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WEATHER IMPACTS ON NATURAL, SOCIAL AND ECONOMIC SYSTEMS (WISE, ENV4-CT97-0448) GERMAN REPORT

by

Michael Flechsig, Katrin Gerlinger, Norbert Herrmann,
Richard J.T. Klein, Matthias Schneider,
Horst Sterr, Hans-Joachim Schellnhuber

P I K

POTSDAM INSTITUTE
FOR
CLIMATE IMPACT RESEARCH (PIK)

Corresponding author:
Dipl.-Math. Michael Flechsig
Potsdam Institute for Climate Impact Research
P.O. Box 60 12 03, D-14412 Potsdam, Germany
Phone: +49-331-288-2604
Fax: +49-331-288-2600
E-mail: flechsig@pik-potsdam.de

Herausgeber:
Dr. F.-W. Gerstengarbe

Technische Ausführung:
U. Werner

POTSDAM-INSTITUT
FÜR KLIMAFOLGENFORSCHUNG
Telegrafenberg
Postfach 60 12 03, 14412 Potsdam
GERMANY

Tel.: +49 (331) 288-2500
Fax: +49 (331) 288-2600
E-mail-Adresse: pik-staff@pik-potsdam.de

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ABSTRACT

The EU project *Weather Impacts on Natural, Social and Economic Systems* (WISE) has analysed impacts of current climate variability to evaluate the sensitivity of today's society to extreme weather. Unlike studies of anticipated impacts of climate change, WISE did not rely on scenarios and projections, but on existing and newly collected data. The research involved *(i)* the statistical modelling of meteorological and sectoral time series, aimed at quantifying the impacts of changing weather variables on sector output, *(ii)* a population survey, aimed at investigating public perception of and behavioural response to unusually hot and dry summers and mild winters, and *(iii)* a management survey, aimed at obtaining insight into managers' awareness and perception of the importance of extreme weather on their operations.

The three activities revealed a wealth of data and information, providing relevant insights into Germany's sensitivity to and perception of extreme weather events. Sectors that were analysed included agriculture, outdoor fire, water supply, human health, electricity and gas consumption, tourism and the insurance industry. It appears from the statistical modelling that extreme weather can have impressive impacts on all sectors, especially when expressed in monetary terms. However, weather variability is generally considered a manageable risk, to which sectors in Germany appear reasonably well-adapted. The population and management surveys reveal both positive and negative impacts of extreme weather. People generally respond to these impacts by adjusting their activities. The utilities (electricity, gas and water) indicate that they are robust to the current level of weather variability and do not consider climate change an important threat to their operations. The tourism sector experiences impacts but typically takes a reactive approach to adaptation, although it is also developing weather-insensitive products.

It appears that the results of the statistical analyses do not always correspond to the perceptions of the population and managers. For example, while people state that they (try to) use less water during hot and dry spells, both the statistical analyses and the management survey suggest that they use more. Such discrepancies are particularly interesting from a policy perspective, because they may undermine public or managerial acceptability of adaptation or mitigation measures, depending on which perception prevails when the measures are designed.

ACKNOWLEDGEMENT

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1. INTRODUCTION

1.1 Background and structure of report

This report presents the work carried out by the Potsdam Institute for Climate Impact Research (PIK) as part of the EU project Weather Impacts on Natural, Social and Economic Systems (WISE, ENV4-CT97-0448). Within this project, PIK conducted research to assess the influence of weather extremes on various socio-economic sectors and the general public in Germany. In addition, the willingness and preparedness for adaptation to weather extremes and climate change were investigated. The research comprised three types of activities:

- Statistical modelling of meteorological and sectoral time series, aimed at quantifying the impacts of changing weather variables on sector output;
- A population survey, aimed at investigating public perception of and behavioural response to unusually hot and dry summers and mild winters;
- A management survey, aimed at obtaining insight into managers' awareness and perception of the importance of extreme weather on their operations.

In view of data availability, the statistical modelling focused primarily on the former Federal Republic of Germany (*i.e.*, Western Germany). The population and management surveys were conducted in the northern part of Germany.

Given the dependence of the statistical modelling on meteorological data, Section 1.2 first provides an overview of the meteorological data that have been collected and presents a descriptive analysis of these data. Section 1.3 then explains the general modelling methodology used for the sectoral statistical analyses. Based on these data and this methodology, Chapter 2 presents results for agriculture, fire, health, energy and water, tourism, and wind storms, respectively. Each sector is treated in a similar way, first presenting the hypotheses and the available sectoral data, then a detailed account of the modelling exercises and results as well as an economic valuation of the impacts, followed by discussion and conclusions. Chapter 3 presents the population and management perception studies, respectively.

1.2 Data

1.2.1 Data availability and acquisition

The first months of the project period were devoted to the identification and acquisition of the required data in the selected sectors agriculture, tourism, energy, property insurance, water and fire. The administrative structure of Germany with federal states and the economic changes following the political reunion of the two German countries in 1990 posed specific difficulties to data identification and collection. The original approach of the German WISE group was to perform analysis for the northern part of Germany, consisting of seven states from former West and East Germany. While Niedersachsen, Bremen, Schleswig-Holstein, Hamburg and West-Berlin have always been part of the Federal Republic of Germany (= "old states", "West Germany"), the other three, i.e. Mecklenburg-Vorpommern, Brandenburg and East-Berlin, were part of the German Democratic Republic (= "new states", "East Germany") until October 1990.

Particular problems to obtain appropriate data were encountered when considering this northern region as a whole. These problems arose mainly under the scope of data assimilation and harmonisation from former West and East Germany. In discussions with the national and state-based statistical offices, the German WISE group has found large constraints in availability and reliability of socio-economic data from former East Germany, in particular for the period before 1991. Hence, in agreement with the project co-ordinator, it was decided to perform WISE impact analysis at the national level, if feasible under data aspects. If not, only former West Germany will be treated as the study area. Additionally, for a more region-specific evaluation of the impacts of weather extremes within individual sectors, the group concentrated on two states: Niedersachsen, belonging to former West Germany and Brandenburg, as a representative area of former East Germany. Niedersachsen has coastal, mountainous as well as intermediate regions, while Brandenburg is a land-locked state with intermediate relief.

In East Germany, there was a structural break in the statistical time series with the German unification. As a result, most of the German series until the year 1990 only cover West Germany, while as of 1991, the eastern states are integrated.

A detailed description of the gathered and used data can be found in Appendix 2.

1.2.2 Meteorological data and its descriptive analyses

The WISE impact assessments of hot summers and mild winters with multiple linear regression models were based on a monthly meteorology for precipitation sum (in mm) and mean temperature (in °C). Most of the time series on impact and economic activity were available for the years 1965 to 1995. The meteorological database for the impact assessments covers the same period for both West Germany (all federal states before German reunification except Berlin) and Niedersachsen. For Brandenburg, a monthly meteorology was compiled for the years 1975 to 1995. Restrictions of the data sets of these periods are mainly caused by data availability. Monthly meteorologies were derived from the meteorological database of daily and monthly values, which is held at PIK. This data originates from the German Meteorological Office (Deutscher Wetterdienst, DWD). For Niedersachsen, data was acquired directly from DWD.

The following procedure was applied to construct the monthly meteorologies: We considered only meteorological stations below 800 metres altitude, because only one percent of the German population lives at higher altitudes (Lerchl, 1998). Moreover, crop cultivation does not play any role in Germany above this altitude. If available, daily data was aggregated to monthly values for each climate and precipitation station (monthly sum of daily precipitation and monthly mean of daily mean temperature). These aggregations were assimilated with available monthly values of precipitation and mean temperature from additional stations. Finally, mean monthly regional meteorology was calculated for those stations for which an assimilated data set existed with a completeness of at least 97.5% of the monthly values within the selected time range (1965/1975 to 1995). For agricultural impact assessments with panel ordinary-least-square methodology, the same procedure was performed for all federal states of West Germany. Fig. 1.2.1 and Tab. 1.2.1 summarise the used stations.

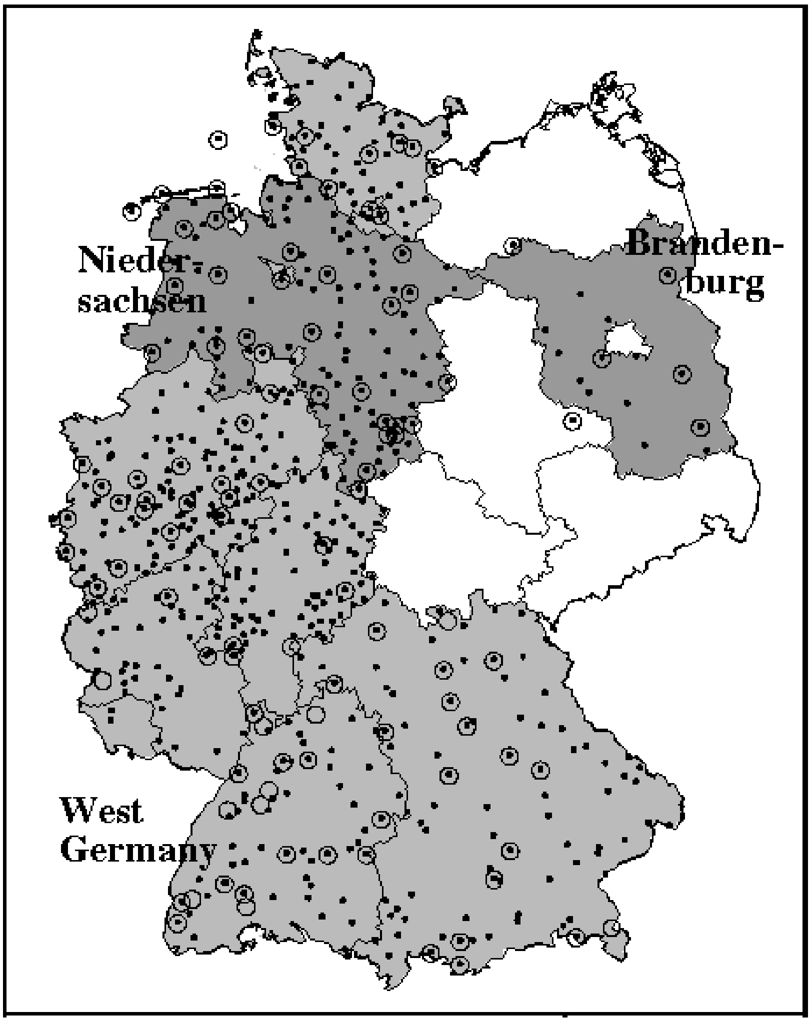

Fig. 1.2.1: *Investigation areas in Germany and meteorological stations for regional monthly meteorology. Circles: mean temperature; dots: precipitation.*

Meteorological element	**Number of used stations**		
	West Germany	**Niedersachsen**	**Brandenburg**
Precipitation sum	616	136	18
Mean temperature	105	26	6

Tab. 1.2.1*:* *Number of used stations for deriving monthly regional meteorology.*

For Niedersachsen and Brandenburg, the regional numbers of frost and summer days on a monthly basis were derived from daily station values. A minimum temperature below 0°C indicates a frost day, while a maximum temperature above 25°C indicates a summer day. Again, monthly characteristics for each meteorological station were averaged to yield a regional data set.

The construction of the meteorological database for windstorm impact assessment on the insurance sector is described in Section 2.6.

Fig. 1.2.2 gives an overview of the derived meteorologies for West Germany, Niedersachsen and

Brandenburg both for summer (June to August) and for winter (January to March). Tab. 1.2.2 summarises monthly means for summer and winter and annual values for 1975 to 1995.

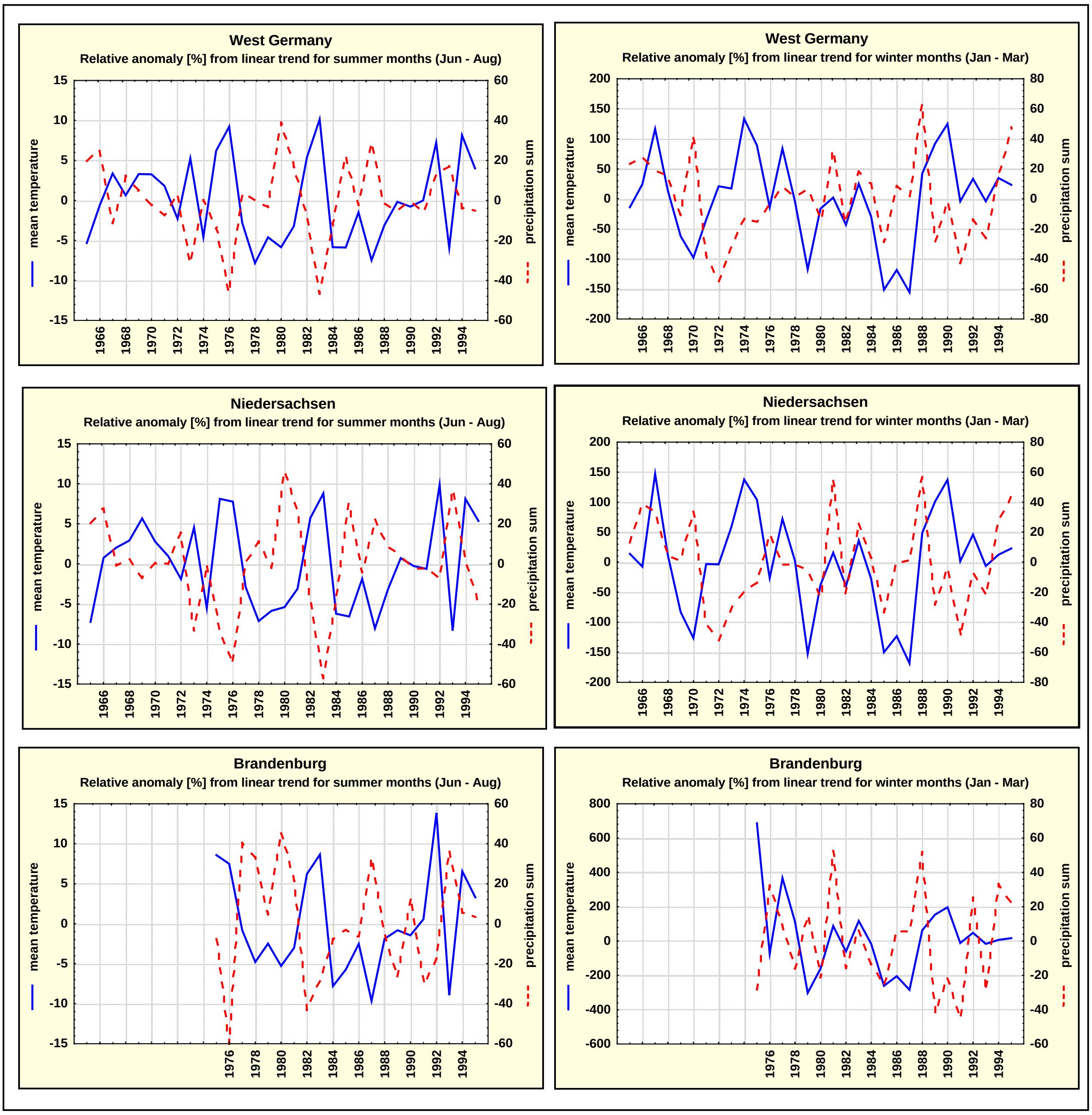

Fig. 1.2.2: *Relative residuals / anomalies from the linear trend of summer and winter precipitation and mean temperature for the investigated regions.*

Meteorological indicator	West Germany	Niedersachsen	Brandenburg
Summer mean temperature [°C]	16.68	16.40	17.40
Summer precipitation sum [mm]	79.24	71.53	59.01
Winter mean temperature [°C]	2.15	2.28	1.42
Winter precipitation sum [mm]	68.87	62.53	39.13
Annual precipitation sum [mm]	863.13	781.57	557.43
Number of summer days		23.15	38.27
Number of frost days		66.53	81.52

Tab. 1.2.2: *Mean values of meteorological elements for the years 1975–1995. Monthly mean for seasonal temperature and precipitation, annual mean for day numbers.*

From the meteorological point of view, Niedersachsen seems to be quite an appropriate representative of West Germany, judging from the annual summer and winter temperature and precipitation values and the annual dynamics. Both West Germany as a whole and Niedersachsen have coastal, mountainous as well as intermediate regions. All three regions coincide in the linear temporal trend for the considered periods, showing increases in summer and winter temperatures, winter precipitation and the number of summer days, and a decrease in the number of frost days. The only exception is summer precipitation. It shows an increase for Brandenburg and a decrease for West Germany and Niedersachsen. The majority of these trends are statistically insignificant. Identification of extreme seasons (Tab. 1.2.3) is based on underlying data of Fig. 1.2.2.

Seasonal extreme	West Germany	Niedersachsen	Brandenburg
Hot summer	1973, 1976, 1983, 1992, 1994	1969, 1975, 1976, 1982, 1983, 1992, 1994	1975, 1976, 1982, 1983, 1992
Dry summer	1973, 1976, 1983	1973, 1976, 1983	1976, 1982, 1983, 1992
Hot and dry summer	1973, 1976, 1983	1976, 1983	1976, 1982, 1983
Mild winter	1967, 1974, 1977, 1989, 1990	1967, 1974, 1989, 1990	1977, 1990
Wet winter	1970, 1981, 1987	1966, 1967, 1970, 1981, 1988, 1995	1976, 1981, 1988, 1992, 1994, 1995
Mild and wet winter	–	1967	–

Tab. 1.2.3: *Identified extreme seasons for the investigated regions. A season is considered to be extreme if temperature and/or precipitation deviate more than 50% from the mean with respect to the maximum deviation over time.*

In view of its more continental location, the state of Brandenburg experiences larger differences between summer and winter temperature than the other regions. Much more important than the temperature regime is the precipitation shortage in Brandenburg, which, combined with poor and sandy soils, leads to special conditions for agriculture, forestry and water management. Detailed analysis of the meteorological station Potsdam in Brandenburg (Gerstengarbe and Werner, 1997) with cluster and rank sum methods confirms the continental nature of this station, which seems to be typical for the state of Brandenburg (Fig. 1.2.3). The characteristics used for clustering and ranking were for temperature, number of summer days, number of hot days (maximum temperature above 30°C), degree days above 20°C (all variables between May and September), and summer mean and monthly extreme value mean (all variables between June and August). For precipitation the following elements were analysed between June and August: mean relative air humidity (hum), number of wet days (hum ≥ 80%), number of dry days (hum < 50%), precipitation sum, and number of days with precipitation.

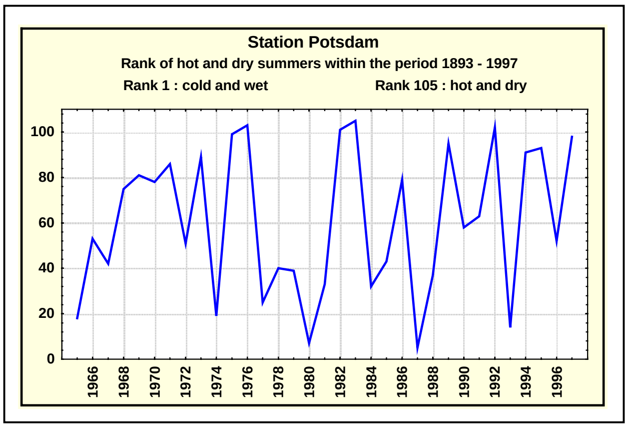

Fig. 1.2.3: *Ranking of hot and dry summers for the station Potsdam.*

1.3 Methodology for regression analyses

According to the proposed methodology in WISE, the general model used for regression modelling is

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 t + \alpha_3 W_t + \alpha_4 W_{t-1} + u_t \qquad \textbf{(Model I)}$$

where:

- t denotes time, used as an explanatory variable to the model to capture all unexplained trends.
- X denotes the data of interest, depending on its lagged value X_{t-1} to indicate that most influences other than weather are the same now and in the past.
- W denotes the meteorological indicator that is assumed to influence X, depending on the sector under consideration. The lagged value W_{t-1} is used to address a dynamic dimension in the model, and because past weather may influence current behaviour in some sectors.
- u_t denotes the error term.
- α_i denotes the regression coefficients to be estimated.

If monthly or seasonal observations of X are available, lagged values of X and W for both the preceding month or season as well as the corresponding month or season in the previous year are considered. For agricultural data on yields, the general model is applied to a panel data structure, covering the time series and cross-section regional data.

We estimate the model by ordinary-least-squares estimators. We run a first estimation, and we check for the significance of the parameters' estimates. We then remove insignificant explanatory variables and re-estimate, checking whether the residuals are stationary.

For some cases a modification of the above method is used: In a first step the residuals RX from the linear trend for the data of interest X are determined by ordinary-least-square estimation. In a second step the following model is identified:

$$RX_t = \alpha_0 + \alpha_1 RX_{t-1} + \alpha_3 W_t + \alpha_4 W_{t-1} + u_t \qquad \textbf{(Model II)}$$

2. STATISTICAL ANALYSIS

2.1 Agriculture

2.1.1 Situation and hypotheses

Agricultural production of all arable crops as well as of horticultural production is influenced mainly by meteorological and soil-fertility conditions. Additional (secondary) effects on production, yields and finally profits include plant treatment and management decisions (e.g., fertilisation and pest, weed and disease control) as well as advances in agricultural technology. Tertiary influences on agricultural production are set by economic and political boundary conditions, such as production quotas and limits, fixed prices or subsidies for set-aside areas or products.

Arable land has steadily declined in West Germany since the mid 1950s, while average yields per hectare for all crops have increased (SBA, 1998). The area of arable land for the production of potatoes has declined dramatically to stabilise at around 250,000 ha. The production area for sugar beet has declined very slowly since the mid 1970s to about 400,000 ha as a consequence of production limits set by the European Union and a mean increase in yields (Fig. 2.1.1).

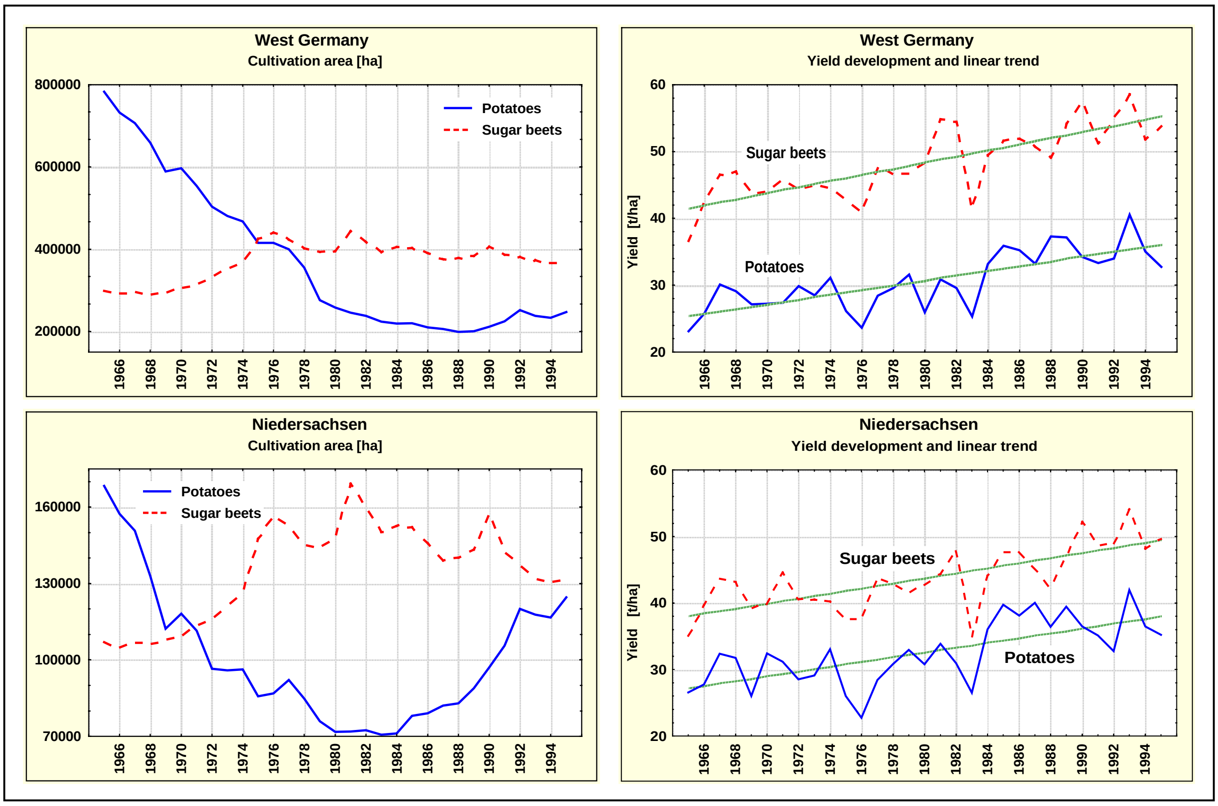

Fig. 2.1.1: *Cultivation area and yield development for potatoes and sugar beets in West Germany and Niedersachsen.*

Before German reunification, agricultural production in the former German Democratic Republic was mainly influenced by the political and economic pressure to supply the population with agricultural products from national production, nearly without any imports. This situation led to intensive production regimes, even in rather unfavourable agricultural regions, such as the north-eastern part of the country, with water deficits and sandy soils. After reunification, structural breaks have heavily influenced East German agriculture. In view of the goals of the WISE project, it was decided to study the influence of extreme seasons on agriculture mainly in West Germany, and to apply the identified meteorological indicators on the state of Brandenburg.

In their agricultural analyses, the three West European countries participating in WISE (United Kingdom, The Netherlands, Germany) focused on sugar beets and potatoes as the main root crops, thus allowing for cross-country comparison. In Germany, sugar beets are cultivated only for industrial sugar production. Annual sugar-beet quotas from the European Union limit production and are coupled to a guaranteed minimum producer price. This price is quite high, compared to the production of other crop commodities.

Sugar beets grow best on deep and humus loamy soils with a constant high water supply (Erdmann and Ellmer, 1994). A wet spring may result in a shift of the sowing date, having negative consequences on further plant development and yield formation. Wet weather conditions during this period restrict the use of machinery and limit germination of the plant, since wet soils are colder than relatively dry ones. The optimal sowing date is around mid April. In the subsequent course of plant development, water is the limiting factor under average meteorological summer conditions in Germany. Sugar beets can partially compensate water deficits after stress periods if water supply is high enough. Harvest finishes at the end of October (Mirschel, 1999).

Based on the above growing conditions, the following hypotheses were formulated and tested: Sugar beet yields are decreased by wet springs and increased by wet summers.

Potatoes prefer well-aired loose-packed soils with good water-holding capacity and water supply. High temperatures support development of the first ontogenetic stages of the plant, while later they limit the formation and growth of tubers (Erdmann and Ellmer, 1994). Appropriate temperatures and a good water supply during the summer months are prerequisites for a proper yield development. From the agricultural reports of the State of Niedersachsen (NLS, 1990-1996), limits can be derived for the precipitation sum during the summer period (June to August). Below 250 mm, drought damages can be expected, while optimal yield conditions may be assumed above 350 mm. Similar to sugar beets, wet soils during the harvesting period may reduce the yield. Late potatoes, which form the majority of this root crop in Germany, are planted as of early May. Harvest normally starts in mid September.

The main hypothesis for the dependence of potato yields on weather conditions is based on temperature and precipitation during the summer months and their relationship: A hot and dry summer reduces potato yields.

Winter wheat is the most important crop in Germany. It prefers soils with a good water-holding capacity. Mild winters support the accumulation of biomass, which can be transformed to grain under optimal meteorological conditions in the course of the growing season. In April and May, water demand is high and precipitation is often the limiting factor. In June and July, high evapotranspiration reduces grain filling and finally yield. Thus hot and dry summers seem to reduce winter wheat yields. Harvest starts at the end of July. Consequently, the hypothesis for the dependence of winter wheat yield on meteorological conditions is based on spring and early summer conditions: Low precipitation in April and May as well as hot and dry weather in June and July decrease yield.

In 1995, about 6000 ha were used to cultivate strawberries in Germany. Normally the plants are irrigated. Strawberry yield suffers from frosty nights in late spring.

A detailed literature survey on the influence of meteorological and environmental conditions on wheat and root crop yield development as well as on model-based assessment studies for different crops is given in Appendix 4.

2.1.2 Available data

Fig. 2.1.1 and Tab.212 illustrate the importance of Niedersachsen for potato production in Germany. In 1995, 40.2% of the German and 50.2% of the West German cultivation area for potatoes was found in Niedersachsen. The sharp increase in cultivation area for potatoes in Niedersachsen after the mid 1980s is likely to be a response to price developments in combination with good soil conditions, especially in the Lüneburger Heide. Potato yields in Niedersachsen are above the West German average. Information on irrigated potato cultivation is not available. Because of higher prices, irrigation is used mainly for early potatoes, which cover about 10% of the total cultivation area.

Region	Years / temporal resolution	Observed variables
West Germany	1950–1997 / annual 1968–1997 / monthly (from 1991 Germany)	For early and late potatoes (*), sugar beets, winter wheat and strawberries: Cultivation area [ha] Harvest yield [t] Producer price index for potatoes
Niedersachsen	1950–1996 / annual	For all potatoes, sugar beets, winter wheat and strawberries: Cultivation area [ha] Harvest yield [t]
Brandenburg	1980–1998 / annual	For all potatoes and sugar beets: Harvest yield [t/ha]
Germany	1991–1994 / annual	Producer prices for potatoes Guarantied minimum prices for sugar beets

(*) = for each federal state except Hamburg and Bremen.

Tab. 2.1.1: *Available data for agricultural modelling.*

Sugar beet dynamics for Niedersachsen show an opposite behaviour. Cultivation area follows the West German trend with large deviations after the mid 1970s. Again for 1995, 25.6% of the German and 35.6% of the West German cultivation area for sugar beets was located in Niedersachsen. Sugar beet yields per hectare are below the West German mean. Both potatoes and sugar beet show yield depressions for the hot and dry summers of 1976 and 1983 in both regions.

Tab. 2.1. indicates the marginality of root crop production for Brandenburg. This is caused mainly by the climatic conditions, with a low mean annual precipitation sum of about 560 mm (cf. Section 1.2.2 on meteorological data) and poor soils with a low water-holding capacity.

Region	% agricultural land from total area	% arable land from agricultural land	% cultivation area from arable land		
			Potato	Sugar beet	Winter wheat
Germany	48.6	68.2	2.5	4.3	21.4
West Germany	43.9	62.7	3.3	4.9	21.0
Niedersachsen	57.0	65.4	7.0	7.4	17.7
Brandenburg	45.3	77.8	1.6	1.4	10.2

Tab. 2.1.2: *Basic statistical data for agricultural modelling (data from 1995).*

Cultivation area for winter wheat in Germany and Niedersachsen shows strong fluctuations (Fig. 2.1.2). The factors that have caused these fluctuations are unknown. Yield per hectare steadily increases, with stronger fluctuations around the trend in Niedersachsen than in West Germany. Fig. 2.1.3 shows the development in cultivation area for strawberry in West Germany and Niedersachsen.

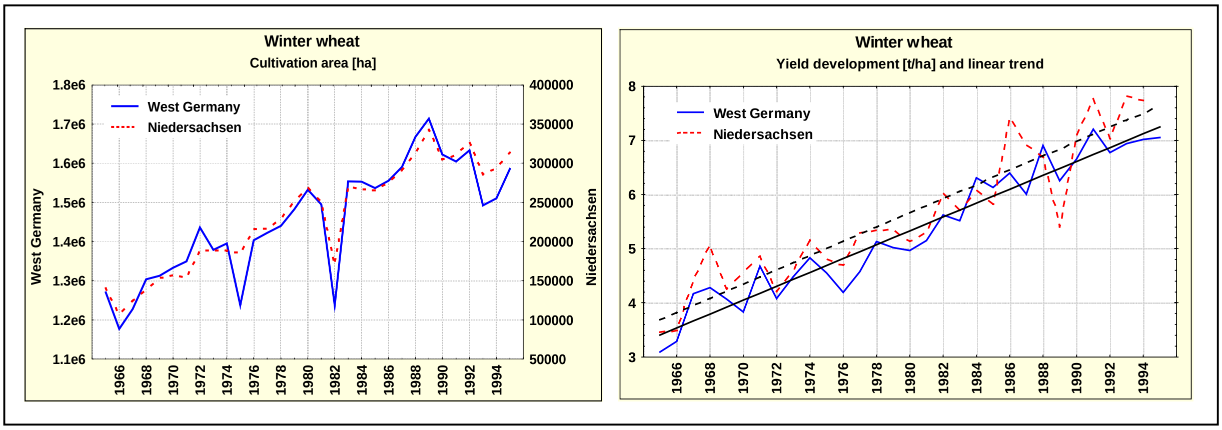

Fig. 2.1.2: *Cultivation area and yield development for winter wheat in West Germany and Niedersachsen.*

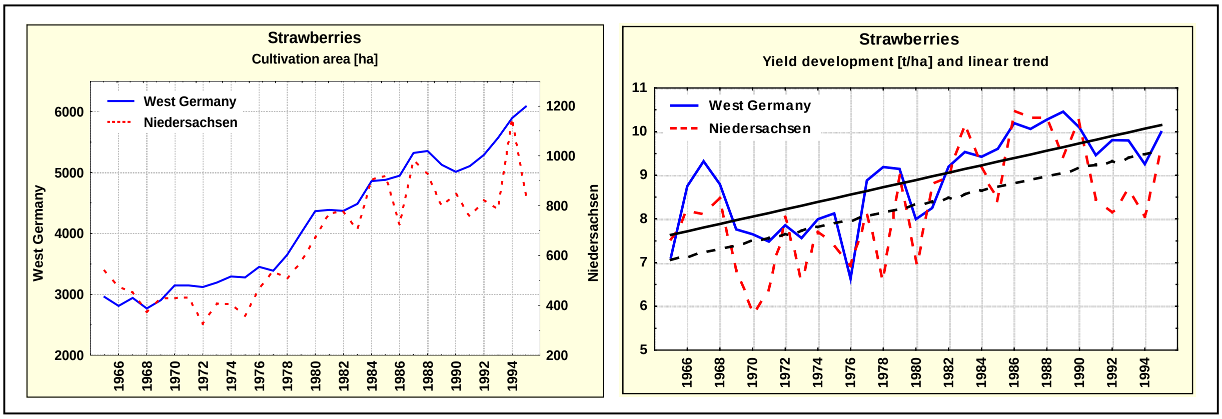

Fig. 2.1.3: *Cultivation area and yield development for strawberries in West Germany and Niedersachsen.*

2.1.3 Modelling

An explanatory correlation analysis was performed as the first step for checking the hypotheses. Yield residuals from the linear trend for yields per hectare were correlated with monthly precipitation sum and monthly mean temperature as well as with their seasonal aggregations (Tab. 2.1.3).

While a West German unique meteorology and mean yields across the whole region (including Niedersachsen) were used for West Germany, here and in the following the West German state approach evaluates yields and a monthly meteorology at the level of each of the eight federal states of West Germany (excluding Hamburg and Bremen). Saarland was excluded when considering sugar beet correlations at the state level for all West German states since there are only some 100 hectares under cultivation for this root crop in this state.

Surprisingly, no significant correlations between the meteorological indicators and the residuals from the yield were found for **winter wheat** in Niedersachsen and West Germany. Additional regression analyses with model type I (see Section 1.3) did not reveal any significant dependence between the meteorological indicators and yields, also with lagged variables. Further investigations are necessary to build statistical models.

The best meteorological indicators for **potato** are summer (June–August) monthly precipitation and temperature mean values. A combination of these two indicators into a heat-dryness index for the summer months from June to August supplies the best correlations. The index:

$$\textit{heat-dryness index} = \frac{\sum mean\_temperature}{\sum precipitation\_sum}$$

can be interpreted as an indicator for water-stress conditions during summer. The higher the temperature and the lower the precipitation, the higher evapotranspiration and water stress in general and the higher the heat-dryness index.

Meteorological variable / indicator	**Potato**			**Sugar beet**			**Winter wheat**	
	West Germany	**West German states**	**Nieder-sachsen**	**West Germany**	**West German states**	**Nieder-sachsen**	**West Germany**	**Nieder-sachsen**
No. of cases	31	248	31	31	217	31	31	31
P03	0.07	0.07	-0.02	-0.08	0.01	-0.20	-0.01	-0.11
P04	-0.18	* -0.16	-0.22	-0.22	* -0.15	-0.25	* -0.43	-0.31
P05	-0.04	* -0.18	-0.10	-0.23	* -0.15	-0.23	0.08	0.17
P06	0.06	0.13	0.35	* 0.36	0.10	* 0.39	0.14	0.03
P07	0.21	0.13	* 0.43	0.02	0.09	0.04	-0.23	-0.04
P08	0.34	0.23	* 0.39	* 0.52	* 0.43	* 0.56	0.05	-0.07
P09	0.19	0.13	0.27	0.03	0.11	0.20	x	x
T03	0.12	0.06	-0.03	0.27	* 0.18	0.21	-0.01	-0.11
T04	0.17	0.06	0.20	0.08	0.09	0.11	0.10	0.22
T05	0.32	* 0.22	0.14	0.34	* 0.24	0.28	0.03	-0.20
T06	-0.22	* -0.26	-0,32	-0.08	-0.09	-0.06	* -0.43	-0.14
T07	-0.34	* -0.28	* -0.49	-0.27	* -0.17	-0.17	-0.01	0.06
T08	* -0.36	* -0.29	* -0.45	-0.12	-0.13	-0.17	0.15	0.04
T09	-0.23	* -0.26	-0.18	0.03	-0.04	-0.19	x	x
P0405	x	x	x	x	x	x	-0.23	-0.10
T0607	x	x	x	x	x	x	-0.24	-0.03
P0607	x	x	x	x	x	x	-0.09	-0.01
T0607/P0607	x	x	x	x	x	x	-0.16	-0.12
T0608	* -0.43	* -0.37	* -0.59	-0.24	* -0.18	-0.19	-0.12	0.00
P0608	0.30	* 0.23	* 0.60	* 0.41	* 0.29	* 0.45	-0.05	-0.03
T0608/P0608	* -0.51	* -0.49	* -0.71	* -0.53	* -0.46	* -0.58	-0.14	-0.10
P0305	-0.07	-0.13	-0.18	-0.28	* -0.15	* -0.37	-0.18	-0.15
P0305/P0608	* -0.36	* -0.39	* -0.54	* -0.54	* -0.44	* -0.65	x	x
P0305/P08	* -0.40	* -0.42	* -0.47	* -0.67	* -0.52	* -0.72	x	x

x : non-relevant
P : precipitation sum
T : mean temperature
i : value for month no. i
ij : mean between month no. i and month no. j
* : significance at least at p-level 0.05

Tab. 2.1.3: *Correlations between meteorological variables/indicators and the residuals from the linear trend for potato, sugar beet and winter wheat yield per hectare.*

Construction of a meteorological indicator for **sugar beet** is more complicated. A high mean precipitation from March to May decreases yields. Judging from the correlation matrix, this influence is weak. Additionally, there is a positive influence of summer precipitation on yield development. The influence of temperature seems to be low under German conditions. Nevertheless, the same heat-dryness index for the summer months as for potatoes results in quite good correlations. So this index as well as the spring (March–May) monthly precipitation mean value were used as meteorological indicators for yield development of sugar beet. As for potatoes, the heat-dryness index describes water stress. A high precipitation in spring decreases yields. The ratio between spring and summer precipitation as an indicator was rejected because of a missing plant-physiological explanation.

For regression model performance of potato and sugar beet, model I (Section 1.3) was used. Predictor for the model is directly the yield per hectare. For the final models, only predictors with significant coefficient model estimates after re-estimation were included in Tab. 2.1.4 and Tab. 2.1.5.

Independent variables	**Yield of potatoes [t/ha]: Coefficient estimates**		
	West Germany Panel OLS	**West Germany**	**Niedersachsen**
Constant		** -736.485	** -738.000
Dummies for federal states	from ** -577.081 to ** -570.776		
Time trend	** 0.307	** 0.390	** 0.393
Heat-dryness index in summer	** -20.553	** -22.901	** -27.86
Number of observations	248	31	31
R-squared	0.60	0.69	0.73
F test	1963.50	31.01	38.67
Durbin-Watson test	1.52	1.58	1.51

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.1.4: *Final regression model for potato yields.*

Independent variables	**Yield of sugar beets [t/ha]: Coefficient estimates**		
	West Germany Panel OLS	**West Germany**	**Niedersachsen**
Constant		** -906.640	** -724.874
Dummies for federal states	from ** -735.131 to ** -724.011		
Time trend	** 0.395	** 0.487	** 0.392
Heat-dryness index in summer	** -18.587	** -27.064	** -18.977
Monthly mean precipitation in spring	* -0.033	* -0.056	* -0.054
Number of observations	217	31	31
R-squared	0.77	0.76	0.73
F test	5372.02	29.08	24.32
Durbin-Watson test	1.64	1.65	1.68

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.1.5: *Final regression model for sugar beet yields.*

All models are statistically significant. According to the models, hot and dry summers have a negative influence on potato and sugar beet yields: the higher the heat-dryness index during summer, the lower the yield. Lagged values from the previous year, both of yields and of the heat-dryness index, are insignificant for yield development. Regression models with summer mean temperature and summer mean precipitation sum instead of the heat-dryness index show that these potential single indicators are insignificant. This result addresses again the importance of the ratio of mean temperature and precipitation sum as a water-stress indicator. The identified models map quite good yields for the hot and dry summers (years 1976 and 1983, cf. Section 1.2.2 and Fig. 2.1.4and Fig. 2.1.5). Although the heat-dryness index for these years is higher for Niedersachsen than for West Germany as a whole, potato yields are comparable. The reason may be better soils for potato growing in Niedersachsen.

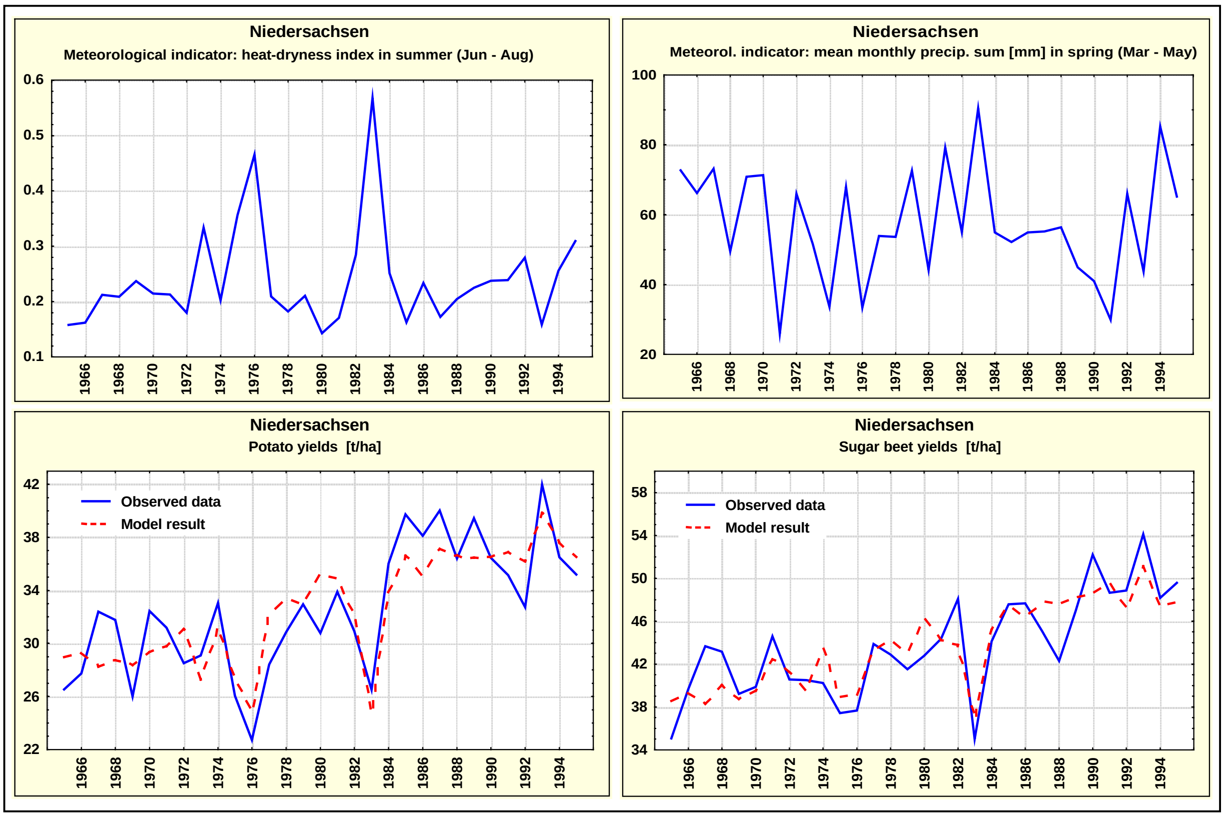

Fig. 2.1.4: *Meteorological indicators, yields and model results for Niedersachsen.*

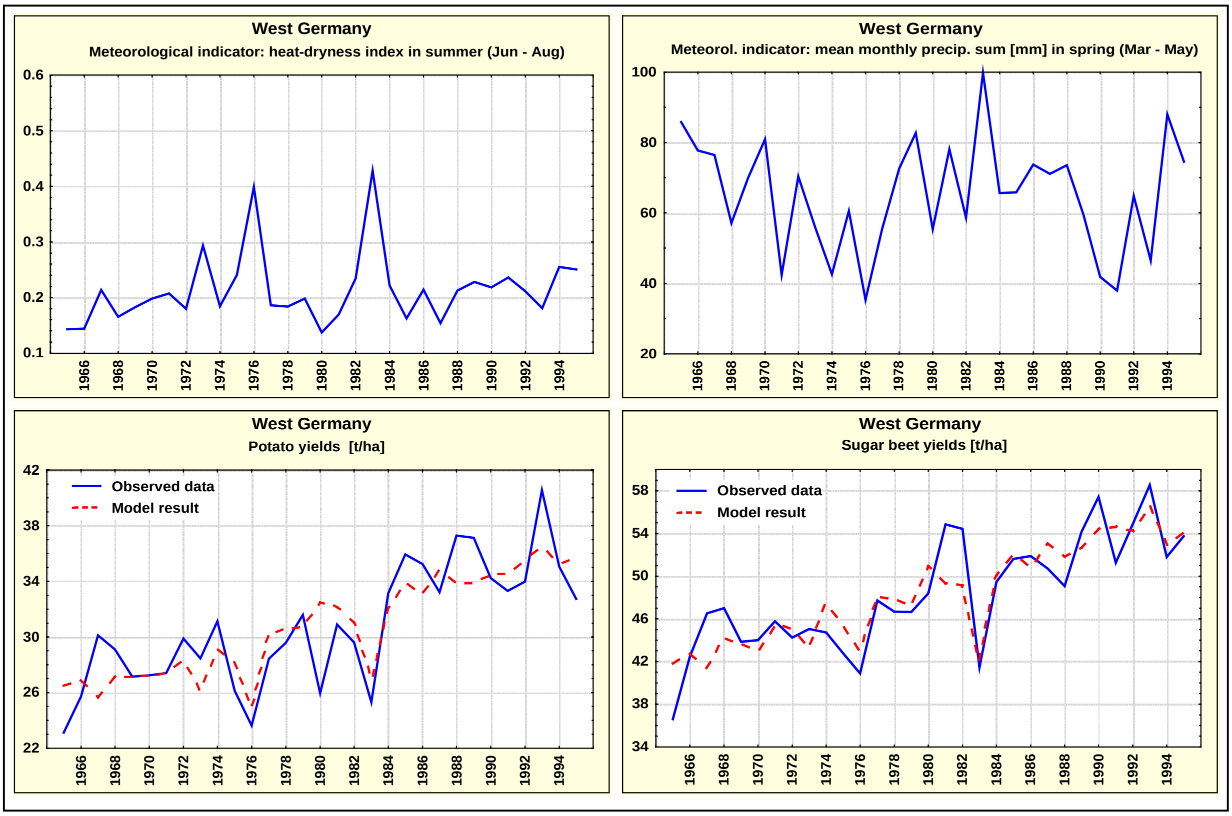

Fig. 2.1.5: *Meteorological indicators, yields and model results for West Germany.*

Spring precipitation shows a negative influence on sugar beet yields. Wet springs depress sugar beet yields. Judging from the significance of the appropriate coefficient at the 0.05 p-level, influence of this indicator seems to be low. Nevertheless, the year 1983, with a hot and dry summer and extraordinary yield depressions for sugar beets in both Niedersachsen and West Germany, also showed a very wet spring.

Application of the meteorological indicators for modelling potato and sugar beet yields in Brandenburg requires the splitting up of the time series into two subseries: before and after reunification in 1990. It appears that for the sugar beet model, spring precipitation is insignificant (possible reason: the generally low precipitation sum for Brandenburg), R-squared is 0.65. The potato model results in an R-squared of 0.44. Coefficients of the heat-dryness index are in the same range as for the other regions for both models.

For **strawberries** we used our starting hypothesis that the number of frosty nights in May depress yields. Since this indicator is a very regional one, no information on it was available for West Germany. Modelling was therefore performed for Niedersachsen only (Tab. 2.1.6). The model confirmed the hypothesis: the higher the number of frost days in May, the lower the yield. Normally, the number of frost days (minimum daily temperature below 0°C) for May is around two.

Independent variables	Yield of strawberries [t/ha]: coefficient estimates
	Niedersachsen
Constant	** -148.545
Time trend	** 0.079
Number of frost days in May	* -0.661
Number of observations	31
R-squared	0.44
F test	10.823
Durbin-Watson test	1.52

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.1.6: *Final regression model for strawberry yields.*

2.1.4 Economic quantification of impacts

Based on the identified linear regression models in Section 2.1.3, we quantified the impacts of hot and dry summers on agriculture using the following approach:

For the model

$$impact = c0 + c1 * met\_indicator \qquad \text{(c0, c1: regression coefficients)}$$

we get

$$\Delta impact = c1 * \Delta met\_indicator$$

Thus, a change in the meteorological indicator is directly proportional to the change of the impact. Using the direct-cost method with a fixed price leads to

$$\Delta cost = \Delta impact * price$$

Since the applied heat-dryness index for potato and sugar beet is a non-linear function of the mean monthly precipitation sum *p* and mean monthly mean temperature *t* we have to consider an incremental change, as follows:

$$\Delta heat\_dryness\_index = \frac{\overline{\sum t} \pm \Delta t}{\overline{\sum p} \pm \Delta p} - \frac{\overline{\sum t}}{\overline{\sum p}}$$

where $\overline{\sum v}$ is the long-term mean monthly value of the meteorological variable *v* over all years.

Fig. 2.1.6 shows the deviation of the heat-dryness index from the long-term seasonal mean between June and August for West Germany (see also Tab. 2.1.7). With respect to the selected ranges for the two meteorological variables, the index is more sensitive to changes in precipitation than to changes in mean temperature. The heat-dryness index depends on temperature in a linear manner and on precipitation in a non-linear manner.

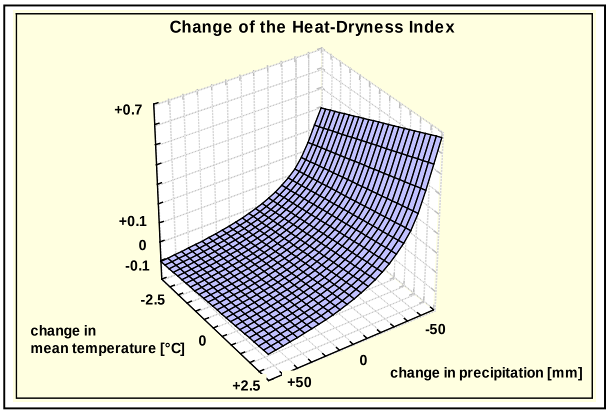

Fig. 2.1.6: *Heat-dryness index, June–August, West Germany.*

Mean monthly values and standard deviation for the modelled years	**West Germany**		**Niedersachsen**	
	mean	**stddev**	**mean**	**stddev**
Mar–May: Precipitation sum [mm]	65.3	15.8	57.5	16.0
Jun–Aug: Mean temperature [°C]	16.6	0.93	16.3	0.95
Jun–Aug: Precipitation sum [mm]	81.8	16.2	73.8	17.4

Tab. 2.1.7: *Seasonal mean and standard deviation for mean monthly mean temperature and precipitation sum for West Germany and Niedersachsen.*

According to the standard deviations in Tab. 2.1.7, we chose increments Δt = ±1°C and Δp = ±15 mm, which corresponds to a mean monthly temperature change of ±1°C and to a monthly change in precipitation sum of ±15 mm, respectively. Together with the mean monthly mean temperature and precipitation sum between June and August for West Germany and Niedersachsen (Tab. 2.1.7), we derived increments for the heat-dryness index with respect to average temperature and precipitation conditions between June and August (Tab. 2.1.8).

Δheat-dryness index	**Δt = ±0°C**		**Δt = +1°C**		**Δt = -1°C**	
	West Germany	**Nieder-sachsen**	**West Germany**	**Nieder-sachsen**	**West Germany**	**Nieder-sachsen**
Δp = ±0mm	±0	±0	+0.0123	+0.0149	-0.0128	-0.0136
Δp = +15mm	-0.0313	-0.0373	-0.0210	-0.0249	-0.0416	-0.0486
Δp = -15mm	+0.0455	+0.0546	+0.0604	+0.0750	+0.0305	+0.0393

Tab. 2.1.8: *Increments of the heat-dryness index for West Germany and Niedersachsen.*

These increments convert to increments for the **potato** yield in t/ha (Tab. 2.1.9) and increments for the proceeds (producer prices) for potatoes in €/ha (Tab. 2.1.10). Finally, increments for total proceeds (producer prices) for potatoes related to the 1995 cultivation area were derived (Tab. 2.1.11:

Increments of total proceeds from potatoes (producer prices) for West Germany and Niedersachsen.

