Forest Architecture of Lambir Rain Forest Revealed by a Large-Scale Research Plot

I. Topography of the Plot

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ABSTRACT

A large-scale research plot 52 ha in area was recently established at the Lambir Hills for the long- term ecological research of tropical rain forest in Sarawak, East Malaysia. The work for plot demarcation including a topography survey was initiated in November 1990 and continued till March 1992. Electronic Tachometers equipped with automatic distance meters were adopted to built the plot with reliable accuracy on steep and complex slopes. The plot 500 m x 1040 m in area was divided into 1300 quadrats 20 m x 20 m in size and further divided into 20,800 sub-quadrats 5 m x 5m in size, by setting land marks at all the corners of quadrats and subquadrats. The compass directions and zenith angles to elevation at the base of respective land marks were carefully surveyed by using tachometers and by following conventional land survey methods. The topography data thus obtained were transformed into the altitude values at land marks. The altitude difference between the lowest and highest points in the plot was ca. 150 m. A topography map was drawn by using the altitude data. Furthermore, a geometrical plane covering each of 1,300 quadrats was numerically determined to calculate the detailed statistics of topographic variables, such as altitude, directions, angles, and convexities of slopes. The statistics of these variables and their distribution maps within the plot suggested the steep, undulating, and complex slope-topography of the plot. These topographic features seemed to result in the fragmentation of plant habitats and might be strongly combined with a rich flora of Lambir rain forest.

INTRODUCTION

A long-term and large-scale research of a tropical rain forest was recently initiated on a hilly slope of the Lambir National Park (latitude ca.4°N longitude ca. 114°E) in Sarawak, East Malaysia, through an international collaboration among foresters, dendrologist, forest ecologists, and botanists from three countries, Sarawak, U.S. America, and Japan. The purposes of the research project declared to the Sarawak State Government by one of us (H.S.L) were: (1) to monitor tree population dynamics in space and time, with reference to the regeneration of key stone species and timber species; (2) to analyze the interaction among species at two contrasting local soil types, sandy and clayish soils, characterizing the Lambir Hills; (3) to provide control observations for silvicultural studies proposed on the basis of the first forest inventory results; and (4) to establish a foundation of botanical knowledge indispensable for wildlife biologists, socio-economists, and park managers (Lee, 1992).

The research program involved an establishment of a large-scale research plot in the Lambir National Park. The plot was expected to be a core facility of multi-purpose use in scientific researches, resource conservation, park management, etc. In October 1990, the first land mark peg for plot demarcation was established within a forest canopy dominated by various dipterocarp species in the park. It took about four years to finish all the necessary field and laboratory works for plot establishment. A proposed plot size before an initiation of plot demarcation was 50 ha, following preceding similar plots already established at Pasoh in East Malaysia (Manokaran, et al., 1990) and Barro Colorado Island (BCI) in Panama (Hubbell & Foster, 1983). However its size was magnified to 52 ha, owing to different thinkings between senior participants, especially two of us (T.Y. and P.S.A.). The plot was divided into 1,300 quadrats 20 m x 20 m in area and further divided into 20,800 subquadrats of 5 m x 5 m, by establishing 21,109 land mark pegs within the plot. A total of 358,905 trees 1.0 cm and greater in stem diameter at breast height (dbh) were individually labeled, mapped, identified to species, and measured by dbh. The species identification has been continuing since 1991 and its finalization is expected by one of us (P.S.A.) in the earliest opportunity.

Although the first forest inventory record from the large-scale research plot should offer an unprecedented opportunity for understanding either a community structure of many species or population structure of single species, the structural aspects of species are ignored and restricted to some unambiguous species in a series of studies, owing to floating species identification at present in 1994. An interesting topic of rare species is also ignored in the studies. The major forest architectural variables handled in studies are confined to several physiognomic dimensions, such as tree height, stem diameter, biomass etc., and these variables are analyzed with reference to big local variations in topography within the plot, since the local variations in forest architecture and floristic composition are commonly recognizable in lowland evergreen rain forest in Borneo. The results from these analyses will offer an empirical basis for discerning an applicability of two contrasting ecological hypotheses, the equilibrium and non-equilibrium hypotheses (Hubbell and Foster, 1986a, 1986b), to the Lambir rain forest. As the first step in the series of studies of forest architecture, the present study outlines the study site and analyzes topographic features of the plot, since the topography is one of determinant factors of forest architecture.

STUDY SITE

Lambir National Park

The Lambir National Park was gazetted for the amenities, researches, education, and reservoir of forest resources and biodiversity in 1975 and has been totally protected since then. The park consists of the central portion of the Lambir Hills with the highest peak of rugged sandstone escarpment 458 m in altitude. It lies about 30 km south of Miri, the capital of the Fourth Division, Sarawak. The access to the park from Miri is provided by a Sarawak skeleton road connecting Miri and Kuching via major cities in Sarawak, such as Bintulu and Sibu (Fig. 1). The park covers a strip of land 6,949 ha in area and is separated into two sections by the skeleton road traversing the park at its narrowest part ca. 1.6 km in width. Thus, an about one-third of the park area is isolated from the major park facilities by the road and is endangered by land use development, such as commercial logging and agriculture. Furthermore, the park boundary was eroded by the pressure of human activities till recently. Therefore, a bird eye appearance of the park looks like a small green island floating on man-made desert derived by a land use syndrome in a recent history in Sarawak (Watson, 1985).

Climate

The climate around Miri including Lambir Hills is everwet but monsoonal due to distinct shifts in prevailing winds; the north monsoon known as the wet Landas season from November to February and south monsoon from April to September. These seasonal changes of winds are determined by shifts in the Inter-Tropical Convergence Zone (ITCZ), i.e. a boundary between northern and southern trade winds. The seasonal shifts of ITCZ is thought to be driven by the changing zenithal position of the sun, since ITCZ is usually situated near the theoretical belt of maximal warming determined by the solar position. When the ITCZ lies to the south of Borneo, the prevailing winds come from northeast (north monsoon). On the other hand, when it lies to the north of Borneo, the winds come from southwest (south monsoon). Although the heavy rainfall and everwet climatic conditions can be explained by an arrival of the north monsoon, anomalous drought also occurs rather frequently than might be expected in former days. Some severe droughts are associated with anomalies in the movement of ITCZ, such as the El Nino event. Borneo including Sarawak belongs to one of areas susceptible to climatic anomalies resulting from the El Nino (Soepadmo, 1984; Watson, 1985; Japan Meteorological Agency, 1994).

