Eindrapportage-formulier TRIAS projecten
Final report format for TRIAS projects.

When a TRIAS project has finished, or is about to finish, a Final Report is required. This report serves several goals simultaneously:

- it enables the program commission to check whether the project has met its goals,
- it enables NWO-ALW to finalize the project administratively, e.g. pay the final part of the personnel costs of the project,
- it provides some of the information needed for evaluation purposes,
- it provides information which can be publicized, e.g. via a web site.

We have integrated the questionnaires from TRIAS and ALW into one, in order to prevent the need to fill in the same answers twice.

Please send in the filled out forms within a month after the project is completed to:

Netherlands Organisation for Scientific Research
Earth and Life Sciences
Carmen van Meerkerk and/or Theo Saat
P.O. Box 93510
2509 AM The Hague

Part I

General information, also intended for publication through the TRIAS website

01 Project Title.
Biogeochemical constraints for sustainable development of floodplains in riverine regions – nitrogen dynamics and vegetation (project part Utrecht University)

02 TRIAS/ALW project number or file number
TRIAS: 835.80.010

03 Research period, at what date did the project start, at what date did it end.
February 1st 2002 – May 1st 2006

04 Names of the researchers involved, the names and addresses of the institutes where the research work was carried out.
Drs. A. Martijn Antheunisse (PhD student)
Prof. dr. Jos. T. A. Verhoeven (promotor)
Prof. dr. Hendrikus. J. Laanbroek (promotor)

Utrecht University, Landscape Ecology, Institute of Environmental Biology P.O. box 800.84, 3508 TB Utrecht, the Netherlands

05 Short scientific summary (500 words) in English of: main research objective, research methods, results and conclusion
The research objective of the project was to assess whether changes in river water quality and sediment characteristics due to human impact, in combination with strongly altered flooding regimes, would form a constraint for the ecological development of floodplain habitats with species-rich riverine vegetation types as one of the major goals. Besides a number of floodplain restoration activities in the lower reaches of the Dutch major rivers, the project also aimed at investigating opportunities for restoration of highly impacted estuaries, with special emphasis on hydrology (tide) and salinity gradients. The Utrecht part of the project specifically studied the (altered) nitrogen dynamics in the floodplain areas and the consequences for the vegetation. A specific question was whether control of plant growth by nitrogen is restored successfully in projects where floodplains are exposed to more frequent flooding. Several extensive field surveys were carried out to investigate correlations between vegetation parameters and nutrient-related sediment and water characteristics, with specific attention to relations with river hydrology (i.e. frequency, timing and duration of flooding). A large set of environmental (soil, water) and plant variables were measured in highly impacted, rehabilitated and also more natural floodplains of rivers (the Netherlands and Poland) and in estuarine floodplain locations (the Netherlands and Ireland). The results of these comparative field surveys were used to set up two large scale hypothesis-based mesocosm experiments. In these experiments, highly frequent, detailed measurements of environmental and plant variables but also process rates in soil-vegetation monoliths were carried out in a (partly) controlled environment. The focus was on the effects of flooding during the growing season and renewed influence of tide and brackish water, respectively. In addition, several smaller scale experiments were executed, often as pilot experiments (by M. Sc. students) to investigate a selected functional compartment of the floodplain systems, i.e. process rates in the soil or plant response to high temperature inundation. The information of these experiments was partly used to design the larger-scale mesocosm experiments and determine the method and frequency of sampling.
The field studies in the lower river floodplains revealed that there were strongly positive correlations of peak standing crop to the soil nitrogen for the pristine river floodplains, indicating that plant is limited by nitrogen, which was confirmed by our analysis of tissue nutrient ratios in aboveground living biomass. These positive correlations of peak plant biomass to soil nitrogen were absent for regulated, impacted river systems, suggesting that primary productivity is no longer controlled by nitrogen in these impacted floodplains. Under