). Mean proceeds for potatoes were set at 65.99 € /t for the years 1991 to 1994 (ZMP, 1998).

Δpotato yield [t/ha]	Δt = ±0°C		Δt = +1°C		Δt = -1°C	
	West Germany	Nieder-sachsen	West Germany	Nieder-sachsen	West Germany	Nieder-sachsen
Δp = ±0mm	±0	±0	-0.28	-0.42	+0.29	+0.38
Δp = +15mm	+0.72	+1.04	+0.48	+0.69	+0.95	+1.35
Δp = -15mm	-1.04	-1.52	-1.39	-2.09	-0.70	-1.09

Tab. 2.1.9: *Increments of the potato yield per hectare for West Germany and Niedersachsen.*

Δproceeds [€/ha]	Δt = ±0°C		Δt = +1°C		Δt = -1°C	
	West Germany	Nieder-sachsen	West Germany	Nieder-sachsen	West Germany	Nieder-sachsen
Δp = ±0mm	±0	±0	-18.48	-27.71	+19.14	+25.08
Δp = +15mm	+47.51	+6.85	+31.68	+45.53	+62.69	+89.09
Δp = -15mm	-68.63	-10.02	-91.73	-137.92	-46.19	-71.93

Tab. 2.1.10: *Increments of potato proceeds (1991–1994 producer prices) per hectare for West Germany and Niedersachsen.*

Δproceeds [10^6 €][a]	Δt = ±0°C		Δt = +1°C		Δt = -1°C	
	West Germany	Nieder-sachsen	West Germany	Nieder-sachsen	West Germany	Nieder-sachsen
Δp = ±0mm	±0	±0	-4.566	-3.453	+4.799	+3.125
Δp = +15mm	+11.740	+8.551	+7.828	+5.673	+15.491	+11.101
Δp = -15mm	-16.958	-12.497	-22.666	-17.185	-11.414	-8.962

[a] for the cultivation area of 1995

Tab. 2.1.11: *Increments of total proceeds from potatoes (producer prices) for West Germany and Niedersachsen.*

The same procedure can be applied to **sugar beets**. The interesting constellation of an increase of spring precipitation and summer mean temperature and a decrease of summer precipitation sum is presented in Tab. 2.1.12.. A guaranteed minimum price of 42.66 €/t for sugar beets (A- and B-classification) cover the years 1991 to 1994 (ZMP, 1998).

Δindicator	West Germany	Niedersachsen
Δheat-dryness index	+0.0604	+0.0750
Δspring precipitation [mm]	+15	+15
Δsugar beet yield [t/ha]	-2.49	-2.23
Δsugar beet proceeds [€/ha]	-106.21	-95.27
Δtotal sugar beet proceeds [10^6 €][a]	-39.223	-12.528

[a] for the cultivation area of 1995.

Tab. 2.1.12: *Increment cascade for sugar beets in West Germany and Niedersachsen (spring: Δp = +15 mm/month; summer: Δt = +1°C/month and Δp = -15 mm/month).*

For **strawberries**, we use one additional frost day in May as the change of the meteorological indicator. Originally, the model is valid only for Niedersachsen, but here we transfer the results for an impact assessment for West Germany (Tab.2.1.13). Strawberry producer prices were reported to be

1769 €/t for the years 1990–1994.

Δindicator	Niedersachsen	West Germany
Δnumber of frost days in May	+1	+1
Δstrawberry yield [t/ha]	-0.661	-0.661
Δstrawberry proceeds [€/ha]	-1169	-1169
Δtotal strawberry proceeds [10^6 €] [a]	-0.980	-7.110

[a] for the cultivation area of 1995.

***Tab. 2.1.13**: Increment cascade for strawberries in West Germany and Niedersachsen for one additional day in May with frost.*

2.1.5 An approach to potato pricing

Yield of early potatoes seems to be a good predictor for yield of all potatoes, as shown in Fig. 2.1.7. The correlation coefficient between them is 0.93. Since early potatoes are harvested in July and late potatoes in September, price building may start in summer. The mean of monthly producer prices from July of the current year to June of the next year is regressed with early potato yield of the current year and producer prices of the previous year. The results are shown in Tab.2.1.14: The lower the early potato yield of the current year, the higher the producer price index of the following market period. The price index of the previous market year influences the current price index negatively.

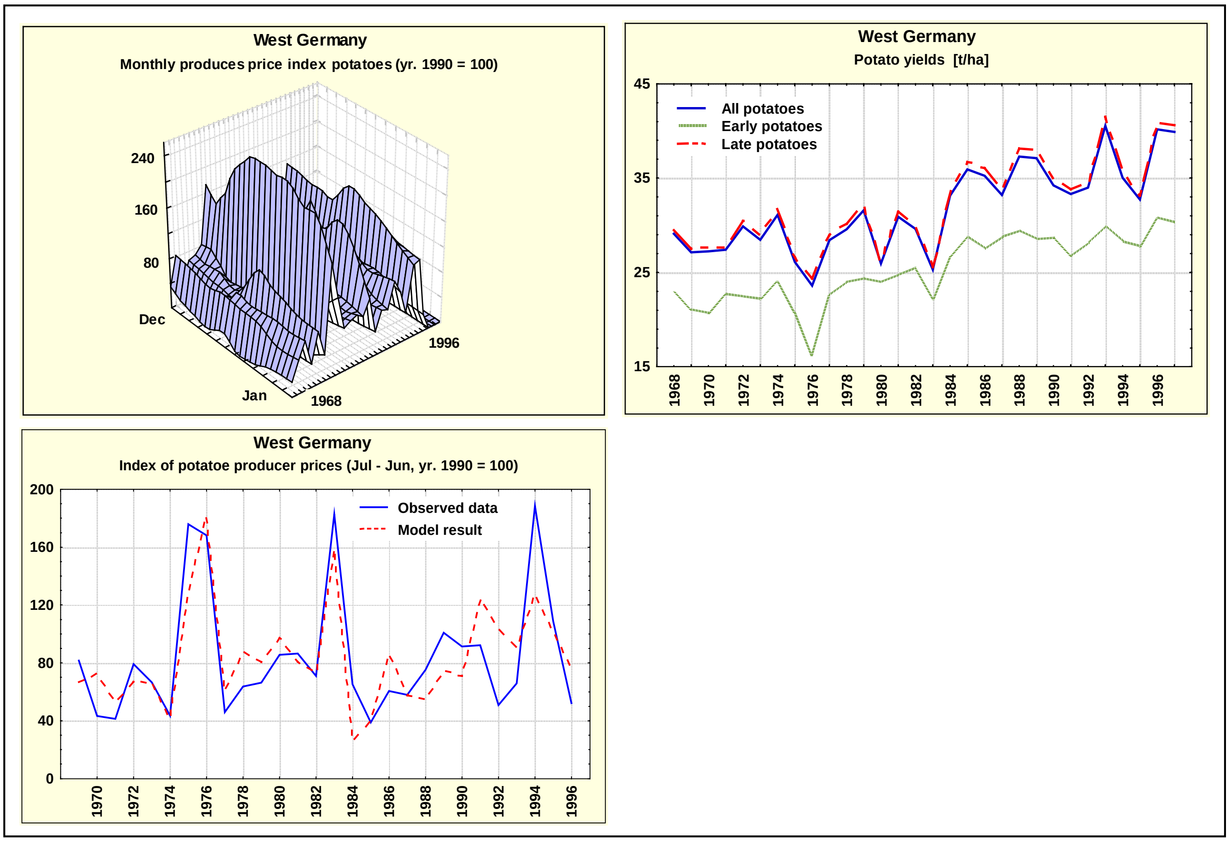

Fig. 2.1.7: *Monthly producer price index, all, early and late yields and final price model for potatoes.*

Independent variables	Coefficient estimates
Constant	** -16202
Time trend	** 8.5
Early potato yield of current year [t/ha]	** -2.1
Mean producer price index of the previous year (Jul–Jun)	* -0.4
Number of observations	28
R-squared	0.65
F test	14.83
Durbin-Watson test	1.69

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.1.14*: Final regression model for potato price model.*

Appropriate regressions with late and all potato yields instead of early potato yield confirm the model assumptions: These alternative models result in R-squared values of 0.39 and 0.41, respectively.

2.1.6 Discussion and conclusions

Regression modelling for crops and strawberries was done, based on annual yields at state and country level and on the appropriate monthly meteorologies.

Analyses of available knowledge on plant development and evaluation of correlation matrices showed for both **sugar beet** and **potato** a significant influence of summer temperature and precipitation on yield development. For both root crops, yield depressions occur under water stress in summer. For average meteorological conditions, water stress is not only a function of precipitation but also of evapotranspiration and hence of temperature. The heat-dryness index, the ratio of mean temperature over precipitation sum for the months June–August, maps water stress and drought in an appropriate manner. The higher the mean temperature sum and the lower the precipitation sum, the higher the heat-dryness index. Identified yield models showed a very good sensitivity of the index to hot and dry summer seasons. This reflects in particular one of the main goals of the WISE project.

In addition, extremely wet springs (March–May) were identified as a yield-reducing factor for sugar beets, because of a possible shift in sowing date for agrotechnical reasons.

For the evaluation of economic implications, the direct-cost method was used. Since the heat-dryness index is a non-linear indicator, increments were supplied for the standard deviation from mean meteorological conditions (Tab. 2.1.7). An increase in the summer mean temperature by 1°C/month and a decrease in the summer precipitation sum by 15mm/month leads to yield depressions of 3.8% (West Germany) and 5.2% (Niedersachsen) for potatoes, and of 4.5% for sugar beets (both regions, including an increase of the spring precipitation sum by 15mm/month). The same relations are valid per hectare and for total proceeds when using the direct-cost method. Nevertheless, there will be differences in reality between sugar beet and potato proceeds, since the market (the yield-price dynamics) does not play any role for sugar beets with a minimum guaranteed price. Scaling up the relative yield depressions to regional depressions in proceeds results in higher losses for sugar beets compared to potatoes for both regions (Tab.2.1.11 and Tab. 2.1.12): Higher producer prices for potatoes cannot compensate the lower total cultivation area.

Especially for potatoes, a shortcoming of the modelling study is that it does not take into account imports. Fig. 2.1.1 addresses the tremendous decrease in cultivation area for potatoes up to the late 1980s. This is partially caused by replacing potatoes by pre-produced feed for pigs. However, potato production also seems to have shifted partially abroad during this period.

Another uncovered problem for this study is the irrigation of early potatoes. Data on irrigation is not available. It could qualify the potato-price model, which shows a dependence of the potato producer price index on the yield of early potatoes and the price index of the previous year.

For **winter wheat**, no significant dependence on the hypothesised meteorological indicators was detected in the yield time series. Additional investigations will have to be made.

Strawberry yield was found to be dependent on the number of frost days in May. Yield depression for an additional frost day in May according to the model is 0.66 t/ha which converts for the year 1995 to about 7% for Niedersachsen and 6.5% for West Germany.

2.2 Forest fires

2.2.1 Situation and hypotheses

About 29% of Germany is covered by forests (Tab. 2.2.1). Despite advantages in forest restructuring during the last decades, forest plantations still form a major part of German forests. They are characterised by evenly-aged and mono-species stands, often dominated by pines in the north and spruces in the south. In 1993, 59% of the West German forest area was covered mono-species plantations (BML, 1992).

Region	% forests from total area
Germany	29.2
West Germany	29.4
Niedersachsen	20.7
Brandenburg	34.7

Tab. 2.2.1: *Forest area (SBA, 1995).*

Droughts in combination with increased temperatures during the summer months seem to be favourable for forest fires. Uniformly structured forest plantations are more susceptible to forest fires than multi-species structures and enable a fast propagation of fires in space. Causes for forest fires listed by forest administrations (e.g., BML 1993; MELF NS 1993; FFE 1993) are arson attacks, negligence, other active influences, natural causes and unknown causes. The importance of the factor weather, which is part of "unknown causes" for forest fires is underlined by different statements of the forest administrations (e.g. FFE 1993).

Our starting hypothesis, based on a literature survey (for references see Viegas, 1996; Whelan, 1997) is that the number of forest fires increases with temperature in summer. Additionally, humidity conditions seem to be important for fire occurrence and propagation in summer. The drier the forests, the higher are the number of forest fires. Humidity has an influence on dead wood, ground vegetation and soil moisture in forests.

2.2.2 Available data

Collected data for forest fires is not comparable across regions because of different counting methods, for instance, including or excluding private and federal forests. Nevertheless, data do show that Brandenburg and Niedersachsen are the regions in Germany with a high occurrence of forest fires. Irrespective of the counting method, 0.18% of forests in West Germany, 1.23% of forests in Niedersachsen and 1.47% of forests in Brandenburg were destroyed by fire between 1976 and 1995. Tab. 2.2.2 and Tab. 2.2.3 give an overview of the available data for forest fire modelling.

Region	Years / temporal resolution	Observed variables
West Germany	1976–1995 / annual 1991–1996 / annual	Number of forest fires Damaged area [ha] Damage costs [DM]
Niedersachsen	1967–1997 / annual	Number of forest fires Damaged area [ha]
Brandenburg	1975–1995 / annual 1991–1996 / annual	Number of forest fires Damaged area [ha] Damage costs [DM]

Tab. 2.2.2: *Available data for forest fire modelling.*

Species distribution by forest area [%]	West Germany	Niedersachsen	Brandenburg
Conifers	63	63	85
Deciduous trees	37	37	15
Spruce	38	21	2
Pine	18	36	80
Beech	17	14	2
Oak	10	8	4

Tab. 2.2.3: *Regional species distribution (BML, 1992, Bruschek, 1994).*

2.2.3 Modelling

Besides temperature and precipitation as potential explanatory variables, Bruschek (1994) and Gerstengarbe and Werner (1997) propose a heat-dryness index, which is the ratio of the number of summer days over the precipitation sum over the vegetation period from April to September, as a predictor for the number of forest fires in Brandenburg:

$$\text{heat-dryness index } hdi1 = \frac{\sum summer\_days}{\sum precipitation\_sum}$$

Since the number of summer days is highly correlated with the mean temperature sum, another index of interest is:

$$\text{heat-dryness index } hdi2 = \frac{\sum mean\_temperature}{\sum precipitation\_sum}$$

From the point of view of data availability, the index hdi2 is as important as hdi1 because data on monthly mean temperature is more often available than data on the number of summer days. Both indices increase with an increase of the number of summer days or of the mean temperature and with a decrease of the precipitation sum. For further discussions of the index hdi2 see Section 2.1.4.

Tab. 2.2.4 shows correlation coefficients between the above-mentioned predictors and the residual from the linear trend for forest fires in Brandenburg.

Predictor	April–August	June–August	April–September
Mean temperature sum	0.64 **	0.66 **	0.66 **
Precipitation sum	-0.76 **	-0.71 **	-0.73 **
Heat-dryness index hdi1	0.93 **	0.86 **	0.88 **
Heat-dryness index hdi2	0.87 **	0.83 **	0.85 **

**: significance at p-level 0.01

Tab. 2.2.4: *Correlations between the residual from the linear trend for forest fires in Brandenburg and different predictors for different periods.*

For model design, we used the indicator hdi2 for April to August and estimated coefficients for Models I and II (Section 1.3) for Brandenburg and West Germany, according to the agreed methodology in WISE. Final regression results are shown in Tab. 2.2.5. The predictor for Model II is the residual of the number of forest fires from the linear trend, for Model I it is the number of forest fires. For the final Model I, only predictors with significant coefficient model estimates were included in Tab. 2.2.5 after re-estimation. Fig. 2.2.1 shows the modelling results.

Independent variables	Number of forest fires: Coefficient estimates			
	Brandenburg (Model II)	Brandenburg (Model I)	West Germany (Model II)	West Germany (Model I)
Constant	** -658.9	* -137.0	** -3740.6	** 179024.0
Time trend				** -91.5
Heat-dryness index hdi2	** 2191.7	** 2159.2	** 18633.7	** 18717.4
Number of observations	21	21	20	20
R-squared	0.76	0.73	0.74	0.80
F test	61.06	52.42	52.13	33.82
Durbin-Watson test	1.92	1.86	1.92	1.89

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.2.5: *Final regression models for the number of forest fires.*

All models are statistically significant. According to the models, hot and dry summers have a positive influence on the number of forest fires: the higher the heat-dryness index hdi2 for April to September, the higher the number of forest fires. Lagged values from the previous year, both of forest fires and of heat-dryness index, are insignificant for the number of forest fires.

Regression models of Model types I and II for the number of forest fires in Niedersachsen result in R-squared values of 0.25 and 0.29, respectively. Nonetheless, the estimated models for Niedersachsen are significant with respect to the estimated coefficients. The poor explanatory capability of the Niedersachsen models could be due to the fact that many stations for monthly meteorology are at or near the coast, while most of the forest area is located in mountainous regions. In this case, detailed studies with an modified sub-regional meteorology will have to be performed in the future.

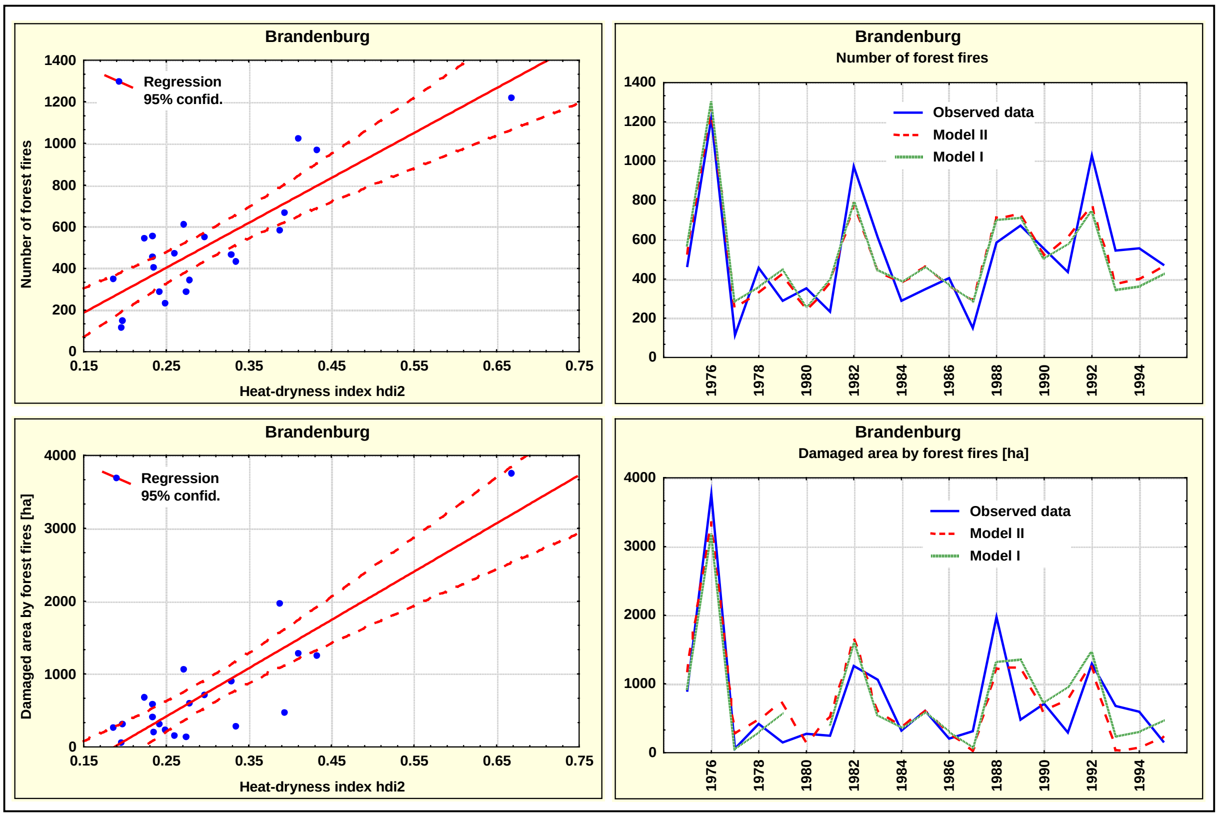

Fig. 2.2.1: *Modelling results for Brandenburg, using the heat-dryness index hdi2.*

Tab. 2.2.6 summarises the modelling results for the area damaged by forest fires. For each region, the results show a significant correlation with the results for the number of forest fires.

Independent variables	**Damaged area from forest fires [ha]: Coefficient estimates**			
	Brandenburg (Model II)	**Brandenburg (Model I)**	**West Germany (Model II)**	**West Germany (Model I)**
Constant	** -1931.2	** -1241.3	** -3135.5	** 184431.7
Time trend				** -94.1
Heat-dryness index hdi2	** 6424.2	** 6634.4	** 15619.5	** 15689.7
Number of observations	21	21	20	20
R-squared	0.75	0.77	0.62	0.72
F test	58.48	61.34	29.89	22.12
Durbin-Watson test	1.66	1.58	1.98	1.97

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.2.6: *Final regression models for the damaged area from forest fires.*

2.2.4 Economic quantification of impacts

Based on the identified linear regression models in Section2.2.3, we quantified the impacts of hot and dry summers on forest fires using the following approach:

For Model I with

$$impact = b0 + b1 * time + residual\_impact$$

and

$$residual\_impact = c0 + c1 * met\_indicator$$

we get

$$\Delta impact = c1 * \Delta met\_indicator$$

and for Model II with

$$impact = c0 + c1 * met\_indicator$$

we also get

$$\Delta impact = c1 * \Delta met\_indicator$$ (b0, b1, c0, c1: regression coefficients)

Thus, a change of the meteorological indicator is directly proportional to the change of the impact. Using the direct-cost method with a fixed price leads to:

$$\Delta cost = \Delta impact * price$$

Since the applied meteorological indicator hdi2 for the number of forest fires is a non-linear function of the mean monthly precipitation sum *p* and monthly mean temperature *t*, we have to consider

$$\Delta met\_indicator = \Delta hdi2 = \frac{\overline{\sum t} \pm \Delta t}{\overline{\sum p} \pm \Delta p} - \frac{\overline{\sum t}}{\overline{\sum p}}$$

where $\overline{\sum v}$ is the long-term mean monthly value of the meteorological variable *v* over all years.

As increments we chose Δt = 1°C and Δp = 10 mm, which corresponds to a mean monthly temperature change of 1°C and to a monthly change in precipitation sum of 10 mm, respectively. In combination with the mean monthly mean temperature and precipitation sum between April and August for West Germany and Brandenburg (Tab. 2.2.7), we derived increments for the heat-dryness index hdi2 with respect to average temperature and precipitation conditions between April and August (Tab. 2.2.8). These increments convert to increments for the total annual number of forest fires (Tab. 2.2.9) and to increments for the annual number of forest fires per 10000 ha of forest area (Tab. 2.2.10). For the calculation, the estimated coefficients of Model I were used.

Mean monthly values between April–August and for the modelled years	**West Germany**		**Brandenburg**	
	mean	**stddev**	**mean**	**stddev**
Mean temperature [°C]	14.1	0.83	14.7	0.88
Precipitation sum [mm]	72.3	12.8	53.2	13.15

Tab. 2.2.7: *Mean value and standard deviation for longterm monthly mean temperature and precipitation sum between April and August for West Germany and Brandenburg.*

Δhdi2	Δt = ±0°C		Δt = +1°C		Δt = -1°C	
	West Germany	Branden-burg	West Germany	Branden-burg	West Germany	Branden-burg
Δp = ±0mm	±0	±0	+0.01384	+0.01881	-0.01384	-0.01881
Δp = +10mm	-0.02365	-0.04366	-0.01150	-0.02783	-0.03581	-0.05950
Δp = -10mm	+0.03125	+0.06390	+0.04731	+0.08706	+0.01519	+0.04073

Tab. 2.2.8: *Increments of the heat-dryness index hdi2 for West Germany and Brandenburg.*

Δnumber of forest fires	Δt = ±0°C		Δt = +1°C		Δt = -1°C	
	West Germany	Branden-burg	West Germany	Branden-burg	West Germany	Branden-burg
Δp = ±0mm	±0	±0	+259	+41	-259	-41
Δp = +10mm	-443	-94	-215	-60	-670	-128
Δp = -10mm	+585	+138	+886	+188	+284	+88

Tab. 2.2.9: *Increments of the number of forest fires for West Germany and Brandenburg.*

Δnumber of forest fires per 10000 ha of forests	Δt = ±0°C		Δt = +1°C		Δt = -1°C	
	West Germany	Branden-burg	West Germany	Branden-burg	West Germany	Branden-burg
Δp = ±0mm	±0	±0	+0.35	+0.40	-0.35	-0.40
Δp = +10mm	-0.59	-0.92	-0.29	-0.59	-0.89	-1.26
Δp = -10mm	+0.78	+1.35	+1.18	+1.84	+0.38	+0.86

Tab. 2.2.10: *Increments of the number of forest fires per 10000 ha of forests for West Germany and Brandenburg.*

Finally, increments for annual economic losses by forest fires were derived from statistical data of the state and federal forest administrations covering the years from 1991 to 1996 (Tab. 2.2.11). This data is available for the economic losses by the reported forest fires at an annual basis. Mean economic losses per forest fire were identified as 1843 € for West Germany and 2746 € for Brandenburg.

Δdamage costs [10^3 €]	Δt = ±0°C		Δt = +1°C		Δt = -1°C	
	West Germany	Branden-burg	West Germany	Branden-burg	West Germany	Branden-burg
Δp = ±0mm	±0	±0	+477	+112	-477	-112
Δp = +10mm	-815	-259	-397	-165	-1235	-353
Δp = -10mm	+1078	+379	+1632	+516	+524	+241

Tab. 2.2.11*: Increments of the damage costs of forest fires for West Germany and Brandenburg.*

2.2.5 Discussion and conclusions

The occurrence of forest fires is influenced primarily by temperature and humidity conditions in forests. Humidity dynamics is a complex network of interacting processes. As a first approach, humidity can be described by precipitation as a widely available meteorological variable. Forest structures (e.g., distribution of species and age classes, ground vegetation and dead biomass) are additional factors determining the occurrence of forest fires, as is the direct influence by men (e.g., arson attacks).

The model approach for Germany was based on annual data on forest fires and a monthly meteorology. Explanatory correlation analyses showed high correlations between the number of forest fires on the one hand, and temperature and precipitation for April to August (i.e. the main vegetation period). The literature suggested that an aggregated heat-dryness index would be an appropriate predictor for forest fire numbers in Germany. The original heat-dryness index is composed of the number of summer days and the precipitation sum. For reasons of data availability, we modified the index by using the mean monthly mean temperature instead of the number of summer days. Fully significant models could be developed for Brandenburg and West Germany, while application of the modified index failed for Niedersachsen. Additional studies will be necessary to address this problem and to build up a sub-regional meteorology.

The non-linear heat-dryness index was evaluated with respect to mean temperature and precipitation conditions. For a change of ±1°C/month for mean temperature and ±10mm/month for precipitation from April to August, increments for the number of forest fires range between –1.26 and +1.84 fires per 10000 ha of forest area for Brandenburg and between –0.89 and +1.18 fires per 10000 ha of forest area for West Germany. These differences in the sensitivity of the regression model to changes in meteorological conditions confirm the higher sensitivity of the Brandenburg forests to forest fires.

The monetary valuation of the impacts of forest fires was based on the heat-dryness index and the direct-cost method. Direct-cost evaluation was based on a relationship between the annual number of forest fires and the assigned economic losses between 1991 and 1996. This is a very general relationship that does not take into account directly the damaged area from a forest fire. These economic losses do not include additional costs for fire fighting and re-forestation. Therefore, the figures in Tab. 2.2.11 can serve only as a first estimate and should be interpreted with care.

2.3 Health

2.3.1 Situation and hypothesis

The influence of weather on mortality has been investigated at different time scales. At the seasonal scale, mortality rates are believed to be influenced by a number of physiological parameters (Stout *et al*., 1996; Woodhouse *et al*., 1993). These physiological parameters are influenced by seasonal fluctuations of temperature, precipitation and photoperiod (exposure to daylight) (Hare *et al*., 1981; Motohashi *et al.*, 1996; Nelson *et al*., 1995).

Normally, winter mortality rates are higher than summer rates. In Germany, however, this seasonal component of mortality has decreased since the mid 1940s (Lerchl, 1998). Studies with daily mortality numbers in Germany showed influences of several meteorological parameters on the perceived temperature as a complex indicator (Staiger *et al*., 1997) and finally on mortality rates (Jendritzky *et al*., 1997). One of the results of the latter modelling study is that mortality is influenced at a daily time scale. A heat wave in summer increases the mortality rate after one or two days. The following weeks show a decline in mortality and thereby a compensation at the monthly time scale.

Within the WISE project, statistical analyses of mortality is performed at a monthly time scale. Although the literature survey indicated problems with this time scale, we focus on summer and winter death rates with the following hypotheses:

- Winter and summer mortality rates are influenced by the corresponding seasonal temperatures. While winter death rate increases with low temperatures, summer death rates are suggested to increase with higher temperatures. This corresponds with the above mentioned perception model and a deviation from an optimum for the perceived temperature.

- Elderly people are especially susceptible to heat stress. Annual mortality rate for the group of persons aged 65 years and older is affected by summer temperature.
- The death rate of people with diseases of the circulatory system is increased by humid and hot summer weather.

2.3.2 Available data

Fig. 2.3.1 shows monthly all-cause death rates for West Germany. Here all death rates are deaths per 1000 inhabitants. Age-class modelling uses death rates as deaths per 1000 persons of the age class. Death rates decrease with time due to the age structure of the population and advances in living conditions and the health system. Fig. 2.3.1 indicates clearly the seasonal differences between summer and winter death rates. Tab. 2.3.1 presents the data sources available for this study.

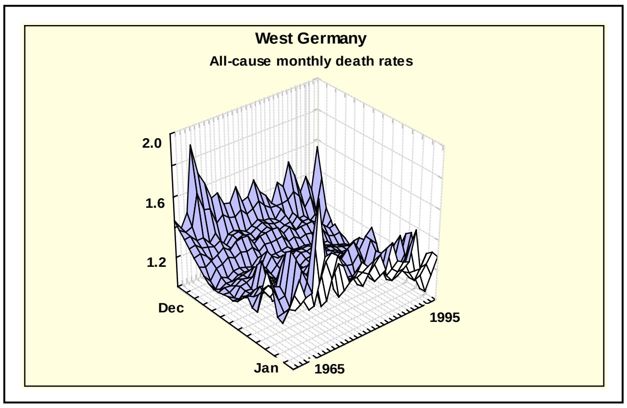

Fig. 2.3.1: *All-cause monthly death-rates per 1000 inhabitants for West Germany.*

Region	Years / temporal resolution	Observed variables
West Germany	1952-1995 / annual 1970-1990 / annual 1965-1995 / monthly	Inhabitants, male/ female, in age classes All cause deaths, male/female, in age classes All cause deaths
Niedersachsen	1968-1995 / annual 1968-1995 / annual 1969-1995 / annual	Inhabitants, male/ female, in age classes Deaths, male/female, in age classes Deaths due to diseases of the circulatory system

Tab. 2.3.1: *Available data for modelling mortality.*

2.3.3 Modelling

First we consider monthly all-cause death rates for West Germany. We regress monthly and seasonal death rates with the temperature of the corresponding months as well as the one-month and one-year lagged temperatures, as well as the one-month lagged death rates. Monthly data is also used for the seasonal approach. Regression results are shown in Tab. 2.3.2.

Independent variables	All-cause seasonal death rates West Germany: Coefficient estimates				
	All year	Summer (Jun–Aug)	Summer (Jul–Aug)	Winter (Jan–Mar)	Winter (Nov–Mar)
Constant	** 10.2897	** 6.00425	** 0.46065	** 16.3972	** 16.5891
Time trend	** -0.00463	** -0.00282		** -0.00759	** -0.00768
Mean temperature of the corresponding months	** -0.00510	** 0.01932	** 0.01295		** -0.01078
One-month lagged mean temperature	** -0.00536	** -0.00733	** -0.01494	* -0.01025	** -0.01098
One-year lagged mean temperature			* -0.00710		** 0.00863
One month lagged death rates	** 0.17581	** 0.45982	** 0.72805		
Number of observations	371	93	60	92	150
R-squared	0.61	0.65	0.80	0.32	0.47
F test	141.20	41.31	54.01	20.58	32.34
Durbin-Watson test	1.94	1.84	1.91	1.83	1.70

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.3.2: *Final regression models for all-cause seasonal death rates in West Germany.*

Based on the model results, monthly death rates throughout the year increase with lower temperatures. Here the seasonal bias is likely to influence the result, as hot summers and cold winters tend to increase the corresponding death rates.

In a second step, we consider age-class related annual death rates for West Germany between 1970 and 1990. We test the assumption that elderly people are stressed mainly by hot summers and that mortality increases owing to hot July and August temperatures.

Tab. 2.3.3and Fig. 2.3.2 summarise all the significant results from this modelling exercise. According to the estimated models, monthly hot temperatures in July and August indeed do increase annual mortality rates of men and women of the age class of 65 years and older for West Germany. For Niedersachsen, the model is only valid for women of 65 years and older.

Independent variables	All-cause annual death rates, 65 years and older: Coefficient estimates			
	West Germany Men & Women	West Germany Women	West Germany Men	Niedersachsen Women
Constant	** 542.046	** 378.348	** 571.085	** 427.134
Time trend	** -0.253	** -0.173	** -0.261	** -0.96
Mean monthly mean temperature Jul – Aug	** 0.858	** 0.842	* 0.884	** 1.252
Number of observations	21	21	21	28
R-squared	0.76	0.64	0.60	0.58
F test	29.01	16.31	13.50	17.48

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.3.3: *Final regression results for age class modelling.*

Death rate per 1000 inhabitants.

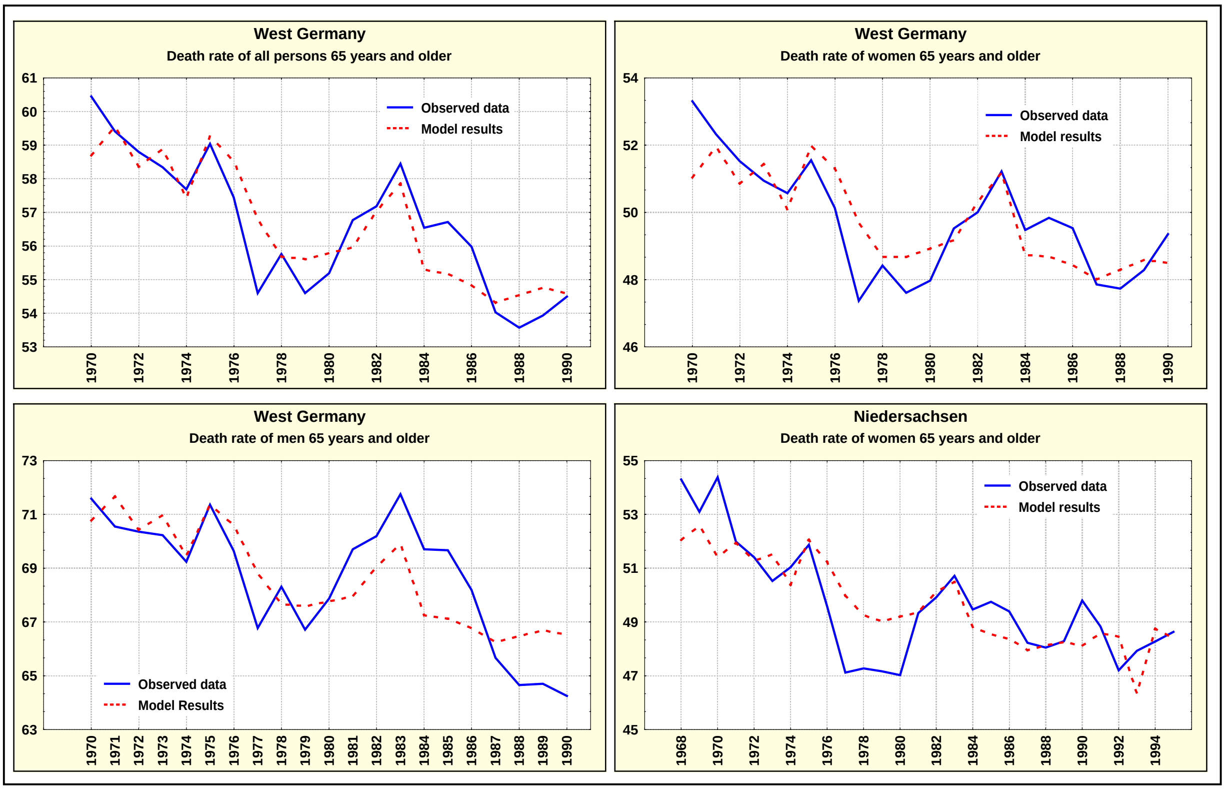

Fig. 2.3.2: *Comparison of observed data and model results for the age-class model.*

The generalised approach of the age-class model for different age classes in West Germany is shown in Tab. 2.3.4. Significant correlations can be found in the age classes of elderly people and for all women. This may imply that women and elderly people are most sensitive to hot summer weather in terms of mortality.

Finally, for Niedersachsen we investigated weather-related death rates of people with diseases of the circulatory system. Several authors stress the importance of appropriate meteorological indicators for the influence of hot and humid weather in summer (Landsberg, 1972; Givoni, 1969; Herrmann, 1959). Because of limited data availability we tried to tackled the problem by means of a standardised monthly index between 0 and 1 for temperature and precipitation for July and August. The overall meteorological indicator is the sum of all four indices. When applying this indicator as the predictor for the annual death rate of people with diseases of the circulatory system, we did find a model with significant coefficients. However, the hypothesis had to be rejected since an increase in the indicator led to a decrease in death rates.

Residuals of death rates from linear trend for	Jul–Aug mean temperature	Jul mean temperature	Aug mean temperature	Annual mean temperature	Jul–Aug precipitation
All	.46*	.44*	.33	-.00	-.33
All younger 35	.25	.13	.32	.32	-.13
All older 34 younger 45	.17	.18	.11	-.01	-.16
All older 44 younger 55	-.01	-.01	-.00	.19	-.02
All older 54 younger 65	.28	.15	.35	.25	-.22
All older 64 younger 75	.46*	.47*	.28	-.03	-.37
All older 74	.54*	.32	.65*	.45*	-.41
All older 64	.66*	.55*	.57*	.12	-.50*
All older 49	.40	.39	.28	-.03	-.34
All men	.34	.37	.17	-.12	-.23
Men younger 35	.26	.15	.32	.33	-.15
Men older 34 younger 45	.08	.12	-.01	-.06	-.10
Men older 44 younger 55	.01	.03	-.01	.10	-.03
Men older 54 younger 65	.28	.14	.37	.27	-.23
Men older 64 younger 75	.26	.32	.10	-.12	-.23
Men older 74	.57*	.37	.64*	.35	-.45*
Men older 64	.51*	.50*	.35	-.11	-.40
Men older 49	.21	.25	.09	-.09	-.22
All women	.54*	.46*	.45*	.12	-.40
Women younger 35	.23	.10	.32	.31	-.10
Women older 34 younger 45	.36	.23	.41	.13	-.24
Women older 44 younger 55	.04	-.04	.14	.51*	-.05
Women older 54 younger 65	.32	.22	.33	.20	-.30
Women older 64 younger 75	.53*	.52*	.37	-.04	-.41
Women older 74	.50*	.27	.63*	.50*	-.37
Women older 64	.65*	.50*	.61*	.23	-.48*
Women older 49	.56*	.48*	.47*	.08	-.43*

n=21, significant correlations are marked by * for p-level = 0.05

Tab. 2.3.4: *Correlation matrix for residuals of death rates in age classes (West Germany) and meteorological parameters.*

2.3.4 Quantification of impacts

Our approach to the quantification of impacts of extreme weather conditions on mortality is based on the identified regression models. We assume a standard increment of ±1°C per month for the meteorological indicators. Since the models are linear, the resulting impact increment can easily be re-adjusted to other indicator increments.

For the all-cause monthly death rate model (Tab. 2.3.2), the summer (July–August) and winter (November–March) death rates per month would change for West Germany as described in Table 2.4.5. For example, according to the model, a 1°C increase of monthly summer mean temperature results in an increase of the corresponding death rate by 2.13%. An increase of the monthly temperature by 1.3°C (the standard deviation of the summer mean temperature) would lead to an increase of the death rate by 2.77%.

	Summer	Winter
Change of the meteorological indicator per month [°C]	+1	-1
Change of the monthly death rate	+0.01295	+0.01078
Average monthly death rate for 1965–1995	1.184	1.331
Relative change of the monthly death rate for 1°C [%]	+1.09	+0.81
Average standard deviation of the meteorological indicator per month for the corresponding period [°C]	1.3	2.3
Relative change of the monthly death rate for the average standard deviation [%]	+1.42	+1.86

Tab. 2.3.5: *Quantification of impacts for monthly death rates caused by hot summers and cold winters.*

The identical approach for the annual death rate model of West Germany (Tab. 2.3.3) is summarised in Tab. 2.3.6.

	All	Women	Men
Change of the met. indicator per month [°C]	+1	+1	+1
Change of the annual death rate	+0.858	+0.842	+0.884
Average annual death rate for 1970–1990	56.6	49.7	68.6
Relative change of the annual death rate for 1°C [%]	+1.52	+1.70	+1.29
Average standard deviation of the meteorological indicator per month for the summer period [°C]	1.4		
Relative change of the annual death rate for the average standard deviation [%]	+2.98	+2.38	+1.81

Tab. 2.3.6: *Quantification of impacts for annual death rates of elderly people caused by hot summers.*

2.3.5 Discussion and conclusions

The presented regression models for climate impacts on mortality assess the influence of mean temperature and precipitation at monthly and seasonal time scales. According to the literature, this temporal resolution of weather variables is rather coarse. Many additional endogenous and exogenous factors determine the morbidity and mortality of a population.

The identified models address cold winter and hot summer temperatures as meteorologically-induced impacts on mortality. Impacts are quantified using standard increments of 1°C to derive standard impacts on death rates. Relative increases of death rates for this increment range from 0.81% to 1.70%. For increments that correspond to the standard deviation of monthly temperature, relative increases range from 1.81% to 2.98%.

2.4 Electricity, gas and water consumption

2.4.1 Situation and hypotheses

Impacts of weather and climate on the consumption of electricity, gas and water are relevant at different temporal scales. Short-term extreme weather fluctuations (e.g., heat waves or cold spells) may change consumption at a daily or weekly scale. Changes in general climatic conditions may influence the demand for energy and water at seasonal and even annual time scales. Impact assessments in WISE on energy and water are based on monthly and annual consumption data and an appropriate monthly meteorology.

The hypothesis for domestic gas consumption is clear: low temperatures during the heating period increase domestic gas consumption for space heating. Normally, the space-heating period in Germany starts in early October and ends by the end of April. Between 1975 and 1995, the number of West German flats with gas heating increased from 15.5% to 39.6%. In 1990, about 35% of all households were connected to local or regional gas networks. 43.5% of all households used oil, 32.7% gas, 8.3% coal and 7.2% electricity for space heating. 7.8% of all households had access to district heating in 1990 (BWG, 1999).

With respect to electricity consumption, the formulation of hypotheses is more difficult. As opposed to countries in a warmer climate, it is assumed that high summer temperatures do not influence domestic electricity consumption, since air conditioning (Andrews, 1989) is not widespread in German households. For total electricity consumption, we assume low temperatures to lead to an increase in electricity demand. Industry, being the main electricity consumer, may need additional energy eduring cold winter periods to keep outdoor processes running.

Finally, domestic water consumption may increase during hot and dry summers. One of the main reasons may be irrigation of private gardens, but also a higher frequency of bathing and taking a shower.

2.4.2 Available data

Tab. 2.4.1 summarises the database that was used for impact analyses on energy and water consumption. All data is only available for West Germany.

Years / temporal resolution	Observed variables
1985–1995 / monthly	Total **gas** consumption from local and regional public suppliers' networks, excluding gas for electricity production in power plants
1977–1990 / annual	Gas consumption of households and small business
1990–1995 / annual	Household tariffs (= average proceeds)
1972–1995 / annual	**Electricity** consumption of the sectors industry, traffic, agriculture, public administration, trade and small businesses, households
1975–1995 / monthly	Total electricity consumption
1990–1995 / annual	Household tariffs (= average proceeds)
1970–1994 / annual	Total **water** consumption from public suppliers' networks
	Domestic water consumption from public suppliers' networks
1990-1997 / annual	Prices for drinking water
1961–1998 / annual	Number of households
1952–1997 / annual	Population
1975–1995 / annual	Heating structure of flats by energy source

Tab. 2.4.1: *Available data for modelling energy and water consumption.*

West German total monthly gas consumption (Fig. 2.4.1c) does not include gas consumption for electricity production in power plants. This consumption is assumed nearly constant, with only small seasonal fluctuations. Differences between seasons for industrial and domestic gas consumption are considerably larger than those for electricity consumption. However, the data set for annual gas consumption per household with gas heating gives values ranging from 28,000 to 35,000 kWh per year. These values are too high for an average household. Small businesses, which are included in the domestic consumption, contribute to this bias.

Total electricity consumption from public suppliers' networks increased by 84% between 1972 and 1995. During these years, private households had an annual share of about 30% of total electricity consumption. Fig. 2.4.1a indicates the important influence of private households' behaviour on total electricity consumption. Total monthly electricity consumption shows a clear seasonal signal: During wintertime (October–March), energy consumption is higher than during summer (Fig. 2.4.1b).

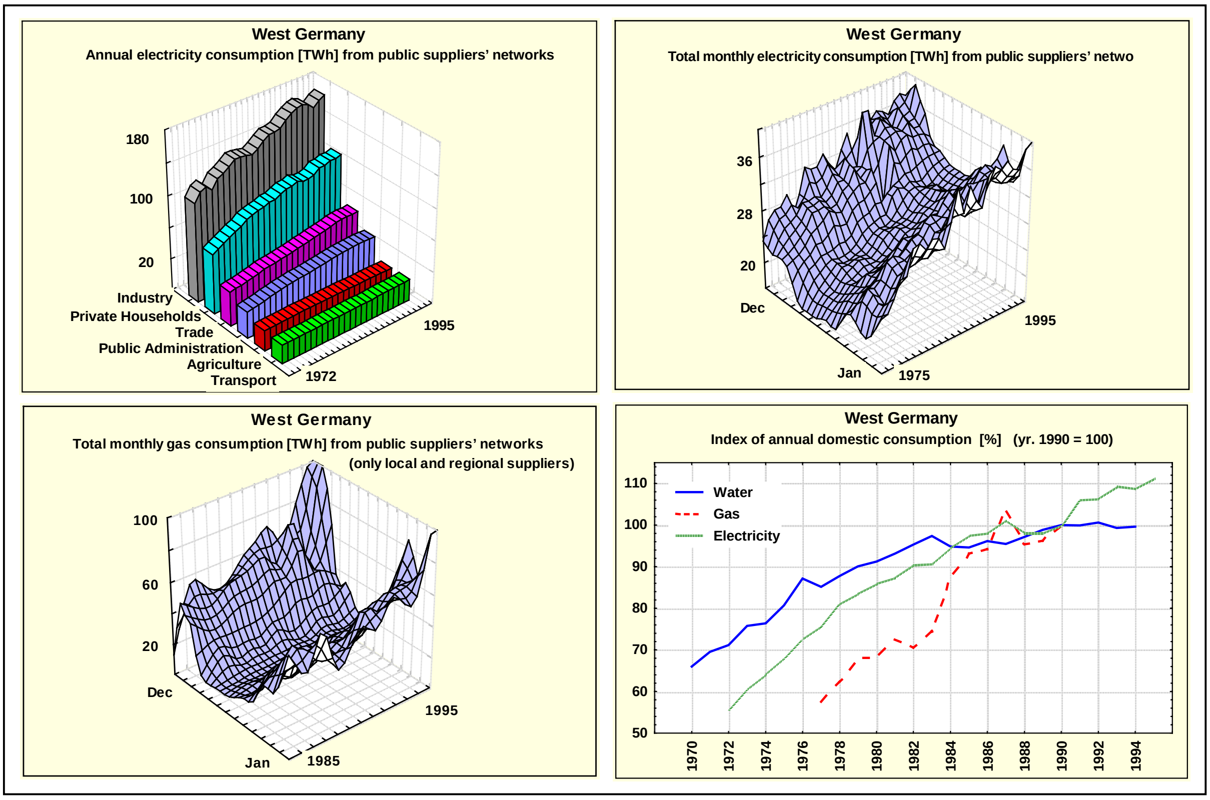

Fig. 2.4.1: *Development of electricity, gas and water consumption in West Germany.* (a | b / c | d)

For domestic water consumption, data is available from 1970 to 1994 on an annual scale. During the early 1990s, domestic water consumption stabilised and has subsequently declined, both in terms of total and per capita consumption. The water management report of the German federal government (BMU, 1999) mentions a 13% decrease of per-capita domestic water consumption between 1990 and 1998. This is caused mainly by increasing water and wastewater prices as well as new water-saving equipment in households. Fig. 2.4.1d shows the influence of the hot and dry summers of 1976 and 1983 on domestic water consumption.

2.4.3 Modelling

2.4.3.1 Gas consumption

Correlation analysis for domestic gas consumption showed a higher influence of the mean temperature sum between January and March than between October and March. Model I (Section 1.3) was used for multiple linear regression modelling with time trend, meteorological indicator (mean temperature from monthly values), meteorological indicator of the previous year and consumption of the previous year as predictors. Tab. 2.4.2 documents only the significant predictors after re-estimation of the model.

Judging from Tab. 2.4.2 and Fig. 2.4.2, the mean annual temperature is a better predictor for domestic gas consumption than the winter (January–March) monthly mean temperature. The lower the annual mean temperature, the higher is the domestic gas consumption in total and per household with gas heating.

Independent variables	West German annual domestic gas consumption: Coefficient estimates			
	Total domestic consumption [TWh]		Consumption per household with gas heating [MWh]	
Constant	** -18976.2	** -20478.5	** 657.6492	** 460.1107
Time trend	** 9.7	** 10.5	** -0.3150	** -0.2065
Annual mean temperature		** -17.3		** -2.1560
Mean temperature Jan – Mar	** -4.5		** -53.43	
Number of observations	14	14	14	14
R-squared	0.97	0.99	0.73	0.87
F test	171.56	423.76	14.693	35.47
Durbin-Watson test	1.74	2.34	1.36	1.27

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.4.2: *Final regression models for annual domestic gas consumption.*

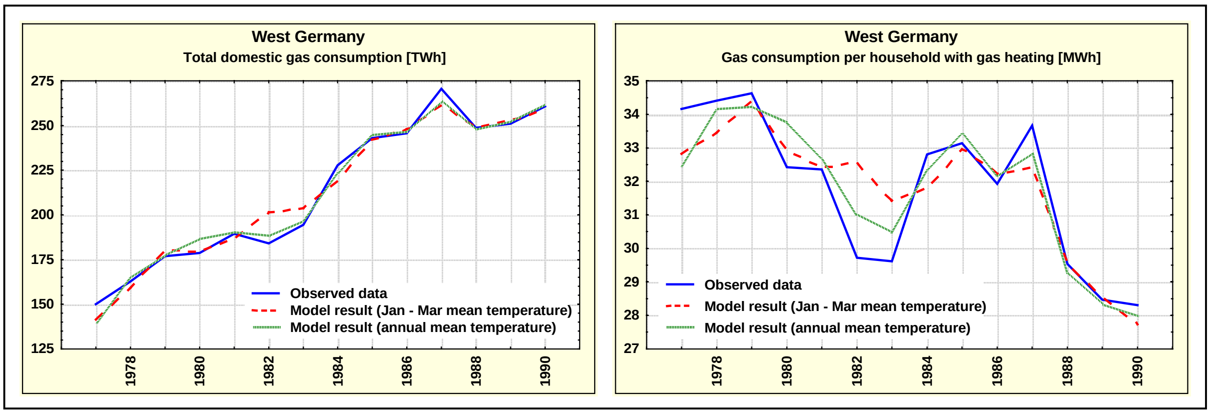

Fig. 2.4.2: *Model results for domestic gas consumption in West Germany.*

Total gas consumption from local and regional suppliers' networks for autumn and winter, without gas for power plants, is shown in Fig. 2.4.3. Again, the mean temperatures of the corresponding months and the time trend are the predictors for the model (Tab. 2.4.3). For consumption in winter and autumn, the corresponding low seasonal mean temperature increases seasonal consumption.

Tab. 2.4.4summarises results from the same data set for a monthly modelling approach. It shows the same behaviour for the influence of temperature on total gas consumption as for the seasonal model. Low temperatures in the corresponding months increase gas consumption for all months of the year, for the summer months and for the winter months.

