

# ClimMani

Climatic change - Manipulation experiments in terrestrial ecosystems



## 2<sup>nd</sup> Scientific Workshop

Climate change and water - what determines terrestrial ecosystem responses and regulates changes and adaptation?

Basel - October 21-23, 2009

### Minutes

**Participants:** Ana Alebic-Juretic (AA/HR), Anke Jenstch (AJ/DE), Bridget Emmett (BE/UK), Beniamino Gioli (BO/IT), Carl Beierkuhnlein (CB/DE), Christian Körner (CK/CH), Claus Beier (CB/DK), Erika Hiltbrunner (EH/CH), Freja Dreesen (FD/BE), Frida Keuper (FK/NL), Franco Miglietta (FM/IT), Giovanbattista de Dato (GdD/IT), Hans De Boeck (HdB/BE), Ivan Janssens (IvJ/BE), Krassimira Ilieva-Makulec (KI-M/PL), Jane Pedersen (JP/DK), Jan-Philip Witte (J-PW/NL), Jofre Carnicer (JC/ES), Josep Penuelas (JP/ES), Karin Hansen (KH/DK), Leon Linden (LL/DK), Marc Estiarte (ME/ES), Petr Holub (PH/CZ), Pascal Niklaus (PN/CH), Rien Aerts (RA/NL), Richard Wright (RW/NO), Sebastian Leuzinger (SL/CH), Sune Linder (SLI/SE), Sally Power (SP/UK), Sean Schaeffer (SS/US), Sophie Zechmeister-Boltenstern (SZB/AT), Thomas Wohlgemuth (TW/CH) and Yiqi Luo (YL/US).

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4	Mr.	Christian	Körner	Professor	University of Basel	Switzerland
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6	Mr.	Leon	Linden	Dr.	Risø DTU	Denmark
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8	Mr.	Petr	Holub	Dr.	Institute of Botany AS CR	Czech Republic
9	Mrs.	Frida	Keuper	MSc.	Vrije Universiteit Amsterdam	The Netherlands
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29	Mrs.	Sophie	Zechmeister-Bc	Dr.	Federal Research and Training Centre for	Austria
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32	Mrs.	Anke	Jenstch	Professor	University of Koblenz-Landau	Germany
33	Mr.	Carl	Beierkuhnlein	Professor	University of Bayreuth	Germany

## 1. Welcome and introduction

CB, the chair of ClimMani, as well as CK, our local host, welcomed the workshop participants to Basel and the second ClimMani workshop and thanked them warmly for coming. Practical information on reimbursement was given.

CB briefly introduced ClimMani and explained the background of the programme as well as the main aims and objectives.

## 2. Adoption of the programme

The programme of the workshop was adopted after slight rearrangements.

## 3. Climate change and water manipulation experiments

During two days oral talks on different subjects within the workshop theme were given. See the overview of talks below.

Session	Speaker	Country	Organisation	Title
Introduction	Christian Körner	CH	University of Basel	Plant and ecosystem water relations in an atmospheric change context
	Yiqi Luo – US	US	Uni. Oklahoma	Ecohydrological responses and feedback to climate change at ecosystem, regional and global scales*
Effects on processes and species	Dato Giovanbattista	IT	Univ. Tuscia	Morphological and functional adaptations in <i>Cistus monspeliensis</i> L. leaves facing a natural and a prolonged summer aridity
	Bridget Emmett	UK	Centre for Ecology & Hydrology	Soil structural and water holding capacity changes in soils after repeated droughts.
	Sean Schaeffer (& Jos Sc	US	University of California	Changes in soil biogeochemistry associated with drought
Community responses	Marc Estiarte	SP	CREAF	Influence of climate change on microbial community structure and functionality at two Mediterranean ecosystems.
	Frida Keuper et al.	NL	FALW	Sub-arctic vegetation under changing precipitation regimes
	Jane Pedersen	DK	KU-LIFE	Plant Community responses to droughts and interactions with elevated CO <sub>2</sub>
	Anke Jentsch	GE	University of Bayreuth	Effects of extreme drought, heavy rain and freeze-thaw cycles on productivity and phenology of plants, and on diversity and enzymatic activity of microbial communities
Ecosystem responses	Erika Hiltbrunner	CH	University of Basel	Potential alpine catchment yield in a high CO <sub>2</sub> world
	Hans de Boek	BE	University of Antwerp	CO <sub>2</sub> exchange under heat waves and droughts in different seasons
	Franco Miglietta	IT	CNR-IBIMET	Linking water and carbon fluxes in Mediterranean ecosystems: experiments and observations in a network of sites (the MIND project)
	Thomas Wohlgemut	CH	WSL Birmensdorf	A rain shelter and watering going on in the Valais on oak and pine, both in situ and in containers.
	Werner Borken	GE	Univ. Bayreuth	Drought effects
	Petr Holub	CZ		Effect of manipulated rainfall on plant aboveground and belowground production of different grassland ecosystems.
Landscape responses	Jofre Carnicer et al.	SP	CREAF	Increasing defoliation and mortality associated with increasing drought in Spanish forests.
	B. Gioli	IT	CNR-IBIMET	Surface energy balance at the landscape scale: measurement and validation

