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Temporal Variation in Snowcover Area During Melt in Prairie and Alpine Environments

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K. Shook and D.M. Gray
University of Saskatchewan, Saskatoon, S7N 0W0 Canada

J.W. Pomeroy
Environment Canada, Saskatoon, Sask. S7N 3H5, Canada

Information on the temporal variation in snow-covered area of watershed during melt is requisite for accurate predictions of runoff. The amount of the gross watershed area that is snow-covered affects runoff primarily in two ways: a) it influences the melt rate, because patches of bare ground affect the energy balance of the snow field, and b) it governs the contributing area of runoff.

This paper examines the area-frequency and perimeter-area characteristics of soil and snow patches that form during ablation of seasonal snowcovers in Prairie and Alpine environments. It uses fractal geometry as a basis for quantifying these properties.

Image analyses are applied to aerial photographs taken during snowmelt on two small watersheds: one in the West-central part of the Province of Saskatchewan in the Canadian Prairies, the other in the alpine region of the Austrian Alps. The results of the study suggest that the soil and melting snow patches behave as fractals, that is their perimeter-area and area-frequency characteristics can be described by simple power equations with patch area. The perimeter-area ratio of the soil and snow patches decreases with increasing size of patch, but at a smaller rate than for Euclidean objects. The area-frequency characteristics of snow patches follow a hyperbolic distribution with relatively few large patches and numerous small patches. It is suggested that the soil and snow patches have the same fractal dimension. It is concluded that snow patches are not random and their size distribution is predictable.

The variation in the edge length of a snow field per unit basin area during ablation is demonstrated. A maximum value of the ratio is reached when a basin has 45-65 % snowcover. With snow coverage in this range the potential for local advection increasing melt under a specific set of climatic conditions is greatest.

Introduction

Hydrologists studying runoff from snowmelt in regions where basin elevation has no significant influence on melt have recognized that the maximum melt and runoff rates occur when the land is only partially snow-covered, often less than 60 %. Differences in these rates under partial and complete snowcover in a Prairie environment are demonstrated by Granger (1977) and Erickson *et al.* (1978). They show maximum runoff rates ranging to 18.6 mm/°C-day from isolated snow patches, depending on land use, compared to maximum surface melt rates ranging from 8 to 12 mm/day for complete snowcovers.

Large areas of bare ground within a snow field significantly alter the energy balance. Bare ground, having a lower albedo than snow, absorbs larger amounts of solar radiation and heats more quickly. Local advection of energy from the bare patches and the turbulent transfer of latent and sensible heat to adjacent snow surfaces increases the melt rate. Melting due to advection is most noticeable along the edges of snow patches. Weisman (1977) suggests the melt rate is a maximum near the leading edge and decreases by one-third in approximately 15 to 20 m. Beyond these distances the rate decreases according to a power-law relationship. Averaged over a snow season the relative importance of radiation and turbulent energy to melt depends on the size of the snow field. Small snow patches are dominated by turbulent melt throughout the season, or until they disappear, but larger snow fields are dominated by radiation melt early in the season and turbulent melt late in the season as they decrease in area.

Most hydrologists agree that sensible heat comprises the major source of the total turbulent melt energy under patchy snowcover. Gray and O'Neill (1974) estimated that over one six-day period on the Prairies, 44 % of the energy supplied to an isolated melting snow patch was by sensible heat; during the same period sensible heat transfer over a complete snowcover was 7 %. Cox and Zuzel (1976), in a study of the energy balance of late-lying snowdrifts in Idaho, reported that 71 % of the energy available for snowmelt and evaporation came from sensible heat transfer.

Knowledge of the extent of snow-covered area under patchy snowcover is important for runoff prediction. It is necessary to include a measure of coverage in the calculations of melt because less meltwater is produced on a basin than if 100 % snowcover is assumed. Erickson *et al.* (1978) reported strong correlations between daily snowmelt runoff, mean daily air temperature and extent of snowcover on small watersheds in the Canadian prairies. Martinec and Rango (1986), warn against compensating a meltwater difference that arises from erroneous snowcover information by "optimizing" the melt factor used to calculate snowmelt.

The above discussion indicates that geometrical features of soil and snow patches play an important role in snowmelt and runoff processes of a patchy snowcover. Conceivably, it may be possible to use these features to adjust "estimated" melt quantities for decreases in snow-covered area as a snowcover ablates. The study reported in this paper uses fractal geometry to describe the perimeter-area and size distribution of soil and snow patches of Prairie and Alpine snowcovers at various stages of melt.

