Use of Treated Water in Forestry and Agroforestry

Basic knowledge

Global changes in rainfall frequency and quantity are increasing the impacts of drought in arid and semi-arid regions, and such impacts are projected to increase under climate-change scenarios. In water-scarce environments, the safe use of wastewater can be an option for irrigating certain agricultural and forestry crops, helping to conserve freshwater. The purpose of this module is to provide forest and land managers with information on the safe use of wastewater for irrigation and soil amelioration in forestry and agroforestry systems in dry and degraded lands. The module aims at guiding users in planning reforestation and afforestation in drylands through the use of water produced in constructed wetlands and fertigation plants.

Forests and scattered trees in drylands provide a wide range of environmental services, such as soil amelioration and protection from soil erosion and desertification. Forests and scattered trees can supplement farmer incomes as sources of woodfuel, fibre products and fodder. Trees also provide shade for livestock and, when planted in shelterbelts, protect agricultural crops by reducing evapotranspiration and acting as windbreaks.

Trees require soil moisture to grow, and they are often seen as competitors of agricultural crops. With their extended root systems, however, they are able to draw water from deeper in the soil profile, to some extent occupying different environmental niches to annual agricultural crops. Moreover, many trees are less demanding than agricultural crops in the quality and quantity of water they require to survive and grow.

In many regions worldwide, the disposal of wastewater produced by industries, agriculture and urban settlements poses significant challenges. Depending on its origin, wastewater may contain pathogens harmful to human health, such as intestinal worms, bacteria and viruses, as well as salts, heavy metals and poisons.

According to FAO's Aquastat database, only 52 percent of the municipal wastewater produced globally is recycled. Many developing countries have inadequate systems for treating wastewater, and there is a lack of sewage networks and wastewater treatment plants. As a result, large quantities of untreated wastewater are discharged into rivers, seas or, after dispersal on land, into groundwater, causing pollution, soil salinity and a reduction in water quality. In countries with limited freshwater supplies and where effluents are unmanaged, the risk of contaminating soils and groundwater and harming agricultural and forestry production is very high. Conversely, the effective treatment of wastewater can transform a potential environmental threat into an important source of additional water while reducing pollution and improving nutrient recycling. Treated wastewater can be used to increase the production of wood, biomass and food.

To minimize or eliminate the need for pumping (and therefore reduce energy costs), treated wastewater should be used immediately downstream of the wastewater treatment site from which it is discharged. Therefore, the use of treated wastewater in forestry and agroforestry should be integrated into urban and peri-urban areas, where it can contribute to the greening of landscapes and help support local farmers in the production of goods and environmental services.

Planted forests irrigated with wastewater may be established for the production of lumber, pulpwood or woodfuel or for environmental purposes (e.g. soil protection), or integrated with agriculture to produce wood, provide shade and fodder for animals, and protect crops from damaging winds. Not all tree species and tree crops are suitable for wastewater irrigation, and special care must be taken when planting trees for fruit production.

Effective wastewater treatment is essential for maintaining high standards of public health. Untreated wastewater should never be discharged into the environment, and, especially in drylands, the safe use of treated wastewater makes environmental sense. Irrigation with treated wastewater may be expensive because of the costs involved in the establishment and maintenance of wastewater treatment plants and the energy required to treat wastewater. The cost of producing wastewater suitable for use in irrigation is likely to be more than offset, however, by the environmental and public-health benefits of eliminating the discharge of polluted water into the environment and by the increased productivity of irrigated lands.

Using treated wastewater in forestry and agroforestry in drylands contributes to SDGs:

In more depth

The good management of treated wastewater builds on two principles:

1. that safe water is of primary importance for people's health; and
2. that water is a valuable resource and should be allocated to the best practical use.

The safe use of treated wastewater in forestry, agroforestry and peri-urban agriculture improves the water economy in drylands, and it helps protect public health by reducing the risk that harmful pathogens and chemicals will enter the food chain and water resources. Treated wastewater can be used to combat land degradation and to irrigate planted trees and crops, including nurseries; it can also help sustain planted forests in drylands and generate revenue by producing wood, agricultural products and environmental services. The use of treated wastewater in forestry requires the good management of all water assets, the training of involved stakeholders (e.g. workers, farmers, the staff of civil-society organizations, foresters and water experts) and effective landscape planning.

Primary, secondary and tertiary wastewater treatment

There are three basic standards of wastewater treatment. **Primary treatment** involves the removal of settling materials as well as floating oils, greases and light solids. **Secondary treatment** uses microorganisms to process the majority of organic matter and nitrogen and significantly reduce the concentration of pathogens. In **tertiary treatment**, secondary-treated water is disinfected chemically or physically (e.g. through the use of ultraviolet lamps) to make it suitable for landscape irrigation (e.g. recreational parks and golf courses) and to meet commercial and industrial water needs. Water subject to tertiary treatment may also be used for groundwater recharge or agricultural purposes; if subject to natural soil filtration (e.g. filtering through sandy soils), tertiary-treated wastewater can be used in the drinking supply. The tertiary treatment of wastewater tends to be energy-intensive, however.

