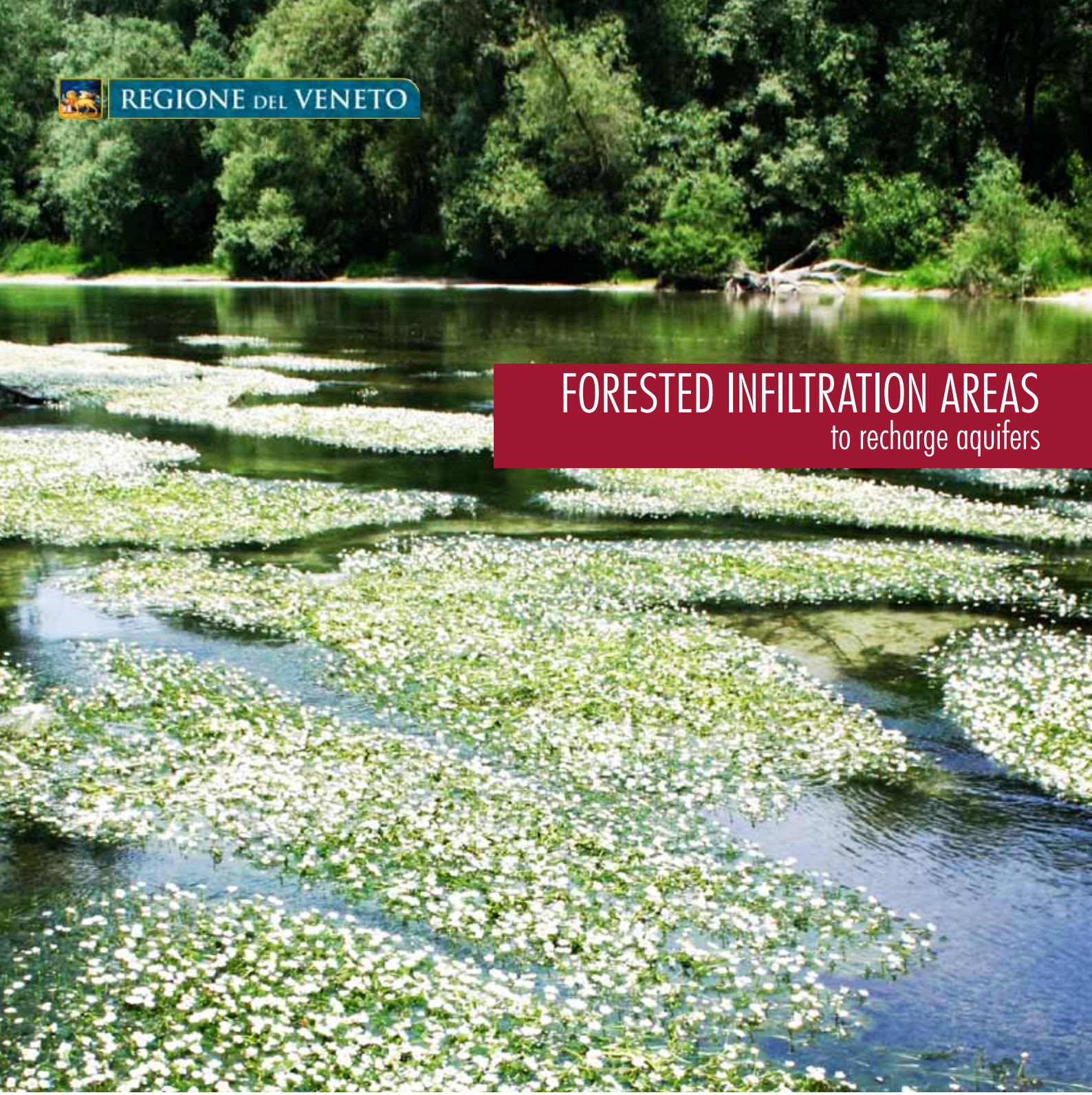


FORESTED INFILTRATION AREAS
to recharge aquifers

IDEASS Veneto, Italy

Innovation for Development and South-South Cooperation

www.ideassonline.org

Presentation

Written by Giustino Mezzalira and Federico Correale Santacroce

The Forested Infiltration Area system was designed and developed for the first time in 2007 by the agroforestry research and management section of Veneto Agricoltura, the Veneto Region agency responsible for the development of agriculture, forestry and agro-food. The FIA system was developed from the numerous initiatives undertaken by the region in the mid-1990s to check the sources of widespread pollution, which were mainly of agricultural origin.

