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# Spatial pattern analysis of weeds in selected rice fields of Samarahan, Sarawak

(Analisis corak spatial rumpai di beberapa lapangan padi di Samarahan, Sarawak)

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Key words: rice field weeds, dispersion analysis, mean crowding, aggregation

**Abstrak**
Kajiselidik telah dijalankan di Bahagian Samarahan, Sarawak pada tahun 1990–1991 untuk mengenal pasti rumpai yang ada di lapangan padi. Corak spesies rumpai di dalam ruang lima kuadrat yang berukuran 1 $m^2$ di setiap 87 bendang/padi huma telah dianalisiskan. Tiga indeks perselerakan (nisbah varians kepada purata, purata kerumunan Lloyd dan pertompokan Lloyd) dan statistik *I* Moran bagi autokorelasi ruang juga telah dikira. Hampir semua spesies terdiri daripada spesies yang tumbuh setahun sekali dengan *Fimbristylis miliacea* dan 30 spesies utama yang lain paling menonjol. Spesies ini menunjukkan taburan yang berkelompok dengan nilai purata kerumunan Lloyd berjulat antara 0.738 bagi *Fuirena umbellata* dengan 21.933 untuk *Fimbristylis miliacea.* Nilai autokorelasi ruang yang berdasarkan statistik *I* Moran adalah positif dan secara ketara melebihi E ($I$) pada $p$ = 0.05 bagi 17 spesies. Keadaan ini menandakan corak pertompokan atau berkelompokan. Darjah pertompokan bagi spesies-spesies tersebut amatlah tidak menentu dan ini menunjukkan taburan tumbuh-tumbuhan itu mungkin dipengaruhi oleh faktor-faktor biologi atau agroiklim.

**Abstract**
Exploratory surveys were conducted in Samarahan Division, Sarawak in 1990–1991 to ascertain common weeds prevailing in rice fields. Spatial pattern of weed species in five 1 $m^2$ quadrats in each 87 farms were analysed. Three indices of dispersion (variance-to-mean ratio, Lloyd's mean crowding and Lloyd's patchiness) and the Moran's *I* statistics of spatial autocorrelation were calculated. Weed species were almost exclusively composed of annuals, dominated by *Fimbristylis miliacea* and 30 other principal species. These species exhibited aggregated distributions with Lloyd's mean crowding values ranging from 0.738 for *Fuirena umbellata* to 21.933 for *Fimbristylis miliacea.* Spatial autocorrelation values based on Moran's *I* statistics were found to be positive and significantly greater than E($I$) at $p$ = 0.05 for 17 species, thus suggesting aggregation or patchiness. The degree of clustering for those species were highly irregular indicating that plants distribution is probably due to biological or agroclimatic factors.

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## Introduction

Plant populations in general or weed populations in particular are always in the state of continuous numerical fluxes. These fluxes, arguably, are an inherent manifestation of the temporal and spatial heterogeneities of the environment in which plant populations prevail. Further, it is these numerical fluxes in population *inter alia* that may help to explain their spatial distribution so as to show pattern, regularity or randomness (*sensu* Greig-Smith 1983). The recruitment of new individuals from the seed bank, the latter in itself, varies in population size according to tillage, herbicide application regimes, cropping systems and other agro-technical factors, may have determining effects on the composition and patterns of weed vegetation within the community (Cavers and Benoit 1989; Cardina et al. 1991; Dessaint et al. 1991; Teasdale et al. 1991; Mohler and Calloway 1992; O'Connor and Pickett 1992).

Numerous studies have been conducted to describe the size and distribution of weeds in rice fields in Malaysia (Baki 1982a, b; Baki and Mohd. Khir 1983; Azmi et al. 1992). These studies, however, were not tailored to highlight the numerical fluxes in weed species and populations prevailing in rice fields. Further, the quantitative study of weed populations raises the question of sampling (van Groenendael 1988; Benoit et al. 1989; Chauvel et al. 1989; Dessaint et al. 1991).

