Federal Ministry of Food and Agriculture

Federal Office for Agriculture and Food

Research for international sustainable forestry (FinW)
Project update

Project title (Acronym):	**KLIMNEM – Sustainable forest management in temperate deciduous forests - northern hemisphere beech (*Fagus*) and southern hemisphere southern (*Nothofagus*) beech forests**
Geographical focus:	Argentina – Central Patagonia
Cooperating partners:	University of Applied Sciences and Art Hildesheim/Holzminden/Göttingen (HAWK) • Faculty of Resource Management, Büsgenweg 1a, 37077 Götingen, Germany Georg-August-University Göttingen (GAUG) • Plant Ecology and Ecosystems Research, Albrecht-von-Haller-Institute for Plant Sciences, Untere Karspüle 2, 37073 Göttingen, Germany • Cartography, GIS and Remote Sensing Dept., Institute of Geography, Goldschmidtstraße 5, 37077 Göttingen, Germany Free University of Bozen-Bolzano (UNIBZ) • Faculty of Science and Technology, Universitätsplatz 5, 39100 Bozen-Bolzano, Italy Centro de Investigación y Extensión Forestal Andino Patagónico (CIEFAP), Ruta 259 Km 16,24, CC 14, Esquel (9200), Chubut, Argentina
Duration:	01.09.2021 – 31.08.2024
Budget:	859,963.90 Euro

Aims of the project (Map see p. 3):

The overall long-term aim of this project is to compare Central European beech forests (*Fagus sylvatica*) and the "southern beech" forests of Central Patagonia (*Nothofagus* spp.) and to deduce recommendations for a transhemispheric and transcontinental sustainable forest management of temperate deciduous and mixed deciduous forests. For this, the adaptations of forest species to climate change and their responses to extreme events and disturbances will be investigated.

In order to achieve this, the KLIMNEM project includes intensive field research in forests of Central Patagonia and the intersection with results from Central Europe, which have been elaborated within the project NEMKLIM (Nemoral Deciduous Forests under Climate Extremes; duration from

31.12.2017 to 30.06.2021, funded by the BfN with funds from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety) in western Romania.

In the Andes of central Patagonia (as in western Romania; see Kasper et al. 2022), a so-called "space-for-time substitution approach" is used. In this approach, vegetation and tree species composition, forest structure, and various abiotic parameters are recorded along precipitation and temperature gradients. In this way, natural vegetation transitions and sequences are mapped, which provide indications of the influence of macro- and microclimatic variables that may lead to large-scale vegetation shifts in the future due to climate change. In comparison with the results of the NEMKLIM project, macroecological hypotheses can be tested and verified for their general validity, and regional deviations can be identified. For the current study area in Central Patagonia, the specific objectives are as follows:
(1) The development of an adaptive integrated data information system (AIDIS) for the Río Puelo watershed to model the past (using old maps), current, and future potential natural vegetation and to derive potentials and risks (e. g. forest fire) of the landscape; (2) the verification of the modeling results in the field and a comprehensive natural and vegetation characterization of the study area, taking into account anthropogenic and natural disturbances; (3) a vitality analysis of the main tree species to determine climate sensitivity; (4) the development of measures for the restoration of forests and their ecosystem functions and services, taking into account the needs of the local population; (5) the derivation of concrete recommendations for action for sustainable land use, taking into account climate change for the study area, but also globally, by comparing and summarizing the results from Central Europe and Central Patagonia.

At the beginning of the project, four transects were selected from west to east along a precipitation gradient in the Central Patagonian Andes based on available vegetation maps. They are located between Lago Puelo in the south and the city of Bariloche in the north and range between 50 to 70 km from the Chilean border to the Patagonian lowlands (Fig. 1). Two of these transects were selected for intensive field surveys after field visits. Due to the large size of the transects and the difficult terrain and accessibility, the transects were divided into four sectors, each about 10 to 15 km apart. In the four sectors, different exposures (north and south exposure) along an elevation gradient from about 500 m to 1600 m above sea level were investigated. While sectors 1 to 4 or from west to east represent a precipitation gradient, the elevation gradient within the sectors represents a temperature gradient. Data collection began in November 2021 in the 2nd transect near the community of El Manso (= El Manso transect, Fig. 1). In the following, the initial survey methods and results after eight months of the project in the El Manso transect are presented.

