Catena 156 (2017) 184–196

Contents lists available at ScienceDirect

Catena

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

Comparison of the results of a small-plot and a large-plot rainfall simulator – Effects of land use and land cover on surface runoff in Alpine catchments

Christoph Mayerhofer[a], Gertraud Meißl[a,*], Klaus Klebinder[b], Bernhard Kohl[b], Gerhard Markart[b]

[a] Institute of Geography, University of Innsbruck; Innrain 52f, 6020 Innsbruck, Austria
[b] Department of Natural Hazards, Federal Research Centre for Forests (BFW), Rennweg 1, 6020 Innsbruck, Austria

ARTICLE INFO

Keywords:
Rainfall simulator
Surface runoff
Runoff formation
Land use
Grazing
Torrential rain

ABSTRACT

Many surveys with differently sized rainfall simulators have been conducted in the past to study runoff and erosion processes on the plot scale. Concerning the understanding of runoff processes on the slope scale, comparative studies have shown that sprinkling devices with large plot sizes (≥ 40 m^2) produce more representative results than small-plot rainfall simulators (4 m^2 and less). Nevertheless, the latter ones are frequently used due to their portability and the reduced effort and water demand compared to large-plot simulations. In this study the results of torrential rain (100 mm h^{-1}) experiments using a small (1 m^2) dripper device and a large (40–80 m^2) spray device are compared regarding to identify site characteristics which allow estimating the representativeness of surface runoff coefficients measured with a small-plot rainfall simulator. We conducted 39 small-plot (1 m^2) and 14 large-plot (40–80 m^2) rainfall simulations at eight selected experimental sites in the Eastern Alps with differing land cover, land use, intensity of grazing and antecedent soil moisture content. At sites with intensive grazing, due to topsoil compaction and the shortened flow path, the small-plot device delivered significantly higher runoff coefficients than the large-plot device. At mainly mowed grassland sites with at most a short grazing period in autumn both sprinkling devices showed similar results or even lower runoff coefficients compared with the results of the large-plot simulator. The measured surface runoff coefficients strongly depended on antecedent soil moisture content and grazing intensity.

1. Introduction

Rainfall simulators for convective rain events have proved to be reliable instruments for the identification and quantification of hydrological processes (Bunza, 1978; Bunza and Schauer, 1989; Dobmann, 2009; Hümann and Müller, 2013; Kienzler and Naef, 2007; Kienzler and Naef, 2008; Markart and Kohl, 1995; Martínez-Murillo et al., 2013; Retter, 2006; Scherrer, 1996; Schmocker-Fackel et al., 2007; Weiler and Naef, 2003; Wilcox and Wood, 1988) and erosion rates (Aksoy et al., 2016; Fister et al., 2012; Hiltbrunner et al., 2005; Iserloh et al., 2012; Karl and Porzelt, 1977/78; Keesstra et al., 2016; Klaghofer, 1988; Lassu et al., 2015; Prosdocimi et al., 2016; Rodrigo Comino et al., 2016; Schindler Wildhaber et al., 2012). However, the results of rainfall simulations cannot be easily compared as the used rainfall simulators are differing significantly regarding their set-up, i.e. the size of the irrigated plot, the type of the nozzles as well as the size and fall height of the rain drops (Schindler Wildhaber et al., 2012).

As to the size of the rainfall devices, large-plot and small-plot rainfall simulators can be distinguished. Large-plot rainfall simulators commonly irrigate plots between 40 and 100 m^2 (Auerswald et al., 1992a, 1992b; Bunza, 1978; Bunza, 1989; Bunza et al., 1985; Markart and Kohl, 1995; Scherrer, 1996). Small-plot rainfall simulators on the contrary sprinkle areas with a size as little as 0.06 m^2 (Hiltbrunner et al., 2005; Iserloh et al., 2013a), a plot size of 1 m^2 being a frequently used format (Iserloh et al., 2013a, 2013b; Naef et al., 2002; Schmocker-Fackel et al., 2007).

The results of comparative studies (Auerswald et al., 1992a, 1992b; Kainz et al., 1992; Markart and Kohl, 1995; Wainwright et al., 2000) show a strong dependence of the measured surface runoff coefficient from the size of the irrigated plot (Fig. 1). Experiments with small-plot devices often produce higher surface runoff coefficients compared to a large-plot rainfall simulation, presumably due to the shortened flow path at small-plot rainfall simulations (Guggenberger, 1980; Sharpley and Kleinman, 2003). After its impact on the soil, water flows a certain distance on the surface before infiltrating (Ghadiri and Payne, 1988). Especially at high precipitation intensities, the possible flow length within the small plot is truncated. Thus, water could possibly infiltrate further down the hillslope but is already caught by the drain

* Corresponding author.
E-mail addresses: gertraud.meissl@uibk.ac.at (G. Meißl), klaus.klebinder@bfw.gv.at (K. Klebinder), bernhard.kohl@bfw.gv.at (B. Kohl), gerhard.markart@bfw.gv.at (G. Markart).