Principles of Fractal Geometry

Since the 1970's, many researchers have employed fractal geometry to quantify complex or seemingly random phenomena. The field of fractal geometry, which was developed by Mandelbrot (1982), provides an alternate theoretical basis for analysing, describing and modelling systems. In applying the approach to study patchy snowcover, the soil and snow patches are assumed to be fractal objects. That is, they have no characteristic size or scale and their quantity of roughness remains constant under increasing magnification. This latter property is known as self-similarity. The parameter that identifies and quantifies fractal objects is the fractal dimension, D. Objects that are easily described by conventional Euclidean geometry have dimensions of 0 (points), 1 (lines or curves), 2 (areas) or 3 (volumes). Fractal objects, in contrast, have non-integer dimensions. The edge of a fractal object or a fractal curve will have a dimension between 1 and 2. The magnitude of the fractal dimension is related to the degree of convolution of the curve. For example, when $D = 1.0$, the curve is non-fractal (Euclidean). Conversely, if $D = 2.0$, the curve is infinitely complex and convoluted, filling up space as efficiently as a two-dimensional Euclidean object.

Perimeter-Area Relationship

The perimeter-area relationship of a collection of objects that behave as fractals is described by the equation

$$P \equiv kA^{D_P/2} \qquad (1)$$

where

P – perimeter,
k – constant,
A – area, and
D_P – fractal dimension (values of $D_P > 1.0$).

Eq. (1) has been established theoretically for synthetic fractals (Mandelbrot 1982) and has also been found to apply for natural objects, such as clouds and rainfall areas (Lovejoy and Mandelbrot 1985).

Korčak's Law

Korčak's law is a rule of thumb that has been found to apply to many fractal systems. The law states that the areas of natural fractal objects will follow a hyperbolic size distribution, *i.e.*

$$F(A) \equiv c\,A^{-D_K/2}, \quad A \geq A_{min} \tag{2}$$

where

$F(A)$ – fraction of the number of objects with a size equal to or greater than area, A,

c – $A_{min}^{D_K/2}$, the area of the smallest resolution cell,

D_K – fractal dimension.

D_K indexes the degree of concentration of area. A small value indicates that most of the area is concentrated in only a few objects; a large value indicates a uniform distribution of areas.

Although both the perimeter-area relationship and Korčak's law may be used to calculate the fractal dimension, the values of D_P and D_K are not always identical, or even similar. One reason for the difference is the tendency for natural surfaces to be self-affine (scaling by different factors in different directions) rather than self-similar (scaling by the same quantity in every direction).

Image Analysis of Ablated Snowcovers

Image analyses were applied to aerial photographs taken during snowmelt on two small watersheds: Smith Tributary (Lat. 51°19'N, Long. 108°25'W) in the prairie region of West-central Saskatchewan, Canada, and an alpine watershed, the Längental catchment (Lat. 47°12'N, Long. 11°E) located in the Austrian Alps near Kühtai, Austria. Smith Tributary (Fig. 1) has a surface drainage area of approximately 1.9 km^2. Its main drainage ways are deeply-incised and act as major areas for the accumulation of wind-transported snow. The primary vegetation on the channel slopes is native Prairie grass and shrubs. Smith Tributary drains an upland area of flat and slightly-rolling topography that is under cultivation for the production of cereal grains by dryland farming. Approximately, 30% of the land is fallowed (bare ground) each year.

The photographs used in the analyses of snowcover on the Smith Tributary were taken in the spring of 1972 (O'Neill 1972). They are composites or mosaics assembled from portions of many air photos taken of the watershed. A separate mosaic was compiled for each day the air photos were taken. Since the area was flown every day or two during the melt period, which extended from March 7-29, 1972, a comprehensive record of the disintegration of the snowcover during ablation was recorded.

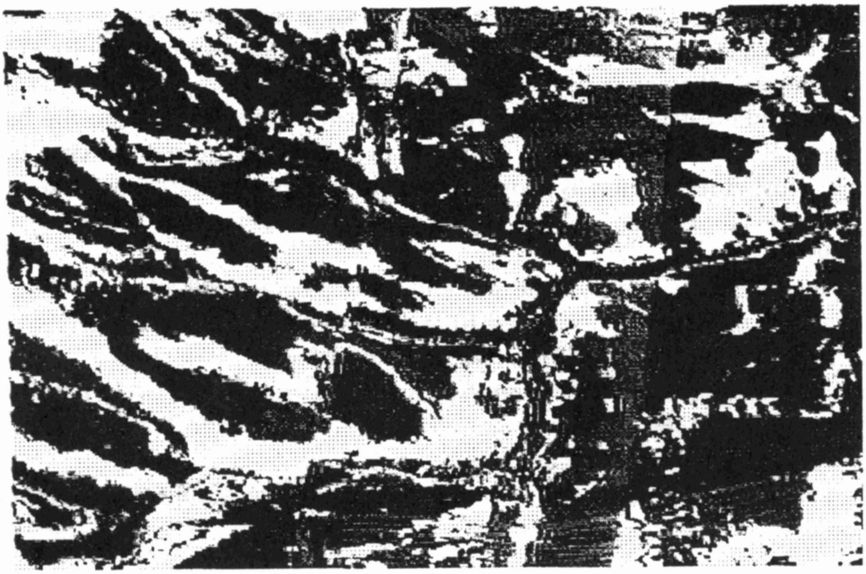

Fig. 1. Image of headwaters of Smith Tributary. Scale approximately 1:4300.