Independent variables	**West German seasonal gas consumption [TWh]: Coefficient estimates**	
	Jan–Mar	**Jan–Mar and Oct–Dec**
Constant	** -20456.6	** -36857.3
Time trend	** 10.4	** 18.7
Mean temperat. for the corresponding season	** -8.4	** -19.2
Number of observations	11	11
R-squared	0.89	0.90
F test	33.12	37.31
Durbin-Watson test	1.84	1.94

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.4.3: *Final regression models for seasonal total gas consumption (from local and regional suppliers' networks, without gas for power plants).*

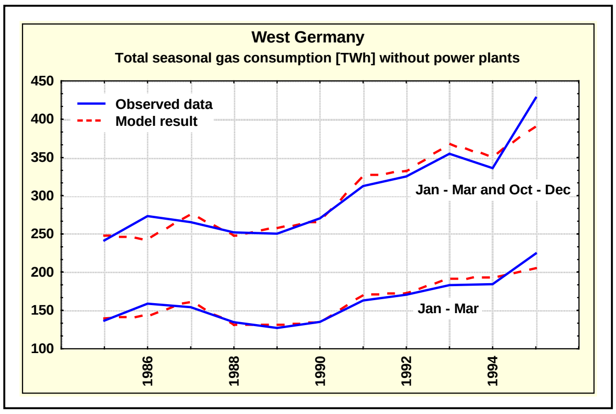

Fig. 2.4.3*:* *Model results for seasonal total gas consumption in West Germany.*

Independent variables	West German monthly gas consumption [TWh]: Coefficient estimates		
	All months	Jan–Mar	Jun–Aug
Constant	** -2331.07	** -6013.40	** -828.905
Time trend	** 1.19	** 3.05	** 0.426
Monthly mean temperature for the corresponding seasons	** -1.86	** -2.06	** -1.038
One-month lagged mean temperature	** 0.50		** 0.426
One-month lagged gas consumption	** 0.21		** 0.461
One-year lagged gas consumption	** 0.32		
Number of observations	120	30	30
R-squared	0.93	0.72	0.96
F test	319.90	34.00	80.47
Durbin-Watson test	2.12	1.74	1.34

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.4.4: *Final regression models for monthly total gas consumption (from local and regional suppliers' networks, without gas for power plants).*

2.4.3.2 Electricity consumption

For domestic electricity consumption, we performed regression analyses for total consumption as well as for consumption of electricity per household and per capita. Model I was used to check the influence of summer, winter and annual mean temperature on consumption. For all three cases, no temperature signal for the summer period was found, while annual and winter (January–March) mean temperature are significant for domestic electricity consumption: The lower these temperatures, the higher is the electricity consumption in German households. Tab. 2.4.5 gives an overview of the modelling results. Some of the models show problems with serial correlations.

Independent variables	West German domestic electricity consumption: Coefficient estimates					
	total [TWh]		per household [kWh]		per capita [kWh]	
Constant	* -762.46	** 7.42	** 726.17	** 561.59	** 230.81	** 170.08
Time trend	* 0.40					
Annual mean temperature	** -2.35		** -88.28		** -38.46	
Winter mean temperature		** -0.65		** -29.64		** -13.23
One-year lagged temp.	** 1.67	** 0.87	** 72.38	** 30.28	** 31.86	** 12.49
One-year lagged consump'n.	** 0.78	** 0.98	** 0.84	** 0.85	** 0.90	** 0.91
Number of observations	23	23	23	23	23	23
R-squared	0.97	0.98	0.98	0.99	0.99	0.98
F test	1433.70	1432.11	542.34	487.15	1285.98	1062.57
Durbin-Watson test	1.74	1.15	1.42	1.30	1.66	1.22

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.4.5: *Final regression models for domestic electricity consumption.*

As a second step, the same model was applied for total electricity consumption in industry, public administration and agriculture. Industry and public administration do not show any dependence on winter, summer and annual mean temperature. Only for the agricultural sector, the regression model reveals an increase in annual consumption for low winter and annual mean temperatures (Fig. 2.4.4).

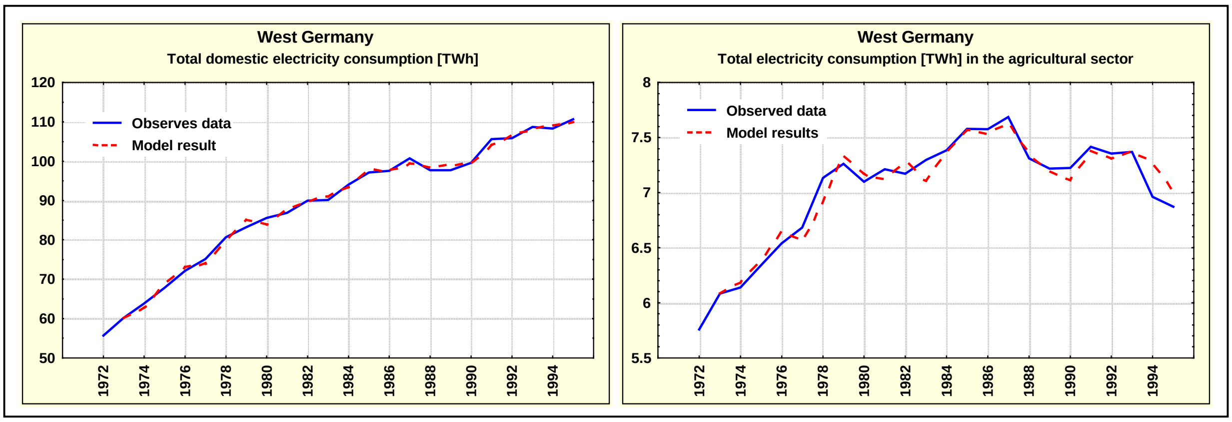

Fig. 2.4.4: *Model results for total electricity consumption in private households and agriculture with winter temperature as a predictor.*

Finally, a monthly regression was performed on the monthly data set on total electricity consumption. It shows the same behaviour as gas consumption. Low monthly temperatures for all months of the year and for winter tend to increase electricity consumption for the corresponding periods (Table 2.5.6).

Independent variables	**West German monthly electricity consumption [TWh]: Coefficient estimates**	
	All months	**Jan–Mar**
Constant	** -594.482	** 3.514
Time trend	** 0.308	
Monthly mean temperature	** -0.235	** -0.268
One-month lagged mean temperature		** 0.276
One-year lagged electricity consumption	** 0.452	** 0.906
Number of observations	240	60
R-squared	0.94	0.97
F test	1136.41	255.96
Durbin-Watson test	1.95	1.66

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.4.6: *Final regression models for monthly total electricity consumption.*

2.4.3.3 Water consumption

The analyses of impacts of hot and dry summers on agriculture and forest fires (Sections 2.1 and 2.2) used the heat-dryness index as an appropriate indicator. For domestic water consumption, it also seems to be a feasible indicator. We compose it as the ratio of the mean monthly mean temperature and precipitation sum over the summer period from June to August:

$$\textit{heat-dryness index} = \frac{\sum mean\_temperature}{\sum precipitation\_sum}$$

The index increases with an increase of the mean temperature and with a decrease of the precipitation sum. For further discussions of the index see Section 2.1.4.

Tab. 2.4.7 shows the summaries of the final regression models. According to the models, hot and dry summers tend to increase domestic and total water consumption. The higher the heat-dryness index between June and August, the higher the water consumption. Fig. 2.4.5 documents the impacts of the hot and dry summers of 1976 and 1983 on the domestic water consumption.

Independent variables	**West German annual water consumption: Coefficient estimates**		
	Total domestic [10^6 m^3]	**Domestic per capita [m^3]**	**Total [10^6 m^3]**
Constant	** 303.950	** 203.576	** 964.416
Time trend		** -0.103	
Summer heat-dryness index	** 431.520	** 7.616	** 635.950
One-year lagged heat-dryness index	** -458.607	** -7.926	** -690.482
One-year lagged water consumption	** 0.899	** 1.021	** 0.788
Number of observations	24	24	24
R-squared	0.99	0.99	0.85
F test	863.16	648.24	39.10
Durbin-Watson test	1.61	1.93	1.87

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.4.7: *Final regression models annual water consumption (from public suppliers' networks).*

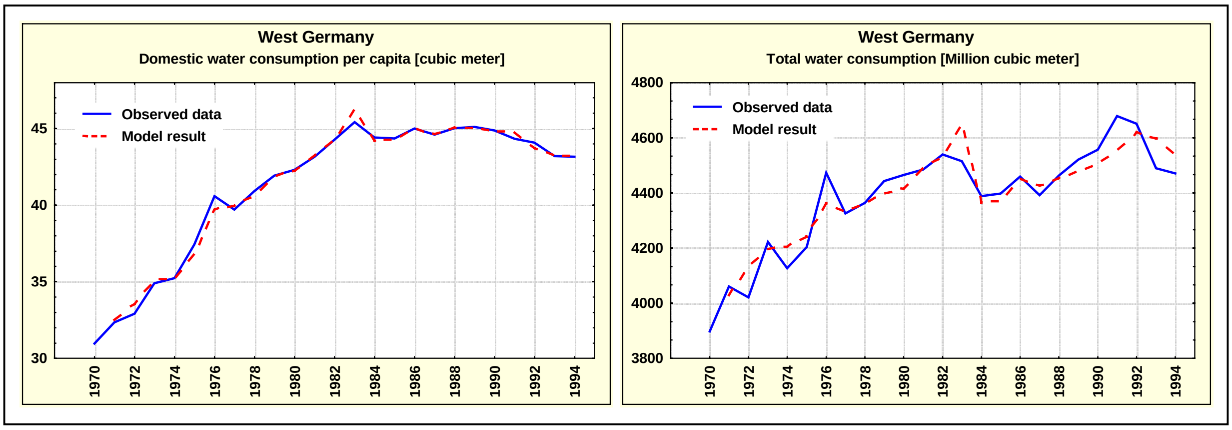

Fig. 2.4.5: *Domestic water consumption per capita and total water consumption.*

2.4.4 Economic quantification of impacts

Based on the identified linear regression models in Section 2.4.3, we quantify the impacts of hot and dry summers on energy and water using the following approach. For the model

$$impact = c0 + c1 * met\_indicator \qquad \text{(c0, c1: regression coefficients)}$$

we get

$$\Delta impact = c1 * \Delta met\_indicator$$

Thus, a change in the meteorological indicator is directly proportional to the change of the impact. Using the direct-cost method with a fixed price leads to

$$\Delta cost = \Delta impact * price$$

Tab. 2.4.8 presents the economic impacts on gas and electricity consumption for a 1°C decrease per month of mean temperature during winter (January–March). Prices are based on mean values between 1991 and 1994.

	Gas consumption		**Electricity consumption**	
	Domestic	**Total**	**Domestic**	**Total**
Change in annual consumption [TWh]	+4.5 (Tab. 2.5.2)	+8.4 (Tab. 2.5.3)	+0.65 (Tab. 2.5.5)	+0.268*3 (Tab. 2.5.6)
Mean price (incl. VAT) [€/kWh]	0.0311	0.0311	0.1326	0.1101
Change in annual costs [M€]	+140	+261	+86	+89
Annual consumption in 1994 [TWh]	[a]260.8	483	108	418
Relative change with respect to consumption in 1994 [%]	+1.73	+1.74	+0.60	+0.19

[a] for 1990.

Tab. 2.4.8: *Economic impact assessment of cold winters (January–March) on gas and electricity consumption in West Germany for a 1°C decrease of mean winter temperature.*

Since the applied heat-dryness index is a non-linear function of the mean monthly mean temperature t and precipitation sum p we have to consider an incremental change for water consumption:

$$\Delta heat\_dryness\_index = \frac{\overline{\sum t} \pm \Delta t}{\overline{\sum p} \pm \Delta p} - \frac{\overline{\sum t}}{\overline{\sum p}}$$

where $\overline{\sum v}$ is the long-term mean monthly value of the meteorological variable v over all years (Tab. 2.4.9 and Tab. 2.4.10).

Mean monthly values and standard deviation for the modelled years	**West Germany**	
	mean	**stddev**
Jun–Aug, mean temperature [°C]	16.6	0.93
Jun–Aug, precipitation sum [mm]	81.8	16.2

Tab. 2.4.9: *Seasonal mean and standard deviation for mean monthly mean temperature and precipitation sum for West Germany.*

Meteorological increment per month	Increment for the heat-dryness index
+1°C mean temperature	+0.012
–10mm precipitation	+0.028
+1°C mean temperature and –10mm precipitation	+0.042

Tab. 2.4.10: *Increments of the non-linear heat-dryness index.*

With these increments, we can perform an economic impact assessment for the impacts of hot and dry summers on water consumption (Tab. 2.4.11).

	Domestic water consumption			Total water consumption		
	+1°C	**-10mm**	**+1°C –10mm**	**+1°C**	**-10mm**	**+1°C –10mm**
Change in annual consumption [10^6 m^3] (Table 2.5.7)	+5.2	+12.1	+18.1	+7.6	+17.8	+26.7
Mean price (incl. VAT) [€/m^3] [a]	1.265			1.265		
Change in annual costs [M€]	+6.5	+15.3	+22.9	+9.7	+22.5	+33.8
Annual consumption in 1994 [10^6 m^3]	2920			4471		
Relative change with respect to consumption in 1994 [%]	+0.18	+0.41	+0.62	+0.17	+0.40	+0.60

[a] without costs for waste water treatment

Tab. 2.4.11: *Economic impact assessment of hot and dry summers (June–August) on water consumption in West Germany for a 1°C increase in mean temperature and a 10 mm decrease in precipitation.*

2.4.5 Discussion and conclusions

The impacts of extreme seasons on energy and water consumption were assessed using regression modelling based on monthly and annual data. Annual mean temperature was identified as a better predictor for domestic **gas** consumption compared to winter temperature (January–March). Gas consumption for households with gas heating is overestimated by the model because the original data set also includes small businesses. West German total seasonal and monthly gas consumption, excluding gas for energy production in power plants, showed the expected dependencies on temperature: Low monthly and seasonal mean temperatures increase gas consumption.

Annual **electricity** consumption in different sectors, including private households, industry, public administration and agriculture, does not show any dependence on summer temperature (June–August). For domestic electricity consumption and for the agricultural sector it was possible to identify an influence of annual and winter mean temperature on annual consumption. Total seasonal and monthly electricity consumption depends on temperature in the same manner as gas consumption.

The heat-dryness index appears an appropriate indicator to assess the impacts of hot and dry summer weather on domestic, per capita and total **water** consumption. The higher the mean temperature and the lower the precipitation, the higher annual water consumption.

The **economic quantification** of weather impacts was based on the identified models and the direct-cost method with mean prices between 1991 and 1994. By assuming a temperature change of 1°C per month for winter and summer and a 10 mm decrease per month in summer precipitation, it was possible to assess monetary impacts. Relative changes in annual domestic and total gas consumption are of the order of 1.75% compared to the consumption level of 1994. For energy, a 1°C colder winter results in a 0.60% increase in annual domestic and a 0.19% increase in total annual electricity consumption. Increases in domestic and total water consumption are in the same range for a 1°C warmer and 10 mm drier summer. Based on the absolute consumption figures and the relative impacts of extreme seasons, annual monetary impacts range from 22.9 M€ for domestic water consumption in years with hotter and drier summers to 261 M€ for total gas consumption in years with colder winters.

2.5 Tourism

2.5.1 Situation and hypotheses

At first glimpse, weather is likely to be an important factor determining the choice of holiday and trip destinations[1]. However, Abegg *et al.* (1997, p.106) state that usually the importance of weather is over-estimated. The overall aim of the statistical analyses presented here is to assess the effect of meteorological conditions on the number of bed nights in West Germany and Niedersachsen.

When assuming that weather plays an important role in the decision of tourists on the destination of their trips, one has to decide which meteorological variables should be used as predictors (and at which regional and temporal scales). Possible predictors include the weather in the region/country of origin, the weather in the destination region/country or the relative difference between the two. In addition, expectations about the weather at the trip destination are important. Such expectations can be derived from the experienced weather at the time of planning or booking the trip, the actual weather (for spontaneous trips), the weather in the previous year or from multiple other sources. Box 2.5.1 sets out the relevant distinctions for tourism in Germany.

Based on our expert interviews and keeping the data limitations in mind, our hypotheses concerning the connection between weather and tourism are:

1. *Residential summer* tourism should be correlated with the temperature of the according month. Thus, we assume residents to decide mainly spontaneously about a overnight travel.
2. *Residential winter* tourism should be inversely correlated with the temperature of the according winter period, thus assuming winter tourism is snow-based and the lower the temperatures the better winter sport facilities can be taken use of.
3. The number of bed nights of *non-residents* should be inversely correlated with precipitation during the pre-period, thus assuming that non-residents pre-book their trips to Germany and derive their expectations of German weather from the pre-period.

[1] For literature review see: Lise and Tol (1999).

Tourism in Germany can be subdivided as follows:

- Bed nights – as the indicator we deal with – can be divided into those from residents and those from non-residents.
- Bed nights comprise tourist trips, business trips and other trips (such as family visits, visiting special events, etc.). We expect that tourist trips are the only ones where a correlation with weather (indicators) can be assumed.
- Tourist trips can be subdivided into booked and spontaneous trips. Booked trips are thought to be the dominating type in coastal areas. The period between booking/planning a trip and its occurrence can vary from one day up to a year.
- Tourist trips can also be subdivided into winter and summer trips.
- Any trips can be subdivided according to type of destination: coastal or non-coastal, metropolitan or rural, flat, hilly or mountainous, and those trips that combine destination types. The primary motivations for tourist trips include sunbathing in coastal areas, hiking and winter sports in hilly and mountainous areas, cultural recreation in cities. However, motivation for trip destinations is likely to be more complex and could also depend on other factors.[2]
- Residential and non-residential winter trips can be assumed to aim at winter sports, but also tourists visiting metropolitan areas might be important.
- Trips of non-residents might be subdivided in the same way as those of residents, although Germany is arguably not a very attractive beach country. Tourist data show that Germany is becoming more attractive for non-residents, but the increase in bed nights does not occur in summer. For non-residents, visits to metropolitan areas and „culture“ tourism seem to be of greater importance, while hilly and mountainous areas also attract many non-resident tourists.

Box 2.5.1: *Relevant concepts for tourism in Germany.*

2.5.2 Available data

Tab. 2.5.1 presents the data available for the analysis which we received from EUROSTAT (1998) and STBA (1998). The available meteorological data is presented in a separate data document.

Region	Years / temporal resolution	Observed variable
West Germany	1980–1995 / monthly 1980–1995 / monthly 1991/1992	Bed nights (residents) Bed nights (non-residents) Expenses per day and overnight tourist [€]
Niedersachsen	1981–1995 / monthly 1981–1995 / monthly 1991/1992	Bed nights (residents) Bed nights (non-residents) Expenses per day and overnight tourist [€]

Tab. 2.5.1: *Tourism data used in this analysis.*

Fig. 2.5.1 shows the monthly time series of bed nights for West Germany by German residents, for West Germany by non-German residents and for Niedersachsen by German residents, respectively.

[2] Such as seeking for adventure in differing areas, getting to know a special area or culture, using special cheep price offers, visiting areas with extraordinary complements or reputation. For more detailed discussion of influence factors for the individual decision making process see PIK (1999).

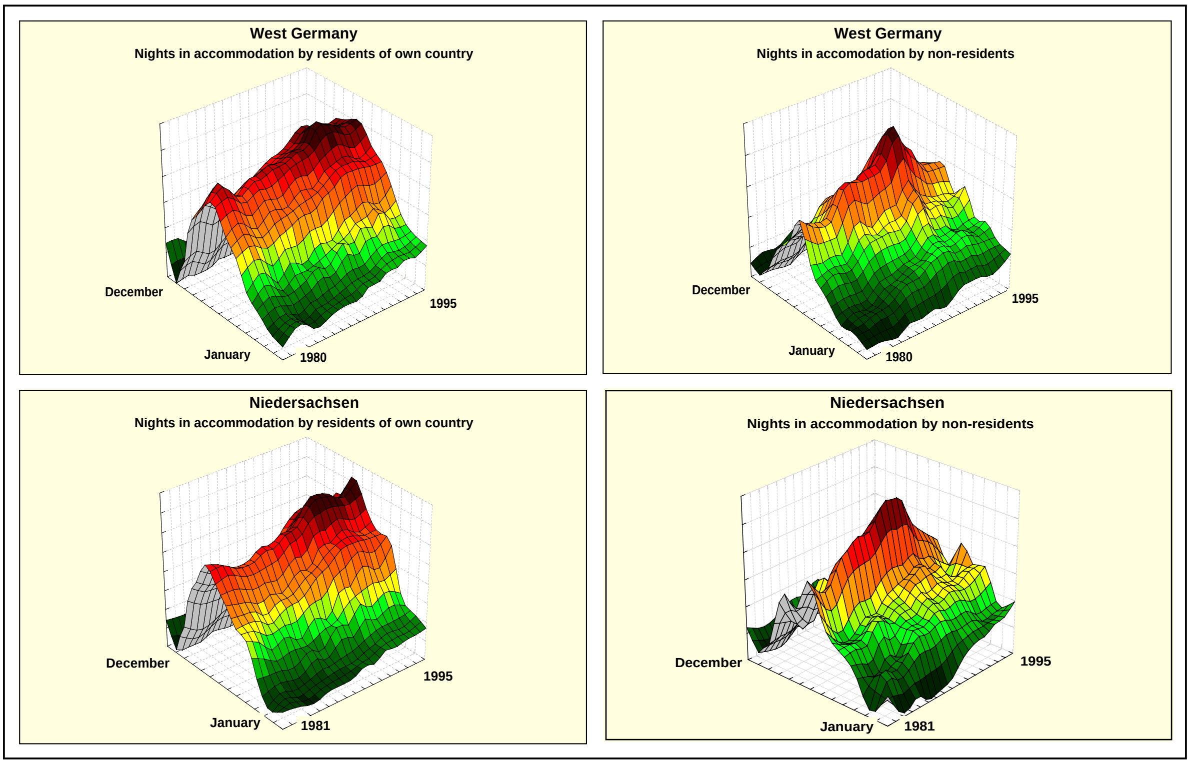

Fig. 2.5.1: *West German and Niedersachsen bed nights from German residents and non-residents.* (a | b / c | d)

Fig. 2.5.1a and Fig. 2.5.1c both show a clear rising trend over time. Fig. 2.5.1b and Fig. 2.5.1d show a summer-peak in 1990, possibly due to the German reunification. The data set for non-residents should therefore be considered with great caution.
We work with highly aggregated data for West Germany and Niedersachsen. Both areas have coastal, rural, mountainous and metropolitan areas. The only difference that could be made is between residents and non-residents. We do not investigate West German residents going abroad. According to figures of the German Tourism Association, in 1998, 70% of the trips undertaken by Germans led to foreign countries (DTV, 1999). The climatic data for Niedersachsen incorporates time series of summer days and frost days, which are not available for West Germany.

The relatively brief time series of the tourism statistics is due to a change in statistics measurement in 1980/1981. Up to 1980, all bed nights were counted in tourist areas only. From 1980 onwards, bed nights are counted in all accommodations with eight or more beds, irrespective from where in Germany they are situated (StBA, 1998). Thus, the statistics we use do not show all bed nights. Especially in summer season, smaller businesses (less than eight beds) do house a substantial amount of guests, which is, however, unknown.[3] In addition, statistics on camping are not included.

2.5.3 Modelling

In Tab. 2.5.2, we summarise the results from multi-linear modelling of bed nights. Only significant results are shown, providing the best fits. Including summer and frost days for the Niedersachsen models did not improve the results. The models for West Germany and Niedersachsen incorporate the same predictors for the equivalent months, so a comparison between results is possible. The models for non-residents should only be considered with great caution, in view of the non-linear trend over time, as shown in Fig. 2.5.1b and d).

[3] Experts on ITB (International Fair of Tourism, Berlin 1998) stated that this amount could be between 20 and 50 percent of all bed nights.

Independent variables	Results of Bed Nights Modelling for West Germany and Niedersachsen					
	West Germany			Niedersachsen		
	Non-Residents Dec–Feb	Residents Jan–Mar	Residents Jul–Sep	Non-Residents Dec–Feb	Residents Jan–Mar	Residents Jul–Sep
Case No.	(1)	(2)	(3)	(4)	(5)	(6)
Constant	**-126594300	* 224200348	**-391050000	** -7494362	** 86195023	** -83556715
Time-trend	** 64542	* -114236	** 199922	** 3817	** -43824	** 41722
Temperature		** 117827	** 224437		* 19464	** 74708
One year lagged temperature			* 211729			** 68923
Precipitation	** -27150			* -262		
One month lagged precipitation			** 15573			* 1931
One month lagged number of bed nights		1.351**	** 0.3907		** 1.964	** 0.444
Number of observations	48	47	48	44	44	42
R-squared	0.67	0.88	0.82	0.48	0.82	0.89
F test	44.7	104.34	38.66	18.61	60.9	60.77
Durbin-Watson test	2.02	1.83	1.55	1.59	1.76	1.74

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.5.2: *Final regression models for bed nights in West Germany and Niedersachsen.*

2.5.4 Quantification of impacts

Case No. 3 in Tab. 2.5.2 shows summer modelling results for residents of West Germany. A one degree rise of temperature in July, August and September, keeping all other indicators fixed, increases the monthly number of bed nights by 224,437. For Niedersachsen (Case No. 6), using the same predictors as for West Germany, a one degree rise in temperature in summer would result in an increase in the monthly number of bed nights by 74,708.

Tab. 2.5.3 presents a quantification of the impacts of a one degree rise in temperature in July, August and September. For the period 1980–1995, the monthly average number of resident bed nights in West Germany in these months is 23,156,267. The model predicts an increase in bed nights due to the stated temperature rise of 0.97%. For Niedersachsen, monthly average number of bed nights of residents in the same period for the same months is 3,219,603. Here an increase in bednights if 2.3% is predicted. This suggests that Niedersachsen, with its greater relative importance of coastal areas, is more sensitive to summer weather than West Germany as a whole.

The average expenditures per day per overnight tourist are €57.83 for West Germany in 1991/1992 (Zeiner and Harrer, 1992). Thus, a one degree rise in temperature in July, August and September would result in an increase of expenditures by about 38.9 M€. In Niedersachsen, where the amount spent per day per overnight tourists is €41.42, the aggregated figure for a similar temperature rise is 9.3 M€.

Residents	West Germany Summer	Niedersachsen Summer
Change in the meteorological indicator per month [°C]	+1	+1
Change in the monthly bed nights	+224,437	+74,708
Average number of monthly bed nights from 1980/1981 to 1995 for July, August and September	23,156,267	3,219,603
Relative change in bed nights [%]	+0.97	+2.3
Average expenditures per day per overnight tourist [€]	57.83	41.42
Increased expenditures due to a one degree rise of summer temperatures [M€]	+38.9	+9.3

Tab. 2.5.3: *Quantification of impacts for summer (July–September) bed nights caused by rising summer temperatures.*

Case No. 2 in Tab. 2.5.2 shows winter modelling results for residents of West Germany. A one degree rise of temperature in January, February and March, keeping all other indicators fixed, increases the monthly number of bed nights by 117,827. For Niedersachsen (Case No. 5), using the same predictors as for West Germany, a one degree rise in temperatures in winter would result in an increase in the monthly number of bed nights by 19,464.

Tab. 2.5.4 presents a quantification of the impacts of a one degree rise in temperature in January, February and March for West Germany and Niedersachsen, using the same approach as Tab. 2.5.3. The results suggest that Niedersachsen is slightly more sensitive to winter weather than West Germany as a whole.

Using the linear models for bed nights of non-German residents, significant models can only be built for winter, as shown in Case No. 1 in Tab. 2.5.2. Temperature was found to be an insignificant variable for winter tourism for non-residents, instead precipitation appeared a significant predictor. As appears from the model, a reduction in monthly precipitation of ten mm in December, January and February increases the monthly number of bed nights of non-residents by 27,150. This corresponds to an increase of 1.8%. These quantitative results are shown in Fig. 2.5.1, which also presents the results for Niedersachsen (Case No. 4), using the same model.

Residents	West Germany Winter	Niedersachsen Winter
Change in the meteorological indicator per month [°C]	+1	+1
Change in the monthly bed nights	+117,827	+19,464
Average number of monthly bed nights from 1980/1981 to 1995 for January, February and March	11,944,463	1,275,294
Relative change in bed nights [%]	+0.99	+1.5
Average expenditures per day per overnight tourist [€]	57.83	41.42
Increased expenditures due to a one degree rise of winter temperatures [M€]	+20.4	+2.4

Tab. 2.5.4: *Quantification of impacts for winter (January–March) bed nights caused by rising winter temperatures.*

Non-Residents	West Germany Winter	Niedersachen Winter
Change in the meteorological indicator per month [mm]	-10	-10
Change in the monthly bed nights	+27,150	+2,620
Average number of monthly bed nights from 1980/1981 to 1995 for December, January and February	1,496,896	77,808
Relative change in bed nights [%]	+1.8	+3.4
Average expenditures per day per overnight tourist [€]	57.83	41.42
Increased expenditures due to a 10 mm reduction in winter precipitation [M€]	+4.7	+0.3

Tab. 2.5.5: *Quantification of impacts for winter (December–February) bed nights caused by decreasing winter precipitation.*

2.5.5 Discussion and conclusions

Given the limitations of our database, the results presented here should be interpreted with some caution. First, the tourism database only covers the period from 1980 onwards. Second, the German reunification has had major consequences for both residential and non-residential tourism, which are likely to be at least as important as meteorological effects (Fig. 2.5.1 b and d). Third, the tourism data for West Germany was only available in an aggregated format, combining all trip purposes without further regional differentiation. Fourth, the finest temporal resolution at which the tourism data is available, is a monthly scale, which is likely to be too course to identify the effects of short-term weather patterns. Fifth, the database does not distinguish between booked and spontaneous trips, while the actual weather is likely to be particularly important for the latter type of trips.

The fact that no significant correlations between summer temperatures and bed nights of non-residents were found confirms that Germany is not a typical summer holiday destination for non-residents. The models found for winter precipitation have a low R^2 and are therefore weak. The hypothesis for non-residents could not be confirmed for the precipitation in the previous year, as this variable was not significant.

For residents, the hypothesis for summer was confirmed for West Germany and Niedersachsen. Higher temperatures lead to an increase in the number of bed nights. The fact that winter bed nights also increase with higher temperatures contradicts the hypothesis. One reason might be that in winter a rise in temperature is pleasant to winter-sport tourists, as long as winter sport facilities are available.

The finding that tourism in Niedersachsen is more weather sensitive than West Germany as a whole deserves further study. The large part of coastal area does not necessarily contradict Lohmann and Kaim (1999), who state that people visiting Northern Germany go there despite or not because of the weather. However, Lise and Tol (1999) suggest that people might change their destinations due to changes in temperatures they expect and prefer. Thus, the findings can be explained in that a rise in temperature attracts additional visitors while the frequent, weather-insensitive visitors are not affected.

2.6 Wind storms

2.6.1 Situation and hypotheses

Between late January and early March 1990, a series of eight severe winter storms hit Northwestern Europe. They caused a total economic damage of about €13 billion. About 70% of these damages were insured. In Germany, the storm series led to damages of about €3.6 billion, with an insurance rate of 50% (all data from MunichRe, 1993a). "Daria" was the first of the storms between 25 and 26 January 1990. Its main pathway crossed England, Denmark and the south of Sweden, but also West Germany was heavily affected. This study is to evaluate the impacts of Daria on the German insurance sector, especially for policies of residential and business buildings as well as household contents, and to draw conclusions for storm impacts on the insurance industry.

2.6.2 Available data

Tab. 2.6.1 summarises the database that was used for the impact analyses of wind storms. All data is only available for West Germany.

Region (Data Originator)	Data
West German two-digit postal code zones (Munich Reinsurance Company)	For a sample of insurance policies of private houses (residential buildings), business buildings and household contents: Number of policies Sum of insured values Number of affected policies Sum of losses
West Germany (German Meteorological Office)	205 meteorological stations with daily maximum gust speed 178 meteorological stations with hourly mean wind speed
West Germany (Federal Statistical Office)	Per district (Landkreis) data from 1990/1991: Number of residential buildings Number of flats
West Germany (infas Geodaten GmbH Bonn)	Geodata of postal code zones

Tab. 2.6.1: *Available data for modelling impacts of the Daria event.*

Insurance data is a sample, collected from different insurance companies by the Munich Reinsurance Company (MunichRe, 1993b,1993c). It only covers the claims from the Daria storm event. For residential buildings and household contents only those policies are considered that cover storm damages. In 1990, about 82% of all policies for residential buildings and about 86% of all policies for household contents covered storm damages.

To evaluate the representativeness of the insurance data for the two-digit postal code zones (Fig. 2.6.1), the number of residential buildings and the number of flats was resampled from the district level to the two-digit postal code level. The geographical information system ARC/INFO was used to overlay the spatial geometries and to resample data. The actual number of business buildings for districts was not available. For each of the available meteorological stations below 800 m altitude, the maximum wind gust and maximum and mean wind speed (as indicators for storm intensity) were derived from data on daily maximum gust speed and maximum hourly mean wind speed, respectively (Fig. 2.5.1). Spatial interpolation at a 10x10 km^2 grid was performed by ordinary kriging, with a spherical semi-variance. Elevation data was not used as additional information. Finally, gridded wind speed data was averaged over all grids of the corresponding two-digit postal code zones.

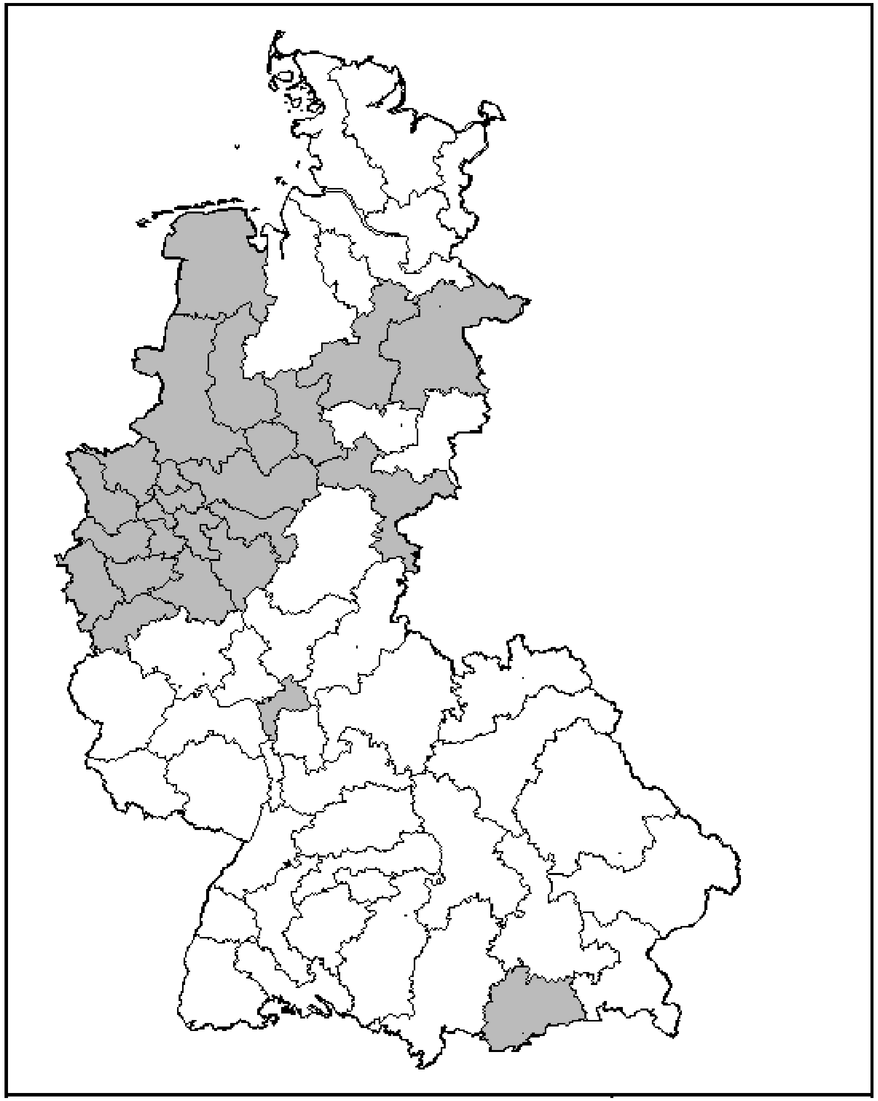

Fig. 2.6.1: *Two-digit postal code zones and zones with data representativity for residential buildings above 8%.*

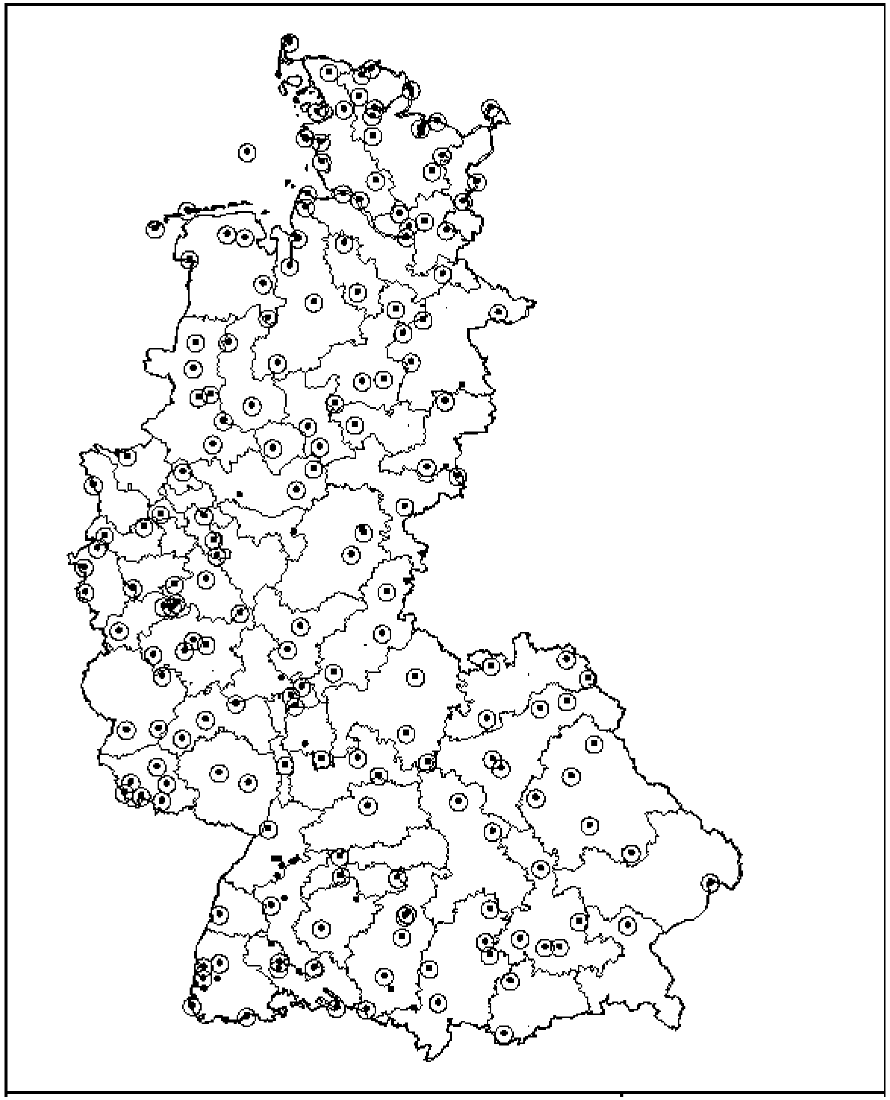

Fig. 2.6.2: *Meteorological stations for wind storm modelling* Circles: *hourly mean wind speed; Points: daily maximum wind gust.*

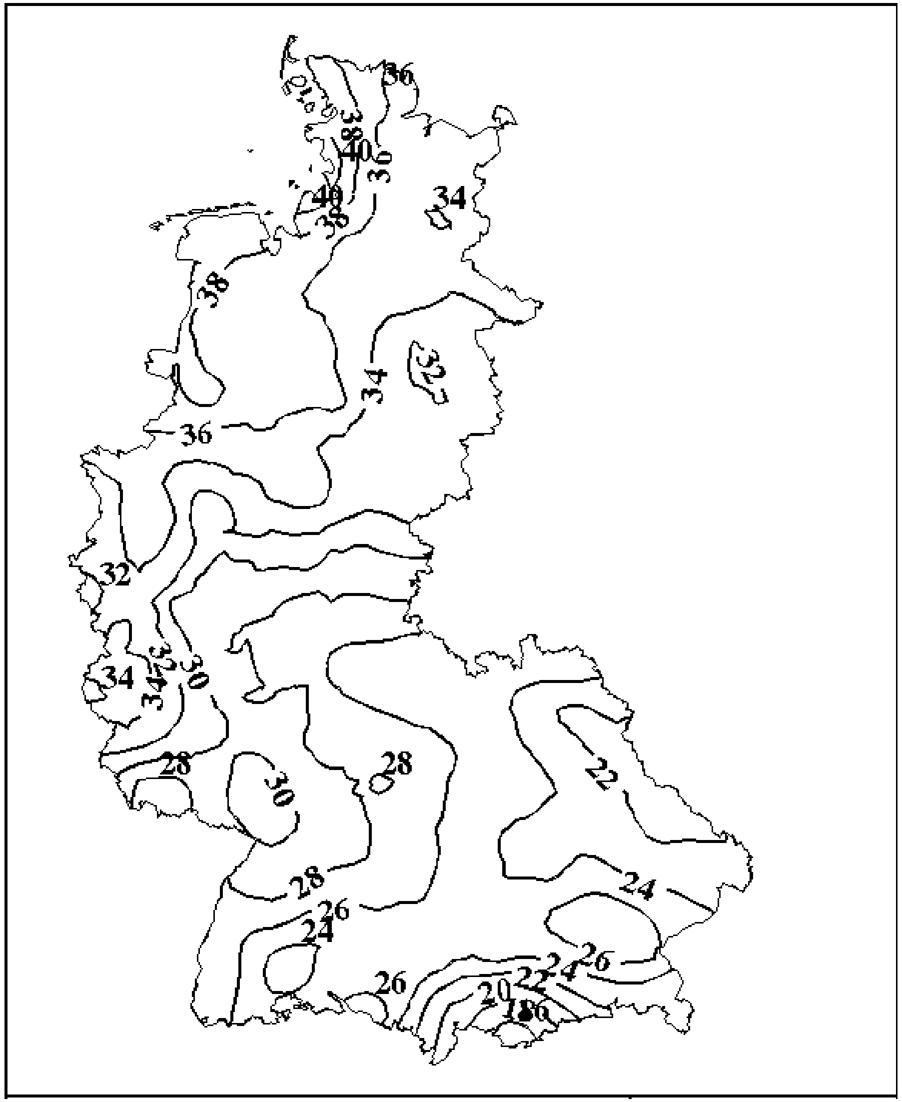

Fig. 2.6.3: *Interpolated maximum wind gust field [m/sec] for the Daria storm event*

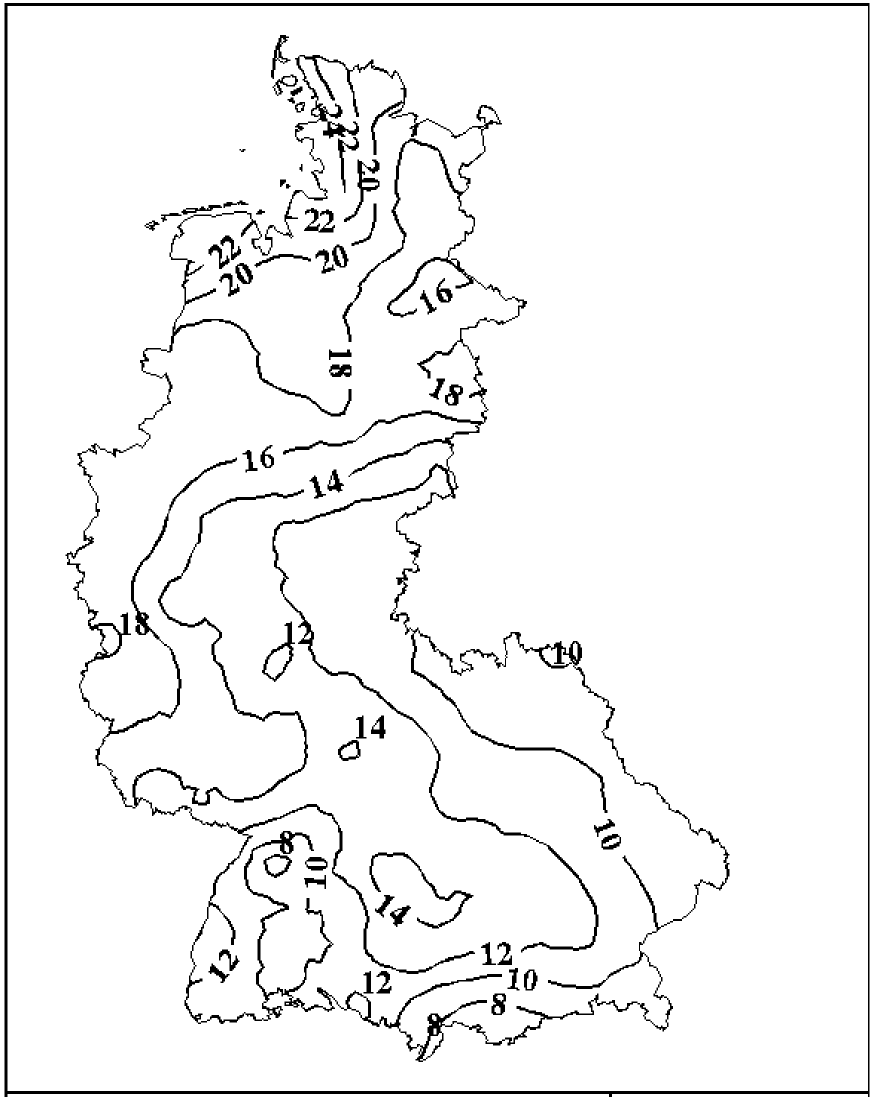

Fig. 2.6.4: *Interpolated maximum hourly mean wind speed field [m/sec] for the Daria storm event*

The results of this analysis are shown in Fig. 2.6.3 and 2.6.4 as wind fields (isolines with a distance of 2 m/sec) for maximum wind gust and maximum hourly mean wind speed, respectively. As appears from these two Figures, the main impact of the storm was in the Northwestern and Western part of the country. However, the representativeness of the database for model design for residential buildings was low. We therefore chose to use only those postal code zones with a representativeness of the data above 8%. These zones are shown in grey in Fig. 2.6.1. For household content insurance all but one zone fulfils this condition.

2.6.3 Modelling

First, the storm variables were tested by correlation analyses for their damage explanation capability. As damage variables, we considered the relative damage sum in relation to the insured values in ‰ and the relative number of affected policies in %. The first indicator is a general measure for the insurance industry. The combination of the second indicator with a distribution of the damage profiles could guide insurance companies to readjust the amount of losses to be covered by the policy holder prior to any payment by the insurance company. Basic analytical results from the data set are shown in Tab. 2.6.2.

Mean value (Standard deviation)	Residential buildings (repr. > 8%)	Residential buildings (all zones)	Household contents (all but 1 zone)	Business buildings (all zones)
Relative damage sum [‰]	0.31 (0.18)	0.20 (0.18)	0.03 (0.04)	0.32 (0.41)
Relative number of affected policies [%]	17.87 (9.86)	10.04 (9.61)	0.35 (0.41)	7.56 (7.15)
Mean zonal representativity [%]	23.31 (18.05)	11.27 (14.52)	14.92 (5.08)	–
Upscaled total damage sum [Million DM]	850	1310	60	–

Tab. 2.6.2: *Basic data for damage indicators.*

According to the literature, squared, cubic and exponential transformations of the wind speed variables were tested. For the storm variables, maximum wind gust showed better correlation results than the maximum hourly mean wind speed field. The exponential transformation of wind gust was identified as the best transformation for the final regression model. This corresponds with outcomes of other studies (e.g., Dorland *et al.*, 1999). Fig. 2.6.5 shows scatterplots for residential buildings and maximum wind gust.

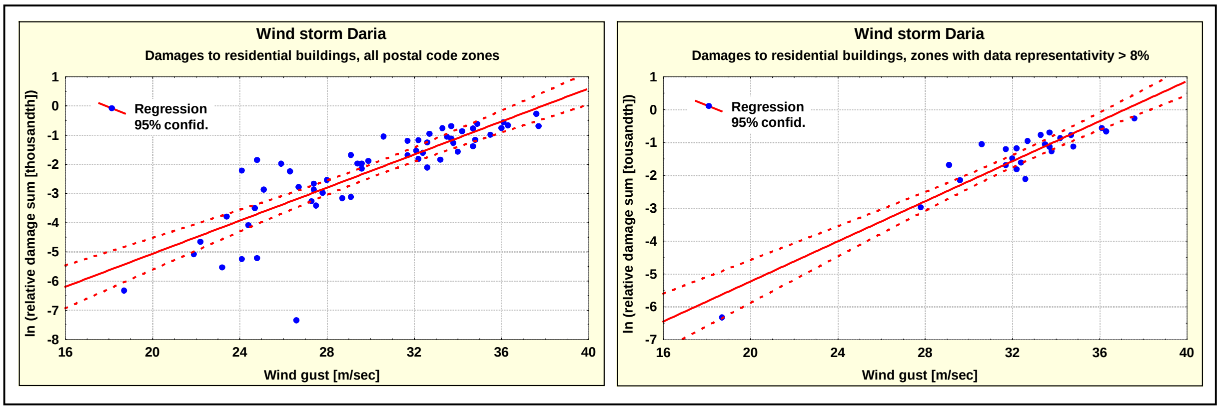

Fig. 2.6.5: *Damages to residential buildings versus wind gust.*

Parameter estimation was performed for all three insurance categories. For residential buildings we considered postal code zones with a representativeness of the data above 8%. Estimation for all zones is supplemented for comparison. The identified models show the expected behaviour: The higher the wind gust, the higher the damages and the number of affected policies (Tab. 2.6.3 and Tab. 2.6.4). Results for business buildings have to be interpreted with care, since no information is available about the regional representativeness of the damage data.

Independent variables	ln (relative damages [‰]): Coefficient estimates			
	Residential buildings (repr. > 8%)	Residential buildings (all zones)	Household contents (all but 1 zone)	Business buildings (all zones)
Constant	** -11.323	** -10.727	** -12.127	** -12.747
Max. wind gust [m/s]	** 0.305	** 0.283	** 0.261	** 0.354
Number of observations	24	61	63	59
R-squared	0.88	0.69	0.63	0.69
F test	154.91	128.55	105.11	129.12

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.6.3: *Regression models for relative damages.*

Independent variables	ln (relative number of affected policies [%]): Coefficient estimates			
	Residential buildings (repr. > 8%)	Residential buildings (all zones)	Household contents (all but 1 zone)	Business buildings (all zones)
Constant	** -6.894	** -6.743	** -9.726	** -7.138
Max. wind gust [m/sec]	** 0.293	** 0.281	** 0.265	** 0.284
Number of observations	24	61	63	59
R-squared	0.83	0.75	0.70	0.69
F test	107.60	174.25	145.05	128.95

*: significance at p-level 0.05
**: significance at p-level 0.01

Tab. 2.6.4: *Regression models for the relative number of affected policies.*

2.6.4 Economic quantification of impacts

Based on the identified regression models we quantify the impacts of winter storms on the insurance industry using the following approach: Since the models transform to

$$damage = e^{c0 + c1 * wind\_gust}$$

we get

$$\frac{damage2}{damage1} = e^{c1 * (wind\_gust2 - wind\_gust1)}$$

with c0 = estimated constant and c1 = estimated wind gust coefficient.

Consequently, a constant difference of the wind gust always leads to a constant damage ratio, determined by the estimated wind gust coefficient and independent on the maximum wind gust value. The impacts of an increase of wind speed between 1 and 3 m/s on relative damage sum and relative number of affected policies are shown in Tab. 2.6.5. For the northern part of West Germany, it appears that an increase in wind speed by 1 to 3 m/s corresponds with an increase of maximum wind gust by 2.5% to 7.5%. For the central part (representativeness of residential buildings above 8%) this is between 3.5% and 10% and for the southern part between 4% and 12%. These values seem to be in agreement with the literature in terms of possible future rates of maximum wind speeds in winter in Western Europe in a warmer world.

Relative increase of damage indicator [%] for increase of wind gust by 1 / 2 / 3 m/s	**Residential buildings (repr. > 8%)**	**Residential buildings (all zones)**	**Household contents (all but 1 zone)**	**Business buildings (all zones)**
Relative damage sum	36 / 84 / 150	33 / 76 / 134	30 / 69 / 119	43 / 103 / 189
Relative number of affected policies	34 / 80 / 141	32 / 75 / 132	30 / 70 / 121	33 / 77 / 134

Tab. 2.6.5: *Relative increase of the damage indicators by an increase of wind gust.*

2.6.5 Discussion and conclusions

An impact assessment of winter storms on the insurance industry was performed for Daria as the first winter storm in a series of storm events in early 1990. The approach combines wind data and a sample of insurance data on the two-digit postal code level for West Germany. The database includes policies for residential buildings, household contents and business buildings. Since the zonal representativeness of the data is rather limited or cannot be determined, upscaled figures, like the total damage sum, can only be a rough estimate. Consequently, the relative damage sum and the relative number of affected policies were used to discuss impacts of storms.

Statistical analyses showed an exponential relation between the damage indicators and maximum wind gust as the best relation for regression modelling for all insurance types. The identified parameters of the regression models are highly significant.

Based on the model findings, a first economic impact assessment was performed. For an increase of the maximum wind gust speed between 1 and 3 m/s, the corresponding growth rates of the damage indicators were determined. The increases in wind gust speed relate to values between 2.5% and 12% of the maximum wind gust for the Daria event. Resulting increases of the insurance indicators range between 30% and 189%. They represent only first guesses on the influence of a serious storm event like Daria. Additionally, the presented findings are a much more conservative approach compared to the findings of the Dutch WISE-group. They extrapolated from scenario analyses an increase of damages to residential buildings by about 700% for a 10% increase of maximum wind gust.

3. PERCEPTION SURVEYS OF CLIMATE IMPACTS

3.1 Public perception of climate impacts

3.1.1 Summary

A survey was conducted to investigate public perception of and behavioural response to unusually hot and dry summers and mild winters in Northern Germany. The survey was conducted in September 1998, using a mailed questionnaire. The questions were framed in such a way as to allow for comparison with earlier surveys as well as with the sectoral analyses carried out within the same project.

