Topoclimates and Topoclimate Mapping: What do the Scientific Abstracts Tell Us about Research Perspectives?

Katrina Richards[1]

[1]Department of Geography
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-8971 Fax: +64 3 479-9037
Email: kr@geography.otago.ac.nz

Presented at SIRC 2002 – The 14th Annual Colloquium of the Spatial Information Research Centre
University of Otago, Dunedin, New Zealand
December 3-5th 2002

ABSTRACT

This paper reviews research concerning topoclimates and topoclimate mapping, as presented in the abstracts and titles of scientific papers indexed by *ISI Web of Science* for the period 1987 to present (September 2002). Topoclimates vary spatially and appear to have explanatory power in a wide range of environmental situations. However, topoclimate-related abstracts seldom explicitly refer to maps or mapping techniques, and few provide details regarding the spatial scale and sample density of the research undertaken.

Keywords and phrases**:** topoclimate, mapping, discourse analysis

1.0 INTRODUCTION

In areas with raised terrain, variations in slope, aspect and elevation create differences in local climates, i.e. at horizontal scales of ~0.1-50 km. Thus, for example, an equator-facing slope receives greater solar radiation, and will experience warmer soil temperatures, compared to an otherwise identical, polar-facing slope. Contrasts in local winds, topographic shelter and cold air ponding are also important, and radiation and energy balances, soil and air temperatures, precipitation patterns, runoff, soil moisture, and plant growth are all potentially affected (Oke 1987).

In the 1980s, Fitzharris (1989) reviewed publications dealing with topoclimatology in New Zealand, with publication dates ranging from 1898 to 1988. The main topics addressed were the growing of grapes (11 publications) and other crops (6), climate parameters (9), alpine climate processes (8), inversions and air pollution dispersion (8), and hydroelectric development (4). Fitzharris stressed the need for topoclimate mapping in New Zealand, to identify areas with a high quality climate, for efficient land use management, and lamented that there is “no systematic programme for the mapping of topoclimates [in New Zealand] at scales that might be useful to horticulture” (Fitzharris 1989: 7) and “no agency formally charged with topoclimate mapping” (Fitzharris 1989: 12). There has been renewed interest in topoclimate research in New Zealand in more recent years. The community and government funded Topoclimate South project measured temperatures in Southland during 1998-2001, and produced a series of heat units (i.e. growing degree day) maps at a scale of 1:50, 000, and the growOtago project is currently mapping a suite of local climate variables for the Otago region.

This paper employs a simple form of discourse analysis to develop a better understanding of texts of relevance to topoclimate research. Discourse analysis has its origins in philosophy. It is a well-established research technique in the social sciences, but also features in studies concerned with environmental management. Although precise definitions differ, a ‘discourse’ is a specific set of communications through which meanings are produced, connected into networks and legitimised (Johnston *et al.* 2000). To illustrate this concept, consider the example of a collection of newspaper articles which address a particular environmental issue, such as irrigation conflicts in Australia (Butteriss *et al.* 2002). Their common theme legitimises them as a collection, and individual texts can be located in a network defined by, say, publication date, source and point-of-view.

In this paper, the discourse consists of the abstracts + titles (hereafter termed 'texts') of scientific papers. This type of discourse was chosen for several reasons. These texts are readily available through on-line, searchable databases. Such databases index reputable and international series, so a measure of quality control and commonality is automatically provided. Finally, an abstract, by definition, contains information which the producers (i.e. authors and editors) believe is important and acceptable for publication. In other words, because abstracts are severely limited in length (e.g. to 100-500 words or less) and required to summarise the main points of the full-length paper (Atmospheric Research 2001; International Journal of Climatology 2001; Geographical Analysis 2002; Physical Geography 2002), they can be inferred to encapsulate the information contained in the full-length paper.

2.0 METHODS

A relatively straightforward, literal consideration of words and phrases was used to identify the main themes, perspectives, and approaches conveyed by the texts. A more advanced analysis of the underlying social practises and belief systems of the authors, publishers and readers, was not attempted.