O'Neill's mosaics were not entirely ideal for analysis because the photographs were shot at oblique angles, which were not consistent from day to day. The obliquity caused some distortion of individual patches and in the shape of the watershed. Despite the distortion, the mosaics have the advantages: a) the quality of the individual photographs is high, b) they are large and provide good detail of small soil and snow patches, and c) the series provided the opportunity to examine the effects of the stage of snowmelt on the fractal dimension.

The data for the alpine basin were copies of a series of nine snowcover patterns for the Längental catchment located near Kühtai, Austria reported by Kirnbauer *et al.* (1991), see Fig. 2. The patterns were generated synthetically from oblique air

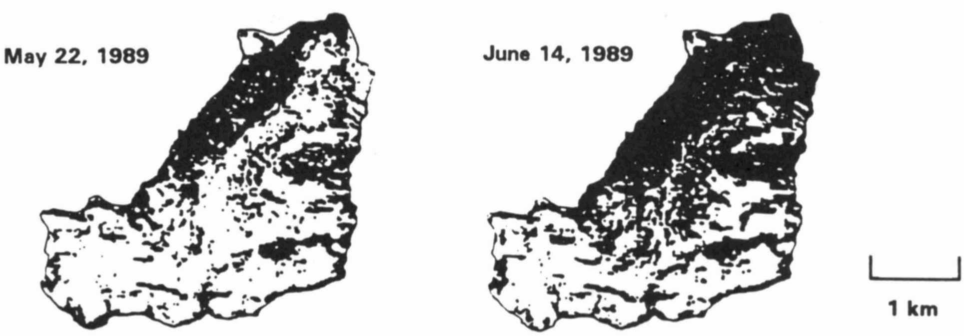

Fig. 2. Snowcover patterns on Längental catchment, near Kühtai, Austria reported by Kirnbauer *et al.* (1991).

photographs and provide a record of changes in snowcover distribution occurring between March 20, 1989 to July 20, 1989. Because the images were acquired from printed material, they were not of photographic quality.

The Längental catchment has an area of 9.4 km^2. Elevations within the basin range from 1,900 to 3,050 m. The landscape of the basin is formed of crystalline bedrock. Most of the basin falls above the timber line and vegetation is limited to a few species: cembra-pines, larches, Alpine roses and Alpine meadows (Kirnbauer *et al.* 1991).

The perimeters and areas of the soil and snow patches on both watersheds at various stages of melt were obtained from analysis of the aerial mosaics. At the beginning of snowmelt, since most of the ground surface is snow-covered, only the soil patches were measured. Conversely, toward the end of melt, only patches of snow remain. When the snowcover was about 50 % of the surface area, either soil or snow patches could be measured.

The measurement procedure involved two steps: Image Acquisition and Image Analysis.

Image Acquisition

Images of the photographs of patchy snowcover were obtained using an image analysis system at the National Hydrological Research Institute, Environment Canada. The sytem consisted of: a) Hardware: Compaq (IBM PC-AT compatible) computer, Video camera, and Framegrabber (acquires image from the video camera), and b) Software: Jandel Scientific JAVA. The resolution of the image analysis camera, framegrabber and computer display is 640 × 480 pixels. Every attempt was made to acquire the images in a consistent manner, however certain difficulties required changes in methodology. Many photos had been printed on glossy paper, which reflected the room lights. The reflections had to be eliminated because, if detected, they distort the tone distribution of the picture and they may be incorrectly identified as snow patches. A second difficulty was the aspect ratio of many photographs was higher than that of the video camera and computer screen. This problem was overcome by scanning the photographs in three or four sections.

Analysis of Scanned Images

The scanned images were analysed using the Jandel Scientific JAVA program. Although a common procedure was followed, some adjustments in technique were required to accommodate the variability in quality of the scanned images. For example, it was not possible to use the same tone setting for each image because the contrast level of the images varied widely. The analysis of each image required the operator to set a tone threshold to distinguish between objects and their backgrounds. Unfortunately more formal analytical procedures are not available in JAVA. The selection of the tone threshold is subjective and affects the values of the data collected from the image. However, it is not obvious exactly how the variation in threshold translates into variation in the processed data. In all cases, the threshold was adjusted so that the resulting picture looked realistic. This involved showing the greatest amount of data without causing continuous patches to divide into smaller patches. Once the threshold had been set, the computer system automatically measured the perimeters and areas of the black or white objects (whichever was selected) in the "area-of-interest". The perimeters and areas measured on the photographs were converted from pixel units to metres and square metres respectively.

