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Use of Geographical Information Systems in Analyzing Large Area Distribution and Dispersal of Rice Insects in South Korea

벼 해충의 분포와 분산의 해석에 있어서 지리정보처리체계의 활용

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ABSTRACT The potential of using GIS in analyzing pest surveillance data was explored. The Spatial Analysis System (SPANS) was used to construct a spatial data base to study pest distributions using pest surveillance data collected from 152 stations in South Korea. The annual spatial distributions of the striped rice borer(SRB), *Chilo suppressalis*, showed that high densities started to expand in the early 1980s, reaching a peak in 1988. The pattern change appears to be related to cultivation of *japonica* and *indica-japonica* hybrid varieties in South Korea. *Japonica* varieties have longer duration resulting in the SRB having more time to mature and hibernate in winter. The locus of SRB spread appears to be located in the mid-west region near Iri, Chun-Buk Province. High brown planthopper (BPH) populations in South Korea are often related to the early immigration and temperature. The simulated distribution of PPH densities in September using these two factors was compared with the actual distribution obtained using 1990 data. The two density maps corresponded closely except for differences in the south eastern valley. By overlaying the simulated map layer with the elevation and rice area maps, more specific BPH risk zones could be identified.

KEY WORDS Geographical Information System (GIS), *Nilaparvata lugens*, *Chilo suppressalis*, modeling, distribution, risk zone

초 록 해충의 발생예찰자료의 분석에 있어서 지리자료처리체계의 활용 가능성을 검토하였다. 전국의 152개 병해충 발생예찰소의 해충 발생자료를 이용하여 해충의지리적 분포정보를 집적하는 "데이터베이스" 체계를 SPANS(Spatial Analysis System)로 구축하였다. 구축된 "지리분포 데이터베이스"로부터 최근 10년간 이화명나방 발생량의 분포변동을 추적한 결과 일반계 품종이 확대 재배되기 시작한 80년대 중반부터 고밀도 분포지가 급속히 확산됨을 볼 수 있었다. 또한 분포의 확산과 수축의 중심은 전북의 이리지역임이 확실하게 나타났다. 벼멸구의 초기(7월초) 비래량의 분포를 비래후 온도조건과 결부시켜 후기(9월중)의 벼멸구 발생위험지역을 예측하는 시뮬레이션 모형을 구성하였다. 모형에 의해 추정된 벼멸구 발생지의 분포도를 1990년 9월의 실재 발생분포도와 비교한 결과 경북 청도지역을 제외하고는 분포양상이 매우 유사하였다. 경사도, 고도, 재배작물 등의 분포도를 추정된 벼멸구 발생도와 함께 투시·분류(Overlay/Modeling)하는 기법을 사용한 결과 서남부지역의 벼멸구 국지적 발생위험지를 구분해 낼 수 있었다.

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Although the temporal dynamics of insect populations take place within a spatial context, population ecology tends to concentrate on the dynamics at single locations (Johnson & Worsbec 1988). Much of the recent attention given to large-scale spatial dynamics of insect populations were related to migration as a factor in synoptic pest studies (Taylor 1986). However, insect distributions and abundances can greatly affected by local conditions.

A recent technology, the Geographical Information System(GIS), for the analysis of geographic variables could be adopted to examine the spatial aspects of population dynamics. Large scale movements and dispersal of insect pests may be investigated. GIS is an information system designed to work with data referenced by spatial or geographic coordinates (Star & Estes 1990). Besides functioning as a database system with specific capabilities for spatially-referenced data, a GIS can be used to work with data.

Geographical information, such as soil type and distribution of varieties, can be stored in the form of spatial map layers. By overlaying these map layers, valuable information such as pest zones or areas prone to pest attacks can be extracted. It is similar to the process of obtaining new information from a classification of stored data in a conventional database. GIS can thus help identify pest risk zones from a classification of spatial information. Subsequent investigations on the ecological basis of why these pests occurred in these areas can be further investigated.

The GIS can improve understanding of spatial dynamics of insect population. Migration of insects and local conditions can be taken into account in understanding large scale movements and dispersal of pests.

