise that philosophy.

Therefore the use of a semi-distributed deterministic model with modular structure is advisable, a combination of physically-based and conceptual approach allows to approximate step by step the simulation progress. The advantage of models with a modular structure is flexibility of model set-up dependent on the simulation objectives and data availability. Data requirements for each simulation objective can be suited or minimised due to model set-up. By gaining higher levels of knowledge, additional modules can be turned on, and the formulation of question allows to get deeper in details.
Considering these aspects the water balance model-package WaSiM-ETH (WaSiM-ETH-Zürich by SCHULLA & JASPER, 1999) was selected which serves various options to use with module parts, algorithm and variable time scales.

According to the demand of the used modular codes a physically-based distributed code was tested. The process description allows spatial discretisation. Processes such as surface runoff and evaporation can be described, and results like soil water balance can be transferred into thematic maps (GIS/ArcView).

Data capture

WaSiM-ETH model system basically needs two types of data sets for the internal simulation. On the one hand the spatially distributed data sets are required, which are temporally invariant and have to be transformed into grid information. Generally geographic data are used to demonstrate the spatial feature of its ecosystem as well as to reproduce their inherent conditions in any time clip (thematic maps). The digital elevation model (DEM) belongs to this category, further land use, soil type or sub-information like hill slope etc., are included in these data sets. On the other hand the programme system deals with temporal information, which is collected during a certain time period. These input data sets belong to the meteorological and hydrological quantity or measured units (e.g. precipitation, temperature or discharge). In most cases the observation or recording take place only at few selected sites (point supports).

We have to distinguish between capturing primary data sets and secondary data sets. The primary or original data come directly from the object or its reproduction (image), the secondary data sets are subject to different pre-processing methods in which the original data are adapted indirectly to the model demand (see Tab. 3).

Status of data

Regarding to the primary spatial data sets, a most common method to get topographic maps are the conventional survey methods and aerial photogrammetry or remote sensing techniques are used to derive the DEM and land use grids. Field visits and sampling or inquiries contribute to collect relevant information. For instance field measurements of plant phenology are made on a horticulture farm to get detailed land use information. Soil types estimation was covered via sampling and drilling, and denominated with geographic co-ordinates.

Table 3 Data requirements

Spatial Data	***Temporal data***		Pre-processing
Geographical data	*Climatological data*	**Hydrological data**	
⇒ **Primary data** • Digital topography (DEM) • Soil data (kf-value, storage capacity, soil type) • Land use (crop type, fallow, meadow forest,...)	⇒ **Primary data** • Station values with different time resolution modelling (temperature, radiation, wind speed, humidity, are pressure, sun shine duration)	⇒ **Primary data** • Discharge data from available gauges	Source of data supply from several places
⇒ Secondary data **Spatial transformation** • Raster data (grid) • All formats with same dimension and size	*⇒ Secondary data* **Temporal transformation** • Uniform format (equal time steps)	*⇒ Secondary data* **Temporal transformation** • Discharge per unit area (l/s(km^2) • Discharge per unit area into inverse discharge per unit area	*Converted data*
Calculation • Exposition • Slope • Flow direction • Flow accumulation • Flow net (river) • Catchment boundary • Topographic factor • LAI	*Calculation* • IDW, regression or Thiessen (geometric topologic), temporal interpolation (statistical method)	*Calculation* • Statistics (average + mean value) *Parameterisation* • recession constants	*Parameter estimation* Auxiliary tools (PC-programs an GIS-application)
Parameter estimation • Pedo-transfer function			

The secondary data are derived from the primary ones by using e.g. auxiliary computer programs and incorporated sub-modules in the main model or with the help of GIS applications. The format of spatial distributed data generally has grid size and has to be transformed into BINARY - format, the internal language of the model run. As preconditions, all spatial input data require an uniform grid size for processing, and all different thematic coverages have to be congruent, so that one grid after the other (grid in row x_1 followed by grid in row x_i) will be read against its grid template which makes calculation just possible. As we will see later, a well-suitable grid size depends on the given size of the catchment area under investigation where the authors of WaSiM-ETH recommend to generate 10 m grids size for areas smaller than 1 km^2 and 5 km^2 grid size for areas bigger than 10.000 km^2 (Schulla & Jasper 1999).

In case of the required spatial data the initial requirement for input grids looks confidently (see examples in Fig. 1).

Based on the DEM some information about slope, exposition and catchment boundaries or flow time etc., with hydrological relevance is extracted and serves as important hydrologic input data (Schulla 1997; Quinn et al. 1996 and Moor et al. 1993). In case of soil properties a classification of the saturated hydraulic conductivity of the soil matrix was done using pedo-transfer functions (SCHAAP 1999). The soil property information is saved in special tables, so that Arc/View is able to load it up and read each location as a theme and transforms it into grids. The land use data comes in fact from aerial photographs, but secondary data were taken indirectly due to limited resources for field measurement.

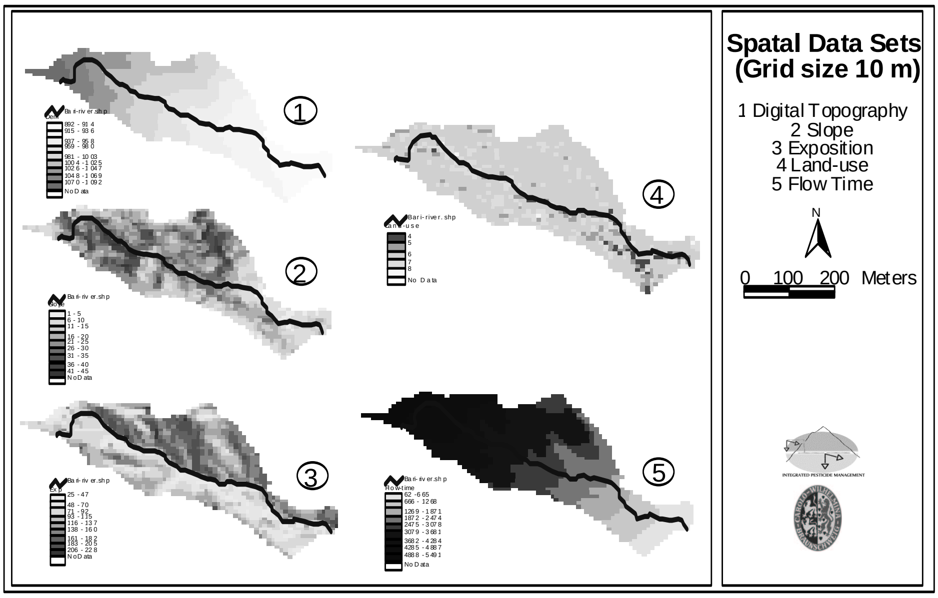


Fig. 1 Examples of spatial data sets

According to the requirements of the temporal data sets, climatological and hydrological data come to use. These temporal data types are variables and are the driving forces in the eco-system and consequently in the model processing. They are obtained by permanent registration from climate stations (humidity, temperature, radiation, wind speed, air pressure etc.) or stream gauges (water level). Secondary data will be provided through transformation using different statistical approaches. In most cases the required information must be transferred to another temporal scale. Statistics can be drawn up to transform the source data into any required time steps (averages and mean values). Further the meteorological input data, especially the temperature may be corrected by interpolation depending on the gradient of the altitude and radiation.

Hydrological data are of high importance for the calibration process. A most essential hydrological variable is in this context the measured discharge, which represents an integral information about the catchment.

It emerges that high uncertainties arose just by capturing these temporal input data. Rebounds were noted in the measurement facilities and devices. Apart from that, instability of political situation caused an earlier ending of the measuring campaign. Therefore these boundary conditions gave uncertainties due to the temporal input data, which are essential for the model processing (driving forces or simulator). Further data treatment due to the cleaning and proving of rugged data, took considerable expenditure, that was not expected. Because of limited data availability or sometimes data inconsistency, only short sequences of rain events could be used for model adaptation and calibration. The Figure 2 shows the actual stage of data capture.

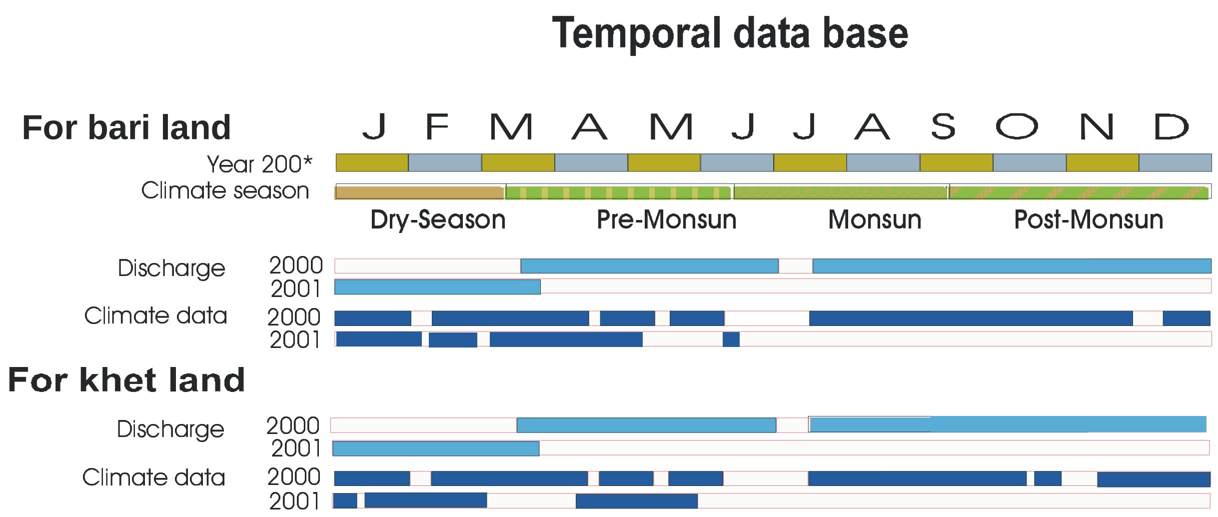


Fig. 2 Temporal data base: graph of periods of record

Model set up and configuration

The model configuration is demonstrated in the model-set-up box in Table 4. This approach tests the physically-based distributed code. The process descriptions allow spatial discretisation. The model application is based on status of data as shown in Fig. 2. Up to now the actual temporal project scale allows only to simulate short sequences (storm events), which demands hourly or daily time intervals (see examples in Fig. 3).

According to the demand of the used module configuration (modular codes for unsaturated soil with RICHARDS equation) this approach gives an acceptable representation of the system, in particular with regard to single storm events. Each event requires new parameter adaptation because of the non-linearity in the system and preferential flow. It is very uncertain to simulate the behaviour of catchment response over a longer period like season. Nevertheless, despite problems with the input data just discussed, and with scale complexity, non-linearity and spatial variability, this type of hydrological catchment simulation model is tenable. How well the model actually fitsthe observed behaviour of the system can be seen in an example of model run in Fig. 3.

Minimal requirements of model components (modules) and input data due to the presented model objectives were utilised, because model application is often restricted due to scarcity of data.

Conclusion

The parameter adjustment requires a lot of expenditure. This is confirmed through the permanent soil parameter adaptation during model processing, even though the first model run was based on a minimal model set-up. The soil properties and consequently the runoff conditions change after each rainfall event. It is assumed that the soil surface is full of macro-pores, fissures and cracks which serve as preferential flow paths. Therefore each actual surface runoff or overland flow is subject to changing conditions. The simulation results allow the assumption, that the catchment system reacts in a non-linear way, but this has to be proved with more model runs in detail. Actually the spatial scale has no great influence on runoff calculation which can be demonstrated with the changing grid sizes of 2.5 m, 10 m or 20 m.

Table 4 Model-set-up box

Model configuration:

Geographic setting:

Climate classification: subtropical, continental, semi-humid area [B2sh LAUER/FRANKENBERG]
Lower Himalaya – middle mountains
Location: Tinpiple valley; co-ordinates x 362822 and y 3.05635e+006
One small catchments,
Catchment size 12,5 ha
Elevation from 891 to 1092 m a.s.l.
Land use rainfed
Soil type: silt loam to clay loam
Catchment orientation NW - SE

Objectives:
Flood hydrograph simulation (single event)

Model set-up:
2 modules, 4_R- grids, 3_R input variables, 2 supplementary data sets, 14_R parameters

Model modules:
Soil modules (RICHARDS-equation) and Routing module

Model domain (resolution):
General for all the formulation of questions scale alternatives
Temporal scale : 1 h and 24 h;
Spatial scale: 2.2 m with amount of grids and 10 m with amount of grids and 20 m with amount of grids

Data sets of observation:
Precipitation, Temperature, Humidity, Windspeed, Radiation

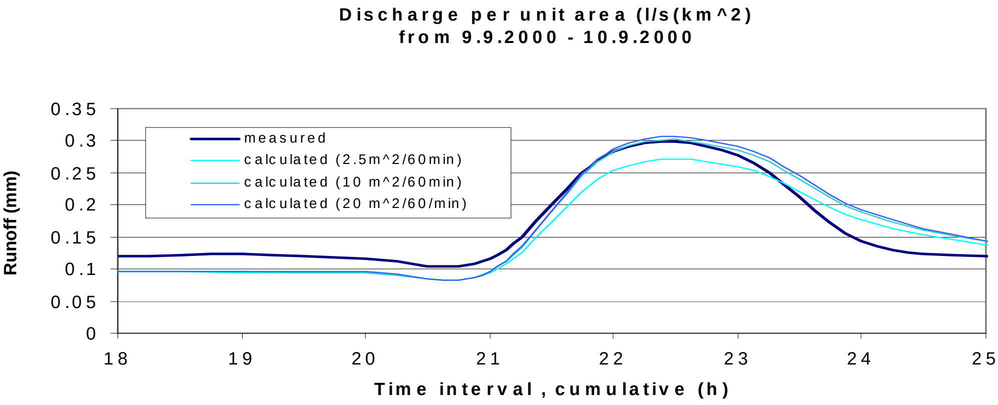
Grid requirements:
Digital elevation model, Land use grid, Zone-grid, Land use grid, Soil type grid

Parameter for:

ETP-module and interception-module are measured directly and taken from literature
9 Parameters
Soil-module indirect by fitting and by the use of pedo-transfer function and soil table
5 Parameters and indirect
Routing-module by topographic survey (DHM) and PC-help tool "TANALYS"
indirect

Simulation periods:
Tests ?
24.08.2000 [5:00h] – 26.08.2000 [12:00h] hourly
09.09.2000 [5:00h] – 10.09.2000 [12:00h] hourly
20.08.2000 [24:00] – 30.09.2000 [24:00h] hourly and daily
other . . .

Measurement for quality:
Discharge from stream gauge



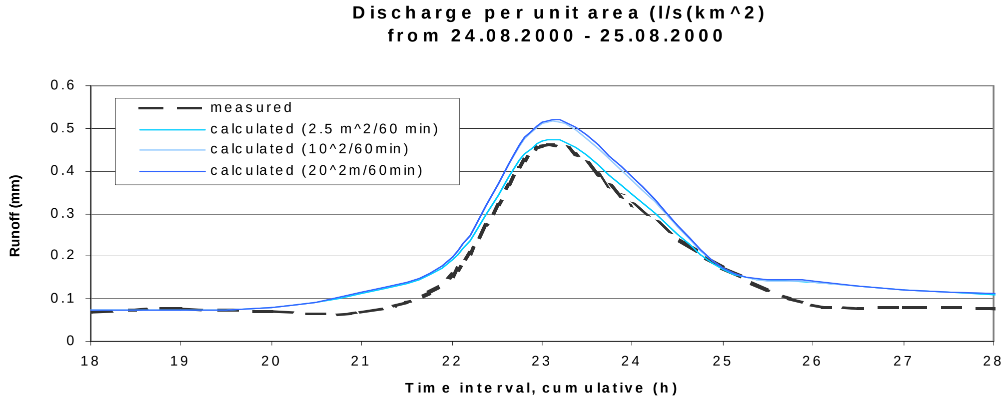
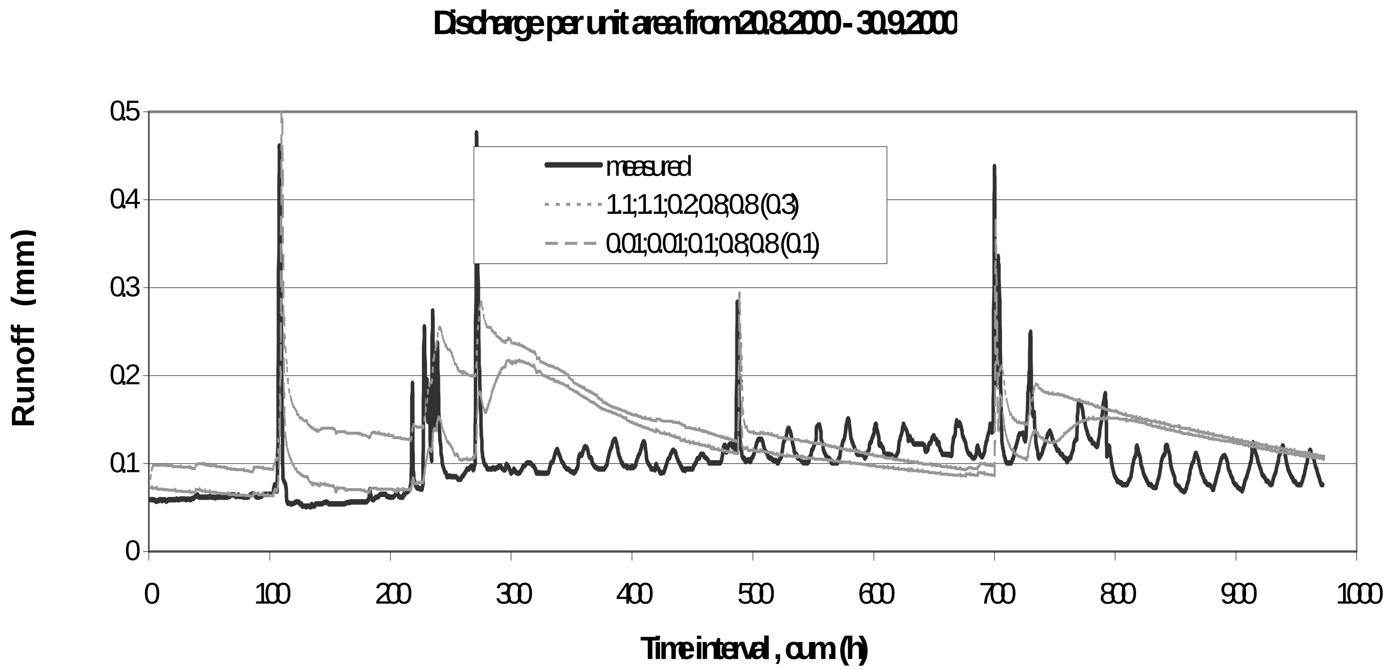


Fig. 3 Application examples of model approach with different time sequence



On the other hand, the application of different temporal resolution (hourly or daily) shows that the chosen time scale cause relatively high sensitivity.

It can be expected, that the estimation of relevant parameters will be time consuming and therefore the possibilities for the application of a very sophisticated model approach is limited. Furthermore, the application of the chosen hydrologic model will make the use of more stochastic approaches for assessing representative catchment parameters necessary. With certain statistical approaches it is possible to regionalise physical properties of soils and to quantify the influence of the uncertainties to the model results. We also assume that alternatives in form of data linkages can be included (indirectly measured or literature data). Due to given project circumstance, it seems to be more attractive to work with indirect information, making the operator independent from local boundary conditions, rather then capturing primary data. If irrigation could be neglected, then the top-approach could be used as an indirect alternative.

Due to the limited time available and considering all problems which arise usually in remote areas, parameter error results from an inability to represent area distributions on the basis of a limited number of points measurements. These basic problems of data capture and parameter up-scaling from site to field scale or the catchment scale are well known (see for example the discussions of BEVEN 1996, REFSGAARD & ABBOT 1996, BLÖSCHL & SIVAPELAN 1995, WOOD ET AL. 1990). There are many examples of such physically-based parameters, including soil properties or soil hydraulic conductivity, canopy resistance and effective root zone depth, plant density or vegetation cover. This creates the necessity to look for alternative strategies to compensate information gaps with reasonable values to reach a certain kind of equivalence.

However, beside the actual constraints, unstable system conditions, high uncertainties and considerable expenditure for pre-processing to provide and co-ordinate the rugged data until they had an usable format ready for modelling), the results presented here are expected to be refined and improved in the near future.

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A study on the impact of different plant extracts on the tomato fruit borer (*Helicoverpa armigera*)

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Abstract

In the Middle Mountains of Nepal with growing population pressure, the demand for food has risen considerably. To meet with this demand, farmers who have easy access to markets and favourable climatic conditions are turning towards commercial vegetable production. One of the best examples for this is the Jhikhu Khola Watershed. The use of high doses of chemical fertilizer and pesticide has become a common practice to maximize production, nowadays.

Pests develop resistance after repetitive use of chemical pesticides. Resistant individual pests make up an increasingly large part of the pest population and pass on their resistance to future generations. Farmers therefore are using stronger and stronger chemicals in higher doses, which is having an adverse affect on the environment and ultimately on human health. Present methods of applying chemical pesticides are also dangerous as farmers lack proper knowledge about their application and their affect on human health and environment.

A long-term answer to pest resistance, ecosystem destruction, and environmental pollution exists in natural alternatives to modern chemicals. An experiment was set-up to study the impact of different plant extracts on the tomato fruit borer (*Helicoverpa armigera*). Three different kinds of treatment were carried out using aqueous solution of *Riccinus communis*, *Artemisia vulgaris* and mixture of four different plants extract (*Riccinus communis*, *Artemisia vulgaris*, *Melia azedarach* and *Vintex nigundo*). The treated productions were compared with an untreated control production.

The results were promising. Both the *Riccinus communis* and *Artemisia vulgaris* treated plots had more than 100% production over the untreated control plot. Though the mixture of four

different plants did not give comparative result to the *Riccinus communis* and *Artemisia vulgaris,* still the production was 63% higher than the production of untreated plot.

The result of the experiment indicates that the *Riccinus communis* and the *Artemisia vulgaris* aqueous solution can successfully replace chemical pesticides to control the invasion of fruit borer on the tomato crop.

Introduction

The farmers of the Jhikhu Khola Watershed (JKW) are in commercial vegetable production, mainly potatoes and tomatoes. This is due to its favourable climatic conditions and easy access to the Kathmandu market. However, they face an accute problem of the tomato fruit borer (*Helicoverpa armigera*) on their spring and pre-monsoon tomato crops. It has been noticed that the farmers have been using a wide range of chemical pesticides (e.g. Nuvan, Fanfan, Cypermethrin, Decis, Rogor etc.) in much greater doses and frequencies than agronomically recommended in order to control the problem. This current practice is not only harmful for the natural ecosystem but also for the environment, health and economy of the local farmers.

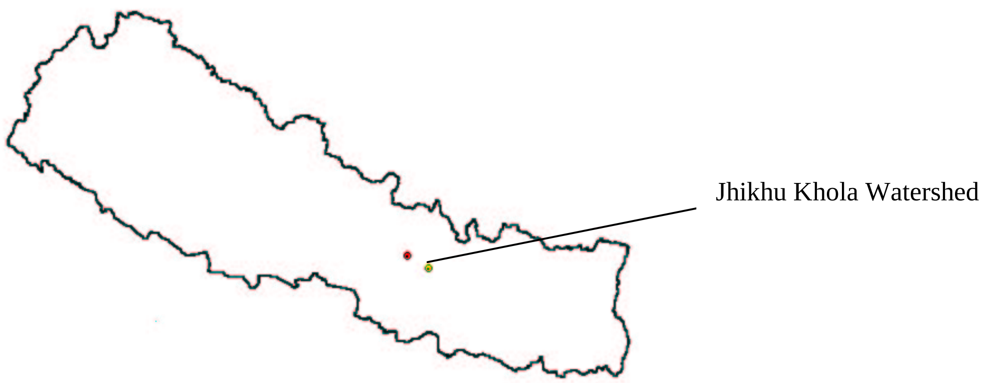

Fig. 1 Jhikhu Khola Watershed

The tomato fruit borer is the larva of the *Helicoverpa armigera* moth of the family Noctuidae. In warm humid places like the JKW it completes several life cycles per year. The moths are very active during evening time and lay eggs on leaves of the tomato plants. The young larvae feed upon the leaves, and as they grow they start to attack the young fruits. They bore holes on the fruit surface and enter into the fruits. The invaded parts of the fruits start to decay. The damaged fruits ripe early but are of no market value. The growing larvae are greenish in colour with blackish spots on the dorsal surface while the mature ones are brownish. Besides tomato the fruit borers attack various other plants such as capsicum, maize etc (Gyawali 1999, Neupane 1989).

Fig. 2 Helicoverpa armigera

The People and Resource Dynamics of Mountain Watersheds in the Hindu Kush-Himalayas Project (PARDYP) in collaboration with Horticulture Farm, HMG/ Department of Agriculture, set up an experimental plot in the Horticulture Farm at Tamaghat in spring season to study the impact of different plant extracts on the fruit borer of tomato crop. A local tomato variety (Lapsi gede) which is very popular amongst the local farmers for the season was selected for the study.

PARDYP is a watershed management 'research for development' project active in many different fields of natural resource management in five watersheds across the Hindu Kush-Himalayas with one watershed in China, India, Pakistan and two in Nepal. Important research components of the project are hydro-meteorology and sediment, water chemistry, rehabilitation of degraded land, erosion control, soil fertility, and agronomy. Overall coordination, guidance and administration are provided by the International Farm for Integrated Mountain Development (ICIMOD). Funding is received from the Swiss Agency for Development and Cooperation (SDC), the International Development Research Farm (IDRC) and ICIMOD.

Investigating alternative pest management systems is an important aspect of the agronomy component that the project has introduced in the JKW, Nepal, beginning in 1998.

The Horticulture Farm is situated in Tamaghat, which is located at 860m asl on the valley bottom of the JKW. Easy access to the Kathmandu market is provided through the Araniko highway at a drive of 43 km. The average annual temperature ranges from minimum 5^0C to maximum 33^0C with average annual rainfall of about 1200 mm (Merz et al. 2000). The farm was established in 1975/76, under HMG/ Department of Agriculture on an area of 7.5 hectares. The farm is presently involved in the production of tropical fruit saplings, vegetable seeds, and technology transfer, on the spot training and collaborative research with other government agencies, NGOs and INGOs.

Aim

The main aim of this study is to recommend alternative measures to control the *Helicoverpa armigera* of the spring and pre-monsoon tomato crops, using locally and easily available natural resources.

Material and methods

In the following are the material and methods applied for the preparation of the field and for the preparation, storing and application of natural pesticides.

Field preparation

Double spacing plots of 4 m * 1 m were prepared. The double spacing plots were prepared in order to conserve soil moisture. Both organic and chemical fertilizers were applied at different times (Table 1): 100 kg organic, 2 kg DAP, 1 kg Urea and 0.5 kg Potash. There were 20 plants on each plot.

Three different kinds of treated plots and one untreated control plot were prepared with 5 replica each. One plot was treated with aqueous extract of Artemisia vulgaris (below Mugwort), another with aqueous extract of Riccinus communis (below Castor) and the other with aqueous extract of a mixture of 4 different plants: Mugwort, Castor, *Vintex nigundo* (below Indian privat) and *Melia azedarach* (below Persian lilac). The concentration and the part of the plant used are shown in Table 2.

Table 1 Record of fertilizer application

Basal dose				Top dressing			Total	
Fertilizer	Date	Applied		Date	Applied		Applied	
		kg	kg/ha		kg	kg/ha	kg	kg/ha
Compost	01-Feb	60	7500	27-Mar	40	5000	100	12500
Potash	01-Feb	0.5	62.5	27-Mar	0	0	0.5	62.5
DAP	01-Feb	1	125	27-Mar	1	125	2	250
Urea	01-Feb	0.5	62.5	27-Mar	0.5	62.5	1	125

Table 2 List of plant resources used

Botanical name	Common name	Local name	Part of the plant used	Concentration
Artemisia vulgaris	Mugwort	Titepati	Leaves	10%
Riccinus communis	Castor	Andil	Leaves	10%
Melia azedarach	Persian lilac	Bakaina	Leaves	10%
Vintex nigundo	Indian privat	Simali	Leaves	10%

Selection of plants

Different plants for treatments were taken under consideration for their medical properties. Finally four plants; Castor, Persian lilac, Mugwort and Indian privat were selected, as they are abundant in the watershed. A brief medical properties of the selected plants are as below:

Castor (*Riccinus communis*)

"Nowadays known as Jatropa curcas. Curcas oil contains a toxin, curcasin. The albumen of the kernel is a poison, toxalbumen cursin, most abundant in the embryo. Another poison, a croton resin, occurs in the seeds and causes redness and pustular eruptions of the skin. The plant is listed as a fish poison. Aqueous extracts of J. curcas leaves were effective in controlling Sclerotium spp., an Azolla fungal pathogen.

The seed oil, extracts of J. curcas seeds and phorbol esters from the oil have been used to control various pests, often with successful results. In Gabon, the seeds, ground and mixed with palm oil, are used to kill rats. The oil has purgative properties, but seeds are poisonous; even the remains from pressed seeds can be fatal" (ICRAF 1998).

Persian lilac (*Melia azedarach*)

"Aqueous and alcoholic extracts of leaves and seed reportedly control many insect, mite and nematode pests. However, because they contain toxic components, care is needed in their use. The fruit of M. azedarach is highly toxic to warm-blooded animals; the consumption of 6-8 fruit can cause nausea, spasms, and in children, even death.

Various parts of Melia azedarach have antihelmintic, antimalarial, cathartic, emetic and emmenagogic properties and are also used to treat skin diseases. Dried ripe fruit is used as an external parasiticide; some toxic components are found in the seed oil, the oral intake of which may cause severe reactions and even death" (ICRAF 1998).

Mugwort (*Artemisia vulgaris*)

"The plant is described as having repellent and fumigant effect against insects due to satonin. Horticulturists used the branches for safe package of fruit. Michael Grange and Saleem Ahmed, 1987 have described the plant as having insecticidal effect upon flies, mosquitoes, lice and cockroaches; antifeedant effect upon Leptinotarsa decemlineata, Phytadacta formica, Pieris brassica and stored grain pests. Experiment on aqueous and alcoholic extract of plant showed cidal effect upon different agricultural pests including Soyabean hairy catterpillars, aphids and mealy bugs. Use of the plant extract in household pest like fleas also gave satisfactory result.

The plant extract is also used as antihelminthic against roundworms, tape warms etc. Externally, it is used in skin disease as antiseptic and detergent. Poultice of harb is applied to gout and joint pain" (Vaidya 1998/99).

Indian privat (*Vintex negundo*)

"Leaves are used in books and clothes to protect from insects. The juice of leaves remove worms, oil extracts are used in sinuses, wounds etc. The flower buds boiled in water are taken to relieve pneumonia" (Vaidya 1998/99).

Extract preparation

One kilogram of aerial parts of the plants (see Table 2) were chopped and ground in a hand grinder. The material was then soaked into one litre of cattle urine for at least 24 hours. The solutions were stored in plastic buckets. Nine litres of water were added to one litre of the solution before spraying.

To prepare fresh extract for each application is time consuming. Therefore 6 kg of each kinds were chopped, ground and soaked in cattle urine. The prepared solutions were then kept in different buckets and diluted according to need at the time of use. This storage method was also useful for off-season application when the leaves of these plants could not be found.

Application of the pesticide

Right before plantation about 10g green bio mass of the chopped plant parts were applied in the places where tomato plants were to be planted. After 45 days of plantation, the plants were treated weekly by their respective extract for 10 weeks. As the adult moths of the tomato fruit borer are very active during evening, the spraying was carried out during afternoon (around 4:00 p.m.) in order to keep the adult moths away.

Pest record

On each plot four sample plants were selected and marked. The sample plants were observed carefully each week a day before application of the pesticide.

Results

Input of water, chemical fertilizer and organic fertilizer in all plots was made uniformly. However a distinct difference in flowering time (Table 3) and production (Table 4) between treated and untreated control plots was noticed. All the plants in treated plots started flowering after two months while it took another half a month more for the plants in untreated plots to flower. This result clearly indicated that the plant extracts used as pesticide facilitated early flowering and fruiting at the same time.

The pest (*Helicoverpa armigera*) was not noticed in any plot before the start of flowering. After flowering (11th April) the pest started to appear and within about one and half months time (23rdMay) it was seen on almost all plots (Table 5).

Table 3 Record of pesticide application

Date	Time	Remarks
01-Feb	Afternoon	Soil treatment/ planting date
15-Mar	Afternoon	
22-Mar	Afternoon	
29-Mar	Afternoon	
05-Apr	Afternoon	All plants in treated plots starting to flower
12-Apr	Afternoon	
19-Apr	Afternoon	All plants in treated plots starting to fruit and control plot started flowering
26-Apr	Afternoon	
03-May	Afternoon	Fruiting started in the control plot too
10-May	Afternoon	
17-May	Afternoon	
24-May	Afternoon	

Table 4 Production

Date	Production/plot (kg)				Remarks
	Castor	Mugwort	Four mixed	Control	Damaged fruits were not recorded
15-May	2	2	1		
17-May	5	4	4		
19-May	10	12	10	8	
22-May	13	12	9	7	
28-May	21	18	16	8	
01-June	10	13	10	5	
02-June	5				
05-June	4	7	4	5	
Total production/20sq m	**70**	**68**	**54**	**33**	
Production/ha	**35000**	**34000**	**27000**	**16600**	
Production/ropani*	**1750**	**1700**	**1350**	**825**	

***Ropani is a local measurement for land in Nepal of 500sq m.*

Table 5 Occurrence of pest

Date	Mugwort	Castor	Mixed	Control	Remarks
04-Apr	0%	0%	0%	0%	Flowering in treated plots
11-Apr	15%	15%	20%	20%	
18-Apr	20%	15%	35%	25%	Fruiting in treated plots/ Flowering in untreated plots
25-Apr	40%	40%	40%	45%	
02-May	35%	40%	55%	60%	Fruiting in untreated plots
09-May	45%	45%	60%	65%	
16-May	60%	60%	80%	75%	
23-May	85%	80%	100%	100%	

The tomatoes grown were used for the seed production by the Horticulture Farm, so the fruits were harvested some days later than they would be for selling in the market for consumption. Though the sample plants indicated almost 100% invasion of the pest by 23rd May and most of the production was harvested from 22nd May to 01st June (Table 4), pest damage on the treated plots were still negligible. This result indicates that the invasion of pest at later stage of fruiting did not effect production, i.e. the young fruits are more vulnerable to the pest than the mature ones.

