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Validity of landscape function assessment methods – a scientific basis for landscape and environmental planning in Germany

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Abstract: One of the most important tasks of landscape and environmental planning in Germany is to preserve landscape functions for both, the ecosystem itself and for human yields. To fulfill this task special methods for the assessment of landscape functions are needed. In the past decades a huge number of different approaches have been developed. However, validity of most applicable methods is predominantly unknown. To ensure acceptance and to avoid legal uncertainty in planning practice landscape and environmental planning requires valid methods.
Within the study presented here several landscape function assessment methods were tested on their validity by means of statistical methods. The investigation has been carried out on a database of different landscape types in Germany which were selected by means of cluster- and principal component analysis. The validation variables were chosen in accordance with their theoretical and empirical foundation.
The results show that there is a large variety of both, valid and invalid methods. Mostly, the validity of different methodological approaches depends on special landscape ecological conditions, e.g. annual precipitation rate or slope steepness.
Considering this, recommendations are made for both, the application of evaluation methods within the practice of landscape and environmental planning and further research.

Key words: *Landscape function assessment methods, validity, landscape and environmental planning*

Introduction

Landscape and environmental planning have a long history in Germany. Their roots can be traced back to landscape improvement and beautification movements of the 18th century as well as the natural and cultural heritage movement at the end of the 19th century in reaction to industrialization and increasing destruction of nature (Kiemstedt et al. 1998). Landscape and environmental planning have been established as legal instruments in Germany since the early 1970ies (Riedel, Lange 2001, Gruehn 2006). The major objective of landscape and environmental planning instruments is to implement environmental principles, such as precautionary principle as well as polluter pays principle, not only by contributing to an environmentally friendly future development, including the protection of landscape functions or ecosystem services, but also by omitting avoidable impairments of nature or landscape and compensating inevitable damages on the environment (Kiemstedt et al. 1998, Gruehn 2006). German federal nature protection law in § 1 defines legal goals of landscape and environmental planning as to sustainably ensure landscape balance or natural systems, regenerative capacity and utilization of natural resources, animal and plant kingdom as well as species' habitats, and the variety, uniqueness and beauty of nature or landscape.

To fulfill this task, special methods for the assessment of landscape functions are needed. In practice about 13 distinct landscape functions, e. g. resistance against soil erosion, biotic production, groundwater protection, groundwater recharge or regulation of surface runoff are considered within the process of landscape or environmental planning, comprising analysis, assessment, as well as development of future concepts. In the past decades a huge number of different landscape function assessment methods have been developed. However, validity of most of those methods is predominantly unknown. There are, for instance, only 3 in 56 groundwater recharge assessment methods, which have been tested before to find out whether they deliver valid or invalid results (Gruehn 2004). To ensure acceptance and to avoid legal uncertainty in planning practice, landscape and environmental planning necessarily require valid methods.

Regardless of this, validation of methods for landscape function assessment is not yet a major, but an emerging topic in landscape ecology and planning sciences (Steinhardt 1998, Krönert et al. 2001, Roth, Gruehn 2005, Mander et al. 2007, Kienast et al. 2009).

Against this background the article deals with the following research questions:

- Which landscape function assessment methods can be recommended from a scientific point of view for application in planning practice?
- Which landscape function assessment methods are inappropriate for planning purposes because of their insufficient or missing validity?
- Which landscape function assessment methods can be recommended for application in planning practice only under specified ecological conditions?