Public response to hot and dry summer weather appeared more outspoken than that to mild winter weather. The effects of hot and dry summers were perceived rather unfavourably. Various behavioural changes were stated, including a shift from the use of cars and public transport to cycling and walking, and an increased preference for outdoor trip destinations. Shorter trips were particularly influenced by the weather. Different socio-demographic groups stated different perceptions and behavioural changes to unusually hot and dry summer weather. Women perceived hot and dry summer weather more unfavourably than men did and were more likely to change their behaviour. Higher-age groups perceived hot and dry summer weather as more unfavourable, while younger people would tend to engage in more activities during such weather.

In spite of the fact that younger people perceive hot and dry summers more positively and prefer higher temperatures in summer, they are more willing to counteract climate change than older people are. In 1998, people considered a rise in the world’s temperature much more likely than they did in 1992, although the effects were assumed less dangerous. Still, the stated willingness to counteract climate change is very high. However, the responsibility to mitigate climate change was clearly assumed to be with the government, although the majority of respondents would accept some change in lifestyle.

3.1.2 Introduction

A public perception survey was conducted as part of the WISE project in the participating countries Germany, Italy, The Netherlands and the United Kingdom. The WISE project consisted of selected sector analyses, based on available, national comparable datasets (see chapter 2). In addition, management and public surveys were carried out. The results of the German public survey on weather perception and reaction are presented in this section.

The main focus in current climate research lies mainly in its scientific and technical aspects (Jäger and Ferguson, 1991). Many of the gases that play a major role in global warming are either exclusively produced by humans or their increase is caused by human behaviour. At present, society as a whole aims at a sustainable development mainly by controlling technical aspects in industry to reduce global warming (UNCED, 1992). This approach has the shortcoming that it neglects the effects of individual behaviour.

In recent years, the sociological aspects of weather and climate perception were studied more intensively, for example in the PIK Project on the Extreme Summer of the Year 1992 in Northern Germany (NOSO’92: Schellnhuber *et al.*, 1994) and the International Social Survey Programme of 1993, which focused on environmental issues (ISSP’93: Witherspoon *et al* 1995). Whereas Schellnhuber *et al.* (1994) focused on the public perception of extreme hot and dry weather conditions, Witherspoon *et al.* (1995) focused on the perception and adaptation of global climate changes, among other topics.

The goal of the WISE study has been to investigate the perception of hot and dry summer and mild winter weather of the general public and to elucidate the individuals' adaptation and mitigation to such unusual weather conditions, which might become increasingly common in Europe as climate changes (Lozán *et al.*, 1998). This study connects weather perceptions and adaptation with climate-change perception and allows for comparisons with the results of the work of Schellnhuber *et al.* (1994) and Witherspoon *et al.* (1995).

3.1.3 Methods

The questionnaire survey was carried out amongst the adult population of Northern Germany, comprising the Federal States Berlin, Brandenburg, Bremen, Hamburg, Mecklenburg-Vorpommern, Niedersachsen and Schleswig-Holstein.

3.1.3.1 Model

The elaboration of the questionnaire and the statistical data analyses were based on the PIK model of weather perception which is shown in Fig. 3.1.1. The model consists of the components weather, perception of weather, adaptation and mitigation to this weather.

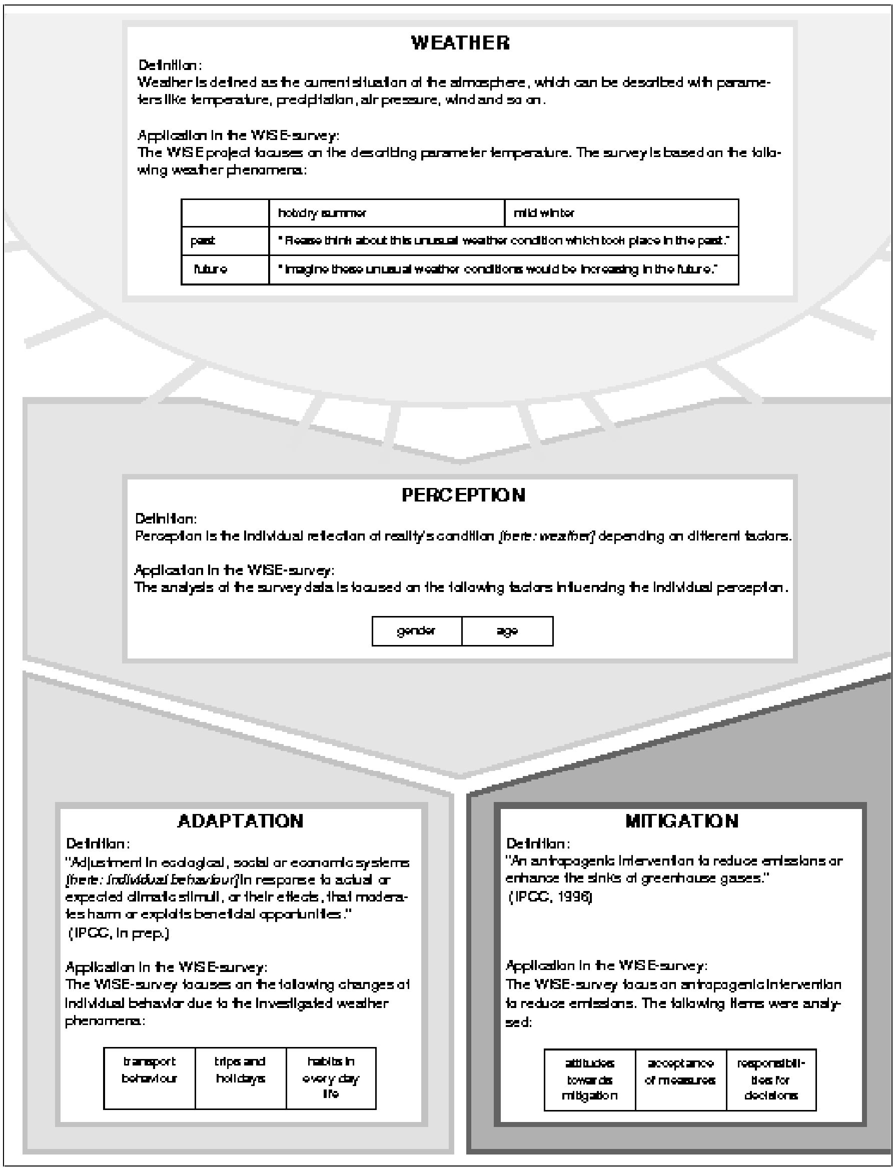

Fig. 3.1.1: *Model of climate impacts on individual behaviour.*

Weather
Unusually hot and dry summers and mild winters were the two weather types of interest for the project WISE and were therefore the focus of the questionnaire survey. Respondents were not provided with precise definitions of what exactly constitutes unusually hot and dry summers and mild winters (e.g., in terms of temperature and precipitation), as this was considered too theoretical. Instead, respondents were asked to consider summers and winters in which hot and dry spells and mild winter weather persisted or would persist for weeks on end.

Perception of weather
Perception reflects an individual's experience of actual conditions, which can depend on a range of different factors. Each individual, therefore, has their own perception of weather, depending on habits, age and other contextual factors. The identification of key factors that determine differences in weather perception amongst people helps to subdivide the population into relevant groups for further analysis.

By dividing the population sampled into these groups, differences in the perception of unusual weather by the different context groups can be investigated. Thus it can be determined, which group is more sensitive to unusual weather. From the multitude of factors possibly influencing individual weather perception, it was decided to analyse the factors age and gender in more detail. These factors allow for detailed analysis while easy adjustments to the data set can be made, should the survey sample not be fully representative for the entire population of Northern Germany.

The distinction between past and *("Please think about...")* and future *("Imagine ...")* was made to distinguish between perception of real experiences and perception of expected weather.

Adaptation
Adaptation is defined as the adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli or their effects, that moderates harm or exploits beneficial opportunities (IPCC Third Assessment Report, in prep.). The survey aimed to solicit information on actual and expected adjustments in individual behaviour. Questions therefore referred to recent unusually hot and dry summers as well as to possible similar events in the future. No questions on adaptation were asked for mild winters.

To allow the survey results to be compared with results from the sectoral analyses carried out within the project WISE, questions addressed the following changes in individual behaviour:

- Changes in habits of everyday life;
- Changes in trip and holiday behaviour;
- Changes in the use of means of transport.

Again, a distinction between past and future was made.

Mitigation
In the context of climate change, mitigation is defined as an anthropogenic intervention to reduce emissions or enhance the sinks of greenhouse gases (IPCC, 1996). Following ISSP'93, the survey focused on emission-reduction measures and solicited information on the following topics:

- Attitudes towards mitigation;
- Acceptance of measures;
- Responsibilities for decisions.

Survey results were then compared with those of ISSP '93.

3.1.3.2 Questionnaire

Based on the questionnaires used for NOSO’92 and ISSP’93 and using the conceptual model shown in Fig. 3.1.1, a questionnaire was designed. The questionnaire (see Appendix 3) contained a core of common questions and an additional set of questions addressing specific national issues. The questionnaire was based on the questionnaire of NOSO’92, the questionnaire of ISSP’93 and results of pre-test procedures at PIK and UEA.

The German questionnaire was subjected to a pre-test in May 1998, involving 35 people. This pre-test led to the following alterations to the questionnaire:

- A question about the effects of hot and dry summers for Germany as a whole was considered too difficult to answer and was deleted.
- The sensitivity to weather changes appeared twice in the questionnaire. The question in which it was addressed for the second time was deleted.
- A question about the preferred extreme weather was split into the summer and winter season since many respondents of the pre-test gave conflicting answers. In addition, as a subjective question it was placed after the objective questions to prevent bias in answering the objective questions.

The questions were divided into one block regarding the past and one regarding the future. The block regarding the past was based on the respondents’ memories of extreme weather, both regarding perception and adaptation (adaptation only for hot and dry summers). Direct reference to a special date, like the summers of 1992 or 1997, was avoided. The pre-test had shown that people find it difficult to remember the exact year of unusual seasons However, providing information on particular years could lead to respondents answering questions based on other memories than those of the weather. People were asked about their perception of and their adaptation.

The block regarding the future was based on the scenario that climate change leads to a rise in world’s temperature and to more hot and dry summers and mild winters in Germany. People were asked about possible effects, their attitudes to this phenomena and their adaptation and mitigation intentions.

The PIK questionnaire also integrated questions that were already posed in two earlier surveys on this subject:

- NOSO’92 survey: For key questions the same wording as in this questionnaire was chosen.
- ISSP’93 survey: Questions 10, 18, 19, and 20 of the final PIK questionnaire (see Appendix 3) are adapted from the ISSP‘93 questionnaire.

The reason for the integration of questions from these earlier surveys was to allow direct comparisons with their results. In addition, possible changes over time in the perception of climate events and climate change can be detected by this approach. The NOSO’92 questionnaire can be found in Schellnhuber *et al.* (1994), while the ISSP’93 questionnaire is available at http://www.za.uni-koeln.de/data/en/issp/quest_pdf.htm.

3.1.3.3 Survey

The present survey was conducted in the same geographical area as NOSO’92. This region comprises the northern federal states of Germany: Berlin, Brandenburg, Bremen, Hamburg, Mecklenburg-Vorpommern, Niedersachsen and Schleswig-Holstein. It was initially planned to conduct the survey in a similar way as NOSO’92, using face-to-face interviews. Owing to budget constraints, however, it was decided to mail out the questionnaire to 4000 people. These people were randomly selected from the database of the direct-mail company AZ Bertelsmann Direct GmbH Berlin, which also performed the complete mailing. The address database of this company is based on the German telephone directory.

The random sampling was stratified by gender and by federal state. A stratification according to age was not possible as the address database did not contain this information. Gender was determined by the first name of the telephone subscriber. The stratification by gender was necessary, as the percentage of female telephone subscribers in Germany is lower than the overall percentage of women in the population. The percentage of women was set at fifty percent for each federal state. The number of questionnaires sent to each federal state was determined using the results of the German micro-census of 1996 (see Table 3.1.1). The questionnaires were mailed out on 9 September 1998, followed by a reminder on 24 September 1998.

State	Number of addresses
Berlin	670
Brandenburg	490
Bremen	130
Hamburg	330
Mecklenburg - Vorpommern	352
Niedersachsen	1502
Schleswig-Holstein	526
total	4000

Tab. 3.1.1: *Number of addresses by federal state for the mailing.*

All analysable responses received by end of February 1999 were integrated in the data analysis. 642 responses were received to that date. Of those 22 were totally empty and 96 (15.5%) were incomplete. With 524 complete questionnaires (response rate 15.5%) the target of 500 analysable responses was reached. After the end of February only two more questionnaires arrived.

3.1.3.4 Statistical analysis

The statistical analysis was done using version 6.12 of the SAS® software running on an IBM-compatible PC under version 4 of Windows NT. A significance level α of 5% was used for all statistical tests.

Data entry

Each questionnaire was manually checked before data entry. Text entries and unclear items were marked for data entry. The data entry was performed using customised data entry screens with automatic edit checks.

Representativeness

The representativeness of the sample was checked for the variable age and for the stratification variables gender and federal state. The variable age, derived by subtracting the stated year of birth from 1998, was grouped into 10-year brackets. Using chi-squared tests, the sample was compared with the overall population of the northern federal states, based on the German micro-census of March 1998 (www.brandenburg.de/statreg/daten_02). Significant differences between the sample and the overall population were found for age but not for federal state or gender. However, a significant gender by age interaction was found: The women responding were younger than the men.

Therefore, the following weighing algorithm was used to obtain a representative sample. The joint distribution of the demographic variables gender and age (per age group 16-<25) in the population sampled was used to weight the observations. For each combination of age group and gender, the proportion of subjects in the population sample was denoted with $p(a,g)$ where a stands for the age group and g for the gender. Then, the proportion of subjects in the sample obtained was calculated and denoted by $s(a,g)$. Each response was subsequently weighted with factor $w(a,g) := p(a,g)/s(a,g)$.

It turned out that the weighing factors for the age group 16-<25 were about 3. This was considered very high, probably owing to this age group being underrepresented in the telephone directory. It was decided not to include this age group in the weighted analysis, to avoid possible bias caused by overweighting single responses. Table 3.1.2 shows the weighting factors for each combination of age group and gender.

Age group (a)	Gender (g)	
	female	male
25-34	1.10752	2.08746
35-44	0.71339	1.28019
45-54	1.05766	0.97898
55-64	0.90406	0.56512
65-74	1.47930	0.65689
75+	1.47074	0.89105

Tab. 3.1.2: *Factors w(a, g) used to weight the sample.*

Descriptive Statistics and Scoring

All analyses were carried out on the adjusted data set as described above. Each of the categorical variables was described by absolute and relative frequencies. In general, percentages were calculated on the basis of all non-missing observations. Ordinal variables were also interpreted as scores and described using the arithmetic means of the scores. The scoring algorithms used for each variable are described in Section 3.1.4.

Comparison

Where possible, an attempt was made to compare the results of the present survey with those of NOSO'92 and ISSP'93. In doing so, it is important to note the following:

- NOSO'92 was organised as face-to-face interviews, held from October 1992 to February 1993, linked directly and exclusively to the hot summer of 1992 in northern Germany. It contained some questions on climate change.
- ISSP'93 was a written survey, attached to face-to-face interviews held in all of Germany. It focused on environmental issues in general, with some questions addressing climate change.
- The present survey was organised as a mailed questionnaire survey, held in northern Germany after the average summer of 1998. It was not linked to a particular hot and dry summer. It focused on a hot and dry summer and mild winter the respondents were asked to memorise, with some questions on climate change.

In view of the above methodological differences, data comparison is restricted to the description of trends, rather than a direct comparison of data.

3.1.4 Survey Results

This section presents the results of the German public perception survey. The items shown in the histograms have been ordered by increasing frequency of the response category "*no effect*" due to extreme weather. This ordering gives a list where those items having the strongest influence are on top of the list and those that have less influence are on the bottom. Some questions had the answering possibility *'I never use'* or *'I never make'*. Due to this fact, bars in these graphs do not fill 100%. The wording of the question is given with each graph.

3.1.4.1 Weather

The questions in the questionnaire of extreme weather perception were primarily based on memories of such weather events. The questionnaire said, "I am sure you can remember experiencing a hot and dry summer in the last few years. Please think about this unusual summer and answer the following questions." As stated earlier, direct reference to a special summer. like those of 1992 or 1997, was avoided.

In the questionnaire, respondents were asked to indicate the year of such a hot/dry summer and mild winter they can remember. It appeared that the memory regarding a special year was rather poor. The capability to bring together certain events that have taken place more then one year ago with the correct date is rather limited. A known phenomena which does not mean that people could not memorise the event at all but shows the difficulties to remember dates.

For that reason, results of the survey can not be related to an exact date, especially the date of a hot/dry summer was difficult to fix after the rather modest summer 98 in northern Germany.

3.1.4.2 Perception of extreme hot and dry summer and mild winter weather in northern Germany

Summer

Fig. 3.1.2 shows how the extreme hot and dry summer weather effected selected items of everyday life of the respondents.

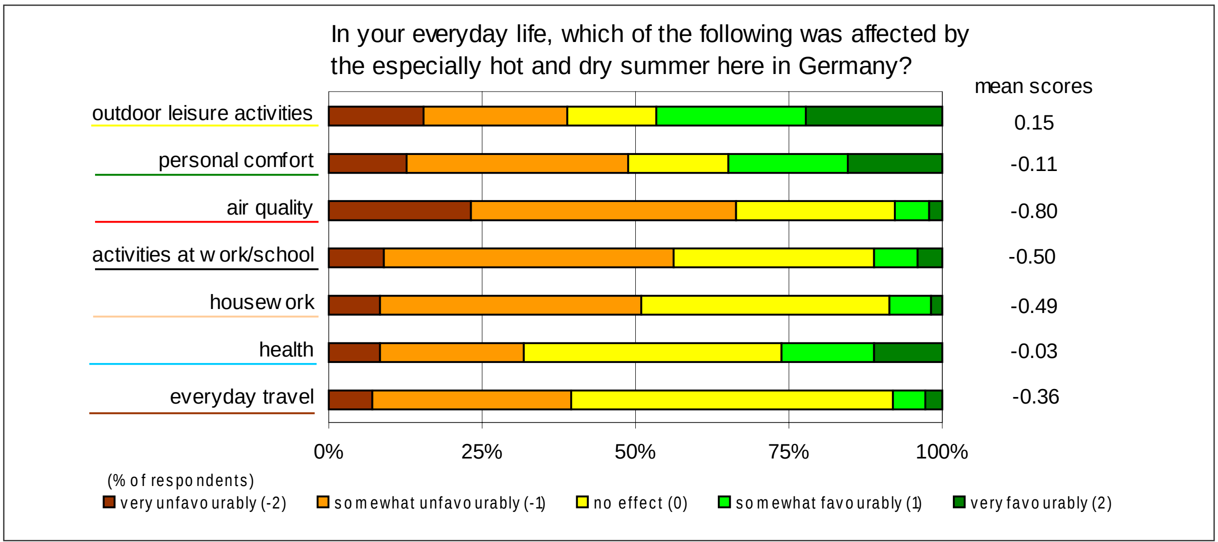

Fig. 3.1.2: *Perceived effects of hot and dry summer weather in everyday life in northern Germany.*

In 1998, most effects of hot and dry summer weather in northern Germany were perceived as being favourable for *'leisure activities'* and to *'personal comfort'*, even though positive and negative effects were almost equal. For *'health'* and *'everyday travel'*, the answer *'no effect'* was ticked most often.

The analysis of the mean scores shows that only '*leisure activities*' yielded a slight positive effect. Regarding '*health*' the negative and positive effects were balanced, 41% of the respondents did not recognise any effect. '*Personal comfort*' had a very slight negative effect. Concerning '*housework*' and '*everyday travel'*, negative effects might be masked by the large number of persons not having perceived any effects (housework 38%, everyday travel 50%). Respondents perceived the most negative effects for '*air quality*' and for '*activities at work or school*'.

The validation of the WISE results with the results of NOSO'92 confirmed the negative effect of hot/dry summer weather to working activities and the positive effect on leisure activities, although the effect on leisure activities was seen as more favourable in 1992. In NOSO'92, *'personal comfort'* and *'health'* were combined in one category, which was perceived slightly favourable.

These results can also be validated with the results of the question for the most important effect shown in Fig. 3.1.3.

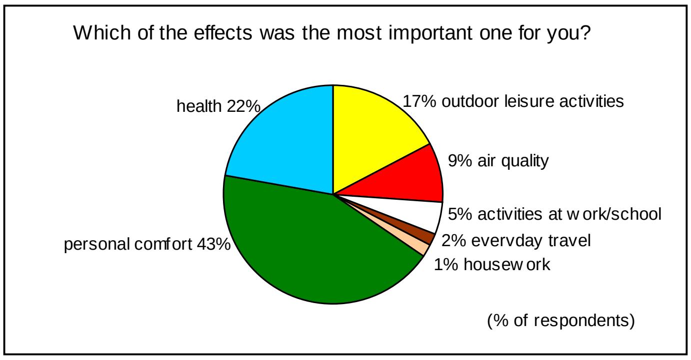

Fig. 3.1.3: *Most important effect of hot/dry summer weather.*

Fig. 3.1.2 and Fig. 3.1.3 show a similar order of the categories except for *'health'*. A rather strong influence was seen on *'personal comfort'* and *'leisure activities'*. Small effects were seen on *'activities at work or school'*, *'every day travel'* and *'housework'*.

Interestingly, *'health'* changed from next to last to second place. Although the majority (41%) did not recognise any effect, 22% of the respondents rated the effects of hot and dry summer weather to *'health'* as the most important one. Certainly the general greater importance of the category *'health'* to for instance the category *'housework'* overlaps the impacts of weather.

Winter

Fig. 3.1.4 shows how mild winter weather affected the everyday life of the respondents.

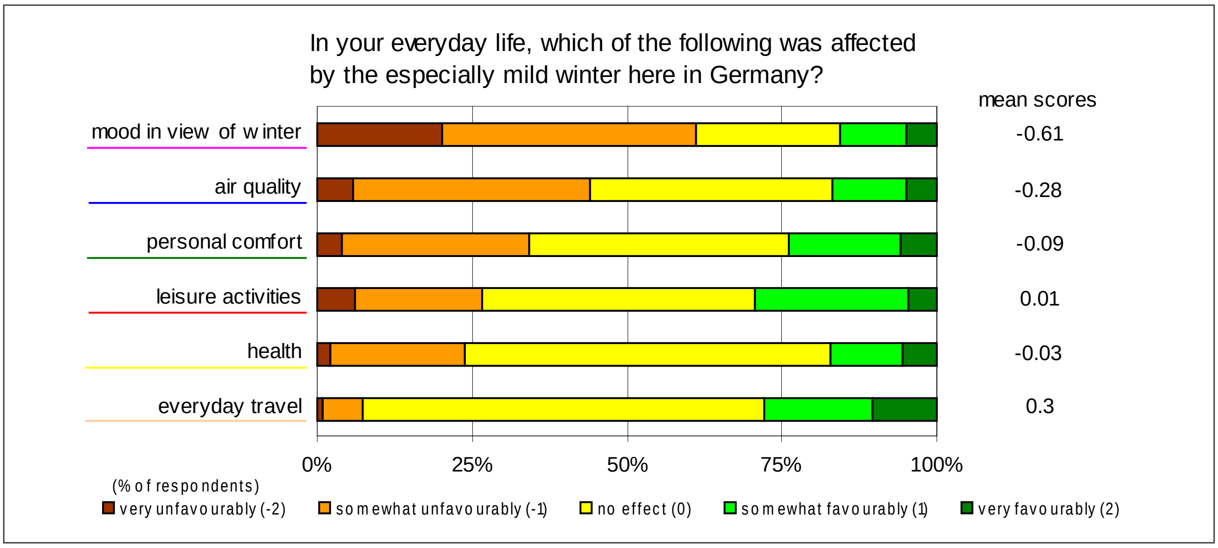

Fig. 3.1.4: *Perceived effects of mild winter weather in everyday life in northern Germany.*

In general, respondents ticked *'no effect'* more often for mild winter then for hot/dry summer. For mild winter weather, fewer effects to everyday life of the respondents were perceived in northern Germany than for hot/dry summer. Most effects of mild winter weather were perceived to the category *'mood in view of winter'* and to *'air quality'*, where a negative influence was perceived for this weather.

The analysis of the mean scores shows that only *'everyday travel'* yielded a slight positive effect, although most respondents did not recognised any effect (63%). Regarding *'outdoor leisure activities'* and *'health'*, the negative and positive effects were balanced and most respondents (42% for *'outdoor leisure activities'* and 57 % for *'health'*) did not recognise any effect. A very slight negative effect is obtained for *'personal comfort'*. *'Air quality'* and *'mood in view of winter'* were negatively affected through mild winter weather.

The negatively perceived effects of mild winter weather to *'air quality'* in northern Germany might reflect the relatively high air humidity under these weather conditions, rather than the pollutant content, which is rather low in northern Germany during mild winter.

These results can be validated with the results of the question for the most important effect shown in Fig. 3.1.5.

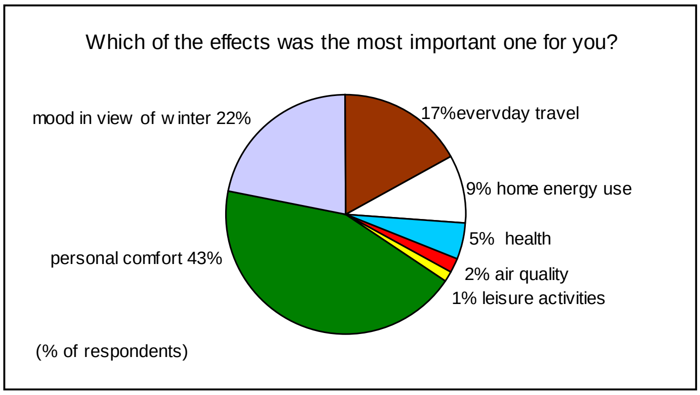

Fig. 3.1.5: *Most important effect of mild winter weather.*

'Personal comfort' and *'mood in view of winter'* are the two categories that were recognised as the most important effects of mild winter weather. Astonishingly, *'everyday travel'* is the category with the highest rate of no effects (63%), while rated by 17% (3rd place) as most important effect.

Impacts on energy and water consumption

The questions on impacts of hot / dry summer and mild winter weather on everyday life also contained items on energy and water consumption. Due to the different scale these items were not integrated in Fig. 3.1.2 and Fig. 3.1.4. but shown separately in Fig. 3.1.6

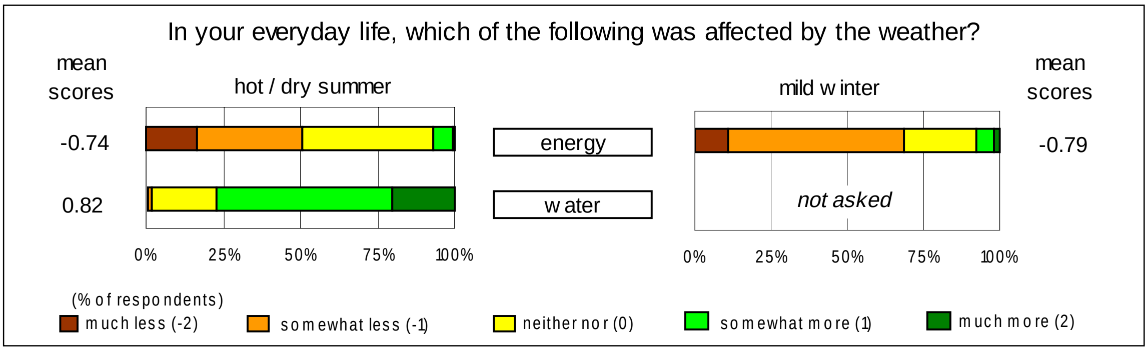

Fig. 3.1.6: *Comparison of perceived effects of hot/dry summer and mild winter weather of energy and water consumption.*

Respondents saw a rather clear weather impact on energy and water consumption. While energy saving during mild winter and increased water consumption during hot and dry summer are obvious, the perceived energy saving at home during hot and dry summer weather is surprising. This perceived effect is also visible in Fig. 3.1.11, where 40.8% of the respondents regarded *'energy saving'* as a positive effect of hot and dry summer. In the question on the most important effect of hot and dry summer weather *'energy'* and *'water consumption'* were ranked least.

The perceived effect of mild winter on energy consumption corresponds with the results of the management survey (Section 3.2), where the weather effect on energy consumption in winter was seen as the most important, and with the results of the sector analysis (Section 2.4).

Comparison of hot/dry summer and mild winter

The comparison of hot summer and mild winter is based on the mean scores of the effects to selected categories of everyday life shown in Fig. 3.1.7.

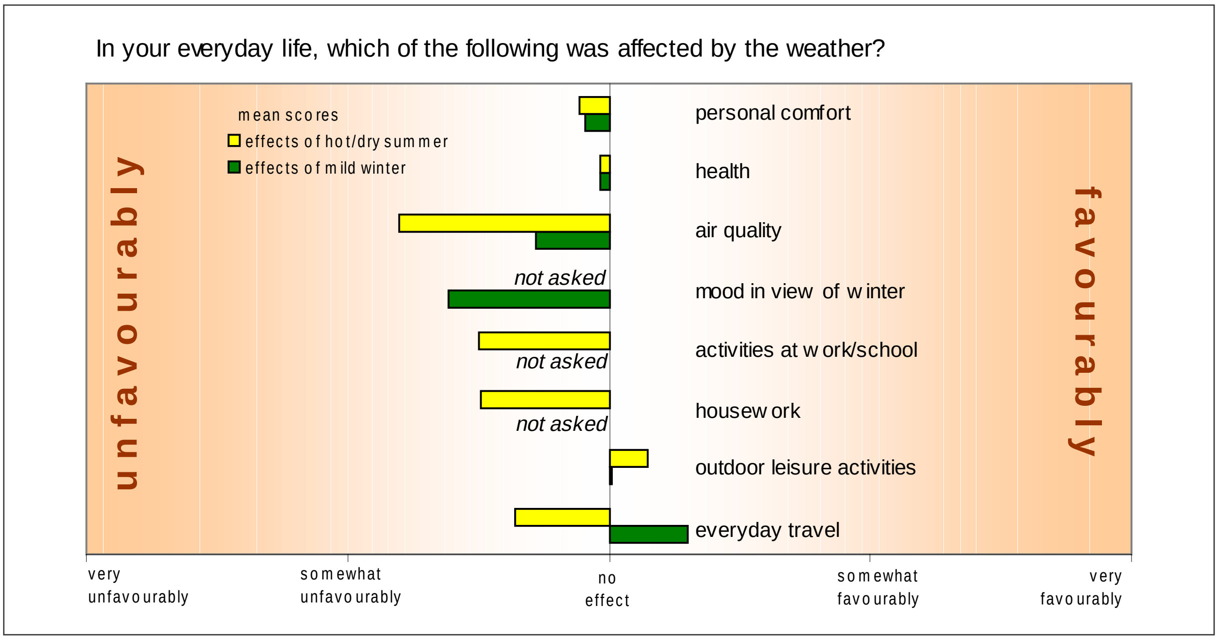

Fig. 3.1.7: *Comparison of effects of hot /dry summer and mild winter weather in northern Germany.*

Hot temperatures in summer and mild temperatures in winter are perceived to have more negative than positive effects to everyday life in northern Germany. Hot summer temperatures show more effects than mild temperatures in winter, in that the category *'no effect'* was ticked more often for mild winter than for hot/dry summer. Fig. 3.1.8 shows which unusual weather the respondents preferred.

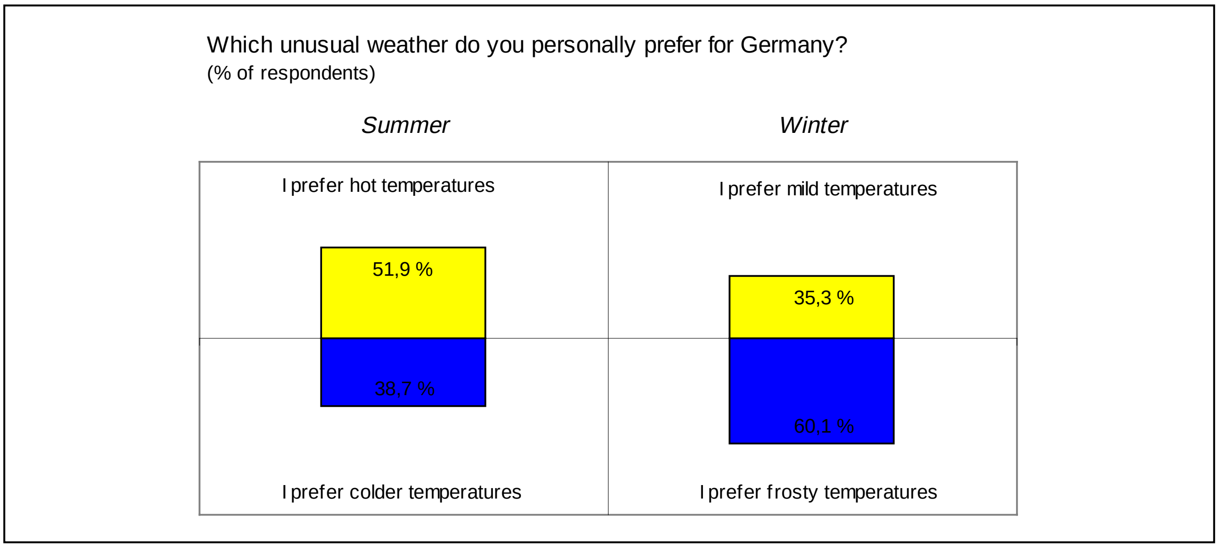

Fig. 3.1.8: *Prefered weather for Germany.*

For winter the results of this question (respondents preferred frosty to mild temperatures in winter) show that mild winter temperatures should have more negative than positive effects. Also the results of preferred summer temperatures are surprising. Although hot and dry summer weather was perceived rather negatively in northern Germany, the majority of respondents would prefer this extreme weather in summer. One explanation might be that respondents had different ideas of what are hot and what are colder temperatures.

Respondents preferring colder temperatures in summer perceived negative effects for all named categories of everyday life while those preferring hot temperatures perceived positive effects only to *'personal comfort'*, *'health'* and *'leisure activities'*. In spite of their preference for hot temperatures, the other categories (work, homework , travel, air quality) were seen as unfavourably affected by the hot/dry summer weather.

Future prospects
The following sections only look at hot and dry summer weather as the main investigated weather phenomena. The question on the perceived probability of increasing hot and dry summer allows for a direct comparison with the survey of weather perception implemented by PIK in 1992 (see section 3.1.3.4). As shown in Fig. 3.1.9, the mode of the 1998 line is much closer to likely, while the mode of the 1992 line is closer to unlikely. In the 1992 survey (after the hottest summer of this century in northern Germany) only 25.7% of the respondents thought it likely that future summers would be increasingly hot and dry and 48.3% thought it unlikely. In the survey of 1998 (after a normal summer in northern Germany), 46.2% considered increasingly hot and dry summers in future likely and only 25.4% thought it unlikely.

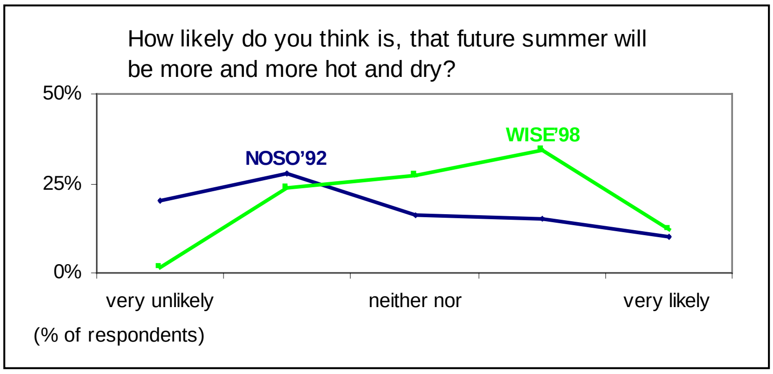

Fig. 3.1.9: *Probability of increasing occurrence of hot/dry summer.*

The next question was focused on the consequences of increasingly hot and dry summers. For this question, a direct comparison was possible with ISSP'93, where the same question for the items *'environment'* and *'themselves'* was asked. Results are shown in Fig. 3.1.10.

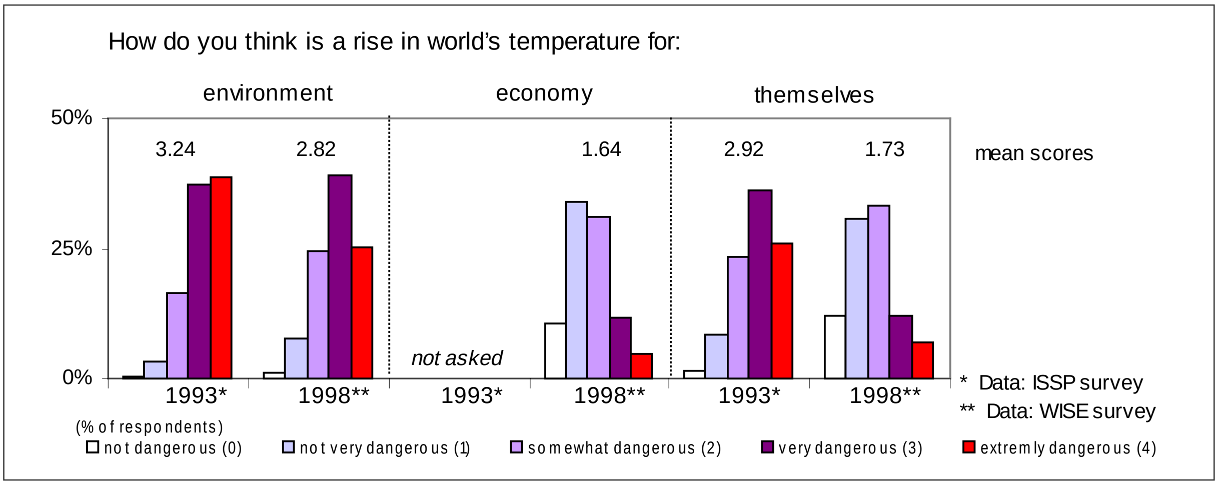

Fig. 3.1.10: *Effects of a rise in world's temperature.*

In 1998, respondents saw almost no difference between the situation for '*economy*' and for

‘*themselves*’. The consequences for the environment, however, were considered much more dangerous than for the other two categories. Overall, the effects of climate change were considered more dangerous in 1993 than in 1998. Hence, even though climate change was considered more likely in 1998, the dangerousness of possible effects decreased in the respondents’ views.
The questions about possible negative and positive effects underline the results of the previous question regarding the item ‘*themselves*’, where the majority of the respondents felt the rise in world’s temperature as somewhat or not very dangerous. Fig. 3.1.11 integrates the two questions on future prospects in one graph. Only the first three items (‘*personal comfort*’, ‘*health*’ and ‘*outdoor activities*’) were asked in both questions.

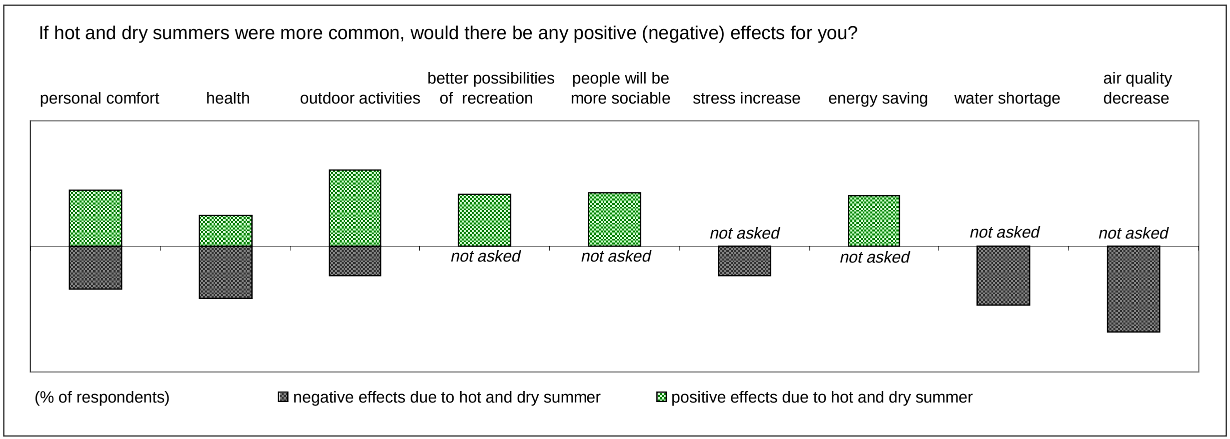

Fig. 3.1.11: *Expected effects of hot and dry summer.*

Fig. 3.1.11 shows that for ‘*outdoor leisure activities*’ (the only positively perceived category of everyday life; Fig. 3.1.2), most positive effects were expected for the future. ‘*Air quality*’, the most negatively perceived category, was expected to be most negative in the future as well. However, while no relevant negative effects were perceived on ‘*health*’ in the past, it is considered more problematic for the future if hot and dry summer become more common. On the other hand, more positive than negative effects to ‘*personal comfort*’ were expected for future hot and dry summers while a slight negative effect was perceived in the past.

3.1.4.3 Adaptation

Changes in the use of means of transport

Fig. 3.1.12 shows how people changed their means of transportation during hot and dry summers.

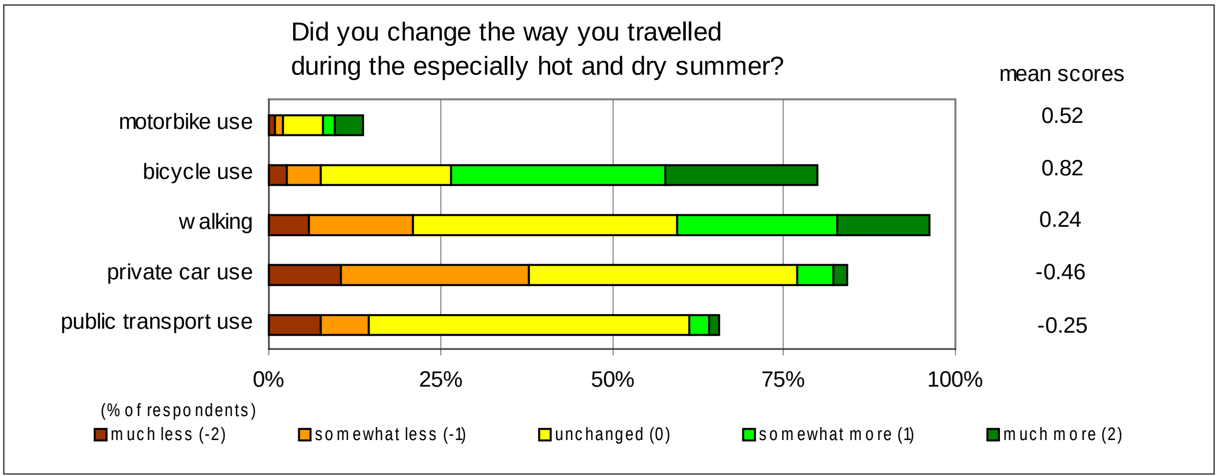

Fig. 3.1.12: *Perceived effects of hot/dry summer weather in the use of means of transport.*

The influence of hot summer weather on *'bicycle use'* was higher than for the other categories, (only 20% gave *'no change'*). Hence, the increase of *'bicycle use'* due to the hot and dry summer weather was higher than for the other categories. There was also a trend that people walk more (36.87% of the respondents walked much or somewhat more, whereas 20.95% walked less or somewhat less). Only minor changes for *'public transport'* and for *'private car use'* were made because of the weather. The answering category *'no change'* was given by 46.58% for *'public transport'* and by 38.92% for *'cars'*. Those who changed their habits used less rather than more. Only a minority of the respondents use motorbikes. Therefore, the mean score has to be qualified given the low percentage of people using them at all (13 % of the respondents).

Compared to the NOSO'92 data, in 1998 respondents changed the use of selected means of transport more than in 1992. The mean score for *'bicycle use´* changed from 0.52 to 0.83, for *'private car use'* from -0.02 to -0.46, and for *'public transport use'* from -0.2 to -0.25. Other means of transport were not considered in NOSO'92.

Changes in trip and holiday behaviours

All outdoor trip destinations benefited from the hot and dry summer, whereas indoor destinations were negatively affected. The results shown in Fig. 3.1.13 should be interpreted in view of the number of people who use these destinations. Therefore the answering *'I never use'* was added to the category *'unchanged'* for calculating the adjusted mean scores shown in Fig. 3.1.14.

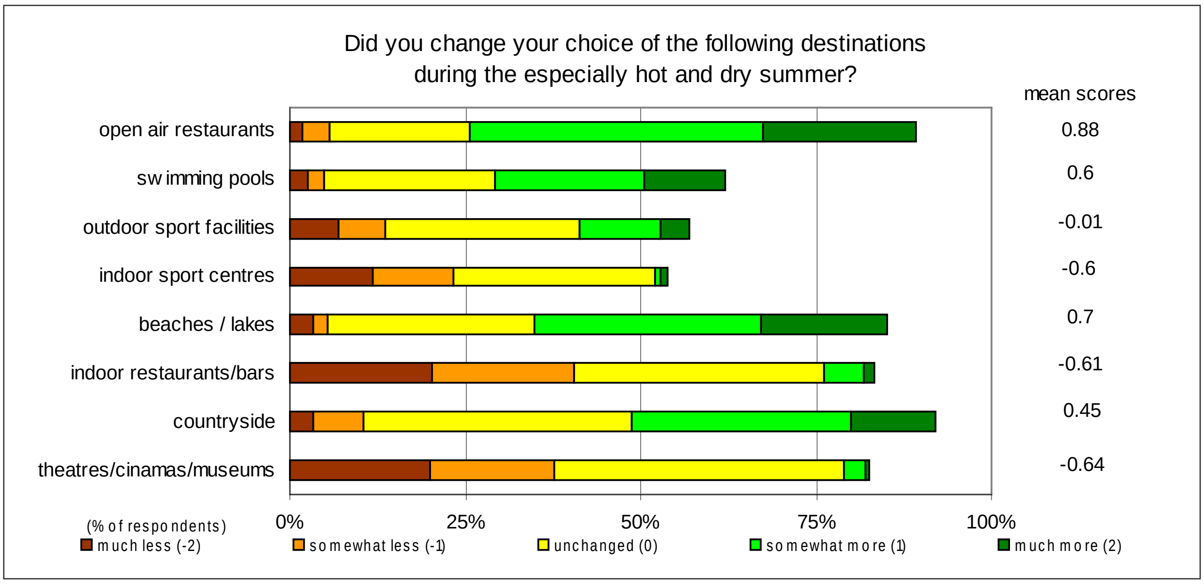

Fig. 3.1.13: *Perceived effects of hot/dry summer weather in the choice of trip destinations.*

'Open air restaurants', *'beaches/lakes'* and *'countryside'* observe most positive effects of hot and dry summer, while *'swimming pools'* has to be qualified because of the rather high percentage of people (31.5%) who never go to pools. As shown in Figure 3.1.14, the negative effects to indoor restaurants *and 'theatres/cinemas/museums'* were even stronger compared to *'indoor sport centres'* than appears from Fig. 3.1.13.

The shorter the trips, the more influence the hot and dry weather. 62% of the respondents recognised changes in day trips, 42% changes in weekend trips or short holiday breaks and only 14% changed their main summer holiday plans. Only 5.7% of the respondents mentioned changes for the following year. According to the survey results, there would have been no net effects as a result of extreme weather, since *'less'* and *'more'* trips were almost balanced for day and weekend trips (Fig. 3.1.15).

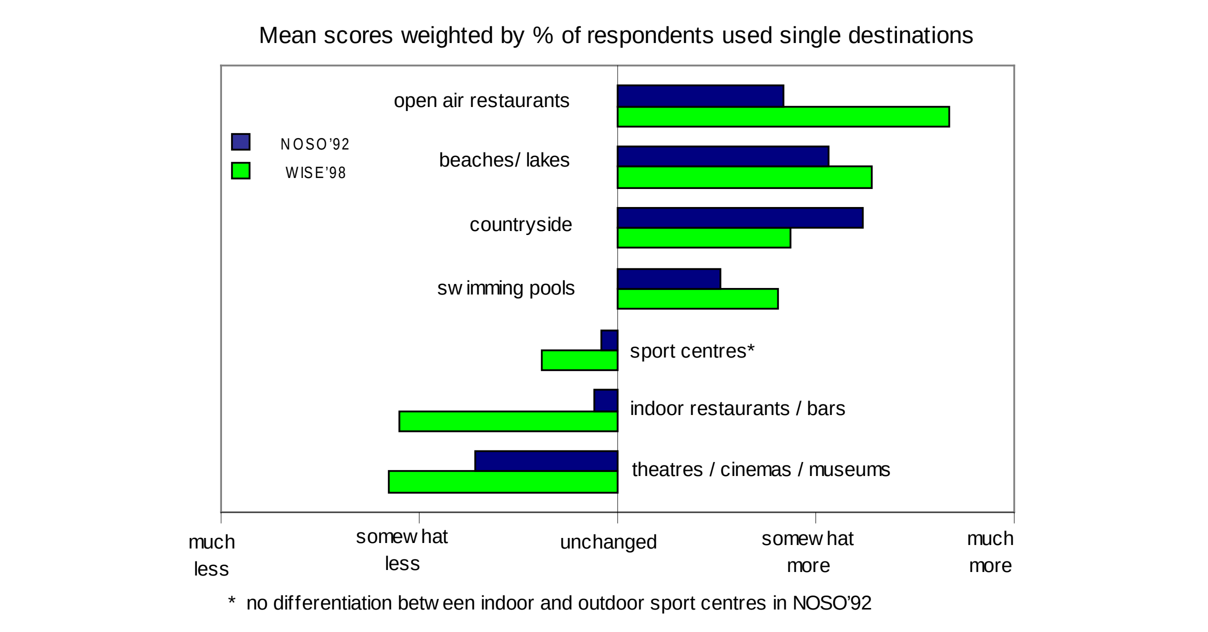

***Fig. 3.1.14**: Effects of hot/dry summer weather to trip destinations.*

With a mean score of -0.2, a slight tendency to closer destinations can be observed. This result corresponds with the results shown above. Respondents were also asked in which way they had changed their holiday plans. Although only 20% of the respondents had changed their plans for the same or the following year, people seem less likely to travel far when the weather is hot and dry. The categories '*stayed in Germany instead of going abroad*' and '*stayed at home instead of going away*' were indicated more often than the other items. This effect is confirmed in Fig. 3.1.16.

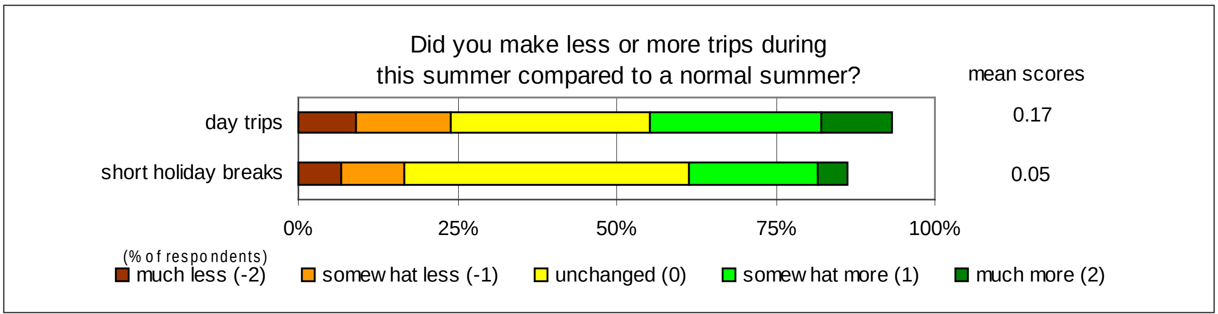

***Fig. 3.1.15:** Perceived effects of hot/dry summer weather regarding trips.*

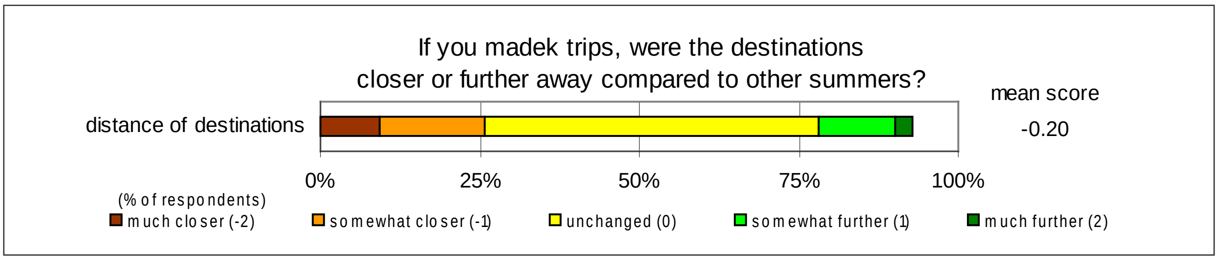

***Fig. 3.1.16:** Perceived effects of hot/dry summer weather regarding distance of destinations.*

Changes in other habits

The question on permanent changes in lifestyle allows the comparison between in past and in future. 86% of the respondents said that they would change their lifestyle or already have made changes because of hot and dry summer weather, only 12% answered negatively, 2% did not know (Fig. 3.1.17).

