1.4 Land Cover

Every part of the earth's surface has a characteristic type of land cover. This can vary from the completely sealed surfaces of urban areas and roads to marshes, salt meadows, and the open sea. In Germany the largest area is covered by agriculturally used land and forested regions. Vegetation is of vital importance for land cover and its effects on hydrological and ecological processes.

Land cover has a significant effect on the water, matter, and energy balances of a region and controls essential processes in the environment. It affects the following:

- *runoff*; i.e. the division of precipitation into interception (storage on plant surfaces) and evapotranspiration, overland flow, and seepage into the ground.
- *processes of matter removal* (soil erosion, washing away of matter, leaching).
- the impact of ecological processes and environmental influences, e.g. the effects of airborne pollutants on ecosystems; the application of fertilisers and chemicals to fields and meadows; smog in urban zones; negative repercussions from mining sites and dumps.

Land cover strongly affects the water balance in the long term, as well as the processes of runoff formation (in the short term). For example, when comparing woodland to farmland, to fields under permanent grass, or to urban zones, in wooded areas more water is held by plant cover and evaporation is higher, but runoff and ground water creation is lower. Land cover has an even greater impact on the removal of matter because this occurs almost exclusively through the passage of water both above and below the surface of the soil.

Land cover in turn is determined by ground characteristics and by precipitation and temperature conditions, thus constituting an integrating element. Favourable natural conditions, access to transportation channels like waterways and old trade routes, and strategic geographic advantages all greatly influenced the choice of settlement location and the expansion of cultivated areas over the course of historical development.

The type of cover and the initial moisture content and infiltration rate determine how much water flows away on the surface during rainfall. In Germany, arable land is at most risk from erosion, since the soil remains uncovered between crops.

The average actual evapotranspiration level (Atlas Map 2.13) of a ground – plant – atmosphere system depends on the land cover, the type of vegetation, annual distribution of precipitation (Maps 2.2 to 2.6), the soil water available to the vegetation (Map 4.3), and annual potential evapotranspiration (Map 2.12). In urban areas, evaporation decreases as sealed surface increases.

The type of land cover is significant for the further division of underground runoff into faster and slower runoff components in drained soils only. Nonetheless, the anthropogenic use – which brings us to the term of *land use*, often applied interchangeably with land cover – frequently also has undesirable effects on the water balance and the flows of matter in the regions under use: agricultural use generally introduces additional nutrients. Underneath cultivated areas, the concentration levels of nutrients and pollutants can be considerable; drained areas have particularly high runoff rates, and vast amounts of substances are transported. Natural marshlands have high evaporation and the nutrients nitrogen and phosphorus are deposited in the peat; when drains or ditches are built to remove water from such regions, the conditions change, runoff from the area increases, and the humus and nutrients accumulated in the soil are broken down or washed out. Dredging or otherwise deepening rivers to improve navigability also has a draining effect on the adjacent landscape. A sizeable amount of badly or wholly untreated precipitation, carrying nutrients and pollutants with it, flows off sealed urban surfaces directly into bodies of water.

How landscape developed: a brief history

After the last Ice Age an unbroken forest extended over central Europe. The extensive, natural forest vegetation very largely prevented surface runoff and erosion processes. With the spread of human settlements and improving weather conditions, the clearing of forested areas for cultivation increased. During the Roman Empire, land used for farming would already have occupied a considerable area in Germany. Then, at the time of the mass migrations, the forests almost completely recovered to their original extent.
A rough estimate of land cover development since the early Middle Ages until the present is illustrated in Figure 1. It is based on church archives, numerous soil studies, and diverse interdisciplinary cause-and-effect analyses of historical landscape development.
In the 7th century AD several plague epidemics decimated the population; therefore, this period was probably when forests constituted the largest share of land cover (approx. 90 %) while the smallest share (less than 10 %) was in agricultural use. After this, the amount of farmland steadily expanded, reaching 80 % in the early 14th century; this was accompanied by an equally expanding population (up to 11.5 million inhabitants in Germany and Scandinavia around 1340). The forests were overused for firewood and grazing. Weather extremes, famine, epidemics (the plague), and war caused population figures to collapse. By 1430 the proportion of forested land had risen again to about 45 %, which was the last time it reached a peak. As the population resumed growing, lands were again cleared of trees and used for farming. Up to the present day, the amount of land in agricultural use has remained below the 14th century level.

