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Istituto di Matematica Applicata e Tecnologie Informatiche

Implication of soil management on biodiversity: a case study from Italian vineyard

Workshop on
BIODIVERSITY IN AGROECOSYSTEMS
Milano, 24-25 February 2011

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Soil biodiversity

Biodiversity: variety and variability of living organisms and the ecosystems in which they occurs → plants, animals, invertebrates and micro-organisms

Soil: one of the most diverse habitats on earth that contains one of the most diverse assemblages of living organisms (Giller et al., 1997)

Ecological function of soil:

- Biological habitat of species and genes
- Supply of nutrient to support plant growth
- Buffering and transformation of potentially harmful elements and compounds
- Exchange of gases and waters between atmosphere and hydrosphere

Soil biota

- Micro-flora (bacteria, fungi, etc.)

PRIMARY DECOMPOSERS

- Micro-fauna (protozoa, nematodes, etc.)

PREDATORS/DETRITIVORES

- Meso-fauna (acari, springtails, etc.)

PREDATORS/DETRITIVORES

- Macro-fauna (insects, earthworms, etc.)

PREDATORS/DETRITIVORES/HERBIVORES

- Roots, that growth in the soil and interact with other species above and below ground

Biota diversity can be affected by changes in ecosystem processes

Measure of soil biodiversity

Microbial diversity as **indicator of ecosystem functioning** and for evaluating disturbed or contaminated systems

Not simply evaluation: number and interaction among species and environment

- **Molecular technique** - DNA sequences (small % of bacteria can be cultured in the laboratory)
- **Chemical compounds in microbial cell walls** - fatty acid analysis of soil extracts
- **Taxonomic or genetic methods** – organisms related to a process of interest (N-fixation).
- **Relation with general soil processes**: differences between soil isolates in decomposition of carbon-rich compounds, metabolism of nitrogen compounds and antagonistic activity against selected microorganisms
- **BIOLOG microplates** to characterize differences among soil and water micro-oganisms on the basis of patterns of substrate usage

Climate change influence on biodiversity

Climate change as a **pressure** that leads to biodiversity change

Natural causes

Anthropogenic driving forces

Pressure = consequence of human activities which have the potential to cause or contribute to adverse effects (impacts)

Change in atmospheric composition, land cover and land use

State of biodiversity = quantity of biological features (measured within species, between species and between ecosystems), of ecosystems' physical and chemical features, and environmental features → vulnerable to pressure

Different adaptive capacity of ecosystems, changes in phenology and distribution of taxa

Biological effects of soil management 1

SOIL EROSION AND COMPACTION

- ***Soil erosion*** is one of the most serious environmental problems

Degrades soil quality in **agricultural**, natural and forest ecosystems:

- Loss of soil
- Breakdown of aggregates and removal of organic matter
- Removal of valuable topsoil for crop growth
- Lower water infiltration

Reduced the productivity of the land and the diversity of plants, animals and microbes

- ***Soil compaction*** → modification of soil structure and soil pore system geometry, due to machinery traffic and tillage operations, influencing physical and hydrological properties (porosity and permeability) that affect surface runoff, soil erosion and plant growth

Different soil organisms reactions due to structural soil properties, site-specific hydrological and climatic conditions

Biological effects of soil management 2

TILLAGE SYSTEM

Degree of **tillage** disturbance affect soil physical characteristics:

- Soil water content
- Soil temperature
- Aeration
- The degree of contact between organic material and mineral particles

↓

Influence on organisms that live within the environment:

- Populations
- Diversity
- Activity

↓

Affect on the physical/chemical environment

Larger organisms more sensitive to tillage operations than smaller organisms; variation in response due to:

- magnitude and timing of tillage
- soil characteristics
- crop
- climate

Consequences of degree in soil biodiversity

- As indicator of ecosystem functioning and for evaluating disturbed or contaminated systems
- Depends by the intensity of management

