

CLIMATE CHANGE RESEARCH

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CLIMEX project: Progress report

December 1992 - June 1993



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Abstract: This report describes the technical installations at Risdalsheia and the establishment of permanent plots for scientific studies of vegetation and soils at the 5 experimental catchments.

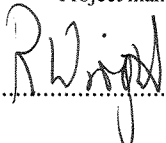
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CLIMEX interim report (December 1992 - June 1993)

EC Contract No. EV5V 0047

CLIMEX (Climate change experiment) is an ongoing project to determine the ecosystem impact of enriching atmospheric CO₂ to 560 ppmv and raising air temperature by 5°C above ambient to an entire forested headwater catchment.

Design of CO₂, heating and ventilation systems

R.F. Wright (NIVA) and R. Storhaug (Aquateam)

The CLIMEX project will use the existing roofed catchments at Risdalsheia. The 2 roofs were constructed in winter 1983-84 as part of the RAIN project (Reversing Acidification In Norway). The systems collect all the incident precipitation on the roof by gutters and storage tanks, filter and ion-exchange the water (at KIM), and reapply the water beneath the roofs using a sprinkler system mounted on the underside of the roof. The watering system starts and stops automatically and is regulated by height of collected precipitation in the storage tanks. Maximum watering rate is 2 mm per hour.

Progress to June 1993 has focused on the planning and engineering design of the greenhouse, detailed costing of the engineering and running overheads and design of the climate control system. All of these are now complete and work will begin in June 1993 for completion by November enabling 5 months of testing prior to the start of the treatment on 1st April 1994.

For CLIMEX the larger of the 2 roofs, covering KIM catchment, will be modified to accommodate the new additional treatment (CO₂ addition and warming). Several major modifications to the structure must be made. The existing walls will be removed and replaced by new fixed transparent double-layer polycarbonate panels. These will be fitted to the bedrock surface to obtain an airtight junction. Along all 4 sides there will be a rank of windows that open to allow ventilation. The upper 20 % of the catchment will be separated by a vertical transparent wall such that the uppermost part can serve as untreated control for the lowermost 80% which will receive treatment.

Heating of the air in the building will be accomplished by means of an 75 kW electric furnace with heating pipes mounted along the walls and suspended from the roof constructional elements. The pipes will have temperature of maximum 40°C above the ambient air temperature and be mounted 50 cm minimum from the vegetation. CO₂ will be added by means of several strings of dosing hoses to be suspended from the roof constructional elements. Mixing of the air within the greenhouse (and the 20% control section) will be accomplished by circulating fans (capacity 1000 m³/hour) placed near the peak of the roof. These move air vertically within the greenhouse (treatment and control). Ventilation will be achieved by opening and closing the ranks of windows mounted along the sides of the greenhouse.

Temperature and CO₂ will be automatically regulated by a climate computer. This equipment includes monitors for CO₂ at 6 points within the greenhouse, monitors for temperature at 6 points within the greenhouse, humidity and precipitation. The software allows the operator to specify protocols for CO₂, temperature and humidity. The computer then controls the flow of CO₂ added and the degree to which the windows are opened for ventilation.

The heating and ventilation system is designed to achieve an 6°C increase (defined as average of the temperature measured at the 6 points within the greenhouse) above outside ambient temperature during the winter (1 November to 28 February). Allowable deviation is maximum 3°C. Maximum allowable range among the 6 temperature sensors is 6°C. The lowest allowable temperature indoors is -10°C. During the rest of the year a 2°C increase is to be achieved, with again maximum deviation of 3°C and maximum range of 6°C. Under extreme conditions a temperature deviation of maximum 8°C is allowable for maximum 8 hours, but this is

compensated by lower temperature increase during the remainder of the day.

The CO₂ dosing system is designed to achieve 560 ppmv CO₂ (daily mean) during the period 1 March to 31 October and during winter days on which temperature within the greenhouse exceeds +4°C. This is defined as the average of measurements made at 6 points within the greenhouse. Deviations are allowed due to excessive ventilation (to hold down the temperature) but these are compensated by extra CO₂ dosing during the remainder of the day such that the daily mean concentration is 560 ppmv. Estimated annual requirement of CO₂ is 200 tons/year. The CO₂ will be delivered by truck at approximately fortnightly intervals by Hydrogas A/S.

