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Optimization of Alternative Route Location/Harvest System Planning for Opening Up of Mountain Forests Using the Integrated Terrain Information Processing System *TERDAS*

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Abstract

This paper deals with how the integrated DTM analysis system, TERDAS, can be applied to opening up planning strategies. The system incorporates four linked sub-functional components of: (1) delineating operational terrain units based on voronoi information, (2) identifying and zoning sensitive terrain sites related to special points or features, (3) synthesizing sensitive terrain factors by overlay, stratification and isolation manners, and (4) optional simulation analysis such as visual landscape modification, drainage pattern, bedding boundary and potential solar radiation. As a case study this system is applied to the opening up planning for Mie University Forest.

Key words: Opening up planning strategie, road network/harvesting system, sensitive terrain, TERDAS, integrated DTM data base, overlay/stratification/isolation

Introduction

During the last decades, there has been a considerable evolution and a greater change in the methods and techniques used in timber harvesting. It can in general be said that all forest operations have been affected by this development. There are, however, certain forested area which are not suitable for the systematic application and use of such techniques. Forests in moutainous regions are an example of sites which by their very nature constitute an obstacle to progress, which it is often difficult to approach. Access development in these forests is presently confronted with ever more varying restrictions integrating engineering, financial, social and environmental concerns. It is therefore not surprising that many experts in this field have become more and more concerned by the limitation of access facilities and relative stagnation of mountain forests compared with general development.

The integrated planning process should permit not only great adaptability to local conditions but also the inclusion of key points for opening up in mountain forests. In addition, it must develop a large number of aids for decision making in the evaluation and choice of alternatives in relation to local circumstances. Loeffler and Duerrstein[1)] have developed this type of problem-oriented approach to work out proposals for planning techniques and the evaluation of different alternatives shown in **Figure 1**.

A particularly interesting part of the opening up planning process is facilitation in generating alternatives routings under the various constrains influencing the location of routes in forest area. This paper attempts to incorporate environmental data, particularly sensitive terrain factors to disturbance, into a route location/harvest

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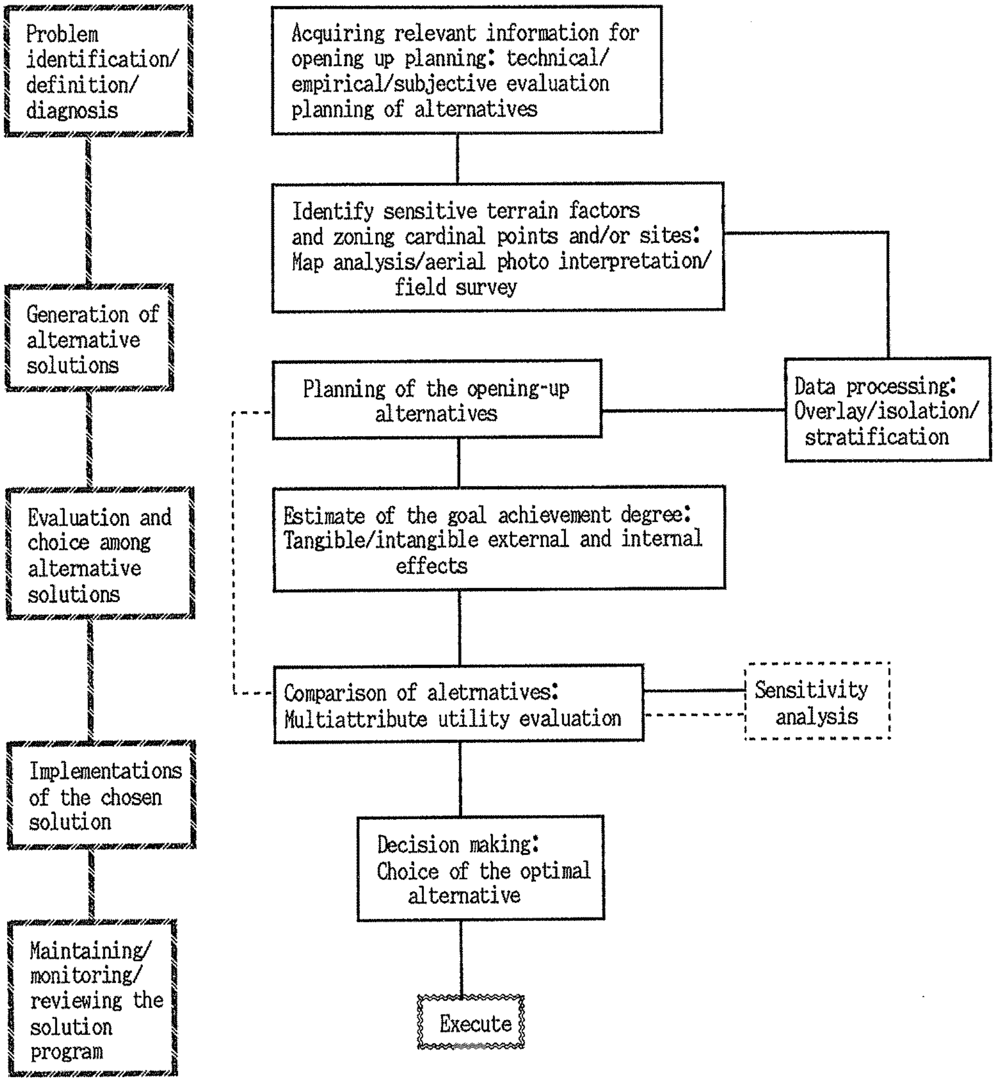


Figure 1. Procedure for general opening-up planning corresponding to five-step problem-solving paradigm.

system planning. The proposed system (tentatively called **TERDAS**), in its present form, incorporated four linked sub-functional components; that include (1) delineating operational terrain units based on voronoi information derived from slope or access distance estimates, (2) identifying and zoning sensitive terrain sites related to specific points or features associated with the severity of engineering difficulties, (3) synthesizing sensitive terrain factors by overlay, stratification and isolation manners, and (4) various simulation analysis, such as visual landscape modification, drainage pattern, bedding boundary and potential solar radiation. **Figure 2** shows an overview diagram of functionally branched components of the **TERDAS**.

A small pilot study designed to test applicability of the **TERDAS** for opening up planning in Mie University Forest is then discussed. It has not yet been possible to this system in its entirely, but no major obstacles to

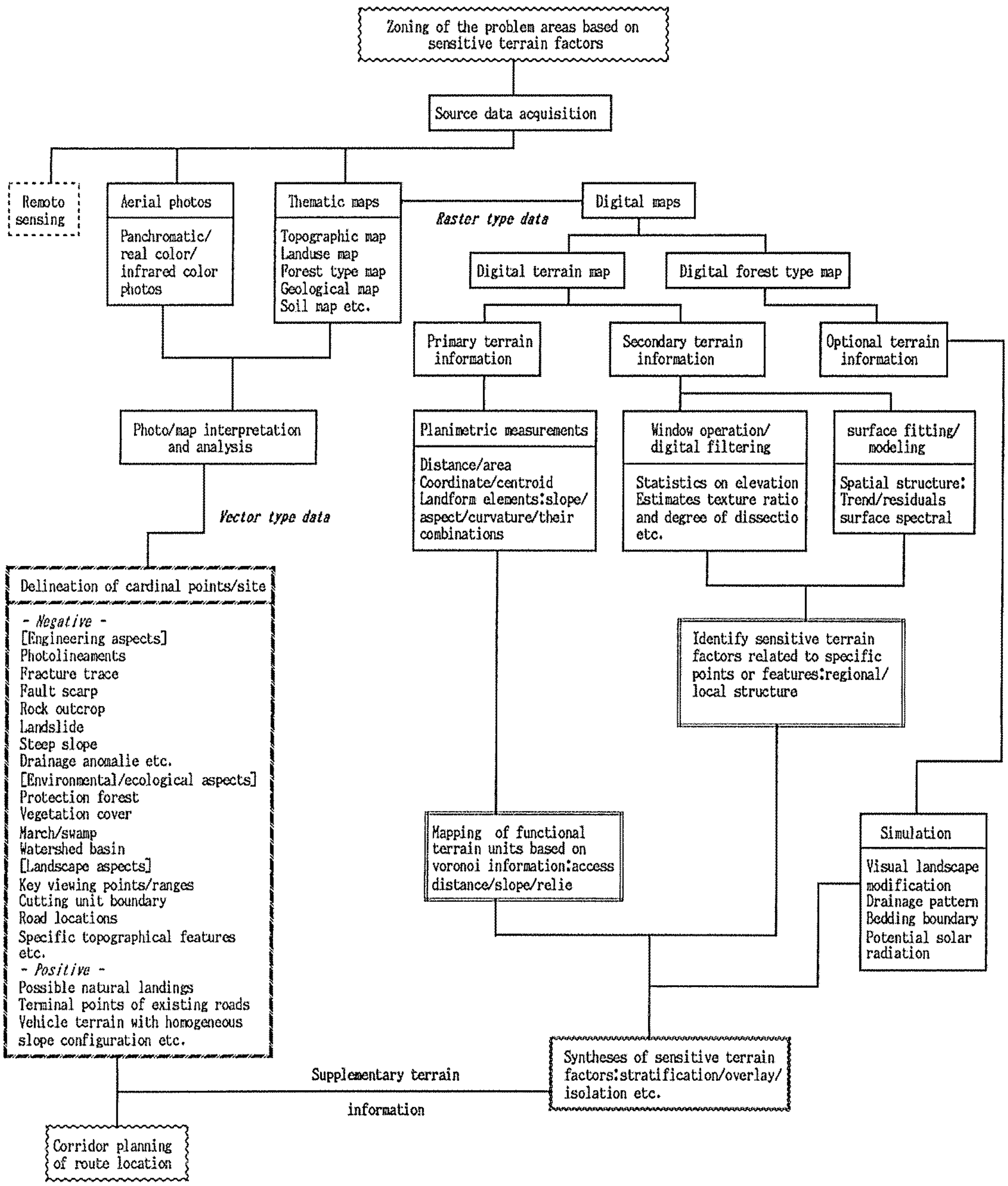


Figure 2. Functional components of the ***TERDAS***, modules to suit various applications in opening-up planning process, such as route location or harvest system plan are added as required to this system.

the adoption are suggested by these preliminary results. It does allow flexibility in route evaluation by producing alternative routing under different sets of constraints, taking engineering and environmental estimates into account.

This study was partly represented at the IUFRO Workshop S3.06, S3.05 and University of Munich in

Feldafing, Germany 1992.

TERDAS as part of an integrated DTM date base

Yang and Lemkow[2] presented a prototype timber harvesting planning system that used a **DTM**. **PLANS** (the **P**reliminary **L**ogging **A**nalysis **S**ystem of the USDA Forest Service 1987)[3] is a software package for integrated timber harvest planning developed for a microcomputer-based, interactive graphics system and includes programs for the harvest unit design of a variety of cable-logging systems, road locations, visual analysis, logging costs, and slope attributes. It uses a **DTM** to provide the topographic data needed to fit harvest and transportation designs to specific terrain.