experimental conditions it turned out that soil-vegetation units of these heavily regulated systems are much less adapted to a flooding event during the growing season compared to communities from more natural sites. A similar strong effect of eutrophication on plant growth limitation and productivity was initially expected for estuarine floodplains. Instead, a hydrodynamic gradient (from MLW to MHW) turned out to be determining the distribution and productivity of the dominant helophyte plant species in the brackish zone of these estuaries, rather than nutrient richness. In experimental conditions the tidal movement increased nitrogen transformation rates in former estuarine sediments with or without agricultural use. Especially mineralization was enhanced by tidal water level fluctuations, resulting in higher inorganic nitrogen availability a year after the start of the experiment in the soil monoliths. In contrast to expectations, oligohaline treatments had no negative effects on plant biomass production in the agricultural grassland soils, while it did have a negative effect on productivity of the vegetation from the former brackish marsh.
The different responses of the floodplain types investigated are directly relevant in discussions on rehabilitation strategies for modified lower river floodplains systems. Measures promoting summer flooding should be considered with care. In estuarine systems, the emphasis of restoration practices should be on re-establishing a tidal gradient with sufficient amplitude, while a salinity gradient or reducing available nutrient concentrations is of much less importance.

06 Popular summary to inform the general public (1/2 to 2 pages of text)
in Dutch. The funding organisations of TRIAS (SKB, NWO-ALW and Delft Cluster) want to inform a more general audience about the results of the TRIAS Research projects. That is why we ask you to give an executive summary of the project in a popularising way and written in the Dutch language.
To be written

07 What impact and relevance has this project's outcome for practicing soil protection and/or soil remediation? Again, please motivate.
Although this project was not specifically aimed on soil remediation or protection, rather more on vegetation development, there are obviously very important connections between both subjects. Therefore we stress that
(1) impacted floodplain sediments are rich in nutrients, which is not favourable for floodplain plant diversity, and
(2) top-soil removal as a measure should be discussed, with attention to hydrological consequences.

08 Please list the presentations held in connection to this project
Oral presentations
Soil&Water Conference, Zeist, June 2003 *Nutrients, water chemistry and sulphate-reducers in floodplain areas*
The 7th Intecol International Wetlands Conference, Utrecht, July 2004 *Summer inundation of riverine floodplains; effects on soil geochemistry and vegetation*
World Ecological Restoration Conference, Zaragoza (SP), September 2005 *Restoration of a closed-off estuary in the Netherlands, consequences for biogeochemistry and terrestrial vegetation*
1st European Annual Meeting of the Society of Wetland Scientists, Bangor (UK), January 2006 *Short-term response of soil nutrient dynamics and herbaceous riverine plant communities to summer inundation*

Additionally, a range of 'internal' presentations were held in which methods and results of field surveys and experiments were discussed with colleagues to improve the methodology and gain a better understanding of the results.

Poster presentations
BodemDiep Conference, Zeist, June 2002
NCR days, Nijmegen, November 2002
Verwey PhD meeting, Texel, January 2003
8th International Symposium on Biogeochemistry of Wetlands, Ghent (B) September 2003
Soil&Water Conference, Zeist, June 2004 (also presentation of supervised MSc. student).
Soil&Water Conference, Zeist, June 2005
World Ecological Restoration Conference, Zaragoza (SP), September 2005

09 Please list publications (published and submitted) in connection to this project. Please indicate publication took place in either a refereed journal, a non-refereed journal (incl. conference

proceedings); whether it was published as a chapter of a book, as a monography or as a dissertation.

Leon P.M. Lamers, Roos Loeb, A. Martijn Antheunisse, Marzia Miletto, Esther C.H.E.T. Lucassen, Andries W. Boxman, Alfons J.P. Smolders and Jan G.M. Roelofs (2006) Biogeochemical constraints on the ecological rehabilitation of wetland vegetation in river floodplains. *Hydrobiologia* 565: 165-186

A. Martijn Antheunisse, Roos Loeb, Leon P.M. Lamers and Jos T.A. Verhoeven () Regional differences in nutrient limitation in floodplains of selected European rivers: implications for rehabilitation of characteristic floodplain vegetation. *River Research & Applications*, accepted / in press