Over-exploitation of water, due to intensive agricultural practices, industrial or civilian needs, involving excavations along river courses, reclamation of land for agriculture and building, and changes in irrigation techniques, is causing a progressive depletion of water resources, particularly in areas where the water balance is delicate and at risk.

Yet, agriculture itself can play an important role in combating this phenomenon. The Forested Infiltration Area (FIA) is a method to recharge groundwater aquifers by channelling surface waters during non-irrigation months (in northern Italy from September-October to April) into designated areas that have been planted with various species of trees and/or shrubs.

This system not only restores original water levels but can also produce a wetland ecosystem to tackle water pollution (natural purification of waste water), improving the quality and availability of' water. In addition, land that is forested to facilitate the infiltration of surface water into the ground can also be managed for a variety of other purposes, such as the production of woody biomass for renewable energy.

Moreover, since the system involves planting trees, it can provide interesting opportunities for farmers to supplement their incomes and the economic benefits would make it viable and sustainable.

Since 2007, forested infiltration area projects have been implemented in the Veneto Region, funded by local governments (Province of Vicenza and the Veneto Region), the Italian Government (Ministry for the Environment, Land and Sea) and the European Union. All the projects are implemented, monitored and evaluated by Veneto Agricoltura in collaboration with numerous public and private partners. In 2010, this method was also adopted up by the Friuli Venezia Giulia Region.

Taking into account the results of these projects, Veneto Agricoltura is currently working on extending the forested infiltration area system to the whole of the high Venetian plain. FIAs are part of Veneto Region's Rural Development Plan together with other thematic programmes, the strategic aim being to balance the historical groundwater levels and stop springs from drying up.

Veneto Agriculture operates with the support of a team of experts specialising in different FIA aspects. In particular, this brochure was written with contributions from Fabiano Dalla Venezia and Roberta Zanin of the Bioenergy and Climate Change Sector.

What problems can FIAs help solve?

The issue of recharging groundwater is of great topical interest throughout the world because the unsustainable exploitation of water resources is lowering groundwater levels and causing the serious depletion of the groundwater that supplies natural fresh water springs. The effects of lowering groundwater levels are severe because they significantly reduce water resources for irrigation, drinking and civil purposes. Moreover, damage to fresh water spring systems, causing many springs to dry up and drastically reducing the total capacity of rivers originating from spring sources, has resulted in the destruction of the habitat for many plant and animal species.

Forested Infiltration Areas help to improve and maintain the quality and quantity of ground water in a given territory. In high plain agricultural areas, underground water infiltration in FIAs can be used to restore original water levels. At the same time, this type of system combines the recharging of aquifers with the purification of water by the roots of trees and by the micro-organisms which live in symbiosis with them. Finally, FIAs can be used to dispose of excess slurry and manure, extending available areas for the distribution of by-products from local biogas plants (known as digestates).

Furthermore, from the economic point of view, FIAs can generate supplementary sources of income for owners, since:

- infiltrated water recharges aquifers, benefiting those who use them for drinking water or irrigation purposes; the companies that run the aqueducts and the bodies that control and manage the use of water (in Italy a role played by reclamation and irrigation consortia) can both derive economic benefits from the infiltration service provided by FIA owners;
- FIAs can be used to distribute excess slurry from livestock or digestate from biogas plants, effectively reducing nitrogen content in organic matter without impacting the environment. FIA owners can receive payment for this service from livestock farmers who must comply with national laws and the European Union Nitrates Directive;
- biomass produced by tree species used in FIAs, such as wood chips for energy conversion, can be sold as fuel for modern wood biomass boilers.