Further application of a **DTM** should include the capacity to synthesize efficiently the data of several map layers, forest stands, geology, soil ecology, hydrology and other physical aspects of the **DTM** coverage area. This would facilitate the complete evaluation of forest areas using all the important planning variables, because an

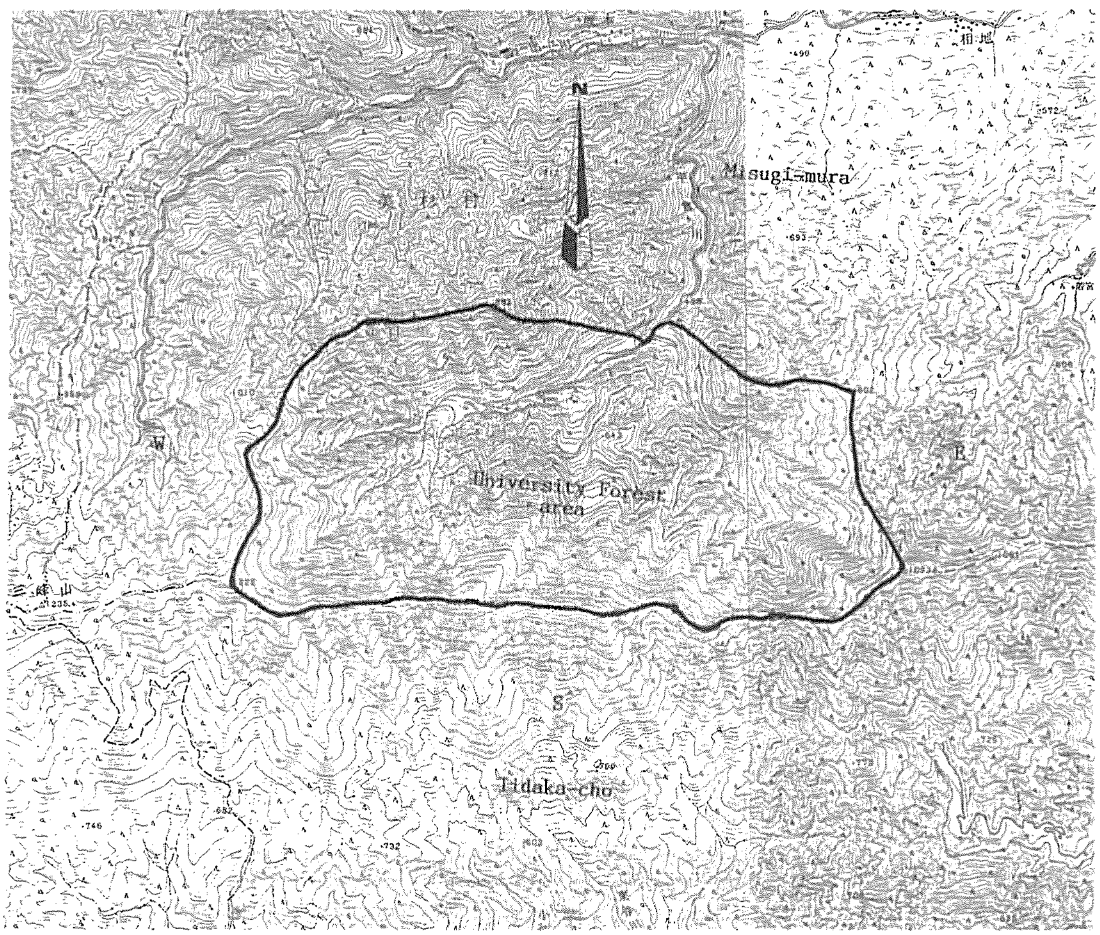


Figure 3a. Overview of terrain conditions covering the University Forest area; modified a 1 : 25000 topographic map.

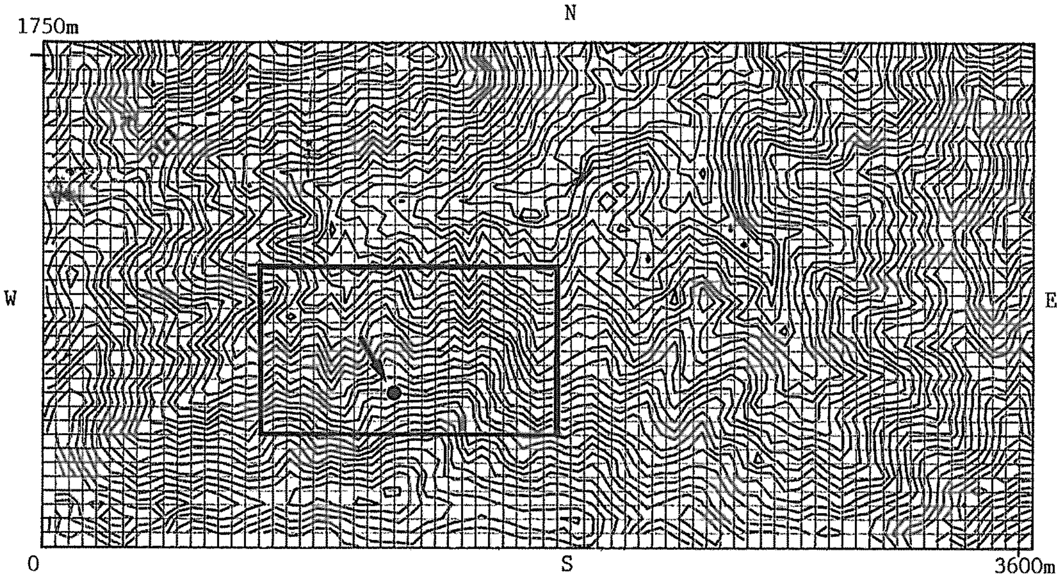


Figure 3b. Computer-generated digital contour map (contour interval: **20 m**) with the square grid of the DTM (**50 m×50 m**); Rectangular portion of the grid blocks bounded by bold lines indicates the model area designed for visual landscape modification by generating perspective drawings shown in **Figure 17** and also the arrowhead shows the specific grid-intersection used to solve for viewing range of the terrain from the selected viewpoint in the DTM coverage area in **Figure 16**.

integrated **DTM** system, as one part of a permanent data base, can be easily accessed for engineering and management information, can make desired changes, and can carry out many more design cycles than would be possible using manual methods.

TERDAS (*Terra-data base system*) is the data processing system for applications of the integrated **DTM** data base incorporated into a preliminary road/harvest system planning[4,5]. It can be used to synthesize the data of several map layers including information derived from aerial photo interpretation and field survey in common scale, and to produce a terrain factor mosaic representation which provide for the possibility of simulating various kinds of opening up measures. A detailed procedure for such computerized mapping and information storage system is described in the literature[6].

This system was applied to the opening up planning for Mie University Forest. The analytical process is simply presented as follows. A **DTM** with 50 m-square grid intervals covering the area on a topographic map scale of 1/5000, was constructed to provide the terrain data needed to fit the level of route location planning (**Figure 3**). Terrain information derived from the resolution of the **TERDAS** were then recorded for each of the resulting 0.25 ha rasters. The field survey data acquired by sampling method, with circle unit 10 m in radius, at grid line intersections on the ground reconnaissance, was converted to a grid map. Linear structural information extracted from aerial photo interpretation and base map analysis, such as opening up boundaries, existing road lines, lineaments, landslide points/area, etc., were defined by a series of x-y coordinates automatically generated by a digitizer.

A considerable volume of computer output was generated by the **TERDAS**. Several of these outputs associated with the identification of critical sites influencing the route locations are shown in **Figure 6–17**. It is interesting to note that the critical sites based on landform attributes and drainage pattern reveal actual terrain conditions comparatively.

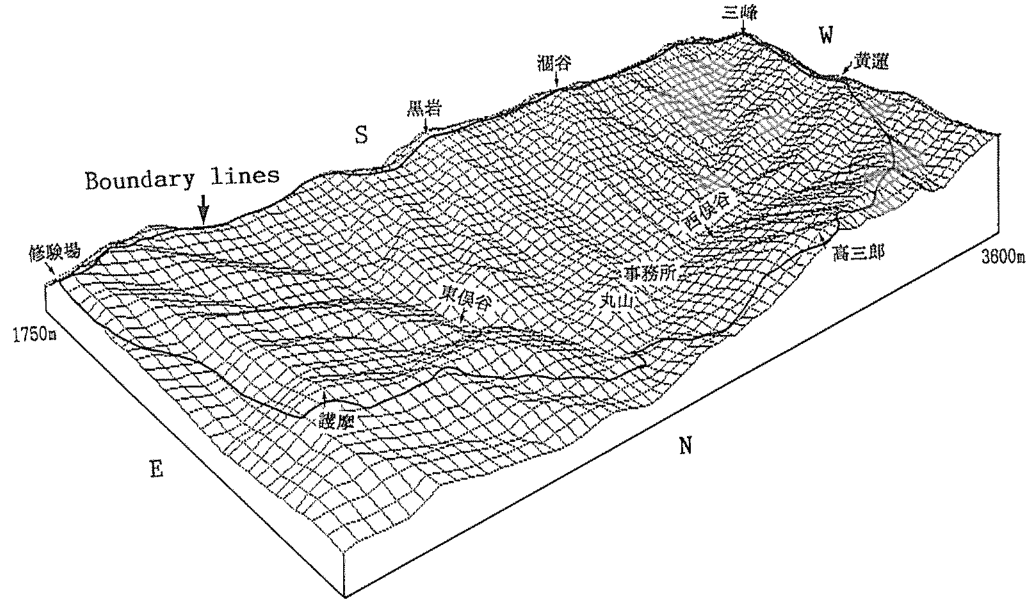


Figure 4. Perspective plot of the DTM surface in the study site; gridline spacing is set at 50 m. Arrowheads indicate the dominant drainage basins and ridges. Bold line shows boundary of the Mie University Forest.

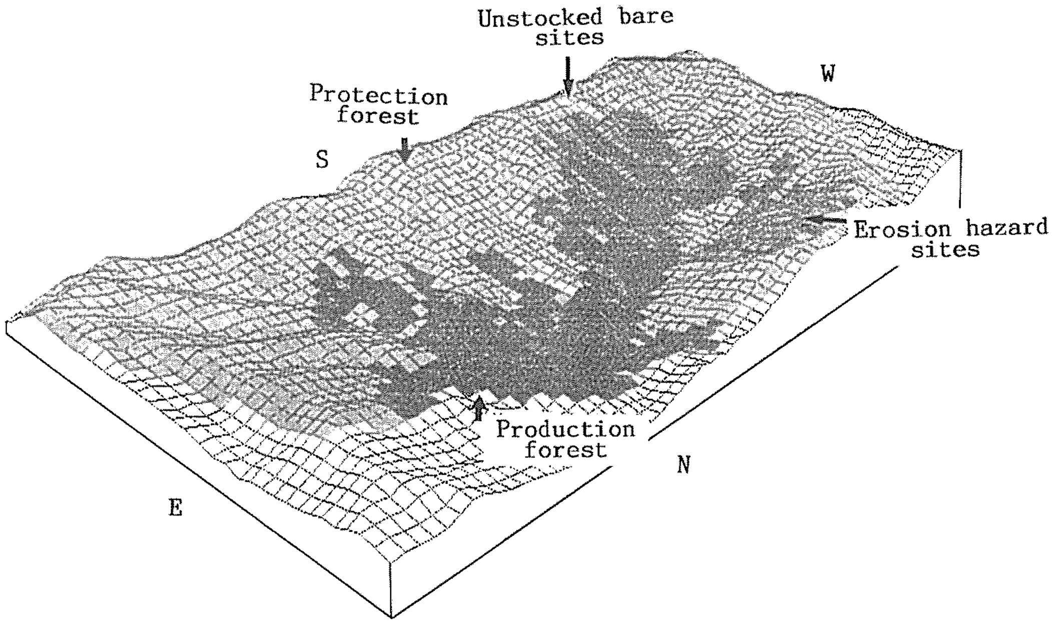


Figure 5. *Stand type subdivision* created by a digital forest type map including the coordinates of the stand boundary or the stand centroid.