This paper explores the potential of applying GIS to rice pest surveillance data. Besides its capability of constructing a spatial database, its use in making pest predictions and for management decisions was also discussed. The data set used in the paper was obtained from the computerized pest surveillance data acquisition system in South Korea.

The authors would like to express their acknowledgment to the pest surveillance personnel, especially Mr. Yun, Ki-Seuk and the other staffs of the Crop Protection Division, Rural Development Administration, for their providing the authors the computerized surveillance data base for this research. This study was conducted at the International Rice Research Institute (IRRI), Philippines, while the senior author was working at the institution as a visiting scientist from 1991 to 1993.

MATERIALS AND METHODS

Computerized Pest Surveillance Data Base

The pest surveillance system in South Korea is organized by the Rural Development Administration (RDA). It currently consists of 152 stations and each uses a field of 0.2*ha*. Three plots, each planted with five major rice varieties grown in the region are maintained in each fields. Insect pest and disease assessments are carries out in two of the pest with the third acting as the control. In addition, a light trap, a spore trap, a areal net trap, and a yellow pan trap are installed in each station(Heong 1989, Lee 1990).

Both field and trap records are obtained by the officer-in-charge. The data sets are entered into microcomputers at each site office using standard data entry screens.

Using a computer network system (DACOM

NET), the data are sent to VAX machine at RDA in Suweon.

Table 1. The three categories of pest surveillance data set in the computerized pest surveillance data acquisition and delivery system in Korea

File name	File size	Collection Frequency	Contents
CALMAIN.MAS	30MB[1]	Daily	Light trap, sport collector & weather data
FLDOBSD.MAS	10MB	Every 10 days	Pest density on the farmers' fields
FLDDATA.MAS	10MB	Every 10 days	Pest density on the pest surveillance fields

[1]MB : Mega Bytes in fixed disk space(1MB is equivalent to one million characters)

At the headquarters, the data sets are processed and stored by the VAX mainframe as a pest surveillance data base. In the data base, three categories of surveillance data sets from the year 1981 up to 1991 (Table 1) were obtained from RDA. CALMAIN which consists of daily trap catches of 20 different pest species as well as 8 meteorological items including temperatures (maximum, minimum, and average), humidity, wind speed, and wind direction, were used for this study.

Preparation of Basic Thematic Map Layers

The SPatia ANalysis System(SPANS, TYDAC Technologies Inc.), a GIS available on microcomputers, was used for the data analysis. SPANS is a raster-based GIS which can overlay several map layers so that information on each layers can be analyzed and the structural relationships between the spatial variables can be identified. Several steps are needed to prepare basic thematic map layers which are essential for building and classifying the spatial database. These include the construction of basic thematic ground map layers, the construction of reclassified map layers, and the importation of topographical layers.

Figure 1 shows some basic maps prepared for South Korea. The county border vector map was manually digitized and the data were imported into SPANS. This translated into a quadtree map. Vector maps are widely used hierarchical data structures as they provide efficient execution time and rapid graphic generations. Quadtrees construct regions by reclusive decomposition, that is, by repeatedly subdividing an area into quadtrees until areas of homogeneous value are attained (Johnson & Worsbec 1988). The quadtree county map can be reclassified based on the characteristics of each county quad. The topographical map of ground elevation was prepared. Since elevation may influences pest abundances, the elevation data was read in quarter kilometer intervals and stored in raster form was imported into SPANS. The data obtained from Dr. B.W. Lee (Seoul National University, Suweon, Korea) is currently available only for Eastern Korea.

From the elevation map layer, a slope map of the ground surface was prepared to estimate rice areas. The slope was calculated from the raster elevation data. By overlaying the elevation and slope map layers, rice areas were identified based on the elevation and slope.

