An international review of rehabilitation techniques used to prevent headcut migration and channel incision

Une étude internationale des techniques de réhabilitation utilisées pour empêcher la migration régressive et l'incision de chenaux

Gabrielle C.L. David[1] and Daniel Cenderelli[2]

[1]Department and Earth and Environmental Sciences, Boston College, 140 Commonwealth Avenue, Chestnut Hill, Massachusetts, 02467, United States (corresponding author: davidg@bc.edu). [2]Stream Systems Technology Center, United States Department of Agriculture, Forest Service, Fort Collins, Colorado, 80526.

RÉSUMÉ

L'incision de chenaux, et la migration régressive, provoquent un changement radical dans le paysage, ce qui peut perturber les terres utilisées pour l'agriculture, menacer les structures adjacentes, provoquer des changements dans les conditions environnementales comme la réduction de la qualité de l'eau et l'augmentation des concentrations de nutriments, accélérer l'aridification de la terre, et l'augmentation de la production de sédiments. L'incision de chenaux est un problème dans le monde entier en raison de la perte des terres, en particulier des terres arables, due à l'érosion. Nous avons examiné les techniques qui ont été utilisées dans le monde et déterminé à quel point la réussite du projet est communiquée dans la littérature technique et de la recherche. Les projets ont été évalués en fonction de l'un des quatre objectifs principaux : i) empêcher le ravinement, ii) empêcher la migration régressive, iii) restaurer un chenal précédemment creusé, ou iv) réhabiliter l'habitat. Sur 101 études de cas, 37% des projets étaient axés sur le creusement de chenaux, et 38% sur l'habitat, mais seulement 9% des projets portaient sur les méthodes pour réduire le ravinement et 16% s'intéressaient à la migration régressive. Au-delà des cinq premières années, seulement 38% des études ont fait état de résultats de suivi du projet. Indépendamment du traitement utilisé, les chercheurs et les gestionnaires ont souligné la nécessité d'un plan plus inclusif de gestion des bassins versants et du recours à des traitements multiples. Pour mieux évaluer l'utilité des méthodes pour d'autres régions, les chercheurs doivent signaler systématiquement les caractéristiques des bassins, telles que les données géologiques, la zone de drainage et l'inclinaison.

ABSTRACT

Channel incision, and headcut migration, causes a drastic change in the landscape that can disrupt land used for agriculture, threaten adjacent structures, cause changes in environmental conditions such as reducing water quality and increasing nutrient loads, accelerate aridification of the land, and increase the production of sediment. Channel incision is a concern throughout the world because of loss of land, particularly farmland, from erosion. We reviewed techniques that have been used around the world and determined how well project success is communicated in the technical and research literature. Projects were analyzed with one of four main goals: i) preventing gullying in a previous non-channelized valley bottom, ii) prevent headcut migration, iii) restore a previously incised channel, or iv) rehabilitate habitat in or adjacent to an incised channel. Out of 101 case studies, 37% of projects focused on channel incision, and 38% on habitat, but only 9% of projects discussed treatments related to reducing gullying and 16% focused on headcut migration. Beyond the first five years, only 38% of studies reported post-project results. No matter what treatment was used, researchers and managers emphasized that project success depended on larger watershed management plans and use of multiple treatments. To better evaluate usefulness of methods for other regions, researchers need to consistently report watershed characteristics, such as geology, drainage area, and slope.

KEYWORDS

Headcut migration, channel incision, restoration, gullying

AN INTERNATIONAL REVIEW OF REHABILITATION TECHNIQUES USED TO PREVENT HEADCUT MIGRATION AND CHANNEL INCISION

1 INTRODUCTION

Incised channels, including gullies, rills and entrenched streams, are a primary source of soil erosion throughout the world. Channel incision causes a drastic change in the landscape that can disrupt land used for agriculture, threaten adjacent structures, cause changes in environmental conditions such as reducing water quality and increasing nutrient loads, accelerate aridification of the land, and increase the production of sediment. The headward migration of a headcut is one of the main mechanisms that an incised channel expands its network, therefore many stream rehabilitation projects are focused on arresting the headcut often using a series of check dams or headcut plugs. The most commonly used method today is the installation of gabion, log, stone, or concrete check dams along with plugging the headcut with a variety of materials. Other methods include design of a step-pool structures or engineered riffles, restoring a meandering channel, the re-establishment of beavers, revegetation, exclosures, or a combination of these methods. We conducted an investigation of the literature to determine how successful these treatments are in reaching their goals and recommendations made by managers and researchers.

2 METHODS

An evaluation of the scientific and technical literature was conducted to assess methods used for dealing with headcut propogation, gullying, and channel incision (Table 1). Gullying is defined as an area where an ephemeral or perennial channel that has eroded material away from the valley, developing a channel where a well-defined channel did not previously exist. Forty-seven studies were found that evaluated the use of hard structures, such as gabions, loose rock check dams, log weirs, stone weirs, brush dams, and concrete dams. Nineteen natural channel design methods, such as construction of step-pool and pool-riffles, were evaluated along with thirty-seven case studies of restoration to a previous state. Restoration to a previous state included meander restoration, revegetation, grazing management, and beaver reintroduction. Some treatments are put in place for the purpose of preventing gully/channel extension along valley sides or valley bottoms that did not previously contain a channel. The goal of other treatments is to decrease or completely stop the incision of an already existing channel. These treatments are put in place to increase roughness, and to reduce slope, flow velocity, and shear stress. Other goals, that accompany the general hydraulic goals, are to restore habitat for aquatic organisms, restore riparian vegetation, and restore the water table to its previous elevation before channel incision occurred. These goals are all considered habitat application of the particular treatment and are discussed as such under each treatment.