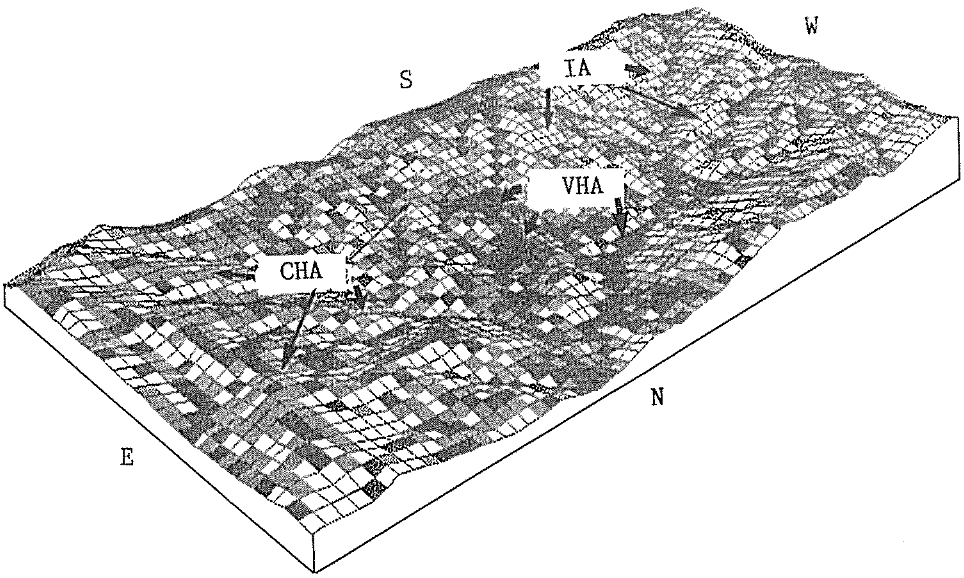


Figure 6. Subdivision of *terrain-harvesting system area* based on slope steepness; slope ranges as follows.
VHA (0–60%): Vehicle harvesting system area
CHA (61–80%): Cable harvesting system area
IA (81%–): Inaccessible area

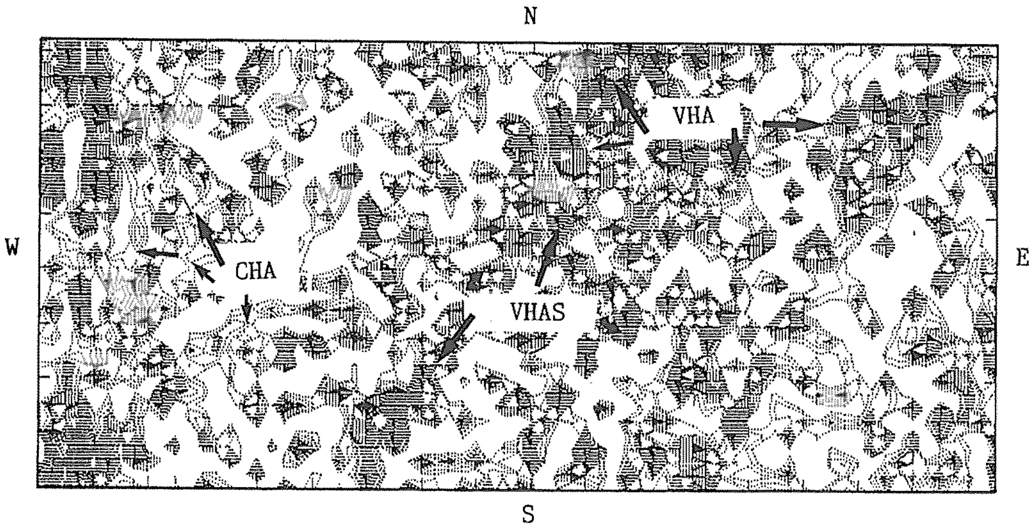


Figure 7. Delineation of the appropriate boundaries of *terrain-harvesting system area*; dotted contour line is set at slope gradient of 10%.
CHA: Cable harvesting system area *VHA*: Vehicle harvesting system area *VHAS*: Vehicle harvesting system area with prepared skid trails

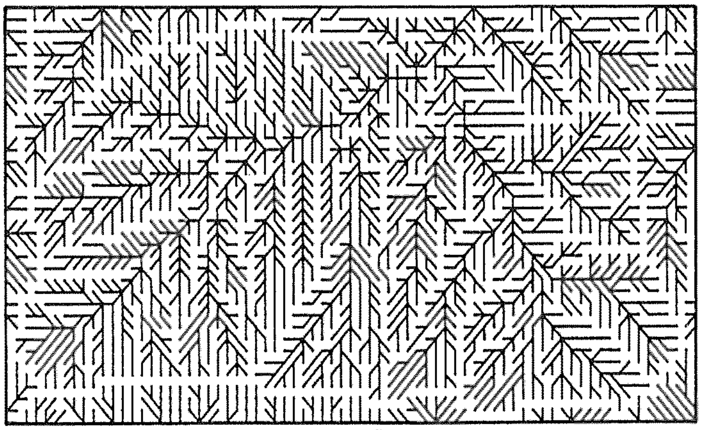


Figure 8. *Network of stream lines* derived from DTM's slope elements.

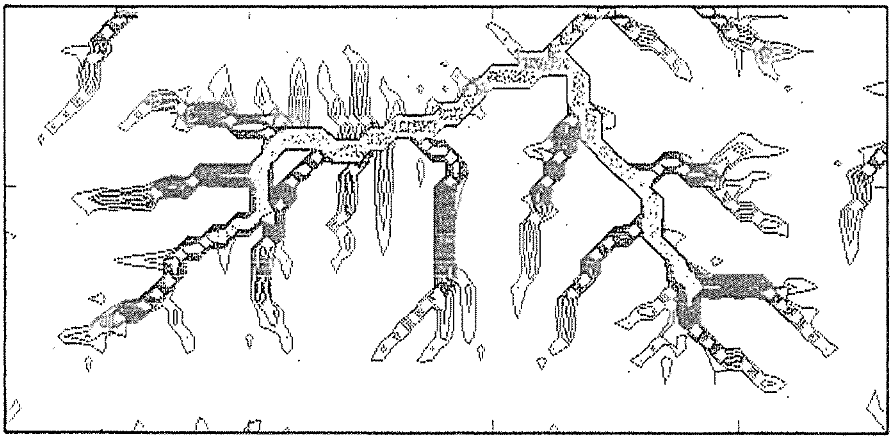


Figure 9. Delineation of the *drainage boundaries* by an interpolation algorithm; contour interval is set at drainage area of 1 ha.

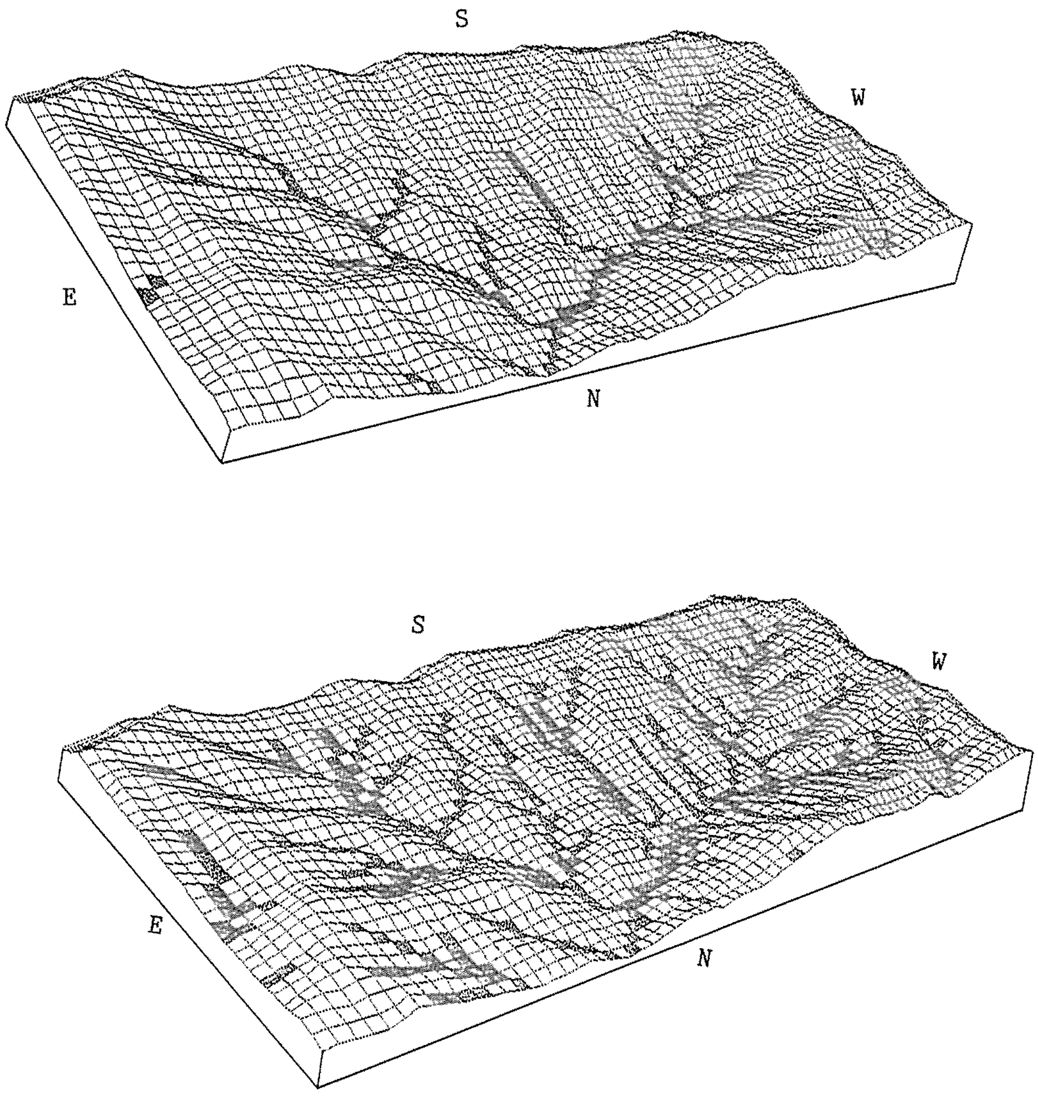
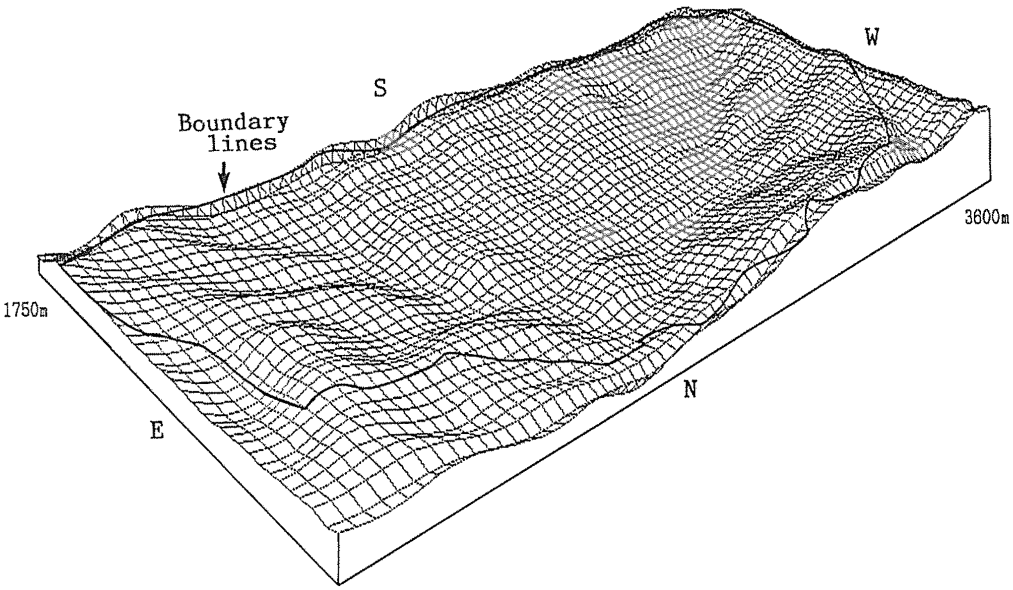


Figure 10. Comparison of two drainage patterns set at 5 ha (upper) and 1 ha (lower) drainage area.