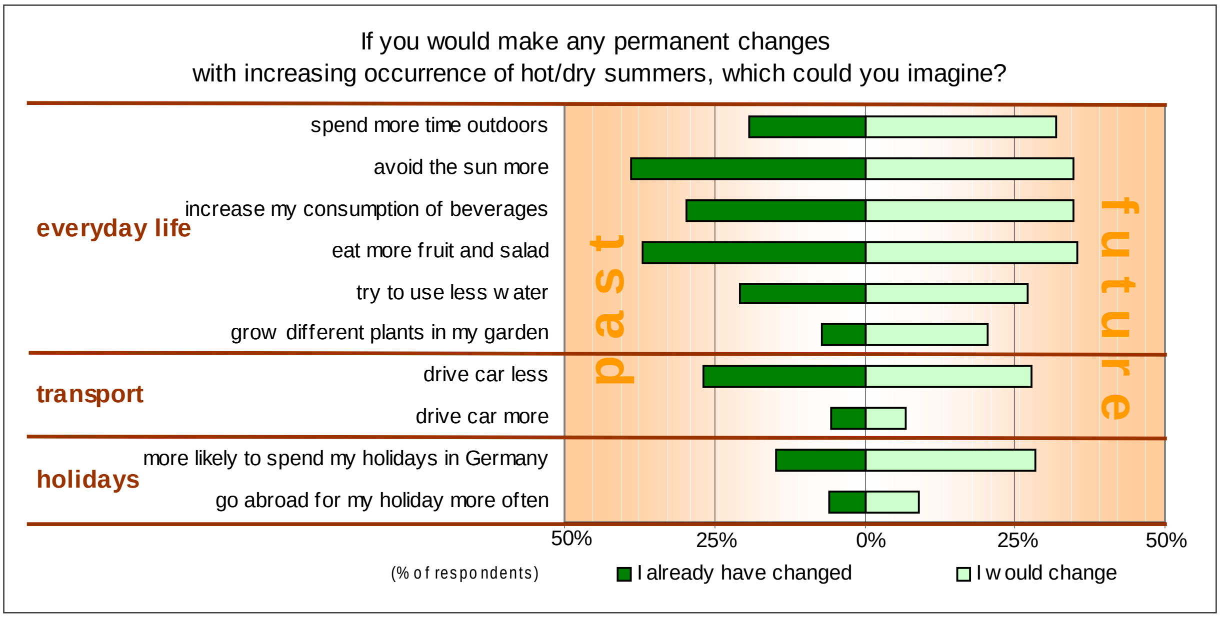

***Fig. 3.1.17:** Adaptation to increasing occurrence of hot/dry summer.*

The majority of the respondents stated that they have already started to adapt or will adapt in future if climate changes. The categories quoted most often were *'avoid the sun more'*, *'eat more fruit and salad'* and *'drink more'*.

There were no considerable differences between past and future (bearing in mind that statements to changes of lifestyle in future are easy to make since their realisation cannot be proven). Changes would already have started, so for instance, traffic ought to have decreased already during hot/dry summers because 27% of the respondents said that they have used their car less often and only 6% stated the contrary. With more hot and dry summers in future, this trend of less car use would continue (28% of the respondents would change in future). The trend of changes would slightly increase for the categories *'spend more time outdoors'*, *'grow different plants in my garden'* and for *'more likely to spend my holidays in Germany'* (see above).

3.1.4.4 Mitigation

88% of the respondents would accept changes in their lifestyle to counteract climate changes. 8.9% of the respondents would accept changes even though they did not see the necessity. Figure 3.1.18 shows how easy or difficult it would be for respondents to accept changes to counteract climate changes.

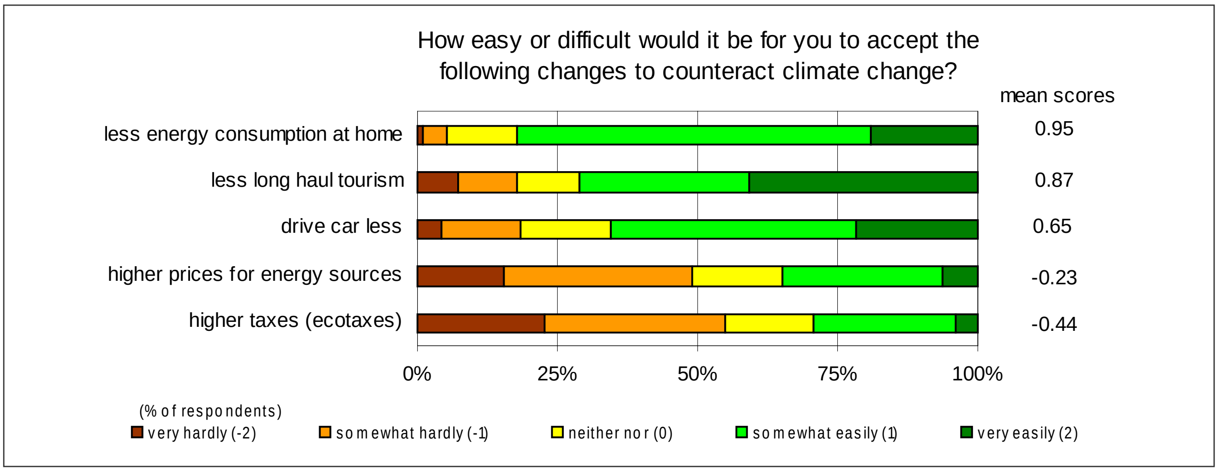

***Fig. 3.1.18:** Mitigation to climate changes.*

Remarkably, respondents would rather easily accept changes in habits but hardly accept higher costs. From the given possibilities, most respondents saw for themselves ‘e*nergy saving at home’* as the easiest way to counteract climate changes. The impact of reduction of *‘long-haul tourism’* is certainly lower as only a minority of people is concerned. The acceptance of *‘drive less car’* concurred with the given answers shown in Figures 3.1.12 and 3.1.17. Only 11% of the respondents did not see the necessity to counteract climate changes, for which they gave the following reasons:

- one person cannot make a difference (91% of the respondents who did not see the necessity)
- it is not yet proven, that human behaviours influences the climate (62%)
- climatic changes are a benefit for me or for our region (42%)
- the engineering progress is sufficient to counteract the current climate changes (40%)
- I do not care (3%)

Some respondents who did not see the necessity of mitigation strategies did not refuse them because of lack of interest, but they gave the responsibility to others. According to this fact, the question about the decision-maker had a clear result in favour of government actions (Fig. 3.1.19).

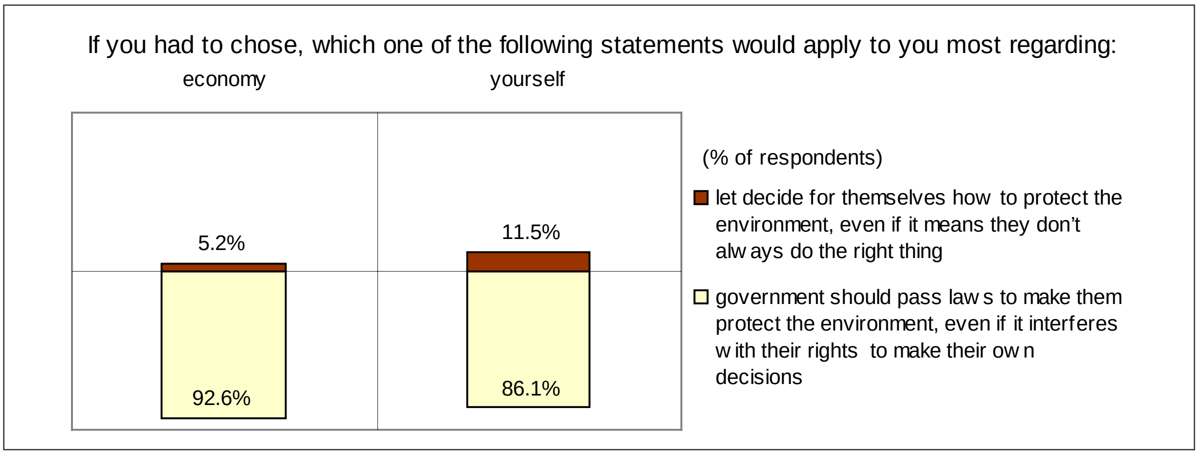

Fig. 3.1.19: *Attitudes of respondents regarding responsibilities for decisions.*

Respondents clearly gave the responsibility of mitigation strategies to the government. On the other hand, they declined classical policy instruments like tax and price changes (Fig. 3.1.18). The refusal to increase financial burden might be explained in view of the tight financial situation of many private households over the last years in Germany. According to the survey results, incentives to counteract climate changes should show more possibilities of savings rather than extra costs for the people.

Comparison to results of former studies

The questions on mitigation to climate changes were partly adopted from the ISSP’93 questionnaire to allow for the comparison of results. However, this comparison have to be interpreted with caution due to different survey methodology (see Section 3.1.3). Results of the question on attitudes show a slight change from 1993 to 1998 (Figure 3.1.20). In 1998, respondents agreed less on the statement *‘it would be too difficult for someone like me to do much about the environment’* than in 1993. According to this, respondents were more willing to do something in 1998 as in 1993. The question on responsibility of decisions was answered in the same way in 1993 as in1998. Respondents clearly gave the responsibility of mitigation strategies to the government in 1993 as well as in 1998.

The question on possibilities to counteract changes was not asked in exactly the same way as in ISSP’93. While in the ISSP’93, the question was focused on the protection of the environment in general, the WISE’98 question was focused especially on climate change. Therefore, the item of the ISSP’93 question *‘cuts in living standard’* was split into the categories *‘less energy consumption at home’*, *‘drive car less’* and *‘less long-haul tourism’* for the WISE survey.

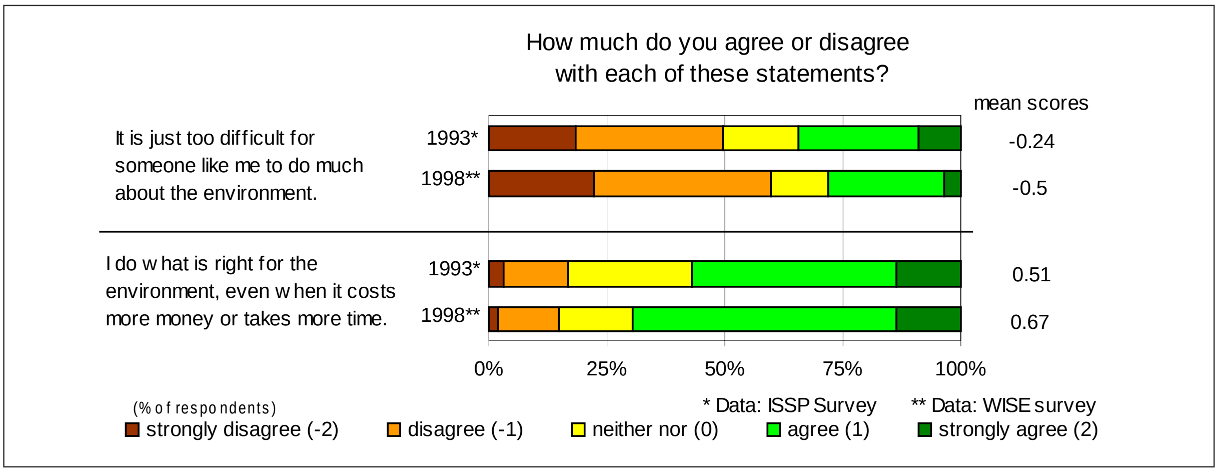

Fig. 3.1.20: *Attitudes of respondents regarding the environment.*

Fig. 3.1.21 shows the acceptability of possibilities to mitigate climate change in 1993 and 1998.

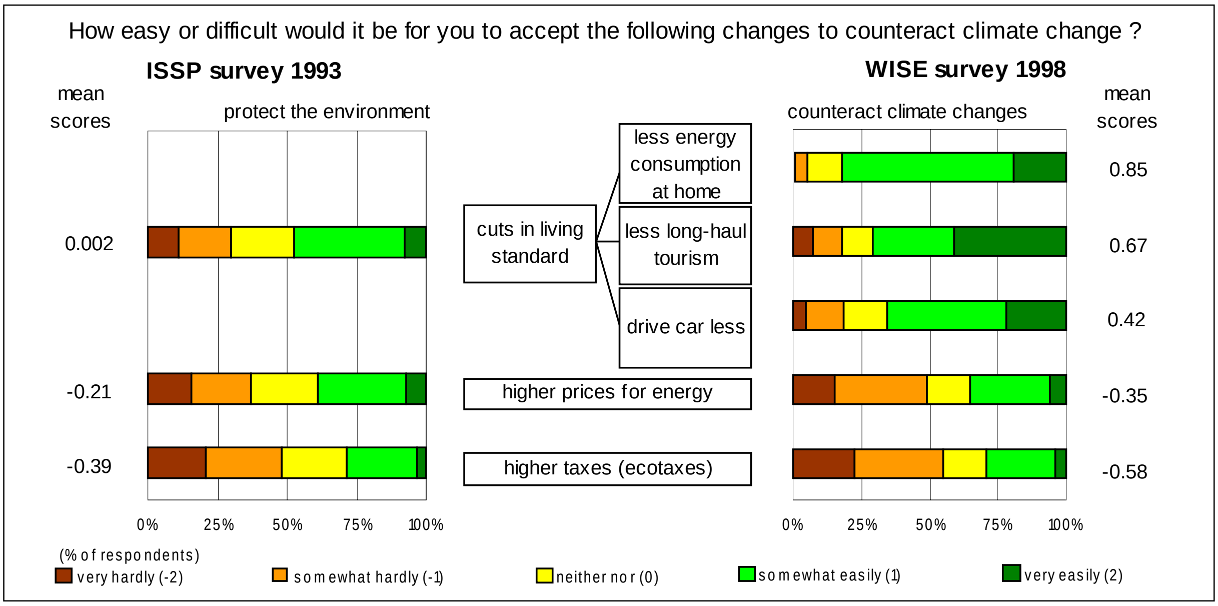

Fig. 3.1.21: *Comparison of the acceptance of mitigation to climate changes.*

Both surveys showed the preference of doing something over paying more, although in 1998 it was more obvious than in 1993. While the refusal to pay more increased between 1993 and 1998, the acceptance to do something for the environment increased in the same period. The reason might be that the category '*cuts in living standard*' was too abstract in ISSP'93 and its subdivision in WISE'98 was easier to understand.

3.1.4.5 Differences between socio-demographic groups

The adjustment procedure of the data set to obtain a better representativeness of the survey results was based on the variables gender and age. These two variables were analysed in more detail, as described below. Figures in this chapter show mean scores or percentage of respondents in order to give a concise description of the results. However, the statistical analyses were done on two-way contingency tables using the χ^2 test.

Differences between female and male respondents

For all items, female respondents perceived more effects (the answering category *'no effect'* was ticked less often) and they perceived hot and dry summer weather for all items more unfavourably than male respondents. All differences between female and male respondents shown in Figure 3.1.22 were significant according the χ^2 test. The perception of mild winter weather did not show such clear differences between women and men. Men perceived mild winter weather more unfavourably than women for *'personal comfort'*, *'health'*, *'outdoor leisure activities'* and *'mood in view of winter'*, but these differences were not significant.

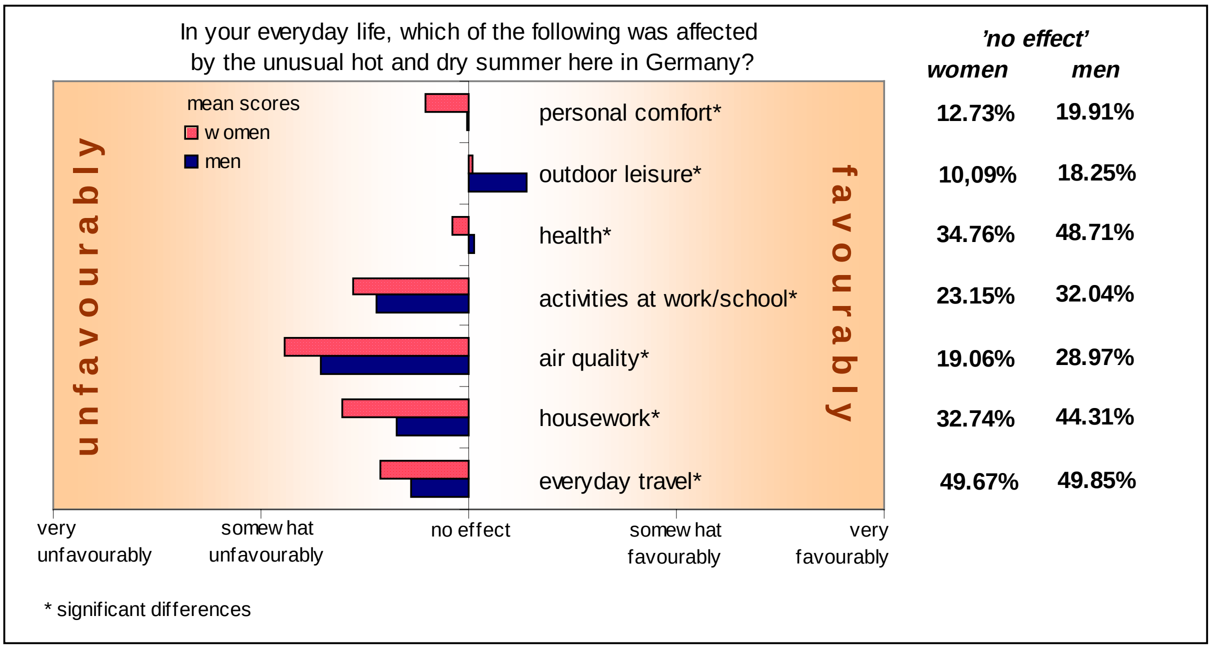

Fig. 3.1.22: *Differences between women and men in perception of hot and dry summer weather.*

Thus, women and men do not perceive the weather differently in general, only certain weather situations affect women and men differently. An increase in temperatures in northern Germany would have more effects in summer than in winter and would burden women more than men.

The validation of the WISE results with the NOSO'92 results confirm the more unfavourable perception of woman regarding *'personal comfort'*, *'health'* and *'leisure activities'*. The differences between women and men in perceived weather effects to all working activities could nor be confirmed by NOSO'92. Even the higher intensity of perceived effects for women was less obvious in NOSO'92.

Assuming that women perceive hot and dry summers more intensively and more unfavourably than men, women might adapt themselves more. As shown in Fig. 3.1.23, women change their means of transport more than men do during hot and dry summers. More women than men use their car less and their bicycle more. The effects of hot and dry summer weather on the choice of the means of transport were more pronounced in women as in men (for all items women ticked the response category *'unchanged'* less often).

There were only minor differences between women and men in their behaviour regarding trips and holidays. Men decreased their trips to the countryside more than women and went more often to open-air restaurants than women. For all other destinations, no significant differences were found. According to the results of the survey, women decreased their day trips slightly more than men and preferred more destinations that were nearer.

In view of future climate change, female respondents considered it slightly more probable than male respondents that future summers will be increasingly hot and dry. Women also assessed the impacts of a rise in the world's temperature slightly more dangerous than men did. How women and men changed or would change their habits in everyday life if future summers would be increasingly hot and dry is shown in Fig. 3.1.24.

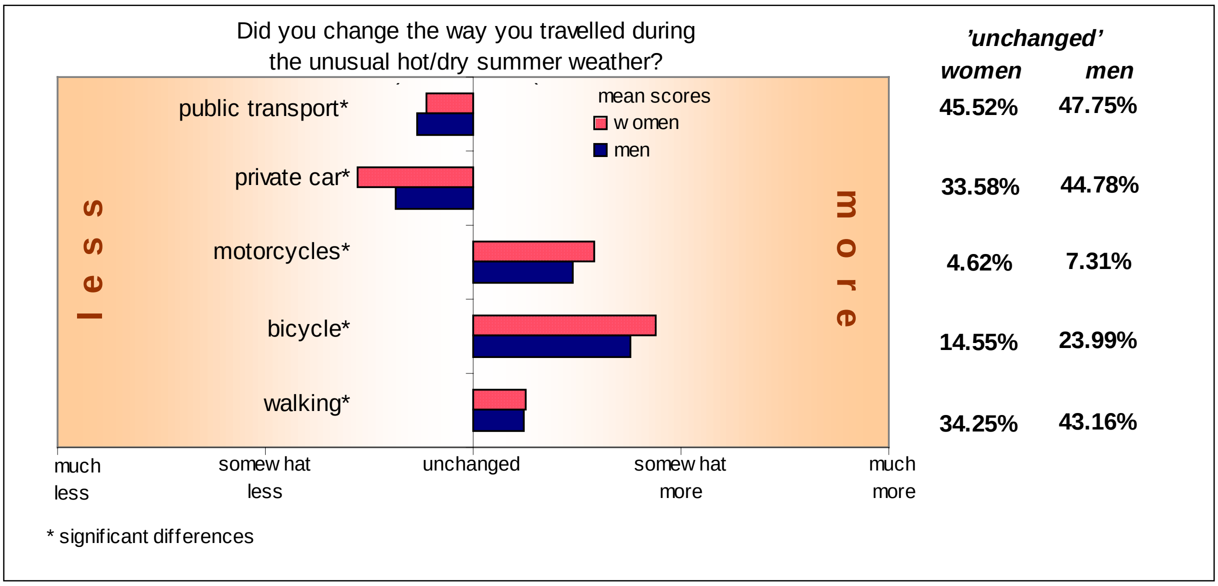

Fig. 3.1.23: *Differences between women and men in the use of means of transport during hot and dry summer.*

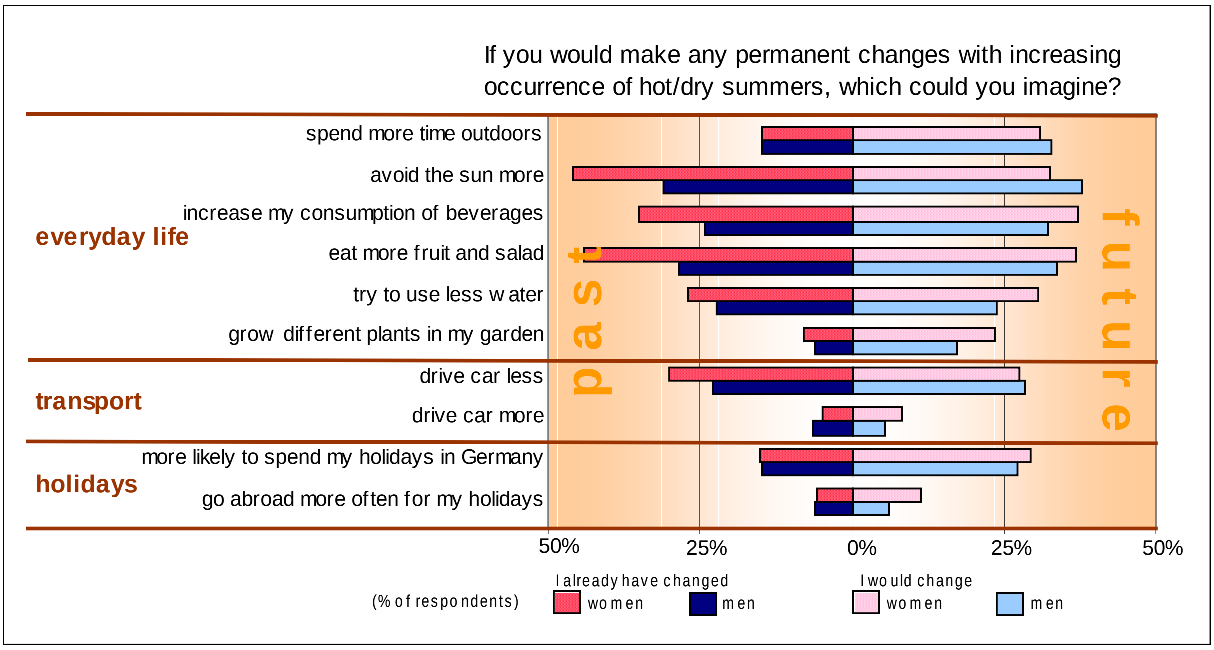

Fig. 3.1.24*: Differences between women and men in adaptation to climate changes.*

Habits in everyday life (except for '*drive car more*' and '*go abroad more often for my holidays*') were already changed more by women than by men. For the categories '*spend more time outdoors*', '*avoid the sun more*' and '*drive car less*', men would change in future if summers would be increasingly hot and dry. For the other categories, women indicated more changes for the future.

Regarding the respondents' attitudes towards mitigation, no significant differences between women and men were seen. Also the question on who should take responsibility for measures was answered in almost the same way. In addition, the percentage of people who would accept changes in their lifestyle to counteract climate changes is nearly the same for women and men. Regarding their contribution to counteract climate change, some differences were found between women and men (Fig. 3.1.24).

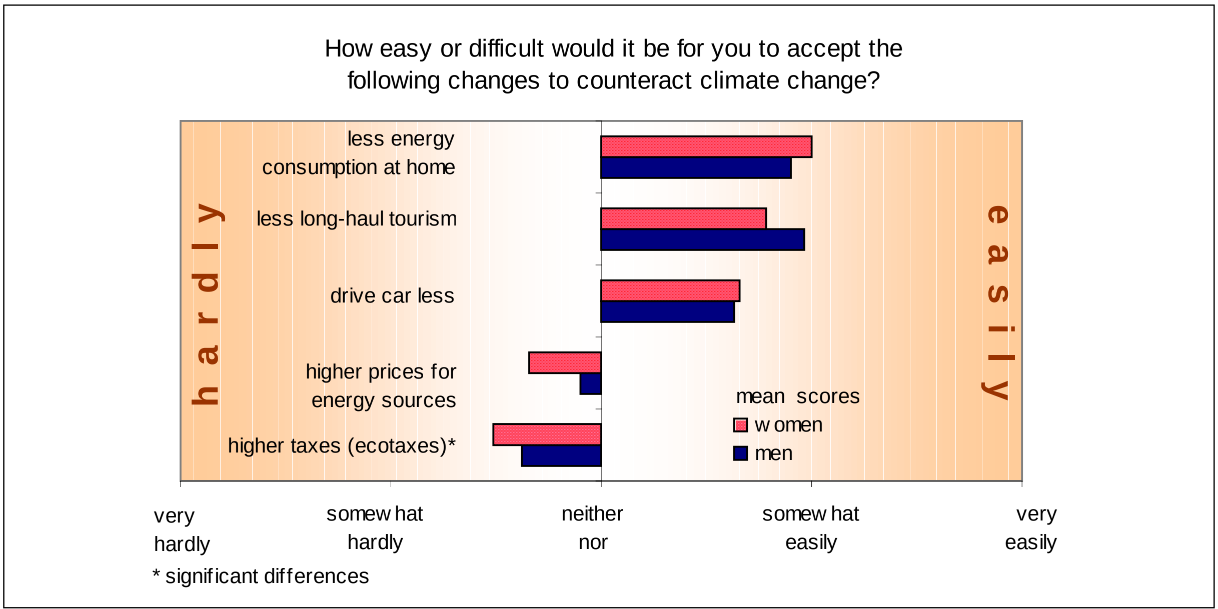

Fig. 3.1.25: *Differences between women and men in mitigation of climate changes.*

There is a slight tendency that women would accept changes in habits somewhat more easily. Higher prices or higher taxes would be more problematic for women than for men. These differences might have economic reasons.

In conclusion, it can be said that women and men perceive extreme hot and dry summer weather significantly differently. This has effects on their adaptation of extreme weather, where women adapt more than men, although differences were not as clear as for perception. Differences between women and men in their attitudes towards mitigation of climate change are less obvious.

Differences between age groups

For hot/dry summers (Figure 3.1.26), the younger the respondents, the more pronounced are their perceptions of weather effects for the various categories. The differences between the categories diminish with increasing age, which is remarkable given that there was no age trend in the answering category *'no effect'*. For the categories *'outdoor leisure activities'*, *'personal comfort'*, *'health'* and *'air quality'* a significant age effect is visible.

With increasing age, the effects of hot and dry summer weather were perceived as less and less favourable for *'outdoor leisure activities'*, *'health'* and *'personal comfort.* Reversely, the younger the respondents, the more unfavourably they perceived the effects of hot and dry summer weather on *'air quality'*.

All age groups ranked the effects of hot and dry summer weather on *'personal comfort'* as the most important one. Only for the age group 25-34, effects on *'outdoor leisure activities'* were more important then those on *'health'*, all other groups ranked effects on *'health'* as second and effects on *'outdoor leisure'* as third.

All significant age differences (except for *'air quality'* which was not asked in NOSO'92) can be confirmed with the NOSO'92 data, although for all age groups the effects of hot/dry summers were perceived slightly more favourably in 1992 than in 1998.

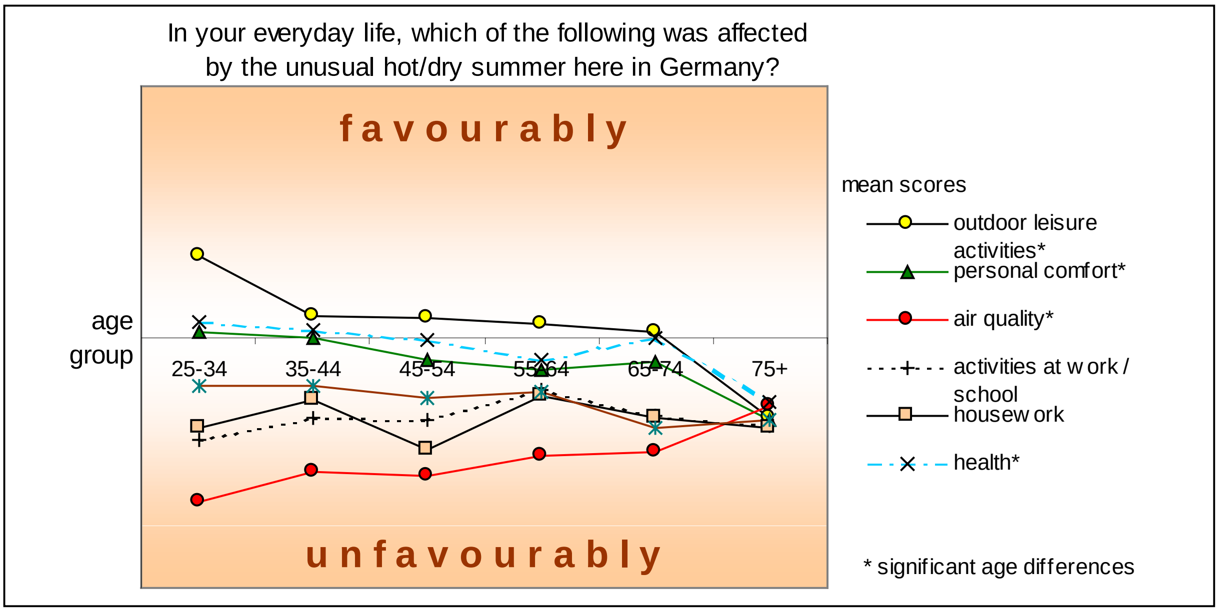

Fig. 3.1.26: *Differences between age groups in perception of hot and dry summer weather.*

Significant differences of perceived effects of mild winter weather (Figure 3.1.27) were found for *'mood in view of winter'* and *'personal comfort'*. These two categories have a continuously increasing trend, which means that older respondents perceived effects of mild winter weather less unfavourably. The analysis of the answering category *'no effect'* did not show any age effect.

All age groups ranked the effects of mild winter weather on *'personal comfort'* as the most important one. Only for the age group 25-34, effects on *'everyday travel'* were considered more important than *'mood in view of winter'*, all other groups ranked *'mood in view of winter'* second and effects on *'everyday travel'* third.

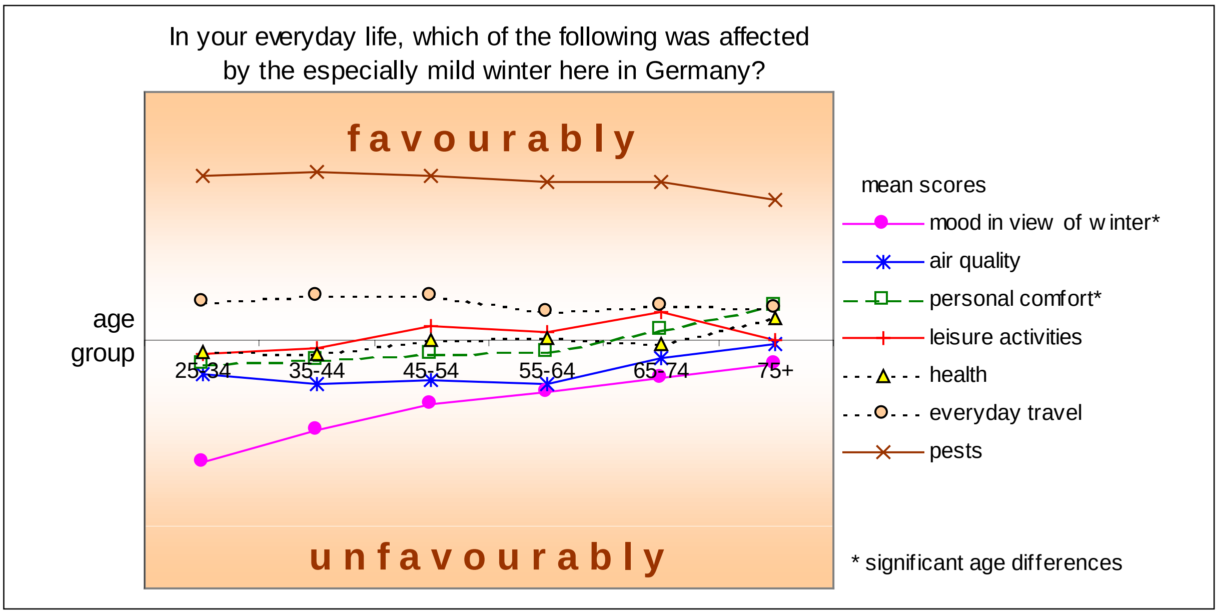

Fig. 3.1.27: *Differences between age groups in perception of mild winter weather.*

According to the results of perceived weather effects, the question on preferred temperature was answered. The number of persons preferring hot temperatures to colder ones in summer decreased with increasing age. For the age groups 65-74 and 75+, the majority of respondents preferred colder temperatures in summer. The younger the respondents, the more they preferred frosty temperatures in winter.

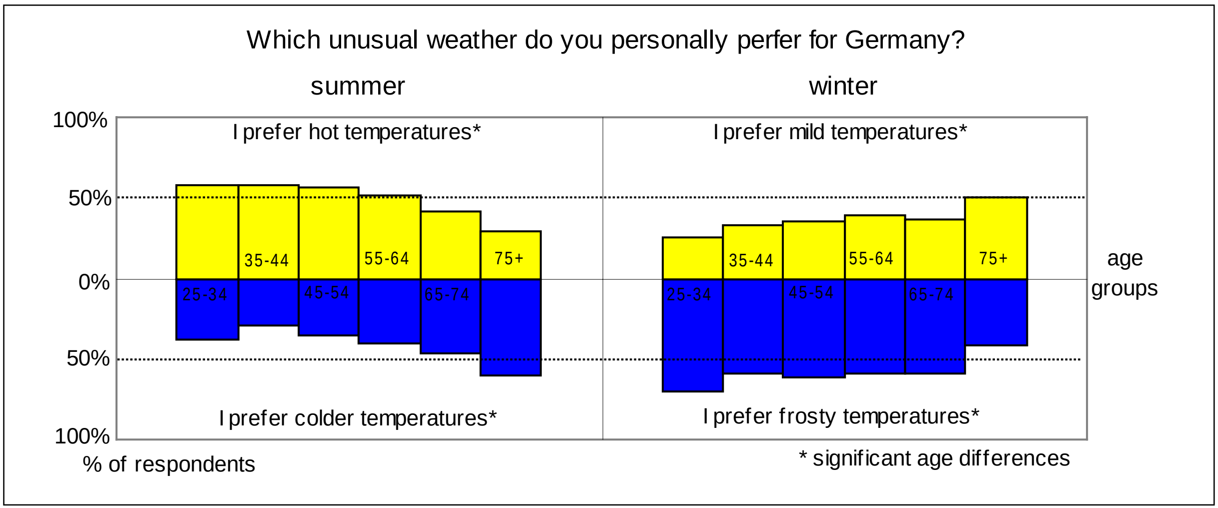

Fig. 3.1.28: *Differences between age groups in preferred temperatures.*

Assuming that with increasing age, people perceive hot and dry summer weather as less extreme (see above), younger people might respond more strongly or actively to this weather. As shown in Figure 3.1.29, significant differences between age groups in the use of means of transport during hot and dry summer were indeed found for *'bicycle use'* and *'walking'*. The younger the respondents, the more they walked or cycled. Although *'motorcycle use'* decreased with increasing age, it was not significant, mainly due to the low number of respondents that use a motorcycle. For the use of *'public transport'* and *'private car'* no differences between age groups are visible.

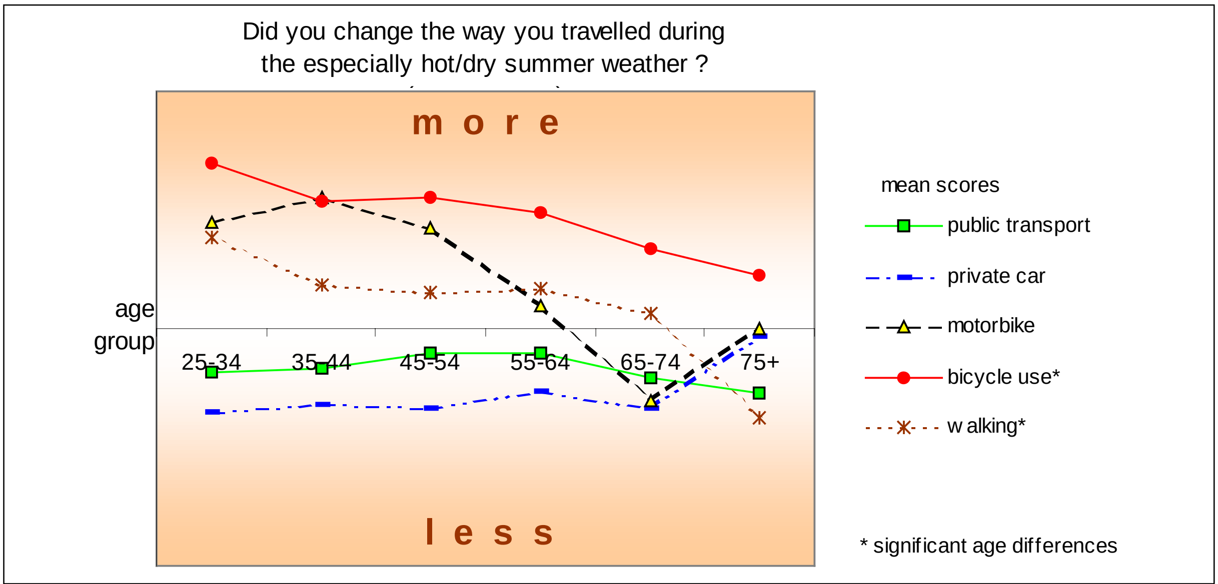

Fig. 3.1.29: *Differences between age groups in the use of means of transport during hot and dry summer.*

As for holiday and trip destinations, most differences between age groups were seen for *'beaches/lakes'*, *'swimming pools'*, *'countryside'* and *'open air restaurants'* (Figure 3.1.30). In general it can be said that the younger the respondents, the more they chose to go to these destinations.

In addition, there was a slight but not significant trend that:

- the younger the respondents, the more day trips and short holiday breaks or weekend trips they made during hot and dry summer weather;
- the older the respondents, the closer the destinations were that they visited during this hot and dry summer.

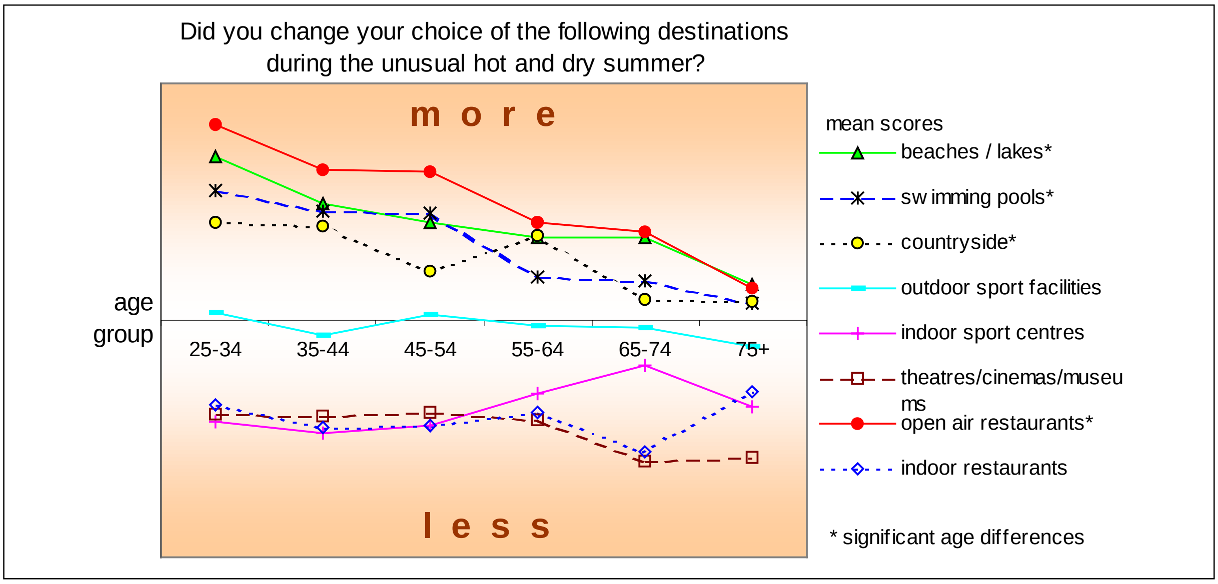

Fig. 3.1.30: *Differences between age groups in the choice of trip destinations during hot and dry summer.*

It can be said that the younger people were, the more they responded to extreme hot and dry summer weather. In general, these adaptations reflected an increase in more physical activities like walking or cycling, and more trips to beaches, swimming pools and countryside. A similar age effect is also visible for the perception of increasingly hot and dry summer in future (Fig. 3.1.31). The perceived positive effects for *'outdoor activities'* and for *'people will be more sociable'* by younger people decrease as age increases. On the other hand, the negative effects regarding *'stress increase'* and *'air quality'* were perceived less with increasing age.

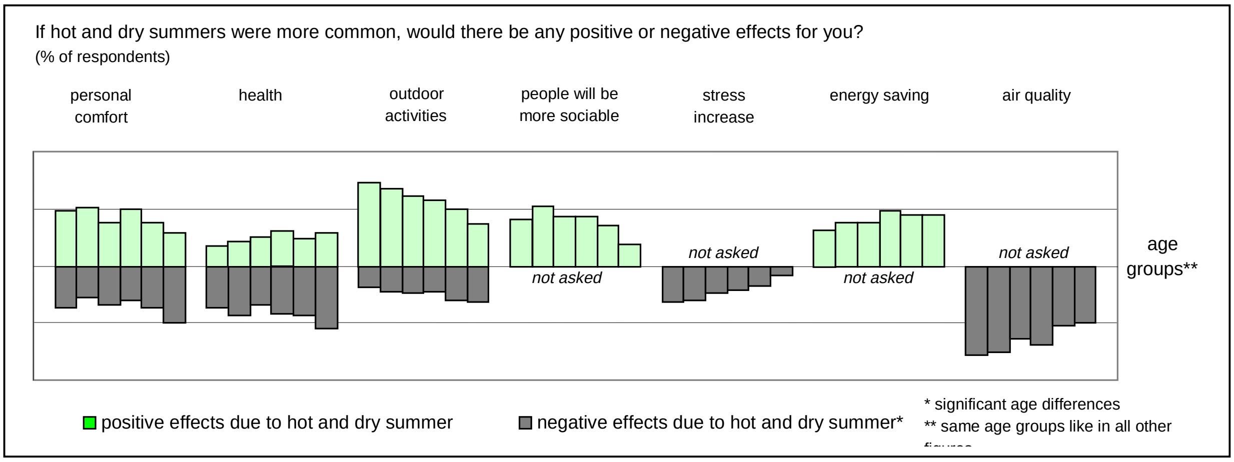

Fig. 3.1.31: *Differences between age groups in future prospests if summer will be more and more hot and dry.*

The most significant differences between age groups were observed for the acceptance of mitigation to climate change (Fig. 3.1.32). The younger the respondents, the more they saw the necessity of mitigation. However, a more detailed look at possible changes (higher taxes, less energy consumption at home) did not show any differences between age groups.

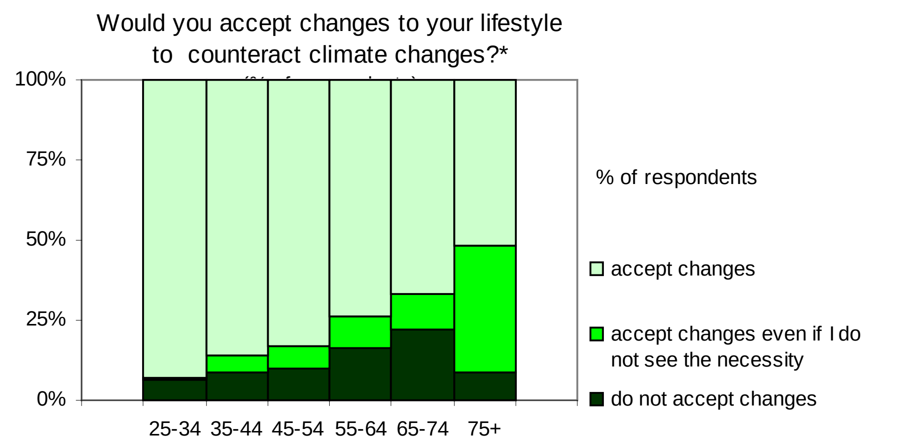

Fig. 3.1.32: *Differences between age groups in acceptance to counteract climate changes.*

3.1.5 Conclusions

Hot/dry summer weather affects people in northern Germany more than mild winter weather. Respondents perceived hot/dry summer weather more negatively than mild winter weather, although there were differences between socio-demographic groups. Hot/dry summer weather affects women more strongly and more negatively than men. For a number of aspects of everyday life, hot/dry summer weather was perceived increasingly negative with increasing age. The effect on respondent's '*personal comfort*' was seen as the most important effect for both men and women as well as for all age groups.

There were different spontaneous adaptations to hot/dry summer weather, such as changes in eating habits or in the use of means of transport, higher preference of outdoor trip destinations and the increase of short term trips. The differences between socio-demographic groups are also observed in these adaptations. Women adapted themselves more than men, that is, they avoided the sun more, changed their eating habits more and drove the car less than men. The differentiation between age groups shows a decrease of physical activities during periods of hot/dry summer weather with increasing age. Thus, younger respondents walked or cycled more, used beaches, pools and countryside more and made more short-term trips.

Respondents thought that the increase of the world's temperature would be fairly likely. Women were more convinced of this than men. The possible effects of global warming were seen as more positive by younger than by older respondents.

The majority (88%) of the respondents would accept changes in lifestyle to mitigate climate change. There were no differences between men and women but significant differences could be observed between age groups. The younger respondents were, the more they accepted changes to mitigate climate changes. Changes in lifestyle were preferred to higher costs. The responsibility for measures was clearly given to the government, with no differences between socio-demographic groups.

3.2 Management perception survey of climate impacts

3.2.1 Summary

Weather is an important factor for the sectors tourism, energy and water. Nonetheless, empirically experienced and observed climate signals that affect these sectors can hardly be identified. Hence, the dynamics within the sectors cannot be described only by changes in weather on the medium or long run.

In addition to weather and climate, there are many factors influencing the demand as well as the supply side of these sectors, producing a strong noise. Here we concentrate on presenting an overview of the factors that influence the amount of tourist activities and water and energy use. This is done at a macro/meso scale for the whole sector, as well as at a micro scale, using a scheme of the individual's decision-process.

Climate change leads to changes in the (short-run) weather, which leads to changes in behaviour. However, these climate signals and impacts on the different sectors can be evened out or are already evened out by adaptive actions from different actors. Those adaptive actions do not necessarily have to be planned, they can be autonomous. Moreover, those adaptive actions do not necessarily have to be directed primarily at climate or weather changes, but may indirectly touch this field.

In tourism, where the overall demand is rising, the regional distribution of tourists is less stable than in the energy and water sector. Potential tourists have the freedom of choice where to go or not to go for their holidays. On the demand side, in tourism the influence of the current weather is said to be an important factor, especially for short-trips, which is an important part of tourism. The tourist suppliers aim at becoming less weather-sensitive. In addition, ecotourism or "regional individualism" is promoted.

In the energy sector, heating is the most weather-sensitive factor, while water seems to be sensitive to summer weather. In the energy sector, especially in the electricity sector, customers are now in the position to change their suppliers because of energy liberalisation in Germany. Even if the demand for water and energy suggests to be fairly stable across all suppliers, the liberalisation of the electricity sector makes the suppliers more prone to customers' wishes. This presents an opportunity for climate-change mitigation actions.

Changes in people's habits of using the goods tourism, water and energy are recognised. Water and energy-saving appliances and attitudes are particularly relevant, both on the supply and the demand side. Ecotourism tries to become more well-known. Mitigation strategies by suppliers can be promoted by ecobalances or ISO-certification.

3.2.2 Introduction

The management survey of the sectors energy, water and tourism within the German part of the WISE-project is based on management interviews as well as a study of the relevant literature.

An important distinction must be made between weather influences and climate or climate-change influences. WISE has not aimed to quantify all impacts of climate change. What we have done here is to study the sensitivity of sectors to weather variability and thus provide insights into the vulnerability to climate change. Thus, this work complements scenario-based investigations or modelling studies.

The goals of the German management survey have been to:

- Develop an overview of all the important factors that influence the demand as well as the supply side in these sectors. Thus, this chapter has provided an input into the statistical analysis presented in Chapter 2 to check and explain the results generated there. Of special interest on the supply side is the management system that acts to make the supply meet demands.
- It is tried to filter out the role of climatic and weather influences. This does not lead to quantitative results, such as factor x plays a role of y% in the decision-making process of the individual (micro-level) or z% in the (economic) performance of the supplier (macro or meso-level). However, the investigation aims to arrive at qualitative estimates of the importance of weather and climate to decision-makers.
- One main focus of this research is the demand side, and here the position of individuals (micro scale).
- Next, it is tried to filter out changing behaviour on the supply and the demand side, which is initiated by changes in weather (and climate). This changing behaviour is divided into adaptation and mitigation. Definitions of these terms are provided in Section 3.1.

The main questions on the management side are: “Can we modify the management of current systems to adapt to climate change?”, “How might climate change impact the design of new management infrastructure and strategies?”, “Should climate change be included in our current planning?” (UNEP and IVM, 1998).

As stated, in WISE we have not concentrated on the impacts of climate change, but on the possible influences of weather variables on a range of sectors. Thus, an indication of vulnerability for these sectors can be obtained. The generated results might help not only to answer whether climate change should be included in current planning, but also to show where and how this planning might be adopted to reduce vulnerability to climate change.

Our main research questions are:

- “What are the factors influencing the demand and the supply[4] side of the sectors tourism, water and energy?”
- “Can the factors connected to weather be identified as important?”
- “Can possible strategies be found to adapt to weather influences, or are strategies already being implemented?”

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[4] The supply side could be divided into geophysical and biophysical and the managing of the supply system. Here we only deal with the management system.

3.2.3 All Energy

As a first approach, we look at the sector "Energy"[5] as a whole. With this approach, shifts between the different energy sources can be ignored. An overview is presented that lists the different factors that influence the amount of energy consumed. Within this list, it can easily be recognised that heating is a factor in which the weather (temperature) plays an important role. Thus, because the heating can be adjusted to different temperatures, it is called a "weather adaptive factor". As a second step, we look at the consumption of gas and electricity separately, to see whether we can filter out peculiarities in these sectors, especially regarding the shifts between these two energy sources[6].

3.2.3.1 Overview

Fig. 3.2.1 illustrates the relative increase of gas within the German energy mix. Tab. 3.2.1 lists a range of factors that affect demand and supply of energy in the short, medium and long run.

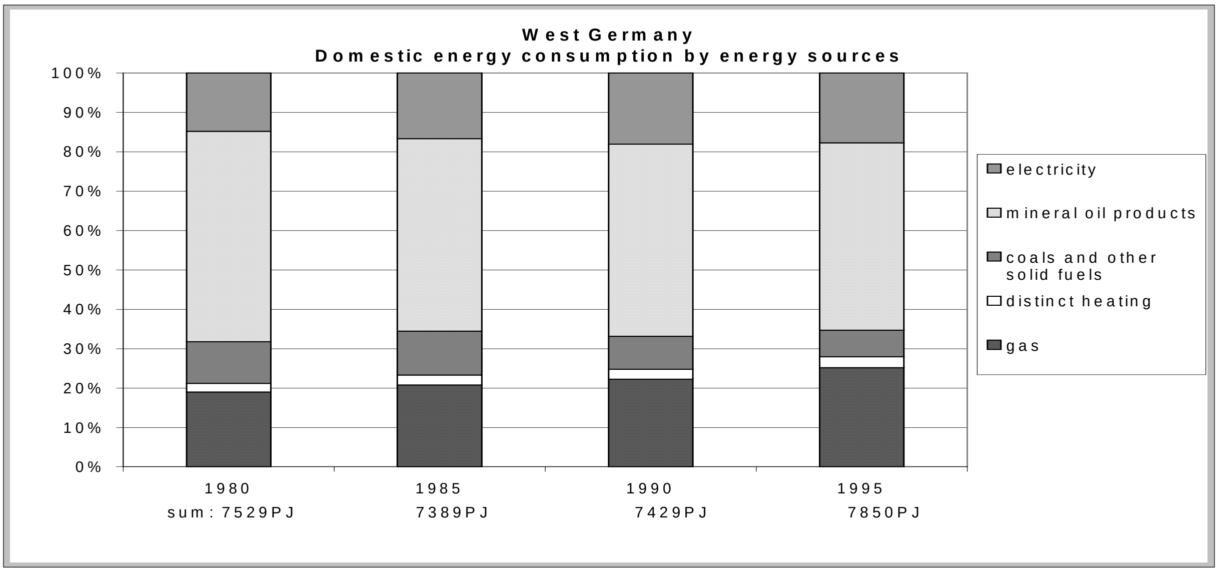

Fig. 3.2.1: *Domestic energy consumption in West Germany (SVR, 1996).*

5 Energy consumption is subdivided by the statistical bureau into: mineral oils, coal and other solid fuels, gas, electricity and distinct heating.