A. Martijn Antheunisse and Jos T.A. Verhoeven () Short-term response of soil nutrient dynamics and herbaceous riverine plant communities to summer inundation. Wetlands, *under review*

A. Martijn Antheunisse and Jos T.A. Verhoeven () Soil nutrients and vegetation along a salinity gradient in tidal rivers in Ireland and The Netherlands, with special emphasis on two common helophytes. *to be submitted shortly to a peer-reviewed journal*

A. Martijn Antheunisse, Roos Loeb, Marzia Miletto, Leon P.M. Lamers, Hendrikus. J. Laanbroek and Jos T.A. Verhoeven () Response of nitrogen dynamics to tides and salinity in estuarine and agricultural grasslands. *to be submitted shortly to a peer-reviewed journal*

A. Martijn Antheunisse (). Nitrogen dynamics in floodplains, consequences of ecological rehabilitation for vegetation. PhD thesis, Utrecht University. *pending*

10 Please list Patent applications or other professional products (including contracts, articles in the popular media, contributions to documentaries or scientific television or radio programs, CD-ROMS, DVD or other (electronic) media).

Short introduction to this TRIAS research-project on the Landscape Ecology web-page
http://www.bio.uu.nl/LandscapeEcology/people/martijn

Interview Bioscope (magazine department Biology) 2005-4 "Natuurontwikkeling en overstromingen"
http://bioscope.bio.uu.nl/archief/2005/bioSCOPE%204%20jrg%205.pdf

Part II

Detailed information, primarily intended for administrative and statistical use by NWO-ALW

11a Under item 5 you have filled in the main research objectives. Please list all the original research objectives as indicated in the project's application and both indicate as well as motivate, to what extent these goals were realised, and/or whether the original research objectives had to be adapted.

The central questions for the whole research project are indicated with some answers provided by the Utrecht subproject (in italics):

1. Given the new river management, what are the biogeochemical constraints for sustainable ecological development of characteristic riverine vegetations, and which conditions are needed to combine space for rivers with ecological goals like biodiversity?

This subproject has shown that nitrogen availability is a crucial characteristic for river floodplain vegetation. Measures reducing nitrogen richness of floodplain sediments should be considered in floodplain restoration activities (to be evaluated fully after completion of all three subprojects).

2. Given the pollution of soils, sediments and surface water with potentially toxic substances, which parts of the river floodplain areas are suitable for the development of characteristic, species-rich ecosystem types?

This subproject has not specifically addressed this question.

3. Given the soil conditions in river floodplains, which hydrological regimes are appropriate for the sustainable ecological development?

Higher flooding frequencies are suitable as they will lead to new, less nutrient-rich sediments covering the current floodplain soil. In the tidal zone, sufficient tidal amplitudes (more than 1.5 m average) are needed for restoration of wide helophyte zones.

4. Given the strong eutrophication of many floodplains due to agricultural use, which methods (such as removal of the top layer) are available to make them suitable for sound ecological development?

Removal of such very nutrient-rich soils should be considered, but evaluation of the hydrological consequences is very important (exposure of the new top soil to surface water and ground water). This evaluation should be carried out at the end of the total project.

Furthermore, several detailed, process-oriented sub questions were formulated, and here also answers provided by the Utrecht part of the project are given (in italics) :

1. How are redox conditions, nutrient cycling and the accumulation (free) sulphide and ammonium affected by the altered flooding-desiccation regimes in floodplains?

In this subproject, attention was given to nitrogen processes and to a lesser extent also to phosphorus dynamics in relation to the altered flooding-desiccation regimes. Especially processes controlling the availability of inorganic nitrogen were highly affected by the flooding regime. Effects on redox and accumulation of toxic substances were not addressed in this subproject.

2. How do these regimes affect overall decomposition and mineralisation, sulphate reduction rates, nitrification and denitrification rates?

This subquestion held the core science of this subproject, in which especially mineralisation and denitrification was given much attention. Especially in the mesocosm experiment concerning the Haringvliet estuary, a clear positive effect of dynamic hydrologic conditions on these processes was found.