Results and Discussion

Korčak's Law

Figs. 3-6 show logarithmic plots of the size-distribution of soil and snow patches on the Smith Tributary and Längental watersheds at two levels of snowcover. As shown, the patches generally follow the hyperbolic size distribution described by Korčak's law over most of the range of sizes. The values of D_K, which were calculated from the slope of the "best-fit" line of the size distribution of each data set available, are given in Table 1. The data show: a) the D_K-values for the watersheds are similar: Smith Tributary: D_K (average) = 1.282; Längental: D_K (average) = 1.408, and b) the D_K-values for the soil and snow patches are in close agreement: Smith Tributary: D_K (average, soil) = 1.279; D_K (average, snow) = 1.284, and Längental: D_K (average, soil) = 1.376; D_K (average, snow) = 1.447.

Although the patches generally conform to Korčak's law, the largest patches appear to deviate most from the distribution. This is unfortunate since the largest patches are generally of the greatest interest. The hyperbolic size distribution of the patches implies that a major part of the total patch area is contained in a few patches. In the majority of cases, the 200 largest patches account for over 90 % of

Table 1 – Values of the fractal dimensions, D_K and D_P, for the Smith Tributary and Längental Catchment at various stages of snowcover ablation.

Smith Tributary				Längental Catchment			
Date	Snow Cover	D_K	D_P	Date	Snow Cover	D_K	D_P
13-Mar-72	87.11%	1.385	1.594	20-Mar-89	70.50%	1.243	1.569
14-Mar-72	78.51%	1.208	1.573	24-Apr-89	77.40%	1.378	1.684
15-Mar-72	69.53%	1.223	1.615	4-May-89	86.80%	1.775	1.673
16-Mar-72	65.06%	1.300	1.592	22-May-89	65.50%	1.260	1.595
18-Mar-72	45.76%	1.324	1.605	9-Jun-89	50.20%	1.226	1.596
21-Mar-72	21.19%	1.320	1.571	14-Jun-89	43.60%	1.299	1.587
22-Mar-72	18.82%	1.278	1.548	26-Jun-89	31.80%	1.359	1.581
26-Mar-72	13.73%	1.232	1.536	5-Jul-89	25.70%	1.625	1.547
29-Mar-72	10.28%	1.268	1.553	20-Jul-89	8.80%	1.505	1.578

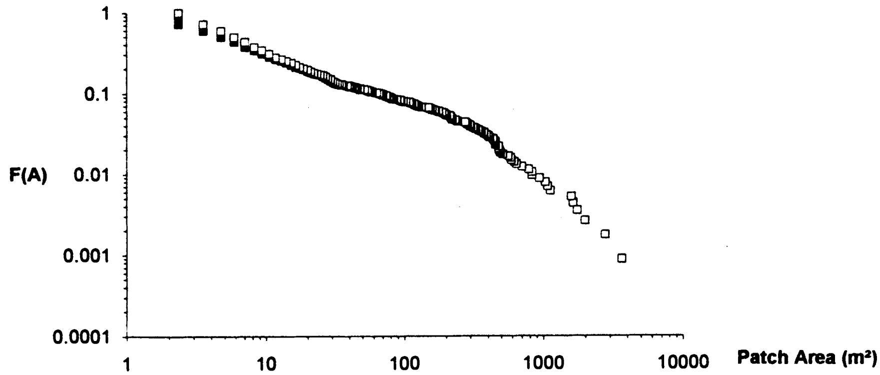

Fig. 3. Area-frequency distribution of soil patches on Smith Tributary, March 13, 1972, 87.1 % snowcover.

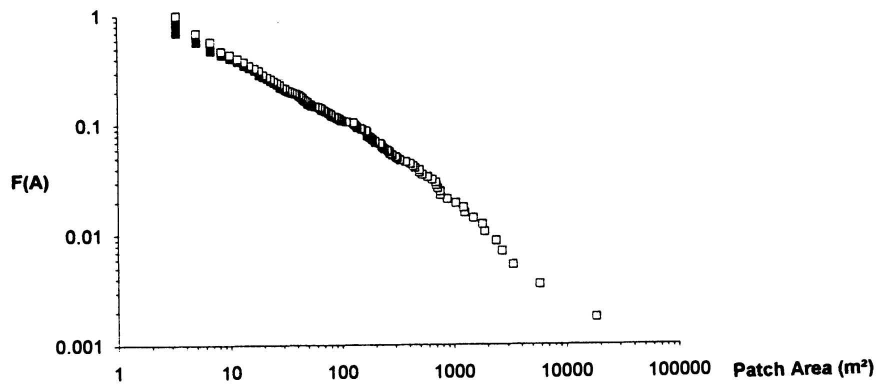

Fig. 4. Area-frequency distribution of snow patches on Smith Tributary, March 29, 1972, 10.3 % snowcover.

the total measured patch area (Shook 1993). The largest patches are generally smaller than predicted by Korčak's law. This has the effect of increasing the number of patches required to comprise a given fraction of the total snow-covered area.

