WATERSEED

Role of water in the spatial structuring of plant biodiversity in vineyard environments

Métaprogramme BIOSEFAIR

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In order to limit the negative effects of agricultural intensification, it is necessary to rethink the role of interstitial elements in agroecosystems—green and blue corridors (ditches, inter-rows of perennial crops, embankments) that host spontaneous wild vegetation. These provide numerous ecosystem services of regulation and self-maintenance and participate in water circulation within landscapes. Empirical knowledge is lacking regarding the hydrological factors and mechanisms explaining patterns of plant biodiversity in these elements—from the soil seed bank to seed dispersal—so as to assess their potential for ecological rehabilitation.

Based on the hypothesis that water is a key driver in structuring plant communities in Mediterranean regions, the WATERSEED project aimed to:

(i) better understand the determinants of potential plant biodiversity structuring in hydrographic networks,

(ii) analyze the factors of seed dispersal by hydrochory, and

(iii) integrate the acquired knowledge into a model simulating dispersal and growth of spontaneous vegetation cover in order to test scenarios of interstitial space redesign for maximizing ecosystem functions of plant cover.

Drawing on experimental plots and domains (Domaine de la Jasse and the Roujan Observatory) of LISAH, we highlighted increased plant diversity and a greater importance of hydrochorous and zoochorous dispersal in ditch networks compared to vineyard plots. From a field experiment, we demonstrated the variability of seed dispersal factors, depending on intrinsic traits (shape, buoyancy) and extrinsic conditions (micro-topography, vegetation cover density). Finally, the model built from these observations and experiments justified the importance of cover management practices to improve the resilience of vineyard systems facing hydroclimatic extremes.

This project re-examined the role of water in agroecosystems as a driver of plant biodiversity structuring. It advocates for a better understanding of the functional properties of vegetation in relation to water flows, in order to design solutions that maximize both water resources and biodiversity.

Results

Seed bank analysis

It highlighted the influence of intra-plot heterogeneity (variability in grass cover practices between rows and alternation between plots, headlands and ditches) on the composition and species richness of the seed bank, with an increase in these indicators in neighbouring uncultivated areas (headlands and ditches).

She also highlighted interactions between the spatial dispersal pattern of seeds and their frequency within the soil seed bank, with, for example, a higher proportion of zoochorous species (i.e. dispersed by animals) within uncultivated areas (Fig. 1). Although studied here at the plot level, these results suggest the importance of non-productive areas within the landscape in the composition and species richness of the soil seed bank.

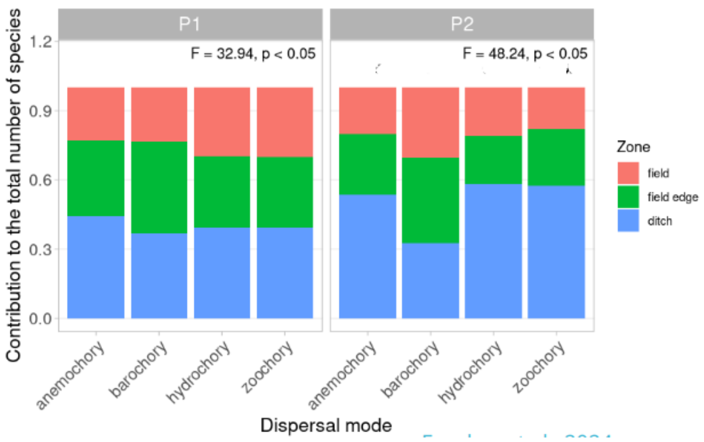

Figure 1. Proportion of species present in the soil seed bank of each uncultivated area sampled, according to their main mode of dispersal according to the TRY database (Kattge et al., 2020). The data in red represent samples taken from the vineyard plot, the data in green represent samples taken from the edge of the plot, and the data in blue correspond to samples taken from the agricultural ditch adjacent to the plot.

Hydrochory experimentation

Seed morphology plays a role in their dispersal potential during secondary dispersal events, with more spherical seeds being more susceptible to being displaced by runoff. Seed morphologies with appendages (hooks, hairs, etc.) were more sensitive to soil surface properties that facilitated their trapping (roughness, vegetation cover).

Secondary dispersal therefore plays an important role in maintaining plant biodiversity within agroecosystems, and even increasing it without direct human intervention.

