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A smart solution for flooding, drought and water pollution

Due to climate change measures to prevent damage by flooding and water shortage are being more and more urgent. Often the question arises: is it possible to temporary store peak floods and simultaneously to conserve water in the same area? And is it possible to improve the quality of retention water to guarantee possible re-use of water, nutrients and biomass?

Park Lingezeegen is being constructed for recreation, nature development and water storage in the Betuwe area between Arnhem and Nijmegen. A water storage basin has been realized in order to prevent flooding in the neighbouring urban area of Arnhem-South and in the greenhouse horticultural complex Bergerden. In this part of the Betuwe water board Rivierenland is also looking for more storage capacity for water to be used later in dry periods to prevent water shortage damage in fruit orchards and nature in the Betuwe. This water however needs to be as clean as possible.

In the research project RichWaterWorld it is investigated if and how temporary storage of high water peaks (water storage) can be combined with conservation of local water surplus (water retention) and natural water purification. The aim is to support sustainable use of water, nutrients and natural energy within the region.

Actual and forthcoming water balance

Alterra Wageningen UR, MeteoGroup and Eijkelkamp Soil & Water cooperate in finding solutions for the regional challenges concerning water quantity. A regional hydrological system analysis of Park Lingezeegen and its surroundings gives insight in the patterns and processes of soil and water. This information has been used as input for an integrated hydrological model, based on the regional ground water model MORIA, used by the water board Rivierenland. For this purpose a surface water module has been added to the model. So the effects of climate change, weather change and the influence of the river Rhine on the regional water system and water balance could be predicted on a regional and local scale. The long term effects of several climate scenarios as well as the short term effects of weather forecast scenarios on the local water balance and water levels can now be predicted.

To validate the results of the hydrological model, field measurements have been executed in a 2-hectare experimental area, which was constructed near the water inlet to a large reed swamp. Sensors register the groundwater levels, surface water levels and soil moisture content. This information is directly available online. Sensor data are regularly checked by observations in the field. The monitoring data, together with data on water levels of the river Rhine at Lobith, are used as input for the hydrological model.

Meteorological observations in the experimental area provide actual information on the amount of rainfall and data needed to calculate the evaporation loss. Data from radar images and weather models are used for multiday weather forecasts. This meteorological information on the actual and forthcoming weather conditions is also available online and used as input to the hydrological model. Based on all these data the consequences of changing weather for water levels and the local water balance for the next fifteen days can be predicted.
Instrument for adaptive water management

Monitoring data from sensors and meteorological instruments, together with data from radar images and weather models, provide a large amount of information. That mass of data is unusable unless it is made available in a coherent and cohesive way. Therefore all weather forecast data are clustered in weather scenarios based on the probability of occurrence, in order to make it possible to anticipate in water management on changing water conditions. The web application Richwaterweb has been developed to store and organize all data for calculating the daily water balance and water levels over a period of fifteen days ahead.

As a result the web application supplies expected water balances and water levels for several weather scenarios (very dry to very wet) and can be used for calculating the actual and future availability of water storage capacity in the next fifteen days.

Bio cascade water purification

Water storage and water retention areas are often developed in (former) agricultural areas, where objectives for water quality and nature development often are not met. As a solution Radboud University and B-Ware Research Centre have developed a bio cascade water purification. In contrast to well-known helophyte filters and water harmonicas the bio cascade water purification is developed as a regenerative system in which the accumulation of nutrients is prevented. Depending on the field situation a tailor-made bio cascade water purification is developed by cleverly using knowledge about soil processes in relation to waterlogging and desiccation, and about aquatic plants in their function as bio-engineers. In the test location in Park Lingezeegen the emphasis in water treatment lies on the removal of nitrogen (N), whereas in the experimental ditches at Radboud University (RU) the emphasis in water treatment lies on the removal of phosphate (P).

Figure 1 shows results from the research in the experimental ditches. It is shown that regardless of
season the water quality in the bio cascade increases considerably thanks to the downstream combination of specific biogeochemical processes. Although the chemical nutrient removal rates in winter are slower they still continue throughout the year. Specific statements on residence time and purification efficiencies are expected by the end of 2015, with the completion of a detailed water balance and the analyses of the latest data on water and soil parameters. The same holds for the field trial research in Park Lingezegen.