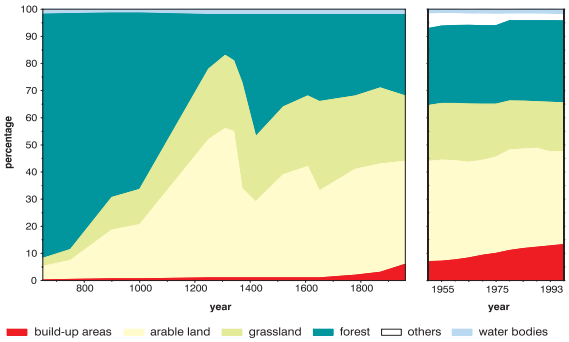

Fig. 1 The development of land cover in Germany since the early Middle Ages (area within present-day borders without the Alps, according to BORK et al. 1998)

Using the surveys of the Statistisches Bundesamt (STBA, Federal Statistical Office), which have now become a continuous activity, developments in land cover can be observed; for example, the actual type of land use based on the real-estate register and agrarian statistics. Such statistics are used in a variety of applications, e.g. for the land use statistics of the Bundesamt für Bauwesen und Raumordnung (BBR, Federal Office for Building and Regional Planning) in its ongoing regional observations. More precise figures and development trends can be deduced from the data collected. Accordingly, the amount of land surface that has been sealed over for settlements and roadways has increased from 7 % in 1950 to 13.3 % in 1997, to the detriment of areas that had been in agricultural use or in a natural state (or nearly so). The data of the BBR indicates this trend will continue especially in the new states, with more intense construction work and consolidation of the infrastructure. Based on currently valid assumptions, the additional surface claimed for urban purposes is predicted to be between 100 and 120 ha daily.

Map Structures

Since the end of the 1980s, the European Union (EU) has developed a classification guideline (TECHNICAL GUIDE 1994) as well as a collection method for land cover data within the CORINE Programme (Co-ORdination of Information on the Environment) that takes environmental concerns into account. The data survey that the Federal Statistical Office carried out in Germany was sponsored by the environmental research plan of the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), the Umweltbundesamt (UBA, Federal Environmental Agency) and the European Union (EU).

As a primary source of information for the survey, images obtained by the LANDSAT TM (Thematic Mapper) satellite sensor system during vegetation periods from 1989 to 1992 were evaluated. This was supplemented by data from topographic maps at scales of 1 : 100,000 (TK 100) and 1 : 50,000 (TK 50), and by panchromatic aerial images at a scale of 1 : 70,000 to determine land cover (Fig. 2). The survey scale was 1 : 100,000, which includes surfaces at least 24 ha in size and linear objects such as rivers, roadways, etc., that are at least 100 m wide. To complete previous surveys, the geographic characteristics of the surface have been entered into a geographic information system. This means the land cover can be correlated with other physical data. The survey is planned to be repeated at ten-year intervals.

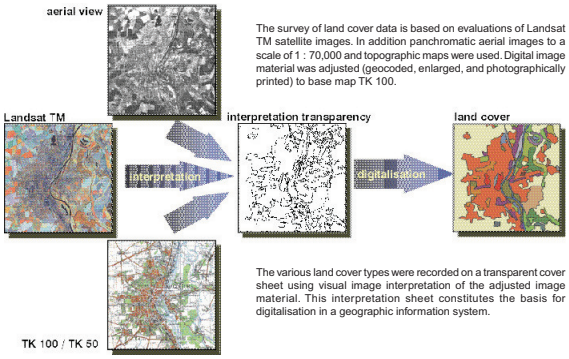

Fig. 2 Additional input data to improve land cover data for Germany based on CORINE Land Cover satellite data