6 Not to forget that gas can also be used to generate electricity.

		Demand for energy	Supply of energy
Long- and medium-term factors	private households	- Population, number of private households, number of flats, size of flats - economic prosperity and income - technological progress (esp. for energy consuming devices) - prices (including taxes) - energy-political guidelines (esp. laws) - information and awareness activities for optimising the energy-use (provided by different organisations) (Boss and Decker, 1993) - energy-using attitude - availability and costs of substitutes	- energy resource - legal regulations energy-mix - politically envisaged energy mix - producer taxes - actually existing status - capacities, net connections, storage capacities - leakage
	small commercial users	- number of employers and rooms for heating - process-heat and work requirements, output - technological progress - prices - energy-political guidelines - information and advising activities for optimising the energy-use - energy-using attitude - availability and costs of substitutes	
	industry	- energy-using machinery and processes - specific requirement factors (like technology, and usage of latest technology) - energy-political guidelines - information and advising activities for optimising the energy-use - energy-using attitude - availability and costs of substitutes	
	traffic	- person- and goods-traffics, industrial growth of production, vehicles - specific energy-requirements, technology, latest vehicles and usage of latest vehicles/technologies - modal split - prices - energy-political guidelines - information and advising activities for optimising the energy-use - mobility-attitude, energy-using attitude of traffic-users - availability and costs of substitutes	
Short-term factors	private households	- special events (like TV-broadcasting) - holiday seasons	- strikes, (local) shortages because of breakdowns/, special events
	small users	- special events/ holiday seasons	
	industry	- special events/ holiday seasons	
	traffic	- special events/ holiday seasons	

Tab. 3.2.1: *Factors that influence the demand and the supply side of energy (adjusted from Prognos/BMWi, 1996).*

3.2.3.2 Supply side

Regarding the supply side, we tried to get more detailed information using expert interviews. Here it should be mentioned that, mostly because of the liberalisation of the German energy market, hardly any company was found willing to give detailed information.

Overall, the energy-providing companies seem to be concerned about mitigating climate change. Adaptation priorities, however, were found to be low. We could not find any indication of plans for adaptation strategies being developed. Reasons for this might be due to following:

- The suppliers have a lack of information on global (and regional) climate change.
- The suppliers assume that weather and climate might not change as much as projected by different studies.
- The industry relies on its capacity for autonomous adaptation or feels that the impacts of climate change are already incorporated into their "normal" future planning.
- There are more important or urgent issues to be dealt with than adaptation to climate change, such as the challenge of liberalisation and competition.

Thus, the energy sector is more concerned about reducing CO_2 emissions (VDEW, 1998; Boss and Decker, 1993) and the recently implemented ecotax (Ökosteuer) and other ways to meet the political commitments of the Kyoto Protocol.

3.2.3.3 Micro-demand side energy

In Fig. 3.2.2, the overwhelming use of energy for heating can be seen. Other sources[7] even list the share of energy spent by private households on heating as being up to 75 to 80 percent. The part of total end-energy use that is consumed by private households in 1995 is about 30 percent. Compared to 1970, the total amount of energy used by the private households in West Germany has risen by about one quarter (DIW/ISI, 1997). Temperature readjustments used by different institutes indicate that weather does affects the amount of energy that is used.

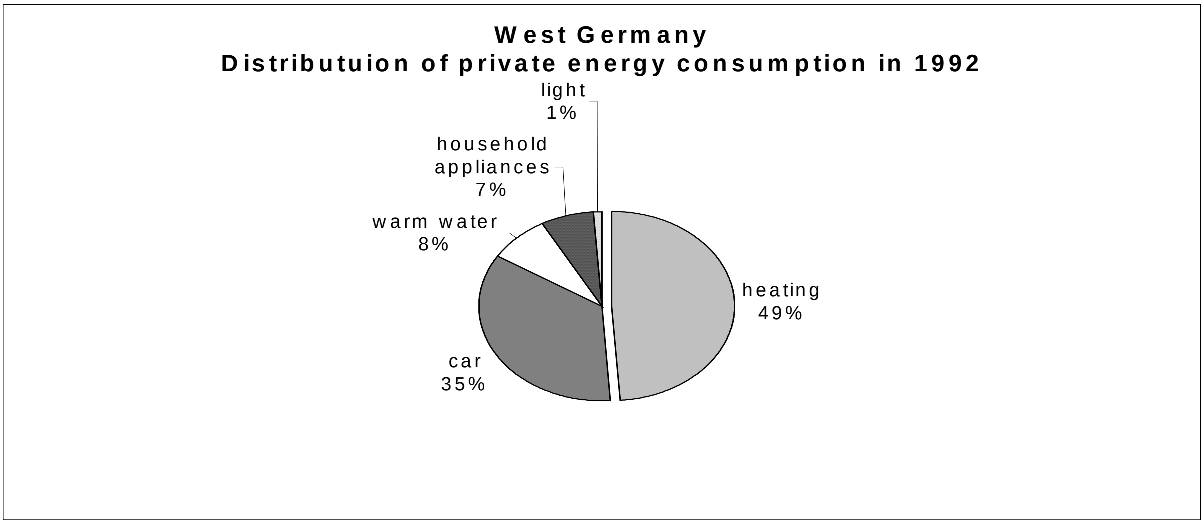

Fig. 3.2.2: *Distribution of private energy consumption (UBA, 1994).*

Fig. 3.2.3 presents a conceptual model that brings together possibilities to use energy (blue boxes). The individual has to decide about the use and the intensity in the use of his energy-consuming devices. This decision is made up by the "energy using attitude" of the individual (yellow). Exogenous factors influence the amount of energy used ("pressure to use energy") These exogenous factors are

[7] DIW/ISI (1997) notes that heating has a part of the sectoral energy-consumption of 75-80 percent. VDEW (1999a) states that for 1996 the amount of energy used by private households for heating was 54%, car 31%, warm water 8%, information technologies and light 1% each.

filtered through the "energy using attitude" of the individual. The supply side of the sector "energy" is lumped up in the green boxes, trying to identify all relevant factors influencing the total amount of energy to be produced by this sector next to the aggregated demand.

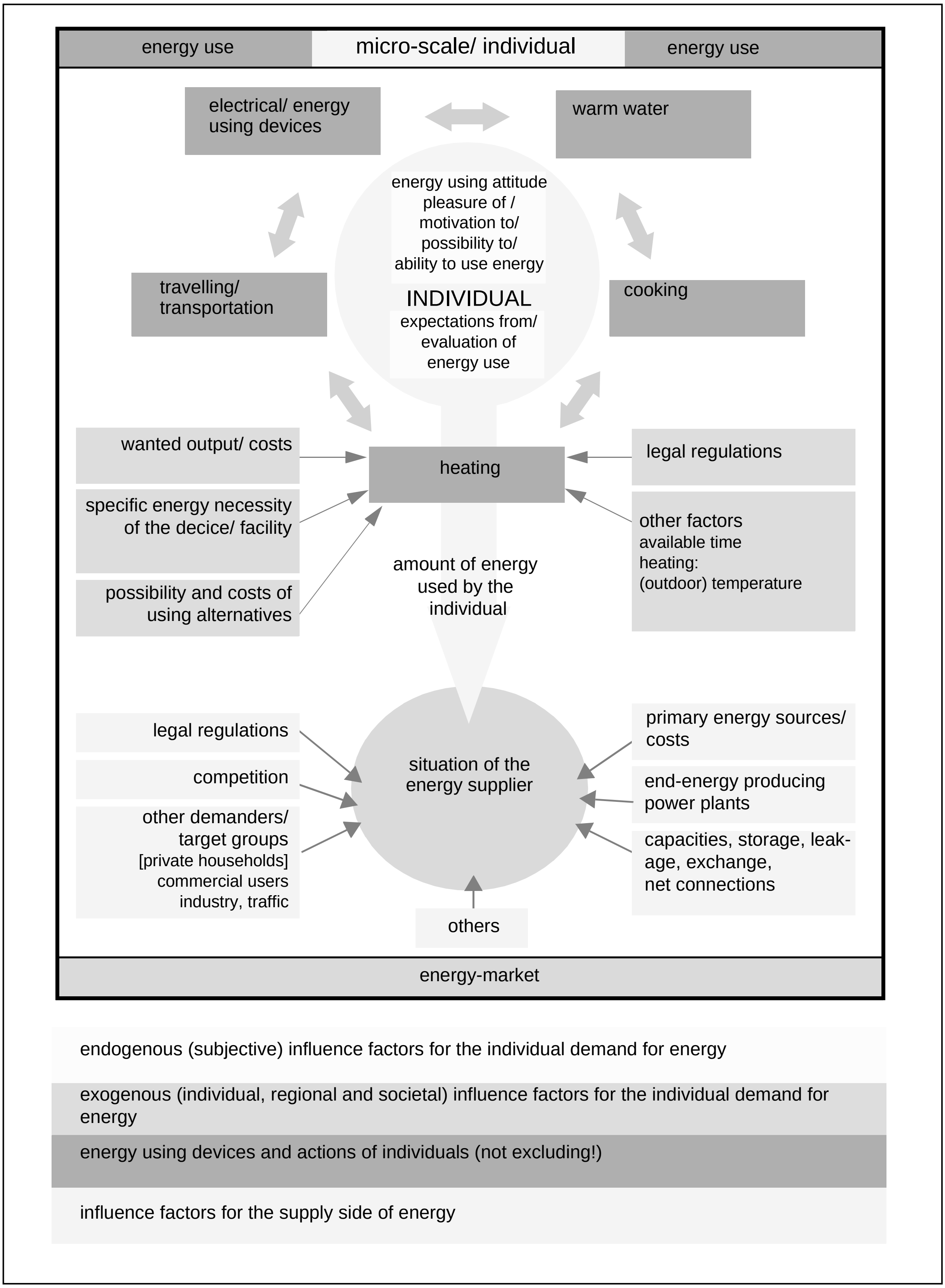

Fig. 3.2.3: *Model of the decision making process of the individual energy consumer.*

3.2.3.4 Weather and climate sensitive factors regarding energy

Adaptation — individual/demand side (households)

The amount of heating, which is mainly used in winter times, is strongly determined by the indoor temperature the individual chooses. As such, the individual adapts to exogenous (outdoor) temperatures. According to UNEP and IVM (1998; chapter 11: Energy), electricity consumption is likely to be affected by climate change for the following end uses: air conditioning, space heating, water pumping, refrigeration and water heating. Looking at the relatively small share of energy used for these end uses in German households (7% of private energy consumption is for household appliances), one recognises the overwhelming importance of heating (48% of private energy consumption is for heating). An increase in end energy use due to hotter summers can be more than compensated by a decrease in energy use due to warmer winters, necessitating less heating.

Adaptation — supply side / companies

We could not find any indication for weather being an important factor for the energy supply side. Only indirect effects from the demand side can affect the supply side and thus causing some weather-sensitivity.

There seems to be no awareness of this sensitivity and the need to adapt, for example by extending or reducing capacity in the future in response to climate change. The industry's projections of future energy needs take into account many indicators, like technological trends and expected political guidelines. As for weather influences, one statement is that the mild winter of 1997 was not a normal one and therefore the predicted changes in energy consumption should not be viewed based on this winter (Eckerle *et al.*, 1998). Thus, the effects of climate change are seen as insignificant compared to other influences on future energy needs.

Mitigation — individual/ demand side (households)

The empirically calculated efficiency of end-energy use by private households in Western Germany has increased from 60.6% in 1987 to 65.2% in 1990 (UBA (1994). DIW/ISI (1997) calculates the end-energy use per capita and per square metre of living space. This calculation is made using temperature-readjusted figures to correct for changes in temperature. As such, the numbers represent a temperature invariant trend.

Increasing efficiency can be the result of technological progress. This encountered in the conceptual energy model as the specific need for energy by the different devices in use. Technological progress for energy consumption is not a linear function, because the individual's decision which heating system to use is made for several years. The "law of big number" might even out these steps on a macro scale.

The rising awareness of people concerning the negative effect of energy-use has also contributed to increased energy efficiency. This increasing energy saving attitude (endogenous factor in Fig. 3.2.3) will cause the individual to attempt to use less energy.

An increase in population in West Germany, an increase in living space and higher consumption levels are counteracting technological progress and increasing energy saving attitude.

Mitigation — supply side / companies

Companies try to mitigate climate change via implementing new technologies or via least-cost planning and demand-side management, due to postponed CO_2 savings (Boss and Decker, 1993; BMWi, 1998). The share of renewable energy sources within Germany is rising, from 4% in 1990 to 4.9% in 1998 (with a peak in 1995 at 5.2%), although from a small absolute base (BMWi, 1999; VDEW, 1999b).

One possible strategy to further promote mitigation is the establishment of ecobalances or ISO-certification. Other possibilities to save energy can be forced (Geiger *et al.*, 1998).

3.2.4 Electricity

3.2.4.1 Overview demand and supply side

Regarding the electricity sector, we do have to take into account the changes in modal split within the different energy providing sources. Fig. 3.2.4 shows the relative importance of industry for electricity demand. The consumption by households is fairly high and stable.

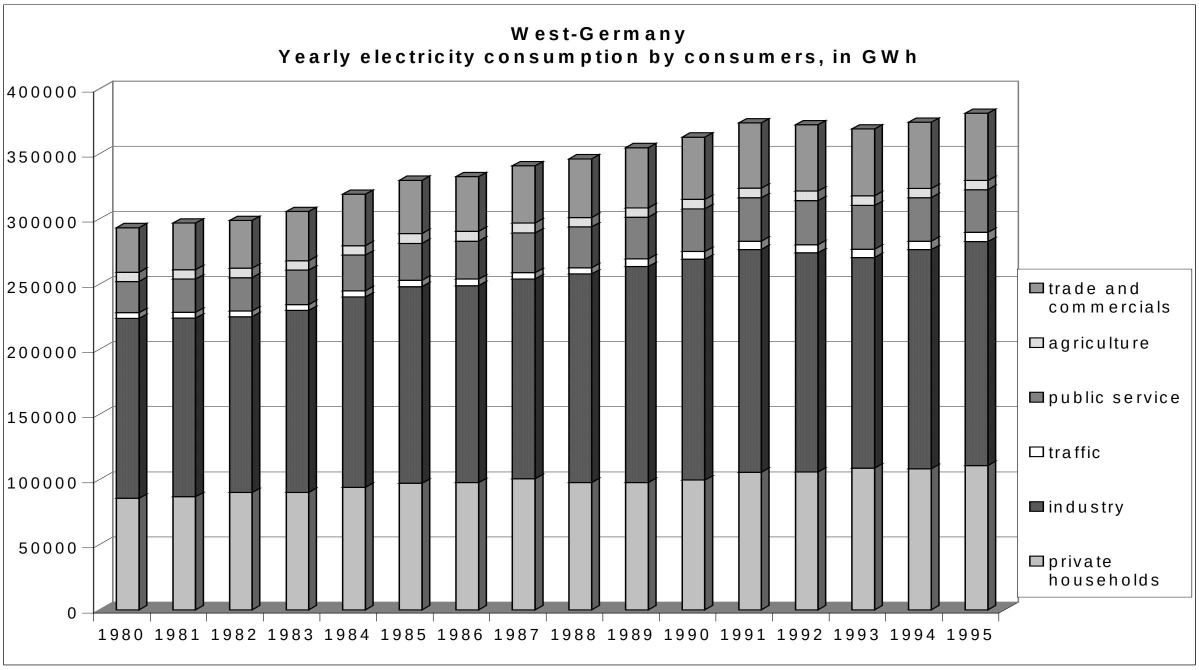

Fig. 3.2.4: *Yearly electricity consumption by consumers (VDEW, 1996).*

Managers in the electricity sector were hardly willing to give information, because the current liberalisation of the German energy market has made them very reluctant to communicate. Managers from different electricity companies[8] see the amount of electricity provided in the winter half-year to take a percentage between 52 and 60 percent of the annual consumption. Mild winters are seen to have a slightly negative, hot summers are said to have an even slighter positive impact on electricity consumption. The identification of extreme seasons varies. The winters of 1992, 1994, 1995 and 1998, and the summers of 1992, 1994 and 1995 were recognised to have been extremely mild or hot, respectively. Within these varying answers, differences between regions become visible.

When asked for the influence of weather on electricity consumption, only one supplier ranked this factor to be the most important. The other suppliers ranked weather to be of hardly any relevance. Especially in former East Germany, the decline of industry is stated to be of such importance that all other factors become invisible. Even if direct electricity heating becomes increasingly rare, domestic appliances are stated to be of much greater importance concerning the dynamics of electricity consumption. Changes in consumption patterns ("sustainable consumption") are not identified to be of big importance. The same goes for changes in constructions for private households.

Prices for electricity should be important, which might indicate a future increase in consumption because of the German liberalisation of the electricity market. However, this could be compensated by adjusted consumption patterns because demanders then have the opportunity to change their suppliers for environmental reasons.

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[8] Managers of the following suppliers admitted an interview: DVG Heidelberg (Deutsche Verbund Gesellschaft), Stadtwerke Hannover AG, Oder-Spree Energieversorgung Fürstenwalde, Energieversorgung Potsdam, Energieversorgung Spree Schwarze Elster Cottbus.

Tab. 3.2.2 shows the factors identified for demand and supply of electricity.

	Demand for electricity	Supply of electricity
Long-term factors	- number of households using electricity (esp. for heating) - energy saving-programmes / legislative conditions (liberalisation, “Wärmeschutzverordnung”) - electricity use in industry - changes of power sources (availability and costs of substitutes)	- liberalisation of the electricity market - (inter)national agreements among energy suppliers - primary energy mix (use of “traditional” versus new types of primary energy - technology - net losses and other leakage
Short-term factors	- temperature: December/ January / February months of highest consumption, cold and wet summers	- pipeline-networks to even out shortages over the regions - transfer of electricity (across borders)

Tab. 3.2.2: *Factors that influence the demand and the supply side of electricity.*

3.2.4.2. Weather and climate sensitive factors

The factors listed in Section 3.2.3.4 for adaptation and mitigation for all energy also apply here. What is particularly relevant is the possible factor of climate mitigation and environment protection when individuals can decide which form of energy source they should use in future. Here both adaptation and mitigation play a role, next to the cost factor. The same considerations might apply for electricity companies when they decide about the type of new power plant to be built.

3.2.5 Gas

3.2.5.1 Overview demand and supply side

Fig. 3.2.5 shows the higher amount of gas delivered in the first and fourth quarters of the year as well as the overall rising trend of gas use. This overall increase is due to an increase in gas-using facilities, whereas the differences for gas delivered during the two winter quarters is due to temperature variations.

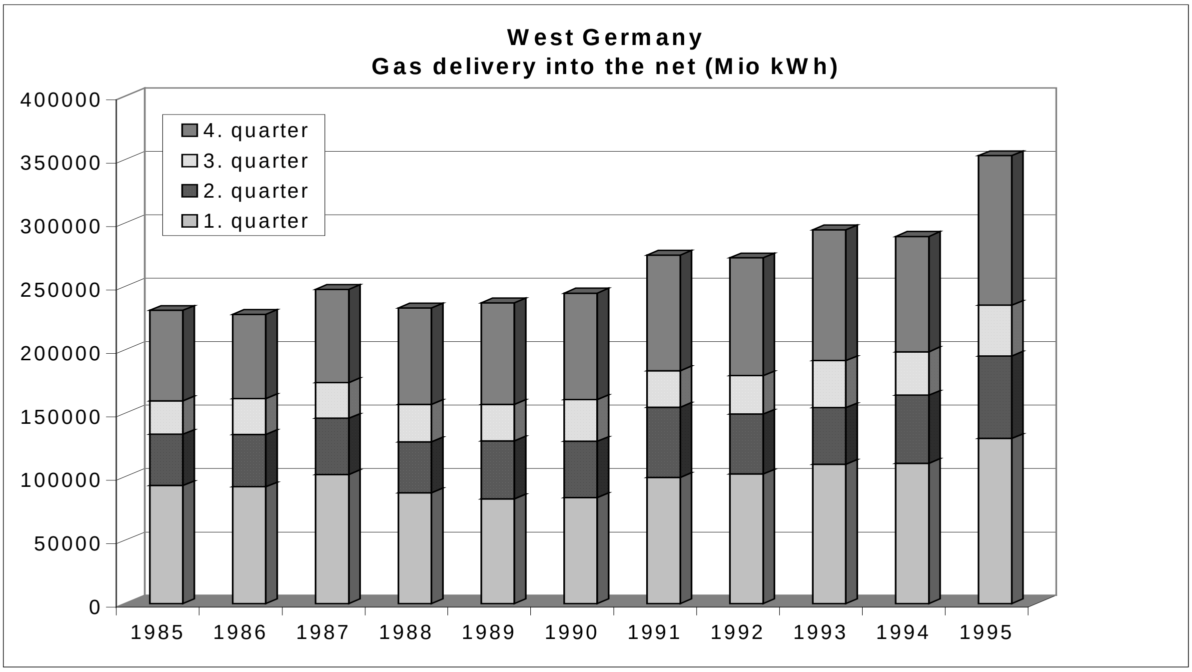

Fig. 3.2.5: *Gas consumption in quarters (BGW, 1999), representativeness about 60%.*

The results of the management survey for gas, shown in Tab. 3.2.3, confirm the overall increase in gas use as well as the importance of the winter half-year for gas use. The reservoirs in this sector are relied upon to prevent bottlenecks.

Demand-side: gas use	
1. How did the demand for gas change during the last years in your area?	
- Sum of gas used?	- altogether (absolutely) increasing use of gas
- Gas-use per capita?	- decreasing
2. What are the influences concerning the change of demand?	
- Weather indicators?	- December to March highest gas consumption (peak in winter 1997/1998), cool and wet summers also show a significant increase in gas consumption
- Other indicators (long- and short-term)?	- Increasing number of supply points (households), the share of gas energy use within the households heating rose from 15.6% in 1975 to 40.6% in 1997 - Due to the oil-crises higher gas consumption, due to federal energy-saving-programmes (e.g. Wärmeschutzverordnung) less demand, increasing supply points more than compensate the savings - The share of gas energy use within the industry sector rose from 18.3% in 1975 to 30.6% in 1995 in West-Germany
3. What are the consequences of these changes in demand?	
- For the business?	- New (expensive) investments due to higher demand or new supply points
- For the environment?	- Gas is seen as a (relatively) clean energy source
- For the capacity planning?	- Reservoirs are big enough for the winter demand-peaks, changes in the longer-term gas sales contracts, but extractions/buys meet the needs (at least statistically)
Supply-side: gas production	
4. Did or do shortages exist?	- Oil crises in the 1970s made the demand for gas increase, in the 1980s sometimes overcapacity, Wärmeschutzverordnung and other gas-saving programmes have also led to overcapacities because of longer-term gas sales contracts
5. What are your precautionary measures concerning the possibility of bottlenecks?	- Reservoirs (1-3 months to even one year in Berlin) and net-system - Different sources as a net against shortages: Germany, Norway, Russia, Netherlands. Sources are said to extend at least 30 (- 60) years, high-security-standards minimise the risk of burst-pipes
6. What influences the supply of gas?	
- Weather/climate-situation	- Extractions/buys meet the needs (at least statistically)
- Statutory regulations	- The EU energy market is not a free one, but might be from 2000 onwards, then competition will increasingly take place, energy saving laws and programmes make the demand decline vs. changes in the energy-mix might make the demand for gas rise
- Others	- Even more supply points in eastern households and especially in industry

Tab. 3.2.3: *Result from management survey gas.*

Tab. 3.2.4 shows the factors identified to be relevant for the demand and supply of gas.

	Demand for gas	Supply of gas
Long-term factors	- number of households using gas (esp. after oil-crises rising demand) - energy saving-programs / legislative conditions (“Wärmeschutzverordnung”) - gas energy use in industry - changes in power sources (availability and costs of substitutes)	- longer-term gas sales contracts but extractions/buys meet the needs (at least statistically) - overcapacity when too little demand - gas-supply is said to reach for up to 60 years - liberalisation - net losses and other leakage
Short-term factors	- temperature: December/ January / February: months of highest consumption (45%), cold and wet summers	- pipe bursts - reservoirs for 1-3 winter months - pipeline-networks to even out shortages over the regions

Tab. 3.2.4: *Factors that influence the demand and the supply of gas.*

3.2.5.2 Weather and climate sensitive factors

For gas, the same factors have to be considered as for the energy sector as a whole. Additionally, taking energy shifts into consideration, the amount of users of gas heating is rising. This suggests that the gas-supply side becomes more sensitive to extreme weather, although the reservoirs are said to be sufficient.

3.2.6 Water

3.2.6.1 Overview

In a recent press release, the German association for gas-and water states that there is no water shortage in Germany, even though the summer of 1999 has been fairly dry and hot (BGW, 1999c). It states that groundwater reservoirs are sufficient and that the overall water consumption is gradually decreasing, which is also shown in Fig. 3.2.6.

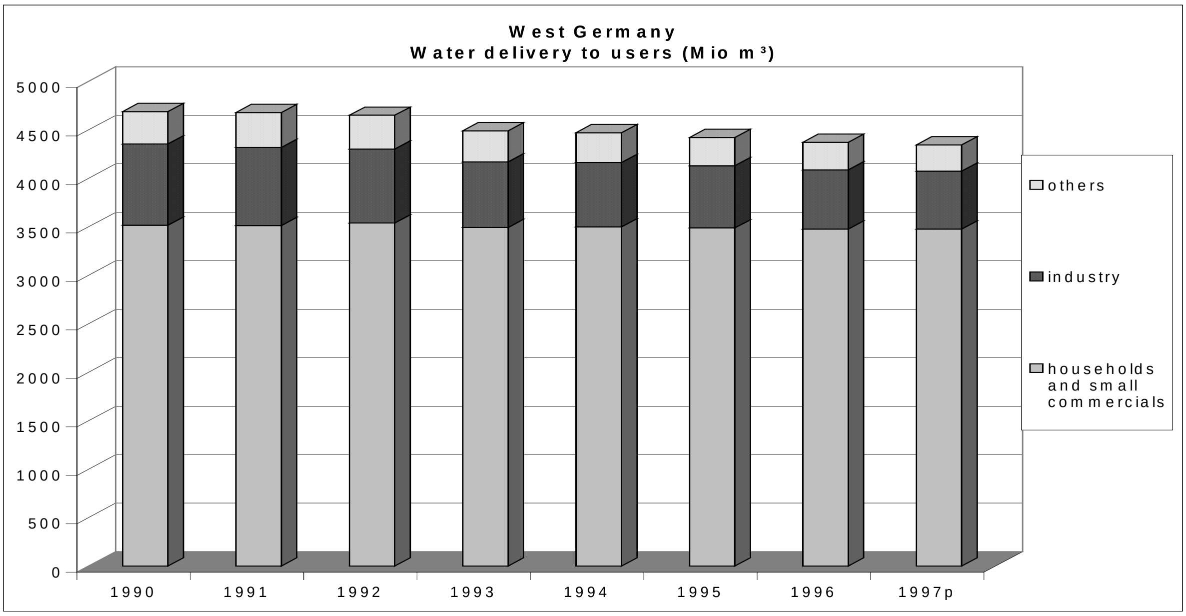

Fig. 3.2.6: *Water delivery to users (BGW, 1999), representativeness about 84%.*

In Germany, most of the drinking water (64%) is extracted from groundwater, only 28% is surface water and 8% is spring water as shown in Tab. 3.2.5.

State	Groundwater	Surface water	Spring water
Baden-Württemberg	49%	35%	16%
Bayern	71%	8%	21%
Berlin	100%	0%	0%
Brandenburg	91%	0%	9%
Bremen	100%	0%	0%
Hamburg	100%	0%	0%
Hessen	81%	6%	13%
Mecklenburg-Vorpommern	78%	0%	22%
Niedersachsen	82%	5%	13%
Nordrhein-Westfalen	41%	57%	2%
Rheinland-Pfalz	75%	10%	15%
Saarland	95%	0%	5%
Sachsen	23%	70%	7%
Sachsen-Anhalt	70%	28%	2%
Schleswig-Holstein	100%	0%	0%
Thüringen	72%	23%	5%
Germany (total)	**64%**	**28%**	**8%**

Tab. 3.2.5: *Sources of drinking water in Germany in 1995 (BGW, 1998).*

Our investigations focused on the northern part of Germany, so we mainly performed telephone interviews with water companies in this region. Only one company in Cologne (Rhine) uses river (surface) water for the production of drinking water. In case of floods, the drinking water in this region is taken from groundwater. All other companies, like the Oldenburgische-Ostfriesischer Wasserverbund (OOWV) and the Berliner Wasser Betriebe (BWB) only use groundwater. OOWV has a particularly large region (in Northwestern Germany) to supply with drinking water.

The results of our telephone management survey is listed in Tab. 3.2.6.

Demand-side: water use	
1. How did the demand for water change during the last years in your area?	
- sum of water used	- in most of the areas the total water consumption is falling rapidly (cut to half), only in few areas the consumption is pretty constant (from 1990 till today)
- water-use per capita	- everywhere declining
- days of highest consumption	- some places declining, but hardly to say, dependent on the weather
2. What are the influences concerning the change of demand?	
- weather indicators	- at the end of long dry periods the consumption is rising
- other indicators (long- and short-term)	- tourism-periods, sum of inhabitants, industry-use (and decline), Prices – whereas the price of water is said to be of relatively small influence because of its low level (average: 3.14 DM per m^3), water-saving measures and habits, changes in autonomous water-supply by households and industry - (end/begin of) holiday-breaks, interruptions TV-transmissions (e.g. football events)
3. What are the consequences of these changes in demand?	
- for the business	- high fixed costs and the necessity of not making losses plus the declining demand result in rising prices ($\Rightarrow$ less demand $\Rightarrow$ higher prices $\Rightarrow$ less demand $\Rightarrow$ ...), but prices are not always seen to be that relevant because of their low level
- for the environment	- if artesian wells are shut, the surrounding area gets wet (wet basements, wet surfaces), - too little demand makes the water stay longer in the pipelines, causing the oxygen to disappear and bacteria to emerge (necessitating the adding of chlorine) - to keep groundwater at the old/permanent level, sometimes water has to be extracted even if there is no demand for this water
Supply-side: water production	
4. Did or do shortages exist?	
- when	- there are hardly any bottleneck-situations
- reasons	- only on autonomous islands in the North Sea, without access to larger networks
5. Which could be potential problems, concerning the requirements for water?	- last three years there was only little rain in winter but there was no water-shortage - if there were five or more years with only little rain between October and April there might appear shortages in water supply
6. What are your precautionary measures concerning the possibility of bottle-necks?	- mostly the need for water corresponds with the quantity of extraction - reservoirs in every well secure at least one day without water-extraction - networks to fight local bottlenecks

7. What does influence the supply of water?	
- weather/climate-situation	- rain in winter (October–April) refills the groundwater-reservoir, but almost everywhere the quantity of precipitation is – even in longer periods –- not (yet) causing problems to the supply situation, the quantity of precipitation is said to be evening at least over 7 years
- statutory regulations	- during the last ten years the need for water supply by law increased substantially, leading to higher costs for keeping the obligations, but the costs can be shifted to the consumer (e.g., the German "Wasserentnahmegebühr", which is normally used for natural and environmental improvements
- others	
8. Are there problems concerning the quality of water and what are your precautionary measures concerning possible quality problems (costs)?	- normally, the more water is going through the pipelines and the faster it is going through, the better the quality of the water. As consumption is declining, the pipelines are too long and so the water quality declines. - nitrate is reduced using the proceeds of the German "Wasserentnahmegebühr" and the limits are kept. Water is rarely blended for keeping the limits, agricultural areas are bought to keep the farmers from fertilising, farmers get money to not fertilise. - wells are dug deeper and sometimes wells are closed and pipelines laid. - "hydrofoil-wells", which only pump up the water without treatment are changed to wells including treatment. - altogether, the water-companies hardly see problems for the quality of water
9. Do you have a strategy for the future concerning climate-changes and also concerning development areas?	- Climate-change does not seem to be an important issue for the water-companies, only the large suppliers use software with which they can plan different strategies and scenarios for the future. - In development areas, the diameter of the pipelines has to fit the maximum demand. The difference between maximum and minimum demand seems to become larger due to water-saving-reasons.

Tab. 3.2.6: *Results from management interviews for water management.*

Based on these telephone interviews and a literature review (especially Batelle-Institut, 1972), Tab. 3.2.7 gives an overview of the most important factors determining demand and supply of drinking-water. Note that the effects on demand and supply of drinking water differ between regions. Also note that all over Germany the demand for drinking water is declining.

The long-term decline in the demand for drinking water has different reasons in different regions. In our findings, the most important reasons are changes in the number of inhabitants, changes in the structure of the industrial sector and, especially for East Germany, the decline of the industrial production as a whole. In addition, there are possibilities for small as well large users to dig their own wells.

	Demand for water	Supply of water
Long-term factors	- number of inhabitants - changes in industry - water-saving attitude/equipment - attitude towards hygiene - changes in water source (availability and costs of substitutes) - prices	- winter rainfall - legislative licenses and conditions (first and foremost concerning water quality) - changes in water sources (spring/surface/ground water) - net losses and other leakage
Short-term factors	- tourism - vacations (industry) - weather period (dryness) - public events (e.g. TV-broadcasts)	- extraction is said to be fixed to demand - accidents - reservoirs to stand shortages - pipeline-networks to even out shortages over the regions

Tab. 3.2.7: *Factors influencing the demand and the supply of water.*

In Germany, the prices of water are not determined by competition because of regional monopolies in this sector. In most cases, prices are set at a level that would prevent losses to the water-supply supplying companies. The combination of fixed costs and reducing demand causes the price to rise, which, in turn, would reduce demand even further. However, one could argue that water prices are not yet such that users would suffer from this amount. Thus, the described feedback loop might not be of much empirical relevance. The average price of one cubic metre of water has risen from 3.19 DM in 1995 to 3.26 DM in 1998 (BGW, 1999a), while the consumer costs of wastewater treatment range from 3.41 DM per cubic metre in Baden-Württemberg to 7.21 DM in Brandenburg (BGW, 1999b).

The reducing demand for water might lead to a water-quality problem on the supply side. The pipeline network was enlarged in the past to meet higher permanent and temporary peak demands. Less demand might lead to quality problems because of the longer residence time of water within the pipes. On the other hand, due to the falling demand, there are hardly any shortages in German water supply. The only possible shortages would be regional and temporary, which is dealt with by pipeline connections and reservoirs. There is no indication of shortages due to supply problems, such as during the hot summer of 1976. Only the OOWV stated that shortages might appear in the event of five or more years with low precipitation. However, they do not consider such a scenario likely. OOWV is also responsible for the drinking-water supply of five islands in the North Sea. There are no connections to the mainland network from three islands and due to high tourist numbers in summer, shortages may occur.

The water-quality issue could, in theory, lead to supply problems if higher standards for drinking-water quality, forced by law, are no longer met. However, the water companies claim that this will not happen and that, therefore, this is not a real problem. No information was available to verify these claims.

Fig. 3.2.7 shows the variation of water use over a period of several years on a monthly scale. Especially for Berlin, the peaks in summer can easily be recognised.

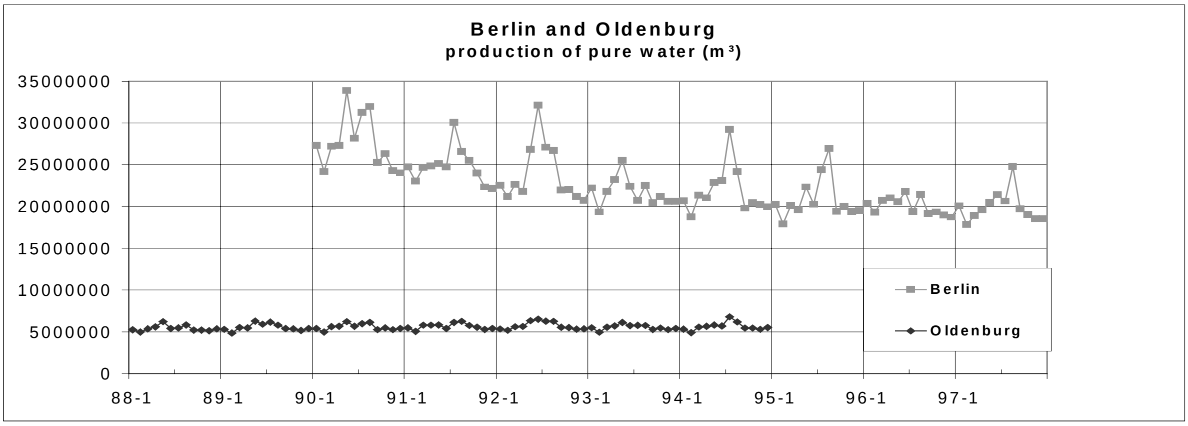

Fig. 3.2.7: *Production of pure water in Oldenburg and in Berlin (OOWV, 1998; BWB, 1999).*

3.2.6.2 Micro-demand side water

Fig. 3.2.8 shows that the water use for gardening is fairly small over the year. However, it seems plausible that the peaks in summer are, at least in part, caused by water use for gardening during hot and dry periods.

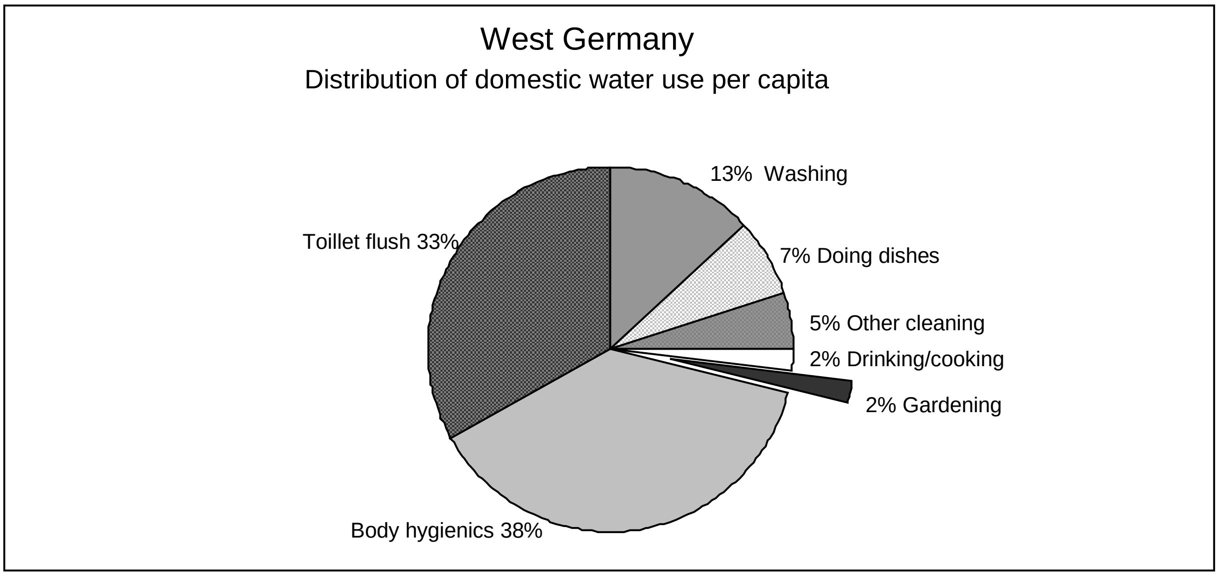

Fig. 3.2.8: *Distribution of domestic water use per day in West Germany (UBA, 1994).*

Fig. 3.2.9 shows a model of the decision-making process of the individual water consumer. Individuals, with their water-using attitude (yellow) decide which water-using machines to use or actions to take (blue) and thus influences the amount of water used. The supply side depends on even more factors (green) than the household’s demand for water.

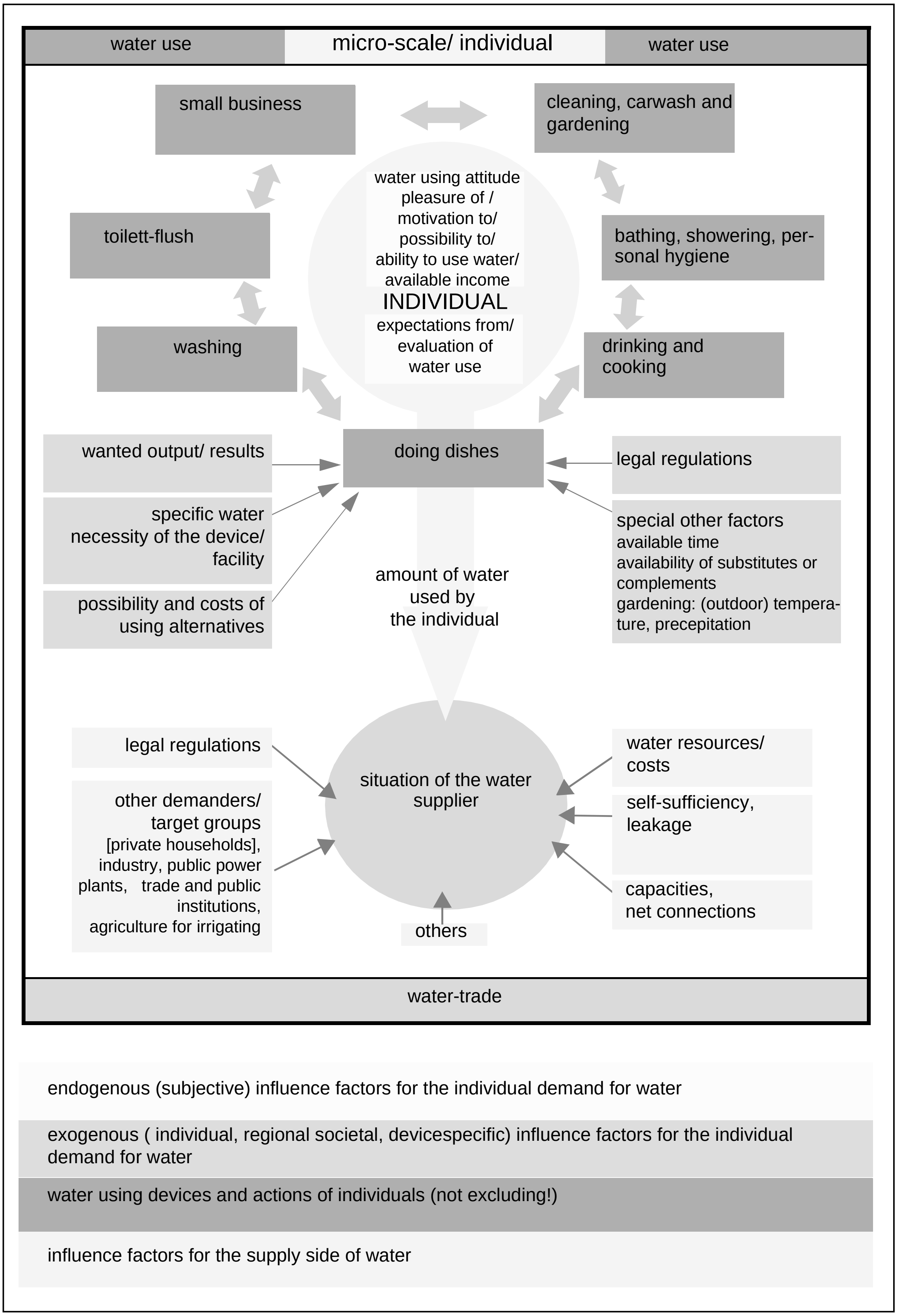

Fig. 3.2.9: *Model of the decision-making process of the individual water consumer.*

3.2.6.3 Climate and weather sensitive factors

Adaptation — individual/demand side (households)

The most weather-sensitive factor is gardening, which is particularly important in summer. Private water reservoirs can serve to even out peaks. However, if all reservoirs are empty before the hot and dry period is over, peaks may increase again. In addition, water-saving attitude and implementation of water-saving appliances help to reduce demand.

Adaptation — supply side/companies

New networks and new reservoirs reduce shortages, irrespective of the cause of the shortages. In addition, water-saving and environment-friendly attitudes can be used as a marketing factor, although the need for marketing is limited in view of the regional monopolies of water companies.

3.2.7 Tourism

3.2.7.1 Results from management interviews

Fig. 3.2.10 shows a strong correlation between bed nights in West Germany and the seasons. Clearly, the summer holiday is the busiest period for the tourism sector. Statistical analyses of tourism data in relation to weather factors are presented in Section 2.5.

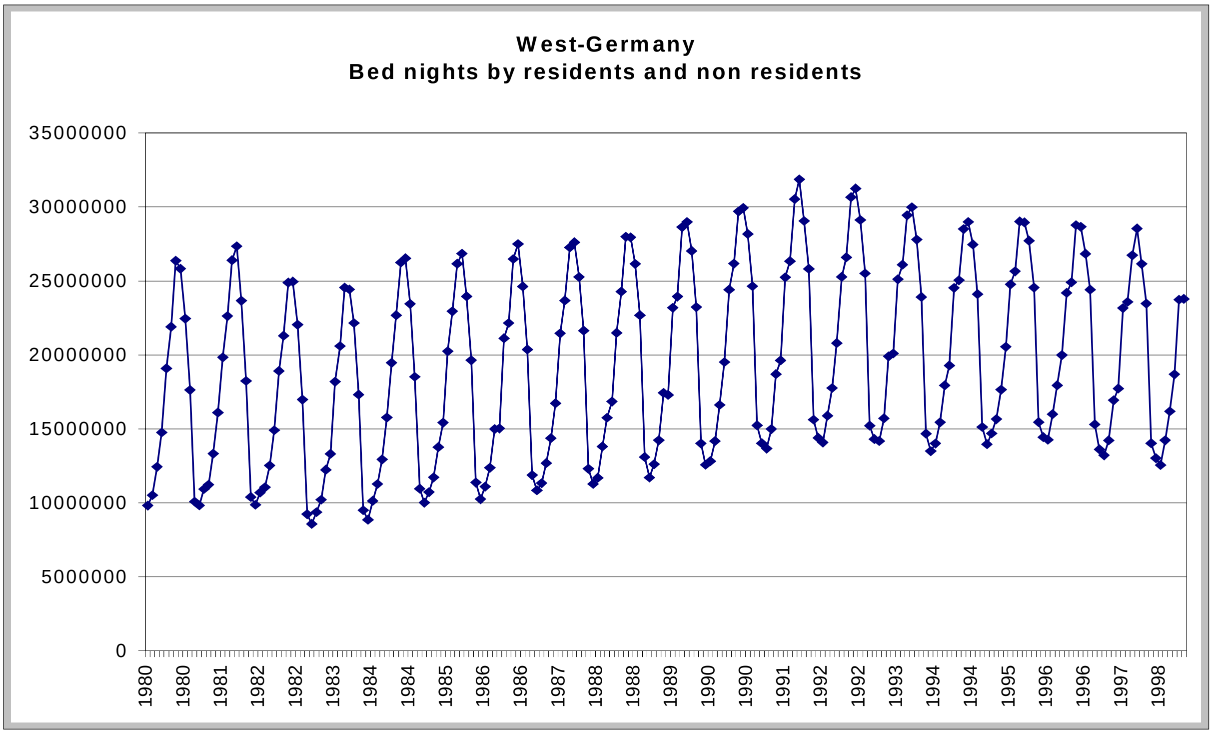

Fig. 3.2.10: *Bed nights in West Germany. (STBA, 1999; EUROSTAT 1998).*

At the International Fair for Tourism (ITB) in Berlin in March 1998, we interviewed tourism managers from northern Germany, both from major tourist companies and from small providers. In addition, we sent out a short questionnaire to gather additional information.[9]

[9] Managers from the following institutions were interviewed: Bremer Touristik Zentrale, Fremdenverkehrsverband Hamburg, Tourismus-Zentrale Hamburg, Tourismusverband Mecklenburg-Vorpommern, Tourismusverband Land Brandenburg, Fremdenverkehrsverband Schleswig-Holstein, Verband der Campingplatzhalter Schleswig-Holstein, Verband der Campingplatzunternehmer Deutschland, Kurverwaltung Nordseeinsel Borkum.

Question 1: What are the impacts of extreme weather situations for your branch?

With the exception of the City of Hamburg, hot summers are commonly regarded to have a positive impact on tourism in all regions and branches. Mild winters do not seem to have any impacts on the tourism industry except for Hamburg, as tourists are then believed to visit this city more often. The fact that Hamburg is also said to be attractive during a very severe winter, due to the frozen Alster river, does not contradict this statement. The second exception is the low mountain range of the Harz (the only important skiing area in central-northern Germany), where mild winters result in bad winter sports conditions.

Question 2: Do you remember (by heart) years that have impacted your branch above average since 1990?

In different regions, almost all years since 1991 are said to have been extreme in summer, but 1993 and 1995 are mentioned most often. Mild winters are said to have occurred nearly every year as well, 1997 and 1993 being the ones mentioned most.

In **Question 3** we asked for the state of and development in tourism capacity in the region.

Answers without a trend.

Question 4: What are the actual impacts of extreme weather situations in your branch?

Total sum of overnight guests is said to rise between 2% and 10% in hot summers, the number of day trip guests is said to rise by 10%, and guests stay up to 20% longer. The capacity utilisation in hotels is said to rise as well as the amount of camping tourists. Mild winters are said to have significant negative effects on winter sports regions only.

In **Question 5** we asked for turnover in restaurants, indoor amusement places, open-air centres and for excursion providers.

In hot summers especially the restaurants and open-air centres have higher turnovers. Mild winters only make the winter sports areas suffer, in other areas mild winters do not seem to have any consequences.

Question 6: Do impacts of weather affect other fields not yet asked for?

Only rental services for beach chairs were mentioned once.

Question 7: Did the dependency/susceptibility of tourism on weather increase or decrease during the last years?

With the exception of Mecklenburg-Vorpommern the dependency of tourism on weather is stated to have enlarged. The reasons for the higher dependency between hot and sunny weather and the number of tourists is said to be the higher competition between German tourism regions, the competition with other regions worldwide, cheap last-minute possibilities, the marketing situation of the competitors and the changing demands of the potential travellers.

We consider these results a snapshot of the overall tourism situation in Germany. It is not representative for all of Germany because both the weather and the tourism industry varies throughout the country, causing different demands and different weather sensitivities.

Table 3.2.8 shows tourist expenditures for all federal states in Western Germany. The higher amount of money spent in metropolitan Bundesländer (West-Berlin, Hamburg, Bremen) can easily be recognised. These differences are caused by the higher costs for overnight stays and the different types of visitors in different areas. It is striking that the coastal states Schleswig-Holstein and Niedersachsen are the ones with the lowest daily expenditures.

Regional area	Expenditure [DM/day] Average of all businesses
Baden-Württemberg	117.5
Bayern	112.9
Berlin-West	272.1
Bremen	193.6
Hamburg	293.0
Hessen	133.8
Niedersachsen	81.0
Nordrhein-Westfalen	117.2
Rheinland-Pfalz	108.5
Saarland	109.5
Schleswig-Holstein	96.7
West Germany	**113.1**

Tab. 3.2.8: *Average expenditures per day per overnight tourist (Zeiner and Harrer, 1992).*

In view of our findings, the most important regional distinctions have to be made between:

- areas with winter sports facilities and those without;
- rural and metropolitan areas;
- coastal and non-coastal areas.

Generally speaking, hot summers seem to improve the situation of the domestic tourist industry (coastal in particular), mild winters only play a negative role in winter sport areas, in all other areas weather changes in winter time seem to be of no to little relevance. Another finding is that a distinction between short trips, pre-booked travels and last minute travels is relevant. The German public perception survey (Section 3.1) shows that the shorter the trips, the more influence hot weather has. **Tab. 3.2.9** summarises these findings.

Sensitivity to extraordinary weather	Short trips and last minute trips		Pre-booked trips	
	Summer	**Winter**	**Summer**	**Winter**
Winter sports		XXX	Weather sensitivity particularly related to weather in preceding seasons	
No winter sports				
Rural				
Urban/ Metropolitan				
Coastal	XXX			
Non coastal				

Tab. 3.2.9: *Overview of sensitivity to extraordinary weather (XXX = sensitive).*

Tab. 3.2.10 presents a list of factors influencing the demand and, via demand, the supply side.

	Tourist demand	Tourist supply
Short and long-term factors	- (changes in) travelling habits [individual view: pleasure of, motivation to, possibility to, ability to, expectations from (expected weather) evaluation of travelling] - special events - available income - available time (holiday breaks)	- attractiveness of target regions landscape, nature, infrastructure, complementing goods, costs to get to and to stay in the region, reputation, fashion, publicity, marketing, capacities of commercial and private accommodation facilities - competition situation, (within the tourist sector as well as between tourism and other sectors) - general income and welfare situation - climate and weather, (expectable: more long term, booked/ main holidays; present: more short term, last-minute, short-trips)

Tab. 3.2.10: *Factors influencing tourism.*

Taking climate change into consideration, Braun *et al.* (1999) state that for the German coast (Baltic and North Sea), negative climate change scenarios would lead to negative impacts on tourism. Possible adaptation strategies, using appropriate measures to compensate for the impacts of negative climate change scenarios, are said to be not satisfactory for the regional tourism industry. Positive climate change scenarios would not have significant positive impacts on tourism industry.