The central problem with many weed population studies is the imprecise estimates of plant numbers over a unit area as these plants have patchy or clustered patterns. This problem is further compounded in populations where plants exhibit both *guerilla* and *phalanx* growth habits (*sensu* Harper 1977). In such a situation, delineation of a *genet* or *ramet* so as to constitute a *physiologic individual* is difficult, if not impossible. Arguably, understanding the spatial distribution of weeds is essential for formulating efficient sampling plans for designing and interpreting field experiments. Aggregated spatial distribution affects the accuracy of population density measurements because intense clustering of individuals induces high sampling variances. A second problem surfaced with the fundamental assumption of the independence of observations in classical inferential statistical analysis (Dessaint et al. 1991). The existence of a spatial structure of the observations suggests that this assumption is not satisfied and makes such tests like ANOVA, *F*-tests, *t*-tests, and correlation analysis too liberal (Lagende and Fortin 1989).

The general consensus is that rice weeds have clustered distribution. Previous work related to the spatial pattern of weeds have concerned primarily with indices such as summed dominance ratio (SDR), importance value (IV) or frequency of distribution of weed species *per se.* Concern for the frequency of weed (species) sample counts such as the negative binomial distribution or Poisson and Normal distributions in the management of weed surveys data in rice have not surfaced. Further, analysis of frequency distribution indicates only whether weed species population counts have clustered spatial distribution, or otherwise but offers little information on the scale and nature of clustering.

Indices of non-randomness in spatial distribution of an organism can be estimated based on the mean and variance of population counts per sampling unit. Numerous indices are used, namely, variance-to-mean ratio, Morisita's index, and Lloyd's mean crowding and patchiness. By employing Iwao's (1968) relationship between Lloyd's mean crowding and mean density, Bigwood and Inouye (1968) carried out an analysis on the spatial distribution of the seed banks.

It appears that these measures of pattern intensity focus on the variance and not on the spatial location of variate values and, thus, result in the loss of information. Dessaint et al. (1991) suggested a third approach based on the weighted Moran's *I* index of autocorrelation as a method which detects clusters by examining the change that occurs in the degree of correlation between paired density measurements of two physical locations in question.

This paper reports results from a study carried out on rice weeds in Samarahan, Sarawak. Emphasis is placed on the spatial pattern of principal species present in the fields surveyed.

**Materials and methods**

Exploratory field surveys of 87 padi farms in the Samarahan Division, Sarawak *(Figure 1)* were conducted between October 1990 and September 1991 to enlist the most common and prevalent weeds associated with padi production following the methodology of Thomas (1985). Five 1 $m^2$ quadrats were placed in each farm. The distance between each quadrat depended upon the size and shape of the farm. Species entity and density of each weed species in each quadrat were recorded. The data were collated and summarized using the quantitative measures as outlined by Thomas (1985). These quantitative measures were: frequency, farms uniformity, density over all farms, density occurrence farms and relative abundance. Speciation of the weeds follows the nomenclature of Soerjani et al. (1987). Species composition data were used to calculate indices of species diversity and heterogeneity. For such purposes, Shanon-Weiner heterogeneity functions (SW) and Simpson's diversity index (SD) (Krebs 1978) were calculated.

The mean (*m*) and variances (*V*) of weed plants per quadrat were calculated for each species. With these statistics, three indices of dispersion were calculated: the variance-to-mean ratio, the Lloyd's mean crowding and Lloyd's patchiness (Lloyd 1967). The variance-to-mean ratio was tested for deviation from unity. Values