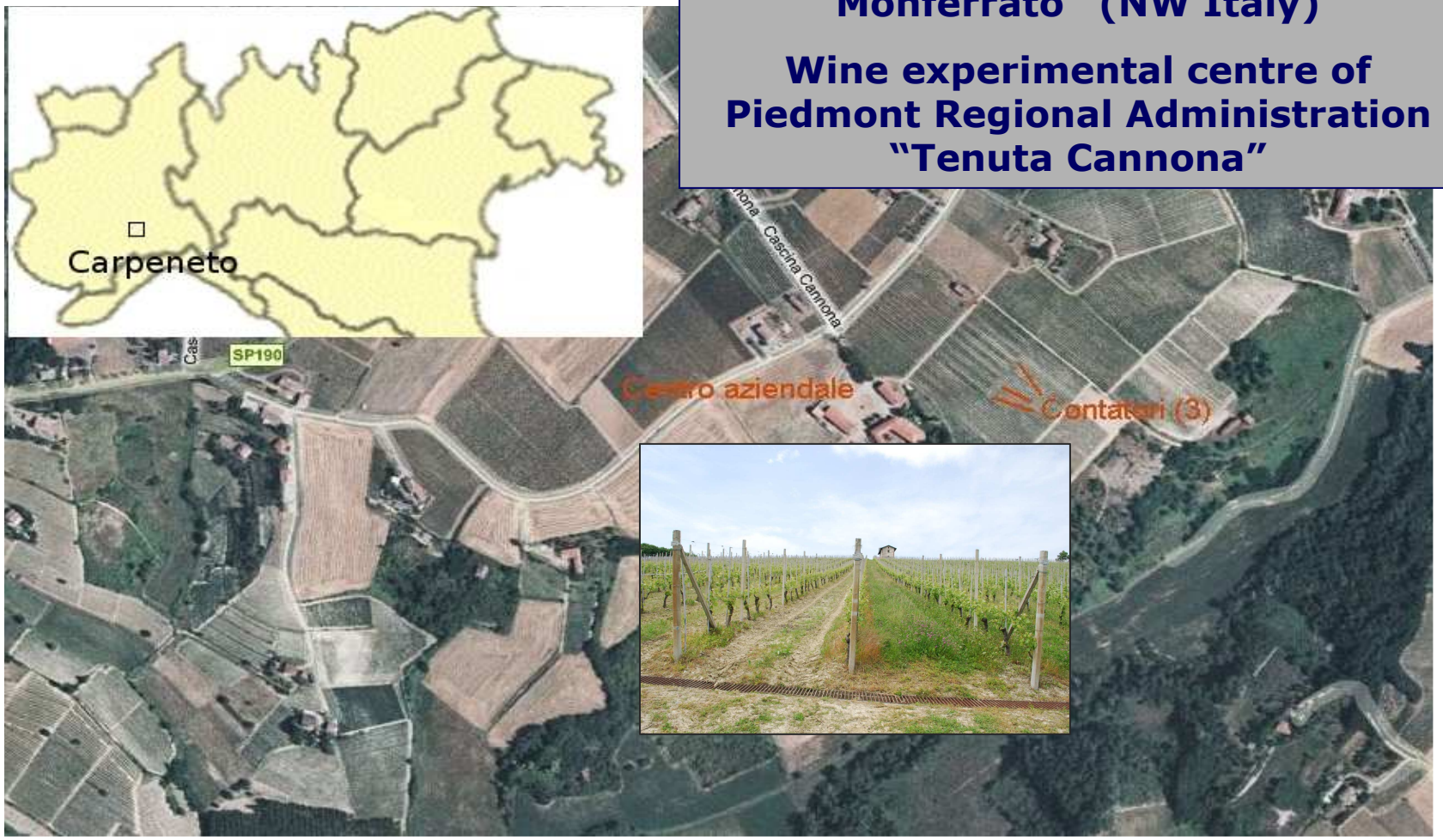
- Reduced diversity in the soil organisms may reduce their ability to perform essential biogeochemical cycles → Reduced tillage has been shown to enhance soil microbial diversity

- Plant biomass, living or dead, may protect the soil → Land area covered by plant reduce soil erosion (raindrop and wind energy is dissipated by the biomass layer), replenish ground water by enhancing infiltration and reducing water runoff