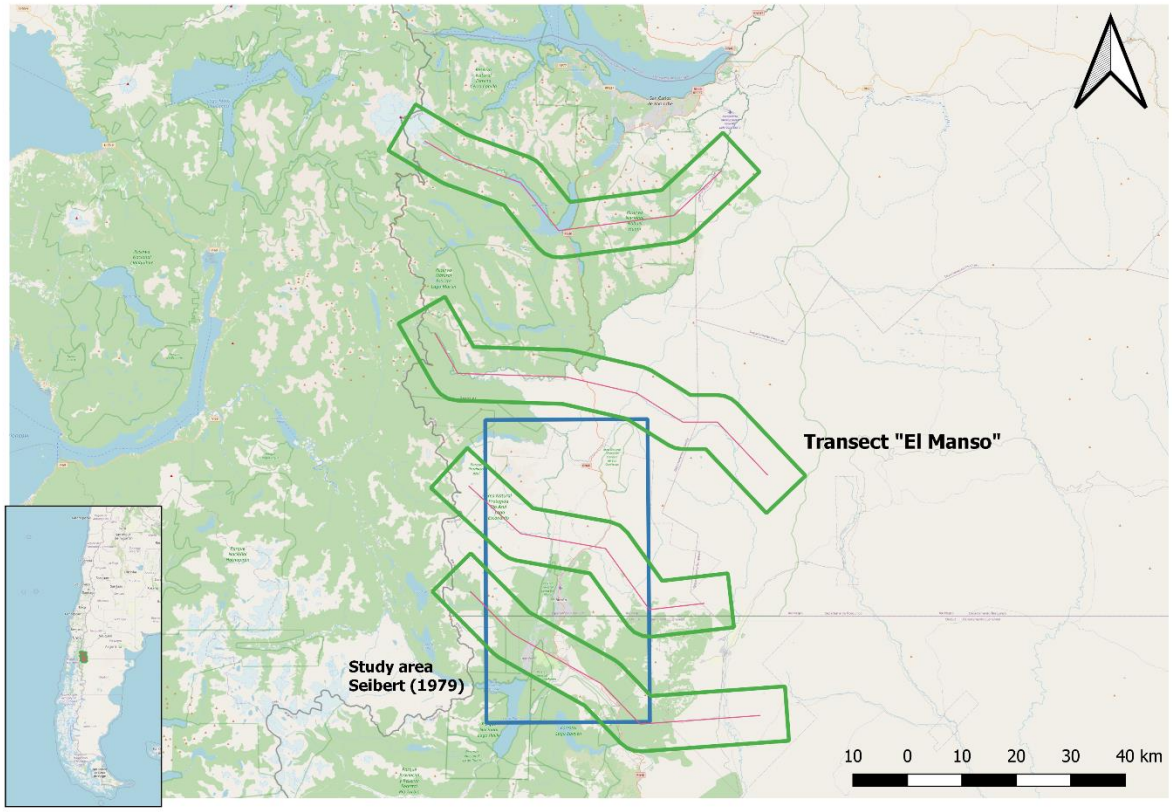

Fig. 1. Study area in central Patagonia with four pre-selected transects. The El Manso transect was studied during the 2021/22 growing season using four sectors from west to east. The blue frame outlines a vegetation map prepared by Paul Seibert in 1979 (Seibert 1979). One of the southern transects will be surveyed during the upcoming growing season, which also depict subsectors of the 1979 vegetation map. © OpenStreetMap contributors, CC-BY-SA; https://www.openstreetmap.org/copyright.

Initial methods & results:

For the development of a comprehensive data information system, high-resolution satellite data were acquired and a digital terrain model (DTM) of the study area was created. This model is to be aligned with terrain surveys and intersected with information on forest types. To be able to carry out a field comparison, drone flights were started in sector 2 of the El Manso transect. In addition, data loggers were installed in the same sector to measure local topographic climatic conditions as a function of elevation and solar exposition (TMS-4 data loggers). Additional data loggers (Hygrochron-iButtons) for measuring temperature and humidity 2 m above ground were distributed in the four sectors to the different forest types along the elevation gradient and also cover forest gaps. These loggers record local climate conditions at 4-hour intervals daily for at least one year. They will also be compared with available climate models to assess their validity for Central Patagonia. In addition, for field comparison with the modeled data, trees were measured by height and diameter at breast height (DBH). The following preliminary results emerge from these field surveys to date:

1. There are strong differences in temperature and soil moisture between sites of high (north-exposed) and low (south-exposed) solar radiation.
2. Differences in temperature and soil moisture between sites of high and low solar radiation exist at all elevations (600, 800, and 1400 m a.s.l.).
3. On the south exposed side, single alluvial fans could be identified, which differ strongly in their water balance from neighboring sites.