The discourse was obtained from the on-line *Web of Science* (2002) database. This incorporates the *Science Citation Index Expanded*, *Social Sciences Citation Index*, and *Arts and Humanities Citation Index* databases. The first two contain documents from 1987, and the latter from 1988 until present (9 September 2002). English language documents of all types containing the string 'topoclimat' were selected. This meant those containing terms such as 'topoclimate(s)', 'topoclimatology', or 'agri-topoclimatology' in their title, abstract or keywords would be selected.

In discourse analysis, the background and interests of the investigator are acknowledged to influence the direction of the research. In this case, the author is a New Zealand climatologist with a background in geography, and topoclimate research experience in association with the Topoclimate South project. This context is associated with, for example, a special interest in New Zealand, and with map making.

3.0 RESULTS

3.1 Main Topics of Research

The on-line search produced 59 texts which included the string 'topoclimat' in their title, abstract and/or key words (Figure 1). On average, this is 3.7 texts per year. In comparison with other possible topics of study, this discourse is small: a similar search for the string 'climate' returned 38,791 texts.

Relatively few of the topoclimate-related texts were published in the period 1987-1990. This may indicate changes in the prevalence of topoclimate related research. However, it could equally reflect changes in the number of relevant series indexed by *Web of Science* during this period. Annual totals peak in 1991 and 2000 (7 publications per year), and the texts are relatively abundant in the period 1998-2001. A review of the texts

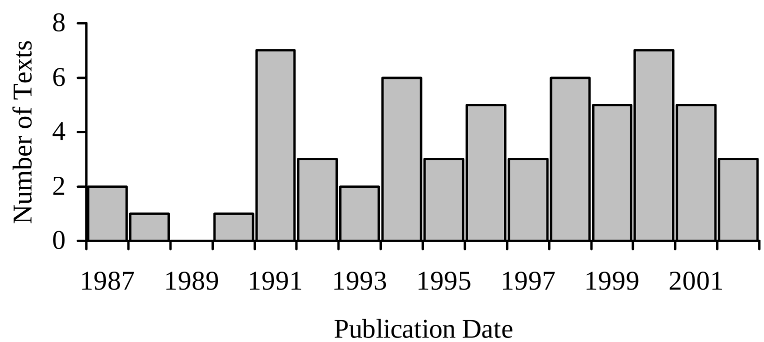

Figure 1: Texts in discourse sorted by year of publication, where data for 2002 are for 1 January to 9 September.

Table 1: Summary of the main research topics of the 59 texts in the discourse.

MAIN TOPIC	COUNT	(%)	TYPES OF ISSUES ADDRESSED
Plant Ecology	14	(24)	Distribution or characteristics of vegetation.
Topoclimate Phenomenon	12	(20)	Airflow, temperature, radiation and energy patterns.
Alpine/Arctic Processes	10	(17)	Cryosphere and landforms.
Agriculture/Forestry	7	(12)	Crop or forestry related issues.
Biology	6	(10)	Distribution and behaviour of insects.
Soil/Groundwater	5	(8)	Soil content and groundwater patterns.
Urban/Built Systems	4	(7)	Urban climate and air pollution.
Historical Review	1	(2)	Review of Austrian biometeorology

shows that these peaks are associated with papers from two particular research clusters, one at the University of Gothenburg, Sweden, where there is an on-going interest in topoclimates, frosts and road conditions (Bogren *et al.* 1991, 2000; Gustavsson 1991; Lindkvist *et al.* 2000), and the other at Bar Ilan University, Israel, which is associated with a series of texts concerning soil conditions in the Judean desert (Steinberger *et al.* 1998, 1999, 2001; Hamadi *et al.* 2000; Xie *et al.* 2001). Aside from authors associated with these two research groups, only four primary authors appear more than once (i.e. twice) in the discourse. These are Dubayah (Dubayah *et al.* 1992; Dubayah 1994), Weiss (Weiss *et al.* 1993, 1998) and Allen (Allen *et al.* 1996; Allen 1998) in the USA, and Humlum (1998, 2000) in Scandinavia.