http://dx.doi.org/10.1016/j.catena.2017.04.009
Received 22 August 2016; Received in revised form 10 March 2017; Accepted 7 April 2017
Available online 26 April 2017

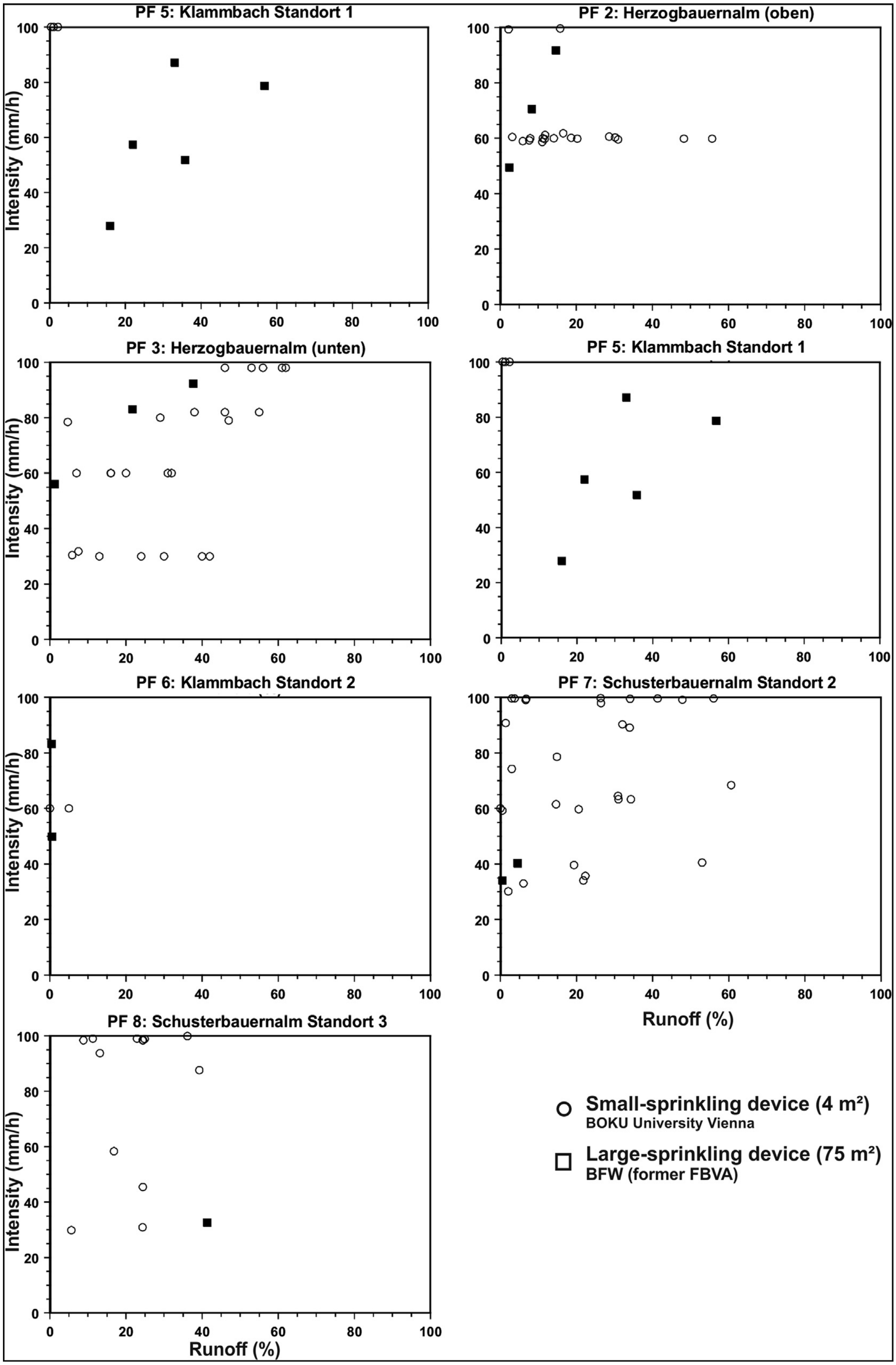

Fig. 1. Comparison of the results of rainfall simulations with a small (4 m^2) and a large device (75 m^2) at Löhnersbach catchment (modified after Markart and Kohl, 1995). The small device was a simulator with swayable nozzles, carried out by Peringer (unpublished), the large simulator was equal to the large device in this study.

(Guggenberger, 1980; Markart and Kohl, 1995). In Sharpley and Kleinman (2003), the higher surface runoff values on a small plot (2 m^2) compared to a larger plot (32.6 m^2) were attributed to the fact that a greater area of the smaller plots, namely > 75% of area, became saturated. On the contrary, the results of 1 m^2 sprinkling experiments may also be regarded to represent the lower limit of possible runoff coefficients as water may rapidly percolate in the not irrigated areas outside the sprinkled plot (Dobmann, 2009). Thus, in order to reduce