The mean annual rainfall during 31 observatory years (1917-1957) at Miri was 3,150 mm and distributed evenly throughout the year. March was the driest month, though it still received 163 mm of rainfall (Department of Civil Aviation & Meteorological Services, British Borneo Territories, 1961). Mean annual temperature during three years (1958-1960) was 26.8° C with its range between 26.2° C in February and 27.3° C in May. The lowest record was 21.5° C (Kurashima et al., 1964).

Topography

The topography of the park is characterized by a hilly and undulating terrain with steep slopes including scars of landslides, though its details are complex to interpret. About 85% of the total park area represents slopes. The other 15 % of the area consists of ridges and valleys, both of which dissect the whole park area and seemed to result in finely fragmented local-habitats of plants. Eight small streams can be seen in the park and are integrated into the tributaries of three major river systems; the Miri, Bakam, and Baram Rivers. These topographic features are highly correlative with the geomorphological evolution of the Lambir Hills and are believed to be a joint outcome of three major cycles of the peneplanation after land uplift at Pliocene or early Pleistocene (Watson, 1985). Following a concept in erosion process, the present topography is thought to be a typical immature erosion stage, though erosion is generally rapid in tropical environment and in a locality with fragile soft rock as in Lambir Hills (Soepadmo, et al., 1984).

Geology

Three geological formations were identified within the park boundary. They were Setap Shale (or Sibuti), Lambir, and Tukau formations deposited in late Oligocene-early Miocene, mid Miocene, and late Miocene, respectively. The Setap Shale is thick and is characterized by fine grained clay and shale, which is bedded well and moderately soft. The Lambir formation occurs above the Setap Shale, widely covers the surface of the park, and is composed of soft fine grained sandstone and shale with calcareous elements suggesting littoral deposit conditions. At the top of the Lambir formation, coarse grained sandstones with various characters, such as lignitic, gritty, and pebbly properties, are recognized, alternating with shale and clay. The calcareous deposits decrease towards the exposed top of the formation. Our research plot was established in a area of the Lambir formation. The youngest Tukau formation outcrops at the eastern corner of the park and is composed of sand and poorly consolidated sandstone alternating with clay. The sandstone is soft and medium grained. The clay is also soft and poorly bedded (Soepadmo, et al., 1984; Watson, 1985). These sandstones and shales of three geological formations offered a variety of parent materials for soils described below.

Soils

Six major soil groups were reported by Wall (1962). They were immature alluvial soils around river banks, red-yellow podosols (ultisols) on slopes and ridges, podosols around the hill summit of Bukit Lambir, and immature regosols on very steep slopes. Among these soils, the red-yellow podosols cover most of the park and further divided into three soil families, Nyalau, Bekeru, and Merit families, characterized by different soil textures or clay contents. The red-yellow podosolic soil is poor in chemical nutrients in general, though it can support huge tropical evergreen rain forest with rich species diversity described below.

Vegetations

The rain forest in the park is consisted of two types of original vegetations common in the whole of Borneo, i.e. mixed dipterocarp forest and tropical heath forest. The former with various dipterocarp trees occurs on sites rich in clay, covers a rather lower area in elevation within the park, and has a territory of 85 % of the total park area. The latter with *Casuarina nobile* dominant is recognizable in a limited area with sandy soil around the highest peak of the Bukit Lambir and covers 15 % of the total area. The change of these forest types can be explained well by a classic ecological or pedological concept, a forest catena, which relates a series of forest types with a connected series of soils derived from similar parent material, found under similar climatic conditions, but showing different properties due to variations in soil forming factors. Our research plot was established within the mixed dipterocarp forest standing on red-yellow podosolic soils.

The mixed dipterocarp forest in Lambir has the richest lowland rain forest flora of the Old World. There is exceptional high local endemism at about 35% and Borneo island endemism at ca. 75%. The reason for the exceptional biodiversity is unclear. However, several hypothetical explanations are possible in terms of historical and biogeographical patterns, climatic conditions disturbance regimes, resource competitions, symbiotic interactions among organismic elements of the rain forest community etc. (Ashton, 1989).

METHODS OF PLOT DEMARCATION

Site Selection of the Plot

Before the initiation of plot demarcation. four small long-term research plots in the park had been monitored since 1963 by the Forest Department, Sarawak and several individual colleagues supervised by one of us (P.S.A.), who was the first forest botanist at the Forest Department (Ashton, 1973; Ashton et al. 1986, Ashton & Hall, 1992). In addition to this, a research group led by Soepadmo at Malaya University carried out an ecological survey of the flora and fauna of the park in April 1981 and listed 684 species, 253 genera, and 77 families of plants (Soepadmo, 1984). Watson also traversed the park for resource inventory in 1982-1983 and proposed a park management plan. Wall (1962) had already made a study of soil in Bekenu-Niah-Suai area including Lambir and prepared a soil map of the park in 1972 as reproduced by Soepadmo et al. (1984). These preceding studies offered a background and justification for a selection of the research site. The position of the plot was planned so as to cover the aforementioned four small monitoring plots (ca. 2.4 ha) established in 1963.

Topography Survey

The setting of land marks and topography survey in plot demarcation were carried out by adopting the conventional methods in a land survey and by using two electronic tachometers (Total-Station-SDM3, Sokkia, Osaka) with reflector mirrors (APS11, Sokkia, Osaka), one electronic digital theodolite (DT2, Sokkia, Osaka) equipped with a electronic distance meter (Red-Mini2, Sokkia, Osaka), and two compasses (Pocket Compass LS25, Ushikata, Tokyo). These major equipments were necessary for establishing the plot with reliable accuracy on steep slopes. Each land mark peg was individually set following the proper angle and horizontal distance determined by the above mentioned equipments without killing any trees. The general strategy in plot demarcation was to first fix a base line at the center of the plot, though the base line position was shifted later so as to satisfy the request from one of us (P.S.A.). Along the base line, the new quadrats were built in step-wise fashion. When survey errors were occasioned, we repeated land surveys. This strategy came from a survey procedure tried in Pasoh and BCI. However, this might be inadequate in Lambir with steep and complex topographies because the land survey is not free from errors and because error corrections exhaust time and man power. The conventional method of plot demarcation, in which the outer boundary lines of the plot are first surveyed, is recommended on steep slopes, though small forest disturbances by killing trees should be approved. A total of 21,109 plastic tent pegs and aluminum poles were used for land marks. Further details are described in a separate paper written by of us (Chai et al., 1995).