## 4. Group discussions

During the workshop participants were divided into three groups discussing different topics related to the workshop themes based on the talks given.

- Group 1: Ecosystem responses (including soil carbon and microbiological adaptation)
- Group 2: Vegetation characteristics – water control
- Group 3: Methodology and modelling – next generation of water manipulation experiments

### 4.1 Group 1: Ecosystem responses

Participants: Bridget Emmett, Ivan Janssens, Marc Estiarte, Giovanbatista de Dato, Sophie Zechmeister Boltenstern, Sune Linder, Sean Schaeffer, Pascal Niklaus, Rien Aerts, Sally Power

#### 4.1.1 Key questions

- Does hydrophobicity of soil organic matter prolong the effect of summer drought on C and N mineralization?
- Soil drought – increase or decrease of soil organic matter stocks? Are there thresholds?
- How important is the 'Birch effect' for annual soil C fluxes?
- How will climate change act upon soil physical properties (water retention and hydraulic conductivity curves) via changes in organic matter?
- How will water generated changes in C/N in leaf litter affect decomposition rates and potentially feed back on climate?
- How do trees react to the current rainfall variation?
- What may be the future bottlenecks/windows of opportunity for forest continuity in the light of projected dryer summer seasons?
- How do droughts affect water quality?
- Is soil drought a stress for soil microorganisms in drought adapted ecosystems or soil horizons subjected to frequent drying and wetting?

#### 4.1.2 Key conclusions

- Understanding the belowground water budget is crucial (overarching need)
- The most important processes to reach this goal are: Soil texture and structure and biological and physical controls on biogeochemical cycles
- We need to understand the legacy effects of past land management and soil development
- Standardized collection methods for samples and for reporting of data are recommended
- 3D models (Soils heterogeneous with depth, structure, pF change, substrate supply, change in root supply) are needed

#### 4.1.3 Topics discussed - Key things we would encourage people to consider

- Generally **standardized methods** in measurements and experiments as well as reporting should be encouraged
- **Soil analyses:** Soil texture analysis, Complete soil water budget, pF curves, infiltration and percolation, hydrologic conductivity, rooting depth and plant inputs into SOM (e.g. C4 soil ingrowth cores (soil from long-term CO<sub>2</sub> experiments)), OM depth and horizons, aggregate stability, N availability, water repellence directly (often people think TDR is not working if they do not see rewetting in lower horizons), how carbon is stabilised i.e. in non-organic soils what determines chemical protection,
- **Plant measurements:** (ANPP, canopy dynamics (e.g. spring phenology, senescence, summer drought, allocation patterns (beyond biomass)), standing biomass, roots, carbon inputs to soil, water balance (up to catchment scale), nutrient contents and ratios.
- **Hydrophobicity:** Hydrophobicity should be in models (more important for water relations and runoff relative to changes in ET), literature concerns the importance for fire in developing

hydrophobicity, repeated drought/hydrophobicity cycles may change PF curves – how resilient, what parameters determine this?, link between hydrophobicity and macro pores / preferential flow, test importance using models by changing % preferential/macro pore flow and changing pF curves.