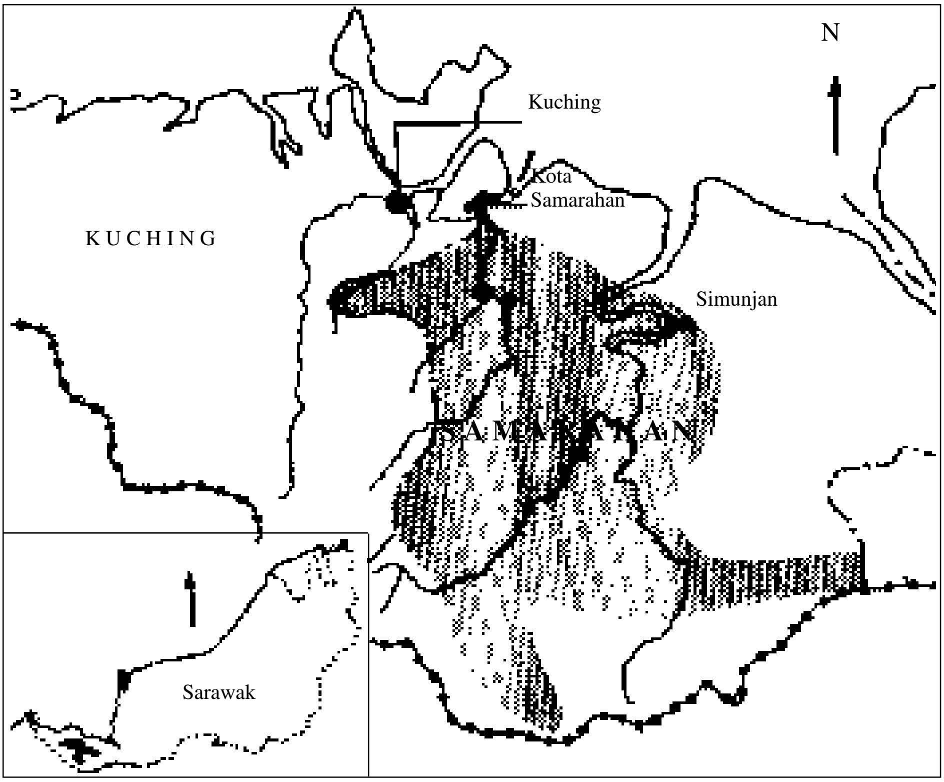


*Figure 1. Samarahan Division: The shaded area represents padi areas covered in the survey*

significantly >1 indicated aggregated spatial patterns. Lloyd's mean crowding ($m^*$) and patchiness ($Ip$) were calculated from the following formula:-

$$m^* = \sum_{i=1}^{Q} x_i \, (x_i - 1)$$

$$Ip = m^*/m$$

where $Q$ = number of quadrats
$x_i$ = number of plants in the $i$th quadrat

The values of $Ip$ were tested for deviation from unity; in a random distribution, the mean density and mean crowding values are equal to each other.

Moran's $I$ statistic of spatial autocorrelation was calculated for each species.

$$I = \frac{(1/W) \sum_{i=1}^{Q} \sum_{i=1}^{Q} [W_{ij}(x_i - x_m) \, (x_j - x_m)]}{(1/Q) \sum_{i=1}^{Q} (x_i - x_m)^2}$$

where $X_m$ = mean
$W_{ij}$ = weight assigned to the join between quadrats $i$ and $j$;
$W$ = sum of all weights.

This statistic protects information on the spatial distribution in the field sampling by using the information on the location of each sample points. Moran's $I = 0$ when no trend is present in the spatial distribution. Values of $I$ are positive (positive autocorrelation) when the variate values in joined quadrats vary in the same direction from the mean suggesting that similar values tend to occur together (aggregated spatial pattern). Conversely, values of $I$ are negative when variate values in joined quadrats vary in opposite directions from the mean (regular spatial pattern). These autocorrelation coefficients were tested against the null hypothesis that sample $I$ does not differ from this expected value $E(I) = -1 \; (Q - 1)$.

## Results and discussion

One hundred and fifty two weed species belonging to 31 families *(Table 1)* were identified within the quadrats of the padi farms surveyed. Of these, 49 species were sedges, 30 species of grasses and the rest were broadleaved weeds.

The most common and the most serious weed was *Fimbristylis miliacea.* It had the highest frequency, field uniformity and highest density values in all the occurrence fields.