Input - Output Budgets

B.L. Skjelkvale, R. Hogberget and R.F. Wright (NIVA)

The sampling and monitoring programme at the sites has continued for the period December 1992 to June 1993 ensuring continuous pre-treatment background data. The variables monitored are;

1. Volume and chemical composition of weekly samples of bulk precipitation outside (ambient acid rain) (analyzed at NILU).
2. Continuous gauging of discharge from all 5 catchments
3. Chemical composition of runoff from the 5 catchments (weekly, more frequently during periods of high discharge and less frequent during the winter). Approximately 25 samples are taken each year.
4. Continuous measurement of air temperature, soil temperature (5 cm), and solar radiation at 2 m height under the 2 roofs and outside.

Catchment Hydrological Response and Residence Times

A. Jenkins (IH)

Progress has focused on two aspects; the establishment of a soil water monitoring system and the establishment of a hydrological model to describe soil water dynamics in the study catchments.

A comprehensive database describing both detailed temporal and spatial dynamics of catchment soil moisture regime is required to achieve the objectives. Rainfall-runoff response at the catchments is of the order of an hour and despite the relatively small soil surface area and depth, variable source areas and dynamic water table response has been observed.

In KIM catchment, soil moisture monitoring has been established at 26 points to give representation of areas of different soil depth and areas dominated by different vegetation cover (Figure 1). In addition, 10 monitoring points have been selected to coincide with soil suction lysimeters installed to collect water for chemical analysis. These are located in 5 pits, 2 in the control and 3 in the climate manipulated enclosures, 2 sensors in each pit at different depths. Soil moisture is monitored at each point using the technique of Time Domain Reflectometry. Measurements are undertaken automatically at hourly interval.

A preliminary application of IHDM has been undertaken on EGIL catchment using rainfall-runoff and climate data from previous studies. For the model application the catchment surface was divided into bare rock, heather and heather with tree cover. The physical representation of the catchment within the model was, for this first and preliminary model application, as a single longitudinal hillslope transect through the catchment. The match between observed and simulated runoff is close. The real benefit of the model, however, is illustrated in Figure 2 showing the soil water matric potential for the catchment profile. In

simple terms soil matric potential values above zero indicate saturation and values below zero are not saturated, the greater the negative number, the drier the soil. Four synoptic views of the system are represented through the storm period. During hour 3 (a in Figure 2) prior to the start of rainfall, the catchment shows saturation at all depths around the outflow. Over the course of the storm all of the catchment wets up until the upper "bowl" also saturates at depth by hour 45 (d in Figure 2). It is interesting to note that the slope between the two "bowls" remains unsaturated due to the high saturated conductivity of 20m hour^{-1} used in the model.

Soil and Soil Solution Chemistry

P.S.J. Verburg and N. van Breemen (WAU)

Data collection to June 1993 aimed to establish differences in measured parameters between KIM, EGIL and METTE catchments. In addition it is important to determine potential differences between the control and treatment sections of the KIM and EGIL enclosures.

In October 1992 lysimeters were installed for monitoring soil solution chemistry. 5 locations were selected in KIM and EGIL, 2 in the reference and 3 in the treatment areas. Lysimeters were installed at 3 depths; below the litter layer, in the organic soil and in the mineral subsoil. Soil solution is extracted using vacuum bottles. Samples have been collected in October, December (1992), April and June (1993). The data indicate that differences in soil solution composition between the 3 catchments occur as a result of differences in precipitation chemistry. The chemistry of the soil solution is in close agreement with the run-off water collected in previous years.

In addition, in October 1992 N-mineralisation measurements were started using the core incubation technique in vegetation plots which were selected in August 1992. 10 plots in both *Calluna* and *Vaccinium* are used in the treatment sections of KIM. In EGIL only *Calluna* is present and 10 plots were located in each of the control and treatment sections. In Mette 10 plots in both *Calluna* and *Vaccinium* have been selected (Figure 1). To date, N-mineralisation has been measured over 3 periods; October - December 1992, December 1992 - April 1993 and April - June 1993. The results exhibit a large scatter and as yet no conclusions can be drawn as regards differences in N-mineralisation rates between and within catchments.

