Ecosystem Services 10 (2014) 111–123

Contents lists available at ScienceDirect

Ecosystem Services

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

Land use trade-offs for flood protection: A choice experiment with visualizations

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ARTICLE INFO

Article history:
Received 3 December 2013
Received in revised form
8 September 2014
Accepted 17 September 2014

Keywords:
Land use trade-offs
Hydrological ecosystem services
Flood protection
Choice experiment
3D-visualization
Mountain catchment

ABSTRACT

Hydrological processes respond to changes in land use. Thus, hydrological ecosystem services can be affected by land use trade-offs and need to be considered in both land use management and water management. In this paper we present a choice experiment study from a medium-sized mountainous catchment area in Switzerland investigating individual preferences for long-term land use changes. The study focuses on trade-offs concerning reforestation, settlement development, and river management and on resulting effects on flow regulation and flood protection ecosystem services. Furthermore, the study investigates the influence of political choice recommendations on individual choice behavior.

We report three major results: (1) Respondents showed clear but heterogeneous preferences for long-term land use changes. (2) Respondents were willing to trade off extensive agricultural land for flood protection ecosystem services, namely through reforestation and widening of the riverine zone. (3) Choice recommendations by political parties and interest groups did influence individual choice behavior in Discrete Choice Experiments but did not, as expected, decrease implicit benefit estimates.

1. Introduction

In Alpine areas, where land is a scarce resource, land use competition and trade-off decisions between land use alternatives are in the focus of land management. High land use competition results in land use changes, such as urbanization, reforestation, or changes in agricultural management. These land use changes substantially affect and alter hydrological processes in freshwater ecosystems (Bronstert et al., 2002; Eshleman, 2004) including effects on stream flows, flood potential, and sedimentation (DeFries et al., 2004). The impact of land cover and land use change on stream flow, water discharge, and flood potential has received substantial attention in the last decades (e.g. Gerten and Lucht, 2012; Gerten et al., 2008; Jones and Grant, 1996; Molnar et al., 2006; O'Connell et al., 2007; Schnorbus and Alila, 2004; Schoonover et al., 2006; Tong, 1990; Zhang and Schilling, 2006). Awareness has risen that, in order to provide flood protection on a sustainable basis, it is necessary to apply a holistic approach, considering not only technical flood protection measures but also land use management (Calder and Aylward, 2006; Wheater and Evans, 2009).

In the mountainous areas of the Swiss Alps, flood prevention plays an important role on the agenda of river and riverine zone management (FOWG, 2001). To avoid unwanted and possibly irreversible effects of land use trade-offs on hydrological ecosystem service provision (as defined by Brauman et al., 2007), land use management needs to take into account ecological, economic, and social values as well as the political acceptance (de Groot et al., 2010). Stated preference methods, such as discrete choice experiments (DCE), are suitable methods for testing the political acceptance of environmental scenarios and for valuing nonmarketable goods and services provided by these scenarios (Freeman, 2003).

In this paper, we investigate the acceptance of long-term land use changes (2010 to 2100) and their impact on flow regulation and flood protection ecosystem services on the catchment scale with a case study in the Swiss mountains. The study focuses on land use trade-offs (concerning forest, agricultural, settlement, and riverbed area) which must be considered in strategies for increasing the capacity of a catchment to provide natural flood protection. In order to address the key challenges in assessing land use trade-offs, we developed a DCE to

Abbreviations: DRZ, downstream riverine zone

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http://dx.doi.org/10.1016/j.ecoser.2014.09.008
2212-0416/

(1) determine individual preferences for settlement development, reforestation, and technical vs. ecological measures for water regulation, (2) to investigate whether people are willing to trade off land for flood protection ecosystem services, and (3) to investigate whether political recommendations influence individuals' decisions on these trade-offs.

The remainder of the article is organized as follows: In Section 2, we describe the study area with a focus on land use trade-offs and their impact on flood protection. Section 3 contains a methodological introduction to Discrete Choice Experiments. Experiment setup and study design are described in Section 4. The study results are presented in Section 5 and discussed in Section 6.

2. Study area

Over centuries, flood protection in Switzerland has moved from local control structures, retaining dams, and barriers in the early modern period to large river corrections and canalizations in the 18th and 19th centuries (Vischer, 2003). In the 20th century the concept of mere flood protection has further evolved to the principles of integrated water management, an intersectoral approach encompassing management of water resources, water bodies and water infrastructures on the catchment scale. The approach encompasses human interventions with all water bodies that need to be coordinated, specifically use of, protection of and protection from water (WA21, 2011). With the introduction of the new concept, the focus of water management has changed from small-scale sectoral to catchment-scale integrated management strategies (FOWG, 2001), targeting ecosystems, their functions, and their positive and negative impacts on human wellbeing across administrative boundaries.