4. Readings from TMS-4 data loggers and iButton data loggers show correlating results and indicate a good sensory coverage of the El Manso transect.

Based on a vegetation and forest structure survey in the "El Manso" transect across all four sectors, six main vegetation types were identified: *Nothofagus pumilio* forests (Lenga), *N. dombeyi* forests (Coihue), *N. antarctica* scrub (Ñire), *Austrocedrus chilensis* forests (Ciprés), *Lomatia hirsuta* forests/scrub (Radal), and mixed *A. chilensis* and *N. dombeyi* forests. Ground vegetation is characterized by either dense bamboo (*Chusquea culeou*) or a diverse mosaic of tree and shrub species. Preliminary results show the highest plant species richness in the mixed forests compared to the other forest types. Human influence increases towards the east and with decreasing elevation and is reflected in a less dense ground vegetation, partly dominated by alien grass species. In addition, most of the forests studied were affected by fire events in the past. Secondary forests that developed after fires generally exhibited low human impact, but this increases with decreasing elevation. The following summary statements can be made based on the forest structure surveys in sectors 1 and 2 of the El Manso transect:

1. Coihue dominates predominantly in the highest-precipitation sector 1 and decreases in presence toward the east (sector 2). Here, the tree species usually occurs only on southern exposures (cool, shaded) in mixture with other tree species (some ciprés).
2. Lenga forests appear from 1,300 m a.s.l. in sector 1 above the coihue forests, while in sector 2 they appear at 1,100 m a.s.l. in southern exposure, but not until 1,500 m a.s.l. in northern exposure.
3. Lenga forests have the highest stand ages and were less affected by wildfires overall. The remaining forest types can be classified more as early- to mid-successional stages after forest fire.
4. Sector 1 had a higher productivity than sector 2. The higher productivity to the west also corresponds to a greater amount of deadwood. Dead material, depending on its dimension, also has an impact on potential fire development, which could become significantly more important under climate change.
5. Natural regeneration is predominantly sparse. This is consistent with the extensive prevalence of dense secondary forests following previous fire events. On the other hand, low regeneration in the lower part of the sectors could be due to some forest use by cattle grazing. A special case with high regeneration density was observed in a lenga forest on very rocky ground (sector 2, south exposure at 1,500 m a.s.l.) as a reaction to dieback events, which can occur repeatedly within the study area.
6. In high elevations, a close interlocking between lenga forests and Ñire forests or scrub can be observed in some places. Here, a climate change-induced shift from tree species that prefer snowy habitats (lenga) to less snow-tolerant species (Ñire) may already be evident.

Accordingly, the results show clear differences in vegetation and tree species composition along precipitation and temperature gradients, which are summarized by their potential natural vegetation in the following table based on the surveys in the El Manso transect:

Table 1. Vegetation sequences along temperature and humidity gradients in the Argentine-Patagonian Andes from the Chilean border eastward into the Argentine steppe region. Entries in the matrix denote the PNV (potential natural vegetation) resulting from the combination of thermotype (colline to high-montane; rows 1 to 3) and ombrotype (humid to arid; columns A to D).

	(A) Sector 1 humid	(B) Sector 2 semihumid	(C) Sector 3 dry	(D) Sector 4 semiarid	arid
(1) kollin	MNd	Ac-Nd	Ac	LNa	Steppe
(2) montan	MNd	Ac-Nd	Ac-Nd	LNa	
(3) hochmontan	MNp	ANp	ANp/LNa	ANp/LNa	

Ac = Gavileo-Austrocedretum chilensis Esk. 1968; **Ac-Nd** = Austrocedro-Nothofagetum dombeyi Esk. 1968; **ANp** = Anenomo antucensis-Nothofagetum pumilionis Oberd. 1960; **LNa** = Lomatio hirsutae-Nothofagetum antarcticae Roig et al. 1985; **MNd** = Myrceugenio-Nothofagetum dombeyi Esk. 1999; **MNp** = Macrachaenio-Nothofagetum pumilionis Esk. 1975.

A comparison with previous vegetation and forest type maps as well as previous vegetation surveys can reveal vegetation shifts that have already occurred due to climate change or increasing degradation due to human influence and may help to identify "winners" (e. g., the drought-tolerant ciprés, which is advancing eastward) and "losers" (e. g., the more moisture-dependent coihue, which is increasingly occurring in mixtures with ciprés) among the tree species.

