Restoration of ditch bank plant diversity : the interaction between spatiotemporal patterns and agri-environmental management

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Summary

The decrease in species diversity of European agricultural ecosystems has been widely documented in recent years. Most of the former agricultural biodiversity is now retained in non-productive landscape elements like nature reserves and ditch banks. Over the past 30 years, however, the species diversity of Dutch ditch banks has been in decline. Management practices aimed at conserving remnants of species-rich sites (i.e. nature reserves) or at enhancing the botanical diversity of agricultural areas (i.e. agri-environment schemes (AES)) have attracted growing attention. However, these practices often produce poor results and the effectiveness of the techniques used is still being questioned. The studies reported on in this thesis focused on restoration of plant species diversity on ditch banks.

The pattern of variation in species composition represents one of the central issues in modern ecology and provides the scientific basis for conservation planning. Compared with the patterns of species richness, however, spatial ddifferences and temporal changes in species composition have received far less attention. One aim of our study was thus to investigate the spatial and temporal patterns of species composition and to use this ecological information to reveal the processes that create or maintain diversity, and are therefore critical for plant diversity restoration on ditch banks (Part I, *Chapter 2* and *Chapter 3*). Previous research into ditch bank systems found that enhancing colonization, for instance by improving dispersal, rather than reducing extinction, might be more effective to increase species richness. Our studies examined the opportunities to improve the dispersal of plant species on ditch banks (Part II). One option is to focus restoration efforts on areas in the vicinity of species-rich locations (such as nature reserves). *Chapter 4* and *Chapter 5* tried to evaluate the possible spatial arrangements of nature reserves and AES-managed ditch banks for the most effective protection of biodiversity. Another aspect we studied is that of mowing regimes, which are likely to have major effects on plant species richness, in view of their impact on seed availability and dispersal. It was therefore important to test the effect of mowing date on seed-setting under different management regimes, to establish the most effective mowing regime for protecting and increasing plant diversity (*Chapter 6*).

Our study focused on the ditch banks located in the Krimpenerwaard area (in the western peat district of the Netherlands), which is among the most intensively exploited areas in Europe and is particularly rich in ditch banks. In this area, an extensive network of shallow ditches, canals, other water courses and dykes is part of the present-day “polder” landscape, which was created by reclamation and cultivation of the peat bogs formed after the last glacial period. Three main

management types are applied on ditch banks in this area: nature conservation, AES and conventional agricultural management. The nature conservation areas (nature reserves) are part of the same landscape as the surrounding areas. Their strategy aims for the conservation and restoration of the traditional farming landscapes with their associated extensive forms of agriculture and diversity of wildlife in a limited number of areas. The AES are characterized by a "no cure, no pay" system, whereby farmers are free to choose a particular management regime, but are recommended to apply the following treatments: first mowing at the end of June or beginning of July, zero fertilizer inputs, low stocking rate and deposition of material dredged from the ditches on the top of ditch banks. Conventional management is the regime implemented by farmers when given complete freedom. We mainly focused on 25 target species of nature conservation in our study. These species are valuable ditch bank plants as defined by the Dutch government and are used in rewarding farmers for AES implementation. They are not only easy to recognize, but are also supposed to be indicative of AES-based management of ditch banks.

Chapter 2 discusses hierarchical additive partitioning of plant species richness to analyze the spatial and temporal patterns of plant diversity on ditch banks. For all species, the beta diversity at different scales contributed more or less equally to the total species diversity, underlining the importance of differences in species composition between different spatial and temporal scales. The analysis of target species revealed that a larger proportion of the beta diversity was explained by spatial scales and much less by temporal scales, compared to that for all species. The rate of distance decay for target species decreased over time, probably due to improved environmental conditions rather than dispersal processes.

The proportions of diversity components differed between nature reserves and agricultural areas, with a higher within-site species diversity and lower between-site diversity in nature reserves. The different patterns of species diversity may be caused by characteristics of the management regimes, such as nutrient levels and grazing intensity. The dispersal of plant species in both nature reserves and agricultural areas is still limited and ecological restoration projects should therefore focus particularly on ways of increasing seed availability.