**Charging phase**

Generally the bio cascade water purification consists of a series of connected water basins. In the experimental area in Park Lingezegen the inlet water flows into a settling basin, where particulate nutrients can settle into sludge. In the experimental ditches at RU the inlet water infiltrates in an iron rich soil sown with flood tolerant plants. Subsequently the water flows to water basins with reed, bulrush or yellow iris. Because these helophytes pump oxygen through their stems from the atmosphere into their rhizosphere a coupling of nitrification and denitrification processes takes place at the root-soil interface due to which dinitrogen gas is emitted to the atmosphere and the nitrogen load of the system is reduced. After the helophyte filter the water enters a water basin with submerged aquatic plants for water polishing purposes. Depending on the phosphorus (P) loads in the system, a final step in the bio cascade takes place when the water passes a filter consisting of iron-coated sand, as is the case in the experimental ditches at RU.

![Figure 1: This graphic indicates how, since the realisation of the bio cascade in summer of 2014 the total concentration of phosphate (P) in the water decreases from an average of two times the European Water Guideline (0.3 milligrams per litre in the intake water to less than 0.05 milligrams per litre) after passing the iron sand. These results are achieved by the running through of several compartments of the bio cascade. The grey dotted line indicates the phosphate guideline norm](http://www.h2o-watermatters.com/includes/partials/printArticle.php?ed=201511&art=07_Artikel)

**Discharging phase**

On longer time scales the accumulation of P to soil particles in the bio cascade water purification system is inevitable. Usually the primary production rates of aquatic plants are too slow to compensate for the supply of P via the water and the release of P from the soil. When measurements show that this is the case, as indicated by soil and water quality parameters, the system will be completely inundated. Due to the presence of reactive organic material at the bottom this will cause the soil to become anoxic and P to be released from the Fe containing soil particles. Floating aquatic plants promote this process because they seal off the water surface preventing oxygen diffusion into
the water layer due to which the redox depended mobilisation of P may continue as P diffuses into the overlaying water. Here the floating plants species may take up the P in their biomass. By regularly harvesting the plants P may be removed from the system. Then, after a desiccation period, the soil in the bio cascade water purification system is able to bind P again from the infiltrating water. This creates a regenerative system that through manageable changes in redox potential, and associated nutrient conversions, can be charged and discharged. Within the time span of Project RichWaterWorld this stage has not yet been reached in neither of the bio cascades in Park Lingezeegen or at RU.

In the bio cascade purification system biomass is produced. Within the framework of RichWaterWorld a first survey was conducted on possible applications of the biomass in bio based products. The biomass can, for instance, be used in food industry (meat substitutes for instance) or for the production of glue or green fertiliser. In addition, biomass residues can be converted to biogas which in turn can be converted to energy and heat. Figure 2 shows that the methane yield of for instance elodea is just as high as more conventional biogas crops like silage maize.

**Conclusions**

RichWaterWorld shows the possibility to combine water storage and retention together with water
purification in one and the same area. As a consequence of the complex geohydrological situation and the changing impact of water levels in the river Rhine, the available water storage capacity in Park Lingezegen is not always fully utilized. Supported by the adaptive water management tool, developed in this project, water managers can be advised on preventive inlet or discharge of water in the water storage basin, anticipating on weather forecast and predicted water levels in the river Rhine.

Water retention offers good chances for biogeochemical water purification using a bio cascade system. During the period of water available in the storage basin, nutrients can partly settle in the sludge and partly being absorbed by water plants. N and P are removed for almost 100 per cent by dedicated water management and frequently harvesting the plant material. Regular harvesting offers possibilities for biomass applications such as recovery of proteins and sustainable energy by bio gasification.

The RichWaterWorld consortium consists of public and private partners and knowledge institutes. This partnership has facilitated that public goals have been realized as well as commercial products have been developed in the project, such as an advice tool for adaptive water management and a well-functioning bio cascade water purification.

RichWaterWorld is carried out by a consortium consisting of the knowledge institute Radboud University Nijmegen and Alterra Wageningen UR, the companies MeteoGroup, Eijkelkamp Soil & Water, B-Ware Research Centre and Alliander and Park Lingezegen as public partner. Projectleader is Thea van Kemenade, Radboud University Nijmegen.

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Summary

Because of climate change adequate supplies of fresh water are not secured anymore, not even in the Betuwe area between the rivers Rhine and Waal. Besides more room for water storage (against flooding) it is becoming more and more necessary to conserve water to combat water shortage. In the project RichWaterWorld, carried out in Park Lingezegen, an innovative concept for adaptive water management has been developed and tested to combine measures against both water challenges in the same area. Before nutrient-rich stored surface water can be re-used the content of phosphate (P) and nitrogen (N) needs to be reduced. In this project an innovative bio cascade purification system has been applied and tested. It uses soil processes and water and swamp plants to absorb N and P from the water. Perspectives for re-using the harvested biomass to make bio based products and energy seem to be positive. RichWaterWorld has given insight how different regional water challenges can be dissolved in an integrated and sustainable way.

Literature

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