An inventory litterbag study has been initiated in cooperation with the Swedish University of Agricultural Sciences. In this study weight loss of fresh pine litter will be determined over the period of one year. Litterbags have been placed in the control and treatment sections of KIM and EGIL and in the previously used reference catchment ROLF. Litterbags were incubated in October 1992 and will be collected in October 1993.

Plant Gas Exchange and Phenology

D.J. Beerling and F.I. Woodward (US)

Predictions of plant gas exchange and community phenology have been made for the ecosystems within the CLIMEX enclosure. The predictions are based on established models of spring bud-burst and leaf gas exchange and are used to test the sensitivity of vegetation responses to the timing of the new treatments which have yet to be imposed in the enclosure (Figure 3).

The results indicate that considerable care is needed in imposing the first year regime of elevated CO_2 and temperature to prevent the phenology of the trees becoming uncoupled from insect larval emergence. The gas exchange predictions are made for two species present within the enclosure (*Pinus sylvestris* and *Vaccinium myrtillus*) based on two mechanistic models of photosynthesis integrated with an empirical model of stomatal conductance. The models predict an increase in photosynthetic rates and a decrease in stomatal conductance of both species with elevated temperature and CO_2 enrichment, which is in accordance with the results from a limited number of experimental studies investigating the gas exchange

responses of vegetation to concomitant changes in CO₂ and temperature.

Plant Productivity and Turnover

W. Arp and F. Berendse (CABO)

In August 1992 plots dominated by either *Calluna* or *Vaccinium* were selected and mapped in the two roofed catchments and in the reference catchment. Each plot has an area of at least 4m². In KIM, five plots of *Calluna* and *Vaccinium* were selected in both the part of the enclosure that will receive elevated temperature and CO₂, and in the control part. In EGIL *Calluna* plots were mapped in both the ambient and elevated parts. In this catchment no *Vaccinium* plots could be selected because this species is only present in low numbers. In the control catchment five *Calluna* and five *Vaccinium* plots were selected. Maps of the three catchments showing the location of the selected plots are given in Figure 1.

The different plots have been used for sampling plant material, for following the growth of individual shoots and for studying root growth and turnover. While some root cores will be taken to determine the below ground biomass, growth and turnover of individual roots will be measured using mini-rhizotron systems. These have been placed in each of the 40 *Calluna* and *Vaccinium* plots (Figure 1).

In April 1993 a greenhouse experiment was started in the Netherlands to attempt to separate the effects of CO₂ and temperature thereby augmenting the catchments scale responses to the combined treatment within the KIM enclosure. The experiment is being conducted in two greenhouses, one at ambient CO₂ and the other at 560ppm. The species selected for this research are *Calluna vulgaris*, *Vaccinium myrtillus*, *Molinia caerulea* (all three of which are present in the enclosure at Risdalsheia) and two fast growing species for comparisons.

Tree Nutrient Status and Growth

E.D. Schulze (UB)

The period Dec 1992 to June 1993 was devoted to;

- evaluating the time sequence of harvests since 1990
- characterising all trees by growth form and dimensions
- estimating above ground biomass
- determining nutrient contents and concentrations

The results show that there are differences between the KIM and EGIL catchment. Pine exhibited K and Mg deficiency in the acid rain catchment, and associated accumulation of nitrogen. The height growth of pine was enhanced in the clean rain catchment. *Betula* did not respond as strongly to the clean rain as Pine. The stable isotopes show a difference between catchments, being ¹⁵N enriched in the acid rain treatment, indicating enhanced efflux of nitrate.

The dwarf shrubs, *Calluna* and *Vaccinium*, were different in their nutrient concentrations, but no differences were found between treatments. On an area basis, the nutrient content of the shrub layer is different between the two treatments but this is due to the difference in species which inhabit the two catchments. It would be expected that the acid treatment with *Calluna* has a higher acidification potential in its litter turnover than the clean rain catchment which is dominated by a mixture of *Calluna* and *Vaccinium*.

Despite these differences it is difficult (or impossible) to separate differences in stand density, type of understorey species and soil depth in addition to differences in exposition and microclimate between site dependent causes and treatments. This data base, however, gives a basis with which to determine changes resulting from the planned increase in temperature

and CO₂.