Other weeds that occurred within the quadrats in frequencies > 40% were : *Emilia*

Table 1. Species richness of Samarahan's rice weeds according to family affiliation[a]

| Family | No. of species |
|---|---|
| Amaranthaceae | 3 |
| Apioceae | 1 |
| Araceae | 2 |
| Asteraceae | 14 |
| Boraginaceae | 1 |
| Butomaceae | 1 |
| Capparidaceae | 2 |
| Commelinaceae | 2 |
| Cyperaceae | 49 |
| Eriocaulaceae | 3 |
| Euphorbiaceae | 4 |
| Hydrocharitaceae | 1 |
| Junacaceae | 1 |
| Lamiaceae | 2 |
| Leguminosae (Fabaceae) | 3 |
| Lythraceae | 1 |
| Malvaceae | 1 |
| Melastomaceae | 1 |
| Onagraceae | 5 |
| Oxalidaceae | 1 |
| Parkeriaceae | 1 |
| Passifloraceae | 1 |
| Poaceae | 30 |
| Pontederiaceae | 3 |
| Protulacaceae | 1 |
| Rubiaceae | 6 |
| Scrophulariaceae | 8 |
| Solanaceae | 1 |
| Sterculiaceae | 1 |
| Verbenaceae | 1 |
| Xyridaceae | 1 |

[a]According to nomenclature of Soerjani et al. (1987)

Table 2. Species diversity indices for weeds in lowland and hill-padi farms in Samarahan, Sarawak

| Rice value* culture | No. of farms | Species diversity | | |
|---|---|---|---|---|
| | | S | SW | SD |
| Wet padi | 50 | 79 | 11.7 | 0.31 |
| Hill padi | 37 | 137 | 29.3 | 0.76 |

*S = mean number of species
SW = Shanon-Weiner heterogeneity function
SD = Simpson's diversity index

*sonchifolia, Sonchus arvensis, Vernonia cinerea, Limnocharis flava, Cyperus iria, C. difformis, C. kyllingia, C. haspan, F. globulosa, Fuirena umbellata, Eleocharis acutangula, Scirpus juncoides, Eleusine indica, Isachne globosa, Leersia hexandra, Ischaemum rugosum and I. magnum*. Frequencies of the remaining species ranged from 0.43% to 39.3%.

The Shannon-Weiner (SW) heterogeneity function and Simpson's diversity index (SD) values *(Table 2)* varied greatly between hill-padi and wet-padi (rainfed) areas. Hill-padi fields registered more than 137 species with SW and SD values of 29.3 and 0.76 respectively. The corresponding figures for wet-padi farms were 79 species, 11.7 (SW) and 0.31 (SD). These discrepancies in indices between the two habitats may be attributed to more soil disturbance in wet-padi fields than the hill-padi farms. It must be stressed here that the SW index gives greater weight to rare species while SD gives greater weight to common species (Krebs 1978). This explains the greater range of SW values compared with SD values. Further, these indices support the concept that species diversity decreases with continued disturbance.

Because some species were small in numbers, the statistical analysis has been restricted to 33 species *(Table 3)*. In this case, only species with a mean of more than 5% coverage per quadrat were chosen for the analysis. These species accounted for more than 90% of the plants estimated in all samples.

The values of the two indices of dispersion (variance-to-mean ratio and Lloyd's patchiness) were significantly greater than unity for all species ($p$ <0.05), indicating the 33 aggregated spatial patterns *(Table 3).*

Mean crowding values ranged from 0.674 for *Borreria alata* to 21.933 for *Fimbristylis miliacea.* To analyse mean crowding, a graph of mean crowding values against mean density was constructed. If all the species are randomly distributed, mean crowding and mean density are equivalent and we observe on the plot a straight line through the origin with a slope of unity. Species with clustered distributions have values above this line and species with regular distributions have values between this line and a parallel line having intercept minus unity; $m^* = m$ indicating aggregated distributions. The relationship between $m^*$ and $m$ calculated for all species is linear *(Figure 2)* and the regression equation was $m^* = 0.41 + 1.46m$ ($r = 0.875$).