A striking result is the virtual absence of seed movement within the most grassy inter-rows (47 seeds moved compared to more than 1,000 in the ploughed inter-rows). The results of this task therefore highlight the need for complementary mechanisms to ensure the development of vegetation cover through the spatial dispersal of seeds. For example, it is likely that the reduction in dispersal by hydrochory caused by the presence of plant cover can be compensated for by increased seed dispersal by animals taking advantage of the ecological corridor provided by a grassy area within a plot.

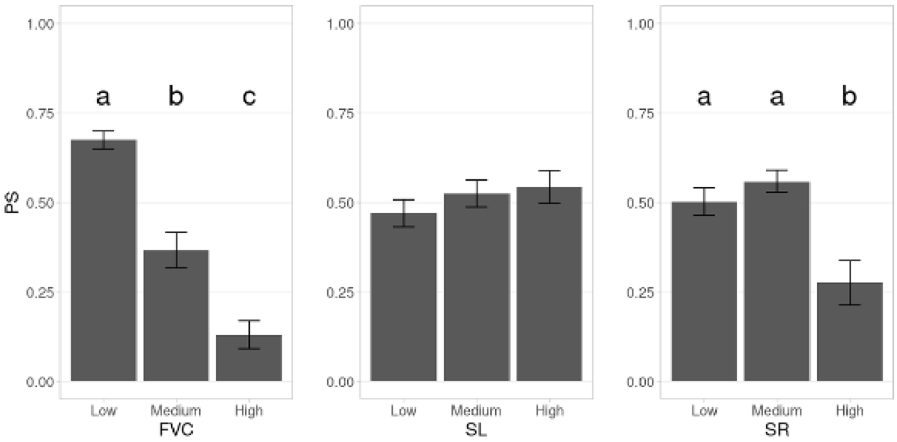

Figure 2. Surface permeability to hydrochory dispersion (PS) according to value classes for three soil surface properties: vegetation cover (FVC), slope (SL), and roughness (SR)

Mechanistic modelling

A multi-species plant growth module was developed for environments that may be subject to water stress. This module was based on the work of Celette et al. (2010) within the WaLIS model, and was calibrated using data collected during the project.

A second module was then developed to simulate the friction of the vegetation cover on the runoff water. Finally, a third module for the transfer of seeds produced by the simulated vegetation cover was developed based on data on seed transfer from the plot to the ditch, as well as on work by team members on transfers within ditches. A numerical exploration of the model was initiated to study the influence of climatic variables (temperature, rainfall, ET0) on the friction generated by vegetation cover on water flow (Manning's coefficient n).

In order to explore the behaviour of vegetation cover in the face of climate change, projections from the ALADIN regional climate model were extracted under the most pessimistic greenhouse gas emission scenario established by the IPCC in 2019. The friction calculated by the plant growth model for these future climate scenarios will be compared to the friction simulated by the model for past climate years, which will serve as a reference. The initial results of this numerical exploration point to an increase in the friction generated by vegetation cover in the coming years, probably as a result of faster and more extensive vegetation growth during periods of heavy rainfall (Fig. 3).