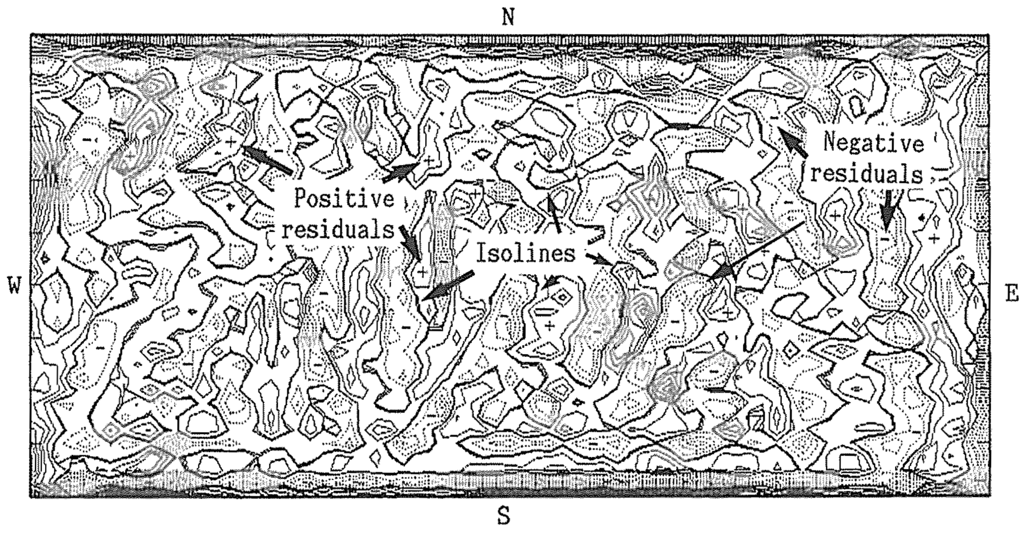
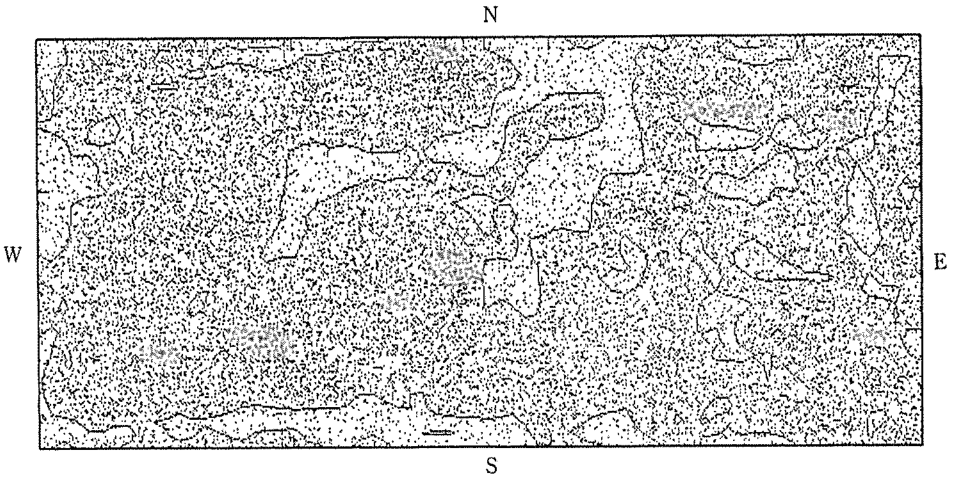


Figure 11. The configuration of the *Fourier trend surface model* obtained by applying the double Fourier series to the DTM surface (**upper**), using ***MAICE*** theory (***Minimum AIC Estimation***) which is statistic estimates of the Kullback-Leibler information criterion, and the *residuals* which are the remainder found by subtracing the autual from the computed trend surface value (**lower**); contour interval of residuals is set at **10 m**.
Solid line corresponds to **positive** and *dotted line* to **negative** residuals respectively. The *MAICE* order of the Fourier model is 13 (*goodness of fit*=92.3%). Trend surface, i.e. the spatial structures of relief represents large-scale or "*regional*" structural features on the landforms and the residuals represent small-scale or "*local*" structure. This method, therefore may suit for local terrain stability analyses directly related to specific features or points within the area.



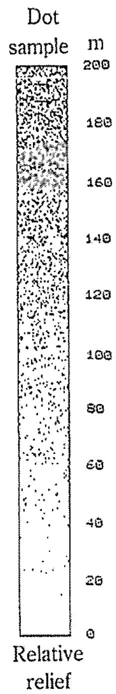


Figure 12. Distribution of **potentially stable slope sites** with homogenous configuration characterized by *relative relief* of surface. Sparsely dotted areas indicate smaller relief of surface and isolines drawn on the dot map are boundary of relative relief below **40 m.** In this procedure, the DTM surface is smoothed mathematically through digital filter windows selected by the user. The program then generates temporarily stored smaller elevation matrix units of window coverage and a central point is established, and elevation and relative relief of surafce are calculated for the center point of the window matrix by converting adjacent grid elevations. For study area, a **4×4 digital filter window** is set.

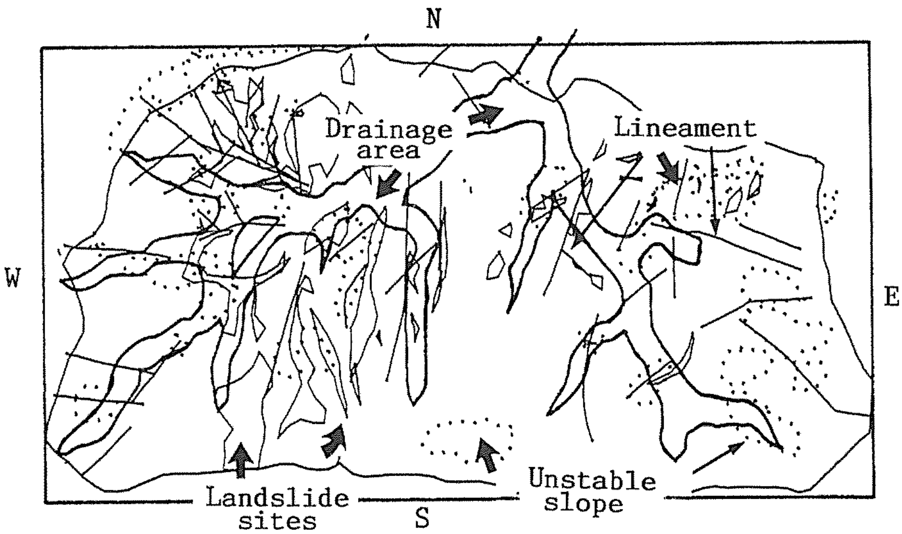


Figure 13. Output of the *sensitive terrain map* for critical sites associated with the location of routes, on the basis of information derived from airphoto interpretation and topographic map analysis. Such sensitive terrain factors are primarily based on landform characteristics, bedding structure, drainage characteristics, forest cover structure and observed landslide activity.

Digital sensitive terrain data base in numerical coded format, including the coordinates or the centroid is then created and stored by digitizing the sensitive terrain map.

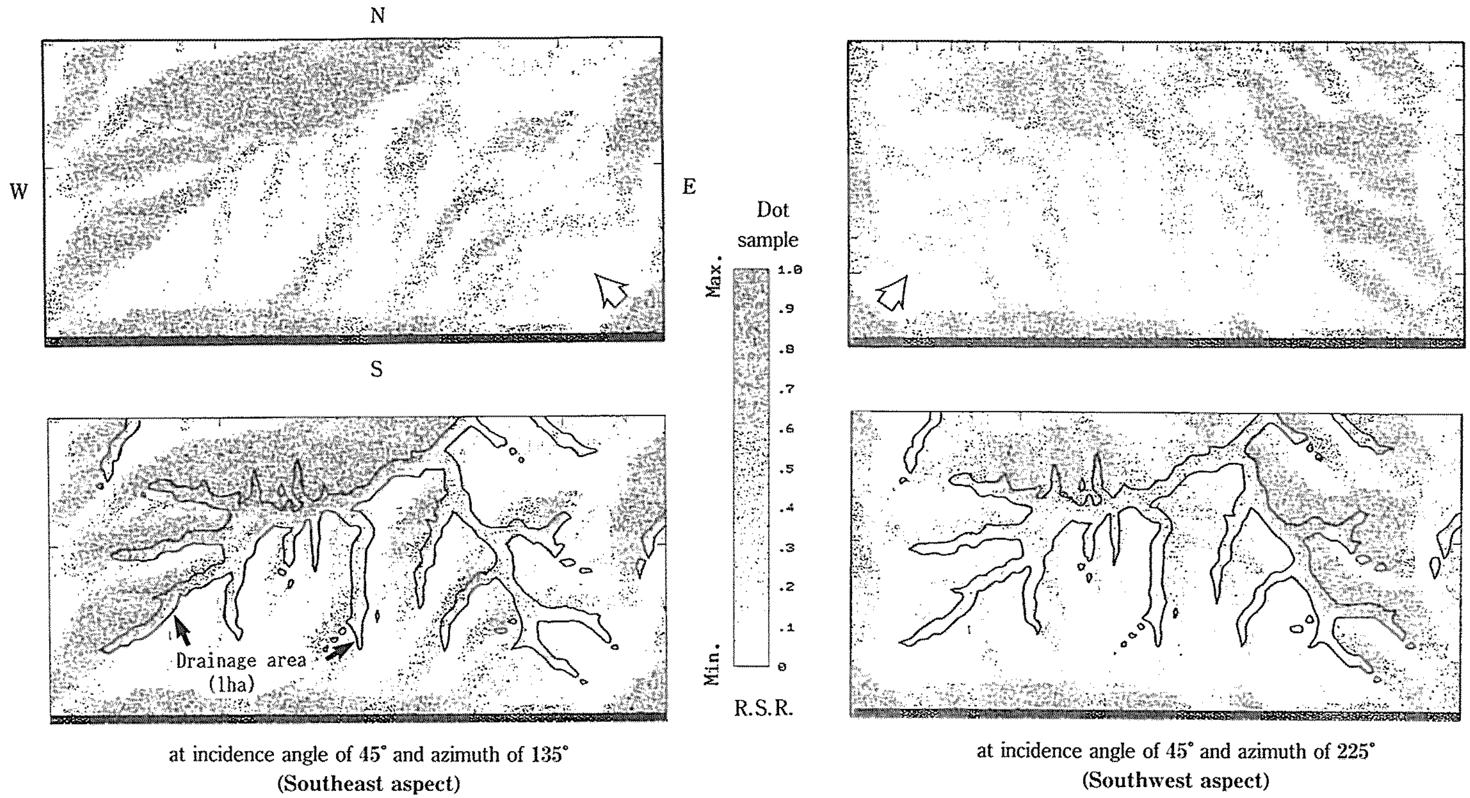


Figure 14. Distribution of *potential solar radiation* on the DTM surface across the study area **(upper)**, and 1 **ha-isolines of drainage area** overlaid on the dot map of potential solar radiation **(lower)**. This example gives the utility of digital terrain simulator in applications where drainage condition is important to phases of opening up planning, such as determining the route location of roads, landings, or defining mobility boundaries suitable for wet or dry weather operations; R.S.R. means the relative solar radiation.