Only 18 of the 59 texts (30%) included the string 'topoclimat' in their title. However, a further 11 texts signalled a potential relevance to topoclimates with the use in their title of phrases such as 'topographic distribution', 'landscape-level', 'complex terrain' or 'local [scale]' in their title. Taken together, these account for 49% of the texts in the discourse.

The main topics conveyed by the discourse can be summarised using eight themes (Table 1). The largest group of texts (14) deals with plant ecology, e.g. the distribution of forest, tundra or alpine species or communities. Twelve texts deal with topoclimate phenomenon associated with airflow, temperatures, frost, radiation, or energy balances. Texts dealing with alpine and arctic processes and features (e.g. glaciers, landforms, or thawed ground) are also relatively abundant (10 texts). Seven texts focus on agriculture or forestry, e.g. crop growth models, frost protection, fertiliser trials, the use of satellite data, and forest sampling; this group includes one text on the Topoclimate South project. Six texts are concerned with biology, e.g. the distribution and behaviour of insects, butterflies or nematodes. Five relate to soil or ground water processes, such as soil chemistry, moisture and litter decomposition, and groundwater patterns. Four concern urban and built systems, and deal with the mapping of urban topoclimates, effects of vegetation on urban microclimates, urban air pollution, or urban temperatures. One text described a historical review of biometeorology in Austria.

The discourse is associated with a wide variety of research locations. These range from sites in North and South America (11 and 3 texts, respectively), to the Middle East (5 texts), China and the Himalayas (4), Australia (1) and New Zealand (1). However, the vast majority of texts (26 texts; 44%) are associated with sites in Europe, especially in Scandinavia (i.e. Sweden and Finland) and the alpine regions of central Europe (i.e. Germany, Switzerland, France and Austria). The discourse shows several regional gaps, e.g. no texts focus on the nations of the former USSR, Africa, or the Indian subcontinent. Eight texts do not specify a research location or are theoretical in nature. When the addresses for the principal authors in the discourse are examined, this set largely mirrors that for the research locations. In other words, most authors report research for their home nation or global region.

The discourse largely ignores spatial scales. In particular, few of the texts quantify the extent of their study area, number of sites, or the density of their sampling scheme. Roughly half of the texts indicate that a certain physical feature is of particular interest, and this sometimes gives an approximate idea of scale. For example, a reader is probably able to visualise the size a road cutting, slope, valley, glacier, lake, or town (Bogren *et al.* 1991; Dubayah 1994; Kuttler *et al.* 1996; Weiss *et al.* 1998; Hannah *et al.* 2000; Cano *et al.* 2002; Smith 2002). However, it may be less straightforward to visualise the extent of a cave, basin, landscape, region, or ice cap (Bradley *et al.* 1987; Lauriol *et al.* 1988; Seguin *et al.* 1993; Dubayah 1994; Judas *et al.* 2002). Nine texts (15%) state the number of sites or grid resolution they use, but provide little information on the size of the area sampled (Gustavsson 1991; Dubayah 1994; Carrega 1995; Antonic *et al.* 1996; Steinberger *et al.* 1998, 2001; Humlum 2000; Jarvis *et al.* 2001; Zomer *et al.* 2001). Only three texts (5%) provide information on both spatial extent *and* sample size: Bogren and Gustavsson (2000) sampled an area of 160×130 km^2 which included 35 field stations, Hutchinson and McIntosh (2000) describe a project involving 850 000 ha and 900 data loggers, and Lindkvist *et al.* (2000) collected data at 38 locations in a 625 km^2 area.