Therefore, agricultural areas converted into FIAs can provide two important environmental services (groundwater recharge and protection of water from nitrate pollution) and an agricultural commodity (wood chips for energy). The sale of wood chips and remuneration for environmental services allow the FIA landowner to earn a supplementary income, making the entire system economically sustainable. The Veneto Region also runs a rural development programme which provides loans for landowners interested in creating and managing FIAs.

In addition to these economic benefits for owners, FIAs play many other positive roles for the community:

- recharging of groundwater;
- regeneration of springs;
- increased availability of water for irrigation;
- improvements in groundwater quality, reducing nitrate contamination in particular;
- production of renewable energy;
- reduction of greenhouse gas emissions;
- enhancement of the landscape;
- increase in biodiversity.

Forest Infiltration Areas in practice

The idea for Forested Infiltration Areas came from traditional irrigation practices and knowledge of the land. In furrow irrigation, for example, a significant amount of water infiltrates into the soil; however, it is not lost but only transferred from the drainage network (river → ditch → channels → field) to the groundwater.

The innovation involves exploiting the high rate of infiltration of the land above the groundwater table, using it for the cultivation of a special crop which maximizes the infiltration rate.

The main aspects of the method include:

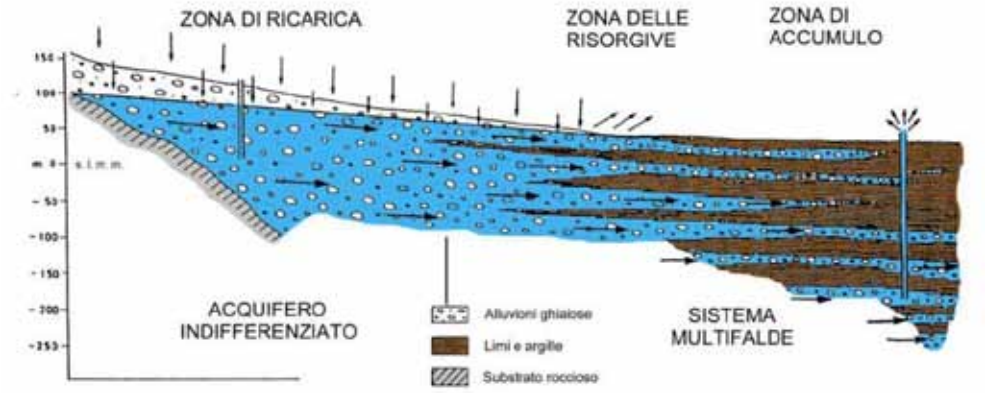
- infrastructure consisting of a system of furrows at the centre of each inter-row (drainage channels of trapezoidal section 70-80 cm deep, 70 - 80 cm wide at ground level and 30 - 40 cm wide at the base;
- drainage channels connected to an irrigation ditch linked directly to the local irrigation network;
- planting of trees and shrubs in rows at a distance of 1-1.5 m from the edge of the furrows, density depends on plantation type (crop or natural forest);
  - crop plantation: five-year Short Rotation Forestry average density of 1,400 plants/ha;
  - natural plantation: from a minimum 1,200 plants/ha to a maximum of 2,400 plants/ha;
  - distance between the rows of 3 - 4.5 m for both types of systems;
- system used continuously for more than 200 days, from the months of September-October until April-May, as long as water can be taken from rivers without affecting the minimum vital flow;
- used on and off during the irrigation period (from April to May and September-October).

To make sure that the aquifers are recharged in depth, FIAs should be planted in high plain areas that have a highly permeable undifferentiated gravel and sand alluvial bed, with a single aquifer that extends from the hills to the spring discharge area. FIA's make use of the great amount of water that flows rapidly in the upper stretches of great rivers, especially during non-irrigated season. Instead of letting the water leave the area (within a few days it reaches the sea), it infiltrates into the ground and accumulates in large underground basins known as aquifers, which tend to drain much more slowly.

Below are some technical characteristics required for the creation of Forested Infiltration Areas.