RESULTS AND DISCUSSION

Topography Map

The map of Fig. 2 represents the topography of our 52 ha plot, 500 m x 1040 m in size, demarcated by the land survey. The plot area was bit greater than the other two similar research plots 50 ha in size at BCI and Pasoh, though the difference of plot area is not intrinsic in research subjects and data comparisons among three sites. Numerals along the horizontal and vertical axes of the rectangular map in Fig. 2 stand for the identification numbers of survey lines, each of which was drawn at every 20 m intervals and was available for the easy recognition of the positions of 20 m x 20 m quadrats within the plot. Any position of a given quadrat is expressed by a set of values (a,b), where a and b represent the identification numbers of horizontal and vertical survey lines, respectively, in the map. Furthermore, the whole plot area was divided into 52 sub-areas 20 m x 500 m, each of which was also given an identification number similar with that of survey lines, for easy descriptions of the plot (Chai, et al., 1995).

A survey point given by a set of values (2,10) in survey line number (Fig. 2) was tentatively assumed to be a standard point with 150 m in altitude in map drawing, since it coincided with the point, at which one of land marks had been established by the Forest Department and Ashton for the demarcation of the aforementioned small monitoring plot (P-2) in 1963 and since it gave the first survey point in topography measurements in this study. Using the altitude at this tentative standard point, the relative altitude values of other survey points were calculated. The points were given by intersections of horizontal and vertical survey lines established at every 20 m intervals (Fig. 2). By using calculated relative altitude values, the contour lines in the map were drawn at every 5.0 m intervals in altitude. The altitude difference between the lowest point (0,1) and highest point (28,11) was 137 m.

A long and steep cliff at the lower side of the map, implied the geological history of the Lambir hills in the past, when sea water washed the land of the hills. Recent land slides resulted from heavy rain might not be able to bring a long and complex cliff such as that in our Lambir plot. A trace of one of a land slide is recognizable around a position (43,15) in the map. To understand the details of land slide patterns, a map should be drawn by using a finer scale and by using altitude data measured at every 5.0 m intervals.

For our easy recognition, the three dimensional expression of the plot topography is given by an another map shown in Fig. 3. Contour lines were drawn at every 5.0 m altitude intervals. A national park trail run along a narrow ridge or the upper part of the aforementioned long cliff extending from southeast to northwest. A major ridge including the highest peak ca. 250 m in relative altitude run along a line connecting the two survey points, (25,0) and (31,25), and separated the plot into the half. An overall view of the plot topography was characterized by the terms, hilly and complex, owing to steep slopes, ridges and valleys finely bifurcated, and land slides with a variety of scales, all of which partition the tree habitats of the whole plot into small blocks.

The hilly and complex topography of the plot could be easily understood by comparing hypsodiagrams in quantitative geography among three sites, BCI, Pasoh, and Lambir (Fig. 4). The altitude differences between the lowest and highest places in the three plots were the largest at Lambir, and smallest in Pasoh, suggesting a very flat and monotonous topography in Pasoh. A relative elevation difference between the lowest and highest points in BCI was about 40 m and medium among three sites, suggesting flatter and simpler topography than that of Lambir. The difficulties of the plot establishment seemed to be parallel to the slope angles and complexity of topographies, according to our experience in Lambir.

Detailed Statistics of Topographic Variables

Several topographic variables, such as compass directions of slopes etc., were computed for each of 1300 quadrats 20 m x 20m in size. In computation, we assumed a three dimensional plane consisting of three orthogonal axes, X, Y, and Z and covering a 20 m x 20 m quadrat (Fig. 5). The X axis of the plane represented the longer side (1040 m) of the rectangular 52 ha plot. The shorter side (500 m) of the plot was assumed to be the Y axis. The other Z axis represented the altitude of any point within the plot. The three dimensional plane thus defined was tentatively designated a slope and could be expressed by the following three dimensional linear equation, i.e.

$$Z = b_o + b_1X + b_2Y, \qquad (1)$$

where units of variables, X, Y, and Z, are [m] and b_o, b_1, and b_2 are dimensionless coefficients specific to the quadrat. Eq. (1) were applied to the four sets of observed variables, X, Y, and Z, which were obtained at four corners of each quadrat by the land survey. The three coefficients were determined for each quadrat by solving simultaneous equations consisting of four linear equations and by using the least squares method. After estimating the coefficients, topographic variables of quadrats were calculated following the numerical principles in geometry.

To calculate a geometrical angle of the hypothetical plane or slope covering any one quadrat, we introduced a variable f derived from a following numerical transformation of the coefficients, b_1, and b_2, i.e.

$$f = (b_1 + b_2 + 1)^{1/2} \qquad (2)$$

By using the above variable f, the slope angle of the quadrat, θ , is given by the equation,

$$\theta = \text{Arcsin}\ (1 / f). \qquad (3)$$

The compass direction of the slope, CDS, is also defined by the equation,

$$\text{CDS} = \text{Arcsin}\ (-b_2 / f / \cos\theta\ ). \qquad (4)$$

The mean altitude of the slope was defined by the average of four observed altitude values at four corners of respective quadrats.

The geometrical form of slopes is an important feature characterizing topographies. We can easily recognize convex slopes (or ridges), concave slopes (or valleys), and monotonous slopes with constant slope inclinations (flat slopes). To express these differences in slope form between quadrats (20 m x 20 m), we tentatively introduce an another plane or square, which covers any one quadrat designated a target quadrat, is demarcated by 12 land mark posts, has a size of 60 m x 60 m in area, and includes the target quadrat at its center, as shown in Fig. 6. Focusing on the 12 land mark posts demarcating the larger square thus defined, we calculated the mean altitude of 12 posts and designated it as the mean altitude of outer posts. On the other hand, the aforementioned mean altitude of a slope or quadrat represents a mean altitude of four inner posts demarcating the target quadrat (Fig. 6). A difference between the mean altitude of inner posts and that of outer posts was tentatively designated the index of the convexity (or concavity) of slopes (ICS), i.e

$$\text{ICS} = (\text{Mean altitude of 4 inner posts}) - (\text{mean altitude of 12 outer posts})$$

The proposed index ICS is positive, when slopes are convex in their shape. It gives negative values for concave slopes. The degree of the convexity or concavity of slopes is expressed by the absolute value of ICS. A monotonous slope with a fixed slope inclination should have a smaller absolute value of ICS.