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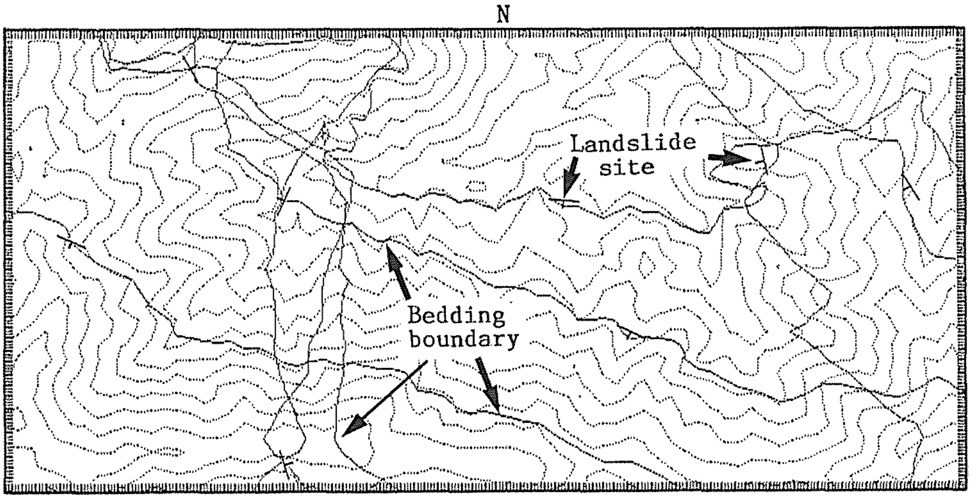

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Figure 15. Computer simulation of *bedding boundary* based on information derived from airphoto interpretation and field survey at 8 observed land-slide sites. Hypothetical bedding boundaries overlaid with digital terrain contour map of **50 m** interval are represented as a series of intersection points between bedding surface and topographic surface, because the bedding boundary is defined theoretically as the **zero-meter contour** of the difference between geological and topographic surfaces on the assumptions that any reverse faults, overfolding and overturning of beds would not occur in the area. *Lineament pattern* extracted from airphoto interpretation shown in **Figure 13** considerably correspond to structure and orientation of these bedding boundaries. The results suggest that it may be possible to designate demarcation points in identifying geological lineaments except artificial linear features in association with the bedding structure. The bedding structure model employed here, has been developed at Osaka City University (Shiono 1987).

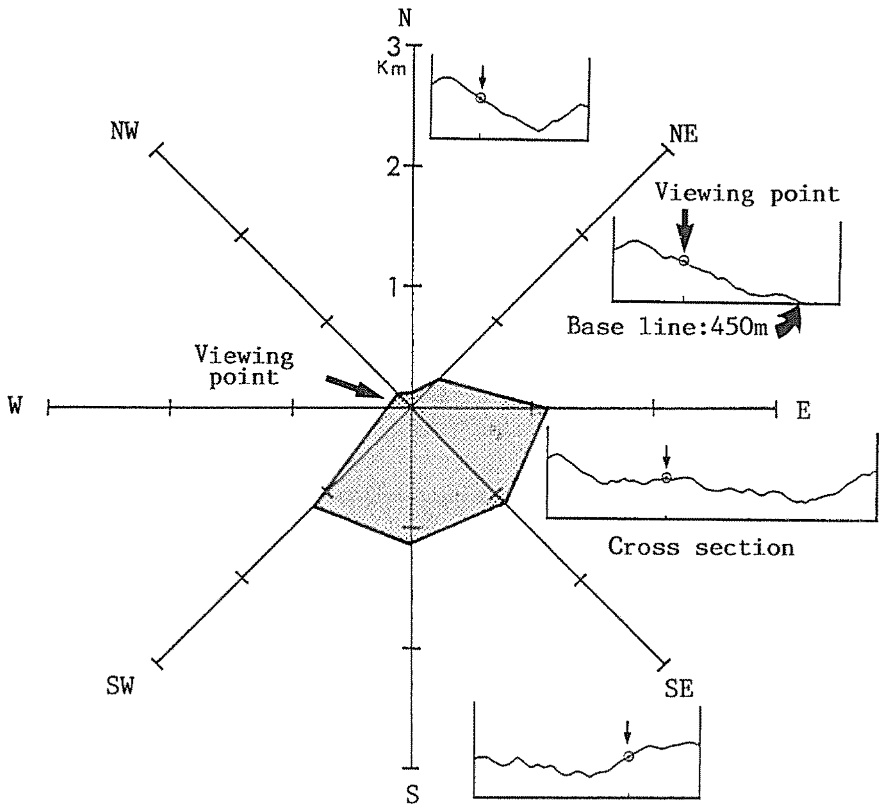

Figure 16. *Rader chart* representing the **viewing range** of the terrain from the selected viewpoint in the DTM coverage area; the coordinates (X and Y) of the given viewingpoint is (27, 12).

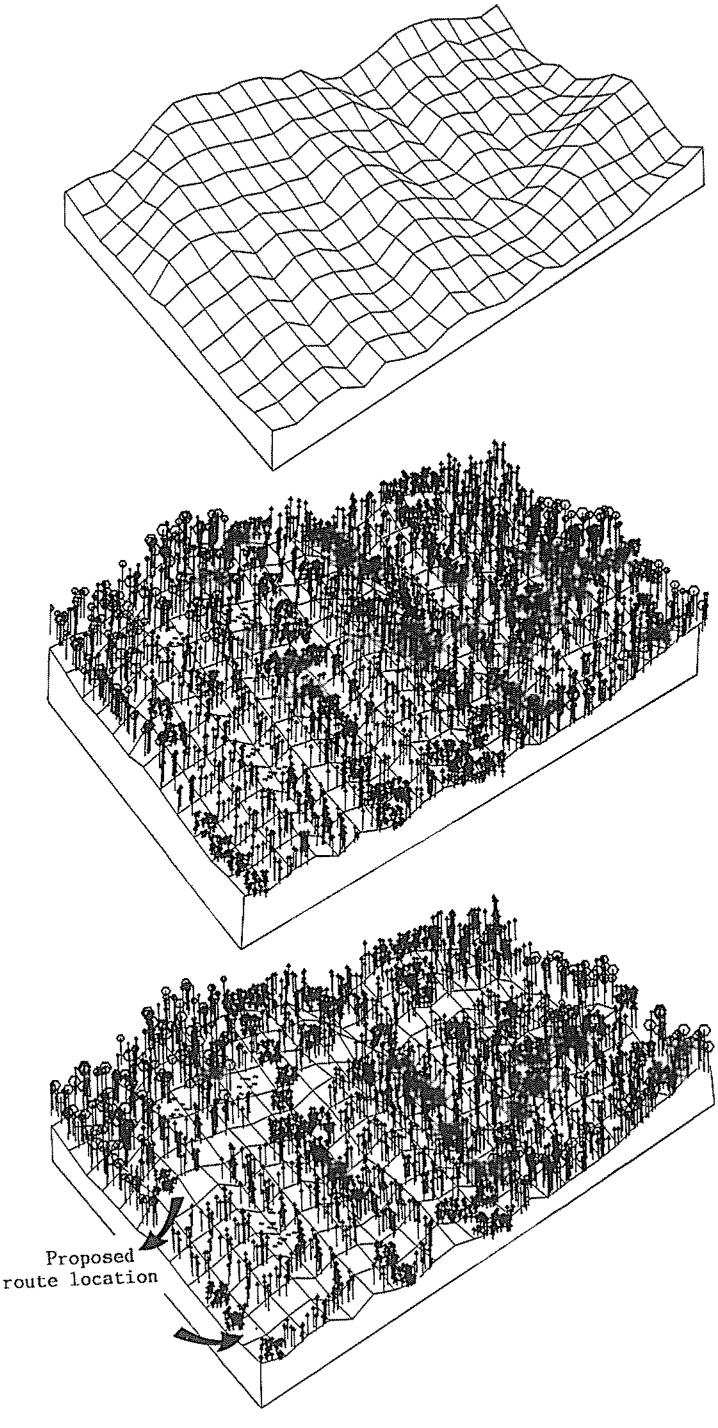
Proposed
route location

Figure 17. Perspective plot of a DTM surface (**upper**), symbolized forest stand cover (**middle**) and proposed route location (**lower**) from the selected viewpoint; the gridline spacing is set at **50 m**. The proposed alternative route location site among 10th, 11th and 12th-compartments is selected as the model area shown in Figure 3. The stand type is classified by the combination of tree species, canopy structure, crown density and age class based on aerial photo interpretation and forest type map analysis. The stand type of this area is divided into 10 kinds of codes. But actually it is very difficult to express all codes with different symbol marks because the number of codes from a symbol table available to a plotter is limited and only few symbol codes in these are visually fit for an image of vegetation. The codes except unstocked site's one were expressed with 6 symbol marks into which tree species were classified. Three and/or four symbol marks were plotted on each grid unit area. The size of symbol marks which would theoretically be propotion to the distance from a selected view point, was assumed to be constant here, and the transformation of symbol marks by the difference of an angle of depression was also disregarded. It is comparatively easy to identify stand type, proposed route location and unstocked site. But at ridge sides the overlapping of symbol marks makes a forest look denser as it is. The density of symbol marks makes us feel as if a forest may be dense at a steep slope and sparse at a hilly site.

Application

Outlines of the study area

Mie University Forest (total area: 457 ha) is located in the headwater zone of Kumozu River and stretches 4 km east to west and 1.7 km north to south in rectangular shape (**Figure** 4). The Forest is surrounded by several ridges above 1000 m and topographical features in the area are configurated with extreme undulations as a result of river dissections. Average gradient of slopes is 72% and steep slopes above 80% occupy about 35% of the total area (**Figure** 18).