1. Soil profile and texture

FIAs are primarily designed to infiltrate water into the deep layers of the soil. Firstly, therefore, an assessment has to be made of soil type and texture. Once a possible site for the FIA has been identified, a stratigraphic survey of the ground needs to be carried out to examine its structure. The subsoil may in fact have characteristics that vary greatly from one area to another, even if they are small and close to each other. For FIA groundwater recharge what is important is to have a large enough area for a given amount of water to infiltrate into the soil and get transferred from the surface to the deep layers. FIAs do not have be joined up, and can therefore be placed wherever the soil is most suitable.



hydrogeological profile of the high and medium high Venetian plain (source: Consorzio di Bonifica Brenta)

2. Link up with the irrigation system

A second important aspect is the link up with the irrigation network. In fact, the channel system that distinguishes FIAs has to be joined to the local irrigation network, or at least there should be a surface flow system to channel the water there. Normally all high plain areas have an irrigation system, given the high demand for water in coarse fraction soils during the growing season. The irrigation system can be gravity based or pressure based. The gravity system is the simplest, because it only requires conveying water into a system of drainage channels. Pressure irrigation is more complex, because the entire irrigation system to which an FIA is linked has to be kept under pressure even during the non-irrigation season.

3. Furrow irrigation: spatial organization and operation

High plain land has a natural average gradient of 4-5 per thousand. After the water is brought to the highest point of the land, it can then be easily made to run along the line of greatest gradient. In FIAs water does not flow over the entire surface area but only along a series of parallel ducts in a comb-like system.

Main parameters to be used in the design of FIA channels:
• average depth: 70-80 cm (A)
• geometric section: trapezoidal
• channel width at ground level:70-80 cm (B)
• channel width at the bottom: 30-40 cm (C)
• distance between one channel and another: 7-8 m (D)

This organization of the surface flow of the water has some significant advantages:

- the land is always free and practicable;
- the bottom of the drainage channels comes into contact with the highly permeable strata that are located below the agricultural soil;
- there is enough distance between the channels for the use of tractors and other vehicles.

In all 1400-1600 m of channels are excavated per hectare. Ordinary excavators or tractor excavators can be used. These machines can also be used to remove deposits of sediment and debris from the bottom of the channels, an operation that can take place at the same time as coppicing (2-5 years).

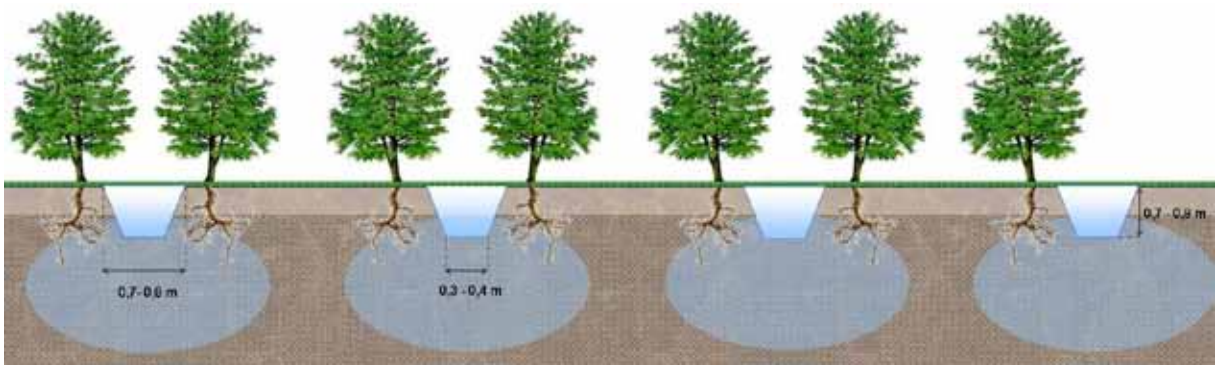


Diagram of a section and longitudinal profile of a channel (source: Veneto Agricoltura).

4. Seasonality of FIA operations

Farming practices and local irrigation needs strongly influence the seasonality of the FIA operations. During the irrigation season, all available water resources are primarily used to irrigate crops. FIAs, therefore, are normally supplied in the rainy season, which in Western and Central Europe is the period from the beginning of autumn to the beginning of spring. In rainy years or climates, FIAs can also be used in the irrigation season. In the Veneto Region, an FIA can be operative about 200-250 days a year (from September-October to April-May). The duration of FIA operations depends on specific weather patterns. In addition it must be remembered that irrigation systems are normally subjected to periodic maintenance in winter and that in the case of moderate river flows or floods water infiltration in FIAs needs to be suspended to prevent the abundant solid material that is transported by water in such situations from settling in the ditches, reducing or cancelling out drainage capacity (clogging effect).