The basic statistics of the aforementioned topographic variables are given in Table 1. Although the altitude values represented relative values and were expected to be transformed into absolute values in the earliest opportunity, we had no other suitable examples of the statistics of topographic variables comparable with those in Table 1, since these statistics are first calculated in the present study. A relationship between mean and standard deviation values in Table 1 is shown in Fig. 7. An increase of the standard deviation (SD) with an increase of the mean (M) was not proportional and approximated by the power equation,

$$\text{SD} = 6.575\ M^{0.3528}.$$

The skewness was negative for altitudes but positive for the other three variables, suggesting a J-shaped frequency distribution of altitudes. The kurtosis was negative for altitudes, slope angles, and compass directions, suggesting the platykurtic frequency distribution of variables. The smallest skewness of compass directions implied a rather uniform frequency distribution of the observed values (Fig. 8). The frequency distribution of the ICS or convexity was characterized by the smallest absolute value of the skewness and the largest positive kurtosis, suggesting a symmetrical but leptokurtic frequency distribution of observed values (Fig. 9). ICS is thought to be important and will be described in its detail in the next paper because it seems to reflect water conditions in quadrats.

The distribution maps of the aforementioned four topographic variables within the plot were helpful for understanding the details of the plot topography and are given Appendix 1 by categorizing respective variables into several classes of variable values. The spatial pattern of altitudes should be parallel with that of contour lines in Fig. 1. Steep slope angles were observed along the aforementioned long cliff and around some ridges and land slides. Compass directions might be biologically meaningless in tropical regions, because solar altitudes are always higher in the tropics than in higher latitudes throughout a year. However, if plants could sensitively identify the light quality differences between morning and evening in their bio-rhythms, compass directions should be important. The pattern of the ICS convexity index corresponded to that of ridges and rivers and seemed to be very important in terms of the fragmentation of local plant habitats. Each of three categorized classes of ICS had similar frequencies and distributed rather randomly in the plot (cf. Appendix 1).

CONCLUSIONS

A large-scale research plot with 52 ha in area was recently established within a mixed dipterocarp forest at the Lambir National Park in Sarawak. The topography of the plot was studied by analyzing the physiography data. The basic statistics of the topographic variables, such as altitudes, angles, directions, and convexities of slopes, were calculated for respective 20 m x 20 m quadrats consisting the whole 52 ha plot. The calculated statistics suggested the steeply sloped, sharply undulating, and complexly bifurcated topography of the plot. These topographic features might be expressed by a term "broken topography and seemed to fragment a whole entity of the plant habitat into small local fractions, which should be strongly combined with the richest flora of Lambir rain forest among all the forests of the Old World.

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Fig. 1. Location of the study site, Lambir Hills, in Sarawak, North Borneo.

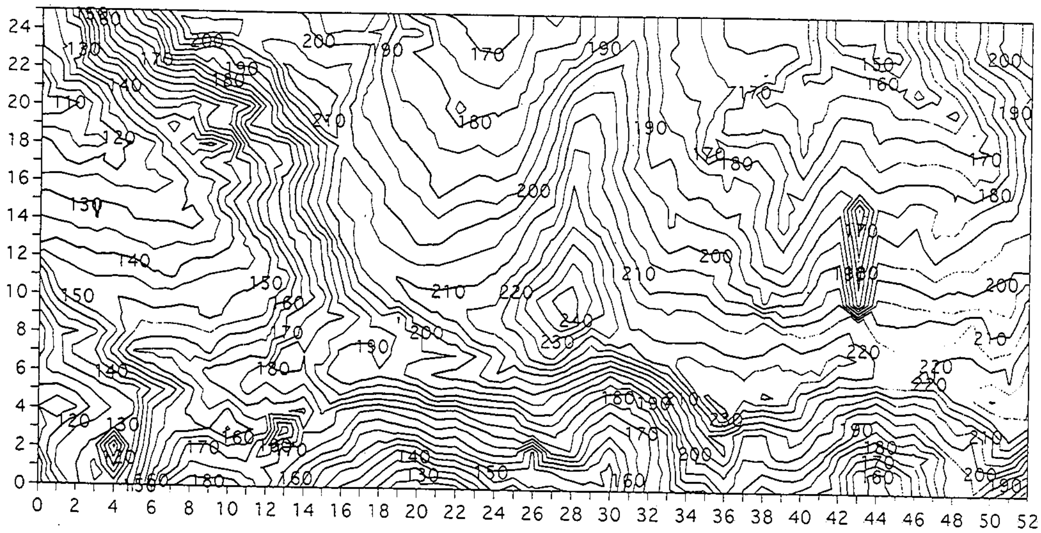


Fig. 2. Topography map of the 52 hectare research plot at the Lambir National Park. Contour lines are drawn at every 5.0 m intervals in altitude. A longer side of the rectagular plot is 1040 m. A shorter side of the plot is 500 m.