Moran's $I$ statistics of spatial autocorrelation was significantly greater than E ($I$) at $p = 0.05$ for 17 species *(Table 3).* For these species, the positive autocorrelation suggests patchiness or aggregation. The larger the values, the greater was the degree of patchiness. Patchiness or aggregation in distribution of weeds warrants reassessment in the control measures imposed upon them. This is especially so for chemical control. It follows that assessment on the efficacy of a herbicide against a particular weed species should not be based on biomass or necromass data but on population counts and/or dynamics over a specific time period. Further the habitat for the 17 species of weeds may be very similar to each other. This being the case, controlling one species may lead to likely succession by one or more of the other 16 weed species. The need for non-selective herbicides or other control measures to which these weed species are susceptible but without harmful effects on the rice crop, is warranted.

Table 3. Estimation of variance/mean ratio (*V/m*), mean crowding (*m**) patchiness (*Ip*) and Moran's *I* autocorrelation[a]

| Species | *V/m* | *m** | SE(*m**) | *Ip* | *I* | *P[I = E(I)]* |
|---|---|---|---|---|---|---|
| *Fimbristylis miliacea* | 5.1160** | 21.933 | 0.793 | 1.327 | 0.281* | 0.098 |
| *Cyperus iria* | 4.0601** | 8.084 | 0.615 | 1.724 | 0.092 | 0.105 |
| *C. difformis* | 4.2667** | 11.009 | 0.623 | 1.626 | 0.192* | 0.032 |
| *Leersia hexandra* | 4.7291** | 19.553 | 0.813 | 1.256 | 0.267* | 0.046 |
| *Isachne globosa* | 3.8824** | 12.817 | 0.790 | 2.176 | 0.252* | 0.030 |
| *Monochoria vaginalis* | 2.0059** | 2.986 | 0.387 | 2.041 | 0.218* | 0.013 |
| *Ludwigia hyppsopifolia* | 2.0177** | 2.956 | 0.268 | 1.190 | 0.195* | 0.025 |
| *Lindernia antipoda* | 2.2209** | 1.481 | 0.666 | 1.582 | 0.261* | 0.042 |
| *L. ciliata* | 2.7882** | 5.322 | 0.393 | 2.079 | 0.183* | 0.007 |
| *L. crustacea* | 3.1133** | 2.222 | 0.410 | 1.507 | 0.196* | 0.025 |
| *Ischaemum rugosum* | 1.5843** | 0.909 | 0.214 | 1.160 | 0.071 | 0.074 |
| *I. magnum* | 1.6134** | 0.933 | 0.251 | 1.523 | 0.053 | 0.166 |
| *Amaranthus spinosus* | 2.0114** | 1.973 | 0.206 | 2.014 | 0.067 | 0.098 |
| *Crassocephalum crepidiodes* | 3.0014** | 11.998 | 0.511 | 1.714 | 0.197* | 0.011 |
| *Emilia sonchifolia* | 3.1137** | 4.583 | 0.626 | 1.254 | 0.204* | 0.013 |
| *Sonchus arvensis* | 2.9394** | 1.488 | 0.593 | 1.875 | 0.020 | 0.583 |
| *Vernonia cinerea* | 2.8878** | 1.455 | 0.606 | 2.361 | 0.098 | 0.403 |
| *C. kyllingia* | 4.9925** | 7.923 | 0.667 | 1.518 | 0.049 | 0.128 |
| *C. haspan* | 4.0021** | 8.003 | 0.443 | 1.482 | 0.088 | 0.112 |
| *Eleocharis acutangula* | 1.6226** | 0.939 | 0.285 | 1.237 | 0.065 | 0.089 |
| *F. dischotoma* | 4.1135** | 7.377 | 0.346 | 1.538 | 0.092 | 0.102 |
| *F. globulosa* | 5.0045** | 13.366 | 0.787 | 1.629 | 0.076* | 0.036 |
| *Lipocarpa chinensis* | 1.3134** | 1.157 | 0.151 | 2.114 | 0.182* | 0.013 |
| *Rhyncospora corymbosa* | 1.3936** | 0.693 | 0.194 | 2.042 | 0.216* | 0.021 |
| *Scirpus juncoides* | 2.2265** | 1.373 | 0.587 | 1.782 | 0.192* | 0.017 |
| *Eleusine indica* | 4.0056** | 8.714 | 0.723 | 1.884 | 0.082 | 0.111 |
| *Borreria alata* | 1.3213** | 0.674 | 0.545 | 1.674 | 0.079 | 0.100 |
| *Echinochloa colona* | 2.4433** | 1.834 | 0.347 | 1.226 | 0.229* | 0.018 |
| *Fuirena umbellata* | 1.2597** | 0.738 | 0.147 | 1.876 | 0.413* | 0.304 |
| *Hedyotis corymbosa* | 1.2228** | 0.938 | 0.204 | 1.558 | 0.055 | 0.157 |
| *Physalis angulata* | 1.2047** | 0.862 | 0.127 | 2.006 | 0.065 | 0.099 |
| *Scoparia dulcis* | 1.2172** | 0.702 | 0.134 | 2.012 | 0.020 | 0.583 |
| *Limnocharis flava* | 1.2826** | 0.896 | 0.119 | 1.898 | 0.072 | 0.166 |