3.2 Perspectives with Respect to Topoclimates

Strong differences are evident in the perspectives which are portrayed in the texts with respect to topoclimatic information. In particular, a contrast seems to be present between, on the one hand, texts which investigate the effect of topoclimates on a certain feature (e.g. temperature) and, on the other hand, those which use topoclimate to explain some aspect of, say, the distribution of a butterfly species.

As shown in Table 2, 27 of the texts (45%) focus on the effect of topoclimate on physical features such as urban microclimates, plant growth, insect mortality, soil chemistry, or frost patterns (Kuttler *et al.* 1996; Wagner *et al.* 1997; Virtanen *et al.* 1998; Steinberger *et al.* 1999; Lindkvist *et al.* 2000). This perspective is often signalled in the title. Examples include "Phenology...in response to contrasting topoclimates" (Wagner *et al.* 1997), "Soil carbohydrates along a topoclimatic gradient...." (Steinberger *et al.* 1999), and "Modelling topoclimatic patterns of egg mortality...." (Virtanen *et al.* 1998). However, this is not always so: Gustavsson (1995) investigates the effect of topoclimates on temperature patterns but uses the title "A study of air and road-surface temperature-variations during clear windy nights". This set of texts discusses a wide variety of topics and methodologies. For example, Wagner and Reichegger (1997) investigated the effects of topoclimate on the phenology of alpine sedges using field surveys and experiments; Kuttler *et al.* (1996) studied the thermal structure of a town in a narrow valley and the influence of topoclimatic factors on features such as cold air drainage; and Steinberger *et al.* (1999) described soil carbohydrate differences along a topoclimatic gradient in the Judean desert.

In 19 of the texts (32%), topoclimate is used to explain at least some aspects of the main feature of interest. For example, Romero *et al.* (1999) investigated air pollution problems in Santiago, Chile, and attributed them in part to topoclimatic conditions; Hannah *et al.* (2000) investigated glacier microclimates and attributed energy balance patterns in part to differences in topoclimate; and Judas *et al.* (2002) investigated beetle distribution patterns at the landscape-level and found that some patterns could be attributed to topoclimatic factors.

Eight of the texts (14%) did not fit easily into either of these two types: five dealt with resource management issues, two with technical issues, and one described a review paper. A further five texts (8%) could not be classified because these texts did not include an abstract.

The two-way classification described above may be somewhat artificial, because the texts could also, perhaps, be located along a continuum. That is, they range from studies which explicitly investigate the effects of topoclimates on a feature, to those where topoclimate is the major (Judas *et al.* 2002) or minor (Hannah *et al.*

Table 2: Main perspectives of the texts with respect to topoclimate.

PERSPECTIVE	COUNT	(%)	TYPES OF ISSUES ADDRESSED
Effect of topoclimate on a feature	27	(46)	Soil, vegetation, temperature, urban climate.
Feature explained by topoclimate (at least in part)	19	(32)	Distribution of vegetation, glaciers, air pollution, insects; Energy balance contrasts.
Other	8	(14)	Resource management; Technical issues; Review.
No abstract provided	5	(8)	

2000) causal factor, to those texts where topoclimate is only suggested as a potentially relevant variable (Zelenko *et al.* 1994).

3.3 Topoclimates and Mapping

Only 16 of the 59 texts (27%) explicitly include mapping or Geographical Information System (GIS) related terms. The phrases which are used included terms such as ‘map’, ‘cartographic’, ‘Digital terrain model (DEM)’, ‘GIS’, or ‘grid’. Thirty-eight texts (65%) do not refer to maps or map making in any manner. These include both texts which described the effect of topoclimate on a feature, and those which use topoclimate to explain a feature. Several texts present a statistical model or analysis that is not explicitly linked to mapping, although in some cases the outcome may well be a map. Some of the texts seem to suggest that a map is present in the full-length paper. For example, Hannah *et al.* (2000) use the phrase ‘showing spatio-temporal data’, from which mapped data can be inferred to exist in the full-length paper.