- **Treatment considerations:** Comparable treatment levels (magnitude of drought treatment relative to site climate, put into context for a given site, incorporate inter-annual variability). Key things we would encourage people to measure
- **Extracellular enzymes questions:** Substrate control is important (eg. DOC), no evidence of link between phenol oxidase and decomposition rate in aerobic environments, enzymes are proteins and will be consumed (but literature says can remain active for 6 months if stabilised by clays or OM), drought/warming could be expected to increase phenolics in litter so decrease decomposition rates but data suggests no evidence in experiments (data are inconclusive), index of lability of organic matter should be developed, establish the response surfaces to moisture of range of enzymes, modelling work (Josh Schimel, Jason Neff) suggests adding just one more box (analogous to substrate supply?) significantly improved performance of a simple decomposition model (test on contrasting sites to test how differs and why to identify universal response that can be put into ecosystem models), Proteomics methods provide a new method linking community to the function e.g. enzyme activity.
- **Biodiversity:** Difference between diversity and composition (“who is there” as opposed to “what they are doing”), is diversity a determinant or response to treatment?, relatively easy for plants - difficult for microbes, very coarse view of functions of microbes (redundancy, different environmental optima (precipitation, temp., substrates, etc.)), meta genomics and proteomics may help assess functional diversity.
- **Aggregate stability:** Aggregates are important for stabilisation of OM and water retention (mechanism unknown), polysaccharide secretion by microbes, mycorrhiza, fungi and algae all important in aggregate formation, some species do it more than others and when under stress (species composition important), roots may accelerate by exudation, important to understand which processes are most important, under which conditions and events, effect of event length, difference across different systems.
- **Autotrophic / heterotrophic respiration:** MAJOR PROBLEM OF METHODOLOGY. Two pools but really a continuum of ages/qualities (we need to make modellers aware it is two separate processes), relationship linked with latitude/vegetation type/temperature. It is important we get numbers in situ (lab incubations miss priming and fungi may be upset).
- **Erosion:** Erosion will be important for soil carbon change, Peat erosion is not well known (thermokarst important in tundra)
- **Changes in soil C:** Changing residence time, effects (erodability, water holding capacity, N mineralization, CEC), feedback to productivity and C sequestration?
- **Linkage between C and N cycles:** Not only look at C, need to understand N availability and other elements (P etc.), need to understand how C and N linkages affect C allocation, impact of soil moisture changes (timing), need for standardized methods and reporting, difference in results across in situ versus lab mineralization rates.

## 4.2 Group 2: Vegetation characteristics – water control

Participants: Jofre Carnicer, Freja Dreesen, Erika Hiltbrunner, Pedr Holub, Iqi Luo, Anke Jentsch, Frida Keuper, Jane Pedersen, Sally Power, Flip Witte, Thomas Wohlgemuth

### 4.2.1 Key questions

- How will characteristics of the vegetation that determine evapotranspiration (e.g. water use efficiency, interception capacity, rooting depth and percentage of bare soil) respond to climate change? How will these responses cascade through the system and affect groundwater recharge and groundwater dynamics?

- Which periods within the year and within the vegetation period are more sensitive than others to effects of changing precipitation regimes on various abiotic and biotic parameters?
- Which water related processes are most important in determining ecosystem responses to changing water conditions and the interaction of changing climatic drivers?
- How do effects of changing water regimes propagate in space and time, across trophic levels, through biotic interactions, etc...?
- How do overlapping root systems of sensitive and less sensitive taxa (one saving water, e.g. *Poaceae*, one spending, e.g. *Cyperaceae*) respond and mediate responses to changing water regimes?
- How do species with different life strategies to drought affect ecosystem responses to drought, and how do we incorporate such mixed vegetation controls in models?
- Summer rain events produce the so-called Birch effect (flushes of soil CO<sub>2</sub> emissions). Could these events be counteracted by the high photosynthetic rates of *Cistus* with an “arid habitus”?
- Vegetation community is made up by different species. Why did you choose to investigate only one species?
- How can plant species composition influence the results of experiments with manipulated rainfall?
- Can stress tolerant plant species mask the effect of reduced rainfall in mountain sites with higher amount of precipitation?
- Are wet plant species in rich communities more sensitive to reduced rainfall?
- Why is the response of vascular plants to simulated increased precipitation in seemingly similar ombrotrophic, permafrost-underlain, low precipitation tundra not the same?
- Species specific moisture retention characteristics of ‘living soils’ might play a major role in the response of ecosystems to changes in precipitation. Should more effort be put into mapping coverage of the world’s tundra to the moss species level?
- What would be an ecologically relevant measure of ‘dry’ (as in ‘dry tundra’) ecosystems?