Soil Fauna Effects

L. Brussaard (IB)

Two types of experiment will be undertaken; a field experiment at the site in S. Norway and a growth chamber/greenhouse experiment. Planning for these experiments has been completed and the field experiment will begin in September 1993 and the chamber study in April 1994. For the field experiment litter bags will be filled with litter material from *Betula*. To obtain the appropriate *Betula* litter, small birch trees have been placed in Greenhouses under normal and raised CO₂ conditions in early April 1993.

During the experiment, litterbags will be sampled to determine weight loss and loss of nutrients (N, P), C:N ratio and lignin:N ratio and to quantify soil meso- and macrofauna, subdivided into functional groups in order to discriminate between saprophagous, fungivorous and other fauna.

Climex Publication List (To Date)

1) Jenkins, A., Schulze, E.D., van Breemen, N., Woodward, F.I. and Wright, R.F. 1992. CLIMEX - climate change experiment. In, Teller, A., Mathy, P. and Jeffers, J.N.R. (Eds) Responses of Forest Ecosystems To Environmental Changes. Elsevier, London.

2) Jenkins, A., Wright, R.F., Berendse, F., van Breemen, N., Brussaard, L., Schulze, E.D. and Woodward, F.I. 1993. The CLIMEX project - climate change experiment. In, Experimental Manipulations of Biota and Biogeochemical Cycling in Ecosystems. EC Ecosystem Research Report (In Press).

3) Jenkins, A. and Wright, R.F. 1993. The CLIMEX project - raising CO₂ and temperature to whole catchment ecosystems. In, Schulze, E.D. and Mooney, H.A. (Eds) The Design and Execution of Experiments on CO₂ Enrichment. (In Press).