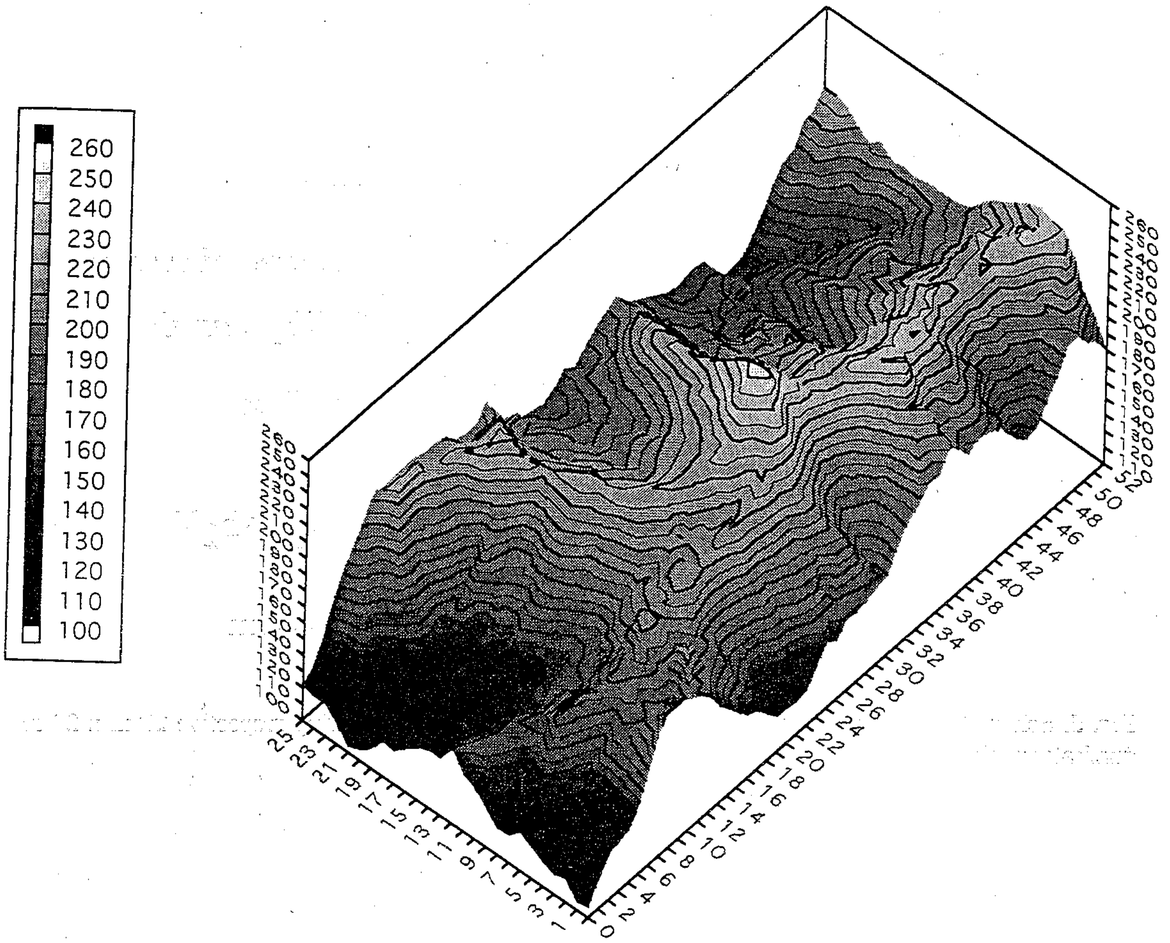


Fig. 3. Tree dimensional representation of the plot topography map given in Fig. 2. Contour lines are drawn at every 5.0 m intervals.

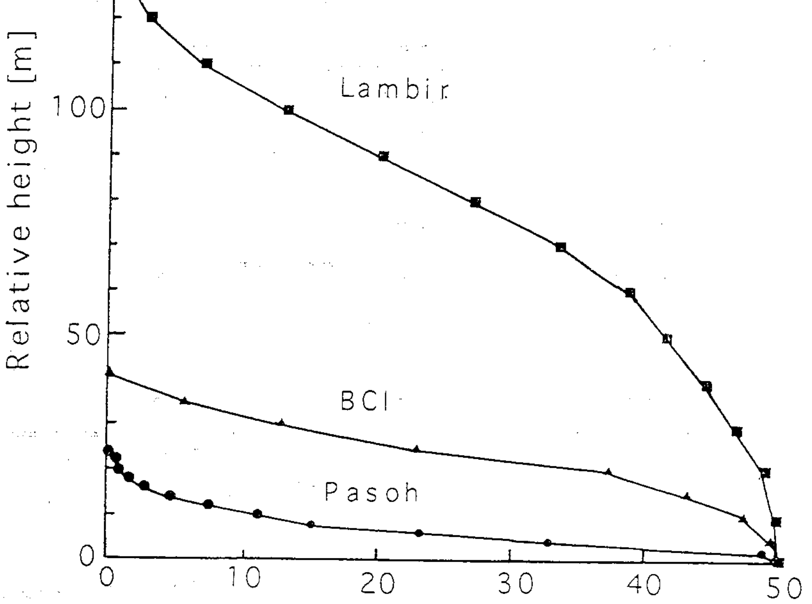


Fig. 4. Hypsodiagram showing the relationship between the altitude and correponding cumulative area in the plot. Our plot at Lambir is the most steep and complex among three sites, BCI, Pasoh, and Lambir.

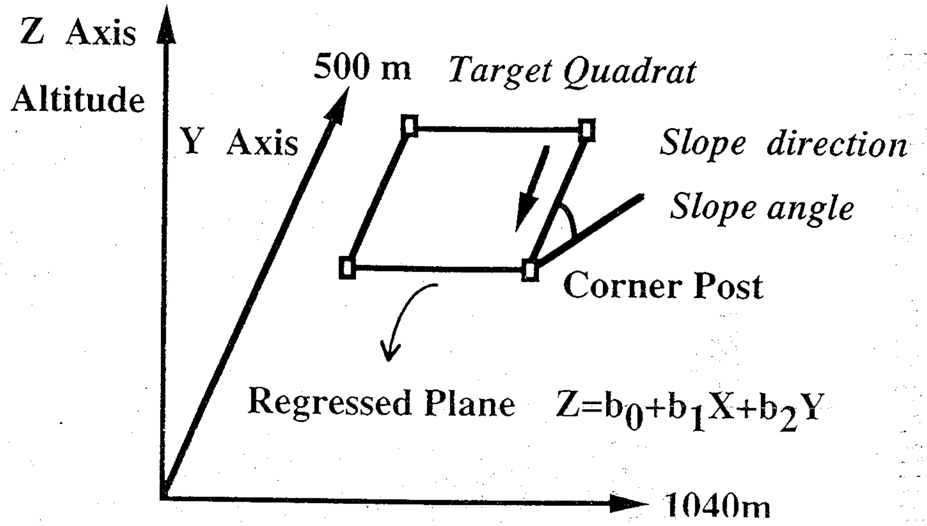
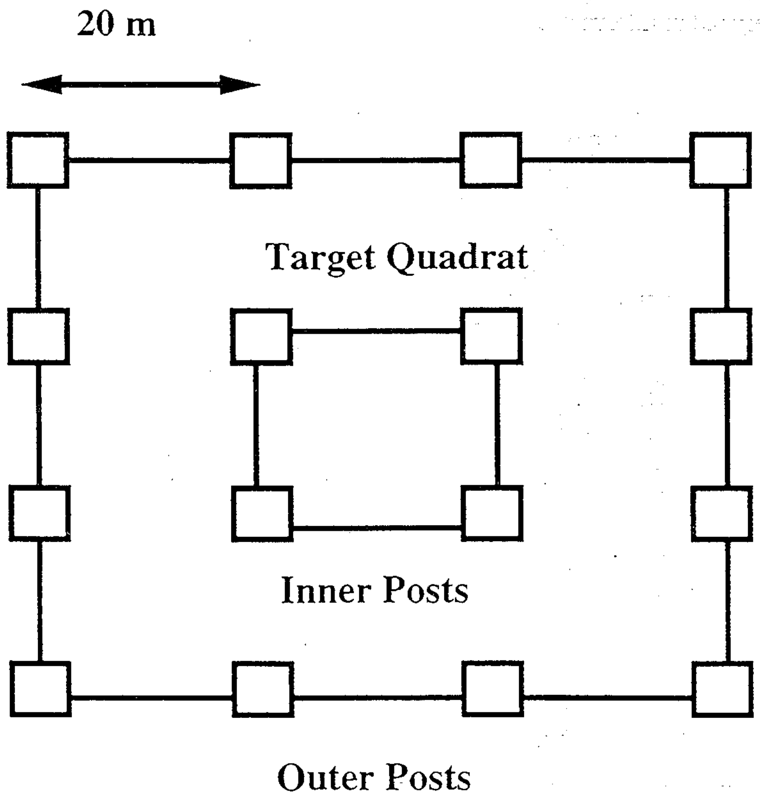