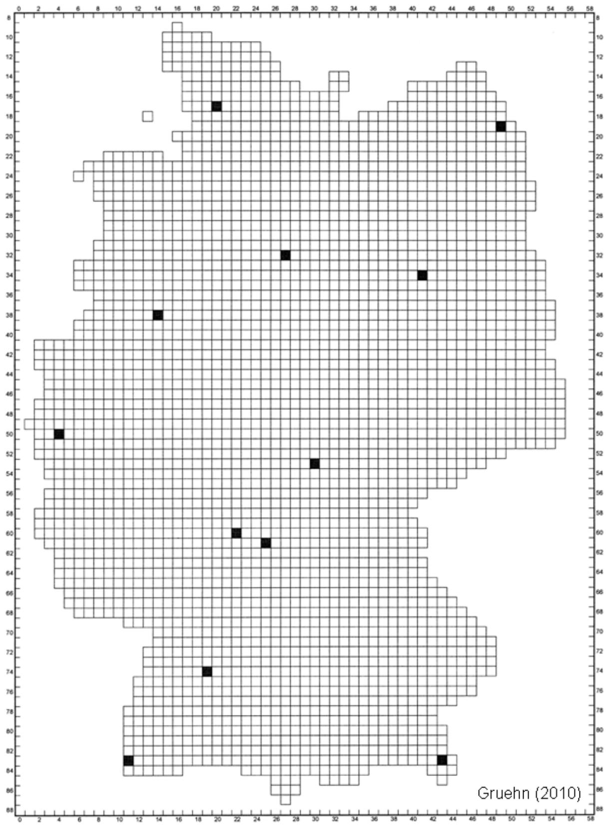
Materials and Methods

Several landscape function assessment methods, concerning e. g. resistance against soil erosion by water (AG Bodenkunde 1982, Hennings et al. 1994, Schmidt 1989, Schwertmann et al. 1987), as well as regulation of surface runoff (Bastian, Schreiber 1999, DVWK 1984 (modified), Zepp 1989) were tested on their validity by means of statistical methods. The selection of landscape function assessment methods considered requirements of planning practice, such as an area-wide availability of required data or applicability of methods in an appropriate scale for certain landscape and environmental instruments. Those methods which are regarded as theoretically and empirically strongly substantiated were chosen as standard of comparison within the validity tests: Schwertmann et al. (1987), supplemented by regional rainfall and runoff factors according to Sauerborn (1994) in case of resistance against soil erosion by water, and DVWK (1984) regarding the regulation of surface runoff.

Validity tests have been carried out by Spearman Rank Correlation Coefficient r_s, which can be used when at least one variable is ordinal and the other is at least ordinal (Weinberg, Abramowitz 2008). Application of Pearson Product Moment Correlation Coefficient requires not only interval or ratio level, but also normal distribution and homoscedasticity of the investigated variables (Backhaus et al. 1996). At least normal distribution did not occur in all variables. Hence, under these circumstances Spearman Rank Correlation Coefficient was the tool of choice. Correlation values of $r_s < 0.4$ indicate a low validity. Correlation values between 0.4 and 0.6 were considered moderate and correlation coefficients above 0.6 were interpreted as a high validity according to Bortz and Döring (2002).

The investigation has been carried out on data of 12 different landscape types in Germany, which were selected by means of hierarchical cluster analysis and principal component analysis from a German-wide data base, comprising geomorphologic, soil and climate conditions of 92 natural landscapes (Gruehn 2004). The principal component analysis was applied with Varimax rotation, hierarchical cluster analysis was carried out using Ward algorithm.

The cluster analysis suggests an aggregation of the 92 natural landscapes to 12 clusters of similar landscape types. Within each cluster one investigation area was randomly selected (figure 1), considering available climate, soil, geomorphologic and land use data as basis for the application of landscape function assessment methods on scale level 1 : 25 000. The described procedure ensures that selected investigation areas at large mirror a high proportion of total ecological variability of German natural landscapes. Hence, landscape function assessment methods could be tested within the whole range of landscape ecological conditions typical for Germany.



Location of investigation areas:
Map section 1720= Weddingstedt, 1949=Zinnowitz, 3227=Eschede, 3441=Garlitz, 3814 Bad Iburg, 5004=Jülich, 5330 Suhl, 6022 Rothenbuch, 6125=Würzburg-Nord, 7419=Herrenberg, 8343=Berchtesgaden-West

Fig. 1. Location of investigation areas in Germany

Results

The validity of tested landscape function assessment methods is presented in tables 1 and 2. Methods for the assessment of resistance against soil erosion by water are strongly correlated with the standard of comparison (table 1). The methodical approach of Schwertmann et al. (1987), supplemented by regional rainfall and runoff factors according to Sauerborn (1994) was used as standard of comparison. In general all tested methods deliver highly valid results with $r_s \geq 0.6$ (table 1). The methods of Schwertmann et al. (1987) as well as Hennings et al. (1994) seem to be optimal because of their extremely high correlation values above 0.9.

