BUFFER STRIPS

To improve water quality and the environment

REGIONE DEL VENETO

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Presentation

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For several years now, the chemical, physical and biological processes of natural systems have been used in many European countries to reduce the amount of pollution in water resources. In fact, experience shows that traditional municipal and industrial water treatment systems are not very effective in treating common sources of pollution, particularly nutrients from agricultural sources.

In the presence of cultivated areas where livestock farming is also widespread, their cost-benefit ratio is often unsustainable, especially as regards finished treated water.

One of the most effective ways of trapping and removing fertilizers, crop chemicals and other pollutants which spread from fields to hydrographic networks is the wooded buffer strip (WBS). This term refers to a linear formation of herbaceous vegetation, trees and/or shrubs of varying width placed between crops and waterways.

Buffer strips may consist of a single row or multiple rows of plants placed along rivers and surface water, using modern planting techniques such as mulching, in accordance with the characteristics of the location and any secondary functions that may be required. The combined use of trees and shrubs is highly recommendable, where possible, because it makes for a more balanced ecosystem and maximizes environmental functions of great importance such as greater biodiversity, the creation of new habitats, greater filtration capacity, reduced erosion of riverbanks, regeneration of woodland areas, and a general upgrading of agro-ecosystems.

In addition to recreating an extensive wetlands system, new and well managed buffer strips in agricultural areas can also provide a source of additional income for farmers if planted with tall trees, producing firewood, wood chips or valuable wood. This is a major factor for the economic sustainability of wooded areas.

In Italy, *Veneto Agricoltura*, a Veneto Region enterprise, has been conducting studies for many years and has developed effective practices for the environmental regeneration of agricultural areas using natural systems. Among these, buffer strips have been successfully applied in several projects to reduce the amount of pollutants that end up in the Venice Lagoon. The most significant trials were carried out by the *Consorzio di Bonifica Acque Risorgive*, a public company that manages numerous canals and a large amount of the surface water that reaches the Venice Lagoon.

Data proving the effectiveness of the system led the region to include in its Rural Development Plan a specific measure to encourage farms to adopt this system. In the 2007/2013 period more than 500 km of wooded buffer strips, including new and existing systems, were funded.

The WBS solution, which was developed between 1970 and 1980 in the United States of America and Europe (particularly in France and England), has been fully implemented in Italy in intensively farmed areas, and specifically in Veneto Region, especially due to the hydraulic artificiality of areas that come into direct contact with the north Adriatic Sea, the coastal lagoons of the Veneto and Friuli, and the Po delta.

As in northern Italy, experiences in numerous French departments also showed the effectiveness of WBSs in combating excess nutrients of agricultural origin in surface waters. They were implemented within the framework of initiatives aimed at complying with the EU Nitrates Directive for vulnerable zones.

This original solution is not only intimately correlated with agricultural land but also regenerates wooded areas and is of great ecological value. WBSs respond to the numerous studies on wetlands conducted worldwide to find solutions that can eliminate nitrates in water, and are compatible, on a large-scale, with the intensive farming that often characterizes the floodplains of our continent.

What problems can they help solve?

Inland surface water and groundwater are under constant pressure from civil, industrial, agricultural and livestock farming activities. The agricultural use of fertilizers, soil amendments, herbicides, fungicides and pesticides is becoming an increasingly insidious threat for water quality and the health of aquatic ecosystems, compromising functionality and reducing biodiversity.

For example, nitrates in surface and groundwater are still a major cause of both eutrophication in lakes and seas and contamination of drinking water. Among the major sources of nitrates in aquatic systems are agricultural practices and livestock farming, which are difficult to measure and regulate because they are widespread over vast areas and are greatly affected by climatic events.

Research has repeatedly confirmed that the preservation and increase of wooded areas or rows of woody plants placed between the sources of pollution and a receiving body of water appears to be one of the most effective strategies, on a large scale, for reducing the quantity of pollutants. In fact, when buffer strips intercept runoff water, they act as a filter between the land and the river, retaining, removing, and actively transforming nutrients and other pollutants. In this way they play an important role in protecting surface water and groundwater.

The importance of these environments, at one time partly made up of networks of hedgerows along the banks of ditches and rivers, maintained for centuries for different functions (such as the production of wood and firewood), has long been underestimated and only their continued demise has brought to the fore their valuable and effective environmental role. During the last century, in fact, the success and expansion of modern methods of agricultural production, aimed at increasing yields per hectare and based on mechanization and intensive farming (including irrigation, fertilizers and soil amendments), resulted in a progressive simplification of agricultural work and a significant impoverishment of the landscape. Many wetlands were drained, trees along the ditches cut down, and ditches for excess water removed, as also riparian vegetation along waterways.