5. Quantity of infiltration water

The flow of water entering the system must be regulated by a bulkhead or sluice gate.

The amount of incoming water must be accurately quantified so that as much as possible gets infiltrated, without creating overflows, maximizing the infiltration surface area.

In areas of land where a hydraulic system of canals is installed, trees are also normally planted. In forest areas, water which infiltrates into the deep layers of the soil is effectively filtered by the roots of the trees, which extend many metres in depth (more than ten in some species). In this way, water not only undergoes a physical filtration process but also a purification process, through the micro-organisms that live in symbiosis with the roots. For this reason, in areas with high concentrations of livestock, FIAs can be used to dispose of excess slurry or the by-products of anaerobic digesters that produce biogas. Trees can therefore be planted for specific purposes. In biomass plantations, species should be chosen that can both take advantage of the presence of water and withstand periods of even severe drought in the system's dry phases, which normally coincide with climatically hot dry periods. The choice of species also depends on the type of wood product desired.

Infiltration capacity is estimated by applying the Darcy formula:
$Qf = K \times j \times A$.
It should be mentioned that a hectare of FIA in the high plains can infiltrate more than 5,000 m3 of water per day. In one year, which means 200 days of operation, a hectare of FIA can thus infiltrate one million m3 of water

Planting techniques involve surface ploughing of the soil after the excavation of the channels, the laying of black ethylene vinyl acetate EVA plastic film mulch 0.08 mm thick and 120 cm wide (which will be removed soon after the first coppicing of the trees) and the planting of young specimens of balled-and-burlapped trees and shrubs of 1-2 years of age.

Example of a FIA biomass plantation with rows of plane trees. Tree species used in plantations for the production of woody biomass for energy production include: narrow-leafed ash, field elm, Siberian elm, black alder, plane trees, various clones of poplar, willow.

Results

FIA methods were first applied in 2007 by the Consorzio di Bonifica Pedemontano Brenta (now Consorzio di Bonifica Brenta) in an agricultural area of 1.18 hectares in the municipality in Schiavon (Vicenza). In the Schiavon FIA, measurements confirmed that small agricultural areas can infiltrate hundreds of thousands of cubic metres of water per year per hectare. The Schiavon FIA has often been visited by technicians, administrators and politicians interested in the topic of recharging aquifers, showing that this type of intervention can help restore groundwater balance.

In 2008, the Province of Vicenza funded a second FIA in the municipality of Schiavon and, in collaboration with Veneto Agricoltura, the possibility of using woody biomass was trialled. Specifically, the system involves a short and very short cycle plantation system, comparing for the first time trees of different species and use for different of periods of time (two years, five years).

A third FIA was created in the spring of 2009 by Veneto Agricoltura in the municipality of Tezze sul Brenta (Vicenza.) The plantation is 1.7 hectares in size and consists of four plots with different species of trees: plane hybrid, paulownia, white willow, and narrow-leafed ash. A team of technicians and researchers from various universities conducted a study on this FIA to assess the technical viability and economic and environmental compatibility of the innovative ways of waste water treatment for in individual farms and farm consortia. Finally, in 2010, the Consorzio di Bonifica Brenta, thanks to a grant from the European Commission and the Ministry of Environment, created, in collaboration with the Autorità di Bacino dell'Alto Adriatico, two FIAs comprising a total of 1.32 acres in the municipalities of Pozzoleone and Marostica (Vicenza).

Trials conducted in 2010-2011 on these pilot plantations focused on the following general and specific aspects:

- Infiltration capacity: measurement and monitoring of liquid flow, measurement of river sediment transport; numerical infiltration modelling, geophysical surveys;
- nutrient processes and dynamics: hydrogeological aspects; root development; nitrogen dynamics and balance; soil nitrogen dynamics; estimates of nitrogen release into the atmosphere, nitrogen accumulation in the biomass; nitrogen accumulation in herbaceous biomass; nitrogen balance in the FIAs and in grass;
- biomass production and harvesting: increase of woody biomass a year and 2.5 years after planting; biomass collected from a site set up at an FIA; productivity in traditional SRF (Short Rotation Forestry).