Table 1. Validity of methods for the assessment of resistance against soil erosion by water

Landscape function assessment method	Validity (r_s)	n
AG Bodenkunde (1982)	0.76	94,602
Hennings et al. (1994)	0.93	149,588
Schmidt (1989)	0.83	146,985
Schwertmann et al. (1987)	0.99	147,879

The methods for the assessment of regulation of surface runoff are expected to deliver results of moderate (Bastian, Schreiber 1999, Zepp 1989) or high validity (DVWK 1984, modified) according to their correlation coefficients figured out in table 2. The method published by DVWK (1984) was chosen as standard of comparison. In general the DVWK (1984, modified) method seems to be more realistic and therefore more advantageous than the methodological approaches of Bastian, Schreiber (1999) as well as Zepp (1989).

Table 2. Validity of methods for the assessment of surface runoff regulation

Landscape function assessment method	Validity (r_s)	n
Bastian, Schreiber (1999)	0.48	147,151
DVWK (1984, modified)	0.95	150,598
Zepp (1989)	0.49	147,151

Tables 1 and 2 give a general impression about the validity of tested methods, based on the above mentioned data comprising 12 investigation areas. A more specific assessment can be obtained by means of sensitivity tests, which not only can contribute to focus the results on specific landscape ecological conditions, but also to indicate the variation of validity depending on different ecological conditions, such as annual precipitation rate, slope steepness, soil texture, available water capacity and type of land use (figures 2–7).

The results of such sensitivity tests reveal a large variety of both, valid and invalid landscape function assessment methods.

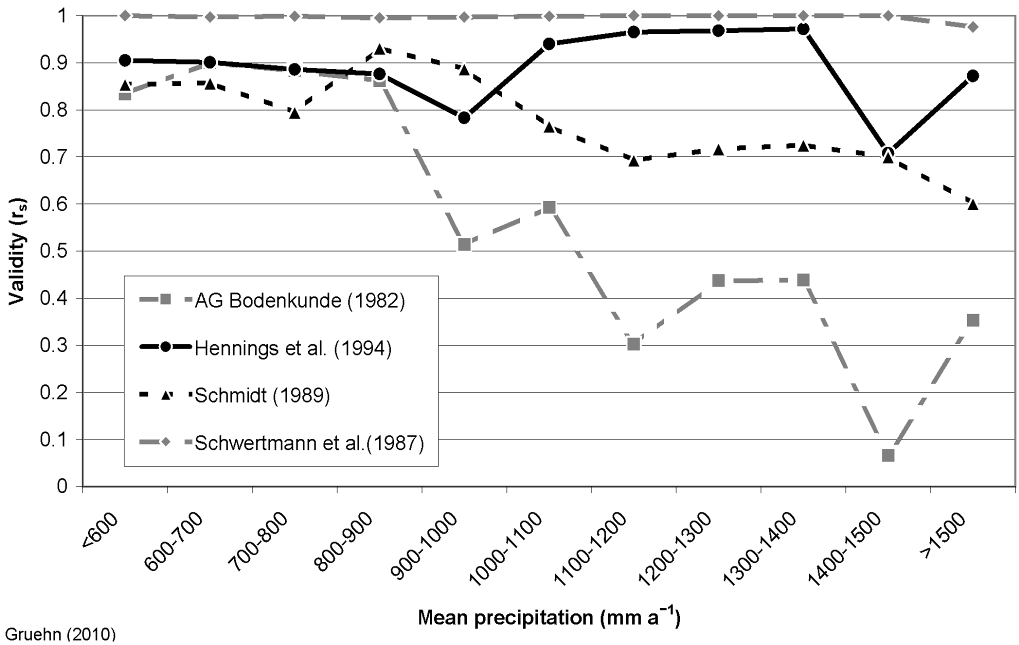


Fig. 2. Validity of methods for the assessment of resistance against soil erosion by water in connection with precipitation conditions