Overall production has shown the best results from the plots that are treated by Castor extract. It recorded 112% better result over the untreated control plots. The plots treated by Mugwort have gives equally good results showing 106% better results than the control plots. Though the plots that were treated by the extract of four mixed plants did not give as good results as the former two, yet it was showing 63% more production than the control plots.

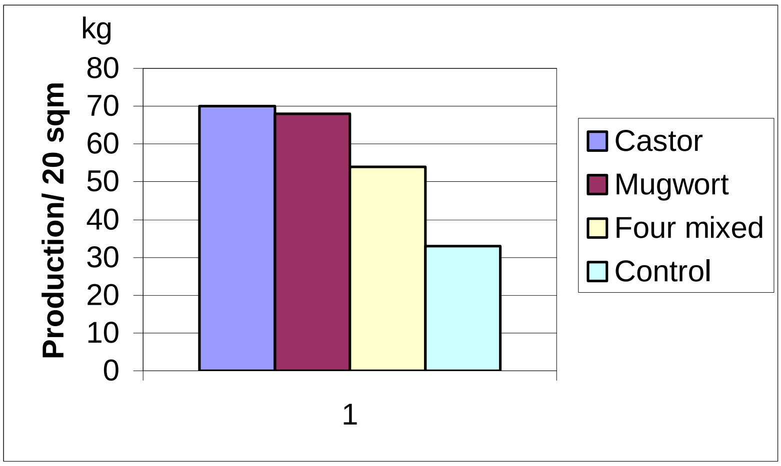

Fig. 4 Production record

Discussion

In comparison to treated plots the untreated plots showed very poor yield for clearly two different reasons:

a) They started to flower and give fruits later than the treated plots, showing nutrient deficiency.
b) By the time they started to fruit the sample plants were showing already 60% invasion of the fruit borers in these plots (see Table 3 and 5). So the fruit borer damage was much more in these plots than in any others.

Though the invasion started with the flowering on the treated plots, the pest started to show up in the untreated plots, that had not yet flowered, at the same time (Table 5). So *Helicoverpa armigera* moth started to get attracted by the flowering of the tomato plants and started to lay eggs on the leaves of the plant irrespective of flowering or non-flowering.

The sample plants indicated 80% invasion in Castor plots, 85% in Mugwort plots, 100% in the plots treated by the mixture of four different plants and 100% in untreated control plots by 23-May. But very little effect was noticed in treated plots in comparison to the control plots. This is because by then about half the fruits were already harvested and the remaining half was ready or nearly ready to harvest in the treated plots. While in untreated control plots the fruits were still in the growing phase. Thus from 24th May the treatment was stopped as almost all the crops in the treated plots were ready to be harvested.

The extract of the mixture of four different plants was taken under experimentation to see its effectiveness in comparison to the individual extracts. If it had been equally effective as the others, it would be more convenient for farmers to prepare the extract. But it was not giving comparative result to the two other individual treatments, but in comparison to the untreated control plots it was showing 63% better yield. Therefore this treatment should be extended for some more times to study its effect in the coming years.

Though the untreated control plots were giving very poor yield (33 kg in 20 sq m, i.e. 16.5 t/ha or 825 kg per ropani), it was comparative to the average tomato production of the area. The average tomato production under chemical treatment of the area for this season is about

881 kg per ropani or 17.6 t/ha (Prajapati-Merz, on preparation). This result clearly shows that the chemical insecticides presently used in the JKW are loosing their effects on the tomato fruit borer.

Conclusion

The Castor and Mugwort had given more than 100% better yield in comparison to the control plots. With little effort environmentally friendly natural products can therefore replace the harmful chemical insecticides currently used.

The plants used in this experiment are green manure and the cattle urine with its nitrogen content also enhanced the net production of the treated plots.

The moth arrives with the flowering of the crop, an early plantation would escape the heavy invasion. Plantation of tomato on ones plots after flowering in the neighboring plots can make problematic for the use of any kind of control measures.

As the borers mostly attack the young fruits, better care should be given to the crop between flowering time to the ripening of the fruit.

Both the Castor and Mugwort extracts gave very promising results for controlling tomato fruit borer. But the farmers of this area are used to applying chemical pesticides, which are easily available in the local market and take no time to prepare a desired solution. They can directly put the chemicals into the sprayer along with water. Thus the main factor that prevents the local farmers from adopting this technology is the lengthy processing method. In order to make it adaptable further experimentation is needed to simplify the processing method. This was tried in the present study by taking the extract of a mixture of four plants and preparing a whole lot of extract at a time that was stored to be used according to need. A social awareness program on the health hazards and non-effectiveness of chemical pesticide on pest after repetitive use may also help the farmers to look for safe alternatives.

Further experimentation with natural pesticides will be carried out in order to see their effect on late blight (*Phythoptera infestans*) of post monsoon tomato crops and bacterial wilt (*Ralstonia [Pseudomonas] solanacearum*) of potato crops.

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Use of pesticides in Jaishidihi sub-catchment, Jhikhu Khola watershed, Middle Mountain in Nepal

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Abstract

The traditional cropping pattern in Nepal particularly in accessible areas has been changing. The increasing use of modern agricultural inputs and response to demand driven by market towns with the improvement in road access have caused such changes. This paper discusses the use of pesticides in changing context of cropping pattern in Jaishidihi sub-catchment. It is found that the production of crops such as potato, tomato, bettergurd and chili has been increasing in recent decades. The use intensity of pesticides in these crops is comparatively high than in other traditional crops such as paddy and maize. Since per unit profit from these crops is still higher and the cost of pesticide is lower, the use intensity of pesticides is likely to increase in the future. People have already noticed different health problems due to mishandling of pesticides in the study area. So, immediate actions to regulate the use of pesticides are necessary for sustainable economic and environmental development of the area.

Background

Pesticide is one of the input factors used to increase agricultural productivity by protecting plants and crops from pests and diseases. The use of pesticides varies with the types of land and crops, access to market and socio-economic condition of the people. Excessive use and inappropriate handling of pesticides cause damages of environmental resources and different health related problems. Nepal has been experiencing various environmental and health hazards due to misuse of pesticides (Klarman 1987, Baker & Gyawali 1994, Dahal 1995). It is in this context that an assessment of the use of pesticide is necessary to develop strategies for avoiding negative impact and sustainable development. This paper aims to assess the use of pesticides in a small catchment from different perspectives.

Methods and materials

Jaishidihi sub-catchment of the Jhikhu Khola watershed in Kabre Palanchock district in the Middle Mountains of Nepal was selected for the study (Figure 1) within the frame of a collaborative project on risk assessment of pesticides by the Technical University of Braunschweig, Germany. There are 120 households with a total population of 795 people in this sub-catchment (CEAPRED 1999). Newar, Brahamin, Chhetri, Tamang and Kami are major ethnic groups in the study area (Pujara 2000). This study is based on data collected from randomly selected 30 households in Jaishidihi. It covers 128 plots with different land types and crops owned by these 30 households. Data were collected by using structured questionnaire and they are recalled and reported by the household heads during field work.

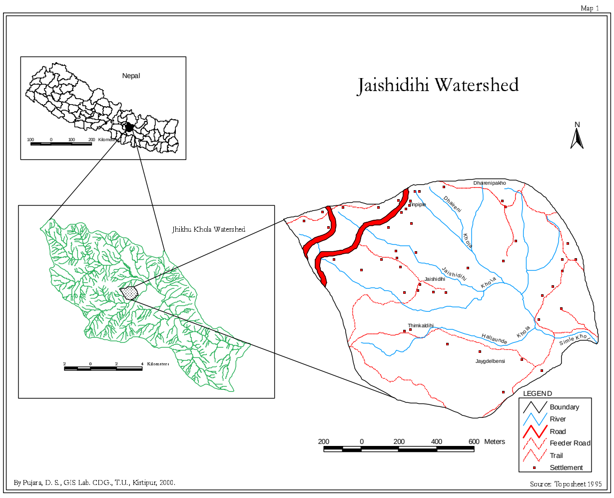

Fig. 1 Geographical situation of Jaishidihi watershed

Introduction to study area

Study area is located about 50 km east from Kathmandu. Arniko Highway (113 km) from Kathmandu to Tibet, which was constructed in 1963, links the area. The altitude ranges from 860 m to 1120 m. Nearly 70 percent of the total area of Jaishidihi sub-catchment is under cultivation followed by forest and plantation (10.2 percent), grazing (5.1 percent) and road (2.1 percent) (Fig. 2). Irrigated *khet* land comprises about 31 percent of the total cultivated land and the remaining 69 percent consist of rainfed *bari* land (Fig. 3).

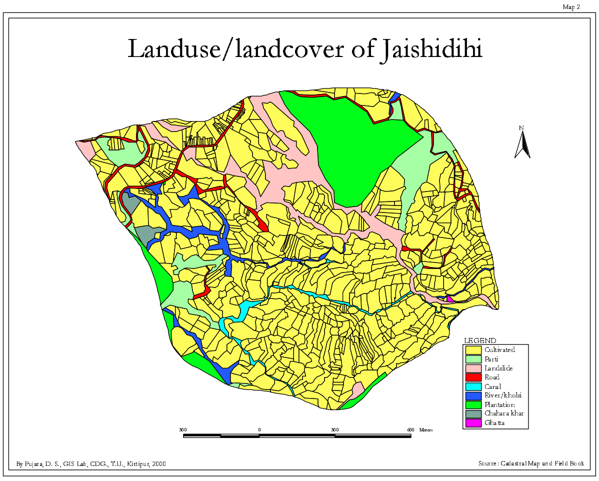

Fig. 2 Landuse and landcover

Figure 3

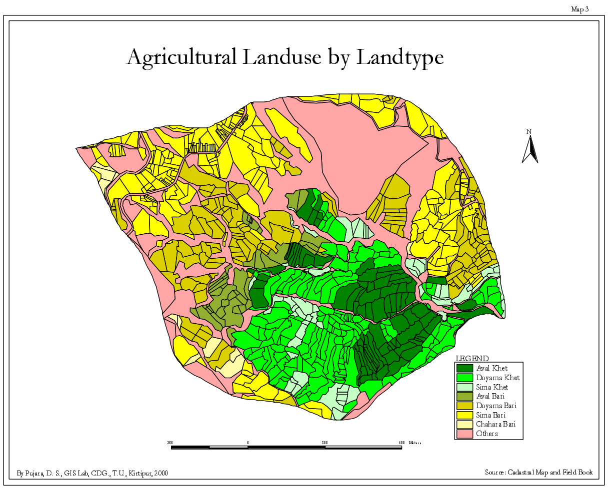

Fig. 3 Agricultural landuse by landtype

Nearly, 70 percent of the total area of the watershed is under private ownership, 29 percent under government and remaining 2 percent is *guthi*, which is religious trust (Fig. 4).

The size of land holding owned by these surveyed household ranges from 2.44 ropani to 48.98 ropani (19.6564 ropani = 1 hectare) and 70 percent households have less than one hectare of land. The land is highly fragmented. The number of plot owned by the farm household ranges from one to ten with an average of 4.27 plots, and these plots are located within 1.5 km distance from the house. Major cereal crops grown in the area are rice, maize, and wheat.

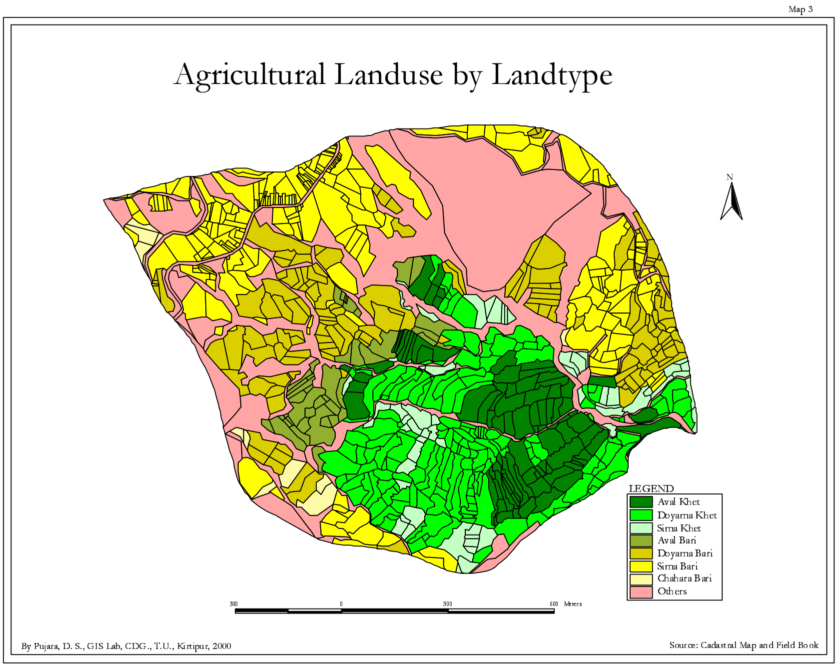

Fig. 4 Agricultural landuse by landtype

Table 1 Number of plots and area under different cropping pattern in *khet* land

Cropping Pattern	Plots		Area	
	Number	Percent	Ropani	Percent
Rice-potato-maize	51	73.9	166.5	75.3
Rice- potato-tomato	6	8.7	8.4	3.8
Rice-potato-maize+tomato	3	4.4	17.5	7.9
Rice-potato+wheat-maize	2	2.9	8.5	3.8
Rice-wheat-fallow	2	2.9	5.3	2.4
Rice-potato-bittergurd	1	1.5	1.5	0.7
Rice-potato-chilli	1	1.5	1.5	0.7
Rice-potato-tomato+fallow	1	1.5	5.1	2.3
Rice-potato-fallow	1	1.5	5.3	2.4
Rice-fallow-fallow	1	1.5	1.8	0.8
Total	69	100.0	221.3	100.0

Source: Household Survey, 1999

People have started to grow cash crops such as potato, tomato, bittergurd, chili and other vegetables with the improvement in access to market towns after the construction of Arniko Highway and introduction of modern agricultural inputs such as chemical fertilizer. At present there are more than 10 different cropping patterns dominated by rice-potato-maize in *khet*

Table 2 Number of plots and area under different cropping pattern in *bari* land

Cropping Pattern	Plots		Area	
	Number	Percent	Ropani	Percent
Maize-fallow-fallow	25	42.3	98.1	40.6
Maize-tomato-fallow	9	15.2	25.0	10.4
Maize-wheat-fallow	5	8.5	20.4	8.4
Maize-tomato+fallow-fallow	4	6.8	26.1	10.8
Maize-potato-fallow	2	3.4	6.4	2.7
Maize-tomato+wheat-fallow	2	3.4	4.8	2.0
Maize+bittergurd-tomato-fallow	1	1.7	3.5	1.5
Maize+tomato+chilli-wheat+potato-fallow	1	1.7	16.1	6.7
Maize-mustard+tomato-fallow	1	1.7	2.4	1.0
Maize-mustard-fallow	1	1.7	4.0	1.7
Maize+bittergurd-fallow-fallow	1	1.7	1.5	0.6
Maize+tomato-fallow-fallow	1	1.7	23.2	9.6
Maize-chilli-fallow	1	1.7	6.3	2.6
Others	5	8.5	3.7	1.5
Total	59	100.0	241.5	100.0

Source: Household Survey, 1999

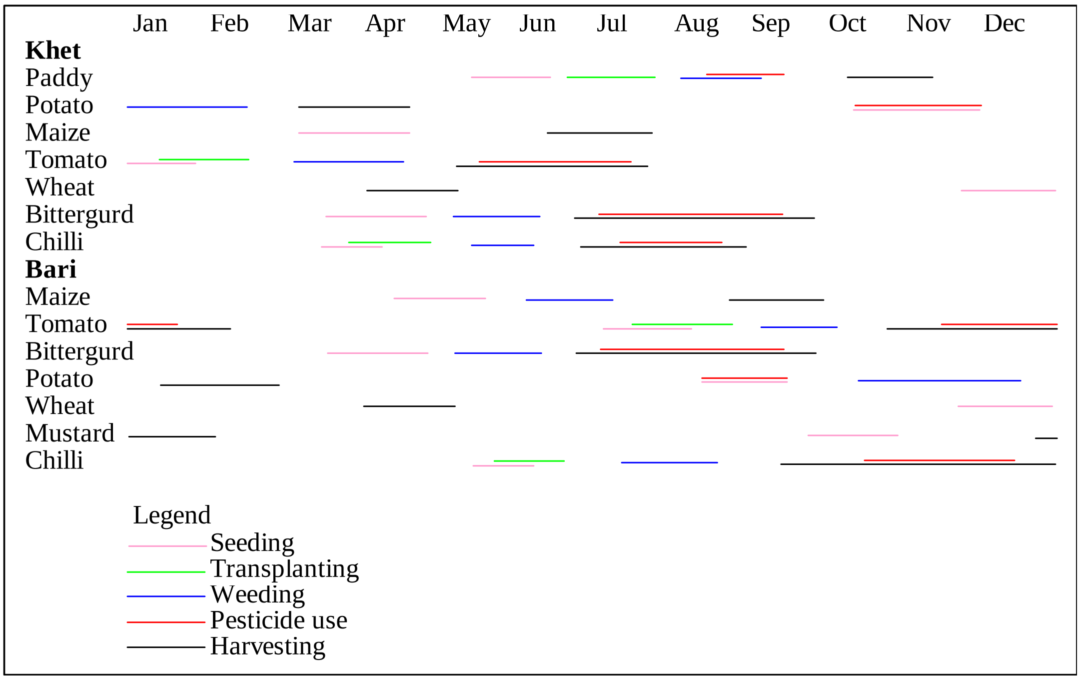

Fig. 5 Cropping pattern in sample households

land and more than 13 cropping patterns dominated by maize in *bari* land (Table 1 and 2 and Fig. 5).

Use of pesticides

Pesticides are used for protection of plants and crops from diseases and pests. Modern chemical pesticides were used in this area in late 1950s for the eradication of malaria by the government. But the use of pesticides for the protection of plants and crops by local farmers in the area started since 1983/84. The use of pesticides has been increasing with the increase in area under cash crops. Local people perceive that more input of pesticides gives more output of crops without paying adequate attention on the negative impact on environment and health.

Both dust and liquid pesticides are used in this area. Pesticides are used in almost all the cash crops in the area. Fig. 5 shows the calendar of crops grown in the area and the timing of the use of pesticides. Pesticides are used in almost all the area under potato, tomato and bittergurd cultivation. Present survey shows that pesticides are used in 34.3 percent of the total area under chili and only 11 percent area under paddy cultivation (Table 3).

Table 3 Area covered by pesticides use (area in ropani) (19.6564 ropani = 1 ha)

Crops	Total area under crops	Area under pesticides use	Percent in total area
Rice	221.3	24.7	11.2
Potato	223.7	223.7	100.0
Maize	397.6	0.0	0.0
Tomato	63.9	63.9	100.0
Wheat	53.7	0.0	0.0
Mustard	5.3	0.0	0.0
Bittergurd	7.5	7.5	100.0
Chilli	11.8	4.0	34.3

Source: Household Survey, 1999

Commonly used dust pesticides in the study area are indofil–45, diathim-45 and Malathion. Similarly, nuvan, rogar, fen-fen, metacid, bavistan, hinosan and dursban are other liquid pesticides used in this area. Table 4 shows the use intensity of dust pesticides calculated on the basis of quantity of pesticides used and actual area under pesticides use. It shows that the use intensity of dust pesticides is comparatively high in *khet* and in cash crops such as potato and tomato than in *bari* and other food crops (Fig. 6).

Table 4 Use intensity of dust pesticides by land type and crops (gram/ropani)

Crops	Land types	
	Khet (irrigated land)	*Bari* (rainfed cultivated land)
Paddy	46	0
Potato	917	532
Maize	0	0
Tomato	575	447
Wheat	0	0
Mustard	0	0
Bittergurd	0	83
Chilli	0	0

Source: Household Survey, 1999

Figure 6

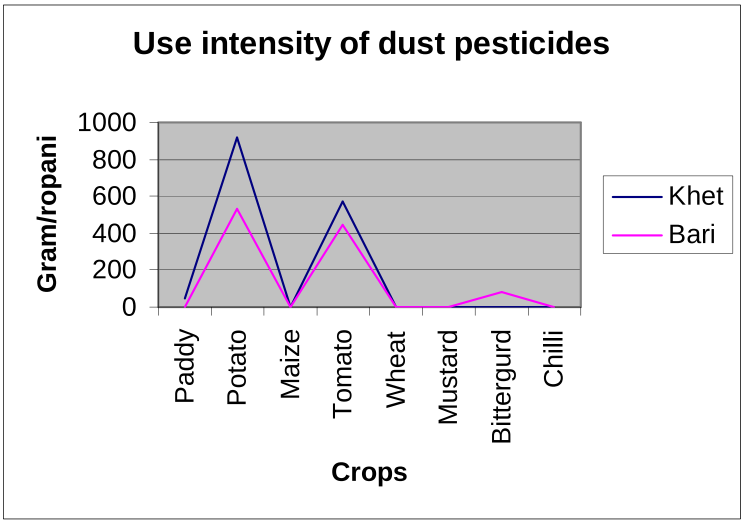

Fig.6 Average application rates for dust pesticides

Table 5 shows the use intensity of liquid pesticides in the area. Again the use intensity is high in *khet* and in high value cash crops such as tomato.

Table 5 Use intensity of liquid pesticides by land type and crops (ml/ropani)

Crops	Land types	
	Khet (irrigated land)	*Bari* (rainfed cultivated land)
Paddy	5	0
Potato	20	88
Maize	0	0
Tomato	258	121
Wheat	0	0
Mustard	0	0
Bittergurd	0	75
Chilli	0	50

Source: Household Survey, 1999

Per household per year use of pesticides in value in Nepalese Rupees is very high in potato followed by tomato and paddy (Table 6). Per household money value of pesticide used in potato ranges from Rs. 232 to Rs. 2149 depending upon the size of the farm with an average of Rs. 755. It ranges from Rs. 64 to Rs. 1130 with an average of Rs. 418 in tomato and from Rs. 26 to Rs. 496 with an average of Rs. 186 in paddy. Average per household money value is less than Rs. 100 in other crops.

Table 6 Per household expenditure on pesticides in a year in Nepalese Rupees

Crops	Minimum	Maximum	Average
Rice	26	496	186
Potato	232	2149	755
Maize	0	0	0
Tomato	64	1130	418
Wheat	0	0	0
Mustard	0	0	0
Bittergurd	42	178	97
Chilli	33	33	33

Source: Household Survey, 1999

Table 7 shows per ropani input, output, benefit and benefit cost-ratio of different crops grown in the area. Per ropani benefit-cost ratio of chili, bittergurd, tomato, paddy and potato is high as compared to other crops grown in the area. In other words, one unit input in monetary value gives 3.06 unit output in chili, 2.65 in bettergurd, 2.59 in tomato, 2.52 in paddy and 1.90 in potato.

Table 7 Input, output and benefit from different crops grown (Nepalese rupees per ropani)

Crops	Input	Output	Benefit	Benefit/ cost ratio
Paddy	1163	2935	1772	2.52
Potato	3393	6456	3063	1.90
Maize	520	731	211	1.41
Tomato	1441	3727	2286	2.59
Wheat	485	706	220	1.45
Mustard	278	324	46	1.17
Bittergurd	1028	2729	1700	2.65
Chilli	530	1623	1093	3.06

Source: Household Survey, 1999

Conclusion

Per land unit profit from potato, tomato, bittergurd and chili in which pesticides are used intensively is higher than other crops grown in the area, and at the same time the cost of pesticides in terms of income from crops is lower. In economic term, additional use of chemical pesticides in these crops is still profitable. So, the use intensity is likely to increase in the future. But people in this area have already been experiencing several health problems such as headache, nasal bleeding, vomiting, neck and eye pains, body ache, dizziness and other respiratory and skin problems due to mishandling of pesticides. It is in this context, immediate actions to regulate the use of pesticides are needed. Emphasis should be given on awareness creation by providing training on proper handling of pesticides. People should be encouraged to adopt integrated pesticide management technique by utilizing locally available organic materials.

Acknowledgements

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Fast estimation of pesticide risk potential on groundwater through the use of a dye tracing technique

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Abstract

Within the frame of the Research Project on IPMS Nepal (Herrmann, & Schumann 1999) a series of dye tracing experiments was carried out, in order to identify preferential flow paths from ponded agricultural fields towards groundwater and to estimate the transport of pesticides along these paths.

The experiments were performed on the Nepalese governmental Horticulture Farm Thamaghat in Jhikhu Khola Catchment (JKC), Kabhre District. There, the soil substrate is loamy. A perched, isolated groundwater table establishes during monsoon time in a depth of about 2,30 m below surface. This hydrogeologic situation is representative for *khet* areas under cultivation in the JKC. As common within the whole area, the experimental fields were terraced and ponding irrigation was used.

As a tracing substance the food-colour dye Vitasin Blue AE 90 was applied in combination with a pesticide mix of Malathion, Metalaxyl, Dimethoate und Fenvalerate.

Results of the experiments are shown, and conclusions drawn on the usefulness of this type of experiments for a first estimation of groundwater contamination risks through pesticide use in agricultural activities.

Introduction

Application of pesticides in agricultural areas generally comes along with a potential risk of groundwater contamination through the applied pesticides and their derivatives. In most developing countries, little is known about the present state of groundwater contamination or possible risks. In Nepal, being one of these countries, an interdisciplinary research project on environmental risks of pesticides (*Environmental risks of pesticides and sustainable development of integrated pesticide management for mountain areas of developing countries considering socio-economic conditions and taking Middle Mountains, Central Nepal as an example*) was set up under the sponsorship of Volkswagen Stiftung Foundation (Herrmann & Schumann 2001). Investigating the risk of a groundwater pollution was one aim within the project's framework.

The project's field site was situated at approximately 50 km east of Kathmandu, at Tinpiple and Tamaghat in Kabhre district, latter shown in Figure 1. Since the area is linked to Kathmandu through the Arniko highway market orientated crops are grown, mainly rice, potatoes and maize on *khet* (irrigated) land and tomatoes and maize on *bari* (rainfed) land. The use of pesticides in Nepal has reached within the last decades a worrying level (Baker & Gyawali, 1995) and a survey in the project area carried out by CEAPRED has shown high application rates, more especially in *khet*, being among the highest in Nepal (CEAPRED 2000).

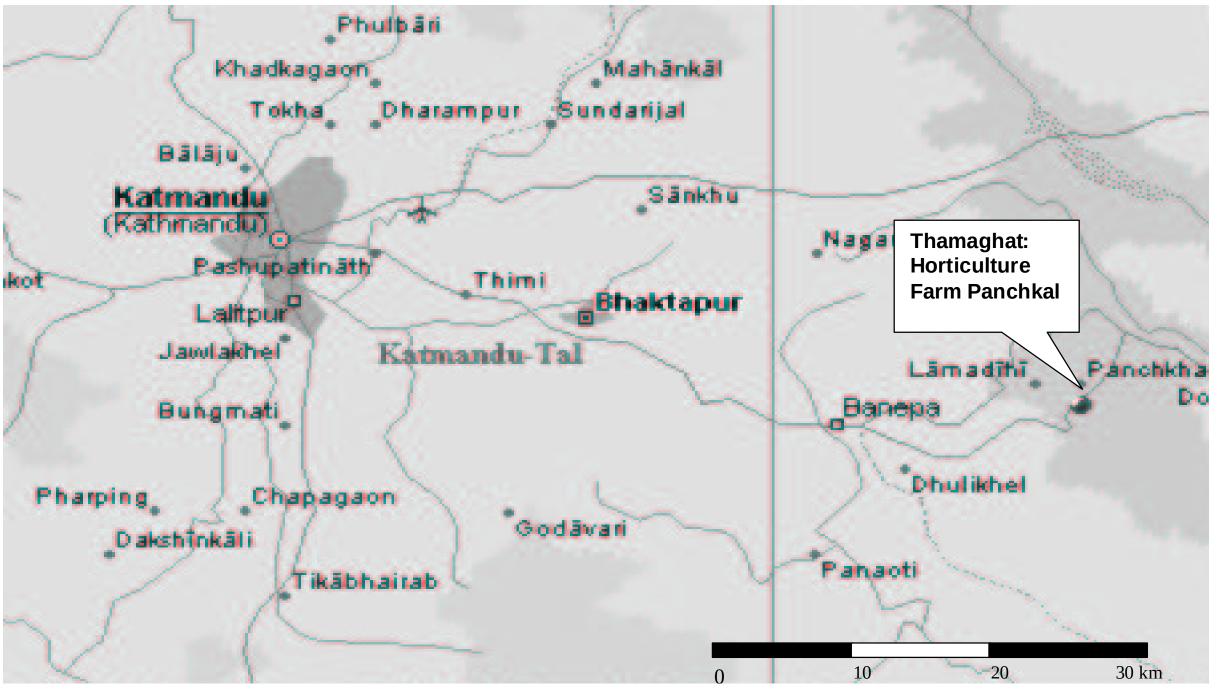


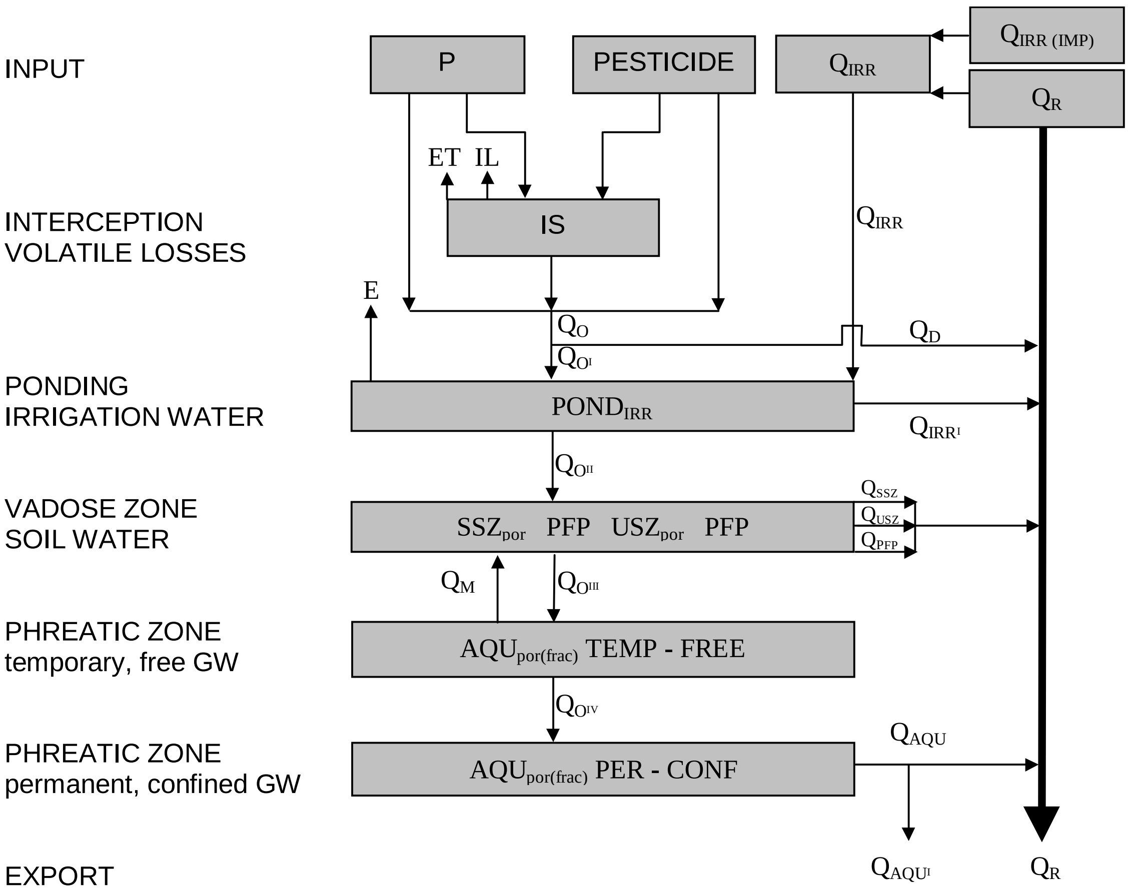
Fig. 1 Geographical situation of pilot test plots. Tinpiple is situated approximately 4 km from Tamaghat

Despite high and very frequent pesticides application rates, samples of groundwater taken during the project duration did not show contamination through recent applications. The vadose zone showed a quasi non-detectable presence of pesticides. Possible reasons for the non-detection of pesticides in the groundwater could be: (a) volatilisation of pesticides, (b) all pesticides accumulate within the first few centimetres of soil, (c) the mean transit times through the vadose zone are high, or (e) the pesticides are subject to such dilution in the aquifer that they fall under limit of detection.

Hydrology and formulation of the problem

The hydrological regime of the area is controlled by monsoon with an average precipitation of 1276 mm for 1976-2000 at Tamaghat (Kansakar et al 2002). Monsoon, including pre-monsoon, lasts roughly from April to September with it's maximum normally in July. Irrigation pattern is also controlled by monsoon since reservoirs do not exist.

A simplified hydrological model as valid for water-bound pesticide transport in *khet* is shown in Fig. 2. Spraying of pesticides takes place such that amounts of the chemicals reach the soil surface, i.e. the upper limit of the **vadose zone**. The soil substrate (at the site under investigation) is loamy, with 45% sand, 37% silt and 18% clay in the first 20 cm. Organic carbon amounts to about 1%. With depth soil composition varies between sand fraction by 40-58%, silt by 30-37% and clay by 12-22%, sand always dominating the substrate. When the lands are irrigated, here always with the system of ponding irrigation, infiltration starts. The infiltration flux ($Q_{0'}$) is controlled through matrix flow and flow following preferential flow paths. Infiltration determined with a double-ring-infiltrometre, shows rates as high as 150 mm/h during the first 5 minutes. It stabilises at 2 mm/h after 3.5 hours and drops finally to 0.6 mm/h after 22.5 hours. The classical sampling methods for pesticides in the vadose zone consists of sampling with a N-min drill at depths until 90 cm below surface. Results of blank samples which were taken in the area showed no presence of pesticides; samples taken during monitoring after known application rates showed often pesticide concentrations close to determination limit and of unusual distribution pattern (Vinke, 2002 personal communication). During degradation experiments at the field site uncommon distribution pattern with soil depth occurred (Interim Report 2001).