Fig. 5. Schematic representation of a hypothetical geometric plane convering respective 20 m x 20 m quadrats within the 52 ha plot.



ICS = Mean Altitude of Inner Posts
- Mean Altitude of Outer Posts

Fig. 6. Relationship among land mark posts determing two hypothetical geometric planes proposed for a calculation of an index of the convexity (or concavity) of slopes, ICS.

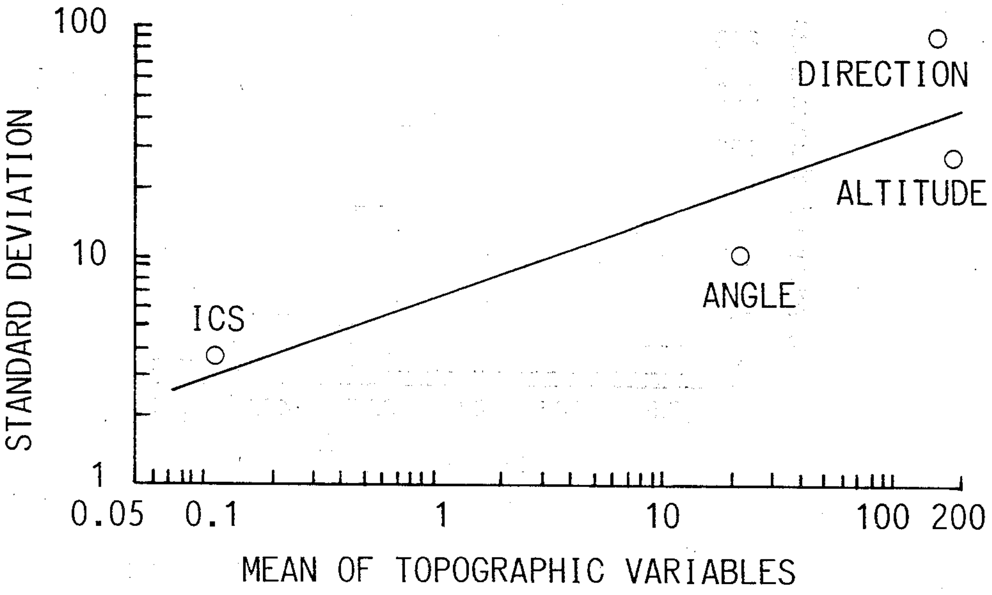


Fig. 7. Relation between the mean and standard deviation of four topographic variables, altitude, angles, directions, and ICS, calculated for each 20 m x 20 m quadrat.

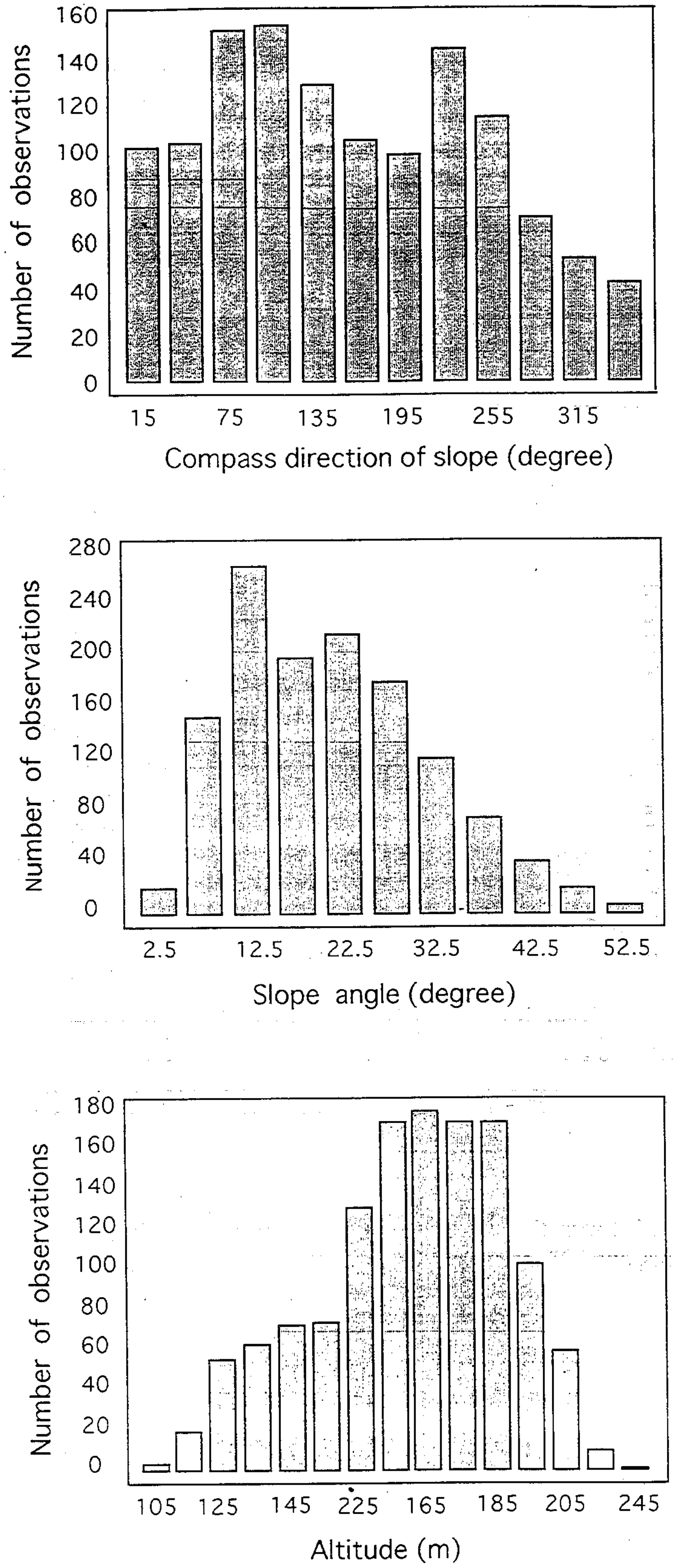


Fig. 8. Frequency distribtuion of three topographic variables, altitudes (lower), angles (middle), and directions (upper), calculated for respective 1300 quadrats.