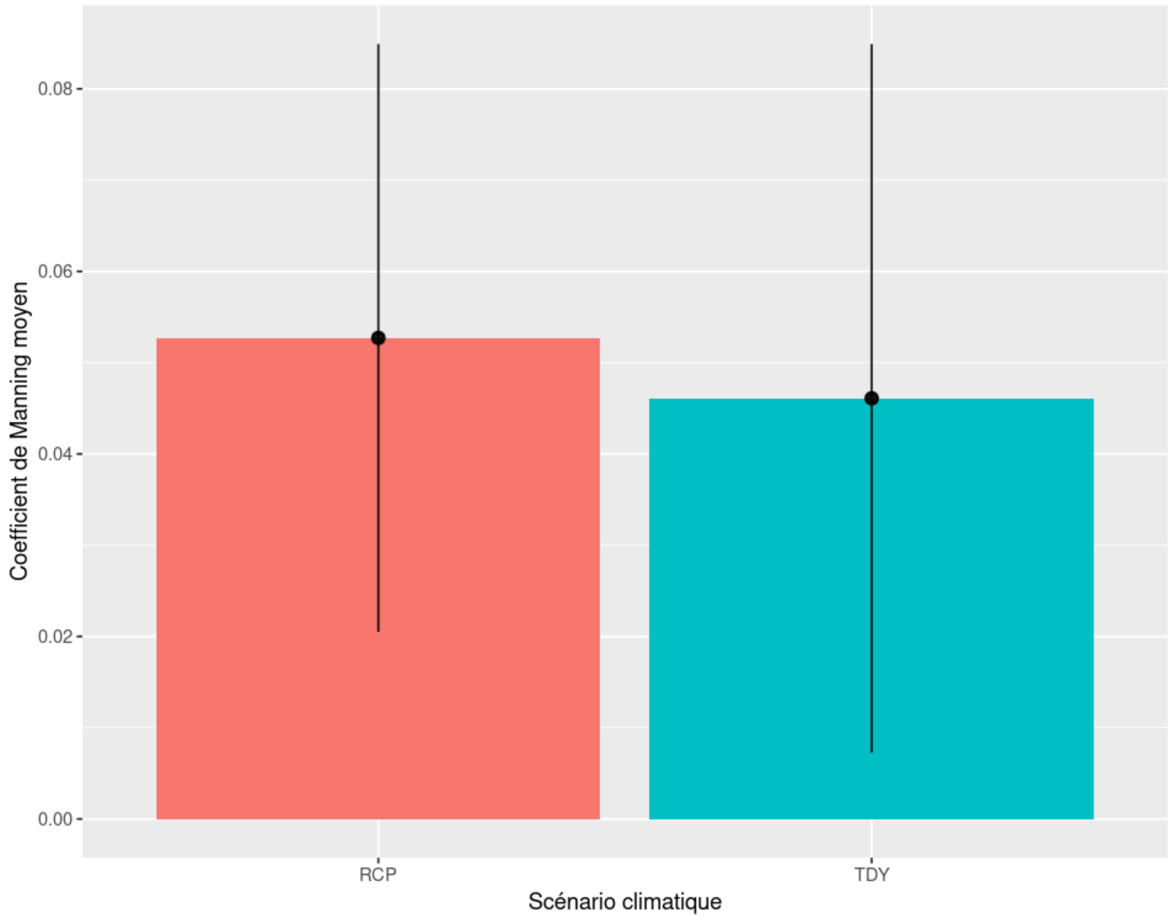

Figure 3. Comparison of the average Manning's coefficient between simulations based on climate warming projections from the RCP scenario (in red) and simulations based on past climate years in the Roujan watershed (in blue).

Scientific perspectives

WATERSEED has raised new research questions that will be explored in the coming years. Given the gaps in knowledge identified during the mechanistic modelling phase of the system, it is important to continue experiments in order to:

• establish a generic model of seed transfer in landscapes, based on the intrinsic and extrinsic factors identified, which can be applied to all environments.

• prioritise other seed dispersal factors: zoochory (including myrmecochory), anemochory and barochory.

• prioritise the importance of plant community determinants: effects of dispersal, competition between species and filtration by practices, hydrological niches and other environmental conditions.

• Link the plant biodiversity of hydrographic networks to the animal biodiversity that depends on them.

The mechanistic modelling stage enabled the creation of an initial prototype that can be used to answer more applied questions, such as: How can the model be used as a virtual laboratory to test new spatial and temporal organisations of landscape elements in order to maximise water resources and plant biodiversity?

Monitoring species development for identification in the Seed Bank task has enabled the collection of a unique dataset of photos of seedling development, which forms the basis of a research collaboration with the Pl@ntNet team to offer a service dedicated to the early recognition of wild species.

Valorisation

Faucher, Martin, Séraphine Grellier, Clémence Chaudron, Jean-Louis Janeau, Gabrielle Rudi, et Fabrice Vinatier. 2024. « Mediterranean vineyard soil seed bank characterization along a slope/disturbance gradient: Opportunities for land sharing ». Agriculture, Ecosystems & Environment 361 (février):108821. https://doi.org/10.1016/j.agee.2023.108821. ⟨hal-04300713⟩

Dagès C.*, Voltz M., Crevoisier D., Bedos C., Beudez N., Lafolie F., Personne E., Coulouma G., Djouhri M., Douzals J. P., Fabre J.-C., **Faucher M.**, Carmelo J.-L., Loubet B., Lagacherie P., Prevot L., Thoni A., **Vinatier F.** (2024-03-07). Evaluation environnementale de stratégies de protection phytosanitaire viticoles. Presented at 15ème Journée Scientifique de la Vigne et du Vin, Montpellier, France (2024-03-07), https://hal.inrae.fr/hal-04505443