$AQU_{por(frac)}$	Aquifer, porous (fractured)	Q_{AQU}	Groundwater Flow
CONF	Confined (AQU)	Q_D	Surface Runoff
E	Evaporation	Q_{FP}	Flux from Preferential Flow Path
ET	Evapotranspiration	Q_{IRR}	Irrigation Water
FREE	Free (AQU)	$Q_{IRR(IMP)}$	Irrigation Water Channel, imported
GW	Groundwater	Q_M	Flow by matric suction
IL	Interception Loss	Q_O	Infiltration\Seepage Flux
IS	Interception Storage	Q_R	River Water
P	Precipitation	Q_{SSZ}	Flux from Saturated Soil Zone
PESTICIDE	Pesticide Application	Q_{USZ}	Flux from Unsaturated Soil Zone
PER	Permanent (AQU)	SSZ_{por}	Saturated Soil Zone
PFP	Preferential Flow Paths	TEMP	Temporary (AQU)
$POND_{IRR}$	Irrigation Water, ponded	USZ_{por}	Unsaturated Soil Zone

Fig. 2 Simplified hydrological model of *khet* land as relevant for pesticide transport under ponding irrigation

The **phreatic zone** of the area consists firstly of perched, isolated, aquifers which depend in their thickness and spatial extension mainly on monsoon and irrigation pattern. The perched aquifers may dry out completely during dry season, and be recharged again during wet season and/or irrigation (Schumann et al. 2002). Therefore, the flux $Q_{0''}$ must be active during irrigation recharging the aquifer. Below the perched, isolated aquifers a second, permanent and confined aquifer lies. Classical sampling for pesticides in the phreatic zone is done by sample withdrawal through wells or piezometres.

Since no pesticides could be detected in the aquifer and results of pesticide detection in the soil were dissatisfying, a study on the vadose zone was set up, aiming on the quantification of the infiltration flux into the vadose zone (Q_0^{II}) and from the vadose zone into the groundwater (Q_0^{III}), and on the description of transport and transit flow paths and accumulation sites for water and pesticides within the soil.

Experimental set-up

In principle, the set-up of the experiment aimed on a visualisation of flow pattern in the ground and a sampling for pesticides along the visualised flow paths as well as in no-flow sectors.

Visualisation was attained by the use of a dye tracer, Vitasin Blue FCF 90. The colour index (C.I.) of the substance is 42090, it's aqueous solubility is greater than 50 kg·m^{-3} (Clariant

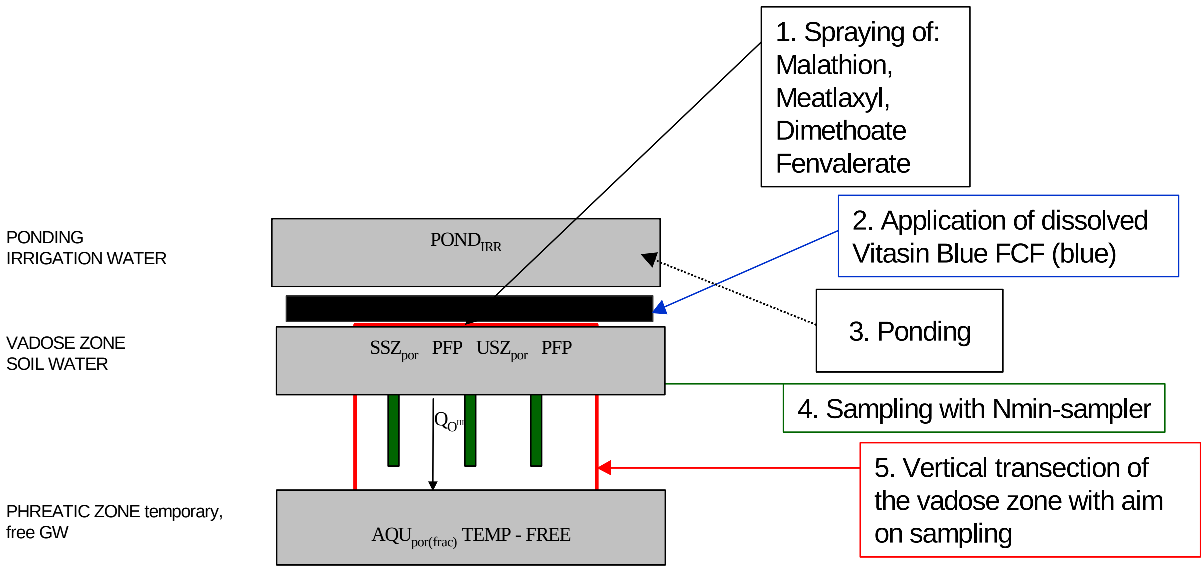


Fig. 3 Experimental set-up at tracer experimental site 1 at Tamaghat Horticulture Farm. Section for sampling after 3 and 14 days, and after 3 month respectively

1999). According to a study by Flury & Flühler (1995) the adsorption coefficient (*K*) ranges from 0.16 to 5.95 $dm^3 \cdot kg^{-1}$. *K* varies in the lower values for $CaCO_3$-free soils. The soil found at the experimental site was carbonate-free.

The experimental set-up is shown in Fig. 3, with running-phases indicated. For the experiment, four experimental plots (2x1 metres) were prepared with Nepalese workers as common for rice production. Then, in step 1 the four target compounds (Vinke et.al. 2002) Malathion, Dimethoate, Fenvalerate and Metalaxyl were sprayed onto the top soil, using common concentrations. They were equal to the concentrations applied during the degradation experiments mentioned before. Thereafter, dissolved Vitasin Blue was applied using a watering can aiming on a concentration of $8 g \cdot l^{-1}$ after ponding the plots with 10 cm water column (step 3).

After a waiting period of three and 14 days and three month respectively steps 4 and 5 were carried out. Step 4 consisted of conservative sampling for pesticides with the N-min drill at three places within the test plots, while step 5 included cutting a section at the centre part of the test plots. This vertical section had a width of 1 m and a depth of up to 2.60 m. Besides

Fig. 4 Application of Vitasin Blue and ponding at experimental site

Fig. 5 Sections after 3 days. View of standardised sampling technique holes (N-min drill)

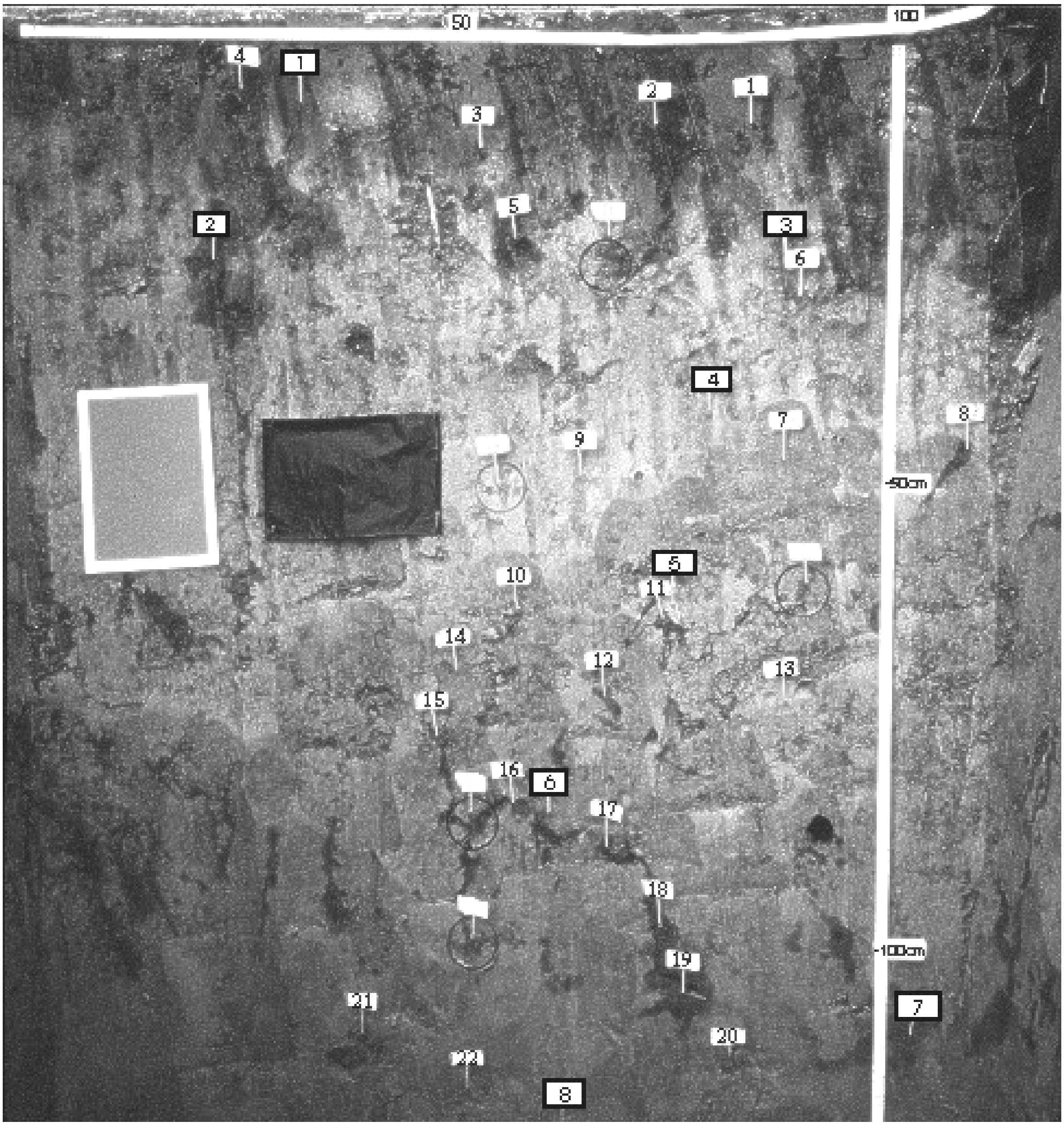
photographing, samples for pesticides and Vitasin Blue were taken along and besides the indicated flow pattern.

The experiment was run on the grounds of Horticulture Farm, Thamaghat.

Fig. 4 shows the application of Vitasin Blue and ponding, Fig. 5 the sections after 3 days in the part of conservative standardised sampling using a N-min drill.

Results and discussion

Here, the results valid for the first experimental plot shall be presented. Sampling for the plot took place three days after the application of pesticides and Vitasin Blue. Field situation of the section for the first 1.20 metre below surface is presented in Fig. 6. Here, bold outlined labels indicate samples for pesticides and Vitasin Blue, and labels without margin samples for Vitasin Blue only. In Table 1 the results for the pesticide concentrations of Fenvalerate, Metalaxyl and Dimethoate are shown in $\mu g \cdot kg^{-1}$. Generally the sample number increases with depth in the soil profile.



O 12: 2,40 m b.s.

Fig. 6 Selective sampling at a section up to a depth of 120 cm, three days after application. Numbers with margins stand for sampling for pesticides and Vitasin Blue, without margin for sampling for Vitasin Blue only. Dark soil parts indicate the presence of Vitasin Blue. Sample 12 (cf. Table 1) was taken at a blue spot in a depth of 2.40 m below surface

It is remarkable that in great depths (2.20 and 2.40 m below surface) strong Vitasin Blue concentrations were observed, and come together with concentrations of Metalaxyl and Dimethoate. At 2.40 m also a non-quantifiable amount of Fenvalerate was detected. Dimethoate and Metalaxyl appear in quantifiable amounts in the uplifted groundwater. This

Tab. 1 Concentrations ($\mu g \cdot kg^{-1}$) of pesticides in 12 soil samples, three days after application following selective sampling. Residue analysis by Bajrachaya K. & Vinke C.

	— Solubility +		
Sample	Fenvalerate	Metalaxyl	Dimethoate
	µg/kg	µg/kg	µg/kg
1	**53**	**62**	**13**
2	**14**	**29**	**21**
3	**n.q.**	**n.q.**	**n.q.**
4	n.d.	**n.q.**	n.d.
5	n.d.	n.d.	n.d.
6	n.d.	**n.q.**	**n.q.**
7	n.d.	**n.q.**	**n.q.**
8	n.d.	**n.q.**	n.d.
9	n.d.	**n.q.**	n.d.
10	n.d.	**n.q.**	n.d.
11	n.d.	**11**	**11**
12	**n.q.**	**14**	**n.q.**
	[ng/L]	[ng/L]	[ng/L]
uplifted GW	n.d.	**1**	**4**

n.d.: not detectable

n.q.: not possible to be quantified

groundwater corresponds to the water of the perched, isolated, aquifer which depends on irrigation pattern. Accordingly, the flux Q_0^{III} must have been active during the experiment recharging the aquifer and transporting pesticides. Transport pattern do not exactly correspond to water solubility, since after Vinke et al (2002) Metalaxyl (with 8 mg/l) is less soluble than Dimethoate (with 25 g/l). However, Metalaxyl has proved to be more persistent than Dimethoate (28:8 DT_{50} under laboratory conditions) and it could be, that degradation had already diminished the amounts of Dimethoate under detection limits (samples 8, 9, 10) or below quantification limit (sample 12). The lower concentrations of Dimethoate than Metalaxyl in the upper two samples (1 and 2) support the assumption that degradation had already started, i.e. especially that directly after spraying the concentration of Metalaxyl was about 1/6 of the concentration of Dimethoate in the top soil.

The relations between Vitasin Blue and the pesticides in the 12 samples are shown in Fig. 7. Fits are not too bad and show for Metalaxyl the best correspondence. Dimethoate, since

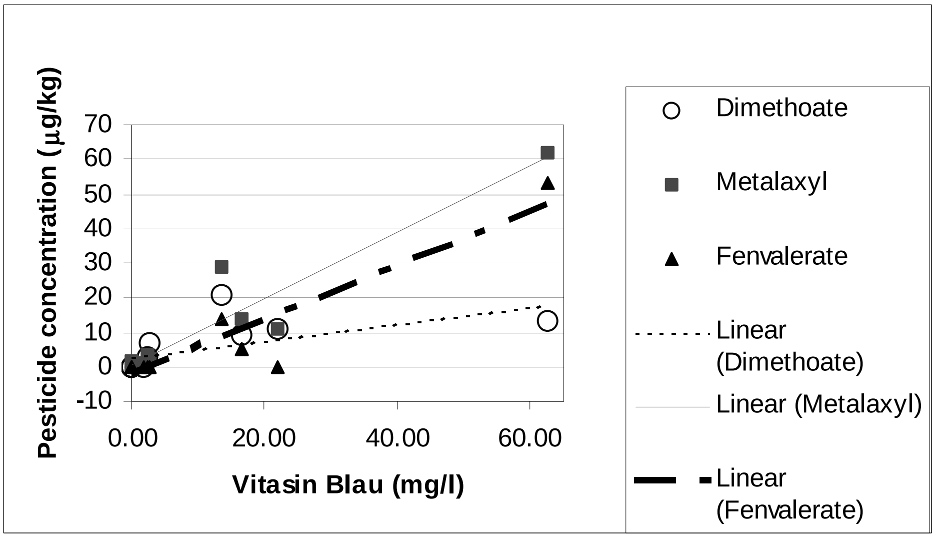


Fig. 7 Relation between Vistasin Blue concentration and pesticide concentrations three days after application. A linear fit was applied

already quite degraded shows the worst relation. In the section cut 14 days after application the correspondence from Vitasin Blue to Metalaxyl is no longer given (not shown) since degradation had also here too strong influences. Hence, no conclusions should be drawn from Vitasin Blue concentrations to pesticide concentrations. For this detailed studies on correspondence under different conditions, and specific for each pesticide would need to be carried out.

However, selective sampling along flow pattern allows pesticide tracking. This has also been shown by Reichenberger et al (2001) for pesticide tracking in Brasilian Oxisols using Vitasin Blue as tracing substance.

Analysis of the samples taken by the N-min drill show for Fenvalerate and Metalaxyl quantifiable amounts only up to 5 cm below surface and a non-quantifiable amount up to 20 cm. For Dimethoate only a non-quantifiable amount in the first 5 cm. In Fig. 5 can be seen that the N-min drill did not remarkably hit the blue parts of soil where, according to the selective sampling technique, the transported pesticides are found. Depths greater than 90 cm, where high concentrations of pesticides still occur are not captured at all.

Conclusion

The presented experimental set-up discloses a rather fast and easily carried out first indication for possible pesticide transport through the vadose zone. It furthermore reveals flow pattern, and allows indication for presence and importance of preferential flow in the substrate. However, repetitions of sections longer than 14 days after application are not useful since then degradation or leaching of pesticides might prevail. This, of course depends on applied pesticides. Furthermore, pesticides seem to be transported mainly through preferential flow paths, which are predominantly active after dry periods, when soils are dry, and become less active with growing water content (Schumann et al 2002). Also Flury et al. (1995) observed a slower transport of herbizides with growing soil water content in loamy soils as then matrix flow outweighs preferential flow.

The method is extremely useful if depth of water table below surface is small. Using the method might save one from carrying out medium-term observations concerning groundwater pollution without results. It furthermore could explain pesticide whereabouts if balancing of pesticides in field trials fails. The easy set-up for the method and the possibility that soil samples can be deep frozen and then be transported to a pesticide analysis laboratory makes the method useful for remote areas, developing countries or countries without a pesticide laboratory.

The method should follow a first sample survey for pesticides in groundwater wells.

The method, at present state, does not allow a quantification of water flux or pesticide transport. It is not possible to draw from Vitasin Blue concentrations to pesticide concentrations. Further detailed studies should follow in order to refine the method and hence enable the quantification of water-bound transport. The use of bromide could be helpful in this context since it allows a quantification of water flux.

Acknowledgement

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Underground water passages and runoff formation pattern in an irrigated *khet* catchment

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Abstract

Since early 1999, within the frame of the Research Project on IPMS Nepal, monitoring for groundwater levels and environmental isotopes is carried out for three distinct hydrological systems. The monitoring is combined with artificial tracing experiments. All three catchments are located at 50 km east of Kathmandu and are built up of loamy and sandy substrates and their hydrological regimes are controlled by monsoon climate and distinct irrigation pattern.

Here, results on the hydrology of one sample-catchment, *khet*, focussing on water passages and runoff-formation shall be presented. In the *khet* catchment intensive ponding irrigation takes place during the cultivation of rice, and channel irrigation during the cultivation of potatoes and tomatoes.

Discharge reactions in the catchment are fast and event water consists mainly of direct run-off. Discharge concentration times are around one hour.

It can be confirmed that the turnover of underground water is minimal and hence transport of solutes through the unsaturated zone also. Fast mass transport takes place through preferential flow paths followed up by slow mass transport through matrix flow. However, transport quantity and velocity depend on antecedent soil moisture where lower soil moistures favour faster and greater mass transport.

Introduction

With the main aim on getting to know more about environmental risks of pesticides in agricultural market-oriented areas of Nepal, an interdisciplinary research project (*Environmental risks of pesticides and sustainable development of Integrated Pesticide Management System (IPMS) for mountain areas of developing countries considering socio-economic conditions and taking Middle Mountains, Central Nepal as an example*) was set up in 1998 sponsored by the Volkswagen Stiftung Foundation (Herrmann & Schumann 1999, 2002).

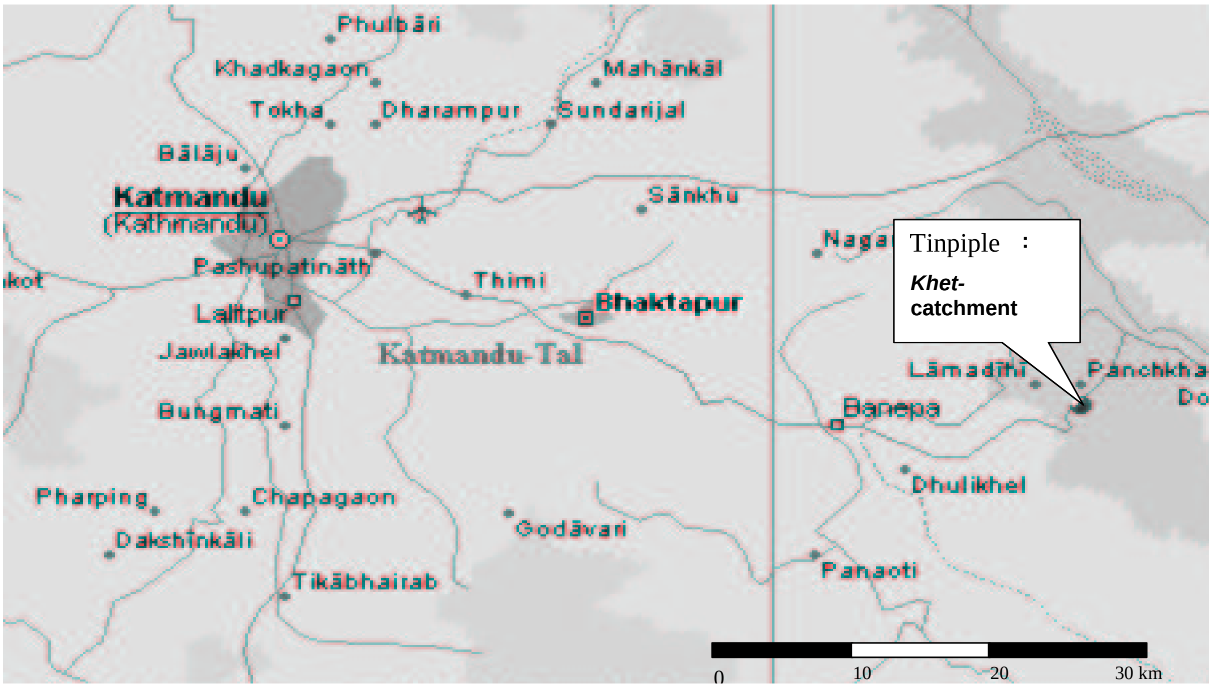


Fig. 1 Geographical situation of the *khet*-catchment, approximately 50 km east of Kathmandu.

As the project's field sites and therefore pilot area for the study, two catchments and one control area were chosen, all situated in Kabhre district within the Jhikhu-Kola catchment at approximately 50 km east of Kathmandu. One catchment, the *khet* catchment represents agricultural activities under irrigated conditions (ponding and channel irrigation) while the other catchment, *bari*, represents rain-fed cultivation. Both areas belong administratively to Tinpiple, which is shown in Fig. 1.

In order to specify on risks of pesticides for the environment and to develop a sustainable pesticide management system, a quantification of water-bound pesticide transport is worth striving for besides other results. Hence a hydrological study was set up to evaluate and to quantify the turnover of water in the terraced agro-ecosystems and to use this as the necessary basis for the transport estimation. Here, results of the hydrological study concerning runoff formation pattern and underground water movement for the *khet* catchment will be presented.

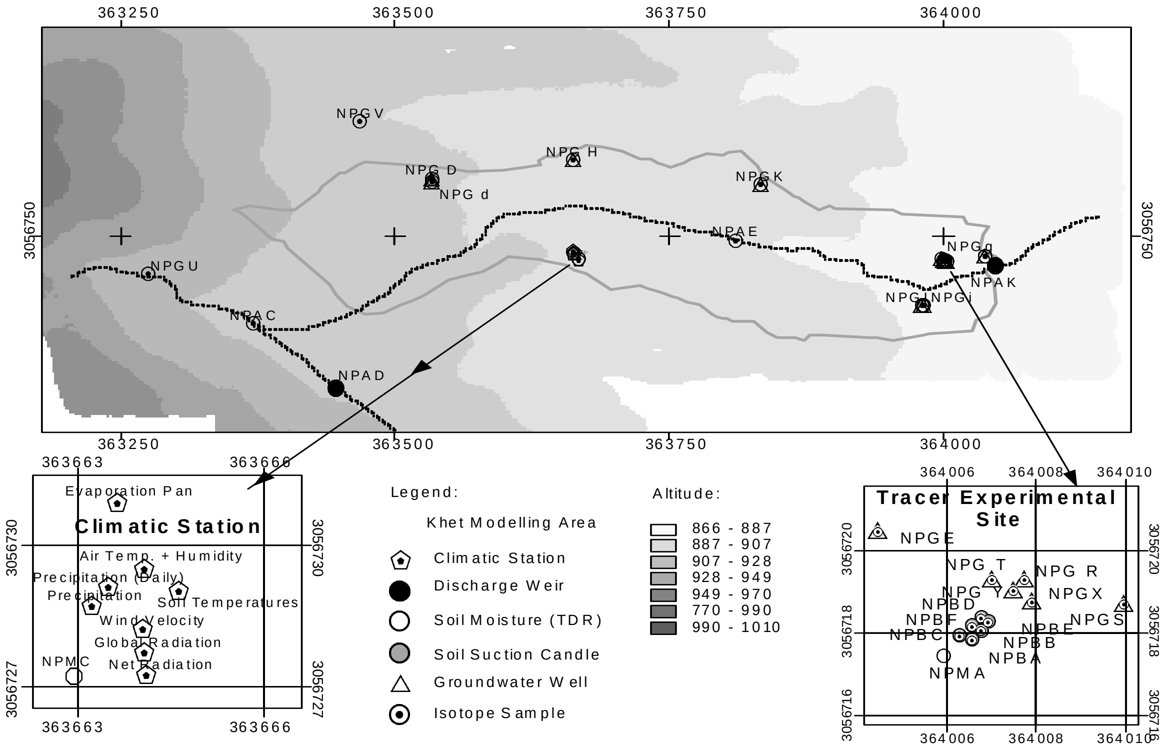
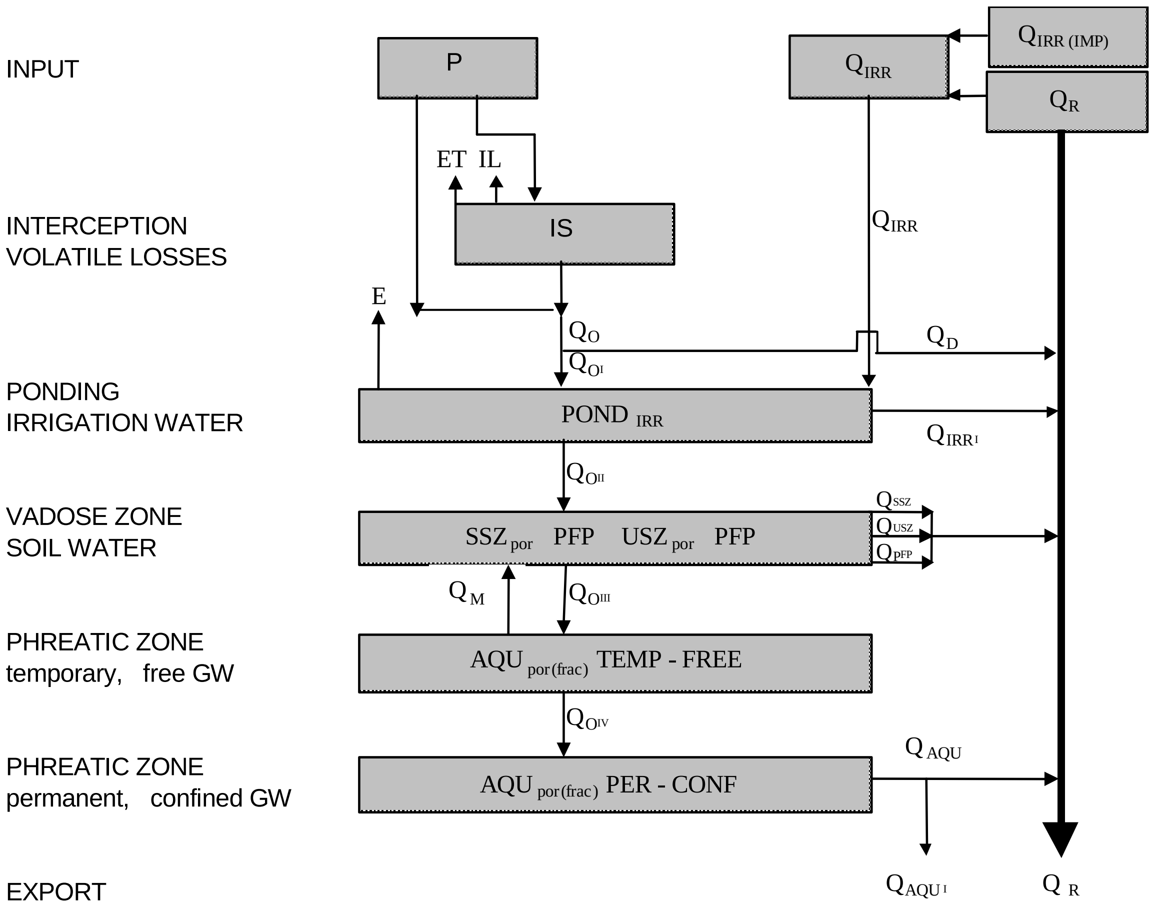


Fig. 2 Simplified topographic map of Tinpiple *khet* basin with measuring network.

Measuring network and hydrological study

The study area lies in the middle mountains of Nepal and the hydrological regime of the area is controlled by monsoon. The average annual precipitation (years 1976-2000) for the station Tamaghat, also situated in Jhikhu-Kola catchment, amounts to 1276 mm (Kansakar et al 2002). In the year 2000 the annual precipitation in *khet*, measured using a full automatic rain gauge, reached 1170 mm. Precipitation pattern is shown in Fig. 5 on daily basis.



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$POND_{IRR}$	Irrigation Water, ponded	USZ_{por}	Unsaturated Soil Zone

Fig. 3 Conceptual hydrological model as valid for *khet.*

Irrigation in *khet* follows the water availability of the area, i.e. since no reservoirs exist, irrigation reaches it's maximum during monsoon and is nil in the month before pre-monsoon. Accordingly the agricultural activity is set with its highlight from July to October with the growth of rice, followed by potatoes (channel irrigation) and then February to June with maize.

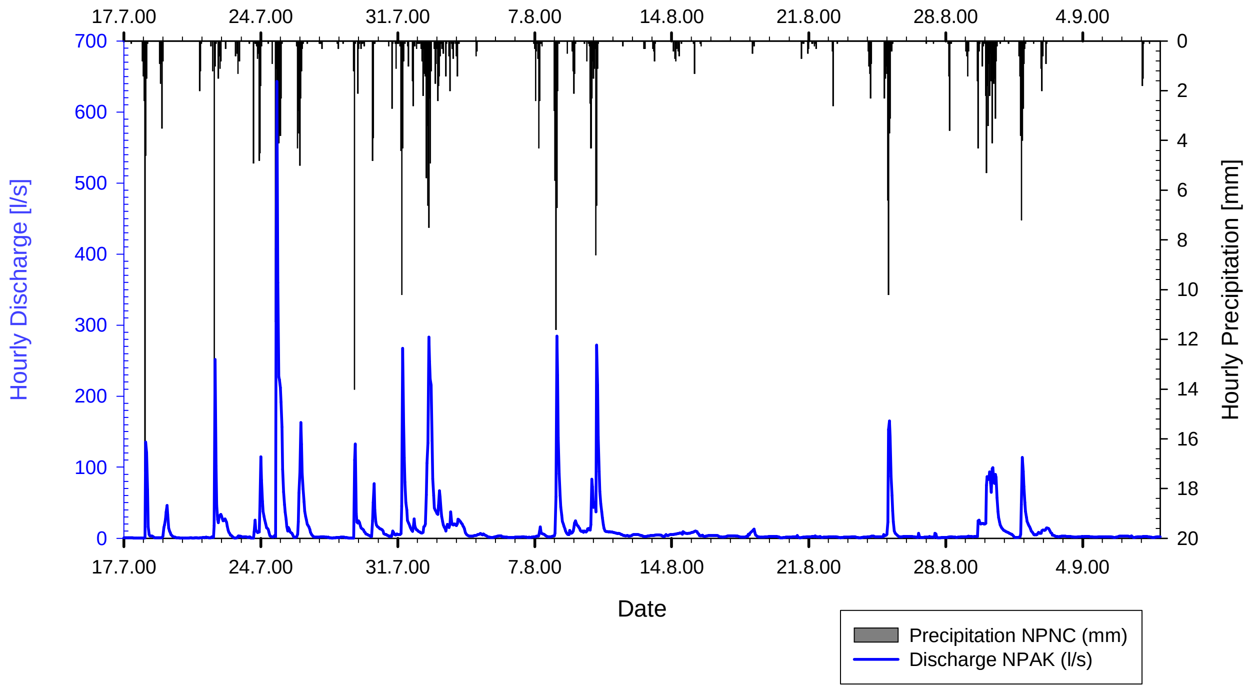

Fig. 4 Hourly discharge (l/s) at catchment outlet (NPAK) vs. hourly precipitation (mm) at *khet* climatic station (NPNC).

In order to study the hydrological system a measuring network for climatic parameters, groundwater levels and discharge was set up on catchment scale. Furthermore, a measuring network was arranged on plot scale focussing on vertical transport processes. Here, tracer studies were carried out and were monitored by piezometres and soil suction candles. Soil moisture, using the Time Domain Reflectors method (TDR) was also monitored. The latter plot is termed tracer experimental site (TES). The complete measuring network for *khet* is shown in Fig. 2, based on a simplified topographic map. Besides physical data collection water samples of precipitation, discharge and groundwater were taken and analysed for stable isotopes oxygen-18 (^{18}O) and deuterium (^{2}H) in order to quantify the turnover of water in the catchment. The sampling sites for isotopes are also indicated in Fig. 2.

The most important water fluxes of the khet catchment are, according to findings of the hydrological study, representable in a conceptual hydrological model as shown in Fig. 3.