#### 4.2.2 Key conclusion/message

A conceptual framework of plant-water relations under changing conditions is missing.

#### 4.2.3 Response parameters of vegetation in climate change experiments

*Vegetation/community characteristics*

<b>1. Leaf area index</b> (relation between leaf area and ground)	potential methods in grassland: (1) fish-eye camera, (2) ceptometer = sun-scan, (2) harvesting and putting leaf on planimeter
<b>2. Interception capacity / Evapotranspiration</b>	<p>potential methods in grassland:  (1) seal surface with rubber  (2) use lysimeters with constructed vegetation  (3) use micro-lysimeter for soil solution but not interception</p> <p>Basics: <math>P = E + T + I - R - \Delta SW</math>; first change with drought is evapotranspiration (P = Precipitation, E = Evaporation, I = Interception, R = Runoff, SW = soil water content).  Hydrologist use in models: <math>ET_{pot} = g \times ET_{ref}</math> (ET = Evapotranspiration, g = empirical crop factor, climate dependent).</p> <p>However, not possible to use <math>ET_{pot}</math> concept in natural vegetation</p>
<b>3. Water use efficiency</b>	methods: natural abundance isotope ratio of 18O and 13C
<b>4. Rooting depth, specific root length as surrogate for BNPP</b>	methods: take root length in different soil depth with minirhizotron cameras in lateral permanent tubes in plots with

	digital image analysis in natural vegetation; harvest in pot experiments, report on soil type
<b>5. Percentage of bare soil</b>	methods: cover estimation
<b>6. Species composition</b>	methods: floristic recording, surrogate variables e.g. functional groups or traits
<b>7. Species Abundance, Evenness, Similarity, Turn-over, Local Extinction</b>	methods: Shannon, Bray-Curtis
<b>8. ANPP</b>	methods: harvest, no good surrogate (common: estimation, biometrical data, height, cover)
<b>9. Plant Cover, Plant height</b>	methods: estimation, point intercept, cranked wire (moss production)

*Species-specific traits (plastic response)*

<b>1. Specific leaf area, leaf mass area, leaf area ratio</b>	Methods: cork driller in brad leaf, or harvest and scan leaf and dry and weigh
<b>2. Phenology</b>	Methods: leaf appearance, flowering onset, period, mid-flowering day; BBCH-cod Comment: not all plants are plastic with response to phenology
<b>3. Feed value / Forage quality / Litter quality</b>	Methods: protein content, closely related to leaf N-concentration, leaf C/N from dried samples
<b>4. Phenolic acid content</b>	Methods: difficult, MS
<b>5. Reproductive fitness</b>	methods: Seed weight, number of inflorescence, flower area, flowering period, germination rate, reproductive biomass
<b>6. Moss growth and bog canopy height</b>	methods: air borne techniques, cranked wire technique (Clymo)

#### 4.2.4 Research priorities for the next generation of experiments

<b>• Timing of manipulations</b>	<ul style="list-style-type: none"> <li>○ Seasonality</li> <li>○ Intra-annual variability</li> <li>○ long-term studies</li> </ul>
<b>• Spatial comparisons</b>	<ul style="list-style-type: none"> <li>○ Across-ecosystem comparisons</li> <li>○ Across-gradient analyses (soil gradients, precipitation gradients, nitrogen deposition gradients, seasonality gradients, diversity gradients)</li> </ul>
<b>• Response dynamics</b>	<ul style="list-style-type: none"> <li>○ Recovery after events</li> <li>○ Delayed responses</li> <li>○ Role of stochasticity</li> <li>○ Longevity of plant species</li> <li>○ If multiple response parameters are tested across various ecosystems, which processes are crucial?</li> <li>○ Key response for water is unclear. (For CO<sub>2</sub> photosynthesis is the foundation, for Nitrogen it is growth and ANPP, See <i>Alan Knapp's BioScience paper</i> (magnitude, ...) - What would be an ecologically relevant measurement of drought?)</li> <li>○ Sensitivity of sites as a function of their wetness (II)</li> </ul>
<b>• Experimental design and scale</b>	<ul style="list-style-type: none"> <li>○ Conceptual framework - Study the Bouchet Curve for experimental design and for doing the metanalysis.</li> <li>○ Design experiments for future experiments, demographic changes</li> <li>○ Data mining from databases is important! Put your data into databases!</li> </ul>