3. What are the interactions of the above processes with river water and groundwater chemistry (sulphur, nitrogen, salinity) and soil/sediment characteristics (clay and organic matter fractions)?

The quality of the soil (nutrient load etc.) turned out to be much more important for these processes than the quality of the river water. In both experimental and field studies only very limited effects of the quality of the flood water was found, whereas differences in soil characteristics (agricultural vs. more natural) were of paramount importance for process rates.

4. How do soil microbial communities linked to sulphur cycling react to these hydrological and hydrochemical changes (structure and functioning) and what is their quantitative role in nutrient cycling?

This subproject has not specifically addressed this question.

5. How do different vegetation types and macrofauna respond to these biogeochemical changes, with respect to primary production and species composition?

The research carried out was restricted to vegetation composition and response as an additional inventory of macrofauna would have been to much time-consuming and would have hampered the detailed biogeochemical approach. Vegetation composition, as governed by primary production, was highly affected by differential biogeochemical conditions.

11b Did the project also include objectives which were not scientific? For instance, did the project also intend to apply research results, or strengthen the economic position of certain businesses?

This project included not only the detection of possible biogeochemical constraints for successful ecological restoration in both lower river floodplain systems and estuarine parts of large river systems, but also how this knowledge could be applied to prevent future failures in ecological restoration. A final project-wide, assessment has still to be carried out, but already it is possible to advice terrain managers and policymaker how to design new riverine nature with respect to renewed river water influence, and soil nutrient status.

11c Did the project's aims include the expanding the (international) network of contacts (at what level), providing education, improve communication, serve as input for policy drafting or policy decisions, etc.? Please motivate.

Although expansion of a contact network was not a specific aim of the project, fieldwork and the attending of congresses abroad (and in the Netherlands), resulted in expansion of a personal network, but also contacts between foreign research groups (i.e. in Ireland) and the Landscape Ecology group in Utrecht were facilitated. On the other hand, this project (in combination with other ongoing projects) resulted in a more elaborate cooperation between the three research groups involved in this project: Landscape Ecology, Institute of Environmental Biology - Utrecht, Department of Aquatic Ecology & Environmental Biology - Nijmegen and the Department of Microbial Wetland Ecology - Nieuwersluis. The three institutes cooperate in the Center for Wetland Ecology, which aims at the generation of funding for collaborative research and development projects in wetland science (www.wetland-ecology.nl).

12 Do the results obtained match the original objectives? Please provide a short motivation why they do or don't.

Our results turned out to be suitable to answer part of the original research questions. We were able to identify possible bottlenecks hampering successful ecological restoration in floodplains, related to nutrient status of these areas. In addition, we have shown that in estuarine systems to be rehabilitated, the nutrient loading is of much less importance, but that hydrology (tides) is a much more important factor.

13 Will the results of this project serve as input for an initiative integrating / and or generalizing input from several projects, for instance into a (numerical) model, or into more understanding at the higher / system level? If so, was this intended and optimised from the beginning or did it occur by chance / spontaneous? Please elaborate.

The data that arose from the field studies in this project can be rather easily combined with data collected similarly (methods) and in the same time frame, but in different wetland systems. In the last years, several PhD students at the Landscape Ecology group in Utrecht have performed such field surveys, i.e. in fen systems, shallow lakes and brook valleys. An overall comparison between the systems with respect to soil and plant variables could provide information on the characteristic functional features of these systems with respect to nutrient cycling and how these affect plant productivity and vegetation diversity. In the next two years, following individual publications of the field surveys, a meta-analysis can be performed and the results will be summarized.

14 To what extent has this research project pointed the way in which further research has to be undertaken? Please motivate the guiding role perceived.