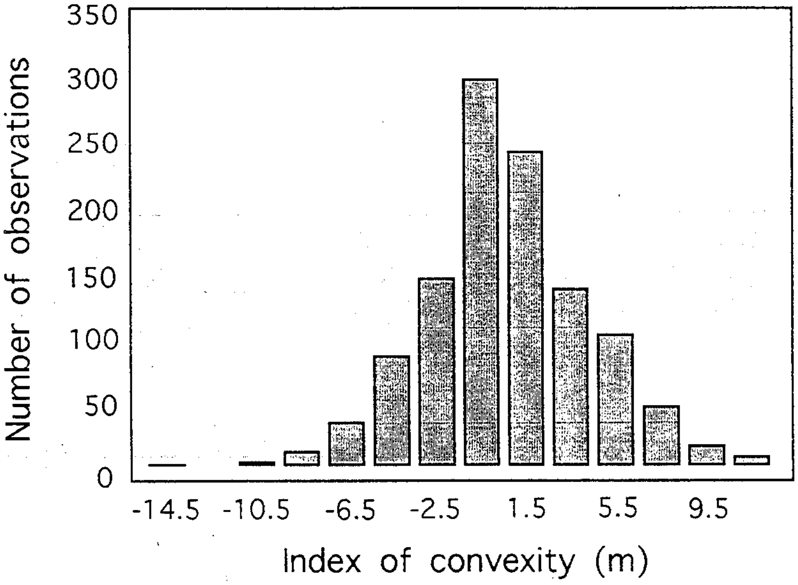
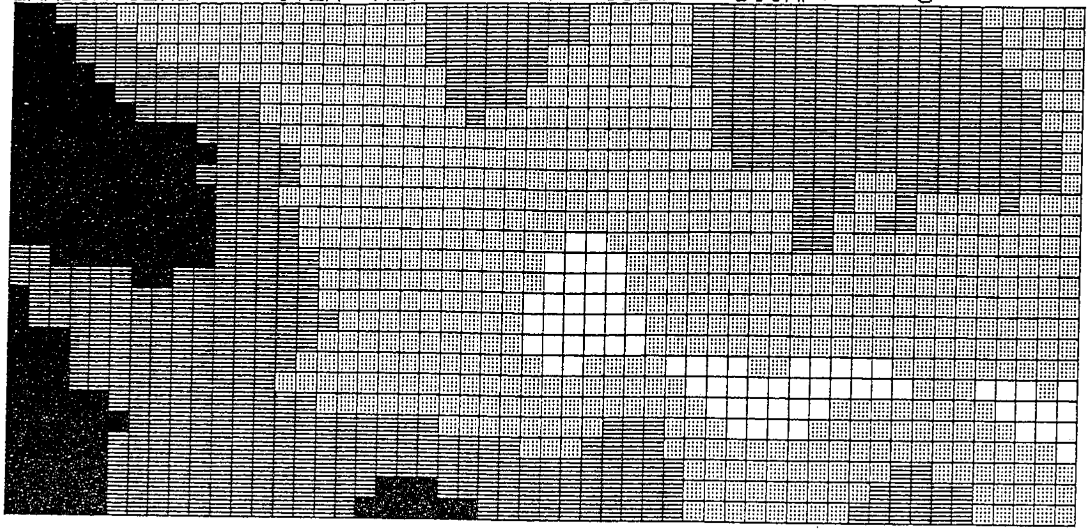


Fig. 9. Frequency distribtuion of ICS or an incex of convexity of slopes.

Appendices (following pages). Maps of topographic variables. Spatial patterns of topographic variables within the 52 ha plot are mapped and represented in Appendices 1-4. the variables are the altitude, angle, compass direstion, and convexity index of slopes, each of which was calculated for respective 20 m x 20 m quadrats consisting the entire plot of 52 ha. In map drawing, the calculated values of respective variables are categorized into several classes. The altitude values are classified into four classes with a class interval of 40m; 100-140, 140-180, 180-220, 220-260 m. Altitude values over 240 m are not recorded (Appendix 1). The slope angles are represented by categorizing their values into four classes; < 15, 15-25, 25-35, and > 35 degrees (Appendix 2). Compass directions are classified into five classes; < 45, 45-135, 135-225, 225-315, and 315-360 degrees (Appendix 3). The index of the convexity are classified into three classes; < -1.5, -1.5-1.5, > 1.5 (Appendix 4).

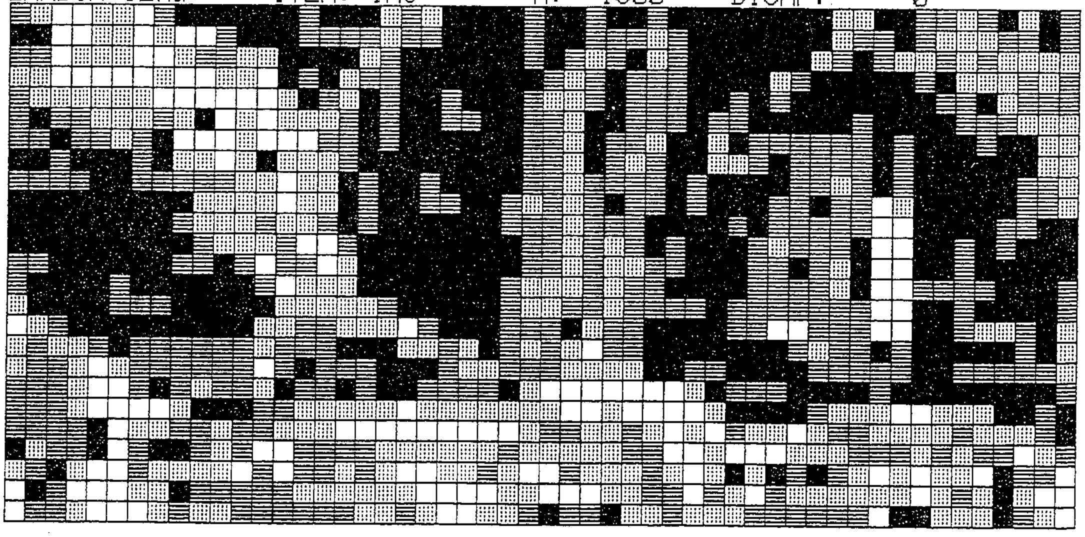
```
LAMBIR 52ha      ITEM: ALT        N:   1300     DISAP:      0
```



```
NUMBER OF CLASS    4
  1    UPPER LIMIT OF CLASS      140.00000  N    142  ■
  2    UPPER LIMIT OF CLASS      180.00000  N    454  ▤
  3    UPPER LIMIT OF CLASS      220.00000  N    633  ▦
  4    UPPER LIMIT OF CLASS      240.25751  N     71  □
```