	<ul style="list-style-type: none"> <li>○ How can we scale our results beyond our plots? Suggestion functional growth analysis: is sensitive to different impact factors such as N, T.</li> </ul>
<ul style="list-style-type: none"> <li>● <b>Interactions of drivers</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Multi-factor experiments</li> <li>○ Interaction between events and trends</li> </ul>
<ul style="list-style-type: none"> <li>● <b>Diversity</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Role of genetic diversity in biotic response</li> </ul>
<ul style="list-style-type: none"> <li>● <b>Biotic interactions</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Constructed versus natural community</li> <li>○ Relationship between phenotypic responses / provenances (III)</li> <li>○ Invasion inclusion into experiments? (Weeding or relating traits of invading individuals? Consequences at an ecosystem scale? Can we develop predictive models).</li> <li>○ How do species with different life strategies differ in their response to D,R,T, Co2, NO3, and multi-factors, and how do we incorporate such mixed vegetation controls in models? Why do species respond in the way they do? Extend this to the community level across ecosystems? (II)</li> </ul>

#### 4.2.5 Ecologically relevant measures of drought-stress

- **Under dry conditions:** Pressure head. If you measured moisture contents, pressure heads can easily be read from the water retention curve (pF-curve) of the soil. From the pressure head and the meteorological demand (potential evapotranspiration) one can estimate transpiration reduction due to drought, a factor that is of direct ecological relevance.
- **Under wet conditions:** The volume of air in the soil, which equals pore volume minus (observed) moisture content. There are also models available that compute respiration reduction due to oxygen stress as a function of soil texture, temperature, organic matter content, rooting depth and plant characteristics. Respiration reduction is, of course, an ecological excellent measure of oxygen stress due to conditions that are too wet.

#### 4.2.6 Models & Measurements (Ying & Yang)

- **Dynamic balance between modelling and measurements are needed.** Models determine what you measure, and measurements determine what you model.
- **Good and validated models ARE available for water studies and should be used** (e.g. SWAP, a model for water flow in the unsaturated zone, and Menyanthes for time-series analyses of groundwater levels) and should be applied by researchers for two reasons: 1) To interpolate and extrapolate observed time series (for instance three years of biweekly observations of moisture content to 30 years of daily values). By doing so, the effect of 'accidental' temporal meteorological variation on the observations will be filtered out, and the significance and general applicability of the studied relationships between habitat and vegetation will be improved. 2) Such models may provide a good estimate of habitat factors that are of direct importance to plant growth, such as the transpiration reduction as a result of drought, and the respiration reduction due to insufficient soil aeration. If data are not available, modellers fall back on more statistical models. Physiological models in theory maybe better, but in practice often too complex to work with and unreliable because not all input variables are known accurately enough. You have to be very careful with how you apply them: a calibrated model should always be validated on independent data. Adapting a model to the available measurements is not necessarily the right way to go.
- **The water balance of the root zone needs to be solved in most plant-water relation studies.** To this end, besides variables as precipitation and evapotranspiration, collect information about site characteristics such as root distribution, the water retention curve (pF-curve) and the relationship between moisture content and hydraulic conductivity (k( $\theta$ )-function). These are necessary to compute the water balance of the root zone on a daily basis.

#### 4.2.7 Considerations about grouping of plant species in order to be able to make generalizing statements

- **Method of grouping should be carefully chosen for desired purpose** (eg. PFTs not useful in response to CO<sub>2</sub> enrichment as within group variance in response traits can be higher than between group variance);
- **Both effect & response traits related to moisture are important.** What are the typical moisture response traits (aerenchym, SLA, rooting depth, shifts in phenology, changes in allocation patterns)?