Experimental site

Hilly wine-growing area "Alto Monferrato" (NW Italy)

Wine experimental centre of Piedmont Regional Administration "Tenuta Cannona"



Experimental plots

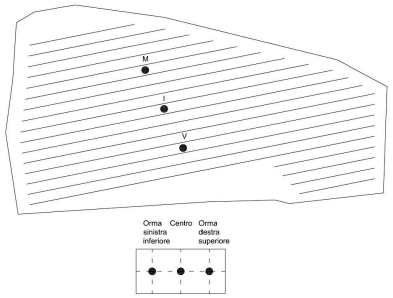
Soil texture: 47% clay, 28% silt, 24% sand

3 experimental plots with rows along the slope:

- **south – est aspect**
- **slope: 15%**
- **size: 74 m x 16,5 m**

1 experimental plot following the contour lines, and inter-row cultivated with controlled grass cover

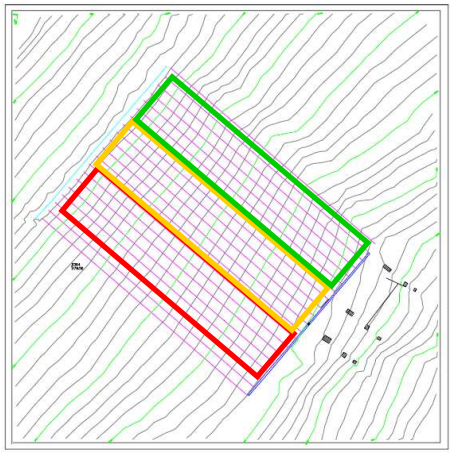
- **south aspect**
- **slope: 15-27%**
- **size: 6090 m²**



Different inter-row soil's cultivations techniques:

- **CT: chisel + rotary cultivator, max depth 0.25 m**
- **RT: rotary cultivator, max depth 0.15 m**
- **GC: grass controlled cut up twice a year**

Chemical weeding under the wine rows



Vineyard case study

Assessing the influence of soil management, focusing on:

- ***Rainfall events parameters***
- ***Runoff***
- ***Soil losses***
- ***Compaction***

Data on runoff, soil erosion and compaction have been collected from 4 plots in an experimental vineyard for 10 years, since 2000

Tillage methods influence soil loss rate and compaction processes

1. Conventional tillage (CT)
2. Reduced tillage (RT)
3. Controlled grass cover (GC)

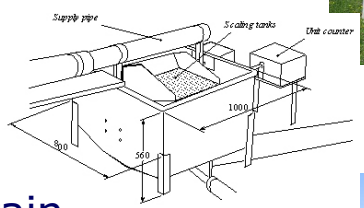
Data observed in the period 2000-2010

Agro-meteorological station located about 200 m from the plots

Rainfall and climate

- Climate: temperate
- Mean annual temperature: ~ 13 °C
- Mean annual precipitation: ~ 830 mm (especially autumn and spring; summer rainfall of high intensity and short duration)
- Rainfall amount and duration after each rainfall event

Runoff, fertilizer and soil losses



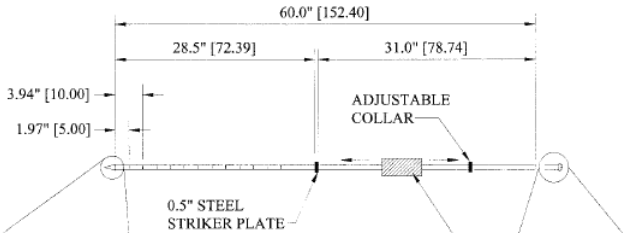
- Plots hydraulically bounded
- Runoff and sediments collected at bottom by a drain
- Tipping bucket device to measure the discharge of runoff
- Sampling of the runoff-sediment mixture
- Analysis of NPK elements
- Processing of sediments ovendried and weighed