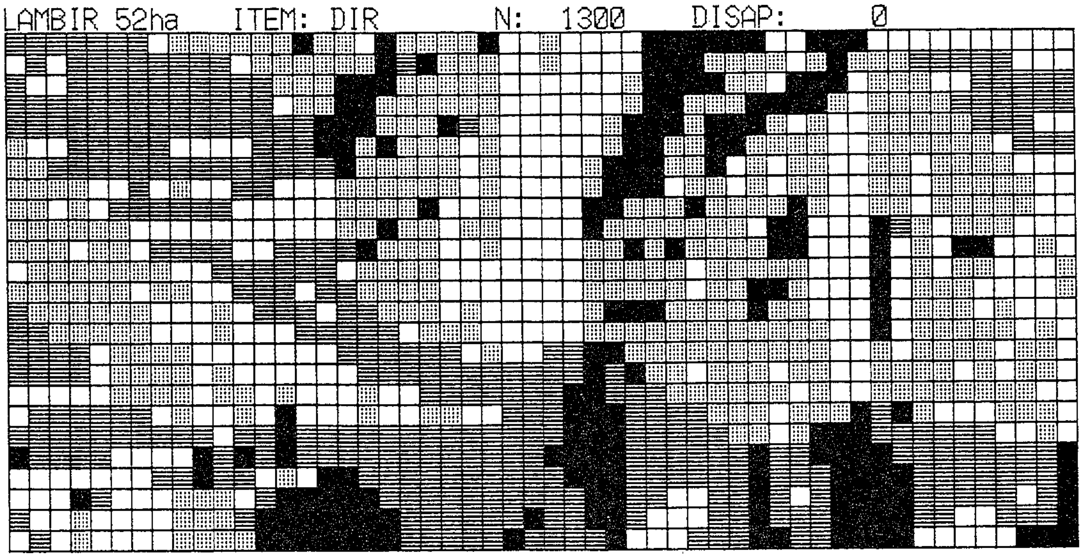
Appendix 1. Spatial pattern of altitude values categorized into four classes in the 52 ha plot.

```
LAMBIR 52ha       ITEM: INC        N:   1300     DISAP:      0
```



```
NUMBER OF CLASS    4
  1    UPPER LIMIT OF CLASS      15.00000  N    442  ■
  2    UPPER LIMIT OF CLASS      25.00000  N    416  ▤
  3    UPPER LIMIT OF CLASS      35.00000  N    300  ▦
  4    UPPER LIMIT OF CLASS      54.05841  N    142  □
```

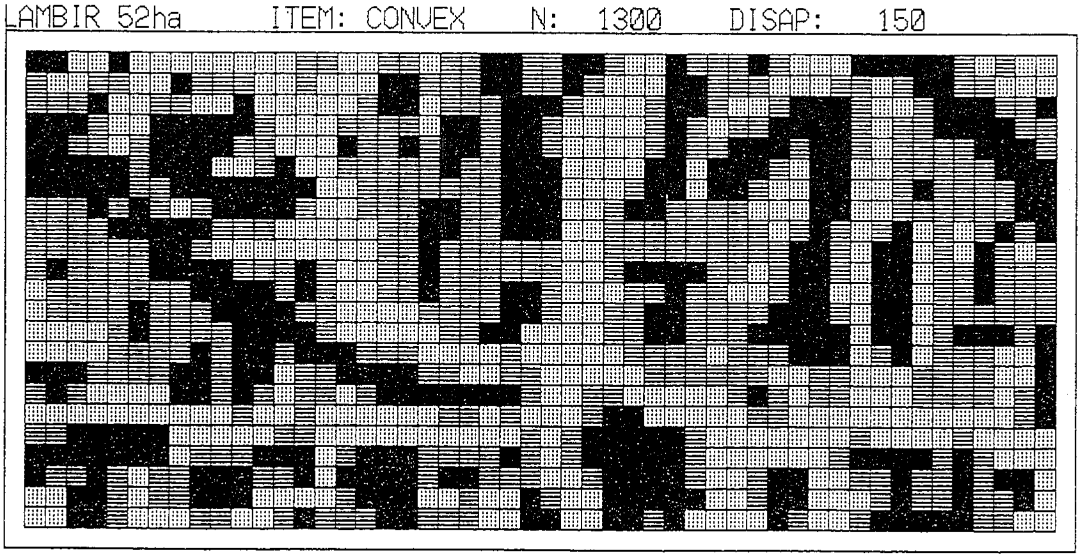
Appendix 2. Spatial distribution of slope angles in the plot.



```
LAMBIR 52ha    ITEM: DIR        N:  1300    DISAP:      0
```

```
NUMBER OF CLASS    5
   1   UPPER LIMIT OF CLASS      45.00000  N    85  ■
   2   UPPER LIMIT OF CLASS     135.00000  N   355  ▤
   3   UPPER LIMIT OF CLASS     225.00000  N   366  □
   4   UPPER LIMIT OF CLASS     315.00000  N   397  ▦
   5   UPPER LIMIT OF CLASS     359.88669  N    97  ■
```

Appendix 3. Spatial distribtuion of compass directions of slopes in the plot



```
LAMBIR 52ha      ITEM: CONVEX     N:  1300     DISAP:    150
```

```
NUMBER OF CLASS    3
   1   UPPER LIMIT OF CLASS      -1.50000  N   362  ■
   2   UPPER LIMIT OF CLASS       1.50000  N   432  ▤
   3   UPPER LIMIT OF CLASS      11.53751  N   356  ▦
```

Appendix 4. Spatial disribution of the index of the convexity of slopes, ICS, in the plot.