#### 4.2.8 Key Questions to address in the future

- How do plants/ecosystems respond to changed water conditions (De Bouche curve is an interesting starting point)
- Why do plants live at the place where they live?
- Which are the patterns & processes that have been/are being studied?
- What is still missing, and what is *the* relative importance of the patterns & processes already under study? (E.g. What is the relative relevance of drought- & excess water-related processes, such as (not in order of importance): hydraulic failure hypothesis; optimal conditions for growth processes and nutrient supply; genetic processes, thresholds: transpiration reduction point and wilting point, survival rates, germination rates, mortality, alteration in growth (quantity and quality[cf. leaf quality and resulting herbivore pressure],) fitness.

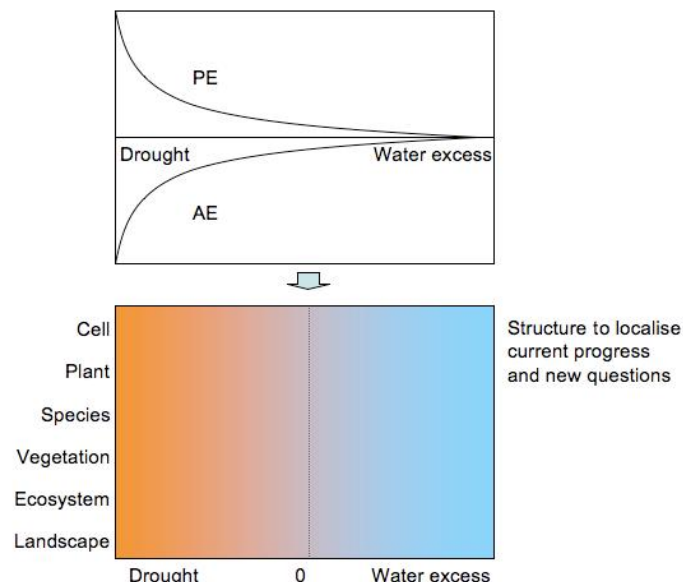
#### 4.2.9 Important organisational levels

(to be taken into account while thinking about the conceptual framework)

1. Cells, 2. Plant parts (stem, root, leaves) (cf. functional growth analysis), 3. Individual (within species), 4. Provenances (within species), 5. Species (species level), 6. Community (many species, including competition and facilitation), 7. Ecosystems, 8. Landscape.

#### 4.2.10 Combination of effects/responses and organisational levels

(Graph provided by Thomas Wohlgemuth)



#### Paper idea:

A conceptual framework and practical guideline/decision tree for precipitation change experiments in ecology and biogeochemistry - How to develop the organizing principles?

### 4.3 Group 3: Methodology and modelling – next generation of water manipulation experiments

Participants: Claus Beier, Christian Körner, Josep Penuelas, Franco Miglietta, Carl Beierkuhnlein, Sebastian Leuzinger, Hans De Boeck, Karin Hansen, Ana Alebic-Juretic, Krassimira Ilieva-Makulec

#### 4.3.1 Key questions

- Do current plot scale experimental approaches provide enough data to model interactions of climatic driver effects on ecosystems?
- Do we know and understand additive versus diminishing signals through interactions between several simultaneous climate change factors and can we model them?
- How do we incorporate seasonal and non linear variation in green biomass in models?
- What are the research frontiers in "winter climate change" in Europe?
- Are almost all CO<sub>2</sub> experiments flawed by soil moisture effects because we assume a photosynthesis driven process chain, while in reality CO<sub>2</sub> experiments are mimicking changes in water relations and therefore interpret changes in moisture regimes rather than 'true' CO<sub>2</sub> effects?
- Should we care about 'observer effects'? (this is an issue which merits some attention)
- Which way of expressing soil moisture makes most sense to both hydrologists and ecologists, in the light of ecosystem responses to alterations in precipitation patterns: water table level; volumetric water content; gravimetric water content; soil pressure head; maybe hygroscopic moisture content or even another hydrological variable?
- Why is it important to study impacts of extreme events in different seasons?
- How relevant is it to recreate extreme events as realistically as possible?
- What should be considered in the next generation of water manipulation experiments?

