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НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

Монография в 5 томах

Том IV Оптимизация сельскохозяйственных ландшафтов

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This monograph shall inform you about up to date methodologies and recent results in landscape research. It is intended as a guide for researchers, teachers, students, decision makers, stakeholders interested in the topic of landscape science and related disciplines. It provides information basis for decision makers at various levels, from local up to international decision bodies, representing the top level of landscape science in a very short form.

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ABSTRACT. Protecting water (and soil) resources has a high priority in Austria. As irrigation is necessary in several regions, the Austrian legislative authorities demand high standards with respect to agricultural irrigation. The basic laws are the Austrian Water Rights Act, the Austrian Food Book, and the Austrian Drinking Water Ordinance. To provide a clearly arranged excerpt of the relevant laws, the Austrian Water and Wastewater Association and a group of experts released guidelines for irrigation, focusing on qualitative, quantitative and technical aspects. This chapter outlines important aspects of these guidelines. Above all, irrigation water has to fulfil physical, chemical, and hygienic criteria, mainly to avoid threatening human health. Furthermore, irrigation management should be oriented on plant water requirements as well as soil properties to facilitate optimal plant growth and at the same time avoid water losses. A key instrument to conserve water resources are water rights, which can be granted based on the strict targets of the Austrian water law.

 KEYWORDS: agriculture, irrigation, water resources, water quality, plant water requirements, technical aspects

INTRODUCTION

The predominant part of the Austrian territory is characterized by the Alps and forests. About 2.8 million ha – representing 35 % of the total area – is agricultural land, of which 55 % are cropland and 45 % are pasture. Cropland is principally distinguished by fertile soils and suitable environmental conditions. A main advantage for crop production is Austria’s positive water balance, exemplified by the fact that the amount of water leaving the state territory (910 mm) is larger than the amount entering (310 mm) [1]. The main reason are large rainfall amounts across the Alps, which contribute substantially to the mean annual precipitation of 1100 mm. Additionally, Austria has large storage capacities in terms of glaciers, rivers, lakes, and groundwater bodies.

Nevertheless, also regions exist where rainfed agriculture is difficult or uneconomic, and thus additional water supply through irrigation becomes necessary. This applies for the eastern part of Austria, where a subhumid climate supports crop production, but lack of rainfall might become a restricting factor for many crops. In total, approximately 110,000 hectares are designated as irrigable area, of which 30 to 50 % are irrigated irrespective of the actual rainfall. The average (40,000 hectares) amounts to an annual water consumption of 28 million m³ with an average water supply of 70 mm per hectare. In this regard, it
is obvious that water resources might be threatened in terms of quantity and – due to unintended leaching of nutrients towards groundwater – quality.

In general, protecting water (and soil) resources has a high priority in Austria. The Austrian Water Act [2] strictly regulates use and protection of water. As a specific measure, the Austrian Water and Wastewater Association (OeWAV) and a group of experts released guidelines for irrigation focusing on qualitative, quantitative and technical aspects. The following paragraphs intend to outline these guidelines, including irrigation from groundwater and surface waters, but not considering treated and untreated wastewater.

CRITERIA FOR GOOD IRRIGATION WATER QUALITY

To achieve sufficiently high and stable yields as a basis for food production, it is necessary to supply plants with both water and nutrients. In areas with insufficient or unfavorable rainfall, irrigation is an essential part of efficient land management. Since foods must conform to high quality criteria, the application of irrigation water must not affect human health – neither directly nor indirectly. Quality-specific criteria of irrigation water can be determined as physical, chemical and hygienic water properties.

**Physical criteria:** With respect to plant-physiology, the optimal water temperature is between 20 and 25°C. For drip irrigation systems, in particular, suspended particles (inorganic or organic) in the utilized water should be less than 100 mg·l$^{-1}$, and dissolved substances should be less than 2000 mg·l$^{-1}$ [3].

**Chemical criteria:** Chemical substances acting as nutrients are typically separated into main components (calcium, magnesium, sodium, potassium) and minor components (trace elements such as aluminum, cadmium, iron, manganese, nickel, mercury, and zinc). While such substances are essential for plant development, excessive (cumulated) amounts may threaten human health. Therefore, the pollutant levels in irrigation water have to be low enough to guarantee that plant parts intended for human consumption do not exceed the critical values as defined by the Austrian Food Book [4]. A straightforward method to determine whether irrigation water contains critical amounts of substances is to measure electrical conductivity (EC), which corresponds to salt content. In this regard, EC-values of the irrigation water between 250 and 2250 μS·cm$^{-1}$ (at 25°C) indicate that moderately salt-sensitive and moderately salt-tolerant plants can be irrigated [5]. Wheat and sugar beet, for instance, are relatively salt tolerant, while maize is much more sensitive to salt content; vegetables like turnip, spinach and tomato are more salt-tolerant than salad, onion, carrots and beans [3]. Furthermore, carbonate, hydrogen carbonate, chloride, nitrate, boron, and trace elements must not exceed certain concentrations in irrigation water.