Figure 2 presents the computed validity of 4 distinct methods for the assessment of resistance against soil erosion by water in connection with mean annual precipitation. The methods Hennings et al. (1994), Schmidt (1989), and Schwertmann et al. (1987) deliver highly valid results with r_s values above 0.6 within the full range of precipitation conditions. In contrast validity of the method published by AG Bodenkunde (1982) is limited to landscape conditions with mean annual precipitation less than 1100 mm a^{-1}. This method should not be applied in landscapes which are characterized by mean annual precipitation above 1100 mm a^{-1} because of its low validity ($r_s < 0.4$).

The validity of assessment methods for the resistance against soil erosion by water in connection with soil texture conditions is presented in figure 3. All investigated methods deliver highly valid results ($r_s \geq 0.6$) within the full range of soil texture conditions (figure 3). Although, the methods of Hennings et al. (1994) as well as Schwertmann et al. (1987) are characterized by extremely high r_s values compared to the methods Schmidt (1989) as well as AG Bodenkunde (1982).

Validity of methods for the assessment of resistance against soil erosion by water is highly dependent on the variation of slope degrees (figure 4), especially in case of the methodological approaches of Schmidt (1989) as well as AG Bodenkunde (1982). The Schmidt (1989) method delivers highly valid results with r_s values above 0.6 only under conditions of slope degrees less than 15. Slope degrees larger than 15 determine a reduction of r_s values. Under these conditions validity is to be considered moderate. The validity of the AG Bodenkunde (1982) method is limited to conditions of slope degrees less than 5 or larger than 20 (figure 4). Slope degrees between 5 and 20 determine results of low validity ($r_s < 0.4$). In contrast to this, the methods published by Hennings et al. (1994) as well as Schwertmann et al. (1987) are nearly independent of slope conditions. Their correlation with the standard of comparison is at least 0.6

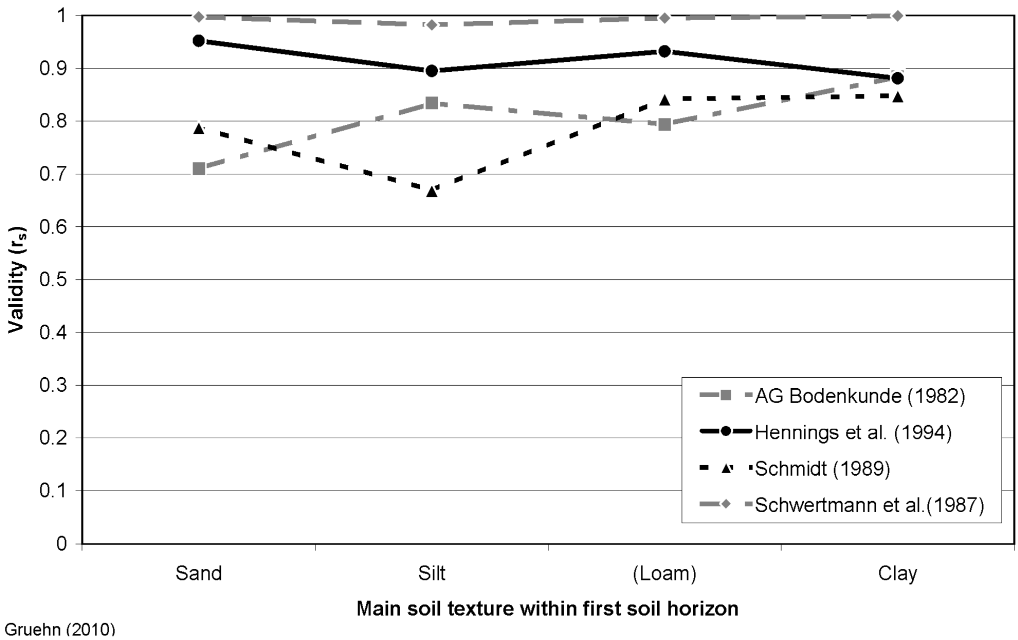


Fig. 3. Validity of methods for the assessment of resistance against soil erosion by water in connection with soil conditions