Interpolation of Point Data

To analyze the spatial patterns of pests, point data from surveillance were used to generate pest distribution map layers. The proximity, or potential mapping routine (POTMAP) of SPANS produced a map based on interpolation from the weighted averages of the point data values. The weight applied to the values at distance **d** from the center was calculated by SPANS from the exponential function of:

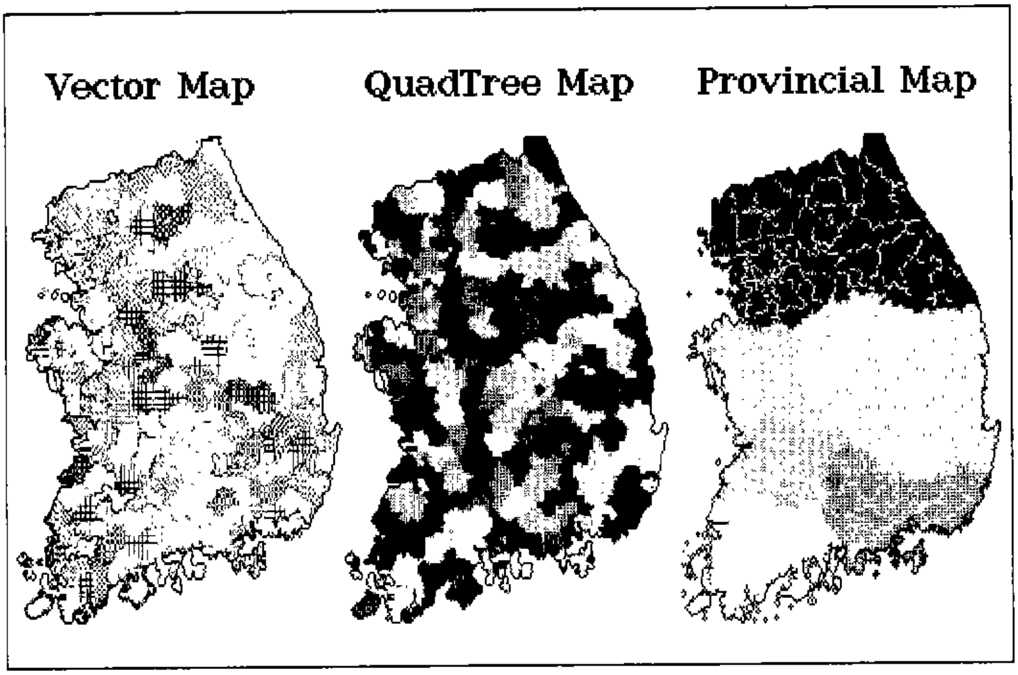

Fig. 1. Some of the basic thematic maps prepared for SPANS analysis in South Korea: A vector map of county borders (left), a quadtree map (middle), and a provincial reclassification map (right).

$$W(d) = n(r-d)/re^{-ad}$$

where **r** is the sampling radius and **d** is the half-weight distance supplied by the user. **a** is a constant, **n** is the number of localities within the sampling circle, and **w(d)** is the weight value at that point.

The thematic pest distribution maps were generated based on this point data interpolation technique. The two insect pests studied were the striped rice borer(*Chilo suppressalis*) and the brown planthopper(*Nilaparvata lugens*).

RESULTS AND DISCUSSION

Changes in *Chilo suppressalis* Distribution in South Korea

The striped rice borer(SRB), *Chilo suppressalis*, was a major insect pest of rice until the mid 1970s. In the early 70s, SRB densities were high, but declined in the mid 70s, and were extremely low in the late 70s (Song *et al.* 1982). Changes in the SRB distribution during the last 10 years (1981~1990) were studied (Fig. 2). Two characteristics are apparent. SRB densities were again high in the 80s, reaching a peak in 1988 followed by a decline. Secondly, the locus of the SRB spread appeared to be located in the mid-west region, near Iri, Chun-Buk Province. This pattern change seemed to be related to changes in cultivars grown (Fig. 3). With the increase in use of *indica-japonica* hybrid in the 1970s, harvesting times were shifted by a month resulting in the SRB having a shorter period to mature and prepare for hibernation in the winter season(Song *et al.* 1982). On the other hand, in the 1980s, the proportion of *japonica* varieties increased from 20 percent of