#### 4.3.2 Priorities

- **Increased water focus:** Water is important in the ecosystem because we can expect direct effects if the water regime is modified. Water is also serving as a key parameter for other changes as it responds to CO<sub>2</sub> and to temperature. Finally, watering and applying drought is rather cost-efficient and less expensive than other approaches of global change oriented manipulations (e.g. CO<sub>2</sub>, ozone, heating).
- **Timing:** Locally, climatic changes are expected to be connected to changes in the amount, frequency, variability of precipitation with shifts in seasonal and regional patterns of precipitation. In general, more extreme and pronounced precipitation regimes are projected. The relative contribution of various types of precipitation such as rain, snow, fog and hail may respond to climatic changes, too. Especially, the performance of ecosystems is likely to react via responses of biota and soils to these rapid changes, and constraints on ecosystem services may result. Future experiments have to refer to the expected and no longer to previously recorded climates. Ecosystem scale manipulations are needed. Use of models to test hypothesis related to timing is needed (e.g. a heat wave is most important during a year).
- **"Pracmatic" experiments:** Since all ecological experiments expose species, communities or ecosystems to artificial influences, experiments have to be designed with care. Heuristic approaches that see the affected manipulation as an ecosystem perturbation are aiming to gain the maximum information on the system. Pragmatic experimental approaches are aiming at a realistic simulation of a probable setting.
- **Land management connections:** Future decisions for land use practises can respond to recommendations on how to manage the water regime. Understanding the responses of ecosystems to modified precipitation can contribute to the development of adaptation strategies for how to cope with climate change.
- **Data mining:** Watering experiments have been carried out in the past in agriculture and forestry but these data have not yet been mined for the purpose of evaluating future developments. Data mining can help in understanding ongoing processes. Archive data exist.

Experience values and indicator values should be looked at (Ellenberg) in order to search for potential winners and losers. At the European level there is a need to bring existing data sets together.

- **Water vs. history:** Land use history and historic disturbance regime affect soil seed banks, life cycles and the population structure and thus impact the legacy of an ecosystem and experiment. An example: Long-term previous regimes of moisture may affect soil texture and chemistry. We have to disentangle treatment (moisture) effects from other mechanisms that are related to history.
- **Community studies:** Which functional traits of the vegetation can contribute to equilibrate the impact of extreme events? Can we design communities that are robust towards impacts and show small amplitude of variation in face of extremes? Species are not uniform across their range of distribution. We have to put emphasis on phenotypes in long-lived species and include various phenotypes in experiments. Clonal plants and long-lived plants (trees, shrubs) are important to investigate with priority. Due to their longevity management practises may need to adapt soon.
- **Experimental design:** There is a need to design amplitude of experiment appropriately. 1) Politically most appropriate based on scenario projections e.g. in regional climate models 2) historical climatic data depends on the length and quality of existing time-series. 3) Ecologically and ecosystem relevant climatic range. Each of these has advantages and disadvantages. Reference systems for the type and intensity of manipulations are recommended. The spatial scale of experiments is important in order to avoid edge effects, to be as close as possible to reality and representative for spatially extended ecosystems. Gradients in small areas over short distances should be investigated! Identify the variability in space! Combined experiments need to know about the shortcoming of the single approaches. Infrared lamps lower the relative humidity and increase VPD. Thus, they may create drought effects and these have to be quantified when water fluxes are concerned. We recommend establishing water manipulation experiments at various levels of biodiversity (functional traits, species etc.).
- **Measurements, parameters and protocols:** Besides ambient controls, artefact controls are required in order to measure the impact of experimental installations (e.g. roofs, fences, wires) on key parameters such as temperature.

## 5. Finalisation and Date and venue of next ClimMani workshop

The discussions were rounded off by CB and he asked for participants to come forward with ideas for review papers on the workshop subject. A possibility is to write a paper on recommendations for future water manipulation experiments.

The meeting was finalised and the local hosts were thanked for the excellent arrangements.

The next ClimMani workshop will be held by SLI in Umeå in the period 22-24 June, 2010. Look for information on the web sites: [www.esf.org/climmani](http://www.esf.org/climmani) and [www.climmani.org](http://www.climmani.org).