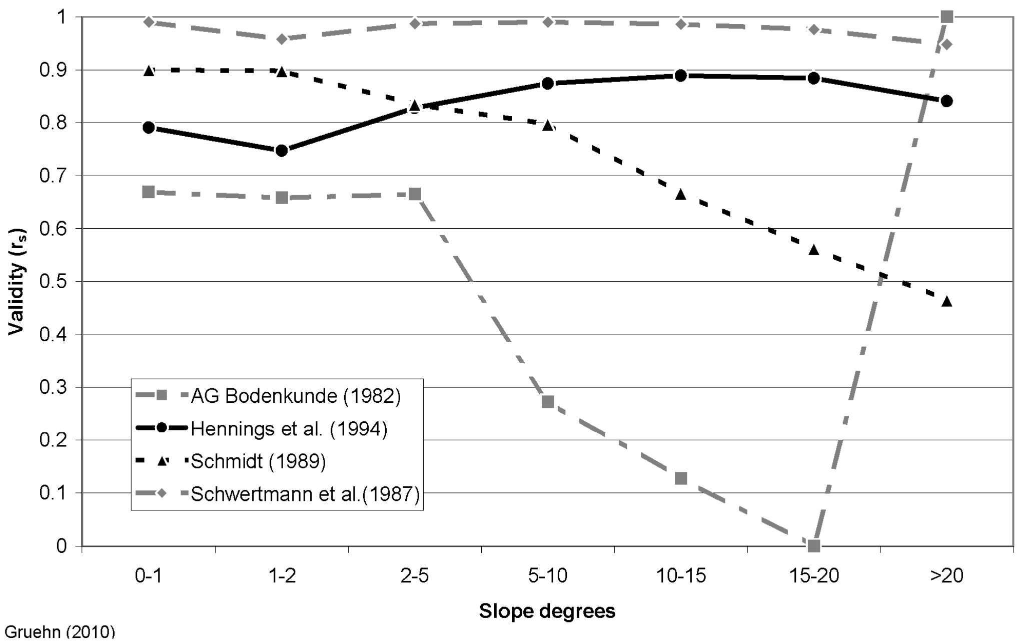


Fig. 4. Validity of methods for the assessment of resistance against soil erosion by water in connection with slope conditions

(figure 4). Therefore both methods can be applied in planning practice without restrictions by different slope conditions.

Figure 5 points out validity of 3 different methods appropriate for the assessment of regulation of surface runoff in connection with slope degrees. Two methods, Bastian and Schreiber (1999) as well as Zepp (1989) deliver highly valid results with r_s values above 0.6 only under conditions of slope degrees less than 5. Slope degrees between 5 and 15 determine a reduction of r_s values. Under these conditions validity is to be considered moderate. Both methods should not be applied if slope degrees are higher than 15, because of their low validity ($r_s < 0.4$). In contrast, the DVWK (1984, modified) method, simplified by omitting the factor 'slope', provides valid results with r_s values above 0.6 within the full range of slope degrees.