3.2.8 Micro-demand side tourism

The outcomes of the German Reiseanalyse of 1997 (Lohman and Kaim, 1999) present a fairly complex picture. Weather alone does not determine the individual's choice of destination. Looking at the north of Germany, people go there despite and not because of the weather. However, weather is identified as one important aspect, next to landscape and prices. Lohmann *et al*. (1998) built a simplified tourism model, in which the micro-scale demand side is subdivided into the factors ability and motivation to travel. On the supply side, the factors attractiveness, amenities and accessibility are listed as inevitable needs for a region to become potentially successful as a tourism destination. Weather is identified as a determinant of attractiveness. Lohmann *et al.* (1998) describe weather as "the perceived weather or the psychological representation of some of the meteorological/physical variables defining the weather, sort of an image." It is stated that it is not only temperature and precipitation but also wind that counts.

Discussions with experts from the German Economic Institute for Tourism (DWIF), the managers we interviewed at the International Tourism Fair (ITB) and a literature survey led us to develop the conceptual model that is presented in Fig. 3.2.11.

First, we differentiate between the demand side and the supply side. The inquiry of the demand side starts from the decision-making process of the individual as a potential traveller. The potential traveller has to decide about travelling at all and about the destination. This decision is not necessarily a sequential one. An important factor for travelling is the possibility to do so. This ability depends primarily on the available income and on the ability of travelling, like the personal health-situation as well as the political situation in the home as well as in the destination country. A second important endogenous aspect concerning travelling should be the motivation of the individual.

The decision-making process of the individual incorporates potential possibilities to spend money and time. The decision-making process is bounded by different exogenous factors. Lohmann and Kaim (1998) divide these exogenous aspects into attractiveness, amenities and accessibility. In our less-sophisticated model, we merge these three aspects on the supply side together as attractiveness. Thus, one can compare different possible targets with other possibilities to spend time and money, which do not necessarily have to have amenity and accessibility as defining aspects.

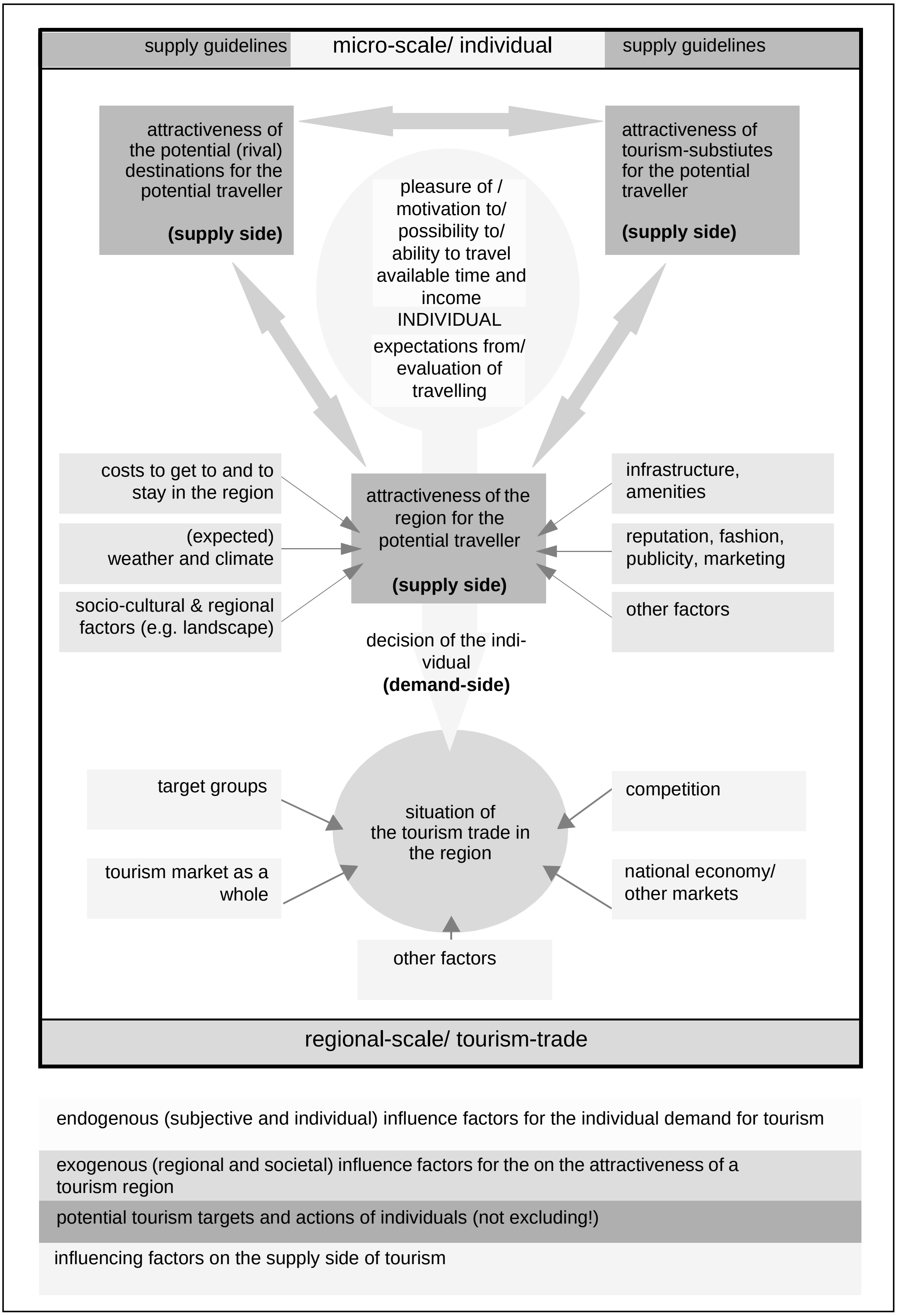

***Fig. 3.2.11**: Model of the decision-making process of the individual tourist.*

The supply side emerges at least with the question for the destination. Travel agencies and other providers try to influence the decision-making process of the individual. The information a potential traveller gets seems the most important tool for the supply side. With respect to the weather impacts on tourism, our findings from the ITB show that the local tour companies are trying to reduce the risks and impacts of "bad" weather. They improve local weather-insensitive facilities and provide alternatives (e.g. indoor swimming pools) for travellers to spend their time and money in their region. However, Lohmann *et al.* (1999) states that "weather-independent facilities will not be able to compensate fully for a low attractiveness of the outdoor weather. Tourists are looking for sun and warm temperatures, not just for the absence of rain.." This argument is also valid for winter sports, as discussed by König (1998).

The exogenous factor we are most interested in is the climatic and weather influence. Climate, geographical location, topography, landscape, vegetation and animal wildlife are the important natural factors (Kaspar, 1991). Additionally, the weather in the home region has to be taken into consideration. Hence, weather is both a "push" and a "pull" factor. The weather of the previous period might form the expectations of the potential traveller to decide on the destination of the forthcoming year. Still, other factors have to be kept in mind.

The clearest actual-weather correlated indicators might be identified for the last-minute booking sector and the spontaneous (short) and day trips.

3.2.8.1 Climate and weather sensitive factors

Adaptation — individual/demand side (households)

With climate change and the assumption of an increasing occurrence of hot summers in Germany, it is expected that more people would stay in Germany. However, the (expected) weather is not the only factor that makes people decide where to spend their holidays.

Short-term trips as well as day trips without overnight stays are identified as the most weather sensitive ones. The spontaneous "nice weather" trips would increase, but as people get used to nice weather, this effect could become less. Another weather-sensitive factor is the length of the stay.

Adaptation — supply side/companies

Tourism companies want to reduce weather sensitivity of their product. This is not in response to climate change but to weather variability. They adapt to weather variability by introducing facilities that are not dependent on weather or make the region attractive irrespective of the weather. Other possible strategies include establishing multi-purpose products (e.g. mountain climbing in summer times), using technology (e.g. to create snow), and changes in the locations of the tourist products (Keyes, *et al.*, 1990). Winter sports regions might have more difficulties to create weather-insensitive facilities than summer holiday regions.

Mitigation — individual/ demand side (households)

"Sanfter Tourismus" (sustainable tourism) can be seen as one outcome of changes in tourism attitude due to an increasing environmental awareness in the population. However, the shift to this kind of tourism is as yet limited. The World Tourism Organisation estimated that about seven per cent of the total tourist expenditures are for "nature tourism".

Mitigation — supply side/ companies

Ecological-correctness is becoming an important marketing factor for tourism companies.

3.2.9 Summary regarding sensitivity, perception, adaptation, implications

3.2.9.1 Sensitivity

The energy, water and tourism sectors in Germany are sensitive to weather, particularly weather extremes, but this sensitivity has not led to important problems in the recent past, nor are problems anticipated in the future. Hence, the need for active adaptation is considered small. However, the sectors apparently do not seem to have looked into the possibility of non-linear climate change, which would lead to important impacts and large adaptation needs. For example, seven consecutive dry years are now considered highly unlikely, yet if they occur, water shortages might occur.

3.2.9.2 Perception

The perception of managers of what have been unusual years and months corresponds with measurements. However, an awareness of a possible change in weather extremes and its impacts could hardly be found. This finding confirms the to take into account climatic or weather changes into sectoral scenario planning.

3.2.9.3 Adaptation

Adaptation strategies aiming only at climate change are not found within the sectors under investigation. However, both suppliers and customers do adapt to weather variability, suggesting that there is also adaptive capacity for climate change.

3.2.9.4 Implications

The lack of awareness on climatic change can be due to:

- a lack of information about the possible effects of future climate change on the different sectors;
- a lack of belief in the reliability or validity of the existing information;
- other issues that are considered to be more urgent.

4. CONCLUSIONS

Human-induced climate change is expected to have significant impacts on natural, social and economic systems throughout the world. Extensive research has been conducted to assess the likelihood and magnitude of such impacts, using future projections of climate and socio-economic development as a basis. This research has provided important insights into the systems' sensitivities to impacts, but given the inherent uncertainty, policymakers are reluctant to formulate adaptation strategies based solely on the assessment of future impacts.

The European Union-funded project *Weather Impacts on Natural, Social and Economic Systems* (WISE; ENV4-CT97-0448) has taken an alternative approach to identifying sensitivities of natural, social and economic systems to impacts. WISE has focused on climate variability instead of climate change, analysing impacts of extreme weather on today's society. This approach does not rely on scenarios and projections, but on meteorological, sectoral and other data. Four scientific institutes from four European countries collaborated in the project:

- Climatic Research Unit, University of East Anglia, Norwich, United Kingdom (co-ordinator);
- Fondazione Eni Enrico Mattei, Milano, Italy;
- Institute for Environmental Studies, Vrije Universiteit, Amsterdam, The Netherlands;
- Potsdam Institute for Climate Impact Research, Potsdam, Germany.

The collectively prepared Summary Final Report to the European Union is attached to as Appendix 1. This report covers the research conducted by the Potsdam Institute for Climate Impact Research within the project WISE. This research aimed to assess the influence of weather extremes on various socio-economic sectors and the general public in Germany. In addition, the willingness and preparedness for adaptation to weather extremes and climate change were investigated. The research comprised three types of activities:

- Statistical modelling of meteorological and sectoral time series, aimed at quantifying the impacts of changing weather variables on sector output;
- A population survey, aimed at investigating public perception of and behavioural response to unusually hot and dry summers and mild winters;
- A management survey, aimed at obtaining insight into managers' awareness and perception of the importance of extreme weather on their operations.

In view of data availability, the statistical modelling focused primarily on the former Federal Republic of Germany (*i.e.*, Western Germany). The population and management surveys were conducted in the northern part of Germany.

The various activities revealed a wealth of data and information, providing relevant insights into Germany's vulnerability to and perception of extreme weather events. Tab. 4.1. presents the sectors that were chosen for statistical modelling, the series that were considered, the impacts that were found, the managerial practices that have led to a change in vulnerability, and a valuation of the impacts. As appears from the statistical modelling, extreme weather can have impressive impacts on all sectors, especially when expressed in monetary terms. However, weather variability is generally considered a manageable risk, to which sectors in Germany appear reasonably well-adapted.

Tab. 4.2. summarises the results of the population and management surveys. Both positive and negative impacts of extreme weather are experienced, to which people generally respond by adjusting their activities. The utilities (electricity, gas and water) indicate that they are robust to the current level of weather variability and do not consider climate change an important threat to their operations. The tourism sector experiences impacts but typically takes a reactive approach to adaptation, although it is also developing weather-insensitive products.

Tab. 4.3. integrates the results for those sectors that were considered in each of the three research activities. It appears that the results of the statistical analyses do not always correspond to the perceptions of the population and managers. For example, while people state that they (try to) use less water during hot and dry spells, both the statistical analyses and the management survey suggest that they use more. Such discrepancies are particularly interesting from a policy perspective, because they may undermine public or managerial acceptability of adaptation or mitigation measures, depending on which perception prevails when the measures are designed.

In conclusion, the German study has been an important first step in the top-down analysis of weather extremes, which, combined with perception surveys, provides an important link between impacts and adaptation and between perception and action. Although a number of methodological obstacles and data limitations have been encountered, preventing the presentation of results at a more detailed scale, much of the data and information that has been collected will provide a sound basis for future research.

Sector	Series considered	Impacts	Change in vulnerability/ Evidence of adaptation	Valuation (change per 1°C / 10mm per month)
Agri-culture	Yields of potatoes, sugar beets, wheat and strawberries	Water stress (low precipitation and high temperatures) in summer decrease yields Additionally for - sugar beets: wet spring decreases yields - winter wheat: dry late spring decreases yields Strawberries: frost in May decreases yields	New varieties, more resistant to pests, weeds and diseases Irrigation of profitable crops (early potatoes)	Change by summer temp. ↑ and precip. ↓, spring precip. ↑, 1 frost day ↑ in May **(*)** t/ha €/ha M€ (1995) Potato -1.4 -92 -23 Sugar beet- 2.5 -106 -39 Strawberries -0.7 -1169 -7
Fire	Annual number of forest fires and damaged area	Hot and dry meteorological conditions during main vegetation period April – August increase number of forest fires and damaged area	Restructuring of forests	Change by temp.↑ and precip. ↓ during vegetation period: **(*)** Western Germany Brandenburg Forest fires/10000 ha +1.18 +1.84 Damage costs M€ +1.6 +0.5
Water	Annual domestic and total consumption from public suppliers' networks	Hot and dry summers increase domestic and total consumption	Supply: pipeline networks, reservoirs Demand: water saving equipment and attitude	Change of annual consumption by summer temp. ↑ and precip. ↓:**(*)** % (1994) M€ Domestic +0.62 +23 Total +0.60 +34
Health	Monthly all cause death rates Annual all-cause death rates per age class	Hot summers increase and mild winters decrease seasonal death rates Hot summers increase annual death rate of elderly people	Medical progress	Change of the corresponding death rates by seasonal temp. ↑: % (1965-95) Hot summers +1.09 Mild winters -0.81 Hot summers for elderly people +1.52
Electricity	Annual sectoral and monthly total consumption	Mild winters (and years) decrease domestic consumption Mild months decrease monthly consumption	Supply: network systems Demand: electricity saving equipment and attitude	Change of annual cons'n by winter temp. ↑: % (1994) M€ Domestic -0.60 -108 Total -0.19 -418
Gas	Annual domestic consumption Monthly total consumption without gas for power plants	Mild winters (and years) decrease domestic and total consumption	Supply: pipeline networks, reservoirs, long contracts Demand: gas saving equipment, insulation standards for residential buildings	Change of annual cons'n by winter temp. ↑: % (1994) M€ Domestic -1.73 -140 Total -1.74 -261
Tourism	Monthly bed nights of residents and non-residents	Hot summers (Jul – Sep) and mild winters increase bed-nights for German residents Wet winters (Dec – Feb) decrease bed nights for non-residents	Supply: weather-independent products, sustainable tourism Demand: last minute trips	Change in seasonal tourists' expenditures by seasonal temp. ↑ and precip. ↑: % (1980-95) M€ Residents in summer +1.0 +38.9 Niedersachsen +2.3 +9.3 Residents in winter +1.0 +20.4 Niedersachsen +1.5 +2.4 Non-residents in winter -1.8 -4.7 Niedersachsen -3.4 -0.3

(*) For valuation the heat-dryness index as the ratio of temperature to precipitation was used.
Linear interpolation of valuation from a 1°C / 10mm change is only possible for temperature. 1 € = 1 Euro

Tab. 4.1: *Sectoral weather impact analyses for Wertern Gernany*

Sector	Target population	Positive impacts	Negative impacts	Autonomous adaptation	Planned adaptation
Population survey	Population in northern Germany	*Hot/dry summer:* Leisure activities *Mild winter:* Energy consumption and every-day travel	*Hot/dry summer:* Personal comfort, air quality and all kind of work *Mild winter:* Mood and air quality (but not so obvious as for hot/dry summer)	*Hot/dry summer:* More walking and cycling instead of using cars and public transport More day trips to closer outdoor trip destinations Changes in eating and drinking habits (people drink more and eat more fruits and salads) Slight preference to stay in the country instead of going abroad for the main holidays	*Hot/dry summer:* Continuation of autonomous adaptations High acceptance of mitigation strategies to counteract climate changes (reduced living standards and changes in habits are preferred over higher prices for energy or higher taxes) Responsibility was clearly given to the policy makers
Management survey	Management of the sectors tourism, electricity, gas and water in the northern part of Germany	*Gas:* A small decline of gas consumption during hot summers. A decline of gas consumption during mild winters *Tourism:* Especially the number of short trips increases during hot summers	*Electricity:* A small increase in consumption during hot summers *Water:* An increase of water consumption during and especially after long dry periods *Tourism:* Mild winters in winter-sport areas	*Electricity, Gas and Water:* Inherent robustness against fluctuations in demand	*Electricity:* Grids are connected to allow for efficient distribution and obviate local shortages *Gas:* Long-term contracts *Water:* Increased use of private reservoirs, infrastructure for inter-catchment water transfer and new reservoirs should prevent shortages *Tourism:* Development of weather-insensitive products

Tab. 4.2: *Perception analyses for Northern Germany*

Sector	Summer	Winter
Domestic electricity consumption	Statistical analyses show no effect of summer temperature on the use of electricity. The management survey suggests a small increase with higher temperatures, while in the population survey, people state that they use less energy in hot summers.	Mild winters lead to reduced electricity consumption, as confirmed by the statistical analyses, management survey and population survey.
Domestic gas consumption	Statistical analyses and management survey show that hot summers lead to reduced gas consumption.	People state that in mild winters, they use less gas for heating. This is confirmed by the statistical analyses and the management survey. The decrease in gas consumption during mild winters is substantially greater than that during hot summers.
Domestic water consumption	Hot and dry summers result in higher domestic water consumption, as confirmed by the statistical analyses. The management survey notes that during a prolonged dry period, the highest water use is towards the end of the period, as people first rely on water from private reservoirs for their gardens. In the population survey, people state that they do (try to) use less water during hot and dry spells.	Not considered.
Tourism	Statistical analyses suggest that a relatively low temperature in one month leads to an increase in bed nights in the following month. No such relation is found in the management or population surveys. The latter surveys find that the shorter the trip, the more sensitive it is to weather. The management survey notes that hot summers lead to more bed nights, more short trips and longer stays.	Statistical analyses suggest that a relatively low temperature in one month leads to an increase in bed nights in the following month. The management survey notes that winter tourism that is not snow-based is insensitive to the weather. Winter tourism was not considered in the population survey.

Tab. 4.3: *Integration of research results*

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LIST OF ABBREVIATIONS

ARC/INFO	Geographical information system
BML	German Federal Ministry of Agriculture *(Bundesministerium für Ernährung, Landwirtschaft und Forsten)*
BMU	German Federal Ministry of the Environment *(Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit)*
BMWi	German Federal Ministry of Economics *(Bundesministerium für Wirtschaft und Technologie)*
BWB	Berlin Water Supplier *(Berliner Wasser Betriebe)*
BGW	Federal Association for Gas and Water *(Bundesverband der deutschen Gas- und Wasserwirtschaft)*
DIW	German Institute for Economic Research *(Deutsches Institut für Wirtschaftsforschung)*
DTV	German Tourism Association *(Deutscher Tourismus Verband)*
DVG	German Electricity Association *(Deutsche Verbundgesellschaft)*
DWD	German Meteorological Office, Offenbach *(Deutscher Wetterdienst, Offenbach)*
DWIF	German Research Institute for Tourism, München *(Deutsches Wirtschaftwissen-schaftliches Institut für Fremdenverkehr, München)*
EUSOSTAT	Statistical Office of the European Commission
FFE	Forest Research Institute, Eberswalde *(Forstliche Forschungsanstalt Eberswalde e.V.)*
IPCC	Intergovernmental Panel on Climate Change
ISI	Fraunhofer Institute for Systems and Innovation Research, Karlsruhe *(Fraunhofer Institut für Systemtechnik und Innovationsforschung, Karlsruhe)*
ISO	International Standard Organisation
ISSP'93	International Social Survey Programme 1993
ITB	International Fair of Tourism, Berlin *(Internationale Tourismus Börse, Berlin)*
IVM	Institute for Environmental Studies, Vrije Universiteit Amsterdam *(Instituut voor Milieuvraagstukken)*
MELF NS	Ministry of Agriculture Lower Saxony *(Ministerium für Ernährung, Landwirtschaft und Forsten, Niedersachsen)*
MunichRe	Munich Reinsurance Company *(Münchener Rückversicherung)*
NLS	Statistical Agency of Lower Saxony *(Niedersächsisches Landesamt für Statistik)*
NOSO'92	North Summer Study 1992
OLS	Ordinary least squares
OOWV	Regional water supplier, Oldenburg - Ostfriesland *(Oldenburgischer-Ostfriesischer Wasserverbund)*
SBA	German Federal statistical Office, Wiesbaden *(Statistisches Bundesamt, Wiesbaden)*
UBA	German Federal Environmental Agency, Berlin *(Umweltbundesamt, Berlin)*
UEA	University of East Anglia, Norrich
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
VDEW	Association of German Electricity suppliers, Frankfurt/Main *(Vereinigung deutscher Elektrizitätswerke, Frankfurt/Main)*
ZMP	Central Market and Price Information Service, Bonn *(Zentrale Markt- und Preisberichtsstelle, Bonn)*

APPENDIX 1. EU SUMMARY BY THE PROJECT COORDINATOR

EC Environment and Climate Research Programme
(1994-1998): Research Area 4
Human Dimension of Environmental Change

SUMMARY FINAL REPORT

Contract n°: ENV4-CT97-0448

Title: Weather Impacts on Natural, Social and Economic Systems (WISE)

Coordinator:
Name: Dr J.P. Palutikof
Institution: University of East Anglia
Address: Climatic Research Unit, University of East Anglia, Norwich NR4 7TJ, UK
Telephone: +44 1603 593647
Fax: +44 1603 507784
E-mail: j.palutikof@uea.ac.uk

Partners:
Name: Professor H.-J. Schellnhuber
Institution: Potsdam Institute for Climate Impact Research
Address: Telegrafenberg C4, P.O. Box 60 12 03, 14412 Potsdam, Germany
Telephone: +49-331-288-2500
Fax: +49-331-288-2600
E-mail: schellnhuber@pik-potsdam.de

Name: Professor Marzio Galeotti
Institution: Fondazione Eni Enrico Mattei
Address: Corso Magenta 63, 20123 Milano, Italy
Telephone: +39-2-52036934
Fax: +39-2-52036946
E-mail: galeotti@unibg.it

Name: Dr Richard S.J. Tol
Institution: Institute for Environmental Studies
Address: Vrije Universiteit, De Boelelaan 1115, 1081 HV Amsterdam, The Netherlands
Telephone: +31 20 4449555
Fax: +31 20 4449553
E-mail: richard.tol@ivm.vu.nl

Key words: Climate change, Climate variability, Extreme weather, Hot summers, Social and economic impacts

Reporting period: 1 November 1997 - 31 October 1999

1. OBJECTIVES

The objectives of WISE were:

(a) To examine the impacts of a recent hot summer, and a recent mild winter, on the natural environment and on national economies. To set a monetary value on these impacts, where possible. The approach should be sector-wise, and the final choice of sectors should be at the discretion of individual participants. A common core must exist to allow international comparisons.
(b) To examine how the impacts of extreme seasons propagate between the national economies of the member countries of the EU. The sectors to be analysed should be tourism and agricultural products.
(c) To examine the impact of climate 'shocks'. The selected shocks are wind storm and cold spells. The sectors to be examined are forestry and property insurance for wind storm, and health and energy supply for cold spells.
(d) To examine how sensitivities and vulnerabilities to climate extremes and shocks have changed over time, by comparing the impact of a recent extreme/shock (e.g., for the western seaboard, the hot summer of 1995) with impacts at an earlier time (e.g. the hot summer of 1976).
(e) To investigate the perceptions of the general public and management regarding climate extremes and shocks.
(f) To use the results, where appropriate, to say something about the possible impacts of a warmer climate on national economies and on the EU.
(g) Dissemination of the results by means of a workshop and final reports, one of which is designed for managers, planners and policy-makers.

2. METHODOLOGY

The aim was to study the impacts of present weather in order to enhance understanding of the impacts of climate change. The 3 principal routes taken to achieve these goals were:

(a) Statistical analyses of activity time series.
(b) Use of questionnaires and interview to understand the perception of impacts.
(c) Modelling the impact of climate shocks (principally, wind storm).

In addition, we looked more briefly at:

(d) Transnational flows of goods within the EU and between EU countries and the rest of the world, in order to establish whether extreme seasons have an impact on these flows.

2.1 Statistical analyses

The statistical analyses sought to model the impacts of weather events (the predictors) on activity time series (the predictands). The models used were regression models, in which the predictor weather variables were principally rainfall, temperature and sunshine. The criteria used in selecting the activity time series as the predictands for analysis were:

(a) that they be readily available in published form in the four countries where the analyses were performed – hence, government statistics were widely used; and
(b) that they are expected to be weather sensitive.

Weather-sensitive sectors for which we could obtain the same activity measures in the four countries were: outdoor fires, agriculture, the all-cause monthly death rate, energy consumption and tourism (number of bed nights for domestic tourism). Time series were extracted and graphed, and any long-term trend was either removed or incorporated in the regression equations as a predictor variable. The assumption is that the residuals from the long-term trend include short-term fluctuations in activity due to anomalous weather conditions. Where the climate variables are significant predictors of the residuals, a measure of the impact on the sector can be extracted and assigned a value.

The observed impacts of the hot summer and the generally anomalous conditions throughout the year were used to draw inferences about the possible impacts arising from a warmer climate linked to global warming. This was done in the context of a two-day Workshop held at the end of the project. On the first day the principal results of WISE were presented and on the second day the participants (chosen from private and public-sector stakeholders and actors in the five activity sectors addressed in the WISE statistical analyses) were asked to consider the impacts of climate variability and of climate change on their sectors.

2.2 Questionnaires and management interviews

Questionnaires were employed to investigate the views of the general public regarding the impacts of extreme seasons at the present day, and of climate change in the future. So far as was possible, the same questionnaire was used in each of the four countries surveyed (the Netherlands, Germany, Italy, the UK). The main classes of question were as follows:

- First, people were asked to recall a recent hot and dry summer. They were asked a series of questions about how that summer had affected their personal everyday life, in terms of their comfort, travelling arrangements, recreational activities, and holidays. They were asked whether they had made any permanent changes to their lifestyle as a result. Finally, they were asked about the impact upon national, as opposed to personal, welfare.
- Then they were asked to imagine that in future, hot and dry summers would become much more common. They were asked to assess how likely this is to be true, and whether the personal, national and environmental implications would be unfavourable or favourable. Would more frequent hot, dry summers cause permanent lifestyle changes?
- Then they were asked to recall a mild winter in the recent past, and how this had affected their everyday life.
- Finally, a set of questions determined gender, age and social status. Respondents were asked to say whether they suffered from any chronic respiratory complaint (since questions were asked about air quality in both hot, dry summers and mild winters).

The management interviews were carried out to determine:

- The awareness of management with respect to the sensitivity/vulnerability of their sector to present-day extremes and to potential future climate change.
- What management believe are the principal risks to their sector from climate change impacts.
- What adaptation strategies are available to management.
- What adaptations have already been made either as a result of the experience of present-day extremes or through awareness of the risks associated with future climate change.

Interviews were carried out by telephone in the following sectors: the utilities (energy and water supply), transport, tourism and insurance. Where possible, the questions were directed to operational management, responsible for smooth running on a day-by-day basis. In order to achieve comparability, a set of basic questions were designed. The idea was that, whatever course each interview might take, at least this core of questions would be posed and answered. In summary, they are:

1. What is the main purpose of the organization?
2. What extreme seasons have the most significant affect on company activities?
3. How does the company respond to these climate extremes, both in the short-term and long-term?
4. Does the company (or specific staff) believe that unusual weather events are occurring more frequently or less frequently? (over the last decade(s))
5. Does the organization incorporate future climate trends in their planning?
6. What assumptions does the company hold about global warming?
7. Are the responses or adaptation strategies for climate change compatible or in conflict with other social and environmental goals?

2.3 Climate shocks – the effect of wind storm

The effect of wind storm on insurance claims for property damage was studied in the Netherlands, the UK, and Germany. Statistical storm damage models were developed to relate the maximum gust speed to the amount of insured damage. For Germany, only insurance data from the storm of 25-26 January 1990 (Daria) were available. For the Netherlands, data for five storms were available, including Daria. For the UK, data from three of these five storms were available, also including Daria. In the development of the statistical models, an exponential transformation of the maximum gust speed data was found to give the best model fit.

2.4 Transnational impacts

A brief study was made of changes in transnational flows of agricultural goods (between EU countries, and between the EU and the rest of the world) in the drought year of 1995 compared to a non-drought year (1993). The produce chosen for analysis were potatoes, strawberries and sugar beet. Simple graphical procedures were used to make the comparison.

3. MAIN RESULTS

3.1 Sectorwise statistical analyses

Agriculture

Crop-climate relationships have already been widely analysed. To add something to this body of knowledge, WISE has concentrated on looking at the contrasts between countries. Differences in the crop-climate relationships between potato yields in Germany and in the UK point to the importance of irrigation in 'weather-proofing' crop yields. In Germany summer rainfall is an important predictor of potato yields, whereas in the UK, where around 45% of the crop is irrigated, this is not the case. The analyses also pointed to the importance of weather conditions in the year prior to the harvest year. This was found for both sugar beet and wheat. It suggests the importance of more subtle factors than the immediate weather conditions.

Fire

Throughout the four countries investigated in WISE, strong and significant relationships exist between summer temperature and rainfall and the occurrence of outdoor fires. These relationships mean, for example, that in the UK the increase in the number of outdoor fires for a 1^{o}C rise in summer temperature is 29%. For a 10mm decrease in monthly rainfall in the summer season, the increase is 10%. In western Germany, the damage costs of forest fires are shown to rise by 1.6 million EURO for a 1^{o}C increase in temperature and a 10mm decrease in rainfall. This figure takes no account of the increased costs of fire fighting or loss of amenity.

Health

The all-cause death rate in Germany and Italy shows a decrease in mild winters and an increase in exceptionally hot summers. Thus, even in southern Europe milder winters have an impact. In the UK, strong relationships with weather could only be found in the winter months (October-March) when a 1^{o}C increase in temperature and/or a 10mm decrease in rainfall produces reductions of the order of 2-3% in the all-cause death rate. The perturbations in Germany and Italy were on a smaller scale.

The utilities

Demand for energy falls in mild winters. The size of the perturbation due to weather events is much greater for gas (the preferred method of space heating) than for electricity. Only annual data were available for domestic electricity consumption, but in all countries the relationship with temperature was inverse. Thus, even in Italy the impact of air conditioning is insufficient to drive the relationship positive. Commercial electricity consumption in the UK has a positive relationship with temperature, indicating that for this sector air conditioning has a substantial impact. The monetary impact of the weather-related perturbation in energy demand is far greater than was found in any other sector in the analysis, and the savings to the consumer are large. For example, for Germany the savings in total electricity demand related to a 1^{o}C increase in winter temperature are estimated to be 420 million EURO.

Tourism

The main results for the analysis of international tourism are:

- Temperature has the greatest influence on international tourism. For example, a 1°C increase in summer temperature in the Netherlands increases outward tourism in the following year by 3.1%.
- The optimal summer temperature for attracting tourists to a country is estimated to be 21°C, there is little deviation from country to country.
- In hot years tourists tend to prefer domestic to foreign beach holidays.

The main results for the analysis of domestic tourism are:

- Temperature is generally the strongest indicator of domestic tourism. The relationship is usually positive in the same month, except in winter sports regions. A summer warming of 1°C is estimated to increase domestic holidays by 0.8-4.7%.
- The climate impact depends on destination type; for example, coastal resorts in Italy respond more favourably to summer temperature increases than inland resorts.
- There is some indication that weather in the intermediate seasons (spring and autumn) has a greater influence on tourist behaviour than is the case in winter and summer.

3.2 Public perception questionnaire surveys

Impacts of hot summers

- The WISE surveys showed consistent and explicable results within and between countries. Perception of and adaptation to unusual hot and dry summer weather have an inverse relation to the daily maximum summer temperature. The higher this temperature the less favourably the weather is perceived and the less actively people react.
- A rather similar answering pattern could be observed for people from the UK and the Netherlands as well as for people from Germany and Italy. While in the UK and the Netherlands unusual hot and dry summer weather was perceived rather favourably, in Germany and Italy it was perceived more unfavourably and as a consequence people there reacted less actively.
- The positive effects of hot and dry summer weather perceived in the UK and the Netherlands were for the variables *personal comfort*, *outdoor leisure activities* and *health*. In Italy no positive effects of unusual hot and dry summer weather were perceived. Negative effects of hot and dry summer weather were perceived for *activities at work or school, housework, everyday travel* and *air quality*.
- In Germany and Italy a higher sensitivity to socio-demographic factors could be observed. In these countries women perceived hot/dry summer weather more intensively and more unfavourably than men. In Germany also the age of the respondents influenced their weather-perception and -adaptation.
- It is concluded that a threshold temperature may exist, where the perception turns from positive to negative.

Impacts of exceptionally mild winter weather

- Clear positive effects of mild winter weather on every day life were perceived for all selected items of everyday life in all countries except for Germany and for the categories *air quality* and *mood in view of winter* (winter "atmosphere"), for which partially negative effects could be observed.

Adaptations - everyday life

- Respondents indicated to adjust their everyday life to hot and dry summers *by spending more time outdoors* and by *changing their eating habits*. They also stated *they tried to use less water* and they *have grown different plants in their gardens*.

Adaptations - tourism

- During an unusually hot summer, people are more likely to change their plans for day trips than they are for short breaks, and more likely to change their plans for short breaks than for their main holiday. In Italy people will take fewer day trips in response to exceptionally hot summer weather, whereas in the other three countries they will take more.
- In an unusually hot summer, most people do not change plans for their main vacation. Those that do change their holiday plans either stay at home or in their own country.
- Even within a single nation, there are regional differences in the response to climate extremes.

Adaptations - transport

- In all countries people stated that they would drive cars rather less than more, if hot summers became more common. This is consistent with their responses regarding modification of behaviour in past hot summers: people stated that they changed to more active means of transport – motorcycles, bicycles and walking. However, in Italy, where hot summers are hotter and less comfortable than in the other countries, people seem to abstain from active means of transportation.

3.3 Studies of management perception by interview

The perceived importance of extreme-weather impacts on operations varies considerably by sector and country. Most managers were able to identify some past impact of weather extremes on their operations, but responses varied. Awareness of climate change and possible impacts also varied but the need for planning was generally considered limited, with the water sector in the UK being a notable exception.

Water-related operations in the UK are highly aware of the importance of droughts. Most water company staff said that they believed that climate in the UK had changed in recent years. Encouraged by national regulation, water companies are taking large-scale measures to increase efficiency as well as other measures to reduce vulnerability. All water-supply companies must now consider climate-change scenarios in their supply and demand forecasts.

Other sectors in the UK (tourism, rail and road transport, property insurance) attach only limited importance to the effects of extreme weather on their operations. This was found to be true for Italy and Germany also. In Italy, the impact of hot and dry summers was seen as particularly relevant for agriculture and outdoor fires. In agriculture, managers attribute low productivity during hot and dry summers to the lack of good irrigation systems, but no measures are undertaken to improve the situation. Anti-fire campaigns have been intensified in response to the increase in fire occurrence in recent years. All equipment must now be available as of early June, which has led to a considerable cost increase. In Germany, tourism, water and energy companies considered impacts of extreme weather to be of only minor importance to their operations. Tourism operators recognise a positive effect of hot and dry summers, particularly for day trips and short stays, but they do not plan for it. The energy and water sectors consider themselves robust to all types of weather variability and its effects on supply or demand. The sectors do not believe that changes in demand as a result of climate change will require additional measures to be taken, apart from the ongoing process of increasing efficiency.

No companies are pursuing active adaptation to climate change. This may be caused by limited awareness of the impacts, or by the conviction that these impacts will be within the operations' current coping range. A number of companies are engaged in activities aimed at enhancing robustness and resilience to current weather variability. These activities also serve to reduce vulnerability to climate change. The strongest developments in this field can be observed for the water sector in the UK. The effects of active government policy are visible here, both in terms of regulation and in creating an enabling environment for adaptation.

3.4 Storm damage analysis in Germany, the UK and the Netherlands

The results of the statistical analysis shows that an exponential relation of the storm damage indicators to the windgust fits the data for all countries analyses (Germany, the Netherlands and the UK) and all severe storm events well. The wind speed parameter found in the regressions for the three countries are in good agreement with each other. This indicates that the vulnerability of the insured objects to storm damage in these countries is very similar.

What changes can be expected due to global warming? According to the literature a 2% increase in storm intensity in NW-Europe can be expected over 25 years if CO_2 concentration were to double over 75 years. Based on the exponential model this would mean that storm damage due to severe storms would increase by 25-40% (excluding an increase due to an increase in the number and value of the stock-at-risk).

3.5 Impacts of weather extremes on transnational flows of goods

Potatoes. Trade is concentrated in NW Europe. In 1995 (an exceptionally hot, dry growing season for much of Europe) imports to Europe from the rest of the world were considerably larger than in 1993 (a 'normal' year), and especially to the Netherlands. In general there was more trade in 1995 than in 1993, possibly because prices were inflated because of the drought (around 40% of the potato crop in the UK, for example, is irrigated, and hence drought-proofed).
Strawberries. Again, the much greater volumes of trade in 1995 compared to 1993 are noticeable. Spain and Italy are the two major exporters. Their trade with the rest of Europe was almost doubled in 1995.
Sugar beet. Volumes of trade in sugar beet are small. Volumes were greater in 1995 than in 1993, but the effect is much less noticeable than for potatoes and strawberries.

4. POLICY RELEVANCE

Statistical analyses of activity time series

Agriculture. The analyses show the importance of weather in the year prior to harvest. This suggests the importance of more subtle factors than the immediate weather. For example, weather in the prior year may affect the occurrence of pests and diseases in the harvest year.

Outdoor/forest fire. Global warming will add substantially to damage and fire-fighting costs. Outdoor fires are seldom due to natural causes alone. Control measures should include: (a) an active programme of public education (b) restriction of public access to vulnerable areas during droughts (c) investigation of alternative forms of fire fighting.

Health. The suggestion is that, as a result of global warming, the seasonal cycle of deaths may change to become less pronounced. Depending on the scale of this impact, there are implications for health care organization and resourcing.

The utilities. Global warming, at least before major penetration of air conditioning, should bring real savings to the consumer. The seasonal cycle in gas demand is likely to become less extreme, as winter demand falls. For electricity, if air conditioning becomes widespread, the seasonal cycle should become more developed, and overall demand should rise.

For the public water supply, demand rises in hot weather. In the Netherlands, consumption was shown to increase with length of drought, which has implications for impacts.

Tourism. Despite the views of management (see below) the tourism industry is responsive to weather fluctuations. These responses are likely to carry through as a global warming impact; for example, in northern Europe, holidays in the home country can be expected to become a more attractive option than is the case at present.

Public perceptions

Respondents distinguished clearly between the prospect of global warming, which they found worrying, and the prospect of more frequent hot and dry summers, which they tended to view favourably. They regard global warming as having negative impacts for the nation as a whole, whereas for their personal well-being they could see an overall pleasanter lifestyle.

- It is fortunate that this distinction is made – otherwise governments might find it more difficult to persuade the population of the need to implement strategies to combat climate change. When asked, respondents overwhelmingly accepted the need to change lifestyles to combat climate change. Equally overwhelming was the view that action and leadership should come from the government. Legislation was regarded as essential.
- This lifestyle would not only be pleasanter, it would be healthier also, since the changes that people visualize are broadly the same as they currently undertake in an exceptionally hot summer (i.e. a healthier diet and more exercise). .

Management perceptions

The level of awareness of the potential risks and opportunities associated with climate change was low, and this was especially true in the tourism industry. It is likely that in the future rapid and flexible responses will be required from this sector in order to optimize the opportunities and minimize the risks arising from climate change impacts, as these develop.

Wind storm

According to the literature, a 2% increase in storm intensity in north-western Europe can be expected over the next 25 years if CO_2 concentrations double over the next 75 years. Based on the exponential model used, this would mean that damage due to severe storms would increase by 25-40% (excluding any increase due to an increase in the number and value of stock-at-risk). This has important implications for building standards, the exposure of insurance companies and for disaster management.

5. COLLABORATION

Collaboration with other EU research projects

i) Two Concerted Action activities are complementary to WISE. All four institutions involved in WISE contribute scientists to ACACIA (A Concerted Action for Climate Impacts Assessment), either as authors or through the Steering Committee, and to EFIEA (European Forum for Integrated Environmental Assessment).

ii) FEEM is partner in the projects: 'CLIMNEG – Adapting and Distributing Climate Targets and Policies', which uses jointly integrated assessment and game theoretic models to clarify the rationale of possible strategies for Europe in an evolving setting, as a function of the perceived or real interest of the EU Member States and of the position of other key stakeholders (United States, Japan and the main developing countries).

iii) PIK has an extensive range of EU-funded contracts which have contributed to and benefited from the WISE project. These include ULYSSES (Urban Lifestyle, Sustainability and Integrated Environmental Assessment), a project which emphasises participation within impact assessment, and hence shares with WISE the need to properly assess public perceptions of climate change.

iv) IVM is a partner in the SIRCH project (Societal and Institutional Responses to Climate Change and

Climatic Hazards). This project has carried out a number of case studies throughout Europe. The expertise gained in carrying out surveys of managements perceptions of risks and responses to hazards has fed into the design of the WISE management surveys.

Complementarity with projects of other research programmes

i) *International activities*. The WISE project involves three lead authors from IPCC Working Group II, which is concerned with impacts of and adaptation to climate change. Richard Tol was a lead author in the recently-published 'Handbook of Methods for Climate Change Impact Assessment and Adaptation Strategies', a joint publication of UNEP and IVM.

ii) The Climatic Research Unit at UEA has worked on a number of projects funded by the UK government to study climate change impacts and adaptation strategies at the regional scale within the UK. Funded from the same source, the Unit is currently involved in drawing up a catalogue of impact studies carried out throughout the world.

iii) PIK carries out a range of projects which are complementary to WISE. In general these take a modelling based approach to the assessment of climate change impacts in Europe (and further a field). RAGTIME (Regional Assessment of Global Change Impacts through Integrated Modelling in the Elbe River Basin) is an example of such a project.

APPENDIX 2. DATA SOURCES FOR SECTORWISE ANALYSES

Description	Region	Time-Frame 19..	Temporal Resolution	Source
Meteorology				
Mean temperature 105 stations Precipitation 616 stations	WD	65-95	Daily / Monthly	German Meteorological Office
Mean temperature 26 stations Maximum and minimum temperature Precipitation 136 stations	NS	65-95	Daily / Monthly	German Meteorological Office
Mean temperature 6 stations Maximum and minimum temperature Precipitation 18 stations	BB	75-95	Daily / Monthly	German Meteorological Office
Maximum wind speed (wind gust) 205 stations Mean wind speed 178 stations	WD	90	Daily Hourly	German Meteorological Office
Agriculture				
Strawberries, *winter wheat* Cultivation area [ha] Harvest yield [t] Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	WD	50-97	Annual	STBA seg 1766 108 (*1740 15*) STBA seg 1766 109 (*1766 4*) STBA seg 1740 30/31/32 (*33*) STBA seg 1766 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	SH	50-97	Annual	STBA seg 1741 30/31/32 (*33*) STBA seg 1767 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	HH	50-97	Annual	STBA seg 1742 30/31/32 (*33*) STBA seg 1768 16/17/18 (*19*)
Strawberries, *winter wheat* Cultivation area [ha] Harvest yield [t] Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	NS	50-97	Annual	STBA seg 1769 100 (*1743 15*) STBA seg 1769 101 (*1769 4*) STBA seg 1743 30/31/32 (*33*) STBA seg 1769 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	HB	50-97	Annual	STBA seg 1744 30/31/32 (*33*) STBA seg 1770 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	NRW	50-97	Annual	STBA seg 1745 30/31/32 (*33*) STBA seg 1771 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	HE	50-97	Annual	STBA seg 1746 30/31/32 (*33*) STBA seg 1772 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	RP	50-97	Annual	STBA seg 1747 30/31/32 (*33*) STBA seg 1773 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	BW	50-97	Annual	STBA seg 1748 30/31/32 (*33*) STBA seg 1774 16/17/18 (*19*)

Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	BY	50-97	Annual	 STBA seg 1749 30/31/32 (*33*) STBA seg 1775 16/17/18 (*19*)
Potatoes all, spring, late, *sugar beets* Cultivation area [ha] Harvest yield [t]	SL	50-97	Annual	 STBA seg 1750 30/31/32 (*33*) STBA seg 1776 16/17/18 (*19*)
Potatoes, sugar beets Harvest yield [t/ha]	BB	80-98	Annual	STLA BB Statistical Yearbooks, Table 8.6
Sugar beets Minimum prices [€]	WD/GD	69-98	Monthly	ZMP
Potatoes Average producer prices [€] Producer price index	WD/GD	71-98 68-97	Monthly Monthly	ZMP STBA seg 3277 32

Fire

Number of forest fires, Damaged area [ha], Damage costs [€]	WD NS BB	76-96 72-97 91-96	Annual	Waldbrandstatistik BML/ Referat 613 – 7171/3, BLE Niedersächsisches Ministerium für Ernährung, Landwirtschaft und Forsten PIK/ Werner/ Oberforstämter

Mortality

Inhabitants, male/ female, in age classes	WD	52-97	Annual	STBA seg 37
All cause deaths, male/ female, in age classes	WD	70- 97	Annual	STBA seg 1125 /26
All caused deaths	WD	52-97	Monthly	STBA seg. 810; VIIIB 179/1-03
Inhabitants, male/ female, in age classes	NS	67-95	Annual	STBA seg 482
All cause deaths male/ female, in age classes	NS	67-95	Annual	STLA NS AIV3-j
Deaths due to diseases of the circulatory system	NS	67-95	Annual	STLA NS AIV3-j

Energy

Total gas consumption from local and regional public suppliers' networks [10^6 kWh]	WD	85-95	Quarterly Monthly	BGW Gas Schnellstatistik
Gas consumption of households and small users [10^9 kWh]	WD	80-90	Annual	BMWI /BGW-Gasstatistik, Tab. 47
Electricity consumption of sectors [GWh]	WD	72-95	Annual	VDEW [Table 18]
Total electricity consumption [GWh]	WD	75-95	Monthly	VDEW: Elektrizitätswirtschaft [Table 15, before 1977 Table 27, until 1982 Table 13]
Household tariffs (= average proceeds) electricity, excluding “Ausgleichsabgabe” and VAT [€]	WD GD	90-95	Annual	BMWi Referat Elektrizitätswirtschaft
Household tariffs (= average proceeds) gas, excluding “Ausgleichsabgabe” and VAT [€]	GD	90-95	Annual	Energiedaten 1999 BMWi

Water

Total water consumption from public suppliers' networks Domestic water consumption of public suppliers' networks	WD	70-94	Annual	BGW Wasserstatistik Tab 27 BGW Wasserstatistik Tab 4
Prices for drinking water [€]	WD	90-97	Annual	BGW Wasserstatistik Tab 11 in: Wasser & Boden (49) 7/1997

Tourism

Bed nights (residents and non-residents)	NS	81-97	Monthly	STLA NS digital transmission
Bed nights (residents and non-residents)	WD	80-97	Monthly	Eurostat NEW CRONOS, TOUR : 4, 1998 (1980-1991) STBA FS 7.1 (1992-1997)
Expenses per day per overnight tourist [€]	WD/NS	91/92	Unique	STBA Tourismus in Zahlen 1998

Wind-Storms

Number of policies, Sum of insured values, Number of affected policies, Sum of losses [€]	Sample of WD	90	Daria event	Munich Reinsurance Company
Number of residential buildings, Number of flats	WD, per district	90/91	Unique	STBA, Statistik Regional 1991
Geodata of postal code zones	WD	90/91	Unique	Infas Geodaten GmbH Bonn

Abbreviations

Regions	GD	Whole Germany
	WD	Western Germany
	BB	Brandenburg
	BW	Baden-Württemberg
	BY	Bayern
	HB	Hansestadt Bremen
	HE	Hessen
	HH	Hansestadt Hamburg
	NRW	Nordrhein-Westfalen
	NS	Niedersachsen
	RP	Rheinland-Pfalz
	SH	Schleswig-Holstein
	SL	Saarland
Organisations/ Sources	AGEB	Arbeitsgemeinschaft Energiebilanzen (Association for energy balances)
	BGW	Bundesverband Gas-Wasser (Federal Association for Gas and Water)
	BLE	Bundesanstalt für Landwirtschaft und Ernährung (Federal Institution for Agriculture and Nourishment)
	BML	Federal Ministry for Agriculture
	BMWi	Federal Ministry for Economics
	BWB	Berliner Wasserbetriebe (Berlin Water Supplier)
	OOWV	Oldenburgisch-Ostfriesischer Wasserverband (local water supplier)
	STBA	Federal Statistical Office seg = Segment of the Time Series Service
	STLA	Statistical Agency of a state
	SVR	Sachverständigenrat zur Begutachtung der Gesamtwirtschaftlichen Entwicklung (Economic Advisory Board)
	VDEW	Vereinigung Deutscher Elektrizitäts Werke (Association of German Electricity Suppliers)
	ZMP	Zentrale Markt- und Preisberichtstelle (Central Market and Price Information Service)
	€	Euro

APPENDIX 3.A.QUESTIONNAIRE FOR PUBLIC PERCEPTION SURVEY (GERMAN)

Erinnern Sie sich bitte an einen heißen und trockenen Sommer, den Sie in den letzten Jahren erlebt haben. Basierend auf dieser Erinnerung möchten wir Sie bitten, die nachfolgenden Fragen zu beantworten.

1. Welche Auswirkungen hatte dieser extrem heiße und trockene Sommer hier in Deutschland auf folgende Bereiche Ihres täglichen Lebens :

(Bitte kreuzen Sie für jeden Punkt ein Feld an)

		sehr nachteilig	*etwas nachteilig*	*unver-ändert*	*etwas vorteilhaft*	*sehr vorteilhaft*	*weiß nicht mehr*
A	Ihr persönliches Wohlbefinden	☐	☐	☐	☐	☐	☐
B	Ihre Aktivitäten in Schule/Beruf	☐	☐	☐	☐	☐	☐
C	Ihre Hausarbeit	☐	☐	☐	☐	☐	☐
D	Ihre Freizeitaktivitäten (draußen)	☐	☐	☐	☐	☐	☐
E	Ihre Gesundheit	☐	☐	☐	☐	☐	☐
F	Ihre Teilnahme am Straßenverkehr	☐	☐	☐	☐	☐	☐
G	Die Qualität der Luft	☐	☐	☐	☐	☐	☐

		viel weniger	*etwas weniger*	*unver-ändert*	*etwas mehr*	*viel mehr*	*weiß nicht mehr*
H	Ihren Wasserverbrauch	☐	☐	☐	☐	☐	☐
I	Ihren Verbrauch von Strom / Gas	☐	☐	☐	☐	☐	☐
K	.... Anderes *(gegebenenfalls benennen)*	☐	☐	☐	☐	☐	

2. Welcher war für **Sie** der <u>wichtigste</u> Effekt in Frage 1?

(Bitte tragen Sie den Buchstaben ein) ☐

3. Haben sie auf Grund des außergewöhnlich heißen und trockenen Sommerwetters Ihre <u>Fortbewegungsmittel</u> anders genutzt?