[a]Species notation follows the nomenclature of Soerjani et al. (1987)
*$p$ <0.05; **$p$ <0.01

This study revealed that most weed species were patchy in their spatial distribution. However, the clustering was highly irregular. Irregularity in clustering of different weed species indicates differences in their growth habits and potential of spread. Species with *phalanx* growth habits like most species of sedges and grasses will be clumped closed to each other and with relatively slow clonal spread and invasion as compared with many broadleaved species which exhibit *guerilla* growth habits. As of agroclimatic factors, weed species that are found in the hill rice habitats of slash and burnt land preparation tend to be more drought tolerant than their counterparts in the wet-rice fields. Further, different land preparation and other agronomic practices in wet and hill-rice fields may contribute to highly irregular clustering of weed species found in them. Detailed studies on the role of these factors and their integration in the modelling of weed population dynamics remain a venue for further research.

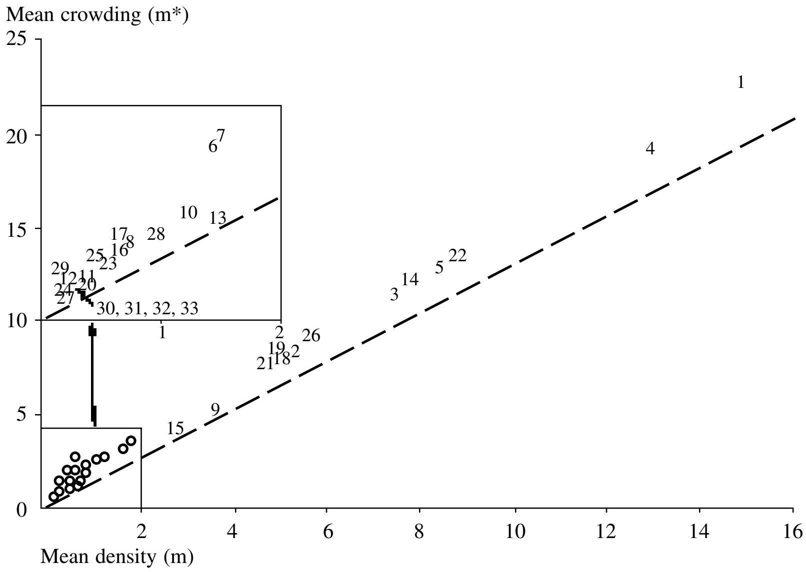


*Figure 2. Mean crowding against mean density; dashed line is the Iwao line (Iwao 1968). The data refer to the species with >5% occurrence per quadrat (see Table 3 for species notation)*

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