The mapping issues which are discussed can be grouped according to four themes, as follows:

- *Spatial variation*: i.e. differences between points (e.g. temperature differences), differences along a transect (e.g. a topoclimatic gradient), and areal variation, e.g. spatial or geographic variability.

- *Spatiotemporal variation*: e.g. spatial and temporal variations in air and road temperature.

- *Heterogeneity and Boundaries*: i.e. heterogeneity (e.g. ‘topographically heterogeneous habitats’), internally homogeneous units (e.g. ‘topoclimatic strata’, and ‘homogeneous space’), and boundaries, e.g. ‘topoclimatic limitations’, and ‘separation of communities along topoclimatic gradients’.

- *Sampling and Mapping Strategies*: i.e. sampling procedures (e.g. ‘uniform methods and agreed procedures’, ‘optimal sampling strategy’, and ‘topoclimatic-based inventory’), and interpolation/extrapolation methods, e.g. ‘DEM to extend the prediction at a regional scale’, and ‘interpolation’.

Text which refer to mapping and also present details of their mapping methods are rare: Jarvis and Stuart (Jarvis *et al.* 2001) state they employed thin plate spline interpolation in their research, but Hutchinson and McIntosh (Hutchinson *et al.* 2000) merely state that isocontour maps will be generated. Only one text deals directly with issues concerning sampling network design, i.e. Beetson *et al.* (1992) discuss methods to optimise the network of permanent sampling plots in forests.

3.4 Topoclimate Mapping in New Zealand

Only one abstract in the discourse addresses topoclimates in New Zealand, i.e. Hutchinson and McIntosh (2000) report on the then on-going Topoclimate South project. In theory, there should be overlap with the publications reviewed by Fitzharris (1989), i.e. for the period 1987-1988. In practice, however, there are no documents in common. This is probably because *Web of Science* does not index the conference proceedings, industrial/government reports (e.g. by the Ministry of Works and Development), and ‘local’ series (e.g. *Weather and Climate*, published by the New Zealand Meteorological Society) that Fitzharris cites.

Table 3: Texts sorted according to whether they explicitly address mapping.

STATUS	COUNT	(%)	TYPES OF ISSUES ADDRESSED
No explicit reference to maps or GIS	38	(65)	Temperature, vegetation, insects, glaciers, frost, resources, energy balances, soil, air pollution
Uses map, grid or GIS terms	16	(27)	Temperature, vegetation, insects, glaciers, frost, resources, solar radiation
No abstract provided	5	(8)	

4.0 CONCLUSION

This paper presents preliminary results of a critically review of published material relating to topoclimates and topoclimate mapping. The discourse analysis method was used to examine the language used in a specific set of texts (abstracts + titles). The method was employed as a tool to developing a better understanding of the different themes and perspectives that were presented. Several generalisations can be made. Topoclimates have explanatory power for certain features of the physical environment and these involve a range of locations and scientific disciplines. Topoclimates inherently possess strong spatial variability. However, topoclimate-related abstracts seldom explicitly refer to maps or mapping techniques. Further, few provide basic spatial details such as the size of the study area, number of sites, or sample density for the research which is presented.

REFERENCES

Allen, T.R. (1998) Topographic context of glaciers and perennial snowfields, Glacier National Park, Montana. *Geomorphology* 21:3-4, pp. 207-216.

Allen, T.R. and S.J. Walsh (1996) Spatial and compositional pattern of alpine treeline, Glacier National Park, Montana. *Photogrammetric Engineering and Remote Sensing* 62:11, pp. 1261-1268.

Antonic, O. and A.Z. Lovric (1996) Numerical analysis of vegetation complexes and community diversity of major coastal Dinaric mountains. *Journal of Vegetation Science* 7:1, pp. 73-80.

Atmospheric Research (2001) Note to contributors. Accessed on 22 August 2001.<http://www.elsevier.com/gej-ng/10/10/49/docs/contrib.htm>

Beetson, T., M. Nester and J. Vanclay (1992) Enhancing a permanent sample plot system in natural forests. *Statistician* 41:5, pp. 525-538.