Classification into a total of 44 types of land cover for Europe, aside from a division into main uses such as built-up areas, agricultural zones, woodland, and bodies of water, also takes into consideration other categories that are essential to nature and landscape conservation. There are 36 such types in Germany. For representation in the Hydrological Atlas, those categories of land cover that are hydrologically similar have been combined. The resulting 11 hydrologically relevant categories and their land cover types according to CORINE have been more fully described on the legend page, and are represented together with their share of the total surface. In addition, Figure 1 on the legend page illustrates the proportion each category represents in the major river basins of Germany.

Due to the high runoff coefficients of built-up areas, and the high concentration of nutrients and pollutants on arable land, both zones are of particular hydrological interest regarding high-water runoff. In the catchment areas of the Baltic Sea and of the Ems, Elbe (region of the Saale and Mulde Rivers), and Odra Rivers, arable land represents the greatest share of overall land use. In the catchment areas of the North Sea, the Danube, and the Rhine, the proportion represented by arable land is below the average. The catchment areas of the North Sea and Danube show a large share of grassland. This is less so in the catchment area of the Saale, Mulde, and Odra Rivers. A relatively large surface particularly in the catchment areas of the Rhine and Danube is wooded; conifers predominate in the Danube area, while woodlands in the Rhine zone are deciduous or mixed. There is little woodland in the north German river zones near the North and Baltic Seas and the Ems River. The Rhine catchment area, especially along the Neckar and Moselle Rivers, shows a higher percentage of permanent plantations (particularly vineyards) as compared to other regions. This is of importance considering the high pesticides application rates in permanent plantations. Within the German river basins, the Rhine and the Maas present a larger proportion of built-up areas, whereas the regions along the North and Baltic Seas and the Danube have relatively little urbanisation. The marshlands that border the North Sea lead to a higher proportion of wetlands within the catchment areas of the North Sea and the Ems River.

Practical Information

The original records on Germany's land cover and a detailed description, Land Cover in Germany, are available from the Federal Statistical Office as a CD-ROM.
Comparisons with other statistics showed that the amount of agriculturally used surface had been slightly overestimated, whereas built-up areas had been slightly underestimated. This is due to the limits to identification mentioned above, but also to deviations among the classification methods used. For example, small settlements (less than 25 ha) and isolated farms were not distinguished as such but fell within the category of the surrounding land.

The presented selection of hydrological categories and the classifications only comprise one possible solution, which should be tested before application to hydrological issues at the general scale. Therefore, using the original records is always recommended. For research covering a small area, further subdividing any hydrological category that appears frequently there may be advisable. For example, evaporation from open spaces is similar everywhere; but runoff will vary widely depending on the surface. While water falling on rocks will flow away over the surface, underground runoff is to be expected beneath beaches, dunes, and surface sand.
Use should be made of any further statistical information on land cover, e.g. to further subdivide the extensive "arable land" category or in determining the varying degrees to which land in urban areas has been sealed over. For further subclassification of agricultural land into distinct crop zones, the major land use surveys should be consulted: the first one was carried out in 1878, and this was renewed since at intervals of approximately ten years. At present, this survey is carried out nationally every four years based on the Agricultural Statistics Act, most recently in the first half of 1999. Livestock counts, which are an important indicator for nutrient-based water pollution, are surveyed every other year in December (most recently in December 1997). The data are available by municipality in most states. Annual harvest estimates are carried out in all districts. How the collected data, which has been rendered anonymously for data protection purposes, can be utilised has been shown by BACH et al (1997). Water and land federations, particularly in the new Federal States, have extensive information on the frequency and location of drainage sites. That information was collected by BEHRENDT et al. (1999) and HUBER (1998), so that observations about the frequency of drainage can be made for every type of natural area in Germany.