Ecological Engineering 35 (2009) 1786–1796

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

The artificial catchment "Chicken Creek" (Lusatia, Germany)—A landscape laboratory for interdisciplinary studies of initial ecosystem development

Werner Gerwin[a,*], Wolfgang Schaaf[b], Detlef Biemelt[c], Anton Fischer[d], Susanne Winter[d], Reinhard F. Hüttl[e]

[a] *Research Center Landscape Development and Mining Landscapes, Brandenburg University of Technology, Konrad-Wachsmann-Allee 6, D-03046 Cottbus, Germany*
[b] *Soil Protection and Recultivation, Brandenburg University of Technology, Cottbus, Germany*
[c] *Hydrology and Water Resources Management, Brandenburg University of Technology, Cottbus, Germany*
[d] *Geobotany, Technische Universität München, Germany*
[e] *Helmholtz Centre Potsdam German Research Centre for Geosciences, Potsdam, Germany*

ARTICLE INFO

Article history:
Received 5 February 2009
Received in revised form 12 August 2009
Accepted 14 September 2009

Keywords:
Artificial catchment
Ecosystem development
Initial phase
Soil development
Hydrology
Primary succession
Monitoring

ABSTRACT

The analysis of water and element cycling plays a key role in understanding ecosystems. The definition of clearly outlined budget areas is necessary therefore and is usually approached by analysis of natural surface and subsurface watersheds. However, many of the elements of natural watersheds, e.g. structures in the underground section or at the catchment boundaries, are often largely unknown and are very demanding to explore fully. To overcome these disadvantages artificially created systems might be an appropriate alternative. Compared to a natural catchment, the boundaries and inner structures of an artificial watershed can be planned and defined in advance. This paper presents the initial development phase of just such an artificial catchment built for interdisciplinary ecological research. The site covers an area of 6 ha and is one of the largest artificial watersheds worldwide constructed for scientific purposes. It was completed in 2005 and then left to allow an ecosystem to develop without further restrictions. Its initial state allows the detailed investigation of the first steps of ecosystem development. The creation and properties of this site as well as the first results of an ongoing monitoring program are presented here. First analysis of soil conditions, hydrology, geomorphology, and vegetation illustrate the initial state of the site. The substrate can be regarded as almost unweathered material. Initial characteristics were found with respect to the hydrological behavior of the catchment such as only low infiltration rates probably due to still missing preferential flow paths into the substrate which result in a dominant role for surface run-off. Accordingly, a strong relationship exists between rainfall events and changes of the lake's water level. Also the vegetation cover demonstrates that the succession began very close to point zero of the development.

1. Introduction

The comprehensive knowledge of ecosystem processes is crucial to understand and estimate the responses of natural systems to climate change, atmospheric deposition, land use changes and other driving forces of environmental shifts (e.g. van der Putten et al., 2004; Emmerson et al., 2005; Arndt, 2006). Reactions of natural systems to environmental changes or disturbances may become more predictable if fundamental mechanisms are understood better.

Long-term monitoring studies provide the opportunity to investigate relationships between different processes and patterns within the systems, and to predict their future development (Parr et al., 2002). Some interdisciplinary studies on terrestrial sites have been concentrating on forest ecosystems, others on agricultural landscapes, or even on entire landscapes (e.g. Ellenberg et al., 1986; Campbell et al., 2007; Fränzle et al., 2008). The International Long Term Ecological Research (ILTER) Network was established with more than twenty countries contributing a large number of monitoring sites (Waide et al., 1998). Recently, several new networks have been emerging, such as the Critical Zone Exploration Network (CZEN) in the USA, or the Biodiversity Exploratories and the Terrestrial Environmental Observatoria (TERENO) in Germany.

The analysis of water and element cycling plays a key role in drawing conclusions about functioning, stability, elasticity and

* Corresponding author. Tel.: +49 355 69 4225; fax: +49 355 69 2323.
E-mail address: werner.gerwin@tu-cottbus.de (W. Gerwin).

0925-8574/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecoleng.2009.09.003

resilience of ecosystems. The definition of clearly outlined budget areas is therefore always necessary, and is typically approached by looking at natural surface and subsurface watersheds (e.g. Likens, 1989). Hence, most of these former ecosystem studies have been based on a catchment as a spatial unit which is defined explicitly by natural boundaries. Integration and up-scaling of results from point investigations, such as borehole measurements or soil pit samples, to landscape level is only possible by means of a defined landscape and budget area. Generally, a catchment (or watershed) is a fundamental landscape unit for understanding both water balance and water quality as well as managing water resources (e.g. Gburek and Folmar, 1999; Lemonds and McGray, 2007). Theoretically, a catchment offers the opportunity to quantify input parameters, the output from the system under consideration, as well as the possibility of quantifying the water and element budgets (Schleppi et al., 1998; Neal et al., 2003).