Bogren, J. and T. Gustavsson (1991) Nocturnal air and road surface-temperature variations in complex terrain. *International Journal of Climatology* 11:4, pp. 443-455.

Bogren, J., T. Gustavsson and U. Postgard (2000) Local temperature differences in relation to weather parameters. *International Journal of Climatology* 20:2, pp. 151-170.

Bradley, R.S. and M.C. Serreze (1987) Topoclimatic studies of a high arctic plateau ice cap. *Journal of Glaciology* 33:114, pp. 149-158.

Butteriss, C., J.A.J. Wolfenden and A.P. Goodridge (2002) Discourse analysis: A technique to assist in environmental conflicts. Accessed on 6 September 2002.<http://www-personal.une.edu.au/~jwolfend/discourse.pdf>

Cano, A., R. Navia, I. Amezaga and J. Montalvo (2002) Local topoclimate effect on short-term cutslope reclamation success. *Ecological Engineering* 18:4, pp. 489-498.

Carrega, P. (1995) A method for the reconstruction of mountain air temperatures with automatic cartographic applications. *Theoretical and Applied Climatology* 52:1-2, pp. 69-84.

Dubayah, R. and V. Vankatwijk (1992) The topographic distribution of annual incoming solar-radiation in the Rio-Grande river basin. *Geophysical Research Letters* 19:22, pp. 2231-2234.

Dubayah, R.C. (1994) Modeling a solar-radiation topoclimatology for the Rio-Grande river basin. *Journal of Vegetation Science* 5:5, pp. 627-640.

Fitzharris, B.B. (1989) A review of topoclimatology in New Zealand. *Weather and Climate* 9, pp. 7-13.

Geographical Analysis (2002) Instructions to contributors. Accessed on 7 August 2002.<http://www.ohiostatepress.org/journals/geocontr.htm>

Gustavsson, T. (1991) Analyses of local climatological factors controlling risk of road slipperiness during warm-air advections. *International Journal of Climatology* 11:3, pp. 315-330.

Gustavsson, T. (1995) A study of air and road-surface temperature-variations during clear windy nights. *International Journal of Climatology* 15:8, pp. 919-932.

Hamadi, Z., Y. Steinberger, P. Kutiel, H. Lavee and G. Barness (2000) Decomposition of avena sterilis litter under arid conditions. *Journal of Arid Environments* 46:3, pp. 281-293.

Hannah, D.M., A.M. Gurnell and G.R. McGregor (2000) Spatio-temporal variation in microclimate, the surface energy balance and ablation over a cirque glacier. *International Journal of Climatology* 20:7, pp. 733-758.

Humlum, O. (1998) The climatic significance of rock glaciers. *Permafrost and Periglacial Processes* 9:4, pp. 375-395.

Humlum, O. (2000) The geomorphic significance of rock glaciers: Estimates of rock glacier debris volumes and headwall recession rates in west Greenland. *Geomorphology* 35:1-2, pp. 41-67.

Hutchinson, G. and P. McIntosh (2000) A case study of integrated risk assessment mapping in the Southland region of New Zealand. *Environmental Toxicology and Chemistry* 19:4, pp. 1143-1147.

International Journal of Climatology (2001) Instructions to authors. Accessed on 21 May 2001.<http://www.interscience.wiley.com/jpages/0899-8418/authors.html>

Jarvis, C.H. and N. Stuart (2001) A comparison among strategies for interpolating maximum and minimum daily air temperatures. Part I: The selection of "guiding" topographic and land cover variables. *Journal of Applied Meteorology* 40:6, pp. 1060-1074.

Johnston, R.J., D. Gregory, G. Pratt and M. Watts, Eds. (2000) *The dictionary of human geography*. London, Blackwell Publishing.

Judas, M., K. Dornieden and U. Strothmann (2002) Distribution patterns of carabid beetle species at the landscape-level. *Journal of Biogeography* 29:4, pp. 491-508.