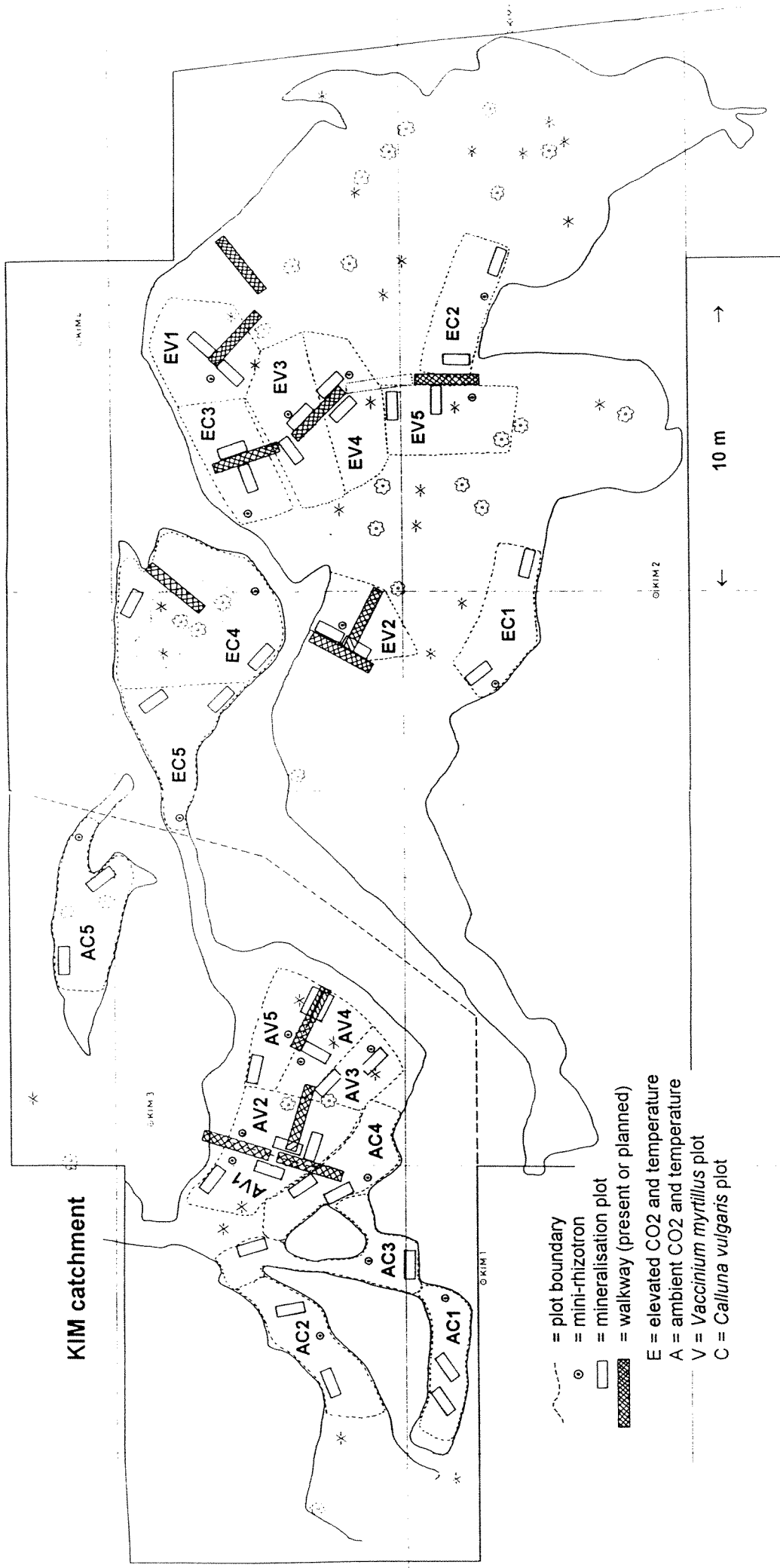


Figure 1a. Map of KIM catchments showing location of plots and rhizotrons.