Fig. 4 shows the discharge at station NPAK (outlet weir) in combination with precipitation at station NPNC. Both time series have an hourly resolution and are plotted for the period

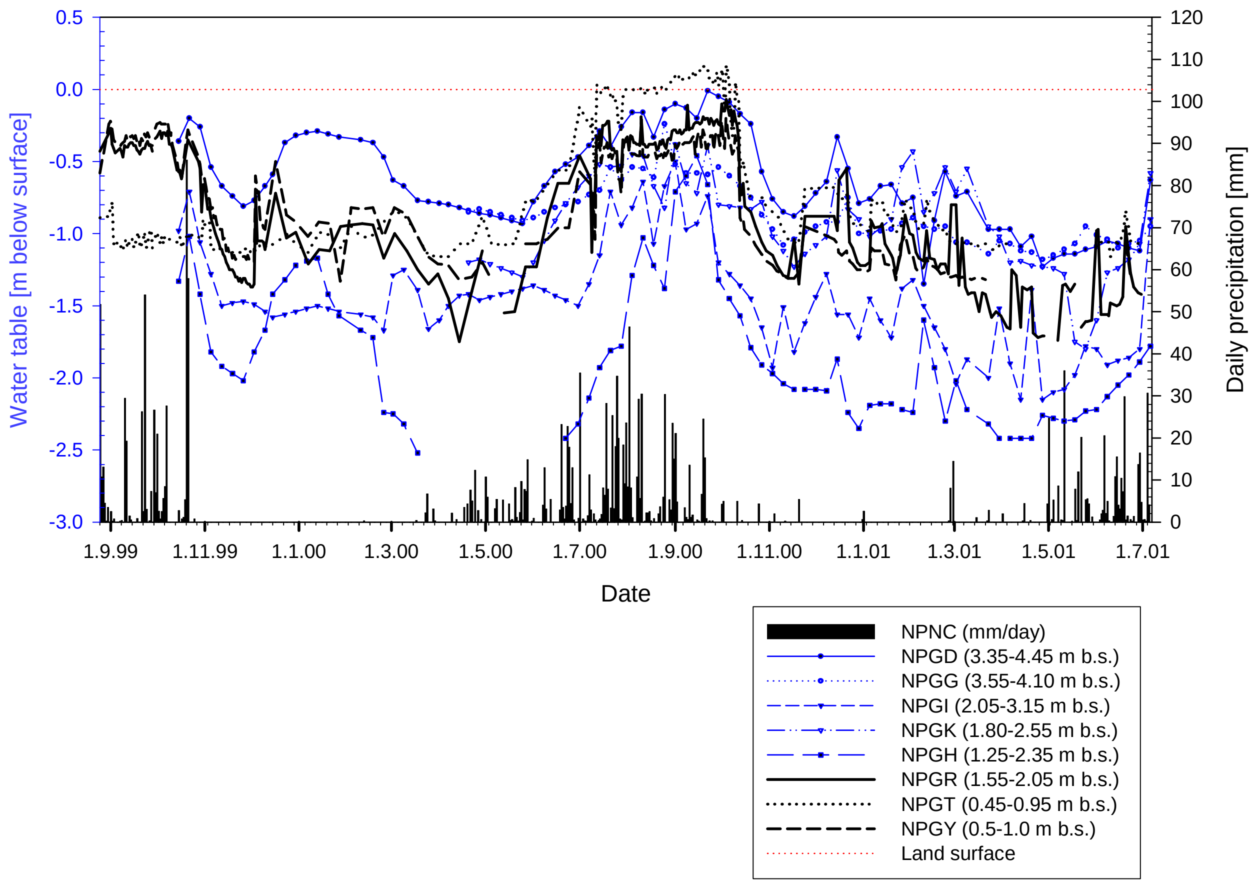

Fig. 5 Groundwater tables (in metres below surface) of selected piezometres (NPG*) in combination with daily precipitation (mm) at *khet* climatic station NPNC. In the legend the depth of well filter in metres below surface is indicated.

17.07.00 to 07.09.00, i.e. for mid-monsoon 2000. Cross-correlations for the same period regarding discharge (dependent) on precipitation (independent) show the maximum correlation of 0.7 at a time lag of one hour and 0.6 at a time lag of two hours. Thereafter the dependence decreases rapidly. With nil hours time lag the correlation coefficient equals to 0.4. The runoff formation in the *khet*-stream is therefore highly dependent on precipitation pattern, and reaction time is around one hour to the less. This is typically either for irrigated systems since here the pre-event antecedent soil moisture is generally high, or typically for systems with low infiltration capacities. Latter differ in *khet* following data from double-ring infiltrometre experiments between 3 and 0.01 mm/h, and constancy is reached after maximal 30 minutes.

Reactions on groundwater levels on daily precipitation are shown in Fig. 5. Wells NPGD to NPGH were monitored with weekly resolution while NPGR to NPGY were subject to measurements every three days. The following deserves attention:

- General trend of high water tables July to October. Drop of water tables from October onwards with a minimum in April. Thereafter increasing water tables until July.
- A general reaction of all wells on monsoon with a time lag of approximately six weeks, differing slightly for the wells. Groundwater levels increase by 1 metre in average. After end of monsoon the water levels decrease again in all wells, delayed by approximately four weeks.
- Well NPGH (filter section 1.25 – 2.35 m below surface) shows very strong reactions. It falls dry during the dry period and increases in water level by two meters following monsoon 2000. NPGT (filter section 0.45 – 0.95 m) reacts accordingly. It falls dry during the dry period and reacts onto monsoon with an increase in water table by one metre standing under such pressure that the groundwater level rises above land surface.
- During dry season some fast reacting wells show rises in water tables, which are independent from precipitation, but appear similarly to the rise in the follow up of monsoon (NPGD, NPGH). Wells show fast, short term water level rises more especially during dry season and lessened during wet times. These reactions must be due to irrigation.

The annual groundwater variations with time delayed monsoon reaction as well as the observed short-term reactions on heavy storm events and irrigation may be due to a compression of the capillary fringe, mass transport or the combination of both. It should be noted, that reaction times are so short that mass transport under these circumstances should be caused by movement through preferential flow paths.

Isotope studies on catchment scale

In order to get results on hydrological turnover in *khet*, isotopic studies were carried out. The isotopic background of a hydrological system is defined by the $^{18}O:^{16}O$ and $^{2}H:^{1}H$ ratios related to an international standard V-SMOW and expressed as the deviation δ [‰] from the standard (Moser & Rauert 1980). The δ values are found to be quite stable in groundwater and

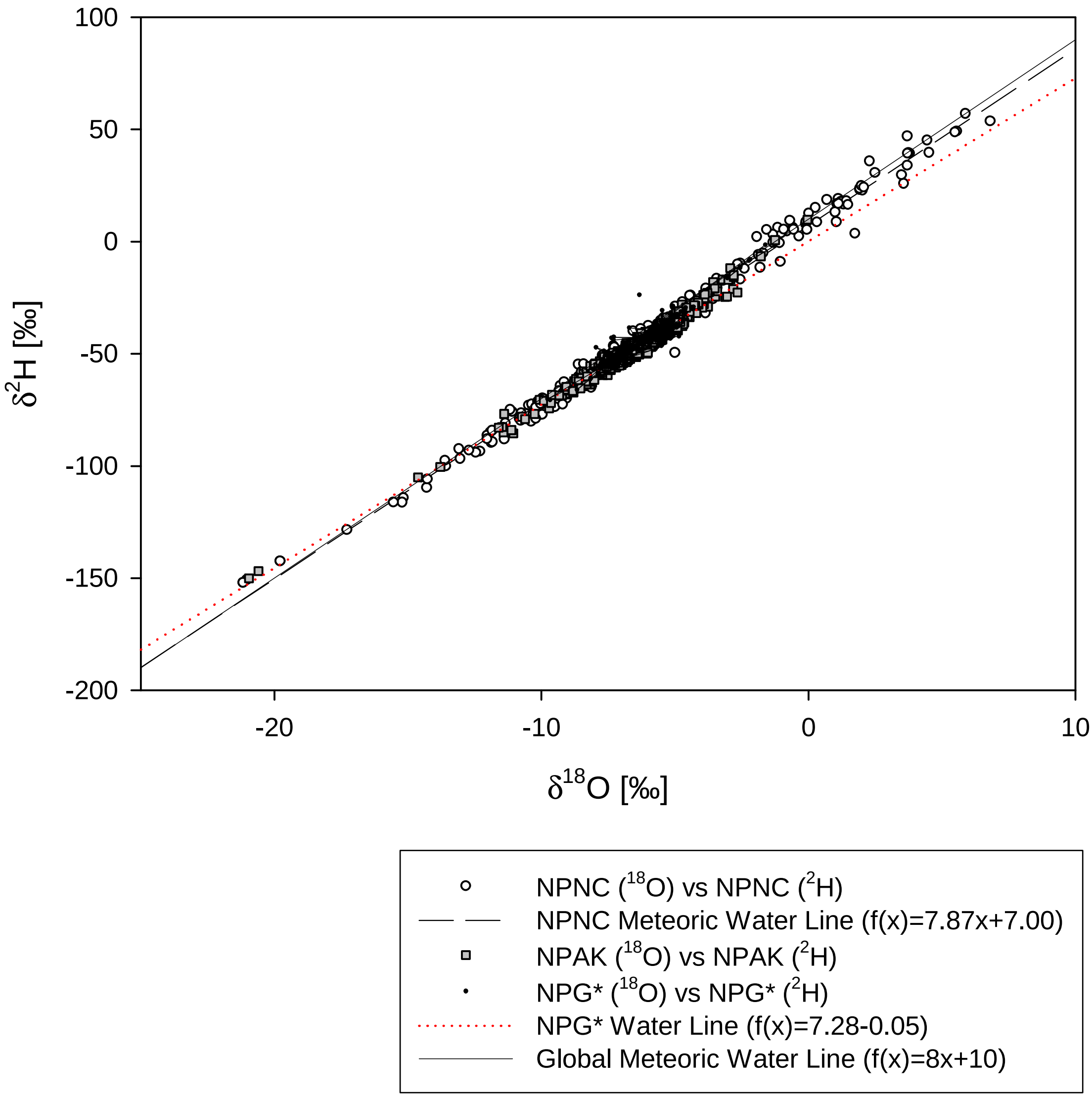

Fig 6 δ^2H to δ^{18}O relation for precipitation (NPNC), discharge at outlet (NPAK) and groundwater (NPG*, several piezometres) in *khet* catchment. The Global Meteoric Water Line and the Local Meteoric Water Line (NPNC) as well as the Water Line for Groundwater are also shown.

vary in precipitation according to the origin of the precipitation. Hence, the isotopic content of discharge varies according to the ratio of base flow to direct runoff.

Fig. 6 shows the Global Meteoric Water Line (GMWL) as well as the Local Meteoric Water Line (for climatic station NPNC) and the water line for the groundwater samples (NPG*). With a slope below 8 both local dependencies indicate evaporation influence. It can be well noted that the groundwater data is clustered while discharge and precipitation data are spread

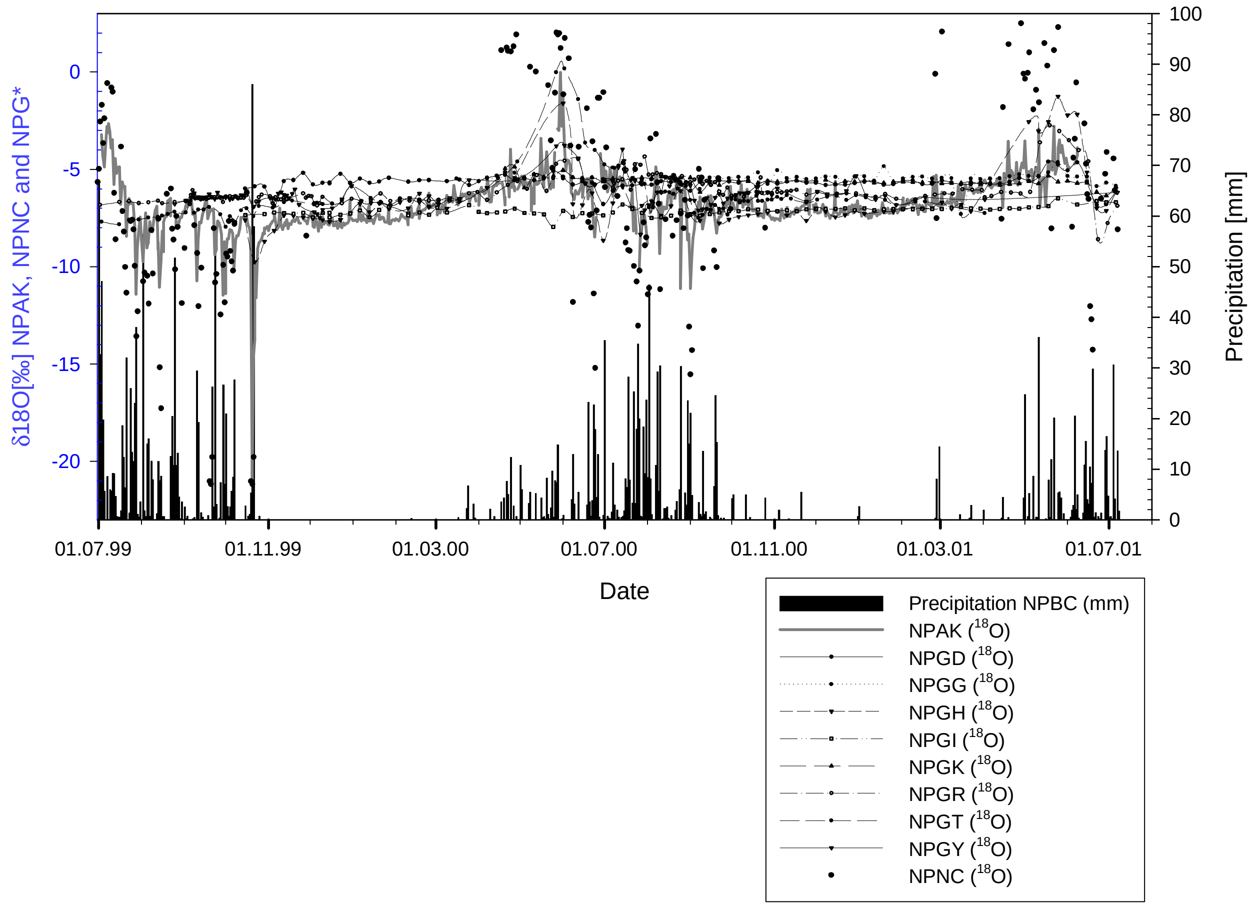

Fig 7 $\delta^{18}O$ values for precipitation (NPNC), discharge (NPAK) and groundwater (NPG*; several piezometres) from 01.07.99 to 01.08.01. Daily precipitation sums (mm) are also shown.

thus indicating higher variations. This is followed up by Figure 7, which shows the isotopic variation $\delta^{18}O$ variations in discharge and groundwater. The isotopic variation in $\delta^{2}H$ follows the same course (not shown).

Attention should also be paid to the following: The ^{18}O contents of precipitation are high during pre-monsoon and change to lower values with the central monsoon precipitation events. This can be attributed to dominant isotopically heavy tropical oceanic air moisture that precipitates at the beginning during less intensive and persistent rain events, followed by more heavy rain showers out of isotopically lighter continental air masses during high monsoon.

From the isotopic evaluation the following results can be drawn: The discharge reacts isotopically on every precipitation event, which stands for a high proportion of direct runoff in the discharge at the *khet* catchment outlet. In groundwater samples an isotopic change can only be noted after strong precipitation events like on 20.10.99 with 82mm WC, and during irrigation events, i.e. for NPGD in January 2000. A combination of pressure transmission and mass transport must be responsible for groundwater level rises.

Tracer studies on plot scale

For the tracer studies on plot scale, two experiments with deuterium (^2H) are presented in Fig. 8 showing the tracer avulsion (in δ2H [‰]) in soil water samples at different depths. Both experiments took place on the same plot and with an identical application quantity. It is important to note that the times for tracer injection are different. One was started at mid-

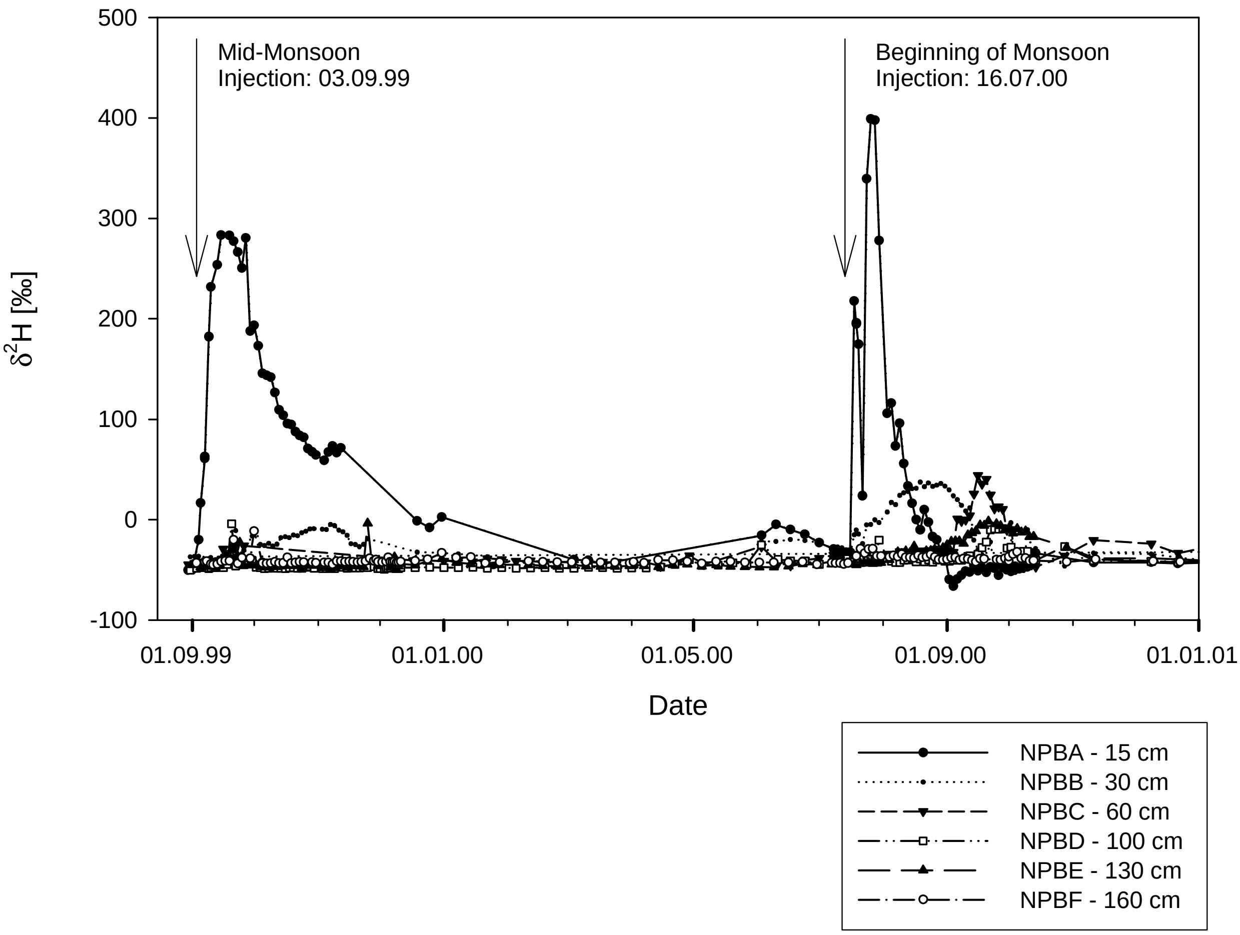

Fig 8 Deuterium (δ^2H [‰]) breakthrough curves for tracer experiments started at plot scale in *khet* catchment. The first experiment was started on 03.09.99 in mid-monsoon, while the second was started on 16.07.00 at the beginning of monsoon 2000. In both experiments one litre of 86% D_2O was applied, and the test plot thereafter ponded as under rice cultivation.

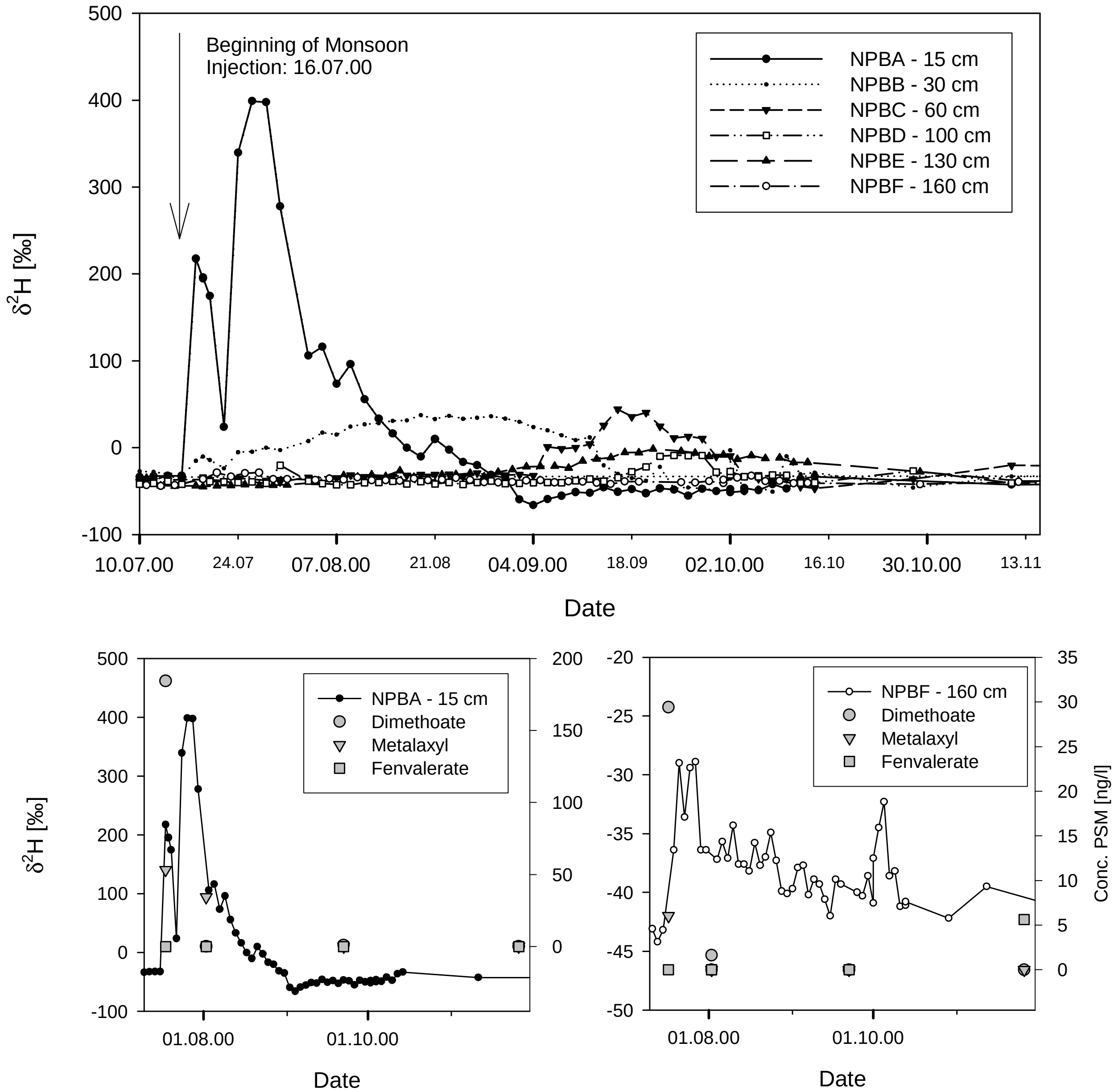

Fig 9 Deuterium (δ^2H [‰]) breakthrough curves at plot scale for the experiment started at the beginning of monsoon 2000. Shown are deuterium concentrations in soil water samples extracted through soil suction candles. The experiment was combined with application of a pesticide-mix of Dimethoate, Metalaxyl and Fenvalerate. Sampling took place at four times. Results for the pesticide concentrations [ng/l] are shown in the lower plots for soil suction candles installed at 15 and 160 cm below surface.

monsoon 1999 with an accordingly high antecedent soil moisture (~40 vol%). The second one was started at the beginning of monsoon 2000 with little antecedent soil moisture (~20 vol%). In both experiments the tracer was applied first, thereafter the plot was ponded similar to conditions during rice cultivation.

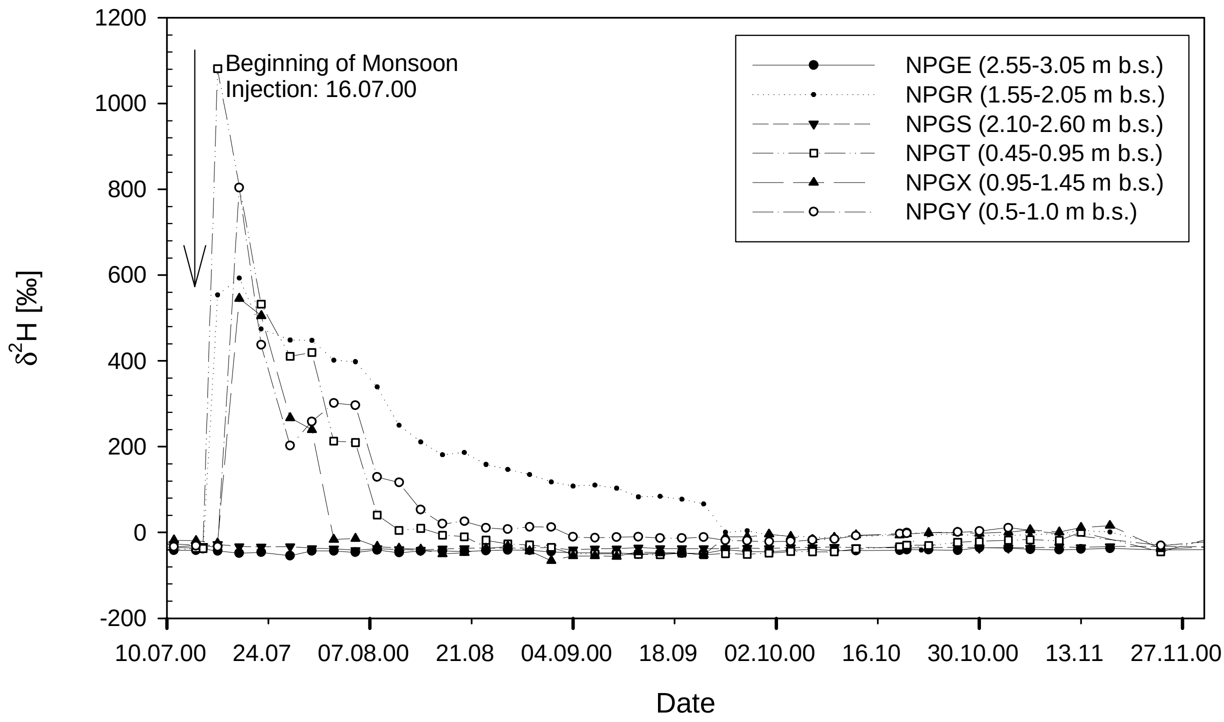

Fig. 10 Deuterium (δ^2H [‰]) breakthrough curves at plot scale for the experiment started at the beginning of monsoon 2000. Shown are deuterium concentrations in groundwater samples (NPG*) taken through scooping. In the legend the depth of well filter in metre below surface is indicated.

Here three results should be noted. When the experimental start-off falls under dry conditions the transport process is faster than under constantly wet conditions. Furthermore the maximum concentrations reaching down into the soil are higher and total mass transport into the deeper soil greater. All breakthrough curves in depths greater than 15 cm indicate a matrix flow with velocities of about 10-20 mm per day. During wet conditions most tracer substance gets stuck within the first 15 cm.

The second experiment (year 2000) was combined with the application of a pesticide mix of Malathion, Metalaxyl, Dimethoate and Fenvalerate. Results of the deuterium breakthrough in combination with pesticide appearance are shown in Fig. 9 for soil water at 15 cm and 160 cm. Due to restriction in the number of analysable pesticide samples only four sampling times could be realised. The results do not allow any conclusion on the correspondence of deuterium breakthrough curves with pesticide breakthrough curves. However, they clearly indicate that pesticides, more especially Dimethoate and Metalaxyl are transported with water fluxes into the soil. Malathion has not been detected at all in the collected soil water samples.

This corresponds to the findings by Vinke et al. (2002), that Malathion disappears most rapidly. Interesting is also the behaviour of Fenvalerate which does not appear in any depth at any sampling date except on 26.11.01, i.e. after 4 month in 160 cm.

Fig. 10 shows the deuterium breakthrough curves (in δ^2H [‰]) for the piezometre (NPGR, NPGT, NPGX and NPGY) on the test plot and for piezometres located topographically above (NPGE) and below (NPGS) the test plot. Samples were taken by scooping every three days. Reaction in NPGT and NPGR are within one day (sampling on 17.07.00) while in NPGY and NPGX reaction takes place within two to three days (sampling on 20.07.00 shows deuterium, while sampling on 07.07.00 shows none). Deuterium loss from the piezometres with time shows an exponential course, indicating less dilution in piezometre NPGR (filter depth 1.55-2.05 metre) than in the surface close piezometres NPGT,-X and –Y. The piezometres above and below the test plot do not show changes in deuterium concentrations.

Sampling for pesticides in the same piezometres show on 17.07.00 in NPGT,-X and-Y considerable Dimethoate and Metalaxyl concentrations and low concentrations on Malathion and Fenvalerate. Unfortunately NPGR was not sampled. Until 22.09.00 Dimethoate is detectable in all four piezometres, and on 26.11.00 only Dimethoate can be detected in NPGR. The observed fast reactions in highly elevated deuterium and in raised pesticide concentrations can only be explained with transport through preferential flow paths, which were active during the beginning of the experiment. Comparable active preferential flow paths and transport of water and pesticides within three days down to groundwater level has also been shown for similar conditions by Schumann (2002). In latter experiments, which took place at the control area of the project, water flow was visualized by a dye tracer (Vitasin Blue FCF 90) and sampling took place along the flow paths down to the uplifted groundwater table at 2.40 m below surface.

Conclusion

The hydrological investigations show that the turnover of subsurface water in *khet* land is slow. On precipitation events a fast discharge reaction of time lag around one hour occurs, formed mainly by direct flow, exporting most of the event water immediately from the catchment. Groundwater table reactions are, to a vast extend, caused by pressure transmission effects. However, during strong precipitation events and regular ponding irrigation mass transport occurs also. Latter is faster and total mass transport greater, the lower the antecedent soil moisture is.

It seems that the first transport processes under low antecedent soil moisture occur through preferential flow paths until soil swelling closes them up. Thereafter, and under high antecedent soil moistures mass transport occurs under matrix flow with seepage velocities of about 10-20 mm per day. Pesticides have proven to fall relevantly under the occurring mass transport. This result is in line with the findings of Schumann (2002) and Apel (2002). However, mass transport is so small that under the given circumstances the risk of groundwater pollution through pesticides can be estimated as little.

Acknowledgement

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Socio-economic contexts on pesticide use in Nepal

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Abstract

Two socio-economic surveys were conducted in Jhiku Khola Watershed (JKW) area in Kabhrepalanchok district of Nepal for understanding the general socio-economics, farming systems and pesticide use in agriculture. An average household owns 0.60 ha of land. Most of the households depend on agriculture for their livelihood and use pesticides for protecting their crops from various pest attacks. Rice, maize, wheat and mustard are treated 1 - 3 times per crop cycle whereas potato, tomato, cabbage, bittergourd and cucumber are treated 2 - 15 times. Farmers have low knowledge on pesticides and their uses, as a result, general precautionary measures are also lacking. The enforcement of pesticide regulation is very poor. The share of pesticides in the cost of production of various crops grown ranges from 0 % (wheat) to 8.41 % (bittergourd). This share being moderate and economically justifiable has stimulated the farmers to use pesticides without thinking their negative impact on human health and the environment. Increasing the awareness of farmers and enforcement of pesticide regulations are needed to improve the situation.

Introduction

Nepal with an area of 147181 square kilometer is a country inhabited by 23.2 million people. Agriculture still plays an important role in its national rural economy with its contribution to Gross Domestic Product going down to 38 percent. The 2001 National Census (CBS, 2001) has put the percentage of population dependent on agriculture and living in the rural area at 76 and 84, respectively. Furthermore, commercialization of agriculture is central to accelerated economic growth and poverty reduction in a country like Nepal, which is an overwhelmingly rural and agrarian economy. However, commercialization entails high input high-value commodities based intensification of agriculture, which often leads to increased use of pesticides. Inappropriate and excess use of chemical pesticides could have hazardous impact on human being, livestock and environment. Therefore, it is important that effective and ecologically sound crop protection programs that combine various alternative pest control measures, including mechanical, biological and chemical methods, should be implemented to minimize harmful effects of toxic pesticides. Chemical pesticides should be used only as a last resort. This requires promotion of appropriate crop protection technology and pest management strategy, and increased awareness of the farmers.

In this context, a research project entitled "Environmental Risks of Pesticides and Sustainable Development of Integrated Pesticide Management (IPM) for Mountain Areas of Developing Countries considering Socio-economic Conditions and taking Middle Mountains, Central Nepal as an example (DEVELOP IPM NEPAL)" (Herrmann, 1997) was implemented by CEAPRED in collaboration with the Technical University of Braunschweig (TUBS), Germany, in JKW area [Ward No. 4, 5, 6 and 9 of Panchkhal Village Development Committee (VDC)] of Kabhrepalanchok district of Nepal. The objectives of the research project were to understand the general socio-economics, farming systems and use of pesticides in agriculture at the research site. Two socio-economic surveys were conducted in connection (the first during May – September 1999 and the second during 4 – 13 March 2001).

Methodology

Selection of sample site

Since JKW area was chosen as the experimental site, the site for the survey was pre-determined. The collaborating institutions (CEAPRED and TUBS) agreed that a total of 200 households in the JKW area would suffice to generate the required information. Hence a sample size of 200 was fixed. For this purpose, JKW area was divided into Lower Catchment Area (LCA) comprising Ward No. 4, 5 and 6 and Upper Catchment Area (UCA) comprising Ward No. 9 of Panchkhal VDC to account for the ecological/environmental diversity of the area. Since the site selection for the first survey was purposive, this study site may not represent the mid-hills of Nepal. However, it represents the numerous micro-ecological belts with JKW characteristics in the region.

Training of technical staff

The first survey was carried out by the technical staff of District Agriculture Development Office (DADO) Kabhrepalanchok. They were given a four-day training by a Socio-economist of CEAPRED. The second survey was conducted by CEAPRED technical staff. They were also oriented to conduct the survey to solicit quality information.

Selection of sample farmers/households

A total of 200 randomly selected households (10 % of the total households based on the voters' list provided by the Panchkhal VDC and Ward Offices) were interviewed during the first survey using pre-tested structured questionnaire. Accordingly, 200 households [(80 in the LCA (3 in Ward No. 4, 20 in Ward No. 5 and 57 in Ward No. 6) and 120 in the UCA (Ward No. 9)] of Panchkhal VDC were interviewed during the first survey. Landless households were not included in the sample.