The tendency for the larger-sized patches to depart from Korčak's law is attributed to several factors.

a) ***Human factors*** – Large patches are the most prominent to the operator of the image analysis system and it is possible that there is an unconscious bias that causes an operator to set the threshold tone incorrectly on the basis of these areas. All analyses were performed after scanning of the photographs, therefore the consequences of setting the threshold are not obvious. Had a more formal image classification system been available, the operator-induced error might have been eliminated.

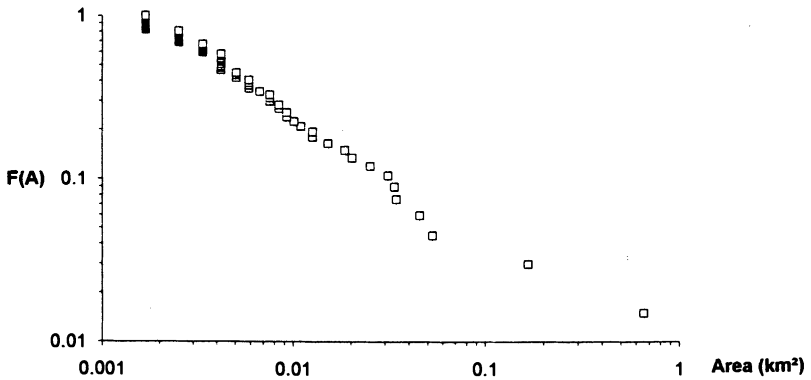

Fig. 5. Area-frequency distribution of soil patches on Längental catchment, May 4, 1989, 86.8 % snowcover.

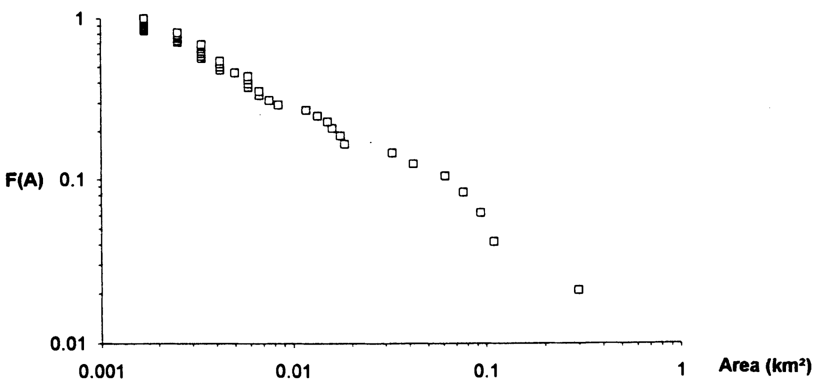

Fig. 6. Area-frequency distribution of snow patches on Längental catchment, July 20, 1989, 8.8 % snowcover.

b) ***Area-of-Interest, AOI*** – The size of the area-of-interest (photographic area scanned) represents the imposition of an artificial scale on a natural landscape. The restriction posed by the size of the AOI may contribute to the departures by "cutting-off" and/or excluding large patches. To study the effects of the size of the AOI on the size distribution of snow patches, one photograph was analysed with several concentric (to eliminate large-scale variation) areas of interest. The results of these analyses are shown in Fig. 7. The data show that the smaller the area-of-interest, the stronger the tendency for the size distribution to deviate from logarithmic relationship described by Korčak's law.

The size of patch at which the departure takes place is not constant, but decreases in area with decreasing size of the AOI. This could imply that the cause of the change in slope is scale-related, perhaps to the width of the AOI. A simpler, more plausible explanation is that it is related to the number of patches. A small

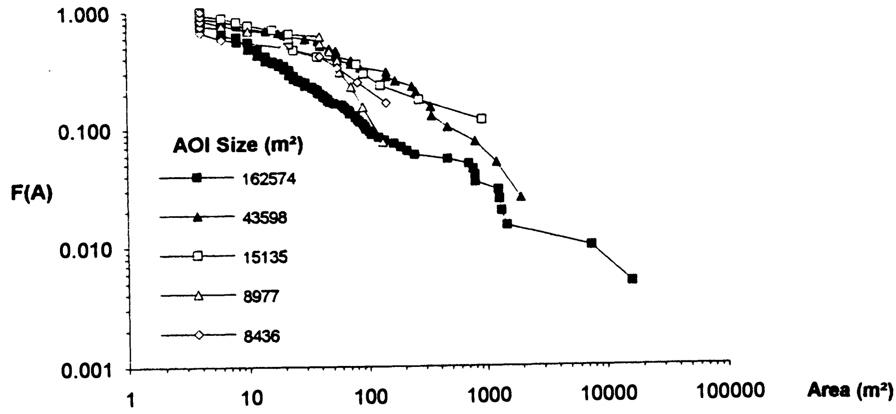

Fig. 7. Influence of the size of the area-of-interest on the shape of the area-frequency distribution of snow patches.

area-of-interest contains few patches. The effect of random variation in patch sizes in a small data set will be exaggerated by the small number of patches. In effect, the problem is one of sampling – a small AOI will result in a small sample that is a distorted representation of the overall set.

c) ***Physical Limitations*** – All natural objects that behave as fractals do so over a limited range of sizes, as most natural processes either have a significant length or only operate over a limited range of scales. Perhaps, the change in slope represents the size limit of fractal processes. It seems reasonable to expect that landscape topography will limit the maximum size of patch(es) that is feasible at any time. Large-scale features of areal snowcover may be dominated by topography. Gullies, ravines, hilltops and knolls and other areas of major snow accumulation or erosion, may form snowcovers that are fractal, only fractal at larger scales, or may have a different fractal dimension.