Data observed in the period 2000-2010

Hydrological and physical characteristics

- Soil water content
- Bulk density

- Soil compaction



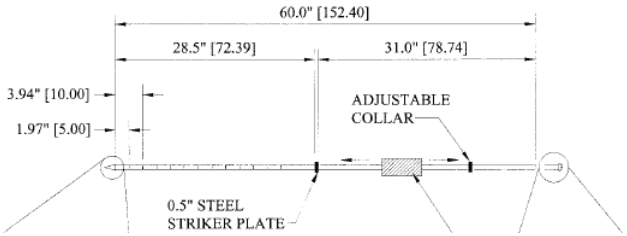
Data observed in the period 2000-2010

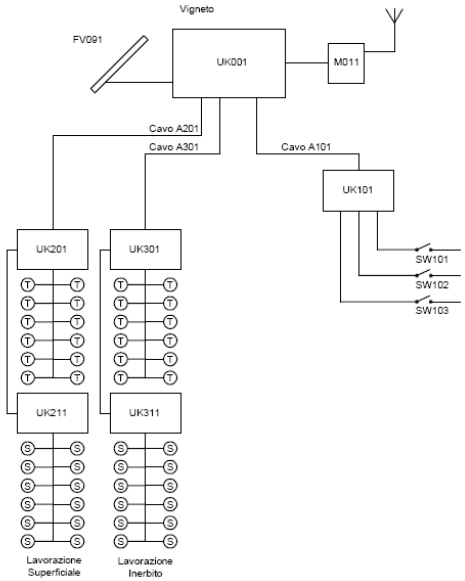
Hydrological and physical characteristics