In recent decades, fortunately, a more advanced culture of the land has developed, aware of the need to regenerate parts of the landscape that were important not only for obvious aesthetic reasons but above all because they played a key role in the conservation of natural resources and the maintenance of biodiversity.

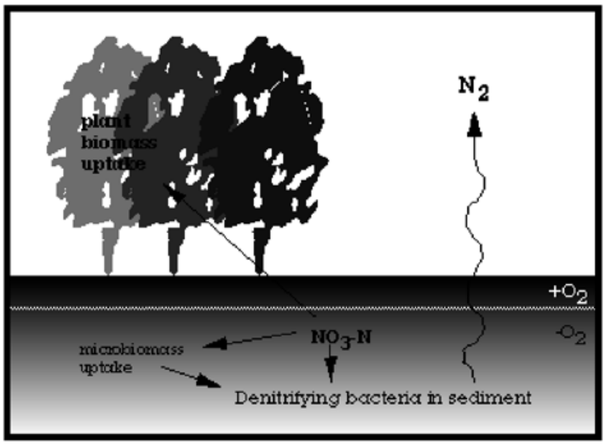
Landscape ecology has highlighted not only the quantitative reduction of natural areas but also the concrete and increasingly worrying lack of ecological continuity in different ecosystems. Watercourses and the vegetation along them can function as natural ecological corridors, small linear oases which, in areas fragmented by man, can help animals in their movements along riparian areas. In addition, one should not underestimate the aesthetic effect provided by these verdant fluvial corridors which, as they coast the riparian environment, embellish the agricultural landscape.

The historic functions of hedgerows have now been revalued and new goals have been added, such as the improvement of water quality, threatened more than ever before by the presence of densely populated areas and intensive crop and animal farming. The proposal to disseminate new models of riparian hedges and woodland, therefore, come at the right time and is effective in several ways, in synergy and not in competition with quality agricultural practices.

Buffer strips in practice

In nature, the transition zone between aquatic and terrestrial ecosystems is called the *riparian ecotone*. This area consists of a strip of land, often covered by vegetation, located along rivers and streams of all sizes and capacities, from tiny streams to wide rivers. This strip of land is subject to frequent flooding and differs from adjacent land because it has special properties, typical of waterlogged soil. One characteristic of the *riparian ecotone* is its high level of biodiversity, since it hosts not only species exclusive to the ecotone but also the typical species of contiguous ecosystems, a phenomenon that is commonly referred to as the *edge effect*.

The key to creating effective wooded buffer strips for nutrient removal is its capacity to recreate these riparian ecotones.



Transformation of nitrogen in wooded buffer strips

Thus, *riparian ecotones* play an essential role in both the hydraulic and biological dynamics of river ecosystems.
Apart from removing excess nutrients, buffer strips of native species of trees and shrubs:

- Consolidate river banks and prevent erosion;
- Slow down the speed of flood waters, mitigating the effects downstream;
- Protect and increase biodiversity;
- Preserve and embellish the landscape;
- Produce shading;
- Provide secondary, edible products such as mushrooms and truffles, fruit, honey, etc.
- Have a trophic function, providing a varied food source for macro and micro-fauna.

A number of mechanisms are at work in buffer strips to combat pollution. Nitrogen is removed from the polluted water both through assimilation by the vegetation and *denitrification*, a bacterial process triggered by a large number of anaerobic microorganisms (which live in the absence of oxygen), transforming the nitrate dissolved in water into nitrogen in its gaseous molecular form. This bacterial process is made possible and supported by the carbon present in plants, in particular deciduous trees and their root masses.

The phosphorus in pesticides (phospho-organic compounds) is fixed and partially removed through *sedimentation*. In fact, buffer strips trap the sediments from the cultivated fields and retain pollutants present in the sediment for periods of time that can be quite long. In the soil, the pollutants undergo physical-chemical degradation due to light, ultraviolet rays (UV), temperature and the catalysing action of some soil constituents. This retention and degradation action of buffer strips also protects against soil erosion and is much more effective in the presence of numerous and diverse groups of species, both animal and vegetable.