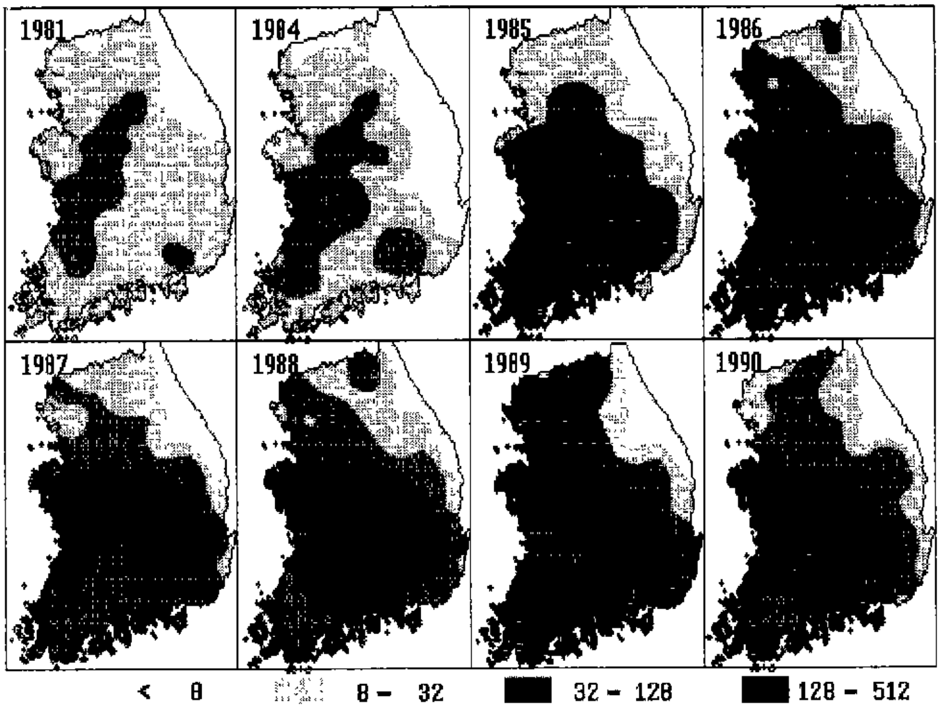

Fig. 2. Annual changes in the striped rice borer, *Chilo suppressalis*, density distribution in the period of 1981 to 1990, based on annual total light trap catches.

the entire rice region in the early 80s to 80 percent in the late 80s. With the *japonica* varieties, harvesting times were delayed thus allowing the borers sufficient time to mature and hibernate in winter.

Changes in Brown Planthopper Distributions in Relation to Immigration Density Patterns and Temperatures.

The brown planthopper(BPH), *Nilaparvata lugens*, can not hibernate in Korea and BPH populations are determined by immigrating population from the South-West (Uhm & Lee 1991). Similar migrations also occur in Japan and this phenomenon is well described by Kisimito (1976, 1987). Thus temperate regions, BPH population starts with low immigration at the beginning of the rice season, followed by rapid increase in the late season (Song & Kim 1988). Thematic maps of BPH distribution (Fig. 4), at different time periods using 10-

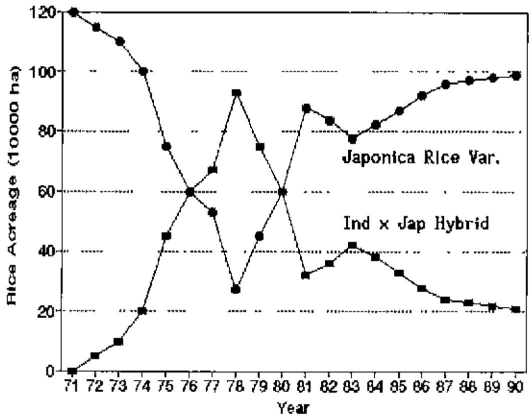

Fig. 3. Changes in the composition of acreage of two major rice variety groups, *japonica* and *indica-japonica* hybrid, grown in Korea in the period of 1970 to 1990.

year average, showed that immigration into the South and South West coastal regions usually occur in late June to July. High BPH densities were also found in late August to September.

The association between early immigration and BPH populations in September is closely related to temperatures. The Overlay/Modelling utility in SPANS was used to simulate the distribution of BPH densities in September from immigration data from late June and the corresponding temperatures. The BPH densities in September expressed as a function of early BPH immigration and temperature. The SPANS model developed is given below.