Practically, natural watersheds have to be considered as "black boxes" (Kendall et al., 2001; Sivapalan et al., 2003) with often widely unknown internal structures which can only be explored by indirect methods, e.g. geophysical methods, or punctual investigations. The interdependencies between the different underlying physical, biological, and chemical structures with the surface properties or with the hydrological behavior are often complex and not well understood. For example, geological layers are not homogenous and surface boundaries, as well as boundaries in the underground, are not clear due to this heterogeneity and/or geological disturbances. Natural systems are usually characterized by a huge complexity that often makes the assumption of well defined clear boundaries for budget investigations delicate, and the margins of error are, necessarily, very high for displaying the natural conditions, e.g. in hydrological models (Grayson et al., 2002).

In contrast to the high complexity of mature natural systems, it can be assumed that ecosystems in initial development stages might be less complex and coupled, as only a few initial components are interacting at this stage. This is certainly especially valid with respect to biological compartments of the ecosystem. In its very first stage an ecosystem only contains a very limited number of organisms, like abundant micro-organisms. Higher plants and animals are completely missing at this stage of development. As additional patterns and processes appear during further development the complexity of the system will grow gradually. Several studies have been carried out on initial ecosystems, e.g. investigations of Surtsey Island near Iceland in the 1960s and 1970s (Friðriksson, 2005) or the research following the eruption of Mount St. Helens (USA) in the 1980s (e.g. del Moral and Bliss, 1993; Bishop, 2002). These studies produced important results for the understanding of ecosystems and their genesis. However, many prerequisites of even those systems, e.g. structures in the underground section and at the catchment boundaries were explored only with great effort.

To overcome these limitations of naturally developed ecosystems for process-oriented catchment modeling and multi-response validation, artificially created systems might be an appropriate alternative (Eckhardt et al., 2003). Compared to natural catchments the boundaries and inner structures of artificial watersheds can be planned and defined in advance. Both local boundary conditions, e.g. the accordance of the surface and the groundwater catchment or the drainage pattern, as well as internal structures, e.g. discharge points and stratification can be influenced and, most importantly, precisely documented during the site construction. The mostly unknown heterogeneity of natural systems, e.g. fluctuating water and mass inputs and fluxes due to plant growth and root water consumption, or the diverse surface and subsurface water divide, are assumed to be either eliminated or under control. Ideally, in the case of an artificial watershed, later exploration measurements can be restricted to a selective validation of the construction plan. Important site conditions can be precisely arranged according to the objectives of the study—and not vice versa as is often the case when investigating natural sites. Further, artificially created sites also offer the opportunity to establish systems of certain and clearly predetermined levels of development, e.g. to create a system that starts its development at "point zero".

Some few artificial catchments do already exist in, for example, China (Gu, 1988; Gu and Freer, 1995), Canada (Barbour et al., 2004) and Spain (Nicolau, 2002). The construction of an artificial catchment represents a major undertaking, both regarding the construction work itself and its financial aspects. For this reason most man-made watersheds are restricted to small dimensions and this limits the transferability of the results obtained to real landscape units. Until now "Hydrohill" in China has been known as "perhaps the largest public works effort in small catchment hydrology", with a size of 490 m^2 (Kendall et al., 2001). Most studies based on artificial watersheds have a strong hydrological background. Interactions of different abiotic and biotic ecosystem compartments have been widely excluded in many former studies of artificial catchments. Others have been designed to test specific manipulation purposes, e.g. reclamation or restoration measures for post-mining landscapes or for erosion studies (Nicolau, 2002; Barbour et al., 2004).

A large artificial watershed representing an entire ecosystem at full landscape scale and starting from "point zero" of its development has not been studied before now. This paper presents first insights into the initial development phase of such an artificial catchment, built in Germany over an area of 6 ha, for the purpose of interdisciplinary ecological research.

2. Objectives of the project

The artificial catchment was established as a joint research site of the Transregional Collaborative Research Centre (SFB/TRR 38) "Structures and processes of the initial ecosystem development phase in an artificial water catchment" which was launched in 2007 with financial support from the German Science Foundation (DFG). The Brandenburg University of Technology, Cottbus (BTU), the Technische Universität München (TUM) and the Swiss Federal Institute of Technology Zurich (ETH) are collaborating within this research centre.

As its central hypothesis the project assumes that initial patterns define and shape the development and later stages of an ecosystem. The objectives of this collaborative project are (1) to reveal which abiotic and biotic structures and processes control the initial phase of ecosystem development; (2) to elucidate which interactions exist between processes and both abiotic and biotic patterns in the initial phase; (3) to investigate differences between processes and patterns of initial systems compared with mature ecosystems; (4) to derive and define different stages during ecosystem development; and (5) to find parameters that allow the transfer of results to other ecosystems in an initial stage.

The option of investigating an artificial catchment from the very first beginnings of its creation to the point of forming various development stages allows precise modeling of its developing abiotic and biotic patterns as well as processes. The research approach aims at the coupling of these patterns and processes under clearly defined hydrological boundary conditions and known initial internal system conditions.

The collaborative research project particularly aims to reveal the complex interactions between the developing patterns at the