Sample households selected for the first survey and their land holdings formed the basis for the selection of farmers for the second survey. Two hundred farmers interviewed during the first survey were classified into small, medium and large farmers using National Planning Commission norms. The TUBS and CEAPRED agreed to conduct second socio-economic survey of 50 (25 %) of 200 farmers. Fifty households were selected using Probability Proportional to Size (PPS) technique to represent VDC Ward as well as different categories of farmers from among the 200 farmers interviewed during the first survey. As in the first survey, farmers interviewed in the LCA and UCA during the second survey constituted 40 % and 60 % of the total (50). Accordingly, catchment area-wise/Ward-wise and strata-wise number of farmers interviewed during the second survey is given in the Table below.

Results

Households and population

The number of households surveyed during the first survey comprised 1320 persons. This translated into a family size of 6.6 persons per household. At the aggregate level, there are more female than male (97.3 male per 100 female). However, sex ratio is more unbalanced in

LCA (93.4 male for every 100 female).

Caste-ethnicity and population

Brahmin and Chhetri constituted 40 percent of sampled households. Newar was the second dominant group accounting for 23 percent of households surveyed, but is predominant in the UCA. Occupational castes (Kami, Damai and Sarki) constitute the third largest caste-ethnic group in the area. Together they share a little more than 14 percent of the sample population but are confined to the UCA. In the LCA, Danuwar is the second largest caste-ethnic group after Brahmin and Chhetri. Other caste people residing in the area are Tamang and Sanyasi.

Distribution of population by age

The sample populations have been grouped into three classes: less than 15 years, 15 - 59 years and 60 years and above. The percentages of economically active population (15 - 59 years) for the LCA and UCA are 55.9 and 53.4 respectively. Younger age population (less than 15 years) does not vary across the settings but the UCA has slightly higher percentage of female children (40.7 %) than is the case for the LCA (37.3 %). However, the percentage of elderly population (aged 60 and above) is more in the LCA (7.9 %) than in the UCA (5.9 %).

Education

Illiterate population is higher in the UCA (34.6 %) than in the LCA (21.4%). In both LCA and UCA, female illiteracy is significantly higher than the male. Likewise, educational attainment of the population is higher in the LCA than in the UCA. For all categories of educational attainment, male educational attainment is higher than female.

Households and landholdings

In rural Nepal, land continues to be the major source of income and employment. Often, the quality of land (irrigated vs. unirrigated), type of land (lowland vs. upland), and accessibility (road head vs. others) are major determinants of a household's social and economic status in the community. Based on the distribution of landholdings, farm households have been categorized into Marginal (< 0.5 ha), Small (0.5 - 1.5 ha), Medium (1.5 - 2.5 ha) and Large (2.5 - 4 ha).

Of the 200 respondents, more than 93.5 (187) % are small and marginal farmers. A little more than half are marginal farmers (103) with an average land holding of 0.26 ha. In the surveyed area, 52 % of households own only 22.5 % of land. In contrast, less than 7 % of households own about 24 % of land indicating rather skewed distribution of productive resource. The average size of landholding for JKW area is 0.60 hectare. The average land holding of a household is 0.78 ha in the LCA while it is 0.49 ha in the UCA.

There is more low land (Khet) in the LCA than in the UCA. Again, the holdings are not in one location, but scattered in a number of small parcels ranging from 3 to 5, which take an average time of 20 - 27 minutes to reach the farthest parcel from the homestead.

Farming systems

Some of the characteristics of Nepalese farming systems are as follows: a) Mixed farming consisting of crops and livestock, b) subsistence farming characterized by smallholdings and low productivity, c) agricultural production dominated by cereal crops for food security, d) mostly rain fed farming, e) labour-intensive farming, f) agriculture not providing full time employment to the people thus paving way for seasonal migration in search of employment, g) lack of institutional credit and organized market in the rural areas h) lack of network of roads in the rural areas.

The project site can be considered as one of the most privileged sites representing the ideal situation of Nepalese farming systems.

Land types

In the hilly regions of Nepal, the agricultural land is broadly classified into two categories, 'Khet' and 'Bari'. 'Khet' refers to land which is usually lowland and suitable for rice cultivation under puddling condition while 'Bari' refers to the upland which is usually not suitable for rice cultivation under puddling condition but suitable for cultivation of several other crops. 'Pakho' is marginally uncultivated land used for animal grazing and 'Ban' means forest. Some farmers also have forest in their personal land.

Major crops grown in the project area

The major crops grown in both UCA and LCA are rice, maize, potato, wheat and tomato. The other crops grown in the area are mustard, cabbage, cucumber, bittergourd, chilli, brinjal and radish. The cropping intensities in Khet land in the LCA and UCA are 250 % and 243 %, respectively whereas in Bari, these figures are 126 % and 134 %, respectively.

Cropping patterns

There are three distinct cropping seasons in the project area: Summer or Monsoon (June - October), Winter (November - February) and Spring (March - May). In Khet, the dominant crop during monsoon is rice followed by potato, wheat, vegetables and mustard during winter and summer seasons. In Bari, the dominant crops during monsoon are maize and tomato followed by wheat, mustard, potato and vegetable crops during winter and summer seasons.

Irrigation

The major source of irrigation in the UCA Khet is Jhikhu Khola and its tributaries and for the LCA Khet is Jhikhu Khola and groundwater (lifted with either motor pumps or rower pumps). About 96 % of LCA farmers and 76% of UCA farmers irrigate their land from the Jhikhu Khola stream. About 48 % of LCA farmers and only 3 % of UCA farmers also use water pumps to lift groundwater for irrigating their crops. Water tariff is being paid by 55 % of LCA farmers and 23 % of UCA farmers, respectively.

Livestock holding

Livestock is an integral part of Nepalese farming system. The major animals raised by the farmers are cattle, buffalo, goat, sheep, pig and poultry. Cattle are raised for milk and draught power, buffaloes for milk and meat and poultry birds for meat and egg.

Pesticide use

During the green revolution time (mid 1960s and 1970s) in India, the Nepalese farmers also started the use of improved seed, chemical fertilizer and pesticides to grow more food. All of these inputs except some seed are being imported from other countries.

The use of pesticides in Nepal started in the early 1950s when DDT was extensively used in the Terai and Inner Terai area for eradicating Malaria disease transmitted by mosquitoes (Anopheles spp.). Of course, DDT was not much used in agricultural crops. Parathion was imported in large quantity followed by endirin, BHC, chlordane, aldrin and dieldrin during the 1950s and 1960s. Nepalese farmers have a preference for highly toxic insecticides with broad-spectrum activity, which result in immediate knockdown of pests (Neupane, 1995). All chlorinated hydrocarbons except endosulfan, phosphamidon and parathion among the organophosphates and organomurcury chloride have been banned, but methyl parathion is still in use, being one of the most popular insecticides (DOPP, 2001).

A long list of pesticides has been approved by the Directorate of Plant Protection (DOPP) under the Department of Agriculture (DOA) of His Majesty's Government of Nepal for various crops (DOPP, 2001). The Pesticide Act was enacted in 1991 and the Regulations approved in 1993 (DOPP, 2001). Due to lack of enforcement of legislation, there have been several misuses of pesticides. For example, anybody can sell, buy and use toxic chemicals; there is no mechanism for consumer safety (the pesticide residues on marketable crop produce); the expiry dates of pesticides and the quality of imported as well as locally produced chemical is unchecked. There have been some pesticides imported from India, which are of doubtful quality. In the past, the major bulk of pesticides were marketed by the Agricultural Inputs Corporation, but currently it is handled by private dealers. There are many dealers of various pesticides in the country. Since Nepal has an open border with India, it is very difficult to estimate the exact quantity of pesticides imported into the country. However, the DOPP has reported the following pesticide import figures, (in terms of active ingredients), for the year 1997: insecticides - 33356 kg, fungicides/bactericides - 15577 kg, herbicides - 6748 kg and rodenticides - 400 kg (unpublished data). The national average consumption of pesticides is very negligible (142g active ingredient/hectare) (Dahal, 1995).
The pesticide application equipment, mostly sprayers (hand compression and knapsack type) are also imported from India by many of the pesticide dealers.

Vegetable production has become very popular in many parts of Nepal, especially near the highway corridors. Farmers have started treating high value vegetable crops with pesticides very frequently. In many places farmers apply pesticides in a routine manner, without considering the waiting period, residue on the treated stuff, human health and the environment as a whole. Panchkhal VDC is very popular pocket for growing different vegetable crops, which are sold at high prices in Kathmandu and other nearby towns. Many people who are concerned about the abuse of pesticides, are frightened to consume the crops (especially vegetables) grown in Panchkhal area. Since there is very limited facility for pesticide residue analysis in the country, it is difficult to judge the amount of pesticide residue present in the plants, soil and water around the treated area. In this context the present collaborative research has aimed at studying pesticide management aspects in the Hindu-Kush Mountain Region, taking Nepal as a representative site.

Pesticides used in the project area

The following pesticides are used by the farmers of the project area for controlling various pests on different crops: Insecticides (aluminum phosphide, chlorpyriphos, dichlorvos, dimethoate, fenvalerate, malathion and methyl parathion), Fungicides (carbendazim, edifenphos, mancozeb and metalaxyl.

Broad use of pesticides in agriculture

In the research site, farmers use pesticides mostly on standing crops in the field. All LCA farmers and 97 % of UCA farmers have been found using pesticides on their crops. Cereals and grain legumes are stored for several months. The grains are used both as seed and food. About 20 % of LCA farmers have been found treating the seed with pesticide and none of the UCA farmers did so. In both the areas, farmers treated the grains meant for human and animal consumption.

Priority crops for pesticide use

In the study area, farmers use pesticides mainly on the following crops for controlling various insect pests (Neupane, 2002) and diseases (Shrestha, 1996): potato, tomato, rice, cauliflower, brinjal (eggplant), chilli, beans, gourds, wheat and mustard. In UCA and LCA, potato, tomato and rice are the important crops followed by different vegetable crops in terms of pesticide use.

Use of pesticides in stored commodities

The major stored commodities in the research site are cereal grains (rice and wheat), which are kept for 3 - 6 months. Very few farmers (6 %) applied following insecticides on cereal grains: aluminium phosphide (Celphos tablets), malathion (dust) and dichlorvos (Nuvan EC). The latter two insecticides are not recommended by DOPP for direct use in grains in the storage.

Use of pesticides in field crops

Crop-wise use of pesticides and their frequencies of application/ (FA) on a crop for one season have been presented below.

Lower catchment area

Rice (i) Insecticides: dichlorvos, dimethoate, fenvalerate and methyl parathion. These are used against chewing and sucking insects. Dichlorvos is very low persistent insecticide and not desirable to be used on rice. FA: 2 - 3 times. (ii) Fungicides: carbendazim and edifenphos. These are used against fungal diseases such as rice blast and brown spot. FA: 1 - 2 times.

Maize (i) Insecticide: chlorpyrifos. It is used against soil and foliage insects. FA: 1 time.

Potato (i) Insecticides: dichlorvos, dimethoate, fenvalerate and methyl parathion. Here again, dichlorvos is not a proper choice. FA: 8 - 12 times. (ii) Fungicides: mancozeb and a mixture of metalaxyl and mancozeb (Krilaxyl). These are used mainly against the late blight of potato. FA: 9 times.

Tomato (i) Insecticides: dichlorvos, dimethoate, fenvalerate and methyl parathion. FA: 7 - 15 times. (ii) Fungicides: carbendazim, mancozeb and Krilaxyl. These are used against the late blight. FA: 4 - 11 times.

Cabbage and Cauliflower (i) Insecticides: dichlorvos and fenvalerate. FA: 2 - 4 times. (ii) Fungicide: mancozeb. FA: 7 times.

Bittergourd (i) Insecticides: dichlorvos, dimethoate, fenvalerate and methyl parathion. FA: 5 - 13 times. (ii) Fungicide: mancozeb. FA: 14 times.

Chilli and Capsicum (i) Insecticides: dichlorvos, dimethoate and fenvalerate. FA: 5 - 11 times. (ii) Fungicide: mancozeb. FA: 8 times.

Cucumber (i) Insecticides: dichlorvos, dimethoate and fenvalerate. FA: 2 - 9 times. (ii) Fungicides: mancozeb and Krilaxyl. FA: 12 times.

Brinjal (i) Insecticides: dichlorvos, fenvalerate and methyl parathion. FA: 2 - 9 times. (ii) Fungicides: mancozeb and Krilaxyl. FA: 2 - 4 times.

Beans (i) Insecticides: dimethoate. FA: 5 times. (ii) Fungicide: mancozeb. FA: 5 times.

Upper catchment area

Rice (i) Insecticides: dichlorvos, fenvalerate, malathion, dimethoate and methyl parathion. FA: 2 - 4 times.

(ii) Fungicide: edifenphos. FA: 2 times

Wheat (i) Insecticide: malathion. It is used for controlling the pests of stored wheat grains. FA: 1 time.

Potato (i) Insecticide: dichlorvos, dimethoate, fenvalerate and methyl parathion. FA: 6 - 8 times. (ii) Fungicides: mancozeb and Krilaxyl. FA: 8 times.

Tomato (i) Insecticides: dichlorvos, dimethoate and fenvalerate. FA: 10 times. (ii) Fungicides: mancozeb and Krilaxyl. FA: 10 times.

Bittergourd (i) Insecticides: dichlorvos and fenvalerate. FA: 6-7 times. (ii) Fungicide: mancozeb. FA: 8 times.

Chilli and Capsicum (i) Insecticides: dichlorvos and fenvalerate. FA: 7 times. (ii) Fungicide: mancozeb. FA: 8 times.

Brinjal (i) Insecticide: fenvalerate FA: 6 times. (ii) Fungicide: mancozeb. FA: 6 times.

Mustard (i) Insecticide: fenvalerate. FA: 2 times. (ii) Fungicide: mancozeb. FA: 1 time.

The rate of pesticides per application used on various crops in LCA and UCA has been found to be normal when compared with the rate of application used in United States of America (Thomson, 1998, 2000).

Criteria for pesticide application

For the application of pesticides on the crops, farmers usually take presence of pests or their damage symptoms or both into consideration. Some farmers also use pesticides even without noticing the above criteria. In case of rice 31.2 % of the households considered the presence of pests and 36.2 % considered the damaged symptoms while 2.5 % considered both in the LCA. While in the UCA, only 4.1 % of the households considered pests and 23.3 % considered damage symptoms. In case of potato 87.5 % of the households considered damaged symptoms. This is particularly true because of potato late blight caused by a fungus (Phytophthora infestans), which cannot be seen by naked eyes. Hence, farmers have to rely on damage symptoms. In most of the crops farmers rely on at least two criteria listed above.

Waiting period

Waiting period can be defined as the period between the last application of pesticide on a crop and the date of its harvest. Generally, during this period the pesticide residue on or in the treated stuff / plants is dissipated and such stuff is usually harmless to human and animal consumption. Now the problem in developing countries including Nepal is that farmers usually do not maintain the recommended waiting period prescribed for different pesticides. This has compelled people to consume agricultural products containing illegal amount of pesticide residues and suffer from various ailments.

The research site is important vegetable growing pocket and a lot of vegetables are sold in Kathmandu and other surrounding areas. The vegetable growers of this area also have not maintained the recommended waiting periods for various pesticides. The waiting periods of mancozeb, fenvalerate, matalaxyl + mancozeb (Krilaxyl), dimethoate and methyl parathion are too short in both UCA and LCA. It means that vegetables grown in these areas are not safe for human consumption.

Use of right dosage of pesticides

About 24 % of respondents took the advice of agricultural technicians (Agricultural Officers, Junior Technicians, Junior Technical Assistants of DADO, Kabhrepalanchok and technical staff of CEAPRED), 11 % decided on their own and 65 % either decided on their own or took the advice of the agricultural technicians in the LCA whereas in the UCA 89 % took the advice of the technicians.

Change in pesticide types

Little changes have been seen on pesticide types in the research site. In the LCA, 27 % of the respondents have switched over to other types of pesticides from the regularly used ones. In the UCA, only 8 % of the respondents did so. The reasons for the changes were agricultural technicians' advice, unavailability of the regularly used pesticides and pesticide dealers' advice.

Know-how about pesticides use

Know-how about pesticides (such as their types, method of dilution and application, residue problems, expiry dates, precautionary measurers etc.) was low among the farmers. In LCA, only 41 % of the male and 23 % of the female had knowledge on the above areas while it was so only with 32 % of male and 8 % of female in UCA.

Other pest control practices

Only 12 farmers have reported using the following means than synthetic insecticides for controlling pests on vegetable crops such as tomato, potato, cauliflower, pea, bean, mustard, gourds and other vegetables:

Botanicals: Azadirachta indica (Neem), Artemisia vulgaris (Mug-wort), Capsicum frutescens (Chilli), Allium sativum (Garlic), Nicotiana spp. (Tobacco) and wood ash.

Miscellaneous: Cow urine, Soap and Light-trap.

Cow urine alone (diluted with water) or in combination with crude water extracts of the above botanicals (especially their leaves, fruits and bulbs) are applied on the plant foliage. Farmers believe that this treatment protects the crops from the damage from various insects and diseases. But published data that confirm farmers' believes are lacking.

Pesticide appliances

In Nepal, pesticides are applied using very simple manual appliances such as sprayers and dusters. The hand compression (usually 9-litre capacity) and the knapsack sprayer (16-litre capacity) are very commonly used. In the absence of a sprayer, locally made brooms are used. Similarly, in the absence of a duster, pesticide dust is spread over plants and soil surface by hand.

Both men and women are involved in pesticide application. In rare cases, even children are involved. About 45.6 % male and 24.7 % female are engaged in pesticide application in the LCA. Similarly, 36.5 % of male and 14.4 % of the female are engaged in pesticide application in the UCA.

About 91 % and 57 % of LCA and UCA households own sprayers. Farmers, who do not own sprayers, borrow from their neighbors by paying Rs. 40/day (LCA) and Rs. 23/day (UCA), respectively.

Marketing of pesticides

In the LCA, farmers buy pesticides from the following retailers in order of priority: agro-vet shop, local agro-shop, Agricultural Input Corporation (AIC) dealers and farmers' cooperatives. Similarly, in the UCA, farmers buy pesticides from local agro-shop, agro-vet shop and AIC dealers.

Pesticidal hazards to human being and environment

<u>Hazards to users</u>:

In the LCA, 94 % of the users did not feel any side effect of pesticides whereas 6 % felt some effects. Similarly, in the UCA, 33.6 % of the respondents did not respond to the side effects of pesticides. About 38 % of the respondents did not experience any side effect whereas 28.3 % of the respondents did experience side effects.

Hazards to general public and environment:

Pesticides applied on the field also have some side effect on general public and the environment. About 85 % and 67 % of the respondents in LCA and UCA , respectively, were aware of pesticide hazards to general public health and the environment.

Use of protective measures

LCA:

A majority of users (85 %) washed their hands with soap, very few (5 %) used gloves; boot; mouth and nose cover; about 19 % used gloves and mouth and nose cover.

UCA:

A majority of users (90 %) washed their hands with soap and 5 % used mouth and nose cover.

Farmers' training on pesticide management

Training of farmers on pesticide management is very important. But it is being neglected by the concerned agencies. Only two LCA male farmers have received a very short training on IPM.

Availability of pesticides

Around 90 % of the households of UCA and LCA stated that pesticides were available in the market whenever they needed. Very few (7 %) commented that they were not available when they required them.

Storage of pesticides by farmers

Generally, farmers buy pesticides before they use while others buy them when needed. In the first case, farmers have to store the pesticides at their residences for some time. In the LCA, 40 % and in the UCA 25 % of the households stored pesticides.

Annual expenditure

Farmers' annual expenditure is grouped into seven categories, namely, foodstuff, education, health, livestock raising, transportation, fuel, festivals and clothing. Average annual expenditure of UCA farmers (Rs. 53809) is less than that of LCA farmers (Rs. 63077). (Table 5).

Income and Expenditure

Income of farmers in the project area is categorized into two: farm income (Value of Production minus Cost of Production) and Income (Farm Income plus Off-farm Income). Table 6 shows that average farm income of UCA farmers (Rs. 66621) is much less than that of LCA farmers (Rs. 145603). This is so because they apply more purchased inputs and produce more in terms of quantity than that of UCA farmers. Similarly, average income of UCA farmers is less (Rs. 108253) than that of LCA farmers (Rs. 190093). Average expenditure (value of home consumption plus annual expenditure) of UCA farmers, which stands at Rs. 103324, is less than that of LCA farmers (Rs. 137573). Thus there is a big difference between the average income of UCA and LCA farmers. Average surplus (excess of income over expenditure) per UCA farmer/household (Rs. 4928) is very low as compared to the same of LCA farmer/household (Rs. 52520).

Table 1 Value of production (NRS)

	UCA				LCA			
	20 Small Farmers	8 Medium Farmers	2 Large Farmers	Total (30)	9 Small Farmers	8 Medium Farmers	3 Large Farmers	Total (20)
Value of Production	**983022**	**668766**	**467015**	**2118803**	**1155021**	**1291520**	**655622**	**3102163**
Average	**49151**	**83596**	**233508**	**70627**	**128335**	**161440**	**218541**	**155108**

Table 2 Cost of production (NRS)

	UCA				LCA			
	20 Small Farmers	8 Medium Farmers	2 Large Farmers	Total (30)	9 Small Farmers	8 Medium Farmers	3 Large Farmers	Total (20)
Cost of Production	**68696**	**39891**	**11578**	**120165**	**68307**	**82614**	**39191**	**190112**
Average	**3435**	**4986**	**5789**	**4006**	**7590**	**10327**	**13064**	**9506**

Table 3 Off-farm Income (NRS)

	UCA				LCA			
	20 Small Farmers	8 Medium Farmers	2 Large Farmers	Total (30)	9 Small Farmers	8 Medium Farmers	3 Large Farmers	Total (20)
Off-farm Income	**856946**	**372200**	**19800**	**1248946**	**160000**	**99800**	**630000**	**889800**
Average	**42847**	**46525**	**9900**	**41632**	**17778**	**12475**	**210000**	**44490**

Table 4 Value of home consumption (NRS)

	UCA				LCA			
	20 Small Farmers	8 Medium Farmers	2 Large Farmers	Total (30)	9 Small Farmers	8 Medium Farmers	3 Large Farmers	Total (20)
Home Consumption	**885993**	**437167**	**162296**	**1485456**	**457621**	**610350**	**421938**	**1489909**
Average	**44230**	**54646**	**81148**	**49515**	**50847**	**76294**	**140646**	**74495**

Table 5 Annual expenditure (NRS)

	UCA				LCA			
	20 Small Farmers	8 Medium Farmers	2 Large Farmers	Total (30)	9 Small Farmers	8 Medium Farmers	3 Large Farmers	Total (20)
Annual Expenditure	**879887**	**478792**	**255596**	**1614275**	**442876**	**467289**	**351380**	**1261545**
Average	**43994**	**59849**	**127798**	**53809**	**49208**	**58411**	**117127**	**63077**

Table 6 Income and expenditure of UCA and LCA farmers (NRS)

	UCA				LCA			
	20 Small Farmers	8 Medium Farmers	2 Large Farmers	Total (30)	9 Small Farmers	8 Medium Farmers	3 Large Farmers	Total (20)
Income	1771272	1001075	475237	3247584	1246714	1308707	1246431	3801852
Value of Production	**983022**	**668766**	**467015**	**2118803**	**1155021**	**1291520**	**655622**	**3102163**
Minus Cost of Production	**68696**	**39891**	**11578**	**120165**	**68307**	**82614**	**39191**	**190112**
Farm Income	**914326**	**628875**	**455437**	**1998638**	**1086714**	**1208906**	**616431**	**2912052**
Plus Off-farm Income	**856946**	**372200**	**19800**	**1248946**	**160000**	**99800**	**630000**	**889800**
Expenditure	1765880	915959	417892	3099731	900497	1077639	773318	2751454
Value of Home Consumption	***885993***	***437167***	***162296***	***1485456***	***457621***	***610350***	***421938***	***1489909***
Plus Annual Expenditure	***879887***	***478792***	***255596***	***1614275***	***442876***	***467289***	***351380***	***1261545***
Surplus (Income - Expenditure)	5392	85116	57345	147853	346217	231068	473113	1050398
Surplus/Household	270	10640	28673	4928	38469	28883	157704	52520

Conclusion

Farmers in the research site have started growing high value crops such as vegetables in place of traditionally grown cereals. They do not like to take any kind of risk such as pest damage in these crops. Hence they have started using pesticides lavishly. The other reasons for high use of pesticides are their cheapness and very low share in the total cost of production of the crops. The farmers have very low knowledge on pesticides and the pesticide regulations have not been enforced properly. For improving this situation, the awareness of the farmers needs to be raised towards pesticides, their alternatives and IPM and enforcing the regulation by the government as well as several developmental agencies.

Acknowledgement

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Modeling overland flow and sediment discharge from agricultural lands on Himalayan foot hills under monsoon conditions

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Abstract

Modeling of overland flow and sediment discharge is a complex process and the procedure differs under different hydrological conditions. Simulation for the Himalayan foothills under monsoon type of climatic conditions requires quantification and interpretation of overland flow and sediment discharge from all the storms of monsoon season, individually and integrally, for small land holdings under the local agricultural practices followed in this region. A physically based distributed numerical model suits well these types of agrohydrological conditions to generate discharge hydrograph and sedimentograph for each storm and integrated simulation graphs for a particular duration. A combination of finite element and finite difference solution for irregular spatial integration and temporal integration, respectively, suits well for modeling under these conditions.

Introduction

The modeling of surface runoff and sediment discharge from the agricultural watersheds started in mid 20^{th} century with the development of rational formula (Ramser 1972) and US soil conservation services method (Anonymous 1969) for runoff estimation and universal soil loss equation (Wischmeier & Smith 1965) for soil loss quantification. These equations are widely used even today especially for ungauged watersheds. Since these equations were developed on more of empirical estimations of the involved parameters, there had been scope for the improvement of the estimation procedures of these processes. The development in technology led to better understanding of the physical behavior of the parameters involved in estimation of overland flow and sediment discharge and as a result, more physically based models came up (e.g. CREAMS: Knisel 1980; WEPP: Nearing et al. 1989, Hairsine & Rose 1992a, 1992b; EUROSEM: Morgan et al. 1998; etc.). Simultaneously, the invention of the fast computation machines complemented the development of the modeling techniques and allowed the use of complex numerical methods for the solution of the governing partial differential equations, reducing the assumptions of homogeneity for otherwise heterogeneous system. Moreover, the stress now is being given on the development of physically based distributed dynamic models to incorporate maximum possible available information for achieving more realistic results. Developing WEPP model (Nearing et al. 1989) and EROSEM model (Morgan et al. 1998) researchers have tried to lay down norms for modeling concepts of 21st century. These models suit best the watersheds under uniformly distributed rainfall over the entire year (WEPP) and single storm analysis under European conditions (EUROSEM).

The agroclimatic pattern of the Himalayan foothills differs from the agroclimatic behavior of the western countries because of monsoon type of climatic season. Most of the rainfall is received in a span of four months (June to Sept.) (Fig. 1) and rest of the months remain dry. The monsoon rains are normally of high intensity and short duration and erratic both in time and space. Therefore, the modeling process for these types of conditions should simulate fluctuations in the overland flow and sediment discharge within one storm span and should continue at least for entire monsoon season or crop season to reflect the scenario for a given span of time. Moreover, since the land holdings of the farmers in these watersheds are either small to marginal (<5 ha), focus needs to be given to simulation situations for small watersheds with provision of integration to the higher scales.

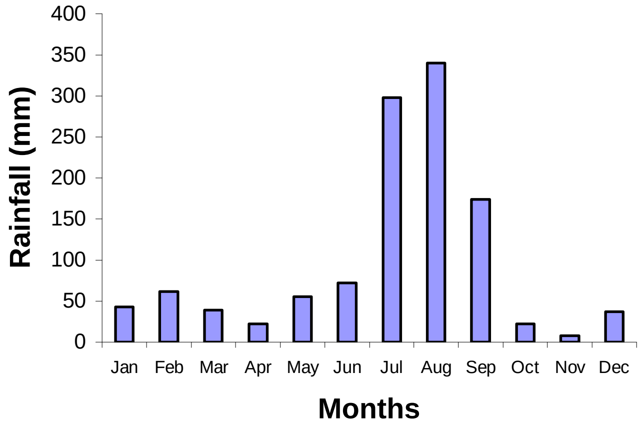

Fig. 1 Monthly rainfall fluctuation in Himalayan foothills

Profile of process

The overland flow and sediment discharge modeling procedures for the arable Himalayan foothills need to have a complex structure involving number of sub-processes in the heterogeneous system. The profile of the processes involved in overland flow and sediment discharge modeling has been presented in Fig. 2.

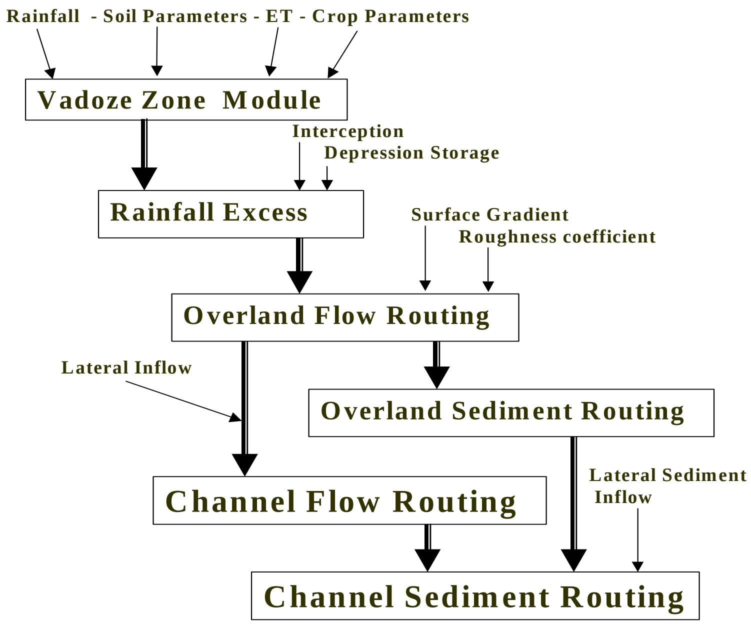

Fig. 2 Profile of processes involved in overland flow and sediment discharge simulation

These processes can be simulated by different modeling techniques viz. stochastic modeling, lumped modeling, distributed modeling etc. Since, at present time, physical basis of these processes has been well understood, the physically based distributed numerical models are preferred over other models.

Broadly, the modeling of overland flow and sediment discharge involves simulation of vadoze zone moisture dynamics for the estimation of infiltration rate, overland flow routing and overland sediment routing. Depending upon the applicability of the model and availability of data, a vadoze zone model may simulate infiltration using simple Philip equation (Philip 1957), moderate Green and Ampt equation (Mein & Larson 1973) or complex mixed form of 1, 2 or 3 dimensional Richards equation (Celia et al. 1990). The 2-D Richards equation (Eq. 1) is recommended for distributed soil water dynamics in vadoze zone. The equation needs a crop growth model for sink term calculation, which further needs estimation of evapotranspiration using some standard site feasible method. The unsaturated soil parameters may be calculated using concepts given by van-Genuchten (van Genuchten 1987). This approach is preferred for its wide acceptance for estimation of unsaturated soil parameters.

$$\frac{\partial}{\partial x}\left(K_x(h)\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial z}\left(K_z(h)\left(\frac{\partial h}{\partial z}-1\right)\right)-S(z,t)=\frac{\partial \theta}{\partial t} \tag{1}$$

where, h is hydraulic head (m), t is time (s), x is the horizontal space coordinate (m), z is the vertical space coordinate (m) (positive upwards), θ is the volumetric moisture content ($m^3 \cdot m^{-3}$), K_x is the hydraulic conductivity in x-direction ($m \cdot s^{-1}$), K_z is the hydraulic conductivity in z-direction ($m \cdot s^{-1}$), S is the source/sink term for root extraction and evaporation ($m^3 \cdot m^{-3} \cdot s^{-1}$).

The numerical solution of the Saint-Venant equations (Huggins 1982) (Eq. 2 to 4) routes the overland flow and give distributed output. The solution of these equations using kinematic wave approximations (Lighthill & Whilhan 1955), assuming gravity forces equaling frictional forces, is recommended for routing of overland flow because of the shallow depth of the overland water.

$$\frac{\partial h}{\partial t}+\frac{\partial V_x h}{\partial x}+\frac{\partial V_y h}{\partial y}=q \tag{2}$$

$$\frac{\partial V_x}{\partial t}+V_x\frac{\partial V_x}{\partial x}+V_y\frac{\partial V_x}{\partial y}+g\left[\frac{\partial h}{\partial x}+S_{fx}-S_{ox}\right]=0 \tag{3}$$

$$\frac{\partial V_y}{\partial t}+V_x\frac{\partial V_y}{\partial x}+V_y\frac{\partial V_y}{\partial y}+g\left[\frac{\partial h}{\partial y}+S_{fy}-S_{oy}\right]=0 \tag{4}$$

where, V_x and V_y are the local depth-averaged velocities ($m \cdot s^{-1}$), h is the local vertical depth (m), q is the lateral inflow ($m^2 \cdot s^{-1}$), g is the gravity constant, x and y are the space coordinates, t is the time (sec), S_{ox} and S_{fx} (resp·S_{oy} and S_{fy}) are the ground slopes and the friction slopes in the x and y directions, respectively.

Sediment routing involves solution of 1 or 2 dimensional continuity equation for sediment routing (Eq. 5 and 6) considering lateral flow of sediment from rill and interrill areas.

$$\rho_s\frac{\partial hc}{\partial t}+\frac{\partial g_x}{\partial x}+\frac{\partial g_y}{\partial y}=D_I+D_R=D_L \tag{5}$$

or

$$\frac{\partial A_s}{\partial t} + \frac{\partial A_s V_x}{\partial x} + \frac{\partial A_s V_y}{\partial y} = D_L \tag{6}$$

where, h is the water depth (m), c is the sediment concentration ($m^3 \cdot m^{-3}$), ρ_s is the mass density of the sediment particle ($kg \cdot m^{-3}$), t is the time (s), g_x/g_y is the sediment transport rate in x/y direction ($kg \cdot m^{-1} \cdot s^{-1}$) and is equal to $A_s \cdot V_x / A_s \cdot V_y$,$\cdot V_x$ and V_y is the flow velocity in x and y direction ($m \cdot s^{-1}$), respectively, $A_s = \rho_s \cdot c \cdot h$ is the mass of sediment under movement per unit area ($kg \cdot m^{-2}$), ρ_s is the particle density ($kg \cdot m^{-3}$), D_I is the delivery rate of sediment from interrill areas ($kg \cdot m^{-2} \cdot s^{-1}$), +ve for detachment and –ve for deposition, D_R is the delivery rate of sediment from rill areas ($kg \cdot m^{-2} \cdot s^{-1}$), +ve for detachment and –ve for deposition, D_L is the lateral inflow rate of the sediment per unit length per unit width of flow regime ($kg \cdot m^{-2} \cdot s^{-1}$).