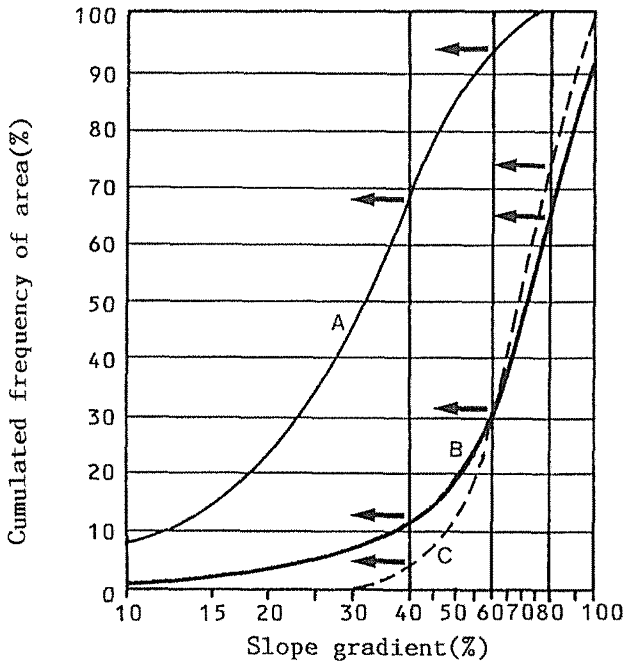

Figure 18. Terrain conditions of mountain forests associated with slope steepness (*cumulated slope frequency curve*); average slope gradient value is obtained by a resolution of all DTM grid cells per slope attribute cells.

District (Miyazaki and Mie Pref.)	Area (ha)	Average slope gradient (%)	Truck road density (m/ha)
A: Miyazaki Univ. For.	502	33.4	64.0
B: Mie Univ. For.	457	71.0	3.9
C: Moroto For. Co. Ltd.	456	74.2	72.9

Mesozoic strata comprising Biotite-hornblende granodiorite rocks which are easily collapsed by the rainfall, are widely distributed. Natural landslides occurring along a fracture trace of irregular slope surface and bare sites without vegetation cover on side slopes of ridges scatter all over the area. Predominantly fine grained cohesive soils derived from weathered sedimentary rocks are generally shallow. The average annual temperature is 12.4°C and the annual precipitation is 2517 mm.

The Forest consists of natural and artifical forests in the proportion of 6 to 4 (**Figure 5**). The natural forests (total area: 262.4 ha) are a mixture of coniferous and deciduous broad-leaved trees, and the stand structure represents the typical vegetation pattern in the northern parts of the Kii Peninsula. They are significant for the watershed conservation, landscape protections and wildlife sanctuaries so that the harvesting activities in this area have been in principle limited. A greater part of the artificial forests composed predominantly of *Cryptomeria japonica* and *Chamaecyparis obtusa* (total area: 162.2 ha) is on steep slopes, and most of the forests are occupied by fairly young trees corresponding to the 7 and 8 age-classes. According, special opening up measures are needed to protect the water quality and wildlife habitat upstream, and a combination of selective cutting with buffer zones near the drainage area and cable yarding further upstream has been agreed upon for artificial forests.

This system results in small area operations of clearcutting and thinnings scattered all over the plantation forests. According to the 9th-term harvest plan (1988–1992) which is renewed every 5 years, the average timber production accounts for 72 m^3/year to final cutting and for 9.96 m^3/year to thinning respectively.

The opening up area itself consists of two major drainage basins called the "*Nishimata*" and the "*Higashimata*". The existing road is part of road network plan of the University Forest (total length: 9539 m, **altenative R1**) and is classified as an all-weather secondary road. It runs about 1176 m to the centralized permanent landing sites located on both drainage basins from public roads. Based on slope ranges and soil conditions within which existing machinery can employed, a skyline cable system to small clearcutting and a monocable system to thinning operations are acceptable on most of slope terrain. Ground skidding with prepared skid trails is also acceptable in the comparatively flat portions on the eastern side of the area.

The development plan requires early extension of the road system from the permanent landing sites of both drainage basins into production forests including stands of advanced immature timber, but it must be decided whether to leave limited area of high erosion potential and steep slope above 80% undisturbed or to develop with special care.

The technical problems to be outlined for the opening-up planning in the area can be briefly described as follows: insufficient accessibility with existing road network, access to the area with operational restrictions concerning seasonal and terrain conditions, restricted route location to circulate all over the opening up area including the reserved forests, and environmental constraints on the routing due to hydrologica, ecological and aesthetic considerations.

Opening up alternatives

Alternative plan is a balancing and optimizing process of road/harvesting system. Instead of arriving directly at the best overall plan, the planner usually starts with a few basic requirements, works through a series of stages and then works back and forth between stages until the best compromises are reached. The alternative plan which follows is the result of the optimizing process, after various options have been tried, rejected and replaced by better one.

The alternative planning steps are outlined below in approximate chronological order.

(a) **Select harvest systems**

(b) **Assess protection requirements**

(c) **Assess silvicultural requirements**

(d) **Propose preliminary road network**

(e) **Block out harvesting systems**

Based on the basic information assembled and also the results of sensitive terrain factor analysis employed the **TERDAS, 5 road network alternatives combined with yarding systems** (cable crane, skidder and their combinations) are proposed (**Figure 19**). Including the status quo, they are named by a simple number

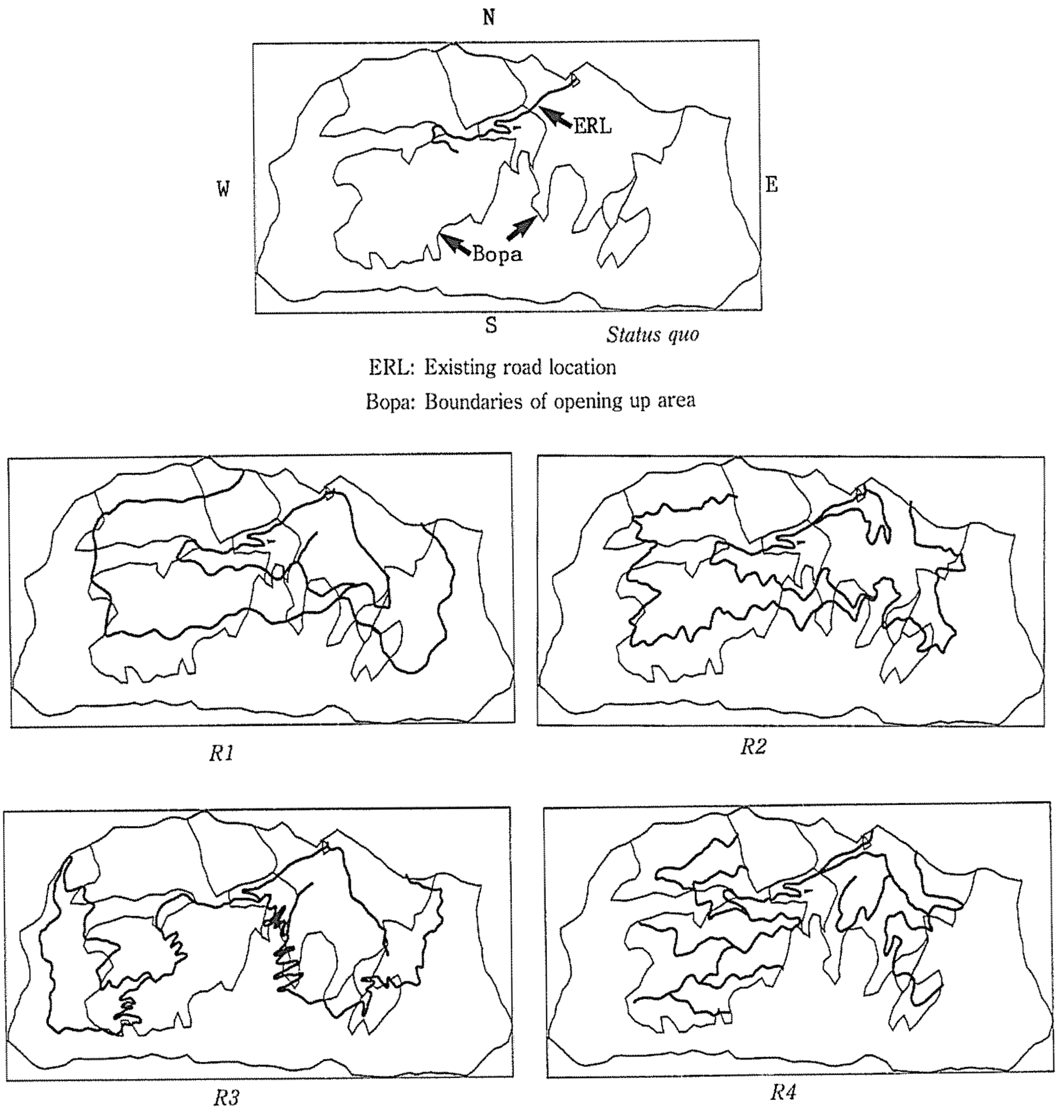

Figure 19. Computer-drawn alternative *route location* with opening up boundaries; alternatives (**Status quo~R4**).

from **R1 to R4** respectively. Proposed all the alternatives are based on a medium road density (21–28 m/ha) combined with cable yarding, ground skidding and their combination. Having in mind that the slope appears to be sensitive to major disturbances of its present equilibrium, the goal of the opening up of the project area has to be developed accordingly to the possibilities to construct roads in the different subareas and to their site qualities. Numerous cableway alternatives isolated as a result of the yarding feasibility are initially laid out on a topographic map by considering yarding system capabilities and terrain configuration, and are then appraised for apparent feasibility by field checks to the site. The best relationship between roads and yarding may not be reached in this attempt. The reuslts should be examined carefully and further improvements made if possible, by changing either road locations or system boundaries. The road/yarding system pattern shown in **Figure 20** is the end result after several trials.