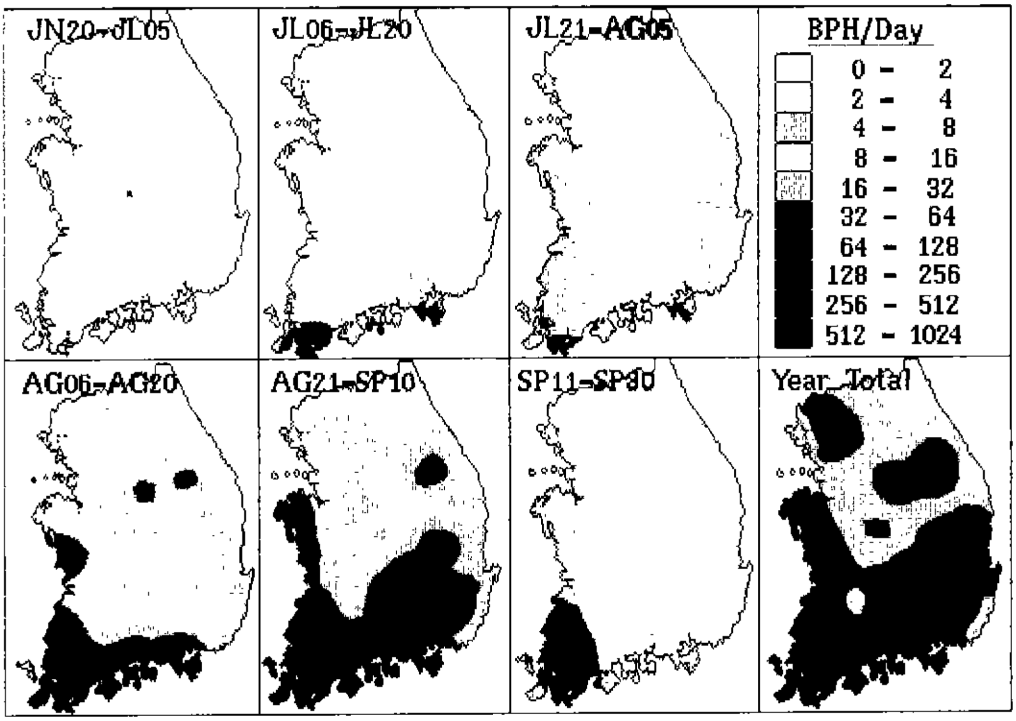

Fig. 4. The temporal changes in the distribution of brwon planthopper, *Nilaparvata lugens*, density in the different time periods, based on the average light trap data for the period of 1981 to 1990.

```
E bphmdl BPHModel=Estimate the BPH
  occurrence in September
: with Immigration in period_1(late June)
: without adjustment of elevation effects
: bp1=Immigrant Population in Period_1
                              (Jun21-Jul10)
bp1=[bp90p1];
: bp2=Immigrant Population in Period_2
                              (Jul11-Jul31)
bp2=[bp90p2];
: bp3=Immigrant Population in Period_3
                              (Aug01-Aug20)
bp3=[bp90p3];
: bp4=Immigrant Population in Period_4
                              (Aug21-Sep10)
bp4=[bp90p4];
: tp1=Temperature Conditions in Period_1
                              (Jun21-Jul10)
tp1=[tm90p1];
: tp2=Temperature Conditions in Period_2
                              (Jun11-Jul31)
tp2=[tm90p2];
```

```
: tp3=Temperature Conditions in Period_3
                                (Aug01-Aug20)
tp3=[tm90p3];
: tp4=Temperature Conditions in Period_4
                                (Aug21-Sep10)
tp4=[tm90p4];
: tp5=Temperature Conditions in Period_5
                                (Sep10-Sep30)
tp5=[tm90p5];
:
: el=Elevation
: el=[elev];
: el=0 for now (No elevation encounted)
  el=0;
:
: r?=Rate of population increase per gene-
  ration in the period_?
: Suppose the rate of increase is depend on
  rice stage (Uhm & Lee 1991)
  r1=90;
  r2=90;
  r3=50;
  r4=50;
  r5=50;
:
: bt=Base(threshold) temperature
  bt=10;
:
: ct=Degree-Day(above threshold) to
      finish one generation of BPH
  ct=400;
:
: pd=The total number of days in one
      period
  pd=20;
:
: cp?=Accumulated degree-days
  cp1=(tp1-el-bt+10)*pd;
  cp2=(tp2-el-bt+10)*pd;
  cp3=(tp3-el-bt+10)*pd;
  cp4=(tp4-el-bt+10)*pd;
  cp5=(tp5-el-bt+10)*pd;
:
: ng?=Number of generation BPH could
       reproduce after immigration
: tr?=Toral rate of increase untill period_
       5 after immigration in period_?
  tr1=pow(r1,cp1/2/ct)*pow(r2,cp2/ct)
       *pow(r3, cp3/ct)*pow(r4, cp4/
       ct)*pow(r5,cp5/2/ct);
  tr2=pow(r2,cp2/2/ct)*pow(r3,cp3/ct)
       *pow(r4,cp4/ct)*pow(r5,cp5/2/
       ct);
  tr3=pow(r3,cp3/2/ct)*pow(r4,cp4/ct)
       *pow(r5,cp5/2/ct);
  tr4=pow(r4,cp4/2/ct)*pow(r5,cp5/2/
       ct);
  tr5=1;