The interrill sediment movement, detachment of soil particles by raindrop impact and transportation of sediment by rainfall distributed sheet flow, may be estimated using relation given by Foster (1982) (Eq. 7).

$$D_I = (COFI)\, C_f K_f I^b (2.96\, S_0^{0.79} + 0.56) \tag{7}$$

where, D_I is the delivery rate of sediment from interrill areas ($kg \cdot m^{-2} \cdot s^{-1}$), COFI is the coefficient for interrill erosion obtained through calibration, K_f is the soil erodibility factor of the USLE for interrill erosion, $kg \cdot h \cdot N^{-1} \cdot m^{-2}$, C_f is the crop management factor of USLE, I is the rainfall intensity ($mm \cdot h^{-1}$), b is an exponent of rainfall intensity depending upon clay content of the soil (b=2.0), S_0 is the sin of bed slope angle (θ) = sin(θ).

The rill sediment movement and sediment movement in the small channels, may be estimated using the equation (Eq. 8 to 10) given by Nearing (1989). The erosion/deposition of the sediment may be assessed using transportation equation given by Yalin (Foster & Meyer 1972) or by Bagnold (Bagnold 1977).

Case 1

$T_c > G$ (Entrainment Case)

i) $\tau > \tau_{cr}$

$$D_R = D_C(1-\frac{G}{T_c}) \quad (8)$$

ii) $\tau < \tau_{cr}$ (No entrainment and no deposition)

$$D_R = 0 \quad (9)$$

Case 2

$T_c < G$ (Deposition Case)

$$D_R = \frac{0.5\,V_f}{q}(T_c - G) \quad (10)$$

where, D_R is the rill detachment rate ($kg \cdot m^{-2} \cdot s^{-1}$), D_c is detachment capacity by rill flow ($kg \cdot s^{-1} \cdot m^{-2}$) and is equal to COFR K_f C_f (τ-τ_{cr}) (Foster 1992), COFR is the coefficient for rrill erosion obtained through calibration, τ is the average shear stress in the flow ($N \cdot m^{-2}$) is equal to γh S_0, γ sp. weight of water ($N \cdot m^{-2} \cdot s^{-1}$), τ_{cr} is the critical shear stress of the soil ($N \cdot m^{-2}$), h is the hydraulic head (m), q is the flow discharge per unit width ($m^2 \cdot s^{-1}$), V_f is the effective fall velocity of the particle ($m \cdot s^{-1}$) equal to $gd^2(\rho_s-\rho_w)/(18\mu)$, g is acceleration due to gravity ($m \cdot s^{-2}$), d is the particle diameter (m), ρ_s is the grain density ($kg \cdot m^{-3}$), ρ_w is the density of water ($kg \cdot m^{-3}$), and μ is the dynamic viscosity of water ($Kg \cdot m^{-} \cdot .s^{-1}$), T_c is transport capacity of water ($kg \cdot s^{-1} \cdot m^{-1}$) and G is sediment load ($kg \cdot s^{-1} \cdot m^{-1}$).

The analytical solution of the governing partial differential equations is difficult in heterogeneous natural systems. Numerical solution for such problem is preferred over the simplified analytical solution. The most widely used techniques for numerical solution are finite element techniques and finite difference techniques. The finite element technique fits better the irregular spatial boundaries of the watershed, whereas use of finite difference method optimizes the integration in time scale. Therefore, a combination of two approaches with finite element technique for spatial integration and finite difference for temporal integration are used for finding the solution.

The simulation process needs to continue for multiple storm sessions, which may run for number of days. Therefore, initial conditions are given as the starter of the program and thereafter, the model simulates the initial conditions for the subsequent storms. The model needs the daily input parameters viz. evapotranspiration parameters, plant growth parameters etc. and extract the information at suitable time increment. The flow chart of the programming procedure for simulation and output of overland hydrograph and sedimentographs has been presented in Fig. 3.

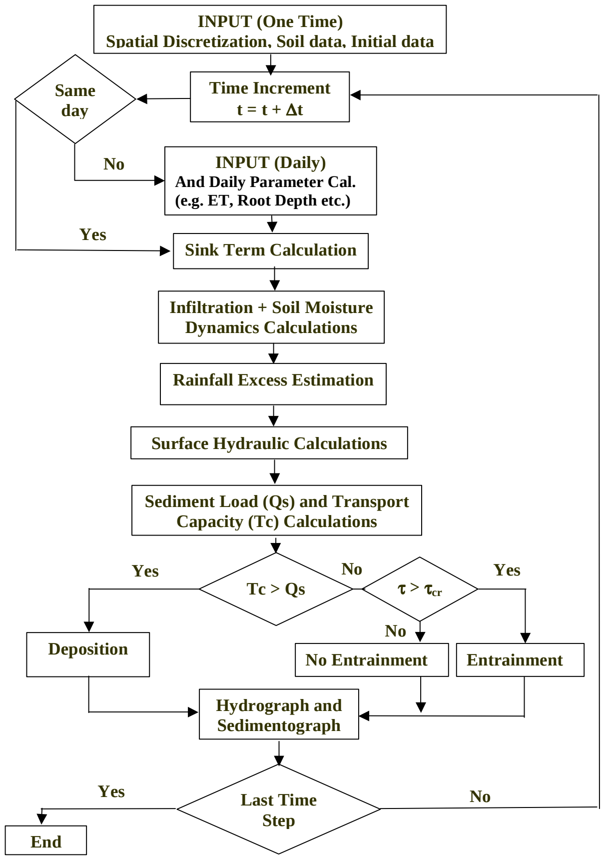

Fig. 3 Profile of processes involved in overland flow and sediment discharge simulation

Model sensitivity and output inferences

For model to give its best performance in the field, especially under rapidly changing boundary conditions like that on the Himalayan foothills under monsoon type climate, sensitivity evaluation of the involved parameters is required. It has been seen that the vadoze zone model and subsequently the overland flow model and sediment discharge model are highly sensitive to the initial moisture content input of the soil. Model results for initial moisture content (IMC) changing from –25 to –300 cm have been presented in Fig. 4a to 4c for infiltration rate, overland flow and sediment discharge. For a storm of 92 cm/day intensity over a period of 60 min, basal infiltration rate is reached within first 10 min of storm for initially nearing saturation soil conditions (IMC = -25 cm). Whereas, infiltration rate starts decreasing at lower rates and at delayed time for initially dry soil conditions and whole of the

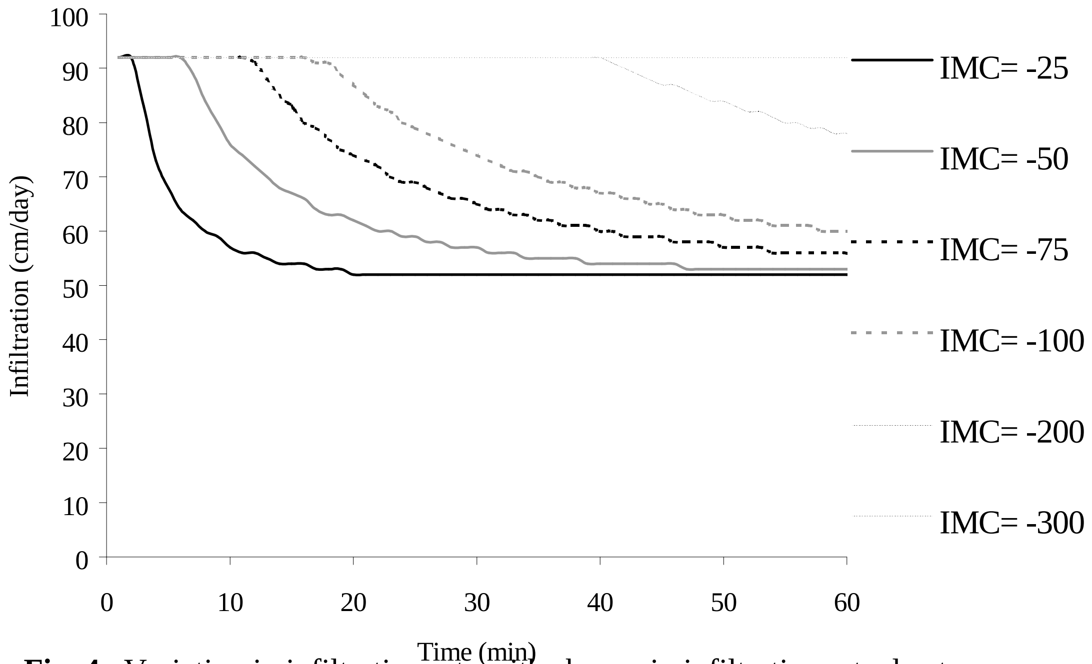

Fig. 4a Variation in infiltration rate with change in infiltration rate due to change in initial moisture content (cm)

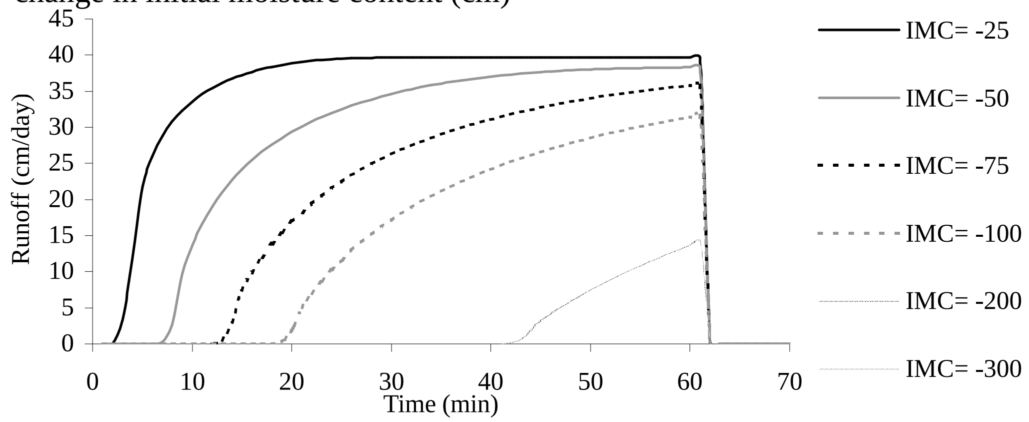

Fig. 4b Variation in runoff rate with change in infiltration rate due to change in initial moisture content (cm)

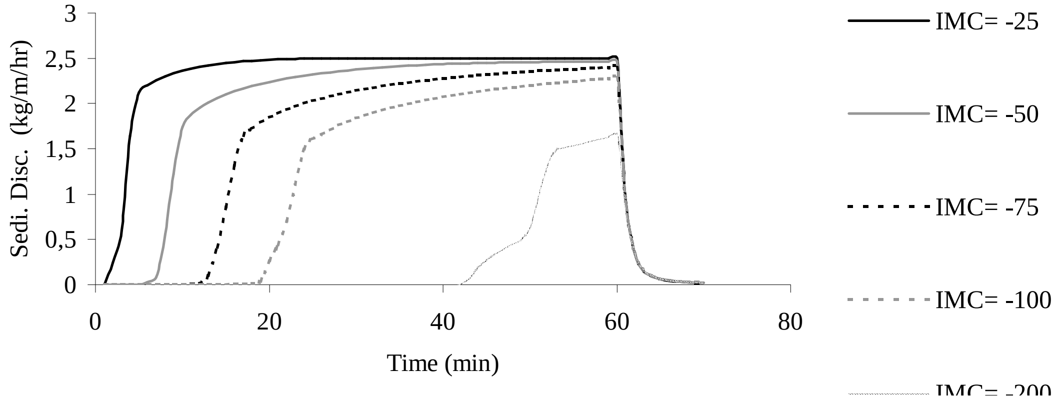

Fig. 4c Variation in sediment discharge rate with change in infiltration rate due to change in initial moisture content (cm)

rain infiltrates into the soil under very dry conditions (IMC < -300 cm). The change in infiltration rate directly affects the rate of overland flow and sediment discharge.

No overland flow could be seen for initially very dry moisture conditions (IMC <300 cm) whereas, initially wet condition resulted in early and higher peak. Similarly, the change in slope from 1% to 10% has not much affect on the peak overland flow but sediment peak increases with the increase in slope. This is largely due to the fact that detachment by rainfall dominates for slopes less than 3% and detachment by overland flow dominate the steeper slopes (Fig. 5a and 5b).

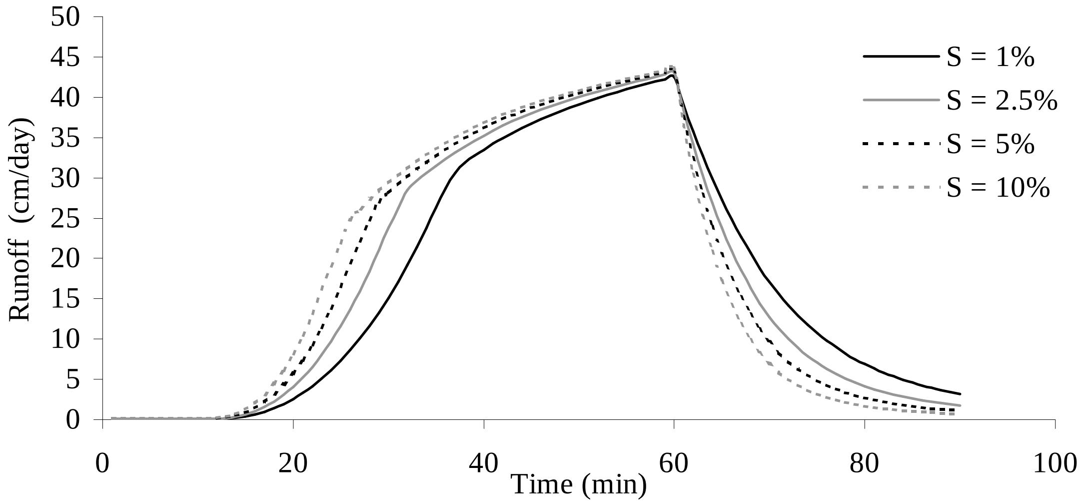

Fig. 5a Variation in runoff with change in slope

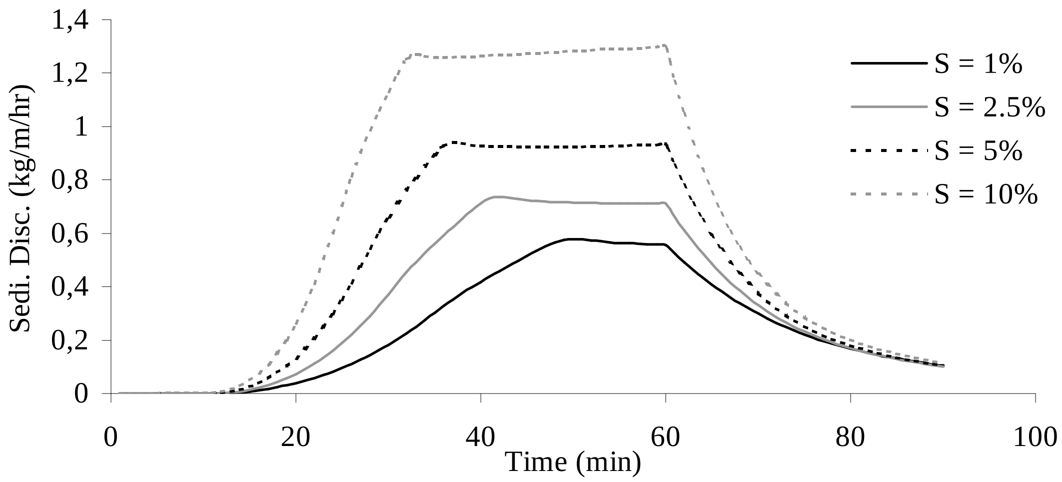

Fig. 5b Variation in sediment discharge with change in slope

As far as roughness coefficient is concerned (Fig 6a and 6b), there is not much change in the peak of overland flow but gradient to peak and after peak is sharper for smooth surfaces.

Whereas, increase in roughness increases the peak sediment discharge and total sediment load. This is due to the fact that shear stress of water is directly proportional to the depth of flow and therefore, any increase in depth of flow increases sediment detachment.

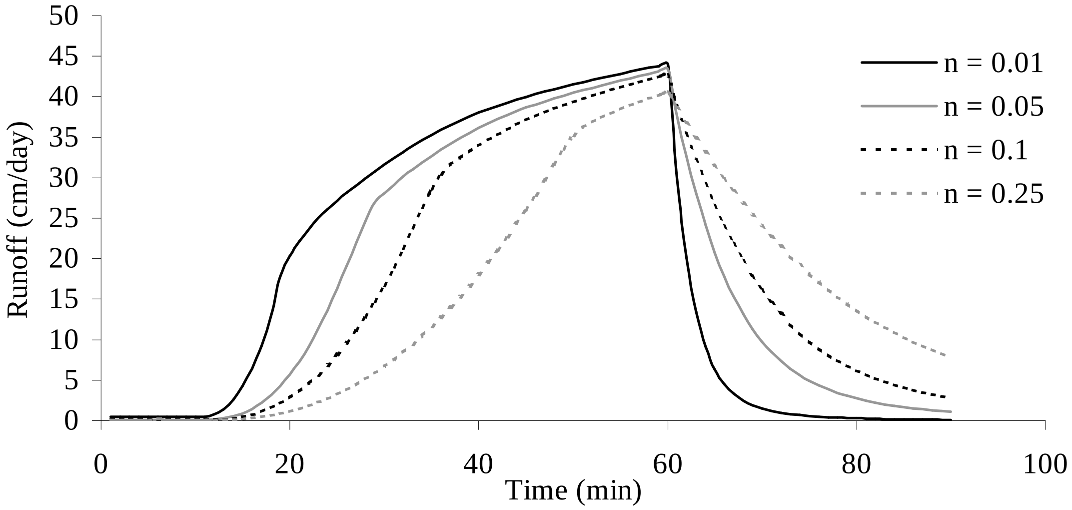

Fig. 6a Variation in runoff rate with change roughness coefficient

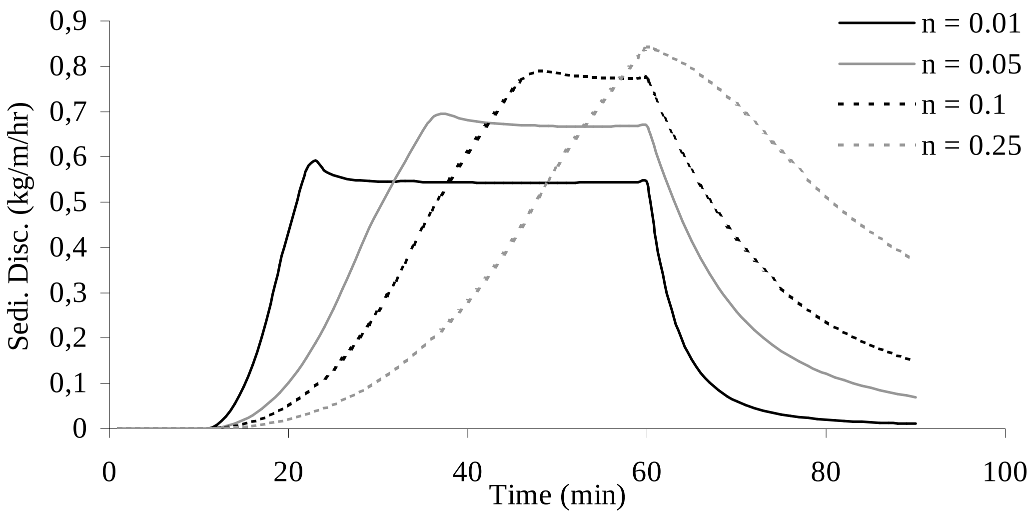

Fig. 6b Variation in sediment discharge with change roughness coefficient

The storm type largely affects the overland and sediment discharge. The two types of storms, delayed and advanced front (Fig 7a and 7b) analysed for their affect on infiltration rate, overland flow and sediment discharge reflect that delayed front storm produces higher peaks and volume of overland flow and sediment discharge. In the advanced front storm, most of the rain gets infiltrated in the soil because of higher initial infiltration rates and there is less overland flow. Since the rainfall intensity decreases with the advancing time, both peak and volume of overland flow and sediment discharge decrease. Whereas in delayed front, the infiltration rate reaches basal infiltration rate during the period when rainfall intensity is low, therefore, with the advancing storm period, both the overland and sediment peak and volume increase.

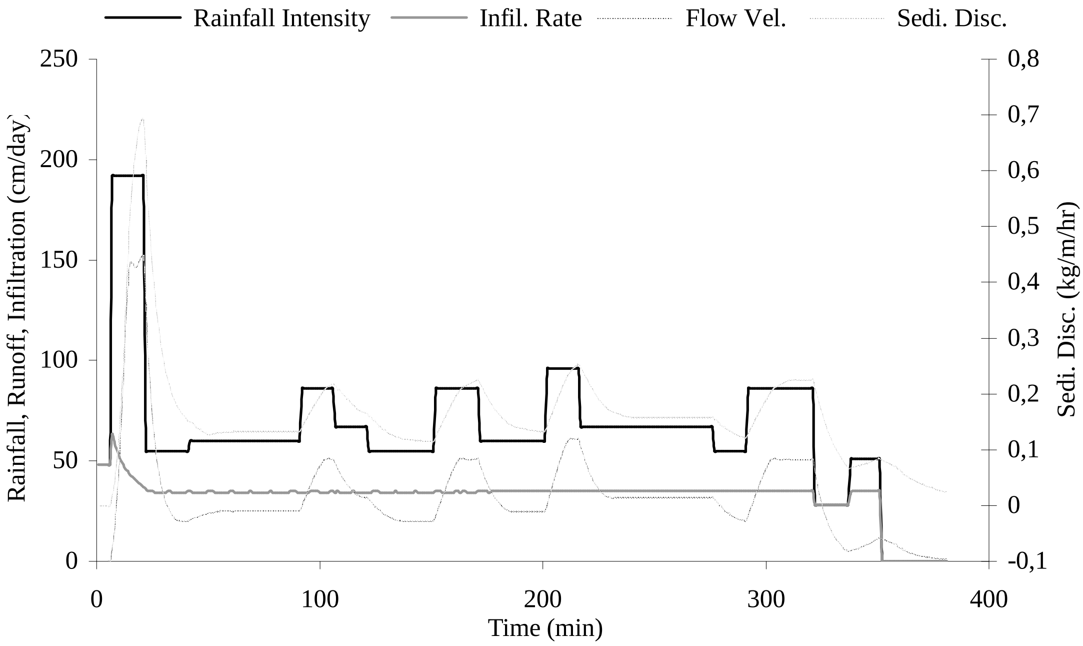

Fig. 7a Rainfall, infiltration, runoff and sediment discharge for advanced front

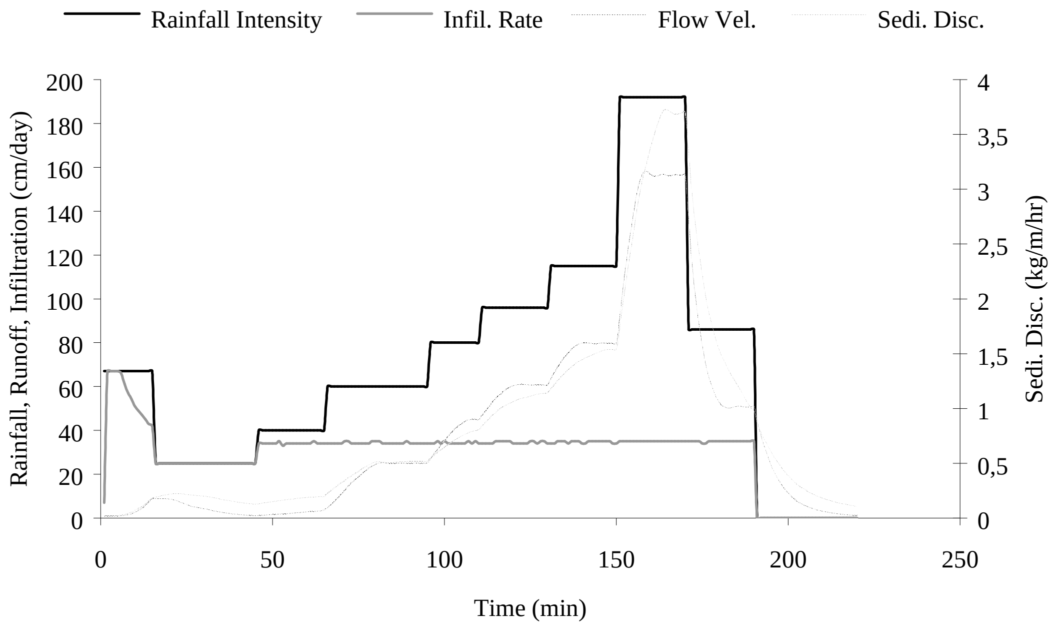

Fig.7b Rainfall, infiltration, runoff and sediment discharge delayed front

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Impact of indiscriminate use of pesticides in a chilli-growing belt

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Abstract

The chilli (*Capsicum annuum* L.) crop occupied an important position in the cropping pattern of the irrigated tracts in Indian province of Rajasthan. In Jodhpur district, the local cultivar *Mathania* of chilli, widely acclaimed for its relatively mild pungency with deep red colour, made it the most coveted commodity among the consumers. Being a cash crop, it received more than its due share of irrigation, fertilizers and growth hormones. The resultant plant growth invited a variety of pests and diseases, inflicting heavy losses. 'Head binding', caused by a complex of mites, jassids and thrips was a feature common to all the chilli cultivating fields, which occupied large acreage in clusters. This necessitated use of pesticides, which worked orderly for some time. Some insecticides imparted lustre to the fruit. Fruit borers warranted preventive sprays, as did vectors of viral diseases in apprehension of their appearance. All the popular and new brands of organophosphates, carbamates and synthetic pyrethroids were tried, with no regard to consumer health. Warnings by a section of scientific community against injudicious use of pesticides went unheeded, as most of the cultivators were illiterate, or occupied by the immediate gains before them. Unscrupulous pesticide vendors, whom peasants relied for advice, made huge profits. With passage of time, pesticides lost their effectiveness. Increased dosages were used to get desired results and interval between two sprays was shortened, followed by combination of more than one insecticide, all adding to the cost of cultivation. Soon the pesticides lost their effectiveness, the pests having developed resistance against them. Chilli cultivation is no more a highly remunerative proposition in this area. The growers now are abandoning its cultivation, a situation created by their own ignorance or neglect or avarice. The area under chilli has constricted considerably since.

Introduction

The chilli (*Capsicum annuum* L.) is an important cash crop of South Asia. It is an essential ingredient of most regional recipes. In addition to its prime use as spice, it is also used in green state as a vegetable either alone or in combination with other vegetables; made into pickles for subsequent consumption and used in the preparation of a variety of edible products. Recently, the demand of chilli has escalated in the wake of introduction of newer products like chilli sauce and others by multi-national corporations (Anonymous 1999). Growing demand inland and overseas made cultivation of chilli highly profitable. A cluster of villages in Jodhpur district of Rajasthan State in India produced a local land race *Mathania* that fetched high price in the market. However, insect pests and diseases inflict great injury to the plants, cutting into profit margins. This led to use of toxic chemicals for protecting the crop from pests. All the popular and new brands of organophosphates, carbamates and synthetic pyrethroids were tried, which worked orderly for some time. Later, the pesticides lost their effectiveness due to development of resistance in the pests.

Genesis of the problem

Being a cash crop, chilli received more than its due share of irrigation, fertilizers and growth hormones. The resultant rich plant growth invited a variety of pests and diseases, inflicting heavy losses. The cultivators resorted to application of pesticides, that being the quickest method of getting rid of the pests. Cultivation of chilli being labour intensive, manual work was often got done by the farm owners through entering into partnership of person(s) providing labour force. Alternatively, the tenancy system followed in this part of the world was that the landowners gave their land for cultivation to a tenant for a definite term for a certain consideration. The tenant was to bear the expense of cultivation and in turn often engaged labour to carry out various field operations. Plant protection operations were left for them to be carried out in the field. The labour engaged was mostly unskilled. The cultivators relied heavily on the advice of pesticide vendors who promoted their sales at the hands of these little literate or mostly ignorant buyers. They used the formulations sold by the vendors as suggested by them.

When a certain dose of chemical proved ineffective, it was increased. Then mixtures of pesticides were used. Interval between two sprays was shortened. Warnings by a section of scientific community against injudicious use of pesticides went unheeded, as most of the cultivators were illiterate, or occupied by the immediate gains before them. Finally, these treatments also lost their effectiveness. It is assumed that the indiscriminate use of pesticides resulted in development of resistance in pests to these chemicals.

Another factor responsible for quick development of resistance in pests against the pesticides was faulty method of application of pesticides. High volume spraying was done mostly with the help of knap sack or foot sprayers. Spray operations were carried out by the labour engaged by the tenants or landowners. These workers were not trained for preparing spray solutions of proper concentrations and for carrying out correct spray operations. The equipment used for spraying was not properly maintained and did not discharge the droplets of minute size. At times the workers let loose the nozzles to finish the spray fluid quickly. Also, nozzles were kept too near the plant surface, letting the spray fluid spill to ground, rather than sticking on the substrate. This led to, in addition to wastage of the spray fluid, in application of sub lethal doses of the applied pesticide, which in turn facilitated quick development of resistance in pests. No systematic studies have so far been conducted about the level of resistance in pests in these areas and as such no data in support are being presented.

Yet another factor contributing to development of resistance was availability of food for the pests all around. Large area was under chilli cultivation in this traditionally chilli growing belt. Not all fields were protected under pesticides at any particular point of time. This provided conditions conducive for the multiplication of the pests in one field and migration to others.

Pests and pesticides

The chilli crop suffers the injury of a number of insect (Table 1) and nematode pests, 'Head binding', caused by a complex of mites, aphids, jassids and thrips is a feature common to all the chilli cultivating fields. The sucked portions remain shrunk while the unaffected portions grow normally, imparting the leaves a curly or uneven shape. The leaves, especially the younger ones, acquire rosette appearance. Affected plants bear fewer flowers and yield is reduced. As a result of feeding activity of these sap sucking pests, the plants are devitalized and remain stunted in growth. Besides, some of these pests also transmit viral diseases in chilli. The initial symptoms of insect injury and viral diseases are often undiscernible. Attack at fruit bearing stage reduces the size of fruit and hence the yield.

Fruit borer damage is quite common in chillies. Affected fruits are rendered unmarketable. Fruit borers also pave the way for fruit rotting, through providing entry point for the fungus. The Jodhpur area being predominantly sandy and arid, termite attack is quite common, especially when interval between irrigation is longer. The crop soon after transplanting suffers the injury of white grubs, the larvae of Scarabaeid beetles, which feed on the growing roots. The root knot disease induced by the nematode *Meloidogyne incognita* in chillies is also a limiting factor in successful cultivation of this crop, as heavy dose of nematicide is required to overcome this problem.

Table 1 Common insect pests on chilli in western Rajasthan

Pest	Injury
Aphis craccivora Koch *Aphis gossypii* Glover *Myzus persicae* Sulz	Devitalize plants by sucking sap, transmit viral diseases
Scirtothrips dorsalis Hood *Thrips tabaci* Lin.	Lacerate plant tissue, lick sap
Polyphagotarsonemus latus (Banks)	Suck sap, deform leaves
Microtermes sp *Odontotermes* sp	Hollow out the roots
Anomala sp *Lachnosterna* sp.	Damage roots
Helicoverpa armigera (Hubner) *Spodoptera exigua* (Hubner)	Bore into pods, stem

The insecticides more commonly used in chilli around Jodhpur have been listed in Table 2. The list however, is not exhaustive, as a large number of brands with different compositions have been in use. As many as 12 sprays or more are applied, the flowering and bearing time included. Little or no attention is normally paid to consequent residues on fruits and waiting periods are not observed strictly, owing mostly to ignorance or to negligence. At times insecticides were used as these imparted lustre to the fruit. Studies on insecticidal residue in/on chilli fruits in the local market (Saxena *et al*; 1990) need to be conducted in this region to know the level of residues on such fruits.

Table 2 Insecticides more commonly used in chillies

Insecticide (alone or in combination)	Used against	Dosages
Acephate	aphids, mites, thrips	0.05-0.75%
Aldicarb*	white grubs, nematodes	0.5 kg a.i.ha^{-1}
Carbaryl	fruit borer	0.1- 0.2%
Carbofuran	white grubs, nematodes, mites, thrips	0.5 kg a.i.ha^{-1}
Carbosulfan	aphids, mites, thrips	0.04%
Chlorpyriphos	termites	3-4 l ha^{-1}
Cypermethrin	jassids, mites, thrips, fruit borer	0.001-0.002%
Dimethoate	aphids, jassids, mites, thrips	0.03%
Malathion	fruit borer	0.1-0.2%
Methyl demeton	aphids, jassids, mites, thrips	0.25%
Monocrotophos	aphids, jassids, mites, thrips	0.04-0.08%
Phorate	white grubs	25 kg ha^{-1}
Phosalone	fruit borer	0.1%
Quinalphos	aphids, jassids, mites, thrips, fruit borer	0.025-0.04%
Triazophos	aphids, jassids, mites, thrips, fruit borer	0.04%

*discontinued later

Current status

There exist opportunities for tapping the growing market of chilli. At the same time limitations exist for increasing the production, largely because of the losses due to pests and diseases. India is the largest producer of chilli in the world. Although its domestic consumption is very high, it still exports chilli to about a hundred countries. There is vast potential to further promote the export, as there is a growing global demand for the product. A large number of varieties and land races exist here. Information about production, acreage and productivity of chillies in respect of Rajasthan State and Jodhpur district in the nineties is presented in Tables 3 and 4 (Anonymous 1997).

The *Mathania* variety cultivated around Jodhpur district in arid zone of north-western India was highly valued for its deep red colour when ripe and powdered, thick pulp and suitability to prepare *Mirchi Bada*, a very popular and famous edible item locally. However, the variety being susceptible to pests and diseases and development of resistance in the wake of indiscriminate use of pesticides, the growers abandoned cultivation of this variety. To cater to the demand of local market, they resorted to other varieties like *Raipur* and others.