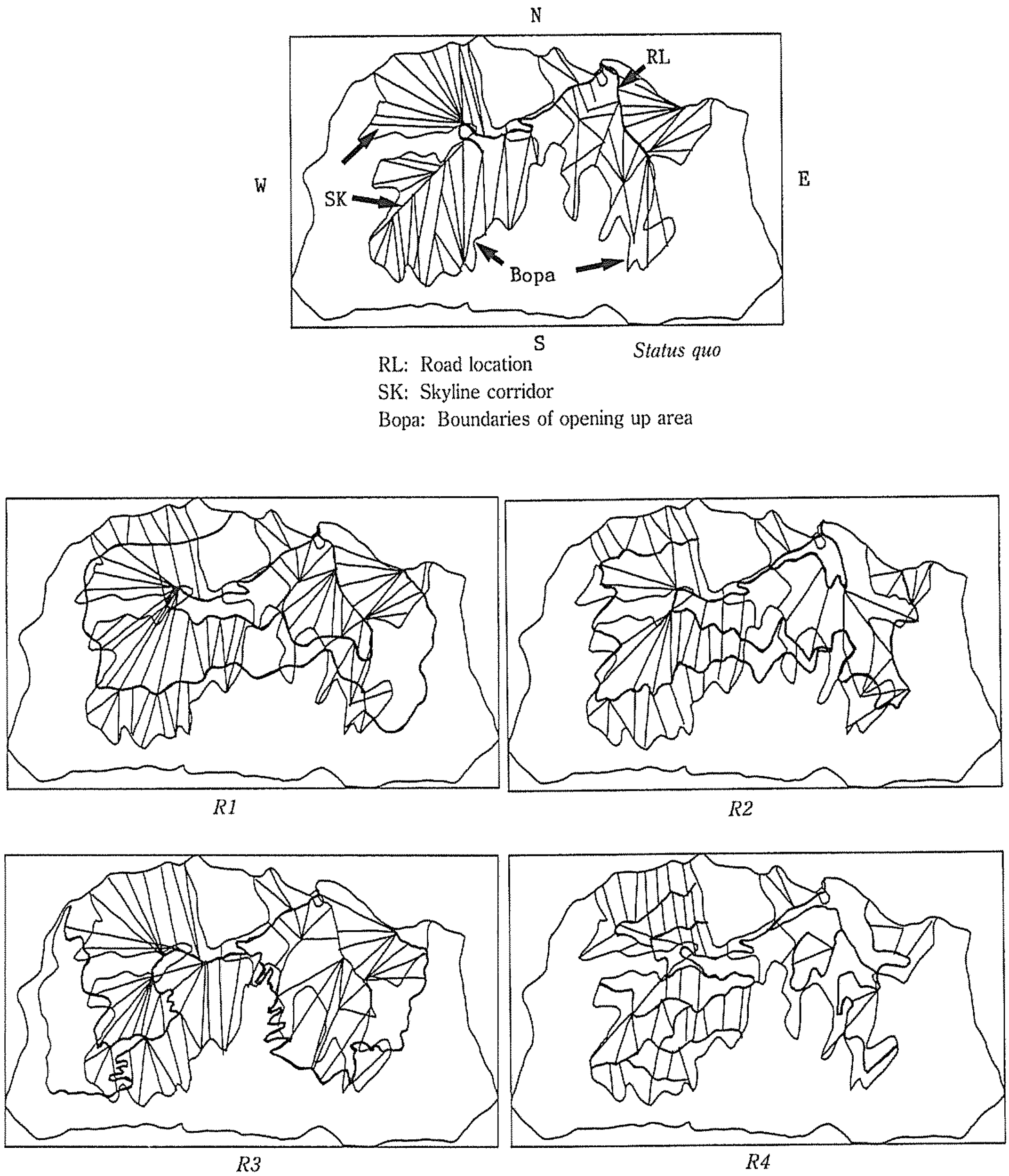

Figure 20. Proposed *skyline corridors* corresponding to alternative route.

R1 and **R2** alternatives are based on the long-term operational planning set at the moderate level of road network/harvesting system in the opening up area. The major area of the plantation forests reached by these roads would be within about 500 m and could therefore be harvested using semistationary cable systems such as Endless Tyler, hoisting carriage and falling block. The upper slope of the Nishimata basin requires to be harvested using a longer reach cable system. Differences between these alternatives are not obvious since it would require similar yarding distance and landing placement in the opening up area. There are, however, minor changes in determining terminal control points, suitable crossings of drainage area, pass-approach for spur road junctions, and the road grade limits. These options do not increase the potential off-road damage to sensitive sites as no further engineering work on steep slopes by suggesting additional raods and take on a major strategy of the protective functions of natural forest stands in the headwater zones stretching upward to the ridge lines. Disadvantages of the alternatives are that the potential improvement of silvicultural measures which could be obtained by providing access by roads would not be enoughly expected in these options. Proposed road locations in western parts of the opening up area need long walking distances for forest workers.

R3 alternative is projected based on the grade limits set, on the occurrence of good terrain for switchbacks and landings, and on the location of mature stands. The best landings and road construction are on the ridge. However, to reach the ridges it is usually necessary to locate a road along the valley bottom until a point is reached where climbing road can be located to a saddle from which ridge roads can branch out. The proposed rutes show the climbing road pattern from the existing roads along the balley. The alternative eliminates a large number of locations where roads are not wanted to construct due to its steep and partly unstable slopes depending on the geomorphological setting and are mainly serving the production forests. A problem is that the desired road spacing does not fit the dimensions of the opening up subareas. For example, calculations of the average off-road transport distance indicate 217 m, with the **spatial adjustment factor** (Road net adjustment factor: *V-corr***Transport adjustment factor:T-corr*) of 3.307.

R4 alternative considers the road length of 11069 m in the opening up area and no skidding roads in the protection forests. Harvesting will be performed by mobile crane yarders (yarding distances within about 300 m) in cable terrain slopes, and by small ground skidder with well-planned skid trail networks in the comparatively flat portions on the Higashimata area. Though the proposed alternative is only serving the plantation forests for the time being, its alignment permits an extension till the natural forest if it is required in the future. The overall road density reaches 24 m/ha and theoretical road spacing about 171 m, permitting the employ of a small cable crane yarder that allows to unload the timber of the road even before the yarder due to its small size. It may suggest an intensive operational effect and also the fulfillment of the overall protection function of the natural forest.

To avoid to lengthy a paper, the further discussion of characteristics on the alternatives is here omitted. A brief summary of the case study results in shown as the following **Table 1–4** and **Figures 21–24**.

Table 1. Area percent corresponding to proposed yarding systems

	Alternative road network														
	Status quo			*R1*			*R2*			*R3*			*R4*		
	UH	DH	Total	UH	DH	Total	UH	DH	Total	UH	DH	Total	UH	DH	Total
System Type															
Cable	0	85.29	85.29	29.80	19.07	48.87	4.16	54.82	58.98	10.62	64.68	75.30	4.09	17.56	21.67
Tractor	0.14	14.57	14.71	19.49	31.64	51.13	16.64	24.38	41.02	9.88	14.82	24.70	30.74	47.59	78.33
Total	0.14	99.86	100	49.29	50.71	100	20.80	79.20	100	20.50	79.50	100	34.85	65.15	100
	Endless Tyler/Hoisting carrige/Falling block systems												*Mobil tower yarder system*		

UH: Uphill yarding *DH*: Downhill yarding

Table 2. Statistics on the off-road transport distance

Distance (m)	—*Geometric transport distance*— Percentage of area (%)				
	Status quo	*R1*	*R2*	*R3*	*R4*
0–100	12.30	60.32	70.11	52.78	83.86
101–300	23.54	39.28	29.63	40.08	13.23
301–500	27.91	0.40	0.26	7.14	2.91
501–	36.25	0	0	0	0
Max	1050.00	447.77	373.26	490.48	354.77
Av	369.41	93.75	76.03	122.28	58.36
SD	239.44	68.84	58.58	103.96	52.86
CV	64.82	73.43	77.05	85.02	90.58
	—*Actual transport distance*—				
0–100	14.21	50.96	43.72	33.33	79.13
101–300	28.01	36.48	41.40	36.20	18.99
301–500	28.00	11.75	12.57	23.76	1.34
501–	29.78	0.81	2.31	6.71	0.54
Max	1137.51	600.00	791.40	725.00	758.60
Av	422.67	134.25	155.06	217.34	74.51
SD	264.32	117.87	139.40	170.60	83.81
CV	62.54	87.80	89.90	78.50	112.48

Max: Maximum distance (m) *SD*: Standard deviation (m)
Av: Average distance (m) *CV*: Coefficient of Variation (%)

Table 3. Characteristics of the proposed alternative routes

Items	Unit	*R1*	*R2*	*R3*	*R4*
RL	m	9538.9	10983.5	12777.8	11068.9
RD	m/ha	50.47	58.11	67.61	58.57
(RD)	m/ha	(20.87)	(24.04)	(27.96)	(24.22)
TRS	m	198.1	172.1	147.9	170.9
TATD	m	49.5	43.0	37.0	42.7
GATD	m	93.8	76.0	122.3	58.4
AATD	m	134.3	155.1	217.3	74.5

RNAF	—	1.892	1.767	3.307	1.367
OTAT	—	1.432	2.040	1.777	1.277
SAF	—	2.709	3.605	5.877	1.746
PSZ	%	52.9	56.6	30.2	73.2

RL: Road length *RD*: Road density
TRS: Theoretical road spacing based on road net models with rectangular area
TATD: Theoretical average off-road transport distance
GATD: Geometrical average off-road transport distance (the shortest distance)
AATD: Actual average off-road transport distance
RNAF: Road net adjustment factor (V-corr)
OTAT: Transport adjustment factor (T-corr)
SAF: Spatial adjustment factor (V-corr*T-corr)
PSZ: Area percent within the service zone of the roads
(*RD*): Road density for the entire area of University Forest

Table 4. Statistics on alternative route evaluation

—*Cost estimates based on proposed construction techniques*—						
Items	Unit	*Status quo*	*R1*	*R2*	*R3*	*R4*
RL	m	—	9011	10506	12056	11069
TEA	m^2	—	18936	24318	22670	20270
TEV	m^3	—	8611.5	11077.5	10371.5	9610.5
CC	yen	—	22579529	26328740	30212035	27738766

RL: Road length *TEA*: Total excavation area
CC: Construction cost *TEV*: Total excavation volume

—*Disturbance levels versus sensitive terrain factors*—						
[Drainage area]						
NCP	—	5	21	21	23	26
MDT	m	235	235	305	235	260
TL	m	745	2360	2640	3070	4760
[Protection forest]						
NCP	—	3	20	15	24	8
MDT	m	600	1135	635	2000	600
TL	m	890	4525	4075	7525	1555
[Erosin hazard sites]						
NCP	—	0	7	9	5	8
[Photolineaments]						
NCP	—	4	26	28	16	33

NCP: Number of cross points traversed by routes
MDT: Maximum distance traversed
TL: Total distance

Road standards (Road class III)
Roadbed width: 3 m Maximum grade: 15% Cut slope ratio: 1.2/1
Minimum radius of curve: 8 m