:
: bph?=Estimated BPH density from im-
         migration up to period?
  bph1=pow(2,bp1-5)*tr1;
  bph2=bph1+pow(2,bp2-5)*tr2;
  bph3=bph2+pow(2,bp3-5)*tr3;
  bph4=bph3+pow(2,bp4-5)*tr4;
  bph5=bph4+pow(2,bp5-5)*tr5;
:
: fa=Flying activity as a function of tem-
      perature in Period_5.
  fp=max(tp5-5)/10,0);
  fa=min(fb,1);
:
: The result of simulation
  (bph1)
```

Fig. 5 shows the comparison of actual BPH trap catches in September 1990 and the simulated and smoothed map. The two density maps corresponded closely except for differences in the South Eastern valley.

Changes were made on the temperature map layers by correcting for elevation. The rice area map was overlayed on top of the density map to eliminate non rice areas, which resulted in a more area-specific BPH distribution map. Figure 6 shows an enlarged map of the South-West region where BPH is often the major problem. The model displayed BPH risk areas more precisely. Further ground validation with actual field density records are needed to determine the accuracy.

Spatial distribution data have traditionally been presented in map form. With the diverse categories of information, such as soil types, temperature ranges, varieties, elevation and land use, it becomes cumbersome to handle the data and maps. Relationships between variables are also difficult to analyze. Recent advances in computer technology and developments in Geographical Information Systems(GIS) provide a powerful way of analyzing spatial data.

Computer maps have been used to display the spatial dimension of insect populations. In England, mapping techniques were used to analyze areal suction trap data of aphids to indicate areas in which crops were at risk. A computer program SURFACE-II, capable of performing difference mapping, was used for these purposes. A microcomputer based mapping program for rice pest distributions was first developed in Korea (Song *et. al.* 1982) and this was further modified at IRRI for general use. However, these systems could only display pest distribution and were not capable of analyzing data.

The GIS enables researchers to generate insect distribution maps from point data through the interpolation algorithm. A time series of such maps may be used to indicate distribution changes. Furthermore, the modelling module in the GIS allows researchers to construct predic-