Table 3 Chilli production in Rajasthan

Year	Area (ha)	Production (t)	Productivity (q ha^{-1})
1993-94	49,200	46,900	9.53
1994-95	36,500	39,400	10.79
1995-96	38,500	37,200	9.66
1996-97	52,200	58,800	11.26

Thus the area lost one of its prize possession, the *Mathania* variety. The growers now are constrained to abandon its cultivation, a situation created by their own ignorance or neglect or avarice. The area under chilli in the traditional belt has constricted considerably, but chilli cultivation is being undertaken in newer previously unirrigated areas around, where underground water has been tapped recently.

Table 4 Chilli production in Jodhpur district

Year	Area (ha)	Production (q)	Productivity (q ha^{-1})
1991-92	11,973	1,19,230	9.96
1992-93	13,764	1,50,740	10.95
1993-94	13,533	1,21,790	9.00
1994-95	13,240	1,19,160	9.00
1995-96	12,580	1,25,460	9.97

What next

Production of chillies in this belt has been quite rewarding for the cultivators. Having enjoyed good economic returns, there is reluctance to adopt to lesser remunerative crops. However, it will be in greater interest of the cultivators to part with this crop for some time and resort to other crops. Potential exists for production of other crops like castor, *isabgol*, *methi*, coriander etc, which could also be quite rewarding. These crops could be raised with much less quantity of water than required for chillies, thereby providing opportunities to occupy larger area, and thus compensating in part the returns. Cumin cultivation though risky, is far more remunerative. Should they stick to chilli cultivation, other means of crop protection should be adopted and use of chemicals should be minimized.

Alternatives available

In order to strike a balance between the opportunities available for marketing of chilli and the threats posed by the pests, IPM strategies need to be devised. The chemical means was the quickest, effective and least labour intensive. Now that the limitations of this method as a result of abuse of chemicals have come to the fore, it would be prudent to look for the alternatives available, even if these are less effective and comparatively slow acting. Biopesticides offer an effective means for management of some of the pests of chilli. NPV formulations are available for *Heliothis* and *Spodoptera* species (Dhandapani & Jayaraj 1989; Somasekhar et al. 1993). Bacterial formulations could also be used (Mathur et al. 1996). A number of plant extracts have been found effective against the sucking pests (Chandrasekharan & Veeravel 1998, Palaniswamy & Ragini 2000) though the concentrations to be used could be higher and these may have to be used more frequently. For cultivators already applying so many sprays of chemicals on chilli, this may not be any additional burden. The advantage of clean environment and hazard free fruit for consumers will be a bonus. Neem (*Azadirachta indica*) and Tumba (*Citrullus colocynthis*) cakes could be used for the soil pests. Apart from providing protection from pests, these cakes when decomposed serve as manure, supplying nutrients to the crop. Use of natural enemies could be made against some pests (Balasubramanian et al. 1989). Table 5 below presents some alternatives available for chilli crop.

Cultivators recognize the usefulness of marigold to suppress root knots induced by the nematodes and have begun raising this plant in chilli fields. Marigold also fetches them additional income through sale of flowers. Inter cropping with castor has proved beneficial in reducing the level of pest injury to chilli, besides protecting the crop from cold winds during frost. Work on barrier crops in chilli (Nelson & Natarajan, 1994) needs to be undertaken under arid conditions of Jodhpur with locally available vegetation.

Efforts were initiated to develop lines acceptable to the local cultivators who prefer blood red colored and pungent variety. The newly developed variety RCH-1 is becoming popular among the cultivators in areas around Jodhpur, as it has good yield potential besides the coveted qualities. Judicious use of highly toxic chemicals, efforts and co-operation of farmers may help restore the glory of this once famous chilli growing tract.

Table 5 Alternatives to synthetic insecticides for chilli pests

Target pest	Tool
Biopesticides	
Helicoverpa armigera *Spodoptera* spp	Nuclear polyhedrosis virus, *Bacillus thuringiensis* var *kurstaki*
Attractants	
Helicoverpa armigera *Spodoptera* spp	Pheromone traps
Natural enemies	
Polyphagotarsonemus sp	*Amblyseius ovalis*
Helicoverpa armigera	*Campoletis chlorideae, Delta* sp, *Chrysoperla carnea, Trichogramma pretiosum*
Tolerant / Resistant lines	
Aphids and mites	Jwala
Aphids	Pant C-1
Polyphagotarsonemus sp	GPC 77, GPC 80, KDSC 5-3-27, Jwala
Scirtothrips dorsalis	Phule Sai (GCH-8), G-4, ACS-92-4, GPC 77, GPC 80, KDSC 5-3-27
Cucumber mosaic virus	PSP111, Pusa Jwala, K-2, Jawahar Mirch, X 235, Muslawad, MS 13, Bhagyalakshmia, Punjab Lal, Perennial,
Plant Extracts	
Aphids	Garlic extract, Neem extract
Mites	*Adathoda vasica, Vitex negundo, Azarichta indica, Aristilochia bracteata, Lippia nodiflora, Argemone mexicana, Aloe* sp
Thrips	Azadirachtin

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The Stockholm convention on persistent organic pollutants (POPs) and UNEP activities on POPs pesticides

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Abstract

Persistent organic pesticides are part of a larger group of chemicals known as Persistent Organic Pollutants or POPs, which also includes industrial chemicals and unwanted by-products such as dioxins that are formed during incomplete combustion processes. POPs persist for long periods in the environment as they resist, to varying degrees, chemical, biological and photochemical degradation (1). Furthermore, POPs bio-accumulate in fatty tissues due to their lipophilic characteristics, and bio-magnify through the food-chain causing adverse effects to health and the environment as critical concentrations build up in living organisms. During the last two decades much attention has been given to this group of substances at the international level after it became apparent that they are transported through the environment across borders. Individual countries alone are unable to control the environmental pollution from such border crossing substances, and critical concentrations have been reached in some regions even in places where they have never been produced nor used. Negotiations of a global legally binding instrument to reduce and / or eliminate releases of POPs was started under the auspices of UNEP in 1998. In May 2001 over 120 countries agreed and adopted this global treaty, now named the Stockholm Convention on Persistent Organic Pollutants (3). Several other international agreements and activities also address POPs, notably the Regional Convention on Long-Range Transboundary Air Pollution (LRTAP) of the UN Economic Commission for Europe (UNECE) (2), the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) (4) and a number of regional seas agreements.

Persistent organic pesticides under the Stockholm Convention

There are presently twelve POPs covered by the Stockholm Convention of which nine are pesticides. The twelve substances are all chlorinated hydrocarbons and constitute an initial list of POPs, which can be expected to increase in the future since the Convention contains a procedure and criteria for adding new POPs as candidates for international action. The pesticides are: aldrin, camphechlor(toxaphene), chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB) (also an industrial chemical and unwanted by-product) and mirex.

Parties can make proposals for adding new POPs to the Stockholm Convention once it has entered into force, which it does when fifty countries have ratified it. Proposals must contain information for both the chemical and its transformation products relating to the screening criteria that concern persistence, bio-accumulation, potential for long-range environmental transport and adverse effects. A POPs Review Committee will review this and other information received from Parties, and will make recommendations to the Conference of Parties that then decides whether to list the chemical in the Convention.

Pesticides scheduled for elimination and restriction under the Stockholm Convention

All POPs pesticides except DDT, have been scheduled for elimination under the Stockholm Convention, meaning that each Party to the Convention shall eliminate their intentional production and use. There are, however, some uses for which it has proven difficult to immediately switch to alternative chemicals or other approaches.

DDT is scheduled for restriction and its production and use for disease vector control is considered an acceptable purpose under the Convention. Parties can produce and /or use DDT for disease vector control when no locally safe, effective and affordable alternatives are available, but production and use of DDT must be notified in a public DDT Register. Each Party that uses DDT must provide information every three years on amounts and conditions of use and the relevance of its use in their disease management strategy. Parties will also be encouraged to develop an action plan *inter alia* to ensure that DDT use is restricted to disease vector control; and to implement suitable alternative products, methods or strategies, including resistance management strategies to ensure the continued effectiveness of such alternatives. The Conference of Parties in consultation with the World Health Organization will evaluate the continued need for DDT for disease vector control at least every three years. By May 2001 32 countries had indicated the need to use DDT for disease vector control.

For other pesticides, except endrin and camphechlor (toxaphene), and for other uses of DDT, Parties may register for specific exemptions that are identified for each pesticide in Annexes A and B to the Convention. Termite control is the most apparent exemption, which is listed for three pesticides, namely chlordane, heptachlor and mirex. By May 2001 there were 11 countries that had indicated the need for one of these as termiticide. Exemptions also include for chlordane the use as an additive in plywood adhesives and for heptachlor the use in wood treatment, and four countries have made such requests.

The Convention also provides for general exemptions that apply to all intentionally produced POPs including exemptions concerning use for laboratory scale research and reference standards, unintentional trace contaminants in products and articles, and constituents of articles manufactured or already in use before or on the date of entry into force.

In addition to these provisions to eliminate or to restrict the production and use, there are also provisions limiting the trade of intentionally produced POPs to environmentally sound disposal or to Parties that have registered specific exemptions or acceptable purposes. Export to non-Parties can only take place for the same exemptions/ urposes under certain conditions and accountability requirements. Another set of control provisions concern the identification and environmentally sound management of POPs in stockpiles and wastes. Parties must not allow recovery, recycling, reclamation, direct reuse or alternative uses of POPs and must not transport these materials across international boundaries without taking into account international rules (e.g. the Basel Convention).

Parties must further develop strategies for identifying contaminated sites and ensure that remediation is made in an environmentally sound manner. Developing countries and countries with economies in transition will need technical and financial assistance and new and additional financial resources will be provided by developed countries to meet agreed incremental implementation costs. The Global Environment Facility has been identified as the principal entity of the interim financial mechanism to handle funding of capacity building and other related activities. Parties are required to develop plans for implementing the obligations of the treaty and GEF eligible countries can receive support for these and similar enabling activities.

UNEP activities related to POPs pesticides and alternative approaches for pest and vector management

From the above it is obvious that the major issues regarding the elimination of pesticides in the present list of POPs concern the use of DDT for disease vector control, in particular malaria mosquitoes, and the use of chlordane, heptachlor and mirex for control of termites. In efforts to eliminate these, governments should seek alternative approaches that are sustainable. In particular, it will be important to ensure that these pesticides are not simply replaced by other pesticides, but that the principles of integrated pest and vector management (IPM and IVM) are adopted. Several problems are associated with pesticides, e.g. ecological failures, secondary pest infestations, health concerns, and, not the least, the development of resistance in pests and vectors to pesticides. Such problems have led to the promotion of IPM and IVM, which constitute ecologically based control systems that combine different techniques e.g. crop rotation, biological control, environmental management, screening, and as a last resort, pesticides. Such approaches help cut external or indirect costs of pesticides that may be quite high including health effects, environmental damages, loss of biodiversity, and costs for regulation and monitoring. Such integrated approaches will also help preserve the efficacy of pesticides for situations when they are absolutely needed.

It will further be extremely important to ensure that the alternative strategies used will not be compromised by measures in other sectors, as has happened when, for example, resistance has developed in disease vectors where the same or similar insecticides are used in agriculture or, environmental modifications have created breeding grounds for malaria mosquitoes. In its efforts to assist countries find more sustainable solutions to POPs, UNEP jointly with World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO), is promoting close collaboration between sectors in order to identify and implement opportunities that can bring mutual benefits (5). Such solutions must be based on the local conditions and can be best sustained through active community participation. Structures established under one sector such as Farmer Field Schools may, for example, very well serve purposes of public health and the environment. The interrelationship between environment, agriculture and health is hence key for identifying sustainable strategies that effectively and efficiently will protect agriculture from pests, communities from diseases like malaria and ecosystems from persistent pesticides.

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The dynamics of herbicides in the water environment of Uzbekistan

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Abstract

The processes of accumulation, detoxification and degradation of herbicides: propanyl, 3,4-DCA and saturn were investigated in laboratory and field conditions. The laboratory experiments were conducted in simulated microecosystems. The dynamics of herbicides contents was investigated in two rice systems in the field conditions. These systems were located in the Syrdarya and Chirchik River Valley and also in the reservoirs on the Southern part of the Aral Sea. There were absent propanyl and 3,4-DCA in the Syrdarya and Chirchik River waters practically. And, saturn was present in all reservoirs on the Southern part of the Aral Sea. The investigation results allow to suppose that contamination of the Uzbekistan's reservoirs with propanyl and its metabolite 3,4-DCA did not occur. Saturn can be saved in the reservoirs for the long time, therefore it can be transferred in long distances.

Introduction

Rice-growing is one of the most developed agricultural branches in Uzbekistan. The effective development of this branch bases on use of many fertilizers and pesticides. Among of them the herbicides is the most dangerous for the water ecosystems because of its high dozes use and its higher stability in the environment.

The irrigation conditions in a rice field promotes to toxicants transfer into a drainage system with consequent their washout of the rice field limits. Herbicides residues can migrate for long distances with discharge and drainage waters and they accumulate in bed sediments, water plants and biota.

The purpose of our work was the research of accumulation, detoxification and distribution processes in the system of water – water plant and bed sediments in the laboratory and field conditions.

Investigation objects

The analysis of herbicides range and use volumes in rice-growing of Uzbekistan has shown that their average quantity changed from 1.0 up to 18.44 kg/ha. In Tashkent (18.44 kg/ha), Syrdarya (15.1 kg/ha), Surkhandarya (15.1 kg/ha) Provinces and the Republic of Karakalpakstan (14.5 kg/ha) the herbicides were used most intensively, while propanyl use in the most cases.

Saturn is the most toxic herbicide, it more toxic in twice than propanyl, in three times than ordran, 20 times than 2,4-D and 2M-4X, and 500 times than basagran (Shilenko 1981). Moreover, saturn is more persistent substance saved in irrigated soils of rice-growing fields for long time (degradation period is 418 days) (Aleshin & Shilenko 1988).

Methods of investigations

Microecosystems were simulated in laboratory conditions. In this case, the aquariums by volume of 15 cubic decimeters were used. The bed sediments, water plants and water of the Syrdarya River (mineralization in 980 $\mu g/dm^3$, pH=7.8) were put into the aquariums. Natural conditions imitated with artificial lighting and aeration. Water temperature in the aquariums was 21-23°C.

It is well known that the rice irrigation system water contains some quantity of propanyl metabolite-3,4-dichlorineaniline always. Therefore, investigations of this substance degradation processes in the water environment it was interesting. This problem was solved by creation of three model microecosystems: propanyl was added to A aquarium; 3,4-DCA to B aquarium; mixture of propanyl and 3,4-DCA to C aquarium, and saturn was added to D aquarium.

The dynamics of herbicides contents was investigated in two rice systems in the field conditions. These systems were located in the Syrdarya and Chirchik River Valley and also in the reservoirs on the Southern part of the Aral Sea. Samples of water, bed sediments and water plants were sampled and analyzed from the rice fields, discharge and drainage systems, irrigation canals and Syrdarya and Chirchik rivers in summer season May to August, i.e. during irrigation and discharges of water from the rice fields. Thus, we tried to trace herbicides residue migration from the rice fields to the rivers. Determination of herbicides in water, water plants and bed sediments was conducted in accordance to the methods which were developed by Toryanikova et al. (1990, 1992).

Results

The results of longtime multifactor model experiment testified that the semi-decay period of propanyl was 6-10 days in conditions of good insolation, intensive filtration and temperature of 23^{0}C. In general, the processes of propanyl disappeararing from water, water plant and bed sediments has the exponential character (Fig.1). Probably, the actual reaction of propanyl degradation in the water environment is hydrolyze to 3,4-DCA, which is increase and reach of the maximum in 6-10 days. The time of 3,4-DCA disappearing is higher too. The period of semi-decay is 10-20 days in various options of the experiment (see Fig.1). The 3,4-DCA degradation to 3,4-dichorineacetaniline (3,4-DCAA) found during laboratory investigations too. 3,4-DCAA substance identified by gas-liquid chromatography and chromatomass-spectrometry methods.

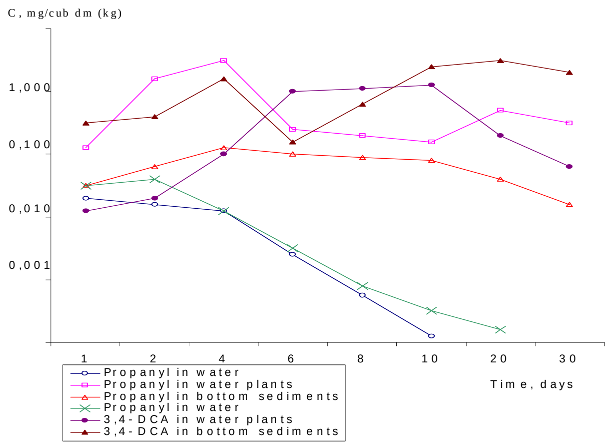

Fig. 1 Propanyl and 3,4-DCA contents in water environment

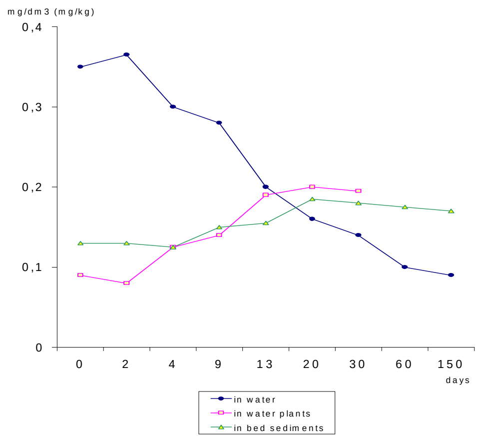

Fig. 2 Saturn dynamic contents in water environment

Saturn is more persistence in model micro-ecosystems conditions. If propanyl and 3,4-DCA are absent in water and water plants to 30-40 days observation practically, then high contents of saturn is observed in water ecosystem after 5 months (Fig.2). Unfortunately, the water plants were not survive even in the lighted and rich with oxygen aquariums not longer than a month. However, indexes of a curve which is indicative of saturn intensive accumulation with water plants, and its identity with a type of herbicide accumulation in bed sediments allow to suppose about saturn high stability in water plants too.

By the field experiment is shown that the propanyl contents has changed from 0.001 up to 0.014 μg/dm^3 for its standard consumption of 6-10 dm^3/ha in water of the rice fields; and 0.5-0.8 μg/kg in bed sediments. As a rule, its metabolite 3,4-DCA contents is higher in 10 times in water and 2-3 times in bed sediments. The saturn contents (its standard consumption of 8-10 dm^3/ha) reached up to 0.03 μg/ dm^3 in water; and 8,5-9,0 μg/kg (maximal contents of 28.8 μg/kg) in bed sediments.

The herbicides contents in discharge and drainage water systems was $C_{propanyl}$ = 0.001-0.009 μg/dm^3; $C_{3,4\text{-}DCA}$ = 0.001-0.08 μg /dm^3; and C_{saturn} = 0.003-0.075 μg /dm^3.

The propanyl contents did not exceed the maximum-permissible concentration in a mouth of a drainage system (Shuruzyak and Myrzachul Main Drain) which is running into the Syrdarya River.

Propanyl and 3,4-DCA did not find out in the water of Syrdarya and Chirchik Rivers practically. Saturn was present in the most reservoirs of the Southern part of the Aral Sea, in bed sediments its contents reached up to 6.5 μg/kg (maximum), average content was 1.25 μg/kg (Figs.1,2,3).

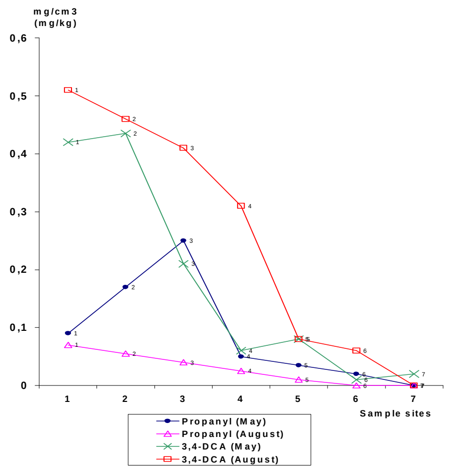

Fig. 3 Propanyl and 3,4-DCA contents in bottom sediments

Propanyl and its metabolite 3,4-DCA contents in the water environment objects of the investigated rice water systems is different. However, the identical tendency of herbicide contents was observed in moving off from the rice fields. Seasonal dynamics of rice herbicides in bed sediments testifies about their maximal contents in summer (Fig.3). As a rule, propanyl and its metabolite 3,4-DCA are absent in early spring and late autumn. Because of high stability, saturn is saved in bed sediments of the reservoirs during an year.

Conclusion

The conducted investigations have allowed to conclude that absolute contamination of the reservoirs with propanyl and its metabolite 3,4-DCA does not occur. Saturn can be saved in the reservoirs for the long time, therefore it can be transferred in long distances.

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Experience ofcommunity IPM in Nepal

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Abstract

Integrated Pest Management (IPM), is a combination of management strategies that farmers use to minimize the impact of pest and diseases on their crop. The emphasis of an IPM farmer field school approach is a sustainable production through the conservation of natural bio-diversity in the field. Nepal started this approach in 1997 and its success with farmers was so immense, that community IPM was introduced in 2000. Farmers developed personal and organizational capacities so they became trainers, planners and researchers to carry out different IPM activities for their communities. Nepalese farmers have become better managers, they have increased their yields, safeguard their health and protect the environment 14000 farmers have gone through farmer field school (40 % are women and 10 % are illiterate).

Introduction

Nepal is an agricultural country and about 81 % of the country's 22 million people depend on the agriculture for subsistence. The share of agriculture in the national GDP is 40 %. Major crops of Nepal are rice, wheat, maize, vegetables, potatoes and fruits. One of the main constraints to increase agricultural production is yield losses due to diseases, insects, pathogens, weeds, nematodes, mites, rodents and birds. An estimate annual yield loss is about 35 % of the total production. To reduce this loss farmers use synthetic pesticides, which are expensive, cause negative environmental consequences and are health hazardous to the growers and consumers. Integrated pest management (IPM) is a priority activity in line with the government's policy for reducing pesticides and increasing food production, food security and sustainable agriculture.

To minimize these economic losses, the farmers themselves are empowered to make their own decisions in applying crop management strategies. These are based on their own analysis of the agro-ecosystem and their knowledge generated by conducting studies in their own field. The farmer's field school (FFS) is a model of a non-formal education process of learning by experiments and discovery and has proven to be very effective. This approach emphasized the need for farmers participating in the farmer field school to understand the rice eco system. The curriculum includes crop physiology, agronomy, identification of natural enemies, pests and diseases, health risks to pesticides and group dynamics. The principle of IPM emphasized in the FFS are; 1. Grow healthy crop, 2.Visit field regularly, 3.Identify and conserve natural enemies and 4.During this process farmers become experts in their field management. Facilitating farmers to understand biological control through field investigation are the key to successful implementation of Integrated Pest Management.

IPM helps farmers to raise their crops yield and increases their income by improve returns on investment. In Nepal program carried out by FAO for Community IPM in Asia, the GCP/RAS/172/NOR has shown that IPM trained farmers increase their rice yield by about 15 to 25 % and reduce the use of pesticides by about 40 %.

Pest management practices and their problems in Nepal

In Nepal, chemical control has been the primary method of pest control in the past since its introduction in 1950s. Pesticides are commonly used to control various economically relevant pests and diseases. The consumption of pesticides per unit area is estimated to be 142 g/ha. Some of the reasons for the increase of consumption of pesticides over the years are:

a. an increase in area and intensity of various vegetables (especially off season)
b. an increase in area under high yielding varieties of rice, for which farmers use high inputs
c. sales promotion activities of pesticide dealers have motivated a large number of farmers to use pesticide indiscriminately without caring for the bad effects on the non-target species and the environment
d. excessive use of pesticides by farmers out of ignorance

At present 255 trade names have been registered in Nepal. In 2000, 108 mt active ingredients pesticides were used. All these are imported. Although pesticide use in Nepal is very low compared to neighbouring countries (India use annually 320 g /ha) the misuse of pesticides has been a problem.

Need for Integrated Pest Management in Nepal

Considering the fact that:

a. Nepal needs to increase its crop productivity in a sustainable way.
b. Pests continue to cause serious crop losses.
c. Use of pesticides is the main method of pest control. Such continued heavy use of chemicals leads to serious environmental and human health problem, pest resurgence, new pest problems, development of resistance.
d. Farmers are often ignorant of pesticide use and need to be educated.

There is a real need for an alternative strategy, IPM therefore is considered to be the alternative strategy.

National IPM Programme

The National IPM Program aims to make integrated pest management in major rice-vegetable growing areas in Nepal and is based on field works and total participation of the farmers and farming communities. The practice of IPM among farmers is achieved through direct training in Season-long Farmers Field Schools (FFSs). Farmers are empowered to make their own decisions in applying crop management strategies based on their own analysis of agro-ecosystem and their knowledge generated by conducting studies in their own field. FFS models of non-formal education process of learning by experiments and discovery has been very effective. As the National IPM Program enters its 4^{th} year of implementation, it now aims at institutionalizing IPM support and activities at the field, district, regional and national levels.

Major thrust are focused on:

A. Core Training Activities

1. Training of IPM Trainers (ToT)

An IPM training of trainers course is a season-long (16–18 weeks) training on IPM for Assistant Plant Protection Officer and Assistant Extension Officers who are responsible for conducting Farmer Field School at the district level.

2. IPM Farmer Field School (FFS)

IPM Farmer Field School is a season-long training on IPM for farmers, facilitated by trained IPM trainers (Assistant Plant Protection Officer APPO). Each FFS comprise of twenty five to thirty farmers.

B. Follow-up Program Activities

1. This activity comprises refresher training to IPM trainers to strengthen technical, management and facilitation skill.
2. Activities aimed to establish IPM communities through farmers' societies, farmers to farmers training, farmers' participatory planning, implementation and farmers' science.

C. Horizontal and Vertical Linkages

Coordinated efforts are made to share the experiences and jointly plan and implement the program. Linkages are made with government institutions (National Agricultural Research Council NARC; Institute of Animal and Agriculture Science IAAS, Commodity Divisions) and NGOs.

D. Focus on Development of IPM in Other Crops

Focus on development of IPM in other crops like potato, vegetable, fruits, tea and cotton is felt.

IPM Activities

Initial activities

- Before Nepal's participation in the Technical Cooperation Project (TCP) 1997 the program interventions were made with a concept of promoting the integrated use of different pest control methods to avoid or minimize pesticide use.
- Program coverage included the use of diseases or pest tolerant varieties, use of biological control of certain economic pests such as fruit flies in citrus and cucurbits, lepidopterous pests in cotton and tomato and wooly aphid in apple and botanical pesticides extracted from plant species such as *Azodiracta indica*, *Acurus calamus*, *Zanthoxylum alatum*.
- These interventions made before 1997 makes it clear that pesticide reduction strategy, guided basically the Nepalese IPM Program rather than application of ecological principles.
- It was the implementation of TCP project in rice in 1997 which brought Nepal into new paradigm of the discovery based, participatory and farmer – based educational process founded on the sound principles of agro-ecosystem analysis by farmers for decision making on pest management strategy promoted through season long Farmer's Field School.

Table 1 Different IPM Activities 1998-1999

Year	Training of trainers for Officers	Number of Field Schools	Number of Farmers Trained
1998	1 / 35	35	875
1999	1 / 35	68	1700
	2 / 70	**103**	**2575**

Current IPM Activities

The current phase of Regional Community IPM Program began in January 2000. The beginning of new millennium is also the start of Community IPM in Nepal. Two year's experience showed that the Rice IPM Farmers Field School is only the beginning, the entry point, for a longer term process while farmers develop the personal and organizational capacities necessary for sustaining agricultural and community development. Activities have started which give focus on:

- *Farmer as IPM Trainers (Farmer ToT, Farmer FFS)*

Farmers have proven to be able and responsible trainers as these farmer trainers gain skill and experience; they become an important resource for their community.

- *Farmers as Planners*

Alumni farmers develop local plan for deepening and disseminating IPM in their communities.

- *Farmers as Researchers*

Farmers master basic scientific principles and learn to design studies and organize local research geared to adverse their specific local problems and conditions.

- *Farmers as Organizers*

Graduates from FFS create forums and local organization for the exchange of information, and for the discussion of study results work plans. Arrange for publication of leaflets, radio program etc.

Three new programs as follow-up activities are introduced:

1. Participatory Planning and Implementation

This is a five session planning activity where FFS graduate farmers participate to do bottom-up planning to solve the agriculture related location-specific problems encountered during conducting FFS. After they have prioritized the activities they plan to implement most in the following season by themselves.

2. Farmer to Farmer FFS

The FFS graduate farmers receive 10 days Training of Trainers so that they themselves can organize and conduct season long FFS for their neighbors and communities with the financial assistance from various sources at the local level.

3. Farmer Studies

Farmers master basic scientific principles and learn to design studies and organize local research geared to address their specific local problem. Farmers develop their scientific attitude and master basic scientific methods. They learn to design, conduct, analyze and interpret their own field research.

All these activities justify the goal of community IPM to institutionalize IPM at the local level by putting farmers in control of the process of planning and implementation of their own IPM Program.

Table 2 Different IPM Activities 2000-2001

Year	ToT / Officers	ToT / Junior Technicians	ToT / Farmers	Number of Field Schools	Number of Farmers Trained
2000			6 / 156	89	2225
2001	1 / 35	1 / 35		206	5150
	1 / 35	**1 / 35**	**6 / 156**	**103**	**7375**

Future Plans and Priorities

Based on the review of the present status of IPM in the country, efforts are be made to sustain IPM in Nepal through governments and NGOs. In the nearby future emphasis will be given to the following activities:

1. improved monitoring of field activities
2. expand the number of farmer trainers
3. strengthening of farmers trainers associations
4. improve and broaden skills of farmer trainers (training, facilitation skills, farmer studies, participatory planning)
5. develop a vegetable IPM Program in the districts
6. strengthen NGO/GO collaboration
7. improve publicity of project activities, raise farmer and consumer awareness
8. increase gender sensitivity among IPM trainers and farmers
9. expand the IPM curriculum with post-harvest exercises
10. strengthening linkages with national scientists and other the institutions involved in research and development of sustainable agriculture,
11. search for ways to secure further funding for the National IPM Program.

2002 and beyond

Although the IPM Program in Nepal has made tremendous progress since its launch in 1997, it is still vulnerable and needs further support in order to sustain the activities. HMG/N will increasingly take over the responsibilities to organise and fund district IPM activities but financial and technical support will be needed for another 4-5 years to come, to:

1. improve the monitoring system
2. strengthen collaboration with NGOs
3. develop farmer trainers skills
4. build up farmers IPM organisations
5. strengthen links with research institutions

Broaden and sustain the IPM approach (different crops, related sectors, institutional development).

Lesson learned

By December 2001, the National IPM Program in Nepal has trained over 121 trainers-of-trainers, and more than 14000 farmers in the main rice growing districts. But so far, high quality replication still remains a challenge. Main point that emerged out of the experience includes:

- Introducing IPM cannot be compared to transfer of technology by experts to non-experts. It requires facilitation of a learning process, and not adoption of a single innovation. This means a paradigm change with respect to extension approach.
- The IPM Farmer Field School is a process, not a body of knowledge. The critical issue in training is discovery learning focused on the ecology of the rice field, which can be learned by observation, if the process is good. This makes the Farmer Field School easy to be replicated.
- Training of IPM trainers requires the same learning process as farmers (season-long, discovery-learning, field based). Learning IPM is directly related to daily farming experiences and problems. It takes time and practice IPM trainers to acquire sufficient knowledge and skills.
- Through their intensive IPM training, assistant plant protection officers became committed to IPM and to the facilitation approach of training. This commitment could sustain because of their position within the structure of the Department of Agriculture. For farmers, season-long IPM training in Field Schools and ten-day training-of-trainers appears to be enough to become good IPM trainers, since commitment and communication skills usually exist among farmer trainers.

- Farmers are considered the best candidates to be the primary IPM trainers for farmers in the future. The IPM Program is then to support farmer-conducted Field Schools with funds and in the future APPOs will no longer able to do the field work which is expanding, but they will be capable to do planning and monitoring of IPM activities at a higher level.
- Several issues of primary concern include maintenance of training quality, institutionalization, and task distribution of government officials or NGO staff who are inevitably involved.

Conclusion

IPM is a program that is particularly suited to poor farmers because it does not require the use of external resources and is compatible with the integrated farming systems associated with poor subsistence farmers. It can increase agricultural productivity, reduce production risks, increase farmer's income, improve their health, protect their environment and over all empower the farmers, therefore it has become a successful and popular program in Nepal.

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Analytical investigations on the fate of pesticides in soils of the Jhikku Khola catchment

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Abstract

Investigations on conventional and integrated pesticide applications and their impact on soil quality were performed at Jhikku Khola catchment. The experimental design was based on laboratory batch experiments for data gathering on degradation and sorption as concentration determining processes for pesticides under defined laboratory conditions. The target compounds malathion, dimethoate, fenvalerate and metalaxyl were applied to khet and bari soil, and batches were incubated at 20°C and 30 C in the dark. Soil samples were adjusted to 15 % moisture corresponding to approximately 40% of maximum water capacity. Further batches were additionally performed under ponding conditions. In most experiments carried out, the disappearance of the pesticides were mainly depending on soil moisture and incubation temperature. The fungicide metalaxyl was found to be the most persistent compound while the organophosphorous insecticide malathion disappeared most rapidly.

Model field studies were carried out at khet and bari investigation sites in order to validate results of the laboratory experiments, as well. On khet land, higher disappearance rates were determined for the target compounds emphasizing the significance of leaching under ponding irrigation. The transport of metalaxyl and dimethoate into deeper soil layers was directly corresponding to their water solubility whereas a transport by preferential flow had to be assumed for the low water soluble fenvalerate.

Introduction

In Nepal as in many other developing countries, the use of pesticides has increased during the last decades to a worrying level leading yield reduction due to resistance, resurgence and secondary pest outbreaks (Baker & Gyawali 1995). Therefore, the joint research project

"Environmental risks of pesticides and sustainable development of integrated pesticide management for mountain areas of developing countries considering socio-economic conditions and taking Middle Mountains, Central Nepal as an example" (IPMS Project) has been established in 1999. One of the main objectives has been the data gathering on Nepalese farming practices and the assessment of their impacts on the environment. The research activities were carried out in the Kabhrepanalchok district approximately 50km east from Kathmandu as an example for an agricultural area with one of the highest pesticide application rates in Nepal (CEAPRED 2000).