The results confirmed conclusively that FIAs are an effective tool for conveying large quantities of water into aquifers and that, by adopting special techniques, their surface area can also be used for the distribution of digestates from biogas plants without affecting the quality of infiltrated water, and even promoting the growth of trees planted along the canals.

With these results in mind, Veneto Agricoltura is now working to promote the creation of a forestry infiltration area system for the whole of the high Venetian plain, as part of a strategic plan to balance historical groundwater levels and stop springs from drying up.

Veneto Agricoltura and the Veneto Region are directing several programmes and initiatives towards this goal. An example is the project RiduCaReflui (reduction of pollution generated by livestock waste in the drainage basin of the Venetian lagoon) which began in 2009 with the help of a team of experts that assists farms to comply with the EU Nitrates Directive without reducing the profitability of production processes. Thanks to the European AQUOR LIFE PLUS project, coordinated by the Province of Vicenza, the Consorzio di Bonifica Brenta will create two new FIAs. Veneto Agricoltura will set up a specific desk to inform regional stakeholders of the opportunities offered by FIAs and will carry out a study of their economic impact.

The Veneto Region, moreover, has set up specific initiatives in the Regional Development Plan to finance the creation of forestry infiltration areas by farmers and other interested landowners.

National and international interest

Veneto Agricoltura is promoting FIA methodologies at national and international level, in particular through European Union initiatives.

In 2010, the Italian Ministry of Environment, Euro-Mediterranean Centre for Climate Change, and the Friuli Venezia Giulia Region took part in the project LIFE PLUS TRUST (Tool for Regional-scale assessment of groUndwater STorage improvement in adaptation to climate change), concluded in 2011. The project was carried out in collaboration with the Autorità di Bacino dei Fiumi Isonzo, Tagliamento, Livenza, Piave, Brenta-Bacchiglione, the regions of Veneto and Friuli-Venezia Giulia, hydrological resources management services, regional environmental protection agencies, target area provinces (Vicenza, Venice, Padua, Treviso, Pordenone, Udine and Gorizia) and land reclamation consortia. Effective local promotion of the project led to the involvement of major stakeholders in the issue of recharging aquifers, thus helping to spread the idea of FIAs, originating in the Veneto Region, to the whole country and Europe in general.

Further information

Information on planting techniques, FIA creation and plantations is available from the Azienda Regionale Veneto Agricoltura, which for many years has been experimenting and implementing multifunctional forestry initiatives using techniques that have now been thoroughly tested and standardized.

The RiduCaReflui project website (http://riducareflui.venetoagricoltura.org) provides information on various features of FIA creation, technical and management aspects, assessments, and results. Also available on the site are documents and publications on FIAs in Veneto (design and creation, infiltration capacity, nutrient processes and dynamics, biomass production and coppicing)

Contacts

Veneto Agricoltura, regional agency for agriculture, forestry and agri-food (www.venetoagricoltura.org) provides information and technical assistance to countries interested in using forested infiltration area methods. For direct contacts, please phone or email:

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In addition, the following officials, experts and university professors are on hand to provide information and technical assistance for specific aspects.
FIA design and implementation: Loris Agostinetto, Cristina Dalla Valle (Veneto Agricoltura); Umberto Niceforo (Consorzio di Bonifica Brenta).
FIA infiltration capacity and nutrient processes and dynamics: Bruna Gumiero, (Università di Bologna); Bruno Boz; Paolo Giandon (ARPAV di Treviso); Micol Mastrocicco, Enzo Salemi, Nicolò Colombani (Università di Ferrara); Francesco Da Borso (Università di Udine).

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Innovation for Development and South-South Cooperation

The IDEASS Programme - Innovation for Development and South-South Cooperation - grew out of the major world summits in the 1990s and the Millennium General Assembly and it gives priority to cooperation between protagonists in the South, with the support of the industrialised countries.

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