Most wastewater is treated to the secondary level; secondary-treated water can be used for certain agricultural crops and for the production of fodder and woody crops (but it cannot be used for horticultural irrigation). Trees are well-suited to irrigation with low-quality water: they can work as additional filters to purify polluted water and to mitigate soil or water pollution.

Tree irrigation with treated wastewater can be implemented close to human settlements in urban and peri-urban areas; indeed, close proximity is preferred because it reduces the cost of pumping. A treatment plant serving a village of 5 000 inhabitants is likely to produce about 700 cubic metres of treated wastewater per day. In drylands with high rates of evapotranspiration, this volume is sufficient to irrigate about six hectares of a high-density tree plantation and more than 15 hectares of a low-density tree plantation.

An important issue to consider in drylands is the seasonality of the irrigation requirements of different crop species. The area of a grass crop, for example, should be limited to the extent that it can be fully irrigated during evapotranspiration peaks in summer. In contrast, woody crops can withstand periods of water stress and therefore a larger area can be irrigated.

Wastewater quality and quantity

The inappropriate use of treated wastewater poses risks for humans and ecosystems, and the use of treated wastewater may also be culturally unacceptable. The World Health Organization, the Food and Agriculture Organization of the United Nations and the International Water Management Institute promote and provide guidance on the safe use of wastewater in agricultural systems in the form of guidelines, handbooks and field projects (see Tools).

The use of wastewater should be made as safe as possible to maximize the nutritional and food-security benefits for rural communities whose livelihoods depends on wastewater irrigation. It is essential, therefore, to ensure that all hazards are identified and that preventative measures are taken to minimize the risk of contamination.

According to FAO's Aquastat database, global freshwater withdrawals worldwide are allocated as follows: agriculture (69 percent), industry (19 percent) and urban settlements (12 percent). Much of the water used in agriculture is unrecoverable because it feeds back into the global water cycle through evaporation and infiltration (although an estimated 32 percent is recoverable from agricultural drainage). It is relatively easier to collect and reuse wastewater produced by industries and urban settlements where sewage networks exist. However, most wastewater produced by industries contains pollutants, including heavy metals, and requires additional treatment prior to discharge into ordinary treatment wastewater plants. Urban settlements constitute the most common source of treated wastewater for forestry and agroforestry, although only about 52 percent of urban water is currently recycled.

Wastewater to be used for agriculture and forestry should be treated to at least the secondary level to avoid the risk that foresters and farmers, and consumers of harvested products, are exposed to pathogens present in wastewater effluents, most of which are capable of persisting in soils and contaminating crops. In situations where wastewater is unsuitable or unacceptable for food crop production, its use in forestry and agroforestry systems could be a viable option for reducing risks to human health and recovering some of the cost of wastewater treatment.

It should be noted that, often, unused secondary treated wastewater (as well as untreated wastewater) is discharged into natural freshwater bodies such as rivers and lakes, from which water for agricultural irrigation is extracted. This constitutes a highly risky use of potentially contaminated water.

Use of treated wastewater in dryland agroforestry systems

Treated wastewater is an unconventional resource that may be available even in drylands with scarce surface water and groundwater resources. It can be used, for example, to establish and maintain intensive productive planted forests (for wood production) or for environmental, agricultural and social purposes through the irrigation of, for example, recreational areas, orchards, urban greenbelts, windbreaks, and shade and fodder trees.

The technical feasibility of forest tree cultivation using treated wastewater has been demonstrated in various studies and afforestation programmes. Algeria, Egypt, Iran, Jordan, Morocco, Oman, Saudi Arabia, Sudan, Tunisia, the United Arabian Emirates and Yemen, among others, have all developed wastewater re-use programmes to irrigate greenbelts and woodlots or for sand-dune fixation. Commonly used species in such programmes are multipurpose and fast-growing trees such as *Eucalyptus*, *Casuarina*, *Acacia*, *Pinus*, *Khaya* (African mahogany) and *Tamarix* (see case studies for more information on these programmes).

Two methods for treating wastewater are commonly used in forestry and agroforestry: constructed wetlands, and the selective modular filtering of secondary-treated wastewater.

Constructed wetlands

Bacteria, fungi, algae and plants have all been shown to store and digest composite molecules and heavy-metal pollutants. *Phytoremediation* uses plants such as reeds, weeds, shrubs and trees to treat polluted water and soils and to recover industrial sites contaminated by the discharge of pollutants.

Wetlands work as natural biofilters, removing water sediments through the filtering effects of reeds and marsh plants. Vegetation in wetlands provides a substratum (i.e. roots, stems and leaves) on which microorganisms can grow as they break down organic materials. Plants have been shown to remove 70–90 percent of pollutants from wastewater; they also provide a carbon source for microbes as they decay. Wetlands can remove pollutants, including heavy metals, from wastewater discharged into the environment.