Kuttler, W., A.B. Barlag and F. Rossmann (1996) Study of the thermal structure of a town in a narrow valley. *Atmospheric Environment* 30:3, pp. 365-378.

Lauriol, B., L. Carrier and P. Thibaudeau (1988) Topoclimatic zones and ice dynamics in the caves of the northern Yukon, Canada. *Arctic* 41:3, pp. 215-220.

Lindkvist, L., T. Gustavsson and J. Bogren (2000) A frost assessment method for mountainous areas. *Agricultural and Forest Meteorology* 102:1, pp. 51-67.

Oke, T.R. (1987) *Boundary layer climates*. London, Routledge.

Physical Geography (2002) Information for authors. Accessed on 6 August 2002.<http://www.bellpub.com/phg.eauthor.htm>

Romero, H., M. Ihl, A. Rivera, P. Zalazar and P. Azocar (1999) Rapid urban growth, land-use changes and air pollution in Santiago, Chile. *Atmospheric Environment* 33:24-25, pp. 4039-4047.

Seguin, B., D. Courault and M. Guerif (1993) Satellite thermal infrared data applications in agricultural meteorology. *Advances in Space Research* 13:5, pp. 207-217.

Smith, I.R. (2002) Diatom-based holocene paleoenvironmental records from continental sites on northeastern Ellesmere Island, High Arctic, Canada. *Journal of Paleolimnology* 27:1, pp. 9-28.

Steinberger, Y., H. Lavee, G. Barness and M. Davidor (1999) Soil carbohydrates along a topoclimatic gradient in a Judean desert ecosystem. *Land Degradation & Development* 10:6, pp. 523-530.

Steinberger, Y., W.J. Liang, E. Savkina, T. Meshi and G. Barness (2001) Nematode community composition and diversity associated with a topoclimatic transect in a rain shadow desert. *European Journal of Soil Biology* 37:4, pp. 315-320.

Steinberger, Y., S. Vishnevetsky, G. Barness and H. Lavee (1998) Effects of topoclimatic gradient on soil dehydrogenase activity in a Judean desert ecosystem. *Arid Soil Research and Rehabilitation* 12:4, pp. 387-393.

Virtanen, T., S. Neuvonen and A. Nikula (1998) Modelling topoclimatic patterns of egg mortality of epirrita autumnata (lepidoptera : Geometridae) with a geographical information system: Predictions for current climate and warmer climate scenarios. *Journal of Applied Ecology* 35:2, pp. 311-322.

Wagner, J. and B. Reichegger (1997) Phenology and seed development of the alpine sedges carex curvula and carex firma in response to contrasting topoclimates. *Arctic and Alpine Research* 29:3, pp. 291-299.

Web of Science (2002) Isi web of science. Accessed on 9 September 2002.<(http://isi0.isiknowledge.com/portal.cgi).>

Weiss, S.B., D.D. Murphy, P.R. Ehrlich and C.F. Metzler (1993) Adult emergence phenology in checkerspot butterflies - the effects of macroclimate, topoclimate, and population history. *Oecologia* 96:2, pp. 261-270.

Weiss, S.B. and A.D. Weiss (1998) Landscape-level phenology of a threatened butterfly: A GIS - based modeling approach. *Ecosystems* 1:3, pp. 299-309.

Xie, G.H., I. Lahav, G. Barness and Y. Steinberger (2001) Dynamics of soil nitrogen along a topoclimatic gradient in the Judean desert. *Arid Land Research and Management* 15:2, pp. 135-146.

Zelenko, B. and I. Lisac (1994) On the statistical wind rose analysis. *Theoretical and Applied Climatology* 48:4, pp. 209-214.

Zomer, R.J., C. Carpenter, S.L. Ustin and J.D. Ives (2001) Structure, composition and community ordination of tropical monsoon forest within the Makalu Barun Conservation Area of eastern Nepal. *Phytocoenologia* 31:2, pp. 161-184.