Possible "winners" and "losers" will be verified by dendroecological studies based on a vitality analysis. For this purpose, 12 study plots were established in the four sectors in the El Manso transect during the last growing season. In each plot, increment cores were taken from a total of 20 trees of the main tree species lenga, coihue and ciprés. Although the results have not yet been statistically analyzed, forest structure, site conditions, and sampled trees appear to be comparable between sites. For the 20 trees per species sampled at each site, the values for DBH and tree height were quite homogeneous. The calculated competition index according to Heygi showed similar values for each species for each site, except for Ciprés in sectors 1 and 4. These higher values follow the same trend as the high basal area (m^2/ha) found in the stands. Initial evaluations of soil profiles at the dendroecological plots, and across the entire elevation gradient of the four sectors also indicate homogeneous soil conditions in the El Manso transect, predominantly characterized by the thickness of volcanic ash. This creates optimal conditions to study the influence of climate on vegetation succession and tree species vitality under similar site conditions in the future.
Observations after recent forest fires in the study area also show the high erosion potential of the soils, which has an influence on future forest regeneration and reforestation concepts.

An intersection of the vegetation, structural and dendroecological data with the microclimatic measurements and validated terrain models will identify the heat/drought limits of the forest-forming tree species and their associated species communities in the west-east gradient of Patagonia in the next evaluation steps. Factors influencing the altitudinal limits of tree species will also be compared transhemispherically and transcontinentally.

To restore degraded forests, e. g. after large-scale forest fires, plantings of new native target tree species are currently being planned, as well as surveys among the local population on desired ecosystem services of the forests and the landscape.

Key statements and policy advice:

The project is still in its early stages. Thus, evidence-based recommendations for policy and land use are not yet available. However, the project overall opens new global perspectives on the response and adaptation patterns of temperate forest vegetation to land use and climate change. From the multilateral, transhemispheric, and transcontinental research collaboration and knowledge exchange, valuable and important conclusions for international sustainable forest management and land use adaptation to global warming and more frequent extreme events can be drawn by synthesizing the results from Central Europe and Central Patagonia at the end of the project.

For the local stakeholders in Central Patagonia, the provision of a regional and freely usable information system consisting of data from a wide range of disciplines (including climatology, ecology, forestry, etc.) for the derivation of possible management options is of priority. This is intended to provide evidence-based support for decision-making by local stakeholders and institutions, e. g. with regard to tree species selection in a changing climate. The experiences with degradation stages in Central Patagonia may also gain importance in Central Europe under an increasing forest fire risk in the future. The results of the project will therefore also be summarized in "policy briefs" in the coming years.

References

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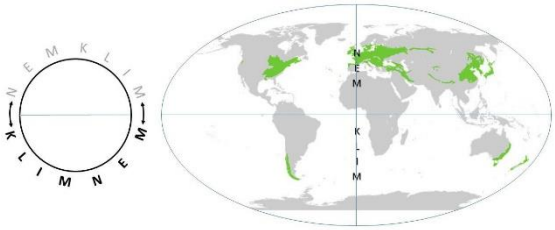
Seibert P. (1979) Die Vegetationskarte des Gebietes von El Bolsón, Prov. Río Negro, und ihre Anwendung in der Landnutzungsplanung. Bonner Geographische Abhandlungen 62: 1-96.

Impressions



KLIMNEM-Logo indicating the transcontinental and transhemispheric approach

Part of the project team in the El Manso valley (February 2022). Photo: CIEFAP

Discussions on site. Photo: CIEFAP

Extraction of increment cores.PhFoto: CIEFAP

Forest fires in the Los Alerces National Park. Photo: Ariel Neri Winter

Adressing soil profiles. Photo: Ariel Neri Winter

El Manso-valley seen from sector 2 to the W. Photo: Jonas Fierke

Installation of iButton-data loggers. Foto: Jonas Fierke

TMS-4 data logger at 1.400 m a.s.l. in a Lenga-forest (*Nothofagus pumilio*). Photo: Jonas Fierke

Lenga-forest (*Nothofagus. pumilio*) at 1.300 m a.s.l. in sector 4. Photo: Jonas Fierke

Lenga-forest (*Nothofagus pumilio*) with *Alstroemeria aurantiaca. P*hoto: Ariel Neri Winter

Vegetation surveys in the El Manso transect. Photo: Ariel Neri Winter