Constructed wetlands are artificial swamps created to purify discharged wastewater through natural filtering. They comprise ponds that grow reeds, shrubs and trees selected for their ability to filter impurities from water. The wastewater settles in a series of connected treatment storage basins and is then discharged in a state suitable for irrigation.

Constructed wetlands are tolerant of fluctuations in hydrological and contaminant loading rates. They are relatively inexpensive to construct and operate and easy to maintain, and they have low or no energy requirements. Constructed wetlands are cost-effective, affordable and sustainable for rural communities in remote dry areas where economic circumstances do not allow the establishment of standard wastewater treatment plants. They produce secondary-treated water suitable for agroforestry systems and tree plantations to produce cash crops, reduce (or prevent) soil erosion, and provide windbreaks, shade and fodder. Constructed wetlands were pioneered in northern Europe and are now being used increasingly in rural villages in arid developing countries.

Constructed wetlands require relatively large areas of land, however, and involve a considerable level of biological and hydrological complexity; their establishment requires considerable skill. Especially when established in drylands, constructed wetlands may deliver relatively lower productivity due to evapotranspiration and infiltration losses, and they may provide habitat suitable for mosquitoes, constituting a health hazard. There is still a lack of knowledge and experience in the use of constructed wetlands in drylands, and there is a need to collect real data for chemical modelling of pollutant removal. The vulnerability of constructed wetland systems to environmental factors such as high winds and sand storms is yet to be assessed.

Selective modular filtering of secondary treated wastewater

The ultimate goal of wastewater treatment is tertiary treatment, which produces water with a sufficiently low content of pathogenic microorganisms to be suitable for human consumption. Tertiary treatment is not always the most efficient way of managing water, however. The removal of all solids and impurities requires significant energy, produces large amounts of sludge (which must be disposed of), and involves the loss of nutrients (such as organic carbon, nitrogen and phosphorus) contained in the organic matter.

New treatment methodologies allow the production of safe secondary-quality wastewater through the selective removal of most pathogens and of part of the solids fraction and other impurities. Selective removal is implemented at the secondary stage of treatment in conventional wastewater treatment plants by using additional physical and chemical filters that remove most of the pathogens and reduce the discharge of nutrients and organic matter. Water can be filtered at different stages of the secondary treatment to increase or decrease the quantity of nutrients based on the needs of the crop and of the soil to be irrigated. Thus, selective removal is a simplified type of secondary treatment that reduces energy costs and sludge and allows the recycling of most soil nutrients and the reuse of water for both irrigation and soil fertilization through “fertigation”.

Selective removal is beneficial for soils and improves soil carbon storage and water retention. It is especially viable for non-food crops (e.g. woodlots for energy or lumber) in drylands, which are often characterized by poor soils, because it provides water and nutrients and increases water retention in soils. Fertigation requires continuous monitoring to minimize the risk of spreading disease and to enable adjustments in the level of fertilization in keeping with the needs of soils and crops.

Further Learning

Braatz, S. & Kandiah, A. 2002. *Use of municipal waste water for forest and tree irrigation.* Rome, FAO.

Dimitriou, I. & Aronsson, P. 2005. Willows for energy and phytoremediation in Sweden. *Unasylva*, 221.

Fernández-Cirelli, A., Arumí, J.L., Rivera, D. & Boochs, P.W. 2009. Environmental effects of irrigation in arid and semi-arid region. *Chilean Journal of Agriculture*, 69: 27–40.

International Water Management Institute. 2008. *Wastewater reuse and recycling systems: a perspective into India and Australia.* Working Paper 128.

Hasselgren, K. 1998. Use of municipal waste products in energy forestry: highlights from 15 years of experience. *Biomass and Bioenergy*, 15(1).

Magen, H. Potential development of fertigation and its effects on fertilizer use.

Myers, B.J., Theiveyanathan, S., O'Brien, N.D. & Bond, W.J. 1996. Growth and water use of *Eucalyptus grandis* and *Pinus radiata* plantations irrigated with effluent. *Tree Physiology*, 16: 211–219.

Rosenquist, H., Aronsson, P., Hasselgren, K. & Perttu, K. 1997. Economics of using municipal wastewater irrigation of willow coppice crops. *Biomass and Bioenergy*, 12(1).

Vasudevan, P., Thapliyal, A., Srivastava, R.K., Pandey, A., Dastidar, M.G. & Davies, P. 2010. Fertigation potential of domestic wastewater for tree plantations. *Journal of Scientific and Industrial Research*, 69.

USDA National Agroforestry Center. 2000. *Wastewater management using hybrid poplar*.

Credits

This module was developed with the kind collaboration of the following people and/or institutions:

Initiator(s): Alberto del Lungo - FAO, Forestry Department

Reviewer(s): Prof. Salvatore Masi - Università della Basilicata; Paolo de Angelis - Università della Tuscia; Sara Marjan Zadeh - FAO, NRL