For buffer strips to perform effectively a wetlands function, close attention must be paid to their location. In fact, different aspects need to be evaluated, such as the texture and permeability of the soil, the depth of the surface water, the amount of carbon in the soil, and the availability of high nitrogen concentrations in the water: these factors are important for the rapid development of denitrifying bacterial colonies.

It is also essential that there is direct contact between the body of water and the soil of the buffer strip; the morphology must be such that the water can move from the fields towards it, formatting a sort of "perched water table" at root level, where the above bacterial activities take place.

On a large-scale, we must consider that minor water bodies make up about three-quarters of the total length of a water network. It is precisely in these sections that the buffering effect of the *riparian ecotones* is at its greatest. In environmental redevelopment projects, focusing on this part of the river network, rather than medium-sized or large rivers, can be decisive in combating widespread pollution. Moreover, the minor hydrographic network, since it is widespread, flows through the majority of cultivated land.

As well as producing a wetlands effect, buffer strips can also offer farms opportunities for additional income, such as the production of woody biomass, beekeeping activities and the cultivation of berry fruit. Moreover, these areas also have an aesthetic and environment function, and can be used for recreational purposes and the promotion of healthy living.


The plant species used to create buffer strips must be suitable for the characteristics of the soil and climatic zone. Each plant species, in fact, has its own optimum environment for high rates of engraftment and growth. Therefore, for each site we need to take into account: the altitude, the average annual temperature and temperature extremes, rainfall, soil humidity, groundwater depth, as well as the characteristics of the vegetation in the surrounding areas, to get a healthy and well developed plantation.

There are also agronomic considerations to be made, since the vegetation chosen for the buffer strips could harbour parasites and pathogens which could raise the level of infestation in the surrounding fields. Instead, the right kind of vegetation can generate a significant increase in useful insects for the biological control of pathogens. The productive element is an important parameter to evaluate in the formation of a buffer strip. Phyto-treatment action, in fact, is not dependent on the species used, provided they are appropriate for the environment and tolerate stagnant water.

The width of buffer strips must also be carefully considered. Numerous studies have shown that the denitrification process is most effective in the first metres of the zone, those in contact with the cultivated land. It follows that, once the capacity to intercept water flows has been verified, the effectiveness of buffer strips depends most often more on their linear extension than their width, although it is recognized that strips of at least 15 metres wide are most effective. In defining the width of the strips we must also consider the relationship between the objectives to be pursued and the size of the watercourses. In practice, although riparian strips are

always very useful, if the goal is the quality of water in the presence of intensive agricultural activities, it is preferable to make them narrow along the myriad of small streams, including reclamation drains and ditches. If the primary aim is to contribute to the control of flooding (wooded areas for programmed flooding) or the protection of habitats and biodiversity, it is preferable to make them wider, along main or secondary rivers and streams.

Mathematical simulation models can be used in the planning and management of buffer strips, providing data to determine the correct width of the strip. In trials carried out in the Veneto Region by *Veneto Agricoltura*, the REMM model was used (*Riparian Ecosystem Management Model*), developed by the USDA (United States Department of Agriculture) to simulate the physical, chemical and biological processes that occur in a riparian strip. This model allowed us to: determine the width of buffer strips, the conditions of the riparian area and the nutrient load resulting from surrounding areas; calculate the variations in the buffer effect due to the increase in load; evaluate variations in buffer effect efficiency resulting from the type of vegetation cover, and determine the effect of cutting down trees on buffer capacity.

Results

The Veneto Region funded a major buffer strip project at Veneto Agricoltura's *Diana Pilot Demonstration Farm* in the municipality of Mogliano Veneto (Treviso). The project, which involved creating buffer strips along the river Zero during 1999/2005, aimed to evaluate the effectiveness of buffer strips, as already trialled in the European NICOLAS project, in cleaning up a watercourse badly polluted by agricultural nutrients that flowed into the drainage basin of the Venice Lagoon.

The results showed that up to 60% of the nitrogen was removed and confirmed that wooded buffer strips in farm areas offered a good water treatment system. Another result of the project was that it started a process of knowledge acquisition for the design and management of strips, which was then used in many other experiences of greater importance, especially as regards the implementation of these technologies in the agri-environmental measures of the 2007-2013 rural development plans of a number of Italian regions (a total of 214 sub-measures). On the basis of the results of the "NICOLAS" project, other wooded buffer strips were created by other institutions (such as the *Consorzio Venezia Nuova*, and other land reclamation consortia) in different parts of the Veneto and other regions.