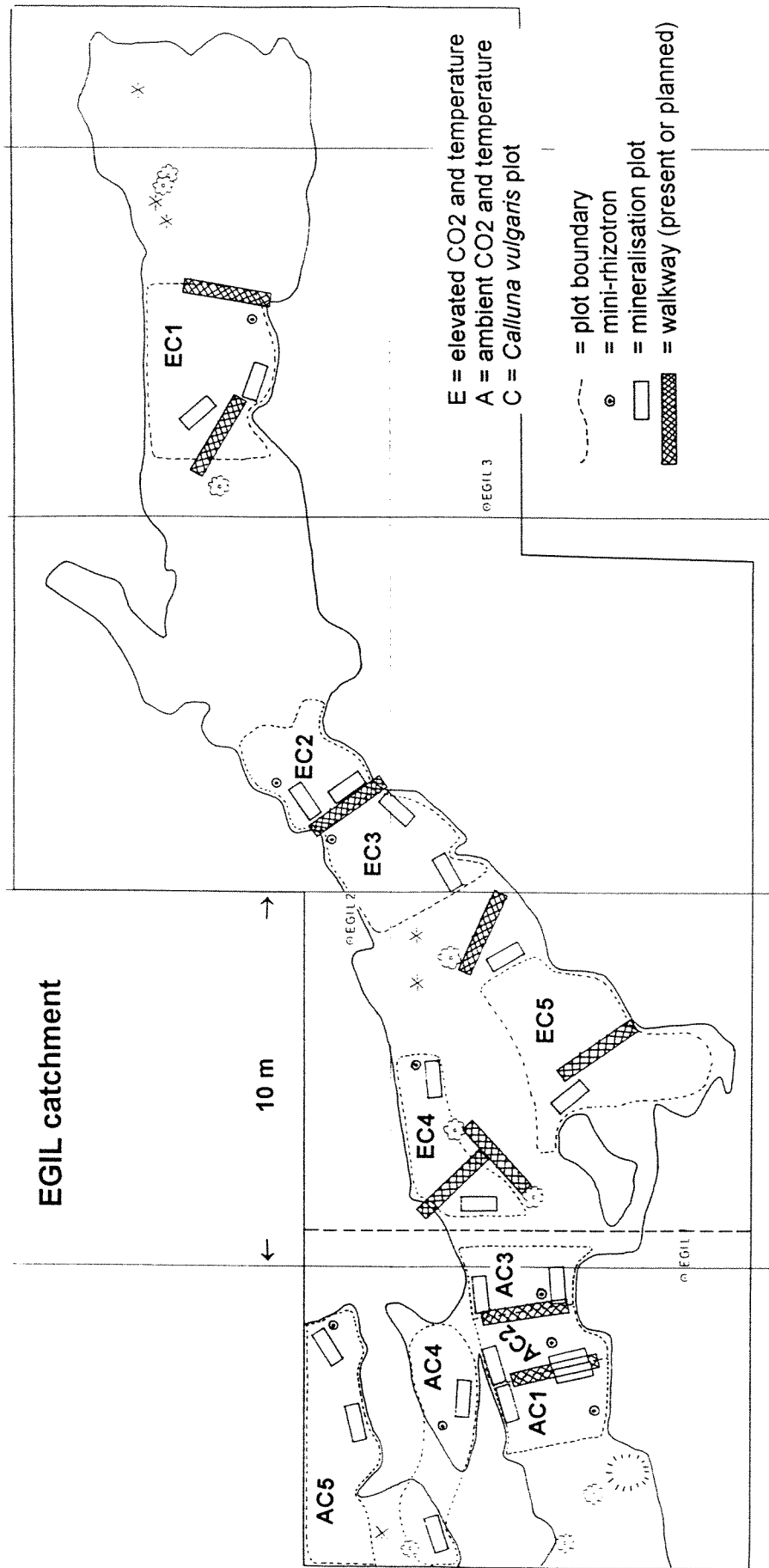


Figure 1b. Map of EGIL catchment showing location of plots and rhizotrons.