Within this project, fate and behaviour of pesticides in soils were investigated by the Institute of Ecological Chemistry and Waste Analysis. According to application amounts and frequencies at bari and khet investigation sites, 4 target compounds were selected: the organophosphorous insecticides malathion and dimethoate, the pyrethroid fenvalerate and the fungicide metalaxyl. Their chemical structures are illustrated in Fig. 1. As to generate a thorough data basis, laboratory batch experiments were performed particularly regarding the dependence of degradation processes on soil inherent moisture and incubation temperature. Consequently, the results of these experiments were validated in field studies with supplementary consideration of leaching processes under ponding conditions.

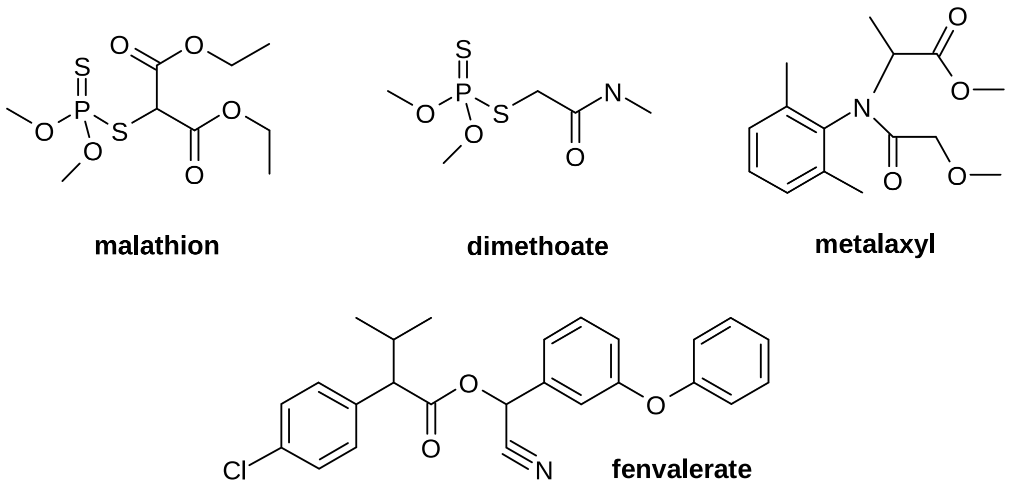

Fig. 1 Chemical structures of the target compounds malathion, dimethoate, metalaxyl and fenvalerate

Experimental design

Laboratory experiments

The laboratory batch experiments were conducted with bari and khet soils concerning rain fed and irrigated land, respectively. Selected physico-chemical properties of both soils are listed in Table 1 indicating only little differences. The first series of batch experiments were performed according to standard degradation experiments at 20 °C and 15 % soil moisture under aerobic conditions in the dark (BBA 1986). Application rates of the target compounds were due to good agricultural practice. Incubation periods were 0, 3, 7, 14, 28, 56 and 102 days. Taking the particular Nepalese climate and cropping systems into account, higher temperature (30°C) and ponding conditions were additionally realized. Supplementary, microbial activity and redox potentials were determined for each batch series.

Table 1 Physico-chemical properties of bari and khet soil

soil	**sand [%]**	**silt [%]**	**clay [%]**	**C_{org} [%]**	**PH**
bari	54	32	13	1	5,0
khet	51	35	14	1	5,3

Field studies

From September 1999 until June 2001, conventional and integrated pesticide applications were monitored at both investigation sites. In order to identify the impact on soil quality, plant protection products containing the 4 target compounds were directly applied to fallow soil surfaces in special model field studies. On bari land, one experiment was carried out after the monsoon season to study the disappearance of the target compounds under rain fed irrigation, only. Samples were taken from the superficial soil layer (0-5 cm) within 17 days after application.

With special respect to the transport of pesticides into deeper soil layers under water ponding conditions, 2 field trials were carried out on khet land, one after the dry season and another after monsoon. Directly after pesticide applications, the field plots were ponded. Ponding height was approximately 10 cm. In the first trial, samples were taken from the 0-5, 5-10, 10-20 and 20-30-cm soil layers. Sampling was conducted 0, 2, 4, 8, 14, 28 and 56 days after the application. In the second trial, sampling activities were focused on 0-5, 5-10, 10-20, 20-30, 30-40 and 40-50-cm soil layers and 0, 5, 7, 13 and 33 day intervals.

Target compound analysis

The analytical procedures followed multimethods usually applied in pesticide analysis (DFG 1991, Steinwandter 1989), which are described in detail by Kreuzig (1998). Field moist soil samples were slurry extracted over night using an acetone/water mixture (2:1). The slurries were subsequently submitted to a liquid/liquid partition with cyclohexane. After phase separation and extract drying, gel permeation chromatographic clean up followed. Finally, the target compounds were determined by gas chromatography using an electron capture and a nitrogen/phosphorous specific detector. Limits of determination were 10 µg/kg dry soil.

Results and discussion

Degradation under standard laboratory conditions

The laboratory batch experiments under aerobic conditions which are predominantly representative for terrestrical topsoils showed different disappearance times of the target compounds applied. In both soils, malathion was found to be the least persistent pesticide under investigation. Fig. 2 illustrates the results for bari soil. Within 14 days after application, residues decreased from approximately 700 µg/kg to 10 µg/kg soil and DT_{50} values calculated were ≤ 2 days. An intermediate persistence was revealed for dimethoate and fenvalerate. DT_{50} were 5 and 16 days. In contrast, the degradation of metalaxyl is characterized by a significant lag phase within 14 days after application. Then, concentrations continuously dropped down from 498 to 177 µg/kg bari soil.

Variation of test conditions

In supplementary batches, incubation temperature was adjusted to 30 °C and ponding conditions were simulated. The disappearance of malathion was again too rapid to show any dependence on the test conditions modified. Therefore, no accumulation under field conditions could be derived from these laboratory tests

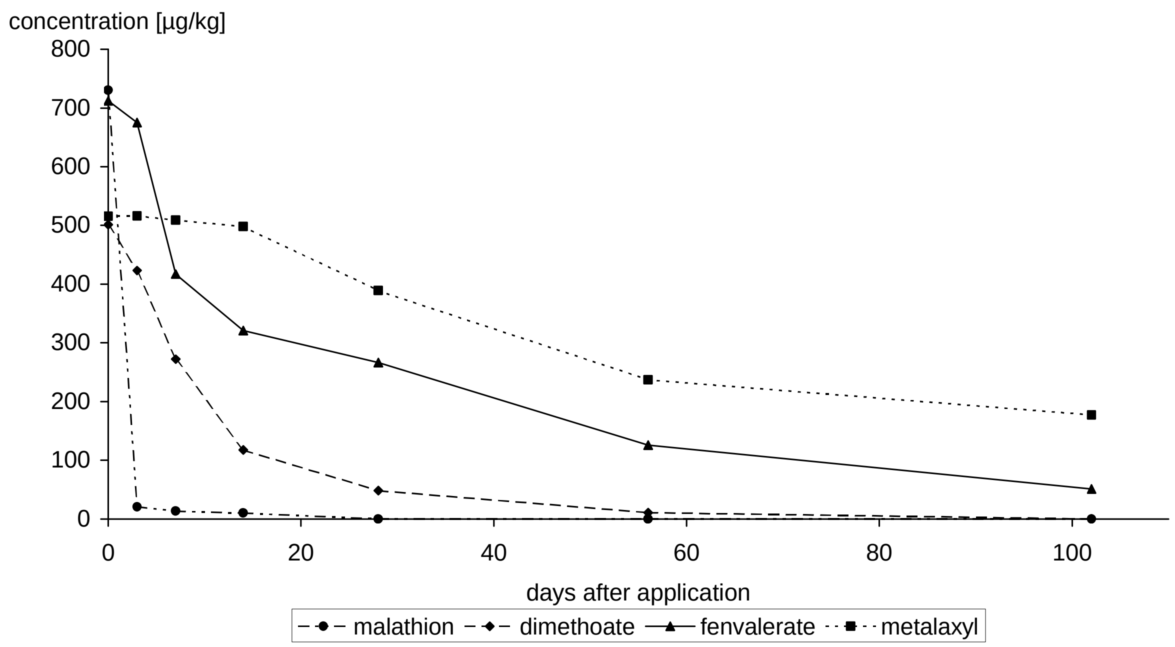

Fig.2 Disappearance of the target compounds in bari soil under standard laboratory conditions at 20°C and 15% soil moisture

In contrast, relevant differences were still determined for dimethoate (Fig. 3). On the one hand, the temperature increase from 20 to 30°C corresponded with a faster degradation due to the enhancement of soil inherent microbial activity. Whereas the residues in the experiment with 15 % moisture and ponding at 20 C decreased from 486 µg/kg to 33 µg/kg and from 720 µg/kg to 48 µg/kg khet soil, respectively, dimethoate disappeared during 28 days in the studies performed at 30°C. Thus, DT_{50} values dropped down from 8 to 2 days at 15% moisture and from 14 to 4 days under ponding conditions. On the other hand, water ponding led to a change from aerobic to anaerobic conditions during a few hours. According to this, dimethoate disappeared slowly.

Particularly under ponding conditions at 20 C, the microbial degradability of fenvalerate is definitely decelerated and a relevant persistence is revealed by the extended lag phase of 48 days (Fig 4). Then, residues disappeared until the end of the incubation period. According to the other batches, differences are not ermerged very clearly and DT_{50} values ranged from 17 to 37 days.

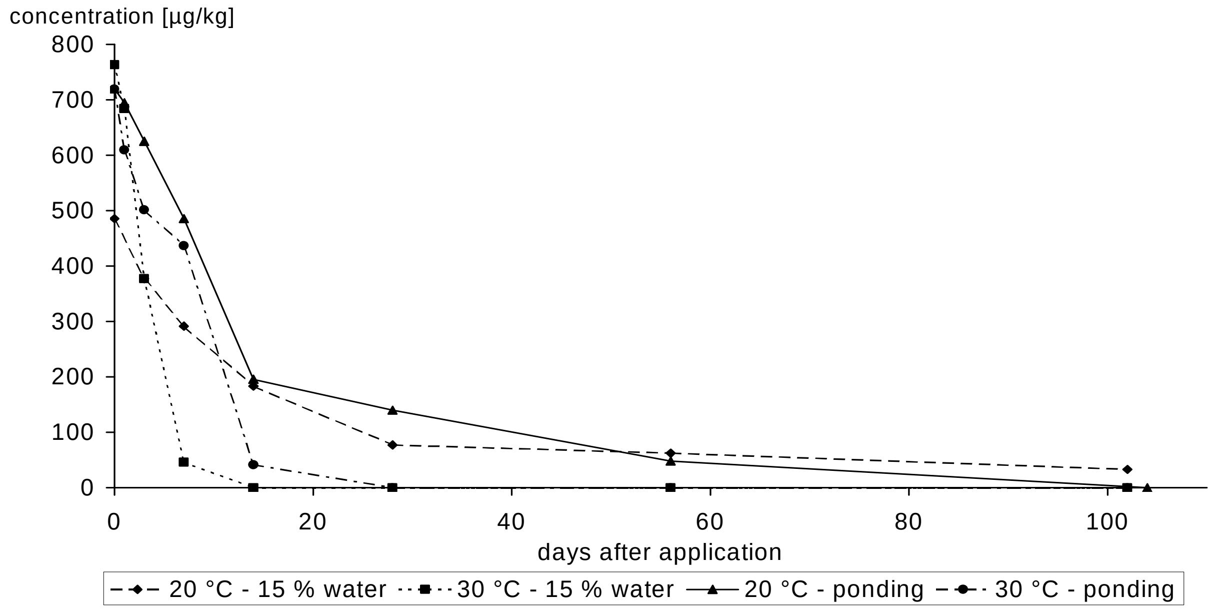

Fig.3 Disappearance of dimethoate in khet soil under laboratory conditions at 20 C and 30 C with 15% soil moisture and water ponding

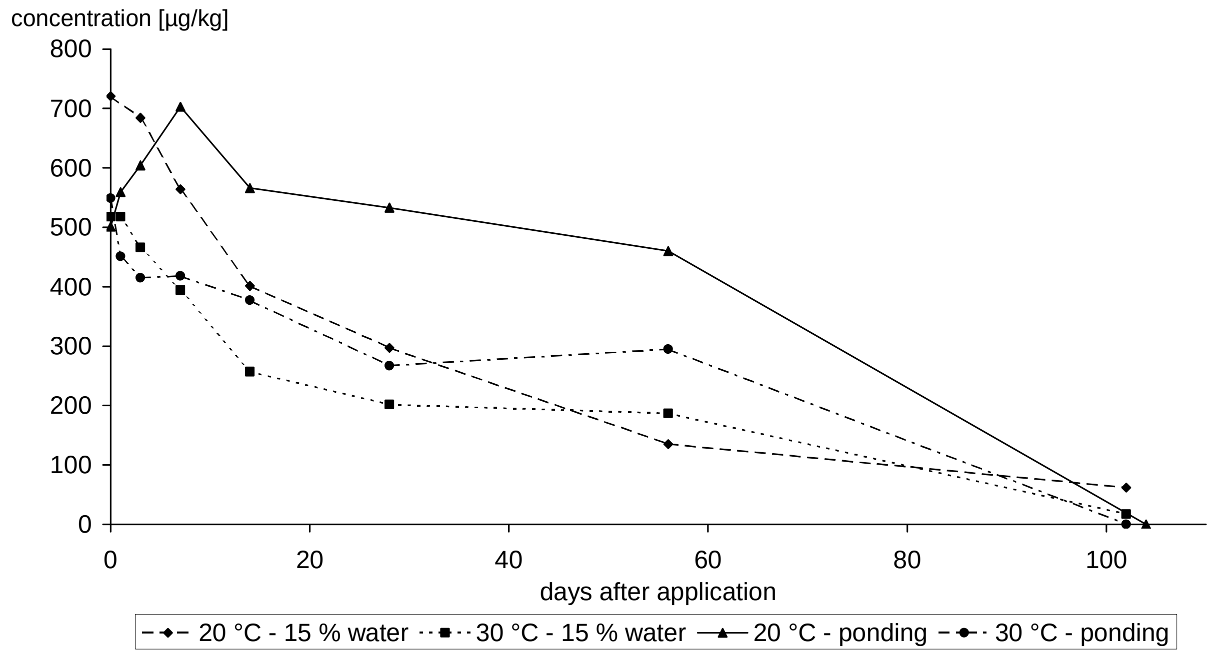

Fig. 4 Disappearance of fenvalerate in khet soil under laboratory conditions at 20 °C and 30 °C with 15 % soil moisture and water ponding

Nearly the same tendency was found for metalaxyl. At 15% soil moisture, this fungicide continuously disappeared and, within 102 days, the residues fell under the determination limit. Under ponding conditions, metalaxyl was identified to be the most persistent compound under investigation although shorter lag phases occurred. Already after 56 days, concentrations were 132 µg/kg at 20°C and 12 µg/kg dry soil at 30°C. Thus, DT_{50} values varied between 8 and 47 days. At the end of the incubation period, no residues were detetectable.

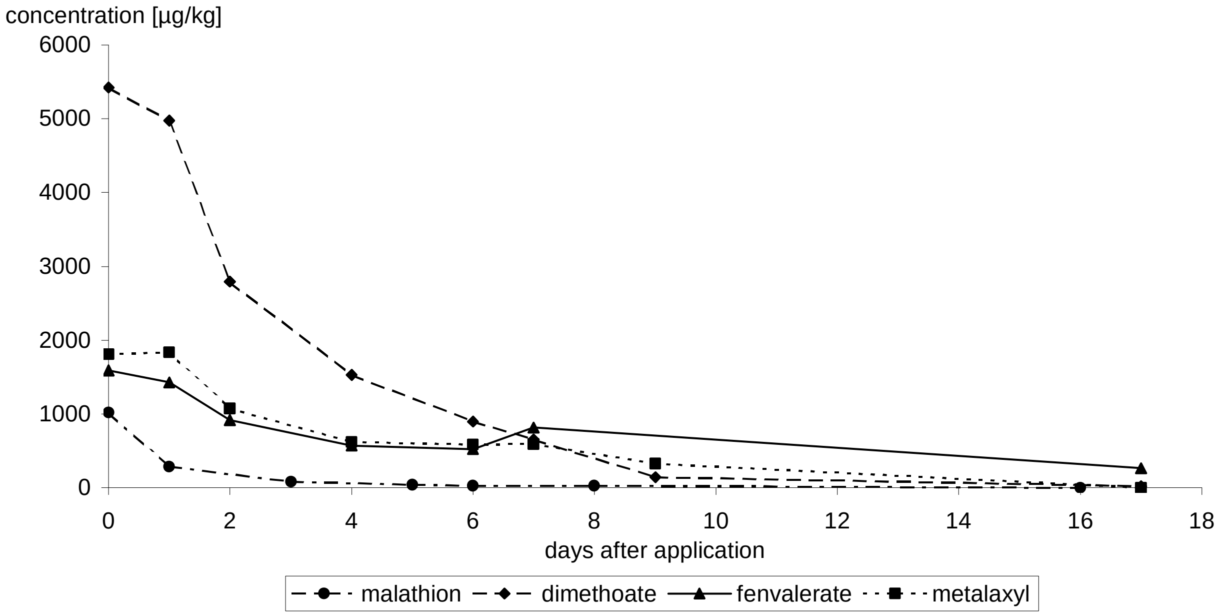

Fig. 5 Disappearance of the target compounds in bari soil under rain fed conditions after monsoon

Degradation under field conditions

Field studies performed at bari and khet investigation sites gave a similar impression on the degradability of the target compounds. As it is examplified in Fig. 5, the concentrations of the pesticides applied on bari dropped down rapidly within 17 days, e.g. the concentration of dimethoate decreased from 5425 µg/kg to 23 µg/kg khet soil. The lag phases were reduced and DT_{50} values listed in Table 2 were definitely below those of the laboratory trials. In total, they met the lower range of the literature data (Perkow 1999, EXTOXNET 2000). Thus, no long-term accumulation in soil is revealed under Nepalese field conditions. In order to transfer results from laboratory to field approaches, varying soil temperatures and moisture contents, differences in the microbial activity and the impact of photochemical processes have to be additionally taken into account for an environmentally relevant risk assessment.

Table 2 DT_{50} values [days] of the target compounds in soils under standard laboratory and field conditions compared to literature data

pesticide	DT_{50} lab khet soil	DT_{50} lab bari soil	DT_{50} field bari soil	DT_{50} literature
malathion	0.2	2	1	1 – 25[1]
dimethoate	8	5	2	4 – 20[1, 2]
fenvalerate	17	16	7	15 – 90[2]
metalaxyl	28	47	4	2 – 56[2]

[1]: Perkow, 1999; [2]:EXTOXNET, 2000

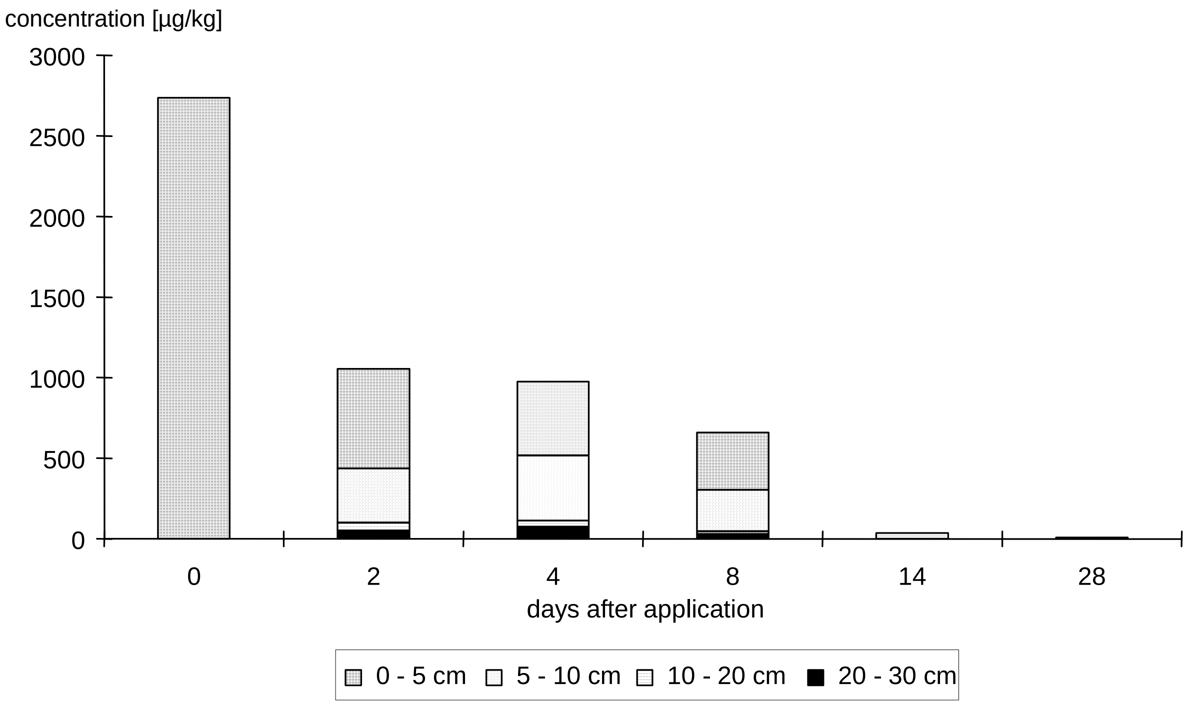

Fig. 6 Degradation and transport of dimethoate in khet soil under ponding irrigation after dry season

Leaching under ponding conditions

Particularly under ponding conditions at khet site, leaching has to be considered as a second concentration determining process for pesticides in soils. The significance of this approach was still confirmed for dimethoate although this insecticide underlay a rapid degradation from 2736 µg/kg to 1055 µg/kg within 2 days after application (Fig. 6). Due to its high polarity and water solubility of 25 g/L, dimethoate was distributed already in the topsoil down to 30 cm. The same situation was given 8 days after application. Subsequently, residues markedly drecreased according to the compound specific degradability. Furthermore, leaching into deeper soil layers could not be excluded.

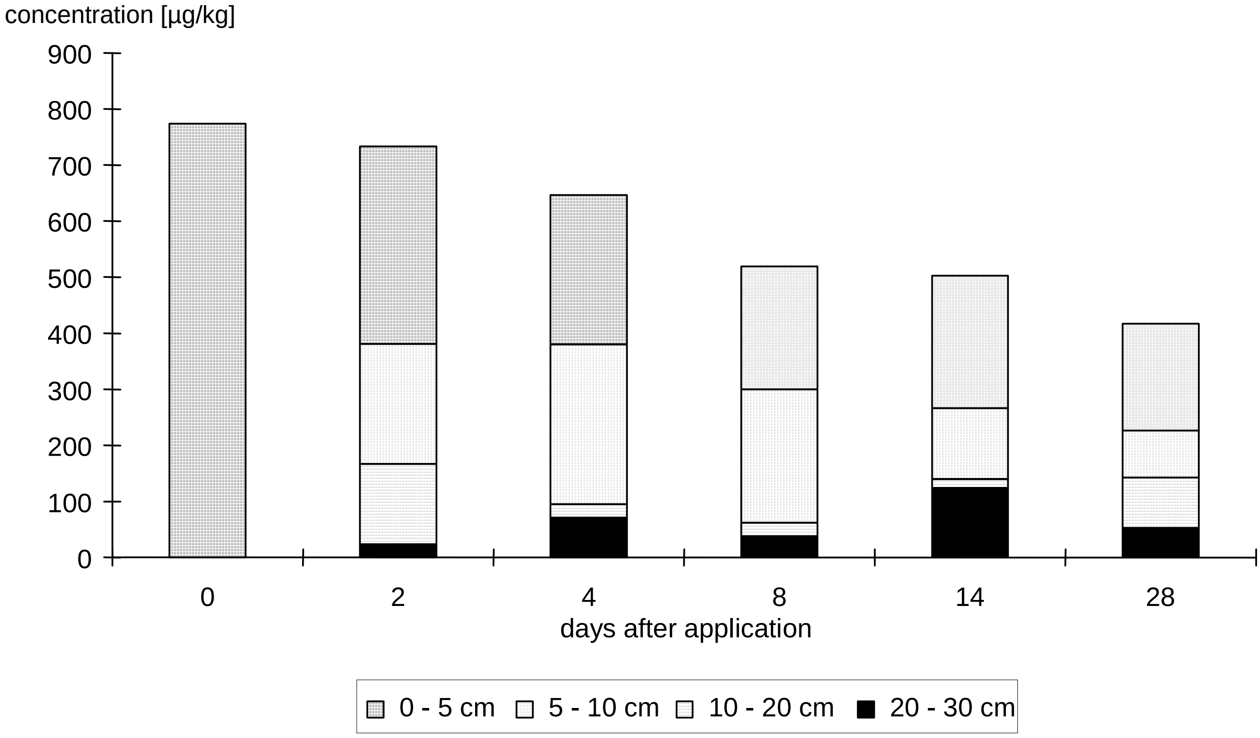

Fig. 7 Degradation and transport of metalaxyl in khet soil under ponding irrigation after dry season

Due to the higher persistence of metalaxyl, leaching tendencies could even be investigated after the dry period in more detail. Directly after the application, residues only were found in the 0-5-cm soil layer (Fig. 7). Here, concentrations of 774 µg/kg continuously decreased to 191 µg/kg within 28 days. In the other soil layers, the distribution consecutively moved on. Due to its water solubility (8 mg/L) and its persistence, highest concentrations occurred in the 20-30-cm layer after 14 days. Due to degradation and leaching into subsoil, residues finally fell under the determination limits. In the next monitoring period after monsoon, sampling was continued down to 50-cm soil depth in order to investigate the transport into deeper soil layers. In this investigation period, however, the disappearance of metalaxyl was highly enhanced (Fig. 8). Thus, only little concentrations of 90 µg/kg and 43 µg/kg dry soil, respectively, were already found in the in the 0-5-cm and 5-10-cm soil layers after 5 days. Contrary to this, the subsoil was not significantly polluted. Therefore, leaching tendencies of the first period could not be confirmed. This special situation may be caused in a water regime changed by the monsoon period from unsaturated to saturated water flow conditions or the formation of preferential water pathways, which are possibly combined with an enhanced microbial activity resulting in higher degradability.

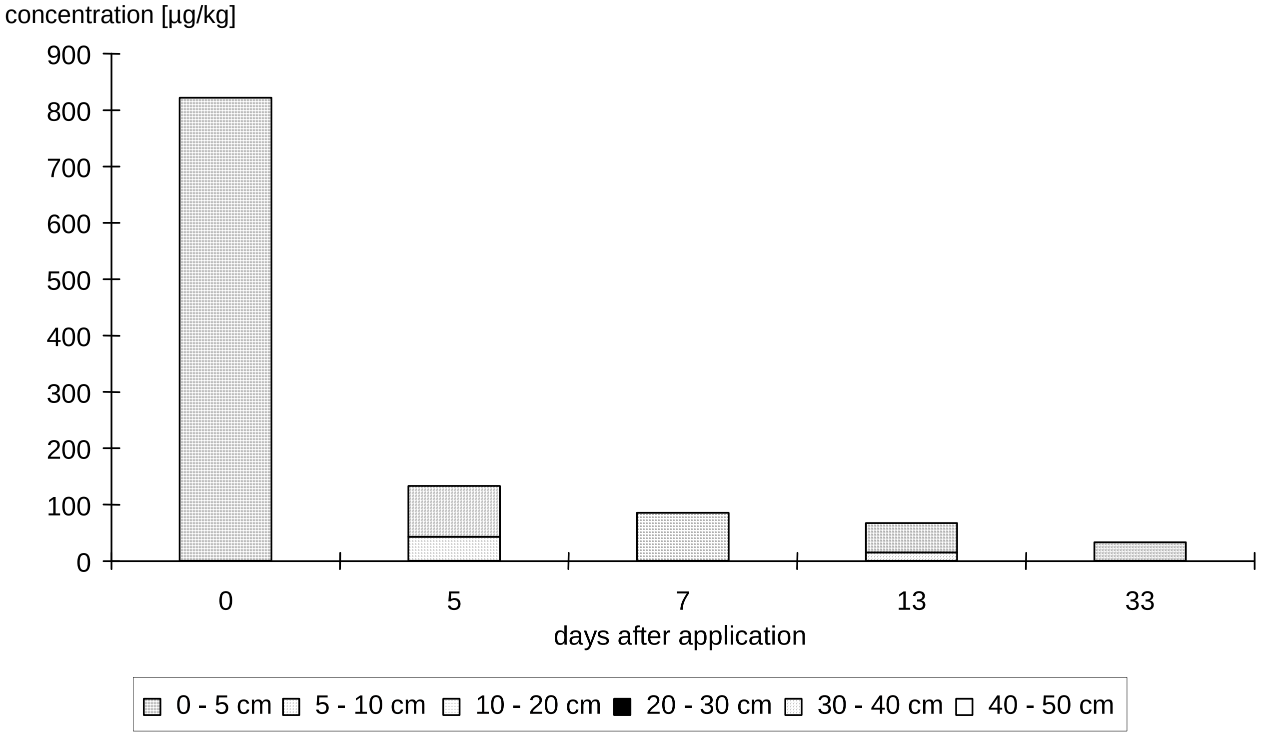

Fig. 8 Degradation and transport of metalaxyl in khet soil under ponding irrigation after monsoon

Conclusion

These research activities on pesticide fate and behaviour in soils emphasized the necessity of investigation site specific monitoring programmes with special respect on climate and cropping system. According to this fact, a multistep control concept have to be applied on the basis of standard and specialised laboratory test systems as well as on long-term field studies in order to establish a pesticide registration procedure in Nepal.

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Conclusions and Recommendations

of the

International Workshop on Environmental Risk Assessment of Pesticides and Integrated Pesticide Management in Developing Countries

Kathmandu, Nepal, 6-9 November 2001

compiled by A. HERRMANN

After three days of presentations and discussion, delegates tackled key issues which had arisen during the workshop. The conclusions and recommendations for improving the utility and effectiveness of future research and extension including education and training were prepared by three working groups. They relate to a number of key issues which were identified during the workshop, and condensed with the following items:

- Pesticide issues
- Environmental issues
- IPM, risk assessment, pesticide regulation

Each item was dealt with by a working group. Based on deficits defined by the working groups and on respective recommendations, a number of general recommendations was concluded, and approved by the workshop participants during the closing plenary session of the workshop. The following compilation comprises the recommendations separately for the three main issues and finally for the whole pesticide topic in general.

With respect to **pesticides** it is recommended:

- To promote the foundation of an independent non-governmental international organisation (similar to ICIMOD) for pesticide education, training and transfer issues taking e.g. care of

  (i) practical education and training of plant protection officers and farmers with special demonstration plots. The cooperation with NGOs, schools and universities (for research) is desirable.
  (ii) existing farmers field schools which should expand in number. Special demonstration sites would support education and training of farmers in proper pesticide application. Teaching experts would get their own education at the institution to be founded.

- To encourage governments to establish liaison institutions for affected ministries and authorities to allow

(i) better coordination of measures with respect to the impact of pesticides for agriculture, consumption, environment and health;
(ii) putting new tax on new pesticides in the market to use the tax income for proper pesticide disposal.

- To encourage governments to ensure

(i) continuity of governmental staff experts on pesticides and IPM;
(ii) to establish two laboratories for (a) pesticide quality and residue analysis, and (b) monitoring purposes which are independent from each other;
(iii) starting international cooperation for knowledge transfer in the fields of residue analysis and concentration limits, e.g. with the EU;
(iv) introduction of licensing pesticide traders, and their punishing for selling banned pesticides;
(v) pesticides being correctly contained and labelled
(vi) safety practices in working with pesticides to be regulated and supervised.

With respect to **environmental issues** it is recommended:

- To promote the ecological awareness to all persons and institutions affected by means of

(i) increasing the level of knowledge of farmers and consumers on pesticides;
(ii) implementing monitoring networks.

- To point out relevant consequences and/or effects of ecological systems on local and regional scales and to promote

(i) interdisciplinary research including medicine, agro-ecology, geo-ecology, hydrology, meteorology/climatology, soil science, socio-economy etc.;
(ii) development of adequate monitoring authorities, systems and networks.

- To develop guidelines for measures of integrated environmental compatibility and sustainability for governmental authorities which consider

(i) sophisticated prognostic models;
(ii) international project-oriented cooperation and technical and scientific knowledge exchange.

With respect to **risk assessment of pesticides, pesticide regulation and Integrated Pesticide Management (IPM)** it is recommended:

- To promote risk perception and awareness of pesticides, risk assessment and risk reduction requiring

(i) knowledge of possible risks at all levels concerned (farmers, traders, extension officers, regulation authorities)
(ii) local infrastructure for residue and exposure analyses
(iii) appropriate techniques (for risk assessment)
(iv) external technical assistance (e.g. laboratory installation and control)

(v) strong pesticide regulation and registration according to risk assessed
(vi) alternative solutions (e.g. IPM)

To build risk assessment capacities by establishing laboratory facilities and knowledge transfer with competent national and international partners and raising efforts for an international harmonisation of pesticide regulation and trade e.g. within SAARC countries including

(i) harmonisation of trade regulations and prohibition of export of banned compounds;
(ii) subsidy cancellation of pesticides and tax harmonisation.

- To put IPM on the priority list of agricultural policies with adequate IPM implementation strategy considering

  (i) governmental and NGO capacity building for education at root level (through e.g. farmers field schools) by staff training through experts and staff expansion;
  (ii) crop pattern regulations by law and subsidies;
  (iii) creating incentives for better adoption of IPM method.

General recommendations

In general it is recommended:

- To improve capacity building (formal and informal) and training on plant protection and the environment for all persons affected (farmers, consumers, traders, experts, extension workers, regulatory people).

- To promote research and combination of knowledge and experience on all scales (village, district, region, nation).

- To establish adequate monitoring and control instances and networks, including laboratory and data processing facilities and modelling techniques.

- To attribute first priority to IPM in all fields of agriculture with all consequences, including policy support.

- To facilitate proper coordination of adequate measures among relevant institutions.

- To promote and survey strict application of international conventions towards pesticide industry to produce more environmentally-friendly products e.g. in line with IPM regulations.

The recommendations shall be broadly disseminated among workshop participants, governmental authorities, extension staff, the scientific community and affected NGOs, INGOs and international governmental bodies.

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