(Bitte kreuzen Sie für jeden Punkt ein Feld an)

		viel weniger	*etwas weniger*	*unver-ändert*	*etwas mehr*	*viel mehr*	*benutze ich nie*	*weiß nicht mehr*
A	Öffentliche Verkehrsmittel	☐	☐	☐	☐	☐	☐	☐
B	PKW	☐	☐	☐	☐	☐	☐	☐
C	Motorrad	☐	☐	☐	☐	☐	☐	☐
D	Fahrrad	☐	☐	☐	☐	☐	☐	☐
E	zu Fuß gehen	☐	☐	☐	☐	☐	☐	☐

4. Haben Sie auf Grund des außergewöhnlich heißen und trockenen Sommerwetters Ihre Ausflugsziele anders besucht?
(Bitte kreuzen Sie für jeden Punkt ein Feld an)

	viel weniger	*etwas weniger*	*unver-ändert*	*etwas mehr*	*viel mehr*	*besuche ich nie*	*weiß nicht mehr*
A Küsten / Seen							
B Schwimmbäder							
C Naherholungsgebiete (Wälder, Flüsse, Naturschutzgebiete)							
D Sportstätten/Freizeitzentren (draußen)							
E Sportstätten/Freizeitzentren (drinnen)							
F Theater / Kino / Museen							
G Gartenlokale /Eiscafès (draußen)							
H Restaurants / Kneipen (drinnen)							
I .... Anderes *(gegebenenfalls benennen)*							

1. Haben Sie in jenem Sommer weniger oder mehr Ausflüge als sonst gemacht?
(Bitte kreuzen Sie für jeden Punkt ein Feld an)

	viel weniger	*etwas weniger*	*unver-ändert*	*etwas mehr*	*viel mehr*	*mache ich nie*	*weiß nicht mehr*
A Tagesausflüge							
B Kurzreisen bzw. Wochenendausflüge							

6. Wenn Sie Ausflüge gemacht haben, waren Ihre Ausflugsziele näher oder weiter entfernt als in anderen Sommern?

	viel näher	*etwas näher*	*unver-ändert*	*etwas weiter*	*viel weiter*	*weiß nicht mehr*
Entfernung der Ausflugsziele						

7. Beeinflußte das heiße Wetter Ihre Sommerurlaubsplanung?

(Mehrfachnennung möglich)

- A Ja, ich änderte meine Urlaubsplanung für jenes Jahr ☐
- B Ja, ich änderte meine Planung für das darauffolgende Jahr ☐
- C Nein, ich habe meine Pläne nicht verändert ☐
- D Ich erinnere mich nicht mehr ☐

Wenn Sie A oder B angekreuzt haben, wie änderten Sie Ihre Pläne?

(Mehrfachnennung möglich)

- A Ich blieb zu Hause statt zu verreisen ☐
- B Ich bin verreist statt zu Hause zu bleiben ☐
- C Ich bin in Deutschland geblieben statt ins Ausland zu fahren ☐
- D Ich bin ins Ausland gefahren statt in Deutschland zu bleiben ☐
- E Ich habe den Zeitpunkt meines Urlaubs verändert ☐
- F Ich habe meinen Urlaub verlängert ☐
- G .... ☐
  Anderes *(gegebenenfalls benennen)*

8. Wissen Sie noch, welchen Sommer der letzten Jahre Sie als besonders heiß und trocken wahrgenommen haben?

(Bitte kreuzen Sie diesen an)

1989	1990	1991	1992	1993	anderer:…...…….
1994	1995	1996	1997	1998	weiß nicht mehr

Bisher haben wir Sie zu einem heißen und trockenen Sommer der Vergangenheit befragt. Stellen Sie sich jetzt einmal vor, die kommenden Sommer würden zunehmend so heiß und trocken wie derjenige, an den Sie bisher gedacht haben.

9. Für wie <u>wahrscheinlich</u> halten Sie es, daß die Sommer heißer und trockener werden?

(Bitte kreuzen Sie ein Feld an)

sehr wahrscheinlich	*eher wahrscheinlich*	*weder noch*	*eher unwahrscheinlich*	*sehr unwahrscheinlich*
☐	☐	☐	☐	☐

10. Wie würden Sie einen weltweiten Temperaturanstieg einstufen für...

(Bitte kreuzen Sie für jeden Punkt ein Feld an)

	äußerst gefährlich	*sehr gefährlich*	*etwas gefährlich*	*kaum gefährlich*	*gar nicht gefährlich*
A Die Umwelt allgemein:	☐	☐	☐	☐	☐
B Die deutsche Wirtschaft:	☐	☐	☐	☐	☐
C Sie und Ihre Familie:	☐	☐	☐	☐	☐

11. Würden Sie bei häufigen heißen, trockenen Sommern irgendwelche <u>Gewohnheiten dauerhaft ändern</u>?

ja ☐ nein ☐ weiß nicht ☐

Wenn **ja**, welche wetterbedingten Änderungen können Sie sich vorstellen?

(Mehrfachnennung möglich)	*würde ich ändern*	*habe ich bereits geändert*
A Mehr im Freien aufhalten	☐	☐
B Die Sonne mehr meiden	☐	☐
C Weniger Auto fahren	☐	☐
D Mehr Auto fahren	☐	☐
E Meinen Getränkekonsum steigern	☐	☐
F Mehr Obst und Salate essen	☐	☐
G Versuchen, weniger Wasser zu verbrauchen	☐	☐
H Andere Gewächse in meinem Garten pflanzen	☐	☐
I Mehr in Deutschland Urlaub machen	☐	☐
K Im Urlaub öfter ins Ausland fahren	☐	☐
L .... Andere *(gegebenenfalls benennen)*	☐	☐

12. Gibt es für **Sie** rein gefühlsmäßig positive Folgen durch häufige heiße, trockene Sommer?

ja ☐ nein ☐

Wenn **ja**, welche?

(Mehrfachnennung möglich)

A Besseres persönliches Wohlbefinden ☐
B Bessere Gesundheit ☐
C Menschen sind geselliger ☐
D (Abendliche) Aktivitäten im Freien nehmen zu ☐
E Energieersparnis ☐
F Naherholungsmöglichkeiten besser nutzbar ☐
G .... ☐
Andere *(gegebenenfalls benennen)*

13. Gibt es für **Sie** rein gefühlsmäßig negative Folgen durch häufige heiße, trockene Sommer?

ja ☐ nein ☐

Wenn **ja**, welche?

(Mehrfachnennung möglich)

A Schlechteres persönliches Wohlbefinden ☐
B Gesundheitliche Probleme (z.B. Kreislauferkrankungen) ☐
C Aktivitäten im Freien nehmen ab ☐
D Streß steigt ☐
E Wasserverknappung ☐
F Qualität der Luft sinkt (z.B. Ozonkonzentration steigt) ☐
G .... ☐
Andere *(gegebenenfalls benennen)*

14. Welche ungewöhnliche Wetterlage bevorzugen Sie persönlich für Deutschland?

(Bitte kreuzen Sie für jede Jahreszeit ein Feld an)

Sommer		**Winter**	
A Ich bevorzuge kühle Temperaturen	☐	A Ich bevorzuge frostige Temperaturen	☐
B Ich bevorzuge heiße Temperaturen	☐	B Ich bevorzuge milde Temperaturen	☐
C Das Wetter ist mir egal	☐	C Das Wetter ist mir egal	☐
D Weiß nicht	☐	D Weiß nicht	☐

Bisher ging es um heiße, trockene Sommer. Durch einen weltweiten Temperaturanstieg könnten jedoch auch die Winter zunehmend wärmer bzw. milder werden. Bitte erinnern Sie sich an einen solchen milden Winter.

15. Welche Auswirkungen hatte dieser milde Winter hier in Deutschland auf folgende Bereiche Ihres täglichen Lebens:

(Bitte kreuzen Sie für jeden Punkt ein Feld an)

		sehr nachteilig	*etwas nachteilig*	*unver-ändert*	*etwas vorteilhaft*	*sehr vorteilhaft*	*weiß nicht mehr*
A	Ihr persönliches Wohlbefinden	☐	☐	☐	☐	☐	☐
B	Ihre Gesundheit	☐	☐	☐	☐	☐	☐
C	Ihre Freizeitaktivitäten (draußen)	☐	☐	☐	☐	☐	☐
D	Ihre Teilnahme am Straßenverkehr	☐	☐	☐	☐	☐	☐
E	Ihre Stimmung in bezug auf Winter	☐	☐	☐	☐	☐	☐
F	Die Qualität der Luft	☐	☐	☐	☐	☐	☐
		viel weniger	*etwas weniger*	*unver-ändert*	*etwas mehr*	*viel mehr*	*weiß nicht mehr*
G	Ihren Verbrauch von Strom / Gas	☐	☐	☐	☐	☐	☐
H	Ungeziefer im nächsten Sommer	☐	☐	☐	☐	☐	☐
I	.... Anderes *(gegebenenfalls benennen)*	☐	☐	☐	☐	☐	

16. Welcher war für **Sie** der <u>wichtigste</u> Effekt in Frage 15?

(Bitte tragen Sie den Buchstaben ein) ☐

17. Wissen Sie noch, welchen Winter der letzten Jahre Sie als besonders mild / warm wahrgenommen haben?

(Bitte kreuzen Sie diesen an)

88/89	89/90	90/91	91/92	92/93	anderer:…...…….
93/94	94/95	95/96	96/97	97/98	weiß nicht mehr

Jetzt interessiert uns noch Ihre Meinung in Bezug auf Maßnahmen, einem weltweiten Temperaturanstieg entgegenzuwirken.

18. Inwieweit stimmen sie folgenden Aussagen zu oder nicht zu?

(Bitte kreuzen Sie für jeden Punkt ein Feld an)

		stimme stark zu	*stimme eher zu*	*weder noch*	*stimme eher nicht zu*	*stimme überhaupt nicht zu*	*kann ich nicht sagen*
A	Für jemanden wie mich ist es einfach zu schwierig, viel für die Umwelt zu tun	☐	☐	☐	☐	☐	☐
B	Ich tue das, was für die Umwelt richtig ist, auch wenn mich das mehr Geld oder Zeit kostet	☐	☐	☐	☐	☐	☐

19. Wenn Sie sich zwischen den folgenden Aussagen entscheiden müßten, welche käme Ihrer Meinung am nächsten in Bezug auf:

Die deutsche Wirtschaft

(Bitte kreuzen Sie nur ein Feld an)

A Die Regierung sollte es der Wirtschaft überlassen, wie sie die Umwelt schützt, auch wenn das dazu führt, daß nicht immer das Richtige für die Umwelt getan wird ☐

B Die Regierung sollte Gesetze erlassen, um die Wirtschaft zu zwingen, die Umwelt zu schützen, auch wenn dies in die Entscheidungsfreiheit der Wirtschaft eingreift ☐

Sie selbst

(Bitte kreuzen Sie nur ein Feld an)

A Die Regierung sollte es jedem selbst überlassen, wie er/sie die Umwelt schützt, auch wenn das dazu führt, daß nicht immer das Richtige für die Umwelt getan wird ☐

B Die Regierung sollte Gesetze erlassen, um die Leute zu zwingen, die Umwelt zu schützen, auch wenn dies in die Entscheidungsfreiheit des Einzelnen eingreift ☐

20. Würden Sie Veränderungen Ihres Lebensstils in Kauf nehmen, um einer Klimaveränderung entgegenzuwirken?

☐ ja *(weiter mit 20.1.)* ☐ nein *(weiter mit 20.2.)*

20.1. Wenn **ja**, wie leicht oder schwer würden Sie folgende Veränderungen akzeptieren?

(Bitte kreuzen Sie für jeden Punkt ein Feld an)

	sehr leicht	*eher leicht*	*weder noch*	*eher schwer*	*sehr schwer*	*kann ich nicht sagen*
A Höhere Preise für Energieträger	☐	☐	☐	☐	☐	☐
B Höhere Steuern (Ökosteuer)	☐	☐	☐	☐	☐	☐
C Weniger Energie im Haushalt verbrauchen	☐	☐	☐	☐	☐	☐
D Weniger Auto fahren	☐	☐	☐	☐	☐	☐
E Weniger Fernreisen im Urlaub	☐	☐	☐	☐	☐	☐
F .... Anderes *(gegebenenfalls benennen)*	☐	☐	☐	☐	☐	

20.2. Wenn **nein**, warum würden Sie Ihren Lebensstil nicht ändern?

(Bitte kreuzen Sie Zutreffendes an)

A Es ist noch nicht erwiesen, daß menschliches Handeln die Klimaentwicklung beeinflußt ☐

B Einer allein kann sowieso nichts verändern ☐

C Der technische Fortschritt reicht aus, um der derzeitigen Klimaentwicklung entgegenzuwirken ☐

D Eine Klimaänderung ist für mich und / oder unsere Region eher gut ☐

E Es ist mir egal ☐

F .... ☐
Anderes *(gegebenenfalls benennen)*

Bitte geben Sie uns abschließend noch einige Angaben zu ihrer Person

S1. Welches Geschlecht haben Sie?

Männlich ☐ Weiblich ☐

S2. In welchem Jahr sind Sie geboren?

(*Bitte Jahreszahl eintragen)* 1 9 ☐ ☐

S3. Welche Postleitzahl hat der Ort, in dem Sie wohnen?

(*Bitte Postleitzahl eintragen)* ☐ ☐ ☐ ☐ ☐

S4. Hatten Sie in dem heißen, trockenen Sommer die Möglichkeit einen Garten zu nutzen?

ja ☐ nein ☐ weiß nicht mehr ☐

S5. Haben Sie oder andere Personen in Ihrem Haushalt chronische Atembeschwerden oder Allergien?

		Sie selbst	*andere Personen in Ihrem Haushalt*
A	Chronische Atembeschwerden	☐	☐
B	Allergien	☐	☐

S6. Wieviel Personen leben insgesamt in Ihrem Haushalt?

(Bitte Zahl eintragen) ☐

Wieviel davon sind Kinder unter 16 Jahren?

(Bitte Zahl eintragen) ☐

S7. Welchen **höchsten** Schulabschluß haben Sie?

A	Noch Schüler	☐
B	Schule ohne Abschluß beendet	☐
C	Volks-/Hauptschulabschluß (Abschluß 8. oder 9.Klasse)	☐
D	Mittlere Reife (Abschluß 10. Klasse)	☐
E	Abitur	☐
F	Abgeschlossene Lehre / Facharbeiterabschluß	☐
G	Fachschulabschluß (auch Meister/ Techniker etc.)	☐
H	Fachhochschulabschluß / Hochschulabschluß	☐

S8. Sind oder waren Sie berufstätig?

	heute	*in dem vorher besprochenen Sommer, (sofern es Abweichungen gibt)*	
A Ja (vollbeschäftigt)	☐	☐	*(weiter mit S8.1.)*
B Ja (teilzeitbeschäftigt)	☐	☐	*(weiter mit S8.1.)*
C Nein	☐	☐	*(weiter mit S8.2.)*

S8.1. Wenn **ja**, welche Berufsgruppe trifft auf Sie zu?

A Arbeiter / Angestellter	☐
B Höherer Angestellter (z.B. wissenschaftlicher Mitarbeiter)	☐
C Beamter/Berufssoldat im einfachen bis mittleren Dienst	☐
D Beamter/Richter/Berufssoldat im gehobenen/höheren Dienst	☐
E Selbständiger bis 9 Mitarbeiter	☐
F Selbständiger mit mehr als 9 Mitarbeitern	☐
G .... Anderes *(gegebenenfalls benennen)*	☐

S8.2. Wenn **nein**, was von der folgenden Liste trifft auf Sie zu?

A Schüler / Student	☐
B Wehr- / Zivildienstleistender	☐
C Hausfrau / Hausmann	☐
D Zur Zeit arbeitslos	☐
E Rentner / Pensionär	☐

Wir danken Ihnen herzlich für Ihre Mühe und bitten Sie, den ausgefüllten Fragebogen in dem mitgeschickten portofreien Umschlag an uns zurückzusenden.

APPENDIX 3B. QUESTIONNAIRE FOR PUBLIC PERCEPTION SURVEY (ENGLISH)

I'm sure you can remember experiencing a hot and dry summer in the last few years. Please think about this unusual summer, and answer the following questions

1. In your <u>everyday life</u>, which of the following was affected by the especially hot and dry summer here in Germany?

   (Please tick one box for each)

	very unfavourably	*somewhat unfavourably*	*un-changed*	*somewhat favourably*	*very favourably*	*can't remember*
A Your personal comfort	☐	☐	☐	☐	☐	☐
B Your activities at work / school	☐	☐	☐	☐	☐	☐
C Your housework	☐	☐	☐	☐	☐	☐
D Your outdoor leisure activities	☐	☐	☐	☐	☐	☐
E Your health	☐	☐	☐	☐	☐	☐
F Your everyday travel	☐	☐	☐	☐	☐	☐
G Air quality	☐	☐	☐	☐	☐	☐

	much less	*somewhat less*	*un-changed*	*somewhat more*	*much more*	*can't remember*
H Your water use	☐	☐	☐	☐	☐	☐
I Your home energy use	☐	☐	☐	☐	☐	☐
K .... Others *(please say what it is)*	☐	☐	☐	☐	☐	

2. Which of the effects in Questions 1was the <u>most important</u> one for **you**?

   (Please state the letter) ☐

3. Did you change the <u>way you travelled</u> during the especially hot and dry summer weather?

   (Please tick one box for each means of travelling)

	much less	*somewhat less*	*un-changed*	*somewhat more*	*much more*	*never use*	*can't remember*
A Public transport use	☐	☐	☐	☐	☐	☐	☐
B Private car use	☐	☐	☐	☐	☐	☐	☐
C Motorbike/scooter use	☐	☐	☐	☐	☐	☐	☐
D Bicycle use	☐	☐	☐	☐	☐	☐	☐
E Walking	☐	☐	☐	☐	☐	☐	☐

4. During the especially hot and dry summer weather, did you change your use of the following destinations?
(Please tick one box for each destination)

	much less	somewhat less	un-changed	somewhat more	much more	never use	can't remember
A Beaches / lakes	☐	☐	☐	☐	☐	☐	☐
B Swimming pools	☐	☐	☐	☐	☐	☐	☐
C Countryside (e.g. forests, National parks et.)	☐	☐	☐	☐	☐	☐	☐
D Outdoor sport facilities	☐	☐	☐	☐	☐	☐	☐
E Indoor sport centres	☐	☐	☐	☐	☐	☐	☐
F Theatres/cinemas/museums	☐	☐	☐	☐	☐	☐	☐
G Open air restaurants/bars	☐	☐	☐	☐	☐	☐	☐
H Indoor restaurants / bars	☐	☐	☐	☐	☐	☐	☐
I .... Others *(please say what it is)*	☐	☐	☐	☐	☐		

2. Did you make fewer or more <u>trips</u> during this summer compared to a normal summer?
(Please tick one box for each)

	much less	somewhat less	un-changed	somewhat more	much more	never made	can't remember
A Day trips	☐	☐	☐	☐	☐	☐	☐
B Weekend trips or short holiday breaks	☐	☐	☐	☐	☐	☐	☐

6. If you made trips, were the destinations closer or further away compared to other summers?

	much closer	somewhat closer	un-changed	somewhat further	much further	can't remember
Distance of destinations	☐	☐	☐	☐	☐	☐

7. Did the hot summer influence your <u>main summer holiday</u> plans?

(Please tick all that apply)

- A Yes, I altered my holiday plans for the same year ☐
- B Yes, I altered my holiday plans for the following year ☐
- C No, I didn't change my plans ☐
- D I don't recall ☐

If you took A or B, in what way(s) did you change your plans?

(Please tick all that apply)

- A Stayed at home instead of going away ☐
- B Went away instead of staying at home ☐
- C Stayed in Germany instead of going abroad ☐
- D Went abroad rather than remaining in Germany ☐
- E Changed the timing of my main holiday ☐
- F Took more days holiday ☐
- G .... Other *(please say what it is)* ☐

8. Perhaps you might even remember which unusually hot and dry summer you have been thinking about.

(Please tick the appropriate box)

1989	1990	1991	1992	1993	other:……..…….
1994	1995	1996	1997	1998	can't remember

Until now we questioned about a hot and dry summer of the past. Imagine the future summer would be increasingly as hot and dry as the summer you was thinking about.

9. How probable do you think is the assumption that future summers will be increasingly hot and dry?

(Please tick one box only)

very probable	*somewhat probable*	*neither nor*	*somewhat improbable*	*very improbable*
☐	☐	☐	☐	☐

10. How do you think would a rise on the world's temperature affect:

(Please tick one box for each)

	extremely dangerous	*very dangerous*	*somewhat dangerous*	*not very dangerous*	*not dangerous*
A The environment in general:	☐	☐	☐	☐	☐
B The German economy:	☐	☐	☐	☐	☐
C You and your family:	☐	☐	☐	☐	☐

11. Would you make any permanent changes to your lifestyle if hot, dry summers become more common?

☐ yes ☐ no ☐ don't know

If **yes**, which changes could you imagine?

(Please tick all that apply)	*I would change*	*I already have changed*
A Spend more time outdoors	☐	☐
B Avoid the sun more	☐	☐
C Drive the car less	☐	☐
D Drive the car more	☐	☐
E Increase my consumption of beverages	☐	☐
F Eat more fruit and salad	☐	☐
G Try to use less water	☐	☐
H Grow plants in my garden	☐	☐
I More likely to spend my holidays in Germany	☐	☐
K Go abroad for my holiday more often	☐	☐
L ……………………………………… Others *(please say what it is)*	☐	☐

12. If hot and dry summers were more common, would there be any positive effects for you?

yes   no

If **yes**, what are they?

(Please tick all that apply)

A Higher personal comfort

B Better health

C People will be more sociable

D Outdoor activities will increase

E Energy saving

F Better possibilities of recreation in the immediate vicinity

G ....
Other *(please say what it is)*

13. If hot and dry summers were more common, would there be any negative effects for you?

yes   no

If **yes**, what are they?

(Please tick all that apply)

A Reduced personal comfort

B Health problems (e.g. circulatory diseases)

C Outdoor activities decrease

D Stress increase

E Water shortages

F Air quality decrease (e.g. ozone concentration increase)

G ....
Other *(please say what it is)*

14. Which unusual weather do you personally prefer for Germany?

(Please tick one box for each season)

Summer

A I prefer colder temperatures

B I prefer hot temperatures

C I hardly notice extreme weather

D Don't know

Winter

A I prefer frosty temperatures

B I prefer mild temperatures

C I hardly notice extreme weather

D Don't know

Until now we questioned about hot and dry summer. Due to a global increase of temperature winter could be more and more mild or warm as well. Please remember such an mild winter.

15. In your everyday life, which of the following was affected by the especially mild winter here in Germany?

(Please tick one box for each)

	very unfavourably	somewhat unfavourably	un-changed	somewhat favourably	very favourably	can't remember
A Your personal comfort	☐	☐	☐	☐	☐	☐
B Your health	☐	☐	☐	☐	☐	☐
C Your outdoor leisure activities	☐	☐	☐	☐	☐	☐
D Your everyday travel	☐	☐	☐	☐	☐	☐
E Your mood in view of winter	☐	☐	☐	☐	☐	☐
F Air quality	☐	☐	☐	☐	☐	☐
	much less	*somewhat less*	*un-changed*	*somewhat more*	*much more*	*can't remember*
G Your home energy use	☐	☐	☐	☐	☐	☐
H Pests (insects...) in the next summer	☐	☐	☐	☐	☐	☐
I .... Others *(please say what it is)*	☐	☐	☐	☐	☐	

16. Which of the effects in question 15 is the most important one for **you**?

(Please state the letter) ☐

17. Perhaps you might even remember which unusually warm winter you have been thinking about?

(Please tick the appropriate box)

88/89	89/90	90/91	91/92	92/93	other:……..…….
93/94	94/95	95/96	96/97	97/98	don't know

Now we are interested in your opinion about measures against a world wide increase of temperature.

18. How much do you agree or disagree with each of these statements?

(Please tick the one box for each)

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree	can't choose
A It is just too difficult for someone like me to do much about the environment.	☐	☐	☐	☐	☐	☐
B I do what is right for the environment, even when it costs more money or takes more time	☐	☐	☐	☐	☐	☐

19. If you had to choose, which one of the following would be closest to your regarding:

The German economy

(Please tick one box only)

A Government should let businesses decide for themselves how to protect the environment even if it means they don't always do the right thing ☐

B Government should pass laws to make businesses protect the environment even if it interferes with business' rights to make their own decisions ☐

Yourself

(Please tick one box only)

A Government should let ordinary people decide for themselves how to protect the environment even if it means they don't always do the right thing ☐

B Government should pass laws to make ordinary people protect the environment even if it interferes with business' rights to make their own decisions ☐

20. Would you accept changes in your lifestyle to counteract climatic changes?

☐ yes *(continue with 20.1.)* ☐ no *(continue with 20.2.)*

20.1. If **yes** , how easily or hardly would you accept the following changes?

(Please tick one box on each line)

	very easily	*somewhat easily*	*neither nor*	*somewhat hardly*	*very hardly*	*can't say*
A Much higher prices for energy sources	☐	☐	☐	☐	☐	☐
B Much higher taxes (ecotaxes)	☐	☐	☐	☐	☐	☐
C Less energy consumption at home	☐	☐	☐	☐	☐	☐
D Use car less	☐	☐	☐	☐	☐	☐
E Less long-haul tourism	☐	☐	☐	☐	☐	☐
F .... Other *(please say what it is)*	☐	☐	☐	☐	☐	

20.3. If **not**, why wouldn't you change your lifestyle?

(Please tick all that apply)

A There is no proof, that human behaviour influences the climate ☐

B One person alone does not have any influence ☐

C The engineering progress is sufficient to counteract the current climatic changes ☐

D The climatic changes are a benefit for me / or for our region ☐

E I don't care ☐

F .... ☐

Other *(please say what it is)*

Could you please provide us with some information about yourself

S1. Your gender?

Male ☐ Female ☐

S2. Your year of birth ?

(Please state the year) 1 9 _ _

S3. Please indicate the postcode of the community you are living in?

(Please state the postcode) _ _ _ _ _

S4.Did you had the opportunity to use a garden during the hot and dry summer?

yes ☐ no ☐ don't know ☐

S5. Do you or somebody in your household have chronic respiratory conditions or allergies?

		you	*Other person in your household*
A	Chronic respiratory conditions	☐	☐
B	Allergies	☐	☐

S6. How many persons live in your household?

(Please state the number) ☐

How many of them are children (under 16)?

(Please state the number)) ☐

S7. Which is your **highest** academic degree?

- A Still student ☐
- B Left school without qualification ☐
- C Elementary school ☐
- D Secondary school ☐
- E Grammar school ☐
- F Completed Apprenticeship ☐
- G Technical college ☐
- H University degree ☐

S8. Were / are you working?

		now	*At the time of the summer you identified earlier*	
A	Yes (full time)	☐	☐	*(continue with S8.1.)*
B	Yes (part time)	☐	☐	*(continue with S8.1.)*
C	No	☐	☐	*(continue with S8.2.)*

S8.1. If **yes**, which of the following describes you best?

A	Worker / employee	☐
B	Higher employee (e.g. scientific employee)	☐
C	Official / regular (simple service)	☐
D	Official / judge / regular (higher service)	☐
E	Self-employed with up to 9 employees	☐
F	Self-employed with more than 9 employees	☐
G	.... Other *(please say what it is)*	☐

S8.2. If **no**, which of the following describes you best?

A	Student	☐
B	Soldier / person doing community service	☐
C	staid at home	☐
D	unemployed	☐
E	retired	☐

Many thanks for answering our questions. Please return the completed questionnaire to us in the enclosed stamped envelope

APPENDIX 4. LITERATURE SURVEY ON CLIMATE IMPACTS ON AGRICULTURE

A3.1 Introduction

The WISE project deals with three main aspects of climate impact analysis in Europe:

(1) the agricultural impact on three different plants (potato, sugar beet, and wheat) that are vital to human beings' daily diet in the western hemisphere
(2) the individual perception of climate change by the population that is analysed through a survey in different areas in Europe
(3) the management of vital resources, i.e. water, gas, and electricity.

To place the findings of WISE in a broader context and compare the results with comparable studies it is important to acquire a good overview of the current state of the art in impact analysis of these three aspects.

A literature survey is the appropriate means to achieve such an overview. Whether these aspects have been relevant to climate impact analysis was the main question to be answered by a literary survey.
To gather relevant literature on agricultural impacts of climate change bibliographies of texts were analysed as well as databases were searched for relevant entries. The major literature findings are presented in this paper according to the main topics and subtopics.

A3.2 Wheat

Regarding methodology, Mearns *et al.* (1992) have set a milestone by their proposals on methodology. Many studies are orientated on their proposed methodology. Mavromatis, T. and P.D. Jones (1998) have partially adapted this methodology and have come up with a comparison of various climate change scenario construction methodologies for impact assessment studies.

Criticism about models and modelling was presented in a paper by Landau *et al.* (1998): Wheat models such as CERES-Wheat, AFRCWHEAT2 and SIRIUS were applied on historical grain yields in the UK between 1976 and 1993. None of the applied models accurately predicted those yields, concerning predictions of both yield and yield loss due to water limitation It is the variability that was not taken into account.

However, Mearns *et al.*. (1997) identified three key aspects that contribute to crop responses. Their findings stem from their determination of the importance of including both mean and variability changes in climate change scenarios in an agricultural context: the marginality of the current climate for crop growth, the relative size of the mean and variance changes, and timing of these changes. Indices for quantifying uncertainty in the impact assessment were developed based on the nature of the climate scenario formed, and the magnitude of difference between model and observed values of relevant climate variables.

Wheat is a vital source for food production all over the world. Its existence might be considerably reduced by climatic changes that could lead to a severe shortage or short supply. That is why wheat as a major part of people's daily diet is often focused on in many scientific publications in the context of potential climatic change.

There certain factors that influence wheat crop growth. A change of variables in that factors might lead to an considerable disturbance in plant growth.

There are already observed changing factors that influence the growth of wheat crops such as elevated levels of carbon dioxide and an increased radiation of UV- B due to an on-going depletion of the ozone layer. These factors have been stressed differently in various studies depending on the setting or environment where the studies were taken out.

A3.2.1 Carbon dioxide

Climate change is closely connected to an elevation of atmospheric carbon dioxide. Most studies that are here taken into account either focus on the correlation between carbon dioxide and wheat growth or include carbon dioxide as a factor among others in studies that used models such as the EPIC (Erosion/Productivity Impact Calculator) model of Williams *et al.*. (1984) or the EU model ESPACE (European Stress Physiology and Climate Experiment) of Herstein and Fangmeier *et al.* (1996)
Elevated carbon dioxide can have two effects on wheat depending on the existence of interacting co-factors that prevail on the soil or farmland.

Bender *et al.* (1998) summarise the main findings of the effects of CO_2 enrichment and other factors such as ozone, drought stress or nitrogen supply on the yield response of spring wheat. But their study evokes the possibility that there are factors which are not accounted in the models due to the unexplained variability in measured datasets.

Brown and Rosenberg (1997) came to the result that interactions between different climate variables resulted in crop yield responses ranging from a multiplicative decrease when humidity and precipitation are decreased to a reduction in crop yield when solar radiation is increased and precipitation decreased. The demonstrated interactions of climatic factors indicate that future studies of climate change impacts should consider the full spectrum of climate variables and changes in atmospheric CO_2 and not just temperature and precipitation.

Using C isotope techniques, Cheng and Johnson (1998) found that elevated atmospheric CO significantly increased wheat plant growth, dry mass accumulation, rhizophere respiration, and soluble C concentration in the rhizophere. Their results indicate that elevated atmospheric CO in a wheat-soil system significantly increased substrate input to the rhizophere due to both increased root growth and increased root activities per unit of roots.

Daiz *et al.*.(1997) came to the conclusion by using the EPIC model that the climate change due to elevated CO_2 would the sustainability of certain soils of the Carcarana River basin (Argentina), particularly the Villa Eloisa series at a higher risk.

Easterling *et al.*. (1993) studied possible agricultural impacts of and responses to climate change in the Missouri-Iowa-Nabraska-Kansas MINK region. An analogue climate to the 1930s was imposed on the agriculture of the region in 1984/87 and again under a scenario of conditions that might prevail in 2030. The study using a modification of the EPIC model (i.e. absent enhanced CO_2 levels) concludes that before farm level adjustments and adaptations to the changed climate and absent CO_2 enrichment (from 350 to 450 ppm), production of dryland wheat was unaffected. Irrigated wheat production actually increased.

Farage *et al.*. (1998) rose the question whether a low nitrogen supply necessarily lead to acclimation of photosynthesis to elevated CO_2. Long-term exposure of plants to elevated partial pressures of CO, (pCO_2) often depresses photosynthetic capacity. Wheat (Triticum aestivum L.) was grown hydroponically and N was added in direct proportion to plant growth. As a result, photosynthesis did not acclimate to elevated pCO_2 even when growth was restricted by low-N relative addition rate.

Garcia *et al.*. (1998) had the unique opportunity to examine the hypothesis that continuous exposure of wheat to elevated pCO_2 will lead to acclimatory loss of photosynthetic capacity. In contrast to some controlled-environment and field-enclosure studies, this field-scale study of wheat using free-air CO_2 enrichment found little evidence of acclimatory loss of photosynthetic capacity with growth in elevated pCO_2 and a significant and substantial increase in leaf photosynthesis throughout the life of the crop.

The study by Hakala *et al.*. (1996) was based in Finland where the arrangement of experiments for simulating the effects of elevated temperatures and elevated CO levels on field-sown crops was demonstrated. Spring and winter wheat are two of the experimental plants besides e.g. potato, strawberry, black currant. The crops were exposed to elevated CO concentrations (by applying open top chambers) and high temperature. The effects of the experimental conditions on plant growth and phenology are discussed.

From 1992 to 1994 Hakala *et al.*. (1998) studied growth and yield potential and nitrogen content of spring wheat (Triticum aestivum L., cv. Polkka) in a simulated changed climate with increased CO_2 and higher temperature. Leaf canopies were exposed to CO_2 concentrations of 700 mu l l(-1) and temperatures 3 degrees C higher than present climate throughout growing season, therefore a future warmer climate was simulated. The study comprises two experiments that examines the interdependence of temperature and CO_2: CO_2 enrichment on its own had no effect on development rate. The total biomass at harvest was significantly higher in CO_2 enrichment in both temperature treatments.

Herrmann and Feller (1998) studied how CO_2, light and temperature influence senescence and protein degradation in wheat leaf segments. Effects of environmental conditions influencing photosynthesis and photorespiration on senescence and net protein degradation were investigated in segments from the first leaf of young wheat (Triticum aestivum cv. Arina) plants. The results from these investigations indicate that environmental conditions that influence photosynthesis may interfere with senescence and protein catabolism in wheat leaves.

In Herstein's paper (1996) the project goals of the ESPACE-Wheat (European Stress Physiology and Climate Experiment -Project 1 - Wheat) are presented. The effect of CO_2 is relevant to the two objectives of the project: (a) experimental investigation of the sensitivity of wheat growth, development and productivity to changes in CO_2 concentration, climatic variables and other physiological stresses, and (b) usage of models for assessments of the influences on crops of climatic change, increasing CO_2 concentration and additional physiological stresses in Europe. The mean observed CO_2-doubling responses was about 1.4, i.e. grain yield and biomass production were increased by about 40% compared to growth in ambient CO_2 concentration. However, there was a large variability of responses between sites and years. Results are discussed with respect to modelling attempts.

In this study by Lal *et al.*. (1998) vulnerability of wheat and rice crops in north-west India to the projected global warming and associated climate change is examined. CERES wheat and rice models were used. Both wheat and rice were exposed to elevated levels of CO_2 as well as to a rise of temperature. While the wheat crops are found to be sensitive to increase in maximum temperature, the rice crops are vulnerable to increase in minimum temperature. In general, acute water shortage conditions combined with thermal stress adversely affect both wheat and more severely the rice productivity in NW India under the positive effects of elevated CO_2 in the future.

Again Argentina is in the focus of another study. This study by Magrin *et al.*. (1997) examines the vulnerability of the agricultural systems of Argentina to climate change. An increase of CO_2 concentrations up to 330 and 550 ppm were supposed to prevail in a future climate for the year 2050. They concluded that wheat yield is likely to increase in the southern and the western parts of the region and decrease towards the north. Wheat production in the pampean region would increase by 3.6 and 20.7% respectively.

McKenney *et al.*. (1992) illustrate a methodology for simulating effects in crop yields to a future climate change induced by greenhouse warming. Wheat was among other plant in focus of this study. The EPIC model was used to represent a set of proposed future technologies in the MINK region. The future technologies increased yields of an average of 72% above current levels, but had little effect on the sensitivity of crop yields to climate change. If the direct effects of increased CO_2 are also considered, yields were equal to or greater than those that occur with no climate change.

Mearns *et al.*. (1997) identified three key aspects that contribute to crop responses. Their findings stem from their determination of the importance of including both mean and variability changes in climate change scenarios in an agricultural context: the marginality of the current climate for crop growth, the relative size of the mean and variance changes, and timing of these changes. Indices for quantifying uncertainty in the impact assessment were developed based on the nature of the climate scenario formed, and the magnitude of difference between model and observed values of relevant climate variables.

Like many other studies, Nonhebel, S. (1996) came to the conclusion that elevation of the CO concentration caused a general increase in yield. Doubling of the CO_2 concentration caused an increase in yield 40% due to higher assimilation rates. It was found that effects of higher temperature and higher CO_2 concentration were nearly additive and the combination of both led to a yield increase of 1-2 ton ha(-1): A very small CO_2-temperature interaction was found: the effect of doubled CO_2 concentration on crop yield was larger at higher temperatures. When water was limiting crop-production effects of temperature rise and higher CO_2 levels were different than for the potential production. Rise in temperature led to a smaller yield reduction, doubled CO_2 concentration to a larger yield increase and combination of both led to a large yield increase (3 ton ha(-1)) in comparison with yield simulated for the present situation. Both rise in temperature and increase in the CO_2 concentration reduced water requirements of the crop. It is concluded that wen no major changes in precipitation pattern occur a climate change will not affect wheat yields since negative effects of higher temperatures are compensated by positive effects of CO_2 enrichment.

Semenov *et al.*. (1996) compared wheat simulation models under climate change. The performance of five wheat models (AFRCWHEAT2; CERES, NWHEAT, SIRIUS and SOILN) was compared. It was carried out for two sites in Europe: Rothamsted, UK, and Seville, Spain. Simulations were run for climate change scenarios derived from a number of two times CO_2 equilibrium and transient GCM (global circulation model) experiments. For most climate change scenarios the model results were broadly similar, and they show that future studies of the effect of climate change on crop yields must consider changes in climatic variability as well as changes in mean climate.

Sicher and Bunce (1998) present evidence that premature senescence affects photosynthetic decline of wheat flag leaves during growth in elevated carbon dioxide. Their findings support the suggestion that premature senescence contributed to the photosynthetic decline observed in wheat flag leaves during growth at elevated CO_2. Changes of alpha-amino nitrogen were correlated with photosynthetic decline, but acid proteinase activity probably was under endogenous control.

Slafer and Rawson (1997) stated that_though it is recognised that CO_2-doubling of a future climate could increase yield through its effects on plant photosynthesis and stromatal behaviour, it is unclear whether CO_2-doubling will change phasic development in wheat. A phytotron study was conducted with two contrasting cultivars of wheat, Condor (spring) and Cappelle Desprez (winter), to determine whether development is affected by exposure to 360 and 720 ppmv CO_2. Plants were vernaliized for 50d (8/4 degrees C, s h photoperiod) before exposure to the CO_2 treatments. Finally, they came to the conclusion that CO_2 concentration does not influence development in wheat to a degree relevant to agronomy.

Smart *et al.*. (1998) examined the hypothesis that elevated CO_2 concentration would increase NO3-absorption and assimilation using intact wheat canopies (Triticum aestivum cv, Veery 10): Their results indicate that 1000 mu mol mol(-1) CO_2 diminished NO3-assimilation. If NO3-assimilation were impaired by high CO_2, then this offers an explanation for why organic nitrogen contents are often observed to decline in elevated CO_2 environments.

In a study by Van de Geijn (1994), the effects of changed climate (atmospheric CO_2 concentration, temperature) on different ecosystems were studied. A high variability of the growth and production enhancement by rising CO_2 was detected. An analysis using crop-growth models produced clues as to the origin of the existing confusion about the variability of the CO_2-enhancement factor for biomass production and yield. Using the growth and weather data of different years, it could be shown that interactions between the growth stage, light and especially temperature in the early growth stages could explain a large part of the variation. Regarding wheat, half of the difference in growth enhancement between e.g. (winter) wheat (16-34%) and faba bean (35-56%) could, according to the model outcome, be ascribed to temperature differences in the early (spring) growth stages.

Williams *et al.* (1998) examined the effects of elevated atmospheric CO_2 on lipid metabolism in leaves from mature wheat (Triticum aestivum L. cv, Hereward) plants. Lipid synthesis was studied in these plants. Increased CO_2 concentrations did not significantly affect the total incorporation of radiolabel into lipids of the whole leaf tissue, but altered the distribution for individual lipid classes.

A3.2.2 UV B-Radiation

The factor of UV B-radiation was not the main focus of any study. Generally, it was a factor among others. It seems that this factor is neglected in most studies taken into consideration.

Chakraborty *et al.*. (1998) found in their study on potential impact of climate change on plant diseases of economic significance to Australia that host resistance may be overcome more rapidly by diseases due to accelerated pathogen evolution from increased fecundity at high CO_2 and/or enhanced UV-B radiation.

Magrin *et al.*. (1997) included global solar radiation in their study on Argentinean agriculture under a warmer future climate.

In the study of Mearns *et al.*. (1997), solar radiation is a variable among others: temperature and precipitation to form a type of climate change scenario. A further examination e.g. for correlation was not carried out.

Brown and Rosenberg (1997) used solar radiation as a part of conditions to simulate the impact on yields using the EPIC.

A3.2.3 Temperature (high/low)

For a future climate, apart from a rise in atmospheric carbon dioxide a higher mean temperature is expected.

Porter *et al.*. (1995) study on modelling the effects of climate change and genetic modification on nitrogen use by wheat came to the result that model output pointed to a decrease in harvest index as a result of coincidental increases in CO_2 level and temperature, and the importance of considering not only changes to averages but also to the variability of environmental driving variables is illustrated. When mean temperatures were raised the model predicted that more nitrate would be left in the soil at the end of the season but that raising CO_2 level could counter this effect.

Although the effects of CO_2 and O-2 on crop growth and yield were acceptably simulated in the study of Bender *et al.*. (1998), observed process-rates often showed variation not related to light intensity, temperature, CO_2 or O-2, i.e. not related to the main driving variables of the models. This unexplained variability in the measured datasets suggested a role of factors which were not accounted for in the models.

Hakala *et al.*. (1998) concentrated on the effects on elevated CO_2 and elevated temperature. And their effects on plant growth and phenology are discussed.

Nonhebel (1996) also examined both factors, using a crop-growth-simulation model based on SUCROS87. For potential production a three degrees C temperature rise led to a yield decline due to a shortening of the growing period on all locations. And as mentioned before, it was found that effects of higher temperature and higher CO_2 concentration were nearly additive. But a very small CO_2-temperature interaction was found: the effect of doubled CO_2 concentration on crop yield was larger at higher temperatures. The inter-annual yield variability was hardly affected. When water was limiting, crop-production effects of temperature rise and higher CO_2 levels were different than for potential production. Rise in temperature led to a smaller yield reduction, doubled CO_2 concentration to a larger yield increase and combination of both led to a large yield increase in comparison with yields simulated for the present situation. Both rise in temperature and increase in the CO_2 reduced water requirements of the crop.

Brown and Rosenberg (1997) came to a similar result of their study: Increases in CO_2 and consequent increases in leaf area index and stomatal resistance increased crop yield and water efficiency, lessening and negative impacts of changes in temperature, precipitation, vapour pressure and solar radiation and amplifying their positive effects.

Mearns *et al.*. (1997) tested the sensitivity of the CERES-Wheat model to combinations of mean and variability changes of temperature and precipitation for two locations in Kansas. With a 2 degree C increase in temperature with daily (and interanual) variance doubled, yields were further reduced compared to the mean only change. In contrast, the negative effects of the mean temperature increase were greatly ameliorated by variance decreased by one-half.

Alexandrov (1997) studied the vulnerability of agronomic systems in Bulgaria. Global circulation model (GCM) scenarios and incremental scenarios for Bulgaria were created and applied. The influence of climate change on potential crop growing season above a base of five degree and ten degree C in Bulgaria was investigated. Increases in temperature can be expected to lengthen the potential growing season, resulting in a shift of thermal limits of agriculture in Bulgaria. Winter wheat yields decreased with increasing temperatures and decreasing precipitation.

Lal *et al.*. (1998) in their Indian study found out that a three degree C rise in air temperature nearly cancels out the positive effect of enhanced CO_2 on the wheat yields. They compared rice to wheat: while the wheat crops are found to be sensitive to increase in maximum temperature, the rice crops are vulnerable to increase in minimum temperature.

Peiris *et al.*. (1996) study on modelling climate, CO_2 and management impacts on sail carbon in semi-arid agroecosystems. They have studied the impact in Scotland using simulation models for three crops of contrasting developmental type. Wheat is one of these crops (AFR-CWHEAT2): Based on GCM predictions, they used eight scenarios of future climate which combine both temperature and rainfall changes. Current temperature (T-0) and rainfall (R-0) were used as a baseline, and each of T-0 + 1 degree C, T-0 + 2 degree C, T-0 + 3 degree C were used with rainfall unchanged at R-0, and increased by seasonally adjusted amounts ranging from 0 to 1.5 mm per wet day. Increased temperatures increase crop development rate which shortens the growing season for wheat.

A3.2.4 Water (stress/drought)

Nonhebel's study (1996) took water into account as far as the model simulated and the water-limited crop production as a base for this study . When water was limiting crop-production effects of temperature rise and higher CO_2 levels were different than for the potential production.

Both rise in temperature and increase in the CO_2 concentration reduced water requirements of the crop. Water shortages became smaller, leading to a reduction in inter-annual variability. It is concluded that when no major changes in precipitation pattern occur a climate change will not affect wheat yields since negative effects of higher temperatures are compensated by positive effects of CO_2 enrichment.

In their MINK study, Easterling *et al.*. (1993) came to the result that irrigated wheat production increased with elevated CO_2 while production of dryland wheat was unaffected.

Brown *et al.*. (1997) had a closer focus on water in their study on sensetivity of crop yield and water use. Increases in temperature accelerated the phenological development for all crops, shortened time to maturity, lowered yields, and decreased water use efficiency. Changes in precipitation and vapour pressure affected crop yield and water use by altering the degree of water stress experienced by the crop. For all crops, changes in precipitation and vapour pressure were positively correlated with changes in yield.

Lal *et al.*. (1998) came to the following result for the future situation in India: in general, acute water shortage conditions combined with thermal stress should adversely affect the wheat in north-west India even under the positive effects of elevated CO_2 in the future.

In their Scottish study, Peiris *et al.*. (1996) concluded that rainfall of an amount suggested in the study do not have an effect the yield of spring wheat, but winter wheat yields are reduced, due to leaching. Changes in variability in wheat was less pronounced and tended to reflect the increase in variability which was assumed to accompany the increased rainfall.

A3.2.5 Diseases and pests

Only few studies focus on pests and diseases in relation to a climate change. However, this aspect that is indirectly effected by a climate change is by all means as important as direct variables of a changing climate (i.e. temperature, CO_2, water, solar radiation):

Regarding diseases, Chakraborty *et al.*. (1998) highlighten this factor that is always not taken into account: carbon-dioxide and pests. They give an overview of projected changes in Australia climate and current state of knowledge on the effect climate change on plant diseases. Based on an assessment of important diseases of wheat and other cereals, climate change in Australia may reduce, increase or have no effect on some diseases. Impacts will be felt in altered geographical distribution and crop loss due to changes in the physiology of host-pathogen interaction. Changes will occur in the type, amount and relative importance of pathogens and diseases. Host resistance may be overcome more rapidly due to accelerated pathogen evolution from increased fecundity at high CO_2 and/or enhanced UV-B radiation. However, uncertainties about climate change predictions and the paucity of knowledge limit our ability to predict potential impacts on plant diseases. Both experimental and modelling approaches are available for impact assessment research. As the development and implementation of mitigation strategies take a long time, more research is urgently needed.

A3.3 Sugar beet

Effects on sugar beet (Beta vulgaris L.) of current and elevated CO_2 and temperature alone and in combination and their interactions with abundant and deficient nitrogen supply (HN and LN, respectively) have been studied in three experiments in 1993, 1994 and 1995 in the study of Demmers-Derks *et al.*. (1998): Averaged over all experiments, elevated CO_2 (600 mu mol mol(-1) in 1993 and 700 mu mol mol-l in 1994 and 1995) increased total dry mass at final harvest by 21% (95% confidence interval (CI) = 21, 22) and 11% (CI = 6, 15) and root dry mass by 26% (CI = 19, 32) and 12% (CI = 6, 18) for HN and LN plants, respectively. Warmer temperature decreased total dry mass by 11% (CI = - 15, - 7) and 9% (CI = - 15, - 5) and root dry mass by 7% (CI = - 12, - 2) and 7% (CI = - 10, 0) for HN and LN plants, respectively. There was no significant interaction between temperature and CO_2 on total or root dry mass. Neither elevated CO_2 nor temperature significantly affected sucros concentration per unit root dry mass. Concentrations of glycinebetaine and of amino acids, measured as alpha-amino-N, decreased in elevated CO_2 in both N applications; glycinebetaine by 13% (CI = - 21, - 5) and 16% (CI = - 24, - 8) and alpha-amino-N by 24% (CI = - 36, - 11) and 16% (CI = - 26, - 5) for HN and LN, respectively. Warmer temperature increased alpha-amino-N, by 76% (CI = 50, 107) for HN and 21% (CI = 7, 36) for LN plants, but not glycinebetaine.

A3.4 Potato

A3.4.1 Carbon dioxide

Bezemer *et al.*. (1998) examined the log-term effects of elevated CO_2 (ambient + 200 mu mol/mol) and temperature (ambient + 2.0 degrees C) on plant chemistry, the abundance of the peach potato aphid Myzus persicae, and on the performance of one of its parasitoids Aphidius matricariae. Model terrestrial ecosystems were set up in the Ecotron controlled environment facility. Total above-ground plant biomass at the end of the experiment was not affected by elevated atmospheric CO_2, nor were foliar nitrogen and carbon concentrations. Aphid abundance was enhanced by both the CO_2 and temperature treatment. Total above-ground plant biomass at the end of the experimentwas not affected by elevated atmospheric CO_2, nor were foliar nitrogen and carbon concentrations.Aphid abundance was enhanced by both the CO_2 and temperature treatment. Parasitism rates remained unchanged in elevated CO_2, but showed an increasing trend in conditions of elevated temperature. Their results suggest that Myzus persicae, an important pest of many crops, might increase its abundance under conditions of climate change.

Miglietta *et al.*. (1998) carried out a FACE (Free Air CO_2 Enrichment) experiment on Potato (Solanum tuberosum L., cv. Primura) in 1995 in Italy. Three FACE ring were used to fumigate circular field plots of 8m diameter while two rings were used as controls at ambient CO_2 concentrations. Four CO_2 exposure levels were used in the rings (ambient, 460, 560 and 660 mu mol mol-l): Crop phenology was affected by elevated CO_2, as the date of flowering was progressively anticipated in the 660, 560, 460 mu mol mol(-1) treatments. Crop development was not affected significantly as plant height, leaf area and the number of leaves per plant were the same ib the four treatments. Elevated atmospheric CO_2 levels had, instead, a significantly effect on the accumulation of total nonstructural carbohydrates (TNC = soluble sugars + starch) in the leaves during a sunny day. Specific leaf area was decreased under elevated CO_2 with a response paralleled that of TNC concentrations. This reflected the occurance of a progressive increase of photosynthetic rates and carbon assimilation in plants exposed to increasingly higher levels of atmospheric CO_2. Tuber growth and final tuber yield were also stimulated by rising CO_2 levels. When calculated by regression of tuber yield vs. the imposed levels of CO_2 concentration, yield stimulation was as large as 10% every 100 mu mol mol(-1) increase, which translated into over 40% enhancement in yield under 660 mu mol mol(-1): This was related to a higher number of tubers rather than greater mean tuber mass or size. Leaf senescence was accelerated under elevated CO_2 and a linear relationship was found between atmospheric CO_2 levels and leaf reflectance measured at 0.55 mu m wavelength. We conclude that significant CO_2 stimulation of yield has to be expected for potato under future climate scenarios, and that crop phenology will be affected as well.

A3.4.2 Diseases

The impact of climate warming on yield losses caused by potato late blight and on the need for disease control was studied by constructing models for timing late blight epidemics and a model of potato growth constrained by late blight by Kaukoranta (1996): Empirical models predicting the date of planting and emergence of potato were based on thermal time, and a model predicting the date of late blight outbreak was based on thermal time on rainy days. Experiments were conducted over 3 years under ambient and elevated (+3 degree C) temperatures to obtain parameter values for the growth model. Potato emergence is predicted to occur at 631 degree days accumulated above 0 degree C after the 16-day running mean temperature in spring exceeds 0 degree C. A blight outbreak is predicted to occur when the effective temperature sum accumulated above 8 degree C after potato emergence, on days with at least 0.1 mm of precipitation, achieves 156 degree days. In the prediction of the outbreak the maximum daily accumulation of temperature is limited to 10 degree days. A preliminary sensitivity study carried out at one site in southern Finland suggests that over a range of 1 to 3 degree C warming, the period during which late blight needs to be controlled by fungicide applications would be 10-20 days longer per 1 degree C of warming. The increase in yield loss of unprotected crops would be of the same magnitude as the increase in yield potential, around 2 t/ha of dry matter per 1 degree C of warming.

Results are presented of a modelling study to estimate the regional suitability and potential productivity of selected crops in Finland under a changing climate by Carter (1996): Model simulations were conducted across a regular 10 km grid over Finland for various cultivars of the following crops: spring wheat, barley, oats, potato and maize, and for two nematode pests and a fungal disease of potato. Models were run for both the present-day (1961-1990) climate and scenarios of future climate. Results are presented as maps. The main findings of the study are: (1) A warming of the climate induces shifts in the northern limit of cereal suitability of some 100-150 km per degree C. (2) Changes in climate and carbon dioxide concentration by 2050 are estimated to enhance average grain yields of present-day barley cultivars in all regions. (3) Under projected warming, the potential distribution of nematode species expands northwards and additional generations of some species are likely. The risk of late blight occurrence increases in all regions. (4) By 2050 grain maize could be cultivated reliably in favourable regions of southern Finland, and satisfactory yields obtained. (5) Uncertainties surround all estimates, including uncertainties in projections of future climate, model errors and assumptions and observational errors.

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