The importance of the NICOLAS system, still in operation, was the opportunity it offered to collect data over a period of many years, making the site unique in terms of quality and quantity of available data. In particular, monitoring and evaluation showed that:

- Two years after planting (trees 4-5 years old), the wooded buffer strips had already reduced total dissolved nitrogen in the water by more than 60%, reaching a maximum of 168 kg/ha/year, measured on site starting with the low concentrations of nitrogen present in the river Zero;
- No significant differences were found between buffer strips 15m wide and 5m wide, from the point of view of nitrogen retention percentage, the latter proving more efficient (the same percentage retention over a smaller surface area).
- There was an increase over time of nitrate retention capacity (NO3-N) in both 15m wide and 5m wide buffer strips, with reductions of 39-43% within a year of plantation and reductions of 84-86% three years after plantation;
- The process of denitrification is closely correlated to sub-surface runoffs due to irrigation. A significant reduction in the latter, in fact, inhibits its process;

- In this type of system, denitrification can by itself provide a major contribution in the overall reduction of nitrogen (with annual averages of between 100-300 kgN/ha/year);
- The measurement of potential denitrification, carried out by placing increased doses of nitrogen in the water subjected to the buffering action on the soil in the area being studied, showed, in the absence of limiting factors, a strong increase in the denitrification rate (up to 2000 kgN/ha/year), so that it would appear that the effectiveness of the system is much higher than actually measured on site.

All data collected were used in the REMM mathematical simulation model (Riparian Ecosystem Management Model), and greatly helped in the planning and management of new wooded buffer strips.

The Nicolas Project

The NICOLAS project (Nitrogen Control by Landscape Structures in Agricultural Environments - DG XII Environment & Climate), funded by the European Union as part of a framework program for research, was completed in 2000. The first experimental area of 0.5 hectares was used as a model (in terms of analytical methods used and the choice, type and frequency of samples) for a much wider buffer zone, which now occupies nearly 30 hectares of land along the river Zero in Agriculture Veneto's experimental farm 'Diana'. Monitoring, carried out on structurally identical plots of 0.35 hectares, was coordinated by the *Consorzio di Bonifica Acque Risorgive*, and buffer strip management was carried out by *Veneto Agricoltura*. Monitoring continued through to 2011 and involved, among others, the following institutions: ARPAV - Osservatorio Suoli e Servizio Laboratori, Centro Meteorologico di Teolo; Haycock Associates St.Albans, Hertfordshire (UK), University of Bologna, Department of Experimental Evolutionary Biology, University of Padova, Department of Agricultural Biotechnology, University of Rennes (France).

National and international interest

The buffer strip is a technique that is in harmony with the European Water Framework Directive 2000/60, which focuses on the need to protect and regenerate aquatic ecosystems, to ensure, today and in the future, the availability of quality water for all priority uses. The environmental objectives of the Directive are based on the concept of *Good Ecological Status*, i.e. the *health status* of ecosystems, and their capacity to conserve and regenerate water quality and sediment quality.

It is also important to note that, in the simplest of cases, any natural system such as a hedge or a pool of water can become, for plant and animal species, an oasis in a *biological desert*. For these reasons, the European Union's Agenda 2000 program redefined the objectives of the Common Agricultural Policy, introducing new principles such as environmental friendliness, protection of the landscape and the recognition of goods and services provided to the community by rural systems and farms in particular.

In a situation characterised by the generalized degradation of aquatic ecosystems (in many ways irreversible), natural water treatment systems are of great significance. For this reason, the Veneto Region has not only established working relationships with the European networks of experimental buffer system areas to get a broader picture, but it is also keen to share the knowledge it has gained with technicians and programmers of countries interested in replicating these methodologies.

For more information

A point of reference for information on buffer strip construction techniques is the *Azienda Regionale Veneto Agricoltura,* which for years has been experimenting and implementing multifunctional woodland interventions using thoroughly tested and now standardized techniques.

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Contacts

The *Azienda Regionale Veneto Agricoltura* can provide information and technical assistance to countries interested in using the buffer strip method. For information, please contact:

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The following officials, experts and university professors are also on hand to provide information and technical assistance on specific aspects: Mr Paolo Cornelio, *Consorzio di Bonifica Acque Risorgive*; Prof. Bruna Gumiero, University of Bologna; Mr Bruno Boz, UNIPD researcher.

Photos and tables: Veneto Agricoltura Archives and Consorzio di Bonifica Acque Risorgive; Bruno Boz; Andrea Rizzi; Fabiano Dalla Venezia; Giustino Mezzalira (cover photo)

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