**Hygienic criteria:** Health damage can be caused by acute or chronic pollutants and pathogens. Since fruits from agriculture and horticulture are sometimes irrigated just before harvest, even pathogens with short survival times can pose a threat to human health when they get in contact with the surface of fruits or other parts of the plant. For this reason, irrigation water must not contain pollutants and pathogens in concentrations threatening human health.

Of the pathogens, mainly those with a fecal-oral pathway of infection are of importance. Contaminated with human or animal fecal matter, they enter the environment and thus water, and can trigger infections by oral ingestion, contact or inhalation of aerosols. Disease pathogens are bacteria, viruses and parasites. An overview and detailed information can be found in the WHO Directive [6]. The presence of viruses in river water is described by WALTER et al. [7].

From a hygienic point of view, irrigation water is categorized based on colony forming units (CFU) of Escherichia coli and enterococci. The four categories are (i) groundwater, (ii) slightly contaminated ground- and surface water, (iii) moderately contaminated surface water, and (iv) highly contaminated surface water. The respective limits for Escherichia coli are (i) $\leq 5$, (ii) $\leq 200$, (iii) $\leq 2000$, and (iv) $\leq 15000$ CFU·(100 ml)$^{-1}$.

To achieve the quality requirements of a certain quality class, adequate measures can be taken in the sense of risk management. That is, for example, improved protection of the catchment area, elimination or reduction of fecal sources, optimized pumping or disinfection measures. When using disinfection methods, the requirements of the Austrian Food [4] must be considered with regard to operation and monitoring. In the case of chemical disinfection measures, the planting toxicity of the disinfectant and those of the possible disinfecting by-products are to be taken into account.

Before using water for irrigation, at least one previous examination of the physical, chemical, and microbiological parameters is necessary. Water used for washing and cleaning vegetables and fruits has to comply with the microbiological requirements of the Drinking Water Ordinance [8], at least during the last cleaning cycle. In Austria, irrigation water is mainly extracted from groundwater that typically fulfills the requirements of drinking water. Therefore, irrigation water is generally regarded as unproblematic.
Drinking water from a public water supply system is definitely suitable for irrigation purposes from a hygienic point of view; additional examinations are not necessary in this case.

**QUANTITATIVE ASPECTS**

Beside qualitative aspects, it is necessary to quantitatively protect Austria’s water resources by saving water. With regard to optimal plant production this means to apply water at times it is needed by the plants, and to apply sufficient amounts without overcharging the water holding capacity of the soil.

**Plant water requirement** depends on the type of crop, its development stage, and weather conditions. As a rule, the water demand increases with the development of the plant until the reproductive phase is reached, and then decreases until maturation. The water is used for biomass production, for nutrient transport and for cooling of the plant tissue. Reduced water supply can cause a reduced metabolism, wilting, and irreparable damage. The underlying physical processes are described as evaporation – the process of water transport from the soil to the atmosphere – and transpiration – the process of water transport through plants to the atmosphere. The actual evapotranspiration (ET) rate results from energy input (mainly due to global radiation) and vapor pressure deficit (driven by air temperature, air humidity, and wind velocity).

**Plant available soil water:** As a porous medium, soil is storing water and making it available for plant uptake. Precipitation replenishes soil- and ground water. Irrigation is generally necessary if the water stored in the rooting zone does not sufficiently meet plant water requirements. The plant available water storage depends on soil type (soil texture), available pore space (soil structure), soil and rooting depth. Coarse pores can contain large amounts of water, but the capillary forces are weak, so the water can easily drain towards groundwater. In fine pores, larger tensions prevail, holding the water against gravity, but making it less available for root uptake. The water potential or pF-value describes the energy of water at a certain point in the soil. Depending on the soil (hydraulic) properties, each energy status corresponds to certain soil water content. The latter refers to the volume of water related to a specific volume of soil. A soil-specific retention function or pF-curve describes the relationship between water potential and water content. The water content ranges theoretically from saturation and complete dryness. Under natural conditions, however, it is rather between field capacity (FC) and permanent wilting point (PWP). Field capacity is usually referred as the water content at a soil matrix potential between 0.06 and 0.33 bar (pF = 1.8 to 2.5). As a rule of thumb, this corresponds to the condition in a natural soil two to three days after intensive wetting. Plants can withdraw the soil water only to the permanent wilting point, which is usually assumed at 15 bar (pF = 4.2). The water between field capacity and permanent wilting point is referred to as plant available water.