Table 1: Summary of watershed characteristics and timing and scale of rehabilitation for the case studies evaluated under each method.

Method	Number of studies	Project Year	Drainage Area (km^2)	Slopes (m/m)	Post-project evaluation (yrs)	Restored legth (meters)
Hard structures	47	1936 to 2001	6.5 to 2002	0.0016 to 0.17	1-70	180 - 5500
Natural channel design	19	1985 to 2008	2.75 to 919	0.0012 to 0.14	1 – 10	36 – 1000
Restore to previous state	37	1936 to 2009	0.004 to 1640	0.0015 to 0.17	1 – 50	200 – 30,000

3 RESULTS AND DISCUSSION

The majority of the evaluated case studies, 78, were in the United States, although 16 were located in Europe, 4 in Canada, 2 in Ethiopia, and 1 in Australia. The scale of each project was identified, based on whether the goal of the project was aimed at stopping headcut migration at a particular section of channel, or rehabilitating an entire watershed, or stream corridor. Assessment of scale of the project revealed that particular methods were used mainly to improve aquatic habitat within an incised channel rather than focusing on returning the channel to a previous state. In particular, log weirs, boulder weirs, and gabions were used to improve the heterogeneity of physical habitat and increase fish abundance. Many of these studies indicate the difficulty in quantifying the effects weirs have on aquatic habitat because of the lack of collection of specific pre- and post-treatment data, or an inappropriate study design. For instance, a control reach does not necessarily help determine increases in fish populations, because fish may redistribute in a stream without an increase in overall numbers (Chapman, 1996).

Missing information from many of the case studies makes assessing methods and determining applicability to other regions very difficult. Only 51% of projects provided information about the drainage area, 42% about slope, and 32% discharge. At least 66% of studies provided some post-project monitoring information, but only 38% provided monitoring results beyond five years. Only 9% of the studies focused specifically on gullying and only 16% on preventing a headcut from migrating further upstream (Figure 1). No studies discussed the effectiveness of headcut plugs. The majority of evaluated projects focused on improving fish habitat (38%), or reconnecting an already incised channel with its floodplain (37%).

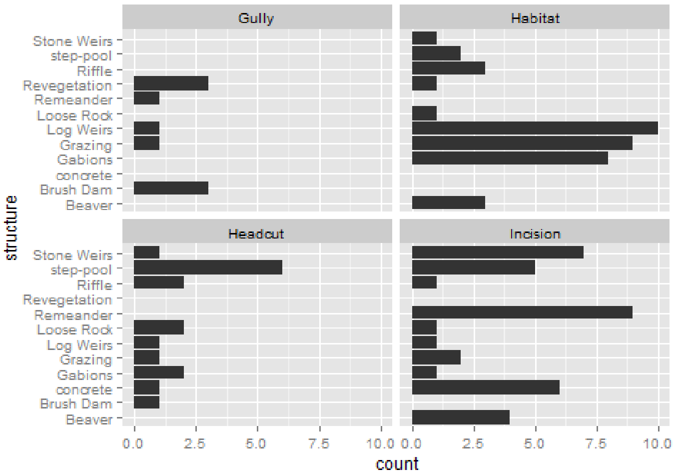

Figure 1: Number of case studies evaluated for each method, separate by one of four major goals.

Generally, researchers emphasized a need for a larger watershed management plan to be used in conjunction with any treatments. For instance, beavers will not do well in areas of heavy grazing, either from cattle or elk, therefore grazing management options would have to be employed along with the beaver reintroduction. Exclosures can work well to improve riparian habitat, but will not necessarily improve aquatic habitat without changes being made upstream of the exclosure (Kondolf, 1993). The timing and placement of a hard structure needs to be planned carefully in conjunction with understanding of geomorphology, local geology, climate, and ecosystem function. Grazing management, revegetation, and beaver reintroduction tend to have reduced costs in comparison to methods used for natural channel design and inclusion of hard structures. Beaver reintroduction has been employed by landholders since 1936 and is becoming an increasingly popular method of meeting multiple rehabilitation goals (Pollock et al., 2014), but has limitations in areas with heavy infrastructure.

4 CONCLUSIONS

There are advantages and disadvantages to many of these methods, and the use of them should be carefully considered after an assessment of the watershed and channel is undertaken. Many of the recommendations that researchers made after assessing the stream rehabilitation project was the need for a watershed management plan in conjunction with use of hard structures or other methods such as beaver reintroduction. Furthermore, post-project monitoring needs to continue beyond five years and results should be written up along with information about watershed size, pre- and post-restoration slope and pre- and post-restoration flows.

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