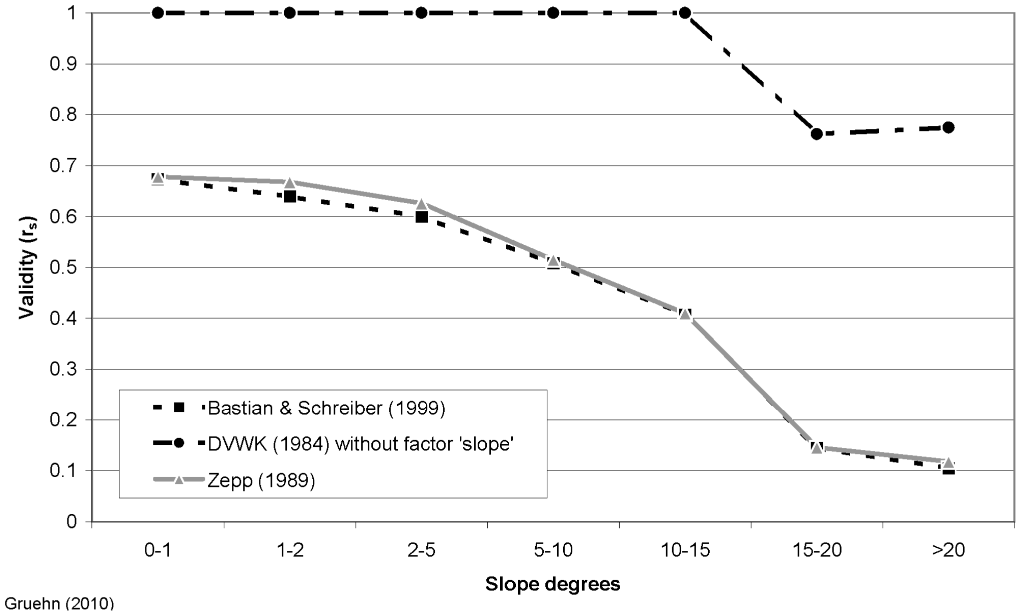


Fig. 5. Validity of methods for the assessment of surface runoff regulation in connection with slope conditions

The validity of methods for the assessment of surface runoff regulation is also connected with land use types (figure 6). Especially validity of the Bastian, Schreiber (1999) method as well as the method of Zepp (1989) depends on specific land use types. The Bastian, Schreiber (1999) method delivers highly valid results with r_s values above 0.6 only within land use types 'heathland' and 'park'. Under conditions of 'arable land' and 'shrubbery' validity is to be considered moderate ($0.4 \leq r_s < 0.6$). Within the land use type 'grassland' this method delivers results of low validity ($r_s < 0.4$) and should not be recommended for application in planning practice. Again, the DVWK (1984, modified) method provides valid results with r_s values above 0.6 within all tested land use types (figure 6).

Finally, sensitivity tests carried out reveal that the validity of surface runoff assessment methods at least partially depends on the available water capacity (figure 7). While the DVWK (1984, modified) method ensures valid results nearly within the full range of available water capacity up to 200 mm sqm^{-1}, the methodological approaches of Bastian, Schreiber (1999) as well as Zepp (1989) deliver results of moderate

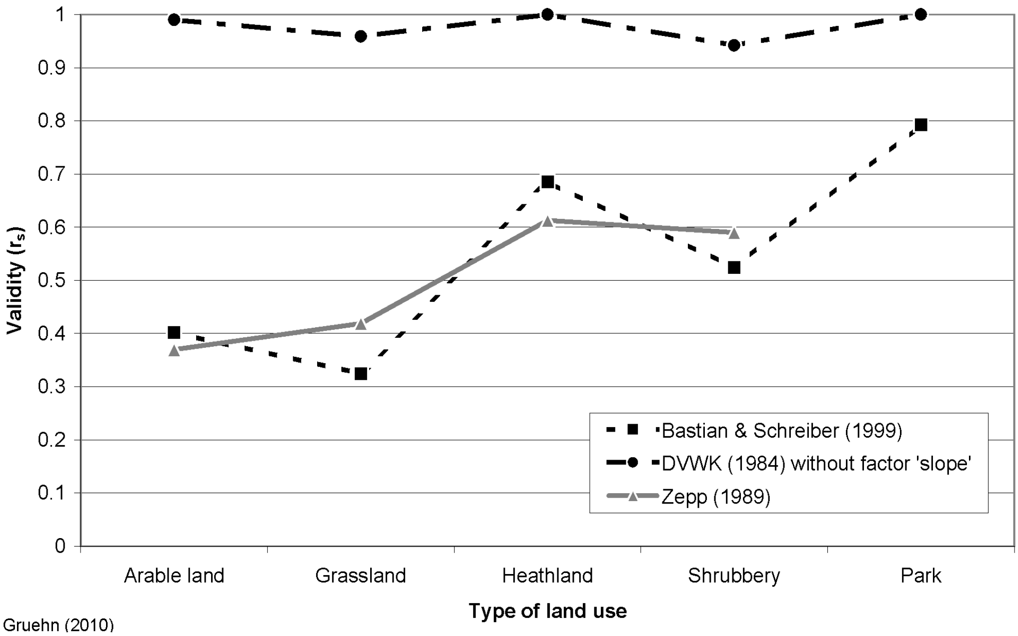


Fig. 6. Validity of methods for the assessment of surface runoff regulation in connection with land use types