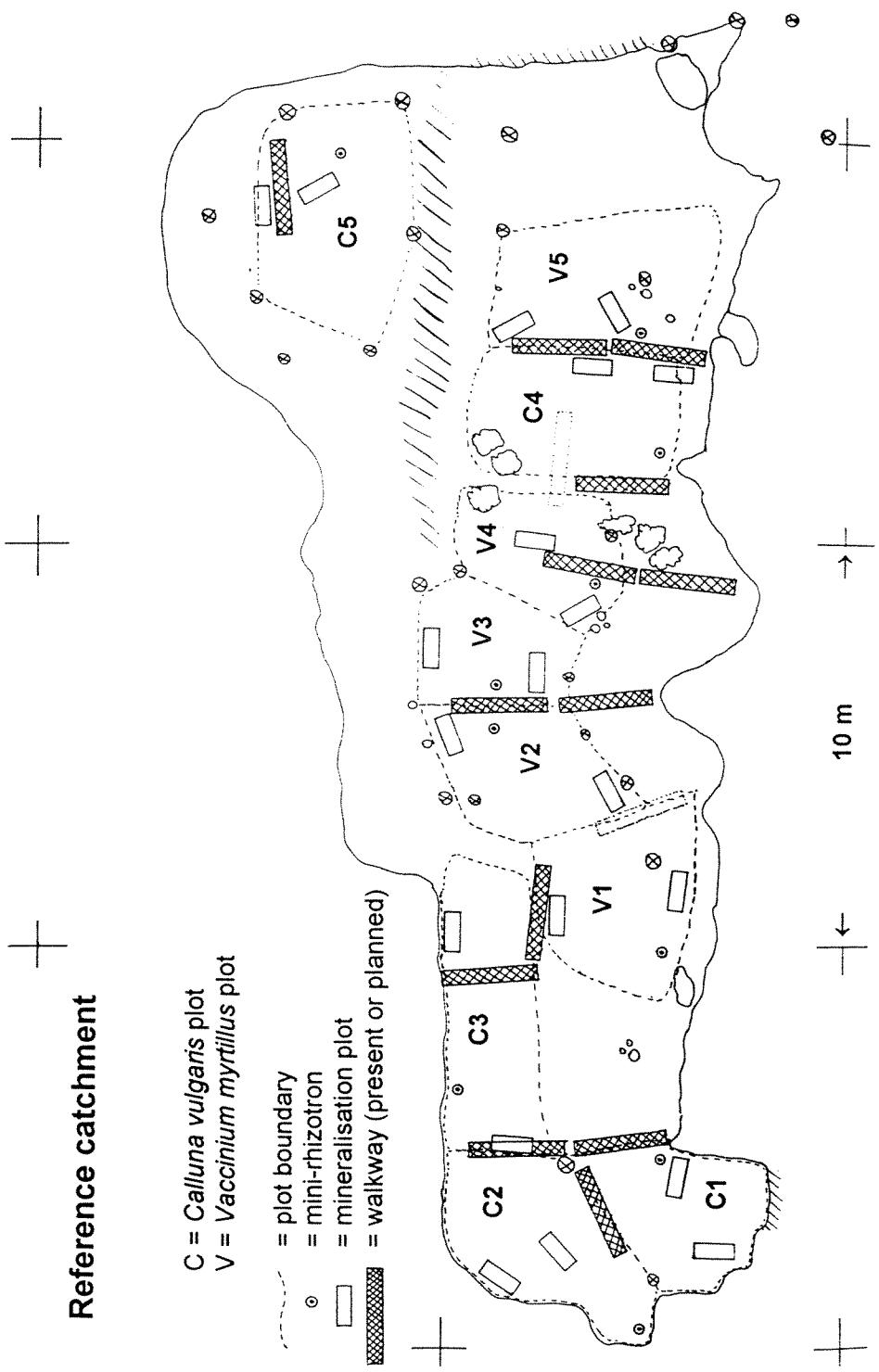


Figure 1c. Map of METTE (reference) catchment showing location of plots and rhizotrons.