- Soil water content
- Bulk density

- Soil moisture and temperature automated remote readings

- Soil compaction





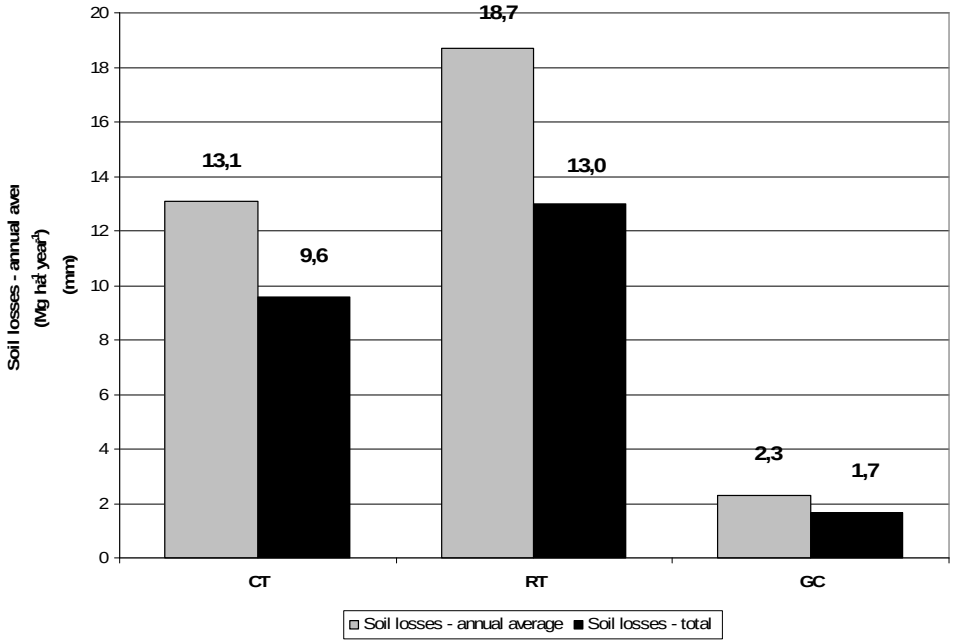
Rainfall – Runoff – Soil losses

161 rainfall events producing runoff equal or higher than 0.03 mm/ha

Average annual rainfall → 711 mm that caused runoff in

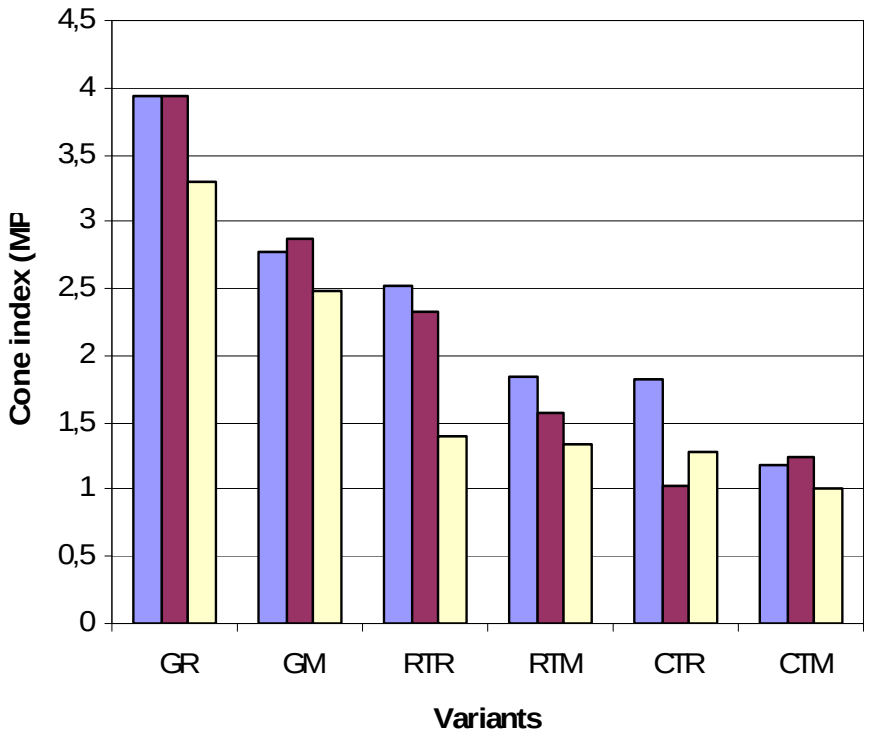
CT = 145 mm
RT = 130 mm
GC = 98 mm

41 most significant events analyzed in order to determine sediment concentrations and soil losses



	CT	RT	GC
SL_{ave} (Mg ha^{-1} $year^{-1}$)	13,1	18,7	2,3
SL_{10} (mm)	9,6	13,0	1,7

Soil moisture and bulk density – Soil resistance



Bulk Density (g/cm3)	Variants					
	GR	GM	RTR	RTM	CTR	CTM
Down	1.42	1.31	1.54	1.51	1.49	1.44
Middle	1.44	1.43	1.57	1.51	1.48	1.41
Top	1.52	1.43	1.53	1.49	1.48	1.42
Average	1.46	1.39	1.55	1.50	1.49	1.42
Increasing on wheel	5.0		3.0		4.3	

Soil Moisture (%DM)	Variants					
	GR	GM	RTR	RTM	CTR	CTM
Down	26.6	27.2	22.3	24.3	24.9	26.1
Middle	25.9	24.7	23.2	24.1	24.4	26.6
Top	24.1	23.7	25.2	25.3	25.5	29.4
Average	25.5	25.2	23.6	24.6	24.9	27.4
Increasing on wheel	1.3		-4.1		-9.0	

Possible use of experimental site

Optimal soil site for the evaluation of:

Erosion and Compaction vs. Biodiversity

- Consideration of the local context
- Site properties (land use, climate)
- Soil properties (soil type, texture, bulk density, organic matter content)
- Soil water retention characteristics
- Water conductivity

Use of **shear test equipment** (root reinforcement) to evaluate the total number of root and its possible identification

Use of **biolog** to classify and characterize microbial communities

Future possibilities

- Quantify the taxonomic diversity of key group of the soil biota in a slope vineyard ecosystem
- Assess plant biodiversity
- Research on interactions among the different groups of organisms at the community level
- Characterize the roles played by all mayor groups of the soil biota in the main processes (i.e. carbon cycle)
- Determine the extent to which soil biodiversity is an indicator of soil ecosystem resilience

THANKS FOR YOUR ATTENTION