When a snowcover begins to ablate, landscape topography is an important factor in determining the location and size of soil patches. Snow patches develop rapidly on the tops of hills, where the snow is thinnest, and on south-facing slopes. As melt progresses, snow on flatter regions ablates. Therefore, the curvature in the size-distribution of soil patches may be expected to be greatest near the beginning of snowmelt and to decrease as the snowcover disappears from the flatter areas, which is less-dominated by large-scale topography.

Unlike soil patches, snow patches decrease in size throughout the period of melt. The size distributions of snow patches on the Smith Tributary generally show increasing curvature with increasing stage of melt. Presumably the snow patches that remain at the later stages of melt lie in gullies and other depressions and are influenced by the large scale topography.

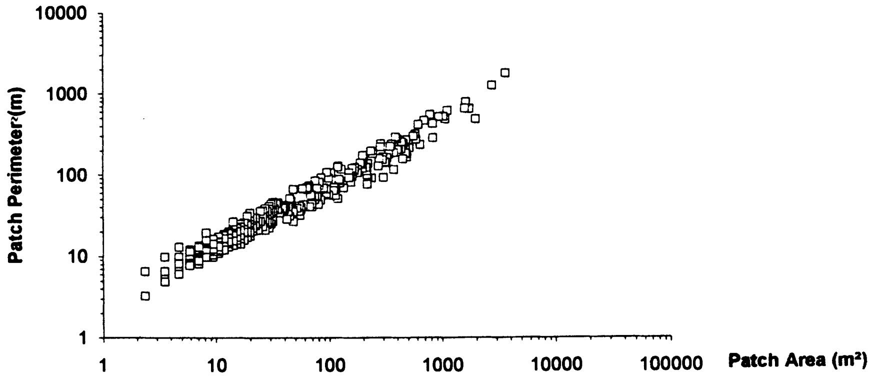

Fig. 8. Perimeter-area association of soil patches on Smith Tributary, March 13, 1972, 87.1 % snowcover.

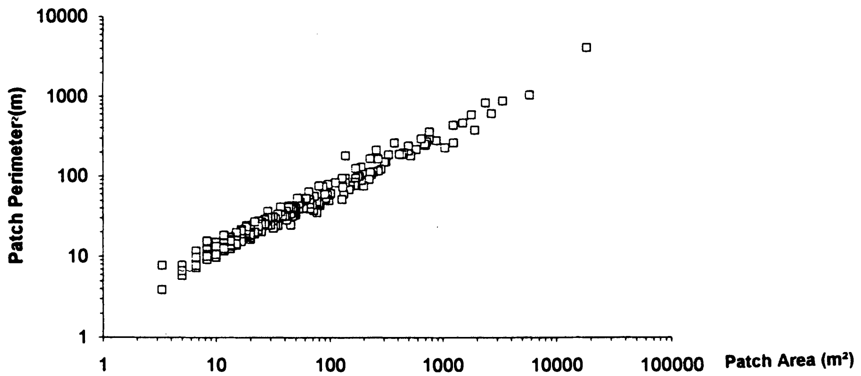

Fig. 9. Perimeter-area association of snow patches on Smith Tributary, March 29, 1972, 10.3 % snowcover.

Perimeter-Area Relationship

The perimeter-area relationships for the soil and snow patches typically resemble those shown in Figs. 8-11. Close association is found between the variables. The strong linear trend (over nearly 5 orders of magnitude) indicates a lack of a characteristic length or a change of dimension, at least in the size range surveyed. The values of the fractal dimension, D_P, are generally higher than the corresponding D_K-values obtained from a size-distribution analysis (see Table 1). On the basis of the agreement in the values of D_P and D_K for the soil and snow patches, Shook (1992) concluded the patches had the same fractal dimension.

