

Impacts of changes in climate and socio-economic factors on land use in the Rhine basin: projections for the decade 2040-49

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Abstract

The purpose of this study was to develop land use projections for the middle of the next century. To separate the influence of climate change from other factors on land use, projections (a Central Projection and two variants) were made under both unchanged and changed climate. They cover the plausible range of alternative land claims of agriculture and urbanization. Impacts of climate change on land suitability as well as overall changes in the acreages of several land use categories are presented.

1. BACKGROUND AND OBJECTIVES

Expected climate change might have a great impact on the discharge pattern of the river Rhine with consequences for agriculture, fresh-water supply, shipping, etc [1]. In addition to the direct effects of changes in temperature and precipitation, changes in land use may also affect the discharge regime through, for instance, changes in water extraction patterns over the season and shifts in the area of arable land.

The current study is a contribution to the Climate Project of the International Commission for the Hydrology of the Rhine (CHR). At the request of of the Institute for Inland Water Management and Waste Water Treatment (RIZA), land use projections for the middle of the next century based on biophysical and socio-economic analyses were developed. Several projections were constructed for both unchanged and changed climate. Results will be used by hydrologists examining the possible consequences of changes in climate and land use for the discharge regime of the river Rhine.

This paper presents some of the results from the Rhine basin study on land use projections, prepared by the DLO Winand Staring Centre [2-5]. The specific objectives of the Rhine basin study were:

- to subdivide the Rhine basin into biophysically differentiated land types (current and future climate/soil/terrain combinations);
- to calculate production potentials and associated water use of major crops (and forest types) for the predominant biophysical land types;
- to assess actual land use;
- to construct different projections of land use for the decade 2040-49: (a) without climate change, i.e. driven by socio-economic factors only, and (b) with climate change, i.e. driven by both climate change and socio-economic factors.

2. APPROACH

The impact assessment approach combines results from biophysical and socio-economic analyses at various stages of constructing the projections.

2.1 Land suitability, crop yields and water use

First, a biophysical classification system for the Rhine basin was designed, combining a bioclimatic classification adapted for present and possible future climates and a soil/terrain suitability grouping integrated in a geographical information system [2]. Subsequently, potential yields and water use were simulated for both unchanged and changed climate for the predominant biophysical land types and crops [3,4]. Under changed climate we refer to Table 1 and a CO₂ concentration of 560 ppmv, based on a Business-as-Usual emission scenario [6], best estimate (BaU-best) as interpreted by [7] for the decade 2040-49.

Table 1
Expected changes in temperature and precipitation applied to the entire Rhine basin

	Spring	Summer	Autumn	Winter
Temperature (°C)	+1.75	+1.50	+1.75	+ 2.00
Precipitation (%)	0.00	0.00	0.00	+10.00

2.2 Construction of land use projections

For thirteen administrative regions, actual land use data were obtained from the latest land use statistics [5]. Based on analysis of technical restrictions, historical-trend analysis and basic assumptions regarding technical, political, demographic and political factors, a trend projection was carried out, the Central Projection of land use for both unchanged and changed climate. As much uncertainty occurred with respect to the basic assumptions, two variants to the Central Projection were constructed. The Plus Variant combines the highest claims of urbanization and agriculture, and the Minus Variant represents the lowest claims [5]. In constructing the projections it was assumed, that land use in the long run is demand-induced, and that claims on land of the various demand categories follow an explicit hierarchy:

1. Urban land needs (including nature claims formulated in official policy plans)
2. Agriculture
 - 2.1 Outdoor horticulture, permanent crops
 - 2.2 Root crops
 - 2.3 Cereals and oil-seeds.
 - 2.4 Grassland and fodder crops
3. Forestry & nature

The rationale behind this 'hierachy' is to be found in the price of land paid by these different land use categories and, for agriculture, in the profitability (per ha) of the various crops and in their land quality requirements.