Chapter 3 presents a model to explain the spatial pattern of species composition in terms of the combined effects of dispersal and environmental factors on ditch banks. Dispersal factors such as geographic distance and spatial limitation of agricultural activities of individual farmers had significantly negative effects on the similarity of all species between plots, while other dispersal factors like the spatial limitation of water systems and environmental factors such as nutrient levels also had statistically significant effects on similarity of target species between plots.

The target species showed a higher rate of distance decay in species similarity compared with other species, and environmental determinants seem to be more important for these species.

Chapter 4 uses a conceptual model to determine whether the effects of restoration measures on ditch banks affect site-related limitations or seed availability limitations or both. We investigated whether nature reserves (seed sources) can improve species diversity in the surrounding areas and to what extent AES can enhance this effect, by studying the plant diversity of ditch bank vegetations at increasing distances from nature reserves. Plant diversity decreased significantly with the distance from the source communities in the reserves. There were considerable differences in species diversity between AES-managed and non-AES ditch banks, with the former showing greater plant diversity especially in the first 200 meters from nature reserves. The presence of all individual species decreased with the distance to a nature reserve, but the strength of this relationship and the effects of AES differed between species. AES-managed ditch banks had less severe site-related limitations for most plant species, but AES management did not affect the seed availability limitation. The study reported on in *Chapter 4* left unanswered the question of trends in plant diversity along banks running parallel to the edge of the reserves, which is necessary to get a clear picture of the impact of the entire network of nature reserves, AES and ditch banks.

The study reported on in *Chapter 5* therefore aimed to estimate the effects of synergy between nature reserves and AES on plant species within a network of ditch banks. Plant diversity was investigated on AES and non-AES ditch banks running parallel to the edge of a nature reserve, and compared with ditch banks running transverse to such reserves (*Chapter 4*). On non-AES ditch banks running parallel to nature reserves, there was a significant decline in species richness with increasing distance from the reserve, which demonstrated that synergy between nature reserves and AES can enhance plant diversity. Furthermore, this decline of diversity with distance appeared to be less pronounced than that occurring on ditch banks running in the transverse direction. Less human disturbance and more appropriate ditch water levels below the field surface would benefit the species diversity in relation to the distance. The effect of AES differed between ditch banks running in the transverse and parallel directions, with a significant effect beyond 200 m on the parallel banks and within 200 m on the transverse banks. Priority should therefore be given to implementing AES on the banks of parallel ditches at some distance from a nature reserve.

Chapter 6 reports on a comprehensive field study about the effect of mowing date on seed-setting on ditch banks. We applied biannual mowing regimes on plots

under different management regimes (nature reserves, AES with short-time management, AES with long-time management and conventional management). The number of seed-setting species at the first mowing rose significantly as the time of mowing was delayed, whereas the number of seed-setting species at the second mowing was highest when the first mowing took place on May 15th and the second on Sept. 1st. Under biannual mowing regimes, considerably higher numbers of seed-setting species were observed when the first mowing was carried out on July 1st and the second on Sept. 1st. This suggests that mowing biannually, on July 1st and Sept. 1st may in principle be a optimal strategy to enhance seed dispersal on ditch banks. On plots under short-term AES and on conventionally managed plots, seed set peaked on Aug. 15th, while in nature reserves and on long-term AES plots this was on Sept. 1st. This suggests that nature reserves and long-term AES ditch banks should be mown at later dates than conventionally managed and short-term AES plots.

Chapter 7 presents a synthesis of the discussions in Chapters 2-6 and discusses options for conservation and further research. The results of the research support the idea of combining nature reserves and AES to increase plant diversity on ditch banks. The locations of AES should be chosen carefully, since their effect differs between banks running in different directions. Other factors which might enhance the effect of AES, such as location downwind of and parallel to nature reserves, and lower nitrogen inputs on adjacent fields, should also be taken into consideration in conservation strategies. Mowing was considered as a possible restoration measure, and the effect of the mowing regime on seed availability for transportation suggested a general mowing scheme to increase seed dispersal. Moreover, for the conservation of some rare and internationally valued species tailored mowing regimes may be needed.