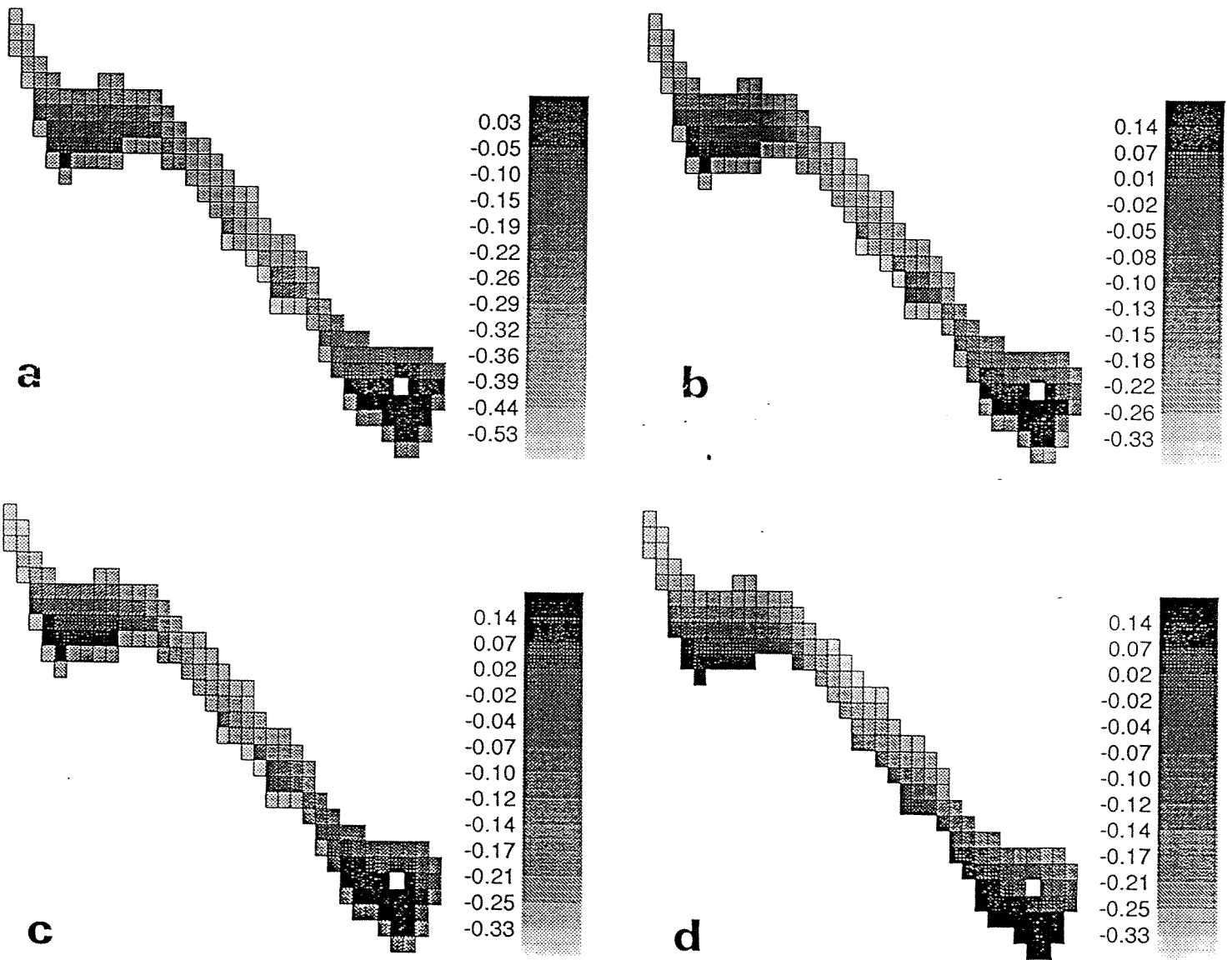


Figure 2. Soil water matrix potentials predicted by IHDM for each soil compartment at four periods through the storm (a) T=3 hrs, (b) T=33 hrs, (c) T=35 hrs and (d) T=45 hrs. Note the scale change in (a) compared to the other three.

CLIMEX predictions for phenology

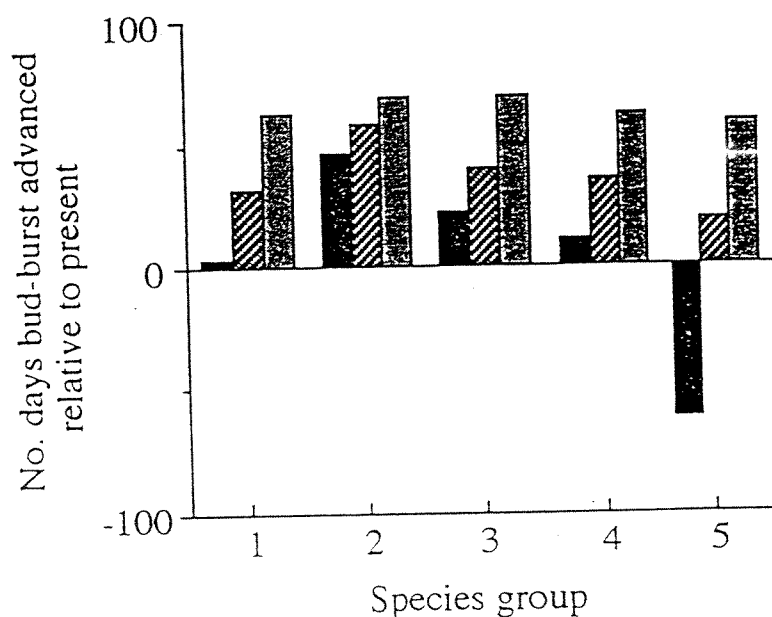


Figure 3. Predictions of phenology for five groups of species in response to different temperature increases within the CLIMEX enclosure. 'Short-winter' - Jan-March (shaded bars). 'medium-winter' - Dec-March (hatched bars) and 'long-winter' - Nov-March (filled bars). Species present within each group were; group 1 *Fagus sylvatica*; group 2 *Robinia pseudoacacia*, *Tsuga heterophylla*, *Picea sitchensis*; group 3 *Rubus idaeus*, *Sorbus aucuparia*, *Betula pendula*, *Corylus avellana*; group 4 *Sambucus nigra*, *Rosa rugosa*, *Salix viminalis*, *Larix decidua*, *Prunus avium*; group 5 *Populus trichocarpa*, *Crataegus monogyna*. headwater catchment ecosystem.



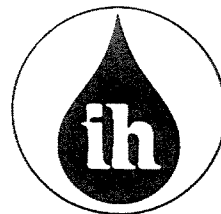
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- 1/1995 Jenkins, A. (ed). 1995. CLIMEX Climate Change Experiment: Progress Report December 1992 - June 1993. 12 pp.
- 2/1995 Jenkins, A. (ed). 1995. CLIMEX Climate Change Experiment: Progress Report July 1993 - December 1993. 31 pp.
- 3/1995 Dise, N. B., and Jenkins, A. (eds). 1995. The CLIMEX project: Whole catchment Manipulation of CO₂ and Temperature. 130 pp.
- 4/1995 Jenkins, A. (ed). 1995. CLIMEX Climate Change Experiment: Final Report on Phase I the first year of treatment May 1994 - December 1994. 47 pp.
- 5/1995 Wright, R.F., Indrøy, A-S., Høgberget, R., Lükewille, A., Sørvåg, T., and Willbergh, M. 1995. CLIMEX Project. Climate data for first year of treatment April 1994 - March 1995. 21 pp.



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