3. RESULTS AND CONCLUSIONS

An increase in CO₂ concentration to 560 ppmv combined with increased temperature and little change in precipitation (Table 1) does not curb crop yields, but improves the conditions for cultivating crops and tree species presently grown. Under baseline climate some ninety biophysical land types have been distinguished in the Rhine basin. Each of them is characterized by soil and terrain characteristics, three temperature characteristics and precipitation [2]. Shifts in their compositions, locations and acreages are considerable under changed climate. One illustrative example is type C2, L-mc/c4, characterized by soil/terrain group C2 and bioclimatic type L-mc/c4. In soil group C2, orthic Luvisols and eutric Cambisols are clearly predominant and the average slope of land is less than 25 %. The bioclimatic type is characterized by 9.0-9.9 °C annual mean temperature (L-), a mean annual temperature amplitude of 16.0-17.9 °C (mc), January mean temperature of 0.0-1.4 °C (c) and 600 - 799 mm mean annual precipitation (4). Under baseline climate, this biophysical land type covers 6426 km², i.e. about 3% of the total Rhine basin area, mainly found in France-Est, the Neckar region, Hessen and Nordrhein-Westfalen. Under changed climate (BaU-best), its area is reduced to 45 km², as soil group C2 located in France-Est, etc. then combines with warmer and less continental climates. In other areas with soil group C2 occurring (e.g. Alpenvorland), future temperature and/or precipitation conditions do not meet the criteria (L-mc/c4). Table 2 illustrates changes in average rainfed potential yields and water use of winter wheat for predominant soil/terrain/climate combinations.

Table 2

Selected biophysical land types (as defined in [2]) and associated simulated yields (rainfed potential yields) and crop evapotranspiration of winter wheat under baseline and changed climate (scenario BaU-best, 2040-2049)

Biophysical land type		Grain yield (t/ha DM)		Evapotranspiration (mm)	
baseline	changed c.	baseline	changed c.	baseline	changed c.
C1, Umc/d2	C1, Mmc/d2	8.7	11.1	391	346
C2, L-mc/d2	C2, L*mc/c2	8.0	10.1	398	343
C2, L-mc/c4	C2, L+m/b4	7.0	10.0	386	341
B, L-m/c4	B, L+m/b3	5.8	8.3	328	291
B, Umc/d3	B, Mmc/d3	7.5	10.0	361	334
B, Mmc/c3	B, L*mc/b3	6.2	8.7	343	309
B, L-mc/c4	B, L+m/b3	5.5	8.2	319	287
B, Mcm/d4	B, L*cm/c4	5.0	9.6	320	294
C2, L-m/b4	C2, L+m/a4	7.7	10.6	368	320

Table 3 summarizes the overall land use changes in the Rhine basin. It is mainly the acreage of cereals (including oil-seeds) leading to decreases in agricultural area: in the

Central Projection (CP) and the Plus Variant areas under these crops will be halved. In the Minus Variant the decrease ranges from 62% (unchanged climate) to 66% (changed climate). Climate change according to the BaU-best scenario adds a surplus (some $0.2 * 10^6$ ha) in comparison with unchanged climate, thanks to higher agricultural yields.

Table 3

Projected changes in urban and agricultural land use (10^6 ha), decade 2040-49, under baseline and changed climate (scenario BaU-best) in the CP and two variants (Source: [5])

	Central Proj.		Minus Variant		Plus Variant	
	basel.	ch.cl.	basel.	ch.cl.	basel.	ch.cl.
agric	-1.57	-1.83	-2.67	-2.84	-1.26	-1.52
urban	+0.68	+0.68	-0.18	-0.18	+1.39	+1.39
total	-0.89	-1.15	-2.85	-3.02	+0.13	-0.13

The given explorations of future land use are largely "status quo-oriented". No surprising dynamics in climate, economic conditions or consumption patterns, to name a few, are taken into account. Therefore, we may conclude that changes in the order of -0.18 to $+1.39 * 10^6$ ha for urban land use and -2.84 to $-1.26 * 10^6$ ha for agricultural land use can be expected, if climate change, biophysical impacts and socio-economic factors develop as described by [2-5]. Projected conversions of agricultural land into built-up area on the one hand and into secondary forest, grassland or a mix of the two on the other would have distinct impacts on the discharge regime of the river Rhine. Most favourable in hydrological terms (reduced run-off) appears to be the Minus Variant.

4. REFERENCES

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