The data from Smith Tributary (Fig. 9) include measurements of snow patches in various landscapes (upland, river valley sides, valley bottom), on which the energy exchange processes and melt sequences differ appreciably. The consistency in the

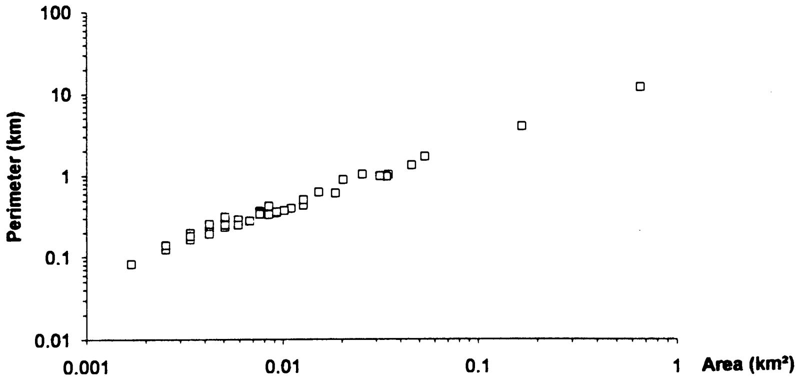

Fig. 10. Perimeter-area association of soil patches on Längental catchment, May 4, 1989, 86.8 % snowcover.

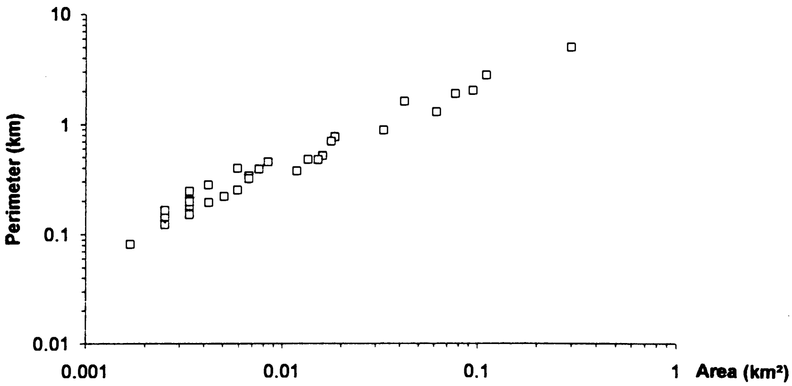

Fig. 11. Perimeter-area association on Längental catchment, July 20, 1989, 8.8 % snowcover.

values of D_P indicates that the processes that form the patches may be similar, regardless of differences in topography of the underlying landscapes. The values of D_P for the Längental catchment are of the same magnitude as the corresponding values for Smith Tributary and independent of temporal variation.

The perimeter-area relationship depends on the roughness of the edges of the patches; the larger the fractal dimension, the rougher the edges. Likely, the association is influenced by the small-scale interactions that take place between the soil and snow and upon the properties of snow. Figs. 8-11 show no major departures from linearity. Evidently, large-scale landscape topography does not significantly influence the roughness of edge of a patch.

The relationships and data presented above are constrained by the precision of the measurement system. Therefore they will not necessarily be reproduced exactly in other studies. When the length of a fractal object is measured, the scale at which the measurement is made is important. Use of small measuring sticks will result in a larger value for the overall length as finer details are measured. Theoretically, using an infinitely-small measuring stick should result in an edge of infinite length. Given a measuring stick of length, l, the estimated total length, L, of a fractal curve is given by Mandelbrot (1982) as

$$L = F\, l^{1-D_D} \tag{3}$$

where

F – a constant, and

D_D – divider fractal dimension of the edge of fractal object.

Measurements of the perimeters of patches from air photos are subject to Eq. (3), and therefore depend on the pixel array and pixel density used for the measurement. For example, the patches on the Längental catchment were scanned at a precision of approximately 36 pixels/km. This results in a minimum caliper width of 27.7 m. The fractal edge of the soil and snow patches allows the perimeter-length to be corrected to any desired scale, once D_D is known.

Application

The perimeter-area relationships and the size-frequency distribution of snow patches can be combined to estimate the total edge length of a snow field. The edge length is considered a useful parameter for modelling snowmelt of patchy snowcover.

The highest rate of meltwater production on a watershed will occur when the product of the melt rate and snow-covered area is a maximum. A patchy snowcover usually experiences higher melt rates than a complete snowcover due to the advection of energy from the patches of bare ground to adjacent patches of snow. Since advective melting is greatest along the leading edge of a snow field, under invariant climatic conditions the average melt rate of a patchy snowcover should vary directly with the total edge length (perimeter), P, of the patches comprising the snow-covered area, A_s. Fig. 12 plots the edge length per unit area of snowcover, P/A_s, against the percentage of the total basin area that is snow-covered at various stages of melt on the Smith Tributary. The data show P/A_s increasing slowly with decreasing snow-covered area to about 70 % snowcover due to the enlargement and increase in numbers of patches of bare ground. Between 70 and 60 % snowcover, P/A_s shows a step increase to its maximum value of 0.49 m/m^2. This is due to the decrease in snow-covered area, which when coupled with the fractal nature of snow patches, causes a rapid increase in the perimeter of the patches. When the watershed is between 50 % and 20 % snow-covered, the ratio declines gradually or remains reasonably constant ($P/A_s \approx 0.41$ m/m^2). Both the total area of snowcover and the sizes of the snow patches, which influence the perimeter length, decrease approximately at the same rate.