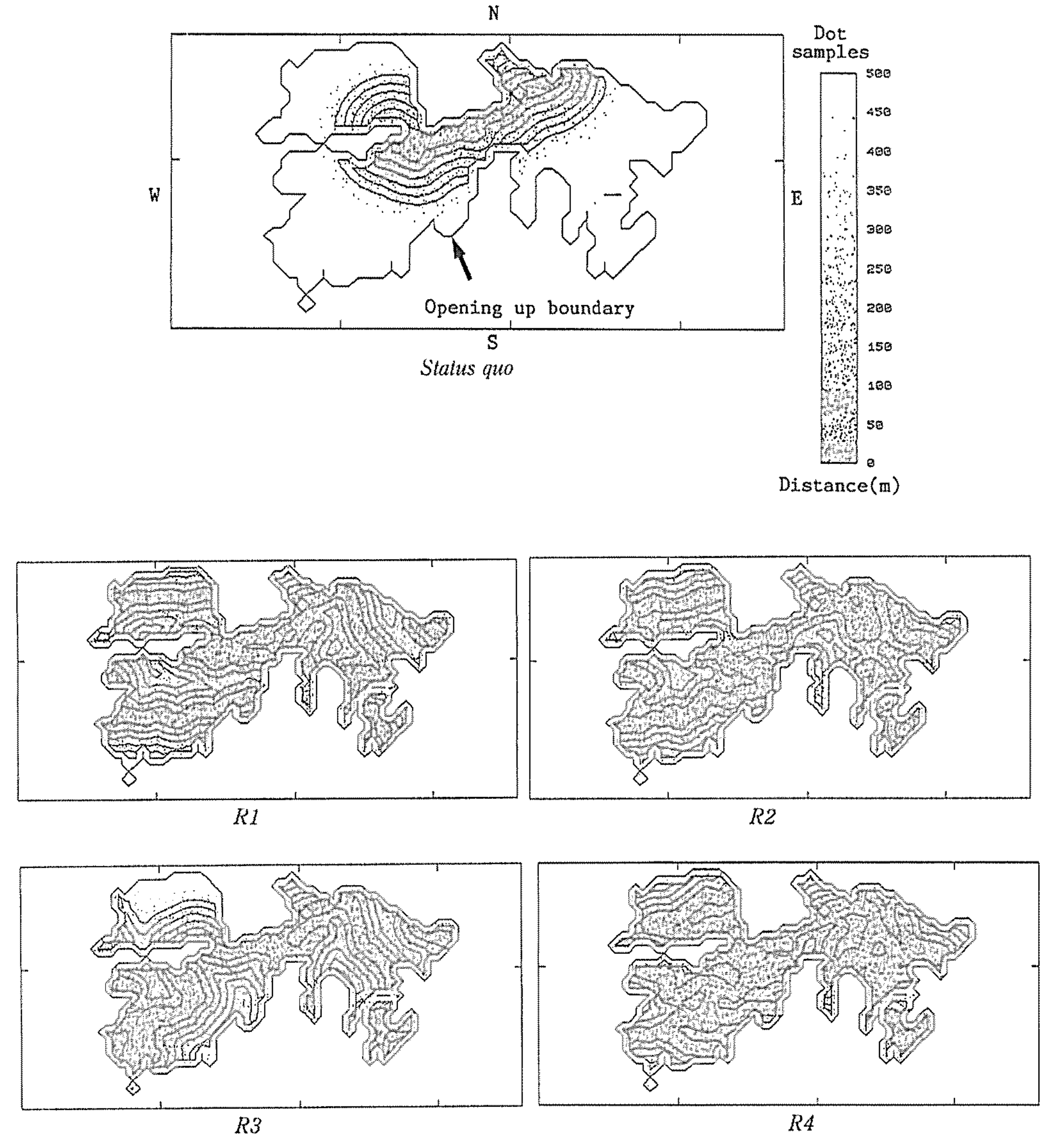

Figure 21. *Voronoi map* showing the *service zone* within the alternative route; **the geometric off-road transport distance.** Contour interval is 50 m and dot samples also represent 50 m unit.

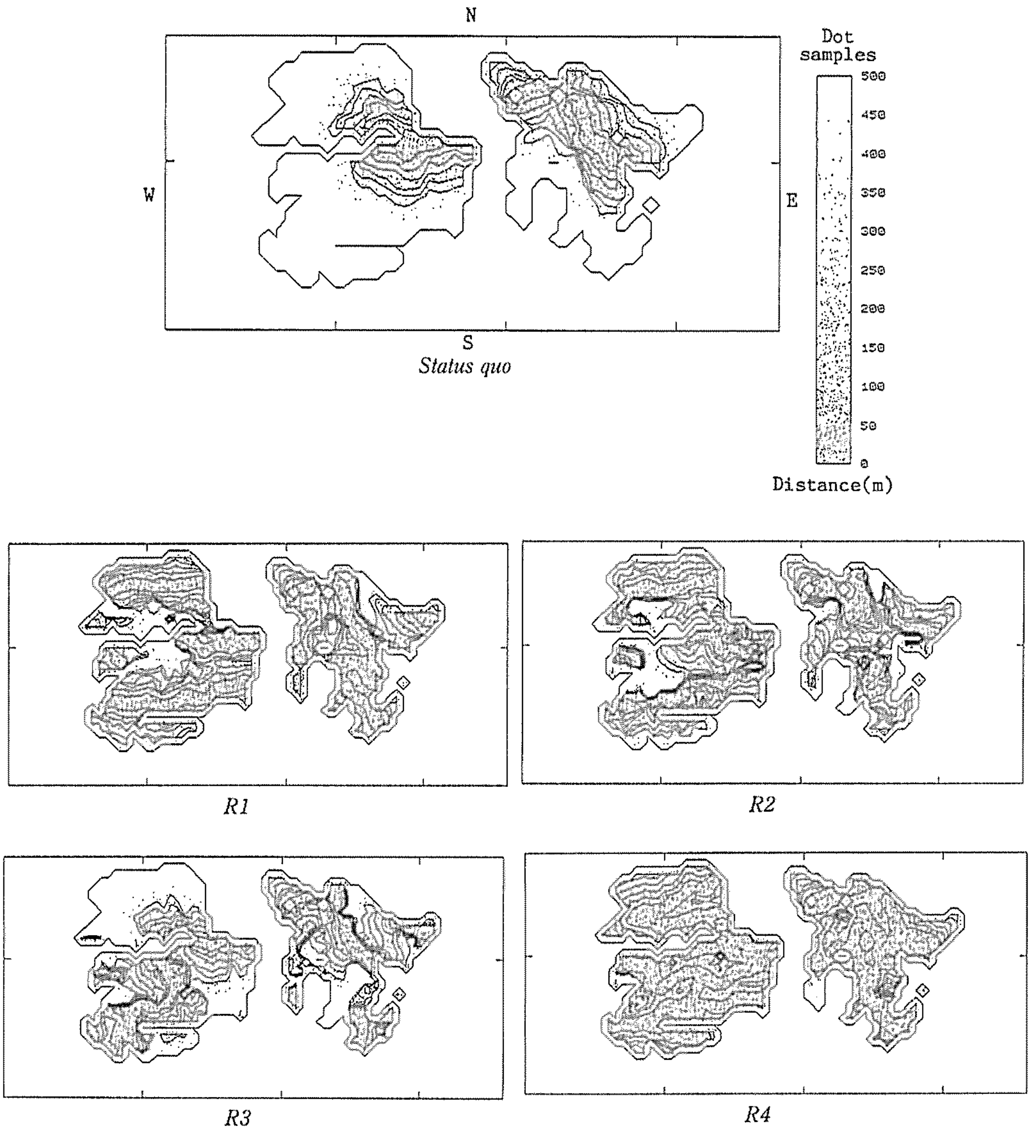

Figure 22. *Voronoi map* showing the *service zone* within the alternative route; **the actual off-road transport distance.** Contour interval is 50 m and dot samples also represent 50 m unit.

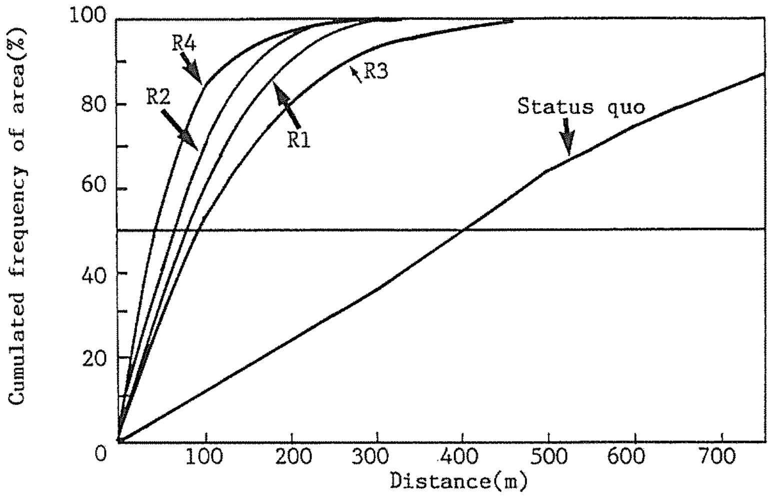

Figure 23. Scatter diagram of *area increase of service zone* within the alternative route; **the geometric off-road transport distance.**

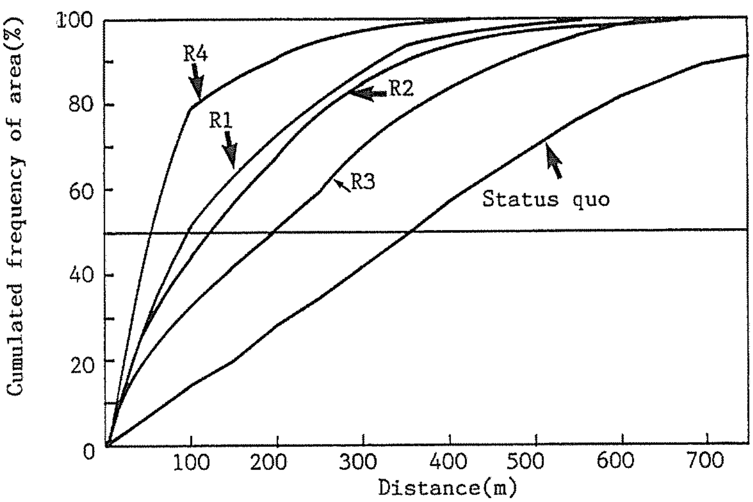

Figure 24. Scatter diagram of *area increase of service zone* within the alternative route; **the actual off-road transport distance.**

Because the unfavorable route location lay partly outside the opening up area, the choice of the most advantageous network is somewhat arbitary. The indication of the proposed alternatives, however, make it easier to provide a firm basis for subsequent discussions.

Conclusions

The development and the widespread use of microcomputer in recent years have created many new attempts on research methodologies of opening up strategies. Especially the fields of map-data processing (e.g. **CAD** or **GIS**) are now developing through making efficient use of computers which have many kinds of softwares including graphic systems, and they come to play a more importnat role in the decision-making process. It may suggest the orientation for solving many technological problems concerned with access to the mountain forests.

In this research it has been tried to describe an appropriate level of total-chance planning for steep slope mountain forests requiring coordination of road-development with several harvesting systems. For simple areas the level of detail is too much; for complex areas, too little. The basic objective of all planning is to minimizing uncertainties. Success in this will depend on:

—reliable thematic maps and information for the sensitive terrains
—well-defined operating objectives
—rational reconnaisance trips
—careful system choices
—thorough paper-planning and field-checking
—thoughtful reivew of all implications of the plan
—a readiness to change the plant for good reasons.

The **TERDAS** softwares and/or documentations used in this paper were developed and tested on a computer platform, **NEC PC-9801VX, GRAPHTEC MP-4300** plotter and **KW-9650** digitizer, and therefore are quite general and could be used without significant revision on any **PC** that uses **MS-DOS BASIC** programming language.

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地形情報処理システム *TERDAS* を導入した山岳林の代案路網配置/伐出システム計画の最適化

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本論は，**TERDAS:** *Terra-database system* と名付けた総合的な地形データ処理システムが，森林経営基盤整備計画における代案路網策定にあたって，どのように応用できるかを検討したものである。このシステムは，解析目的に応じた4つのサブシステムから構成されている。

すなわち，

(1) ボロノイ量情報に基づく作業方式単位別の地域利用区分

(2) 地形的特徴点・形態に関連した感受性領域（***Sensitive terrain area***）の判別とゾーニング

(3) 重ね合わせ，層化及び境界線処理による地形的な判別要素間の合成

(4) 視覚景観解析，流水域パターン，地層境界線及び相対日射量分布等のシミュレーション

の解析機能である。事例研究として，三重大学演習林の代案路網計画に，このシステムを応用している。