($0.4 \leq r_s < 0.6$) or high validity ($r_s \geq 0.6$) only under medium conditions, characterized by an available water capacity between 90 and 200 mm sqm^{-1}. Hence, the latter methods should only be applied in planning practice under medium conditions of available water capacity.

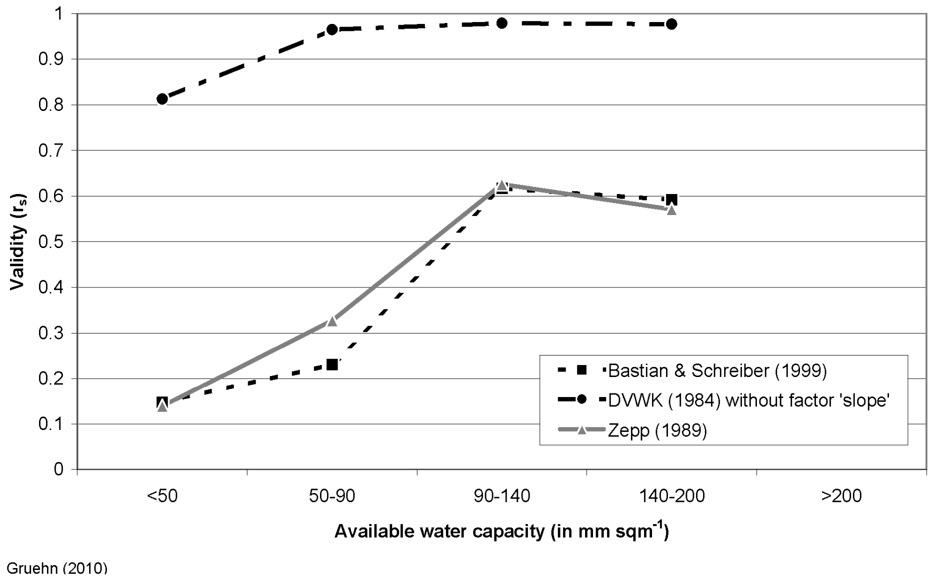


Fig. 7. Validity of methods for the assessment of surface runoff regulation in connection with available water capacity

Discussion

The results reveal that landscape function assessment methods are characterized by considerable differences with regard to their validity. Even if validity tests of landscape function assessment methods, based on a broad range of landscape ecological conditions typical for Germany, suggest a general validity of methods according to tables 1 and 2, results of sensitivity tests reveal that the validity of those methods can be highly dependent on distinct landscape ecological factors, e. g. precipitation or slope conditions. Therefore, it does not seem to be reasonable to give general recommendations for the application of landscape function assessment methods in planning practice. Instead of that sensitivity tests provide a deeper insight whether and how validity depends on specific ecological factors.

Considering specific ecological conditions, substantiated and detailed recommendations for landscape and environmental planning can be concluded from this research, using information on validity of the investigated assessment methods. Furthermore the results reveal that not always the most complex method is the best. For instance, the application of the Schwertmann et al. (1987) approach, without using regional rainfall and runoff factors suggested by Sauerborn (1994), does not necessarily lead to invalid results. In addition to this, reduction of complexity by omitting the factor 'slope' within the DVWK (1984) method, only contributes to a slight and therefore acceptable reduction of validity under extreme slope conditions.

The findings of this research seem to be transferable to other countries under the precondition of comparable landscape ecological conditions.

Further research should include critical reflection about statistical coefficients, especially correlation coefficients, as validity criteria as well as application of supplementing approaches, such as the total skill score according to Frank et al. (2004).

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