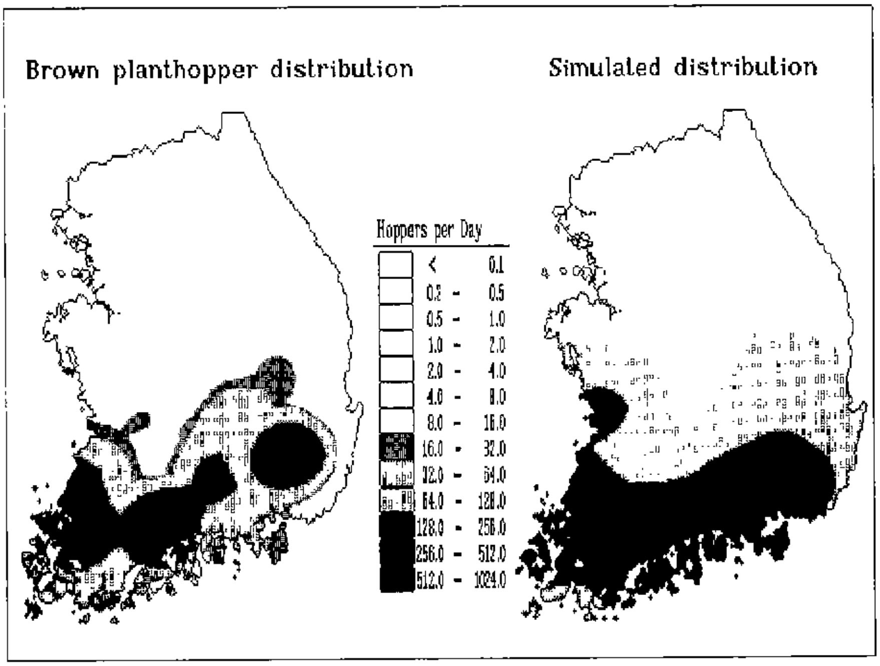

Fig. 5. The comparison of the actual density of brown planthopper in September 1990(left) and the simulated density(right).

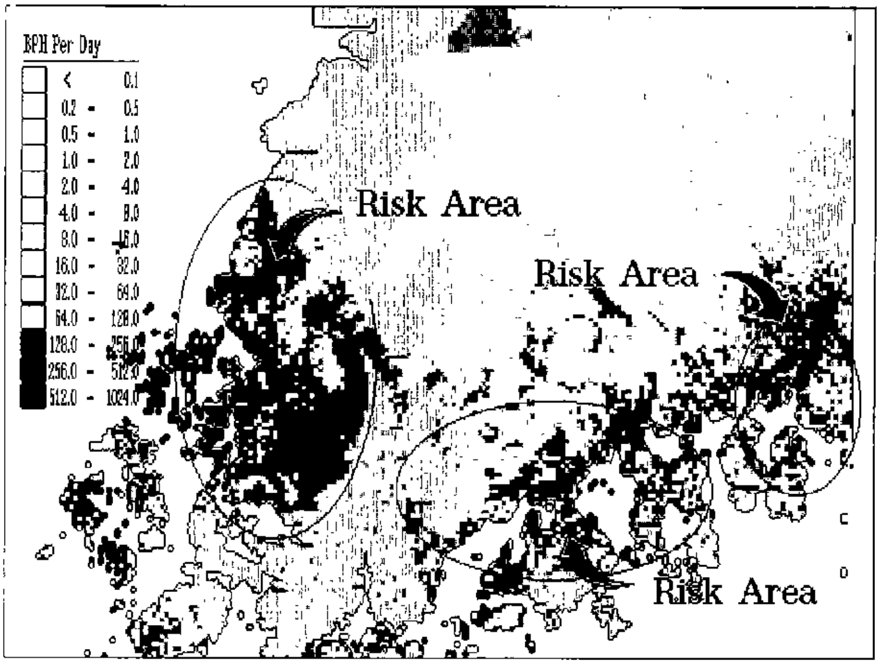

Fig. 6. The identified risk zones of brown planthopper in the South-Eastern coastal region of Korea.

tions. These may be used to indicate the risk zones. In the case of South Korea, where BPH populations are highly dependent on initial immigration and temperatures, risk zone identification is a useful pest management tool. In addition, further research to reveal factors contributing to high pest densities in these areas, may be designed. Using this approach, Johnson and Worsback(1988) revealed that geographic abundance was more related to soil type than other factors.

Many rice growing country in Asia has pest surveillance progrms(Heong 1988). Large volumes of such data are collected annually. Often such data are presented in summary tables. The GIS may be used to generate historical information on both temporal and spatial spread of pests. Spatial modelling may also be used to develop forecast models.

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