The Kleine Emme catchment underlies a nivo-pluvial-prealpine runoff regime (LHG, 1992) and does not contain any barrier lakes. Precipitation mainly consists of rainwater, which is directly transformed into discharge due to the geological and pedological conditions of the catchment, which may lead to flooding during all times of the year, although mainly in summer (Stadelmann and Lovas, 2000). Management measures, such as an increase of the riverine zone, protection forests, and accurate settlement planning, may add to the catchment's natural flow regulation capacity and thus support technical flood protection.

2.1. Catchment characteristics

The Kleine Emme catchment (Fig. 1) with an area of 478 km^2 is situated in central Switzerland, in the Canton of Lucerne, and includes the UNESCO Biosphere Entlebuch. The upland of the river encompasses 320 km^2 of mountainous area. The rural to periurban lowland covers 158 km^2. Approximately 35% of the study area are covered with deciduous, coniferous and mixed forests. Currently, development pressure is high in the periurban area adjacent to the city of Lucerne (north-east of the catchment) and decreases with increasing distance to Lucerne. In the upland, the population remains constant with around 16,000 inhabitants.

Overuse of forest resources between the 7th and 19th centuries led to devastating floods, causing the need for technical protection measures and reforestation. Documentation of technical flood protection measures in the study area goes back to at least 1800 (Fellmann, 1917). Since 1880, afforestation in the catchment raised the area covered by forest from 22% to 35% (Stadelmann and Lovas, 2000). Additionally, extensive technical protection measures were taken at the beginning of the 20th century (Fellmann, 1917). Nevertheless, minor flood events that cause noticeable damages happen every 10 years on average. The last major flood event

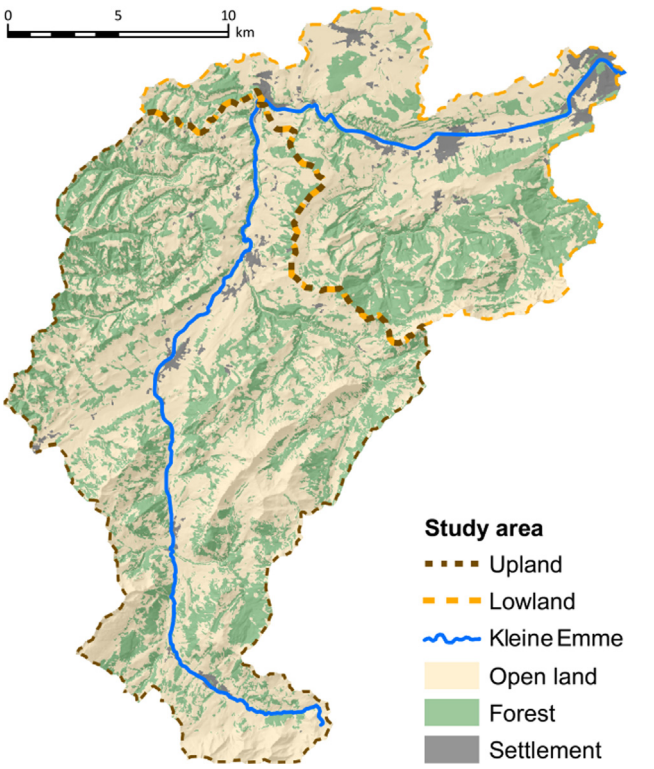

Fig. 1. The Kleine Emme catchment, divided into upland (upstream area) and lowland (downstream area), with forest, open land, and settlement area. Settlement pressure is highest in the north-eastern corner of the catchment and lowest in the southern mountainous area.

happened in 2005, causing damages of more than 100 million CHF[1] and initiating a large flood protection and renaturation project in the downstream area.

Based on an extensive analysis of global and regional climate models in the European climate research projects PRUDENCE (Christensen et al., 2007) and STARDEX (Goodess, 2003) and their specific evaluation for the Alps (Frei, 2006; Frei et al., 2006; Schmidli et al., 2007), Schädler et al. (2007) conclude that by 2050, as compared to 1990, an increase in the mean annual temperature and seasonal precipitation combined with snowmelt will result in higher flood peaks and flood volumes particularly in the winter half year. Furthermore, soil has a limited natural potential for water retention, therefore, due to a change of snowfall to rainfall and increased rainfall intensity, increasing sediment transport is expected (Schädler et al., 2007). Flood protection is thus of particular importance in the Kleine Emme catchment and will become even more important in the future as large volume flood events are expected to happen more frequently.

2.2. Land use trade-offs with effects on flood protection

In the Kleine Emme catchment, productive ground (i.e., settlement area and agricultural land) is a scarce resource. Research question (2) investigates whether and to what extent residents in the Kleine Emme catchment are willing to trade off land (forest, agricultural land, settlement area) for flood protection ecosystem services.

In the upstream area, respondents are expected to make a trade-off between forest and agricultural land use (meadows and

[1] 1 USD = 0.937 CHF (website of the Swiss National Bank, accessed on 10/06/2013).