**Irrigation planning and demand-based irrigation scheduling:** For planning irrigation in general, the long-term plant water requirements should be estimated based on available weather data, considering average conditions, but also dry and wet years. Soil conditions have to be considered with respect to storage capacity, but also with respect to infiltration rates. The infiltration determines maximum irrigation intensities to avoid clogging or soil erosion.

The time and duration of irrigation are usually defined subjectively (based on experience) by observing weather conditions (heat, dryness), plant conditions (wilting phenomena) and soil moisture (color, finger sample). A more efficient irrigation scheduling is possible when accessing decision support systems. The latter might include regional and local weather data and weather forecasts as well as information about plant status or soil water content. Some decision-making tools are freely available via various media; others are customized and therefore liable to pay costs. In general, information and forecasts are typically based on measurements or model calculations. Simple (climatic) water balance models, for example, consider only precipitation and evaporation, whereof the latter is usually determined with established ET-models (e.g., after Penman and Monteith, [9]).

A more objective method for on-demand irrigation is based on frequent observations of soil water status. Extracting soil samples and gravimetrically determining water content (weighing – drying – weighing) is a traditional method connected with simple equipment and low costs, but also with a great deal of time. A relatively old technique is represented by neutron probe measurements, which can detect the water content very precisely. However, the equipment is expensive and the measurements are time-consuming and due to the radioactive radiation associated with appropriate safety requirements. A modern alternative are soil water sensors, which measure either the water content or the soil matrix potential in the root area of the plant [10]. For an optimal water supply of the plant, the measured values should move in a certain range. The corresponding switching values depend on soil and plant. Wireless sensors networks for irrigation management are commercially available in Austria, and they are operated in some regions,
mainly in horticulture and viticulture. However, there is still a lot of potential to establish such systems and accordingly improve irrigation management with respect to sustainability.

Figure 1 – Selected irrigation systems operated in Austria (sprinkler with movable pipe system, raingun with mobile reel system, and stationary subsurface drip irrigation), and typical well for groundwater withdrawal

WATER RIGHTS

Withdrawing water from ground- or surface water for agricultural irrigation as well as the construction or alteration of facilities used for this purpose is always subject to the authorization of water rights. The district administrative authority (district management team, municipal authorities) is responsible for approving water rights. If neighboring countries are affected (e.g., border waters), water related issues lie in the responsibility of the government.

Generally, the allowed amount of water must be determined in such a way that public interests and existing rights are not violated. It is important to consider the needs of the applicant as well as the existing water management conditions. In particular, this refers to water availability with respect to quantity and quality. In this context, changing water levels, groundwater recharge and economical use of water have to be considered. When surface waters are involved, their ecological functionality has to be ensured in any case.

According to the water law, all allowances have to be limited to the longest justifiable period of time, balancing the applicant's needs against water-related interests, and considering technical development. In case of larger projects with several owners being involved, the organizational form of water co-operatives has proven feasible. Water co-operatives are bodies governed by public law that are granted legal personality by means of acknowledgment of approval by the water authority. Membership usually requires ownership of a property ahead.

The water right also regulates which documents have to be provided when applying for an approval according to the water law. From a technical point of view, an irrigation facility project in any case requires an application form, a technical report, and planning documents approved by an expert. Comprehensiveness and level of detail of the application documents may be determined by the competent authority depending on the size of the project. In any case, crop water requirements have to be verified, and a plan of the irrigation site illustrating irrigation areas (plots) with crop types and crop rotations, and announcing irrigation seasons. Furthermore, relevant soil information has to be specified regarding storage capacity.

CONCLUSIONS

1. To avoid threatening human health, irrigation water has to fulfil physical, chemical, and hygienic criteria.
2. To guarantee optimal plant growth and at the same time avoid water losses, irrigation management should be oriented on plant water requirements as well as soil properties.

3. To conserve water resources, water rights can be granted based on the strict targets of the Austrian water law.

REFERENCES