Table 2 shows a similar trend in the temporal variation of the edge length per unit basin area, $P/A_B = P/A_s{}^*F$, in which F is the fraction of total basin area, A_B,

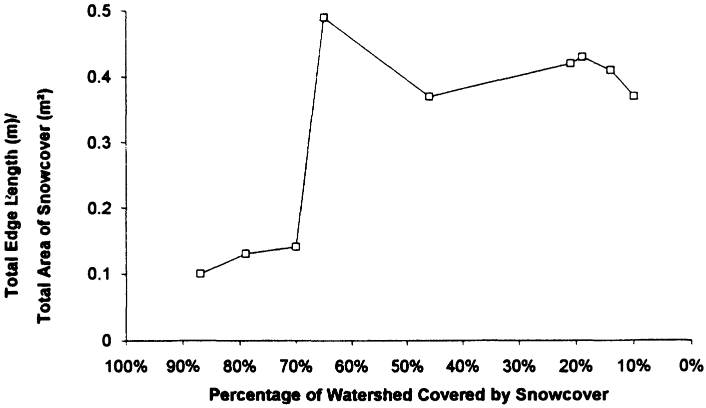

Fig. 12. Variation in the ratio, total edge length: total area of snowcover, with the percentage of basin snow-covered at various stages of ablation, Smith Tributary, 1972.

that is snow-covered, *i.e.*, $F = A_S/A_B$. The values confirm that in terms of the geometrical aspects of a snow field, specifically its edge length, the "potential" for local advection increasing melt rates likely is greatest when a watershed is between 45 and 65 % snow-covered. Although it is well-documented that the relative importance of the turbulent energy transfers to melt of a Prairie snowcover increases over the period of ablation, the role of local advection in the process is not understood. Edge length is but one factor affecting advection, excluding climatic factors others include the orientation of a snow patch to the prevailing wind and the areas, lengths of fetches, surface roughnesses and albedos of the patches of snow and bare ground. Nevertheless, when local advection is important to melt, the findings rationalize adjustments to melt calculations (and perhaps runoff coefficients) during ablation to account for the effects of changes in the edge length of the snowcover on snowmelt.

Table 2 – Variation in the edge length of a snow field per unit basin area during snowcover ablation on the Smith Tributary, 1972.

Date	P/A_s m/m^2	Fraction of Basin Snow-covered, F	P/A_B m/m^2
13/mar/1972	0.10	0.87	0.087
14/Mar/1972	0.13	0.79	0.103
15/Mar/1972	0.14	0.70	0.098
16/Mar/1972	0.49	0.65	0.319
18/Mar/1972	0.37	0.46	0.170
21/Mar/1972	0.42	0.21	0.088
22/Mar/1972	0.43	0.19	0.082
26/Mar/1972	0.41	0.14	0.057
29/Mar/1972	0.37	0.10	0.037

Summary

The geometrical properties of soil and snow patches that form during ablation of seasonal snowcovers in Prairie and Alpine environments are examined. It is assumed that the patches behave as fractal objects. That is their area-frequency distribution, $F(A)$, and perimeter, P, can be described by simple power equations with patch area, A.

Image analyses are applied to aerial photographs taken during snowmelt on two small watersheds: one in the West-central part of the Province of Saskatchewan in the Canadian Prairies, the other in the alpine region of the Austrian Alps. Logarithmic plots of $F(A)$ *versus* A and P *versus* A for both the soil patches and the snow patches show linear trends. The association is strongest in the perimeter-area plots; the area-frequency relationship gives areas for large patches that are smaller than those predicted by a hyperbolic distribution (Korčak's law). The departures of the large patches from the Korčak's law are attributed to human factors, the size of the photographic area scanned and physical features.

The slopes of the "best-fit" lines of the logarithmic plots of $F(A)$ *versus* A and P *versus* A index the fractal dimensions of the soil and snow patches. Analyses of these values suggest: a) soil and snow patches behave as fractals, b) soil and snow patches have the same fractal dimension, independent of the stage of melt, and c) the fractal dimensions of patches in Alpine and Prairie regions do not differ appreciably, despite large-scale differences in topography and snowcover in the regions. It is concluded that snow patches are not random and their size distribution is predictable.

The variation in the edge length of a snow field per unit basin area, P/A_B, during ablation in a Prairie environment is demonstrated. Starting at the beginning of ablation, P/A_B increases with decreasing snowcover and reaches a maximum value when a basin is 45-65 % snow-covered. With continued ablation it decreases gradually until the snowcover disappears. The potential for local advection increasing melt under a specific set of climatic conditions is greatest when P/A_B has its maximum value. It is suggested that the variation may assist the adjustment of snowmelt and runoff calculations for patchy snowcover.

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Address:
Kevin Shook and D.M. Gray,
Division of Hydrology,
University of Saskatchewan,
Saskatoon, Sask.,
S7N 0W0, Canada.

J.W. Pomeroy,
National Hydrology Research Institute,
11 Innovation Boulevard,
Saskatoon, Sask.,
S7N 3H5,
Canada.