Two main gaps in scientific knowledge were identified and partly covered in this project. Firstly, the relation between nutrients in the soil, environmental conditions and vegetation establishment and development was addressed. Due to the limited time of the project, it was not possible to study the temporal aspects of these interactions directly, but only by deducing temporal relations from data along spatial gradients. Therefore, it is of vital importance to establish and fund long-term soil and vegetation monitoring projects in rehabilitated

floodplain areas to check if the results from this research projects have resulted in reasonably correct predictions of temporal change. Secondly, tackling the systems heterogeneity, especially with respect to the soil, and the effect of that on system average process rates turned out to be very difficult. In relation to new European legislation (WFD), it is very important to be able to scale-up results from the site scale to the catchment scale with a reliable estimate of the errors involved. Present methods require a high degree of spatial replication to be able to make accurate judgements. More work is needed on how local variability can be addressed by spatial modelling and geostatistics.

15 In what way, and to what extent, are the results reached of importance to research done by others? Please motivate or elaborate

The results obtained in this study are of prominent importance for the work carried out in the two other subprojects of this program. The work of the three subprojects has been carried out in close mutual contact.

16 Are you aware of any essential gaps or obstacles standing in the way of applying the results from your research project? Please elaborate.

Unfortunately, the largest obstacles for applying the results can not be overcome by extending or deepening the scientific research. At present, the public awareness of potential ecological values of floodplain systems and the need for giving the rivers more space to prevent catastrophic flooding, high just after floodings of 1993 and 1995, is diminishing. Political choices are made mostly in favour of short-term economical gain and 'cheap' safety and are overlooking the increase of long-term natural values. Measures in favour of natural development are mostly at the bottom of the list, and firstly dropped when there is no sufficient budget. A renewal of public awareness is necessary when the results of this project concerning the relation between nutrients in the soils and vegetation, but also the affects of off-season flood events can be applied in areas to be rehabilitated.

17 Which new research questions were generated through this project? Were these new questions addressed within this research project itself? Or will these new questions, or the results from your research project lead to new research projects (to be) funded by either 1st , 2nd,or 3rd category funding or funding through international funding agencies? Please elaborate.

At present, before a retrospective project-wide discussion, no distinct new research questions have arisen from this study, significantly different from the original research issues. On the other hand, we can already conclude that interactions between soil, hydrology and vegetation are very complex and especially in areas to be rehabilitated, long term research is needed to also understand the time and succession effects involved in these relationships. Unfortunately, this type of ecological studies is costly (in time), and due to its lengthy nature not suitable for 2nd or 3rd category funding.

18 In what way did you link this project to other projects within the TRIAS-program or link it to projects outside TRIAS? Did you cooperate within the TRIAS-program and did this cooperation lead to integrated results?

Linking the Utrecht University part of this project to other TRIAS programmes or SSEO projects will mostly be restricted to the 'soil' compartment, as the study of vegetation is quite restricted in other TRIAS projects. Most projects are oriented towards ecosystems health, and deal with pollution of systems with heavy metals or organic compounds. The difference between research fields became clear during the annual Soil & Water conferences in which it was sometimes not easy to detect any congruency between this project and others. Therefore, until now, no efforts were made for a programme broad linking. Nevertheless, as many projects within the programme are finishing or have already finished, opportunities for linking might surface.

19 Can you elaborate on the impact on society as a whole of your results (e.g. societal organisations, NGO's, businesses, schools, municipal authorities, etc.)

At present, no impact of the results of this part of the project on society is present. Still, during the continuation of the project (parts RUN and NIOO) and the final synthesis of all results, a combined effort will be made to reach out to NGO's and regional and national government agencies to inform them on our findings on ecological rehabilitation of floodplains.

20 What actions were taken to disseminate the results in the direction of the general public, besides the usual scientific channels?

None until now, but this is expected to be done at the time of the publication (and defence) of the thesis.

21 Have the researchers involved obtained a new position or employment after the project came to an end? Please specify and elaborate!

Yes, Drs. A.M.Antheunisse continued to work at the Landscape Ecology group. He is now working as a researcher in a project funded by STOWA in which the mechanisms and role of riparian buffer strips in the retention of nitrogen and phosphorus from agricultural run-off are studied. The experience gained in the TRIAS project on nitrogen process measurements are the primary reason for the application. The duration of this project will be approximately 1.5 year, and besides extensive field monitoring, results will be scaled up to help in evaluating the potential role of such buffer strips in agricultural landscapes.