Gully erosion in winter crops: a case study from Bragança area, NE Portugal

T. de Figueiredo

Instituto Politécnico de Bragança (IPB/ESAB), CIMO – Mountain Research Centre, Bragança, Portugal

Foreword

This text is an adapted and extended version of a poster presentation, quoted below, and was also the subject of a lecture prepared for SPinSMEDE 2008 edition. Discussion of this case study, although a very important part of the lecture, is not included in this text. Quotation is: Figueiredo, T. de, Poesen, J., Vandekerckhove, L., Oostwoud-Wijdenes, D., Araújo, J. 2000. Contribution of ephemeral gullies to erosion on cultivated areas: field measurements in four small catchments in Bragança, NE Portugal. Poster presented to International Symposium on Gully Erosion under Global Change, Catholic University of Leuven, Belgium, April 16-19, 2000 (book of abstracts).

Introduction

In Northeastern Portugal, a region where steep slopes dominate and most soils are thin, acid and highly stony, soil erosion affects the sustainability of agricultural and forest areas. Conversely, cultivation practices may strongly influence erosion rates. Measurements at plot scale, in the region, show that interrill erosion rates are normally low, due to protection provided by surface rock fragments.

At small catchment scale, however, linear erosion features are commonly observed in fields, meaning that conditions for erosive overland flow generation occur. Empirical observation indicates that ephemeral gullies affect mainly cultivated areas and that their occurrence depends on the combination of crop cover status and rainfall characteristics.

The relative importance of linear erosion is not known in the regional context. The most affected areas, and for which damage has more evident consequences, are cereal fields. In order to have a quantitative insight on the magnitude of linear erosion, field measurements were performed in four small cultivated catchments in the Bragança area (NE Portugal).

***Figure 1**: Location map of study area.*

Study area and methodology

1. The agri-environment

At Bragança (42ºN, 7ºW, 650m elevation), mean annual Temperature (T) and Precipitation (P) are 11.9ºC and 740mm, respectively. Climate is Mediterranean sub-humid (Koppen Csa). Summers are hot and dry (highest monthly T>20ºC and Summer P<10 % annual P). Autumn and winter correspond to the wet semester (about 70 % annual P).

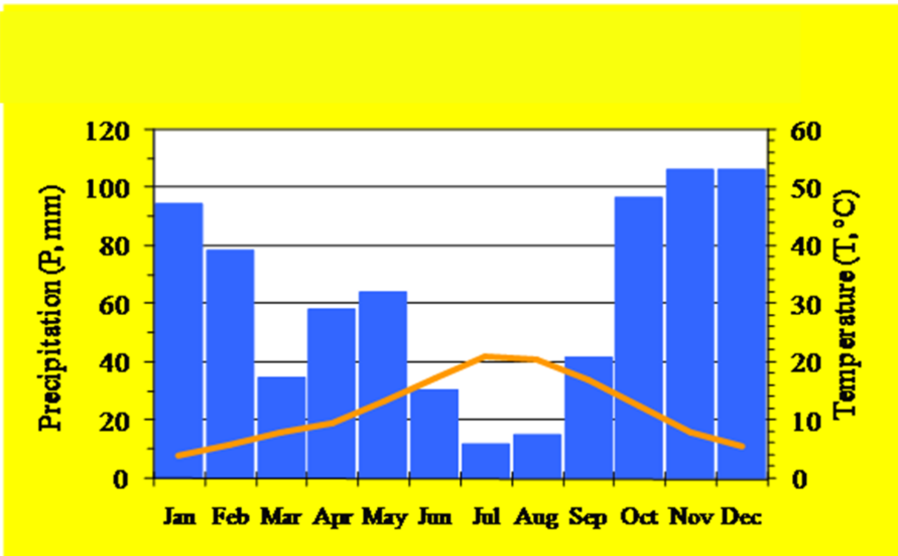

***Figure 2**: Monthly average Temperature and Precipitation at Bragança.*

Rolling landforms dominate, with gentle to moderately steep slopes. The area is a wide plateau (750 to 900m altitude), strongly dissected by the Sabor river system, from which rise three main elevations: Serra de Montesinho (1483m), Serra da Nogueira (1318m) and Serra da Coroa (1272m).

Schists (mostly Silurian) dominate around Bragança area. The Bragança complex is composed by a Precambrian dark and green schists area, patched by pre-Hercinic basic and ultramaphic rocks. Pliocenic sedimentary deposits, Hercinic granites and sparse Quartzitic crests are also found.

Dystric Leptosols (schist derived) are dominant. Chromic Luvisols (derived from basic rocks) are common in Bragança area. Both are associated with Cambisols in gentle slopes and Regosols in colluvial areas. Alisols occur on sedimentary deposits. Fluvisols cover narrow alluvial valleys.

Fallow - Winter Cereal is a very common crop rotation (almost 30 % of Bragança area). Cereal is Wheat (or Rye in the poorer soils) and Fallows are tilled twice in the year. Other land use types are (% of the area):

"Mato", Mediterranean shrubs (28 %);
Pinus *and* Quercus *forests (9 % each);*
Castanea *stands and Permanent Pastures (6 % each).*

2. Conditions prior to measurements

At the time of measurements (March 1996), the area was very much affected by linear erosion features (rills and gullies), mainly found in cultivated fields.

Heavy rainfalls occurred during the late Autumn - early Winter period. By the end of January 1996, the cumulative Precipitation since September (wet season) was twice as that of the average year (924mm against 446mm). Maximum daily Precipitation recorded was 61mm.

Most probably, erosive events generating incisions all over the area occurred between December 22, 1995 and January 9, 1996. This was confirmed by local farmers. Also maximum daily precipitation (January 7) and highest peak discharge (January 8) in Bragança, were recorded in that period.Cereal fields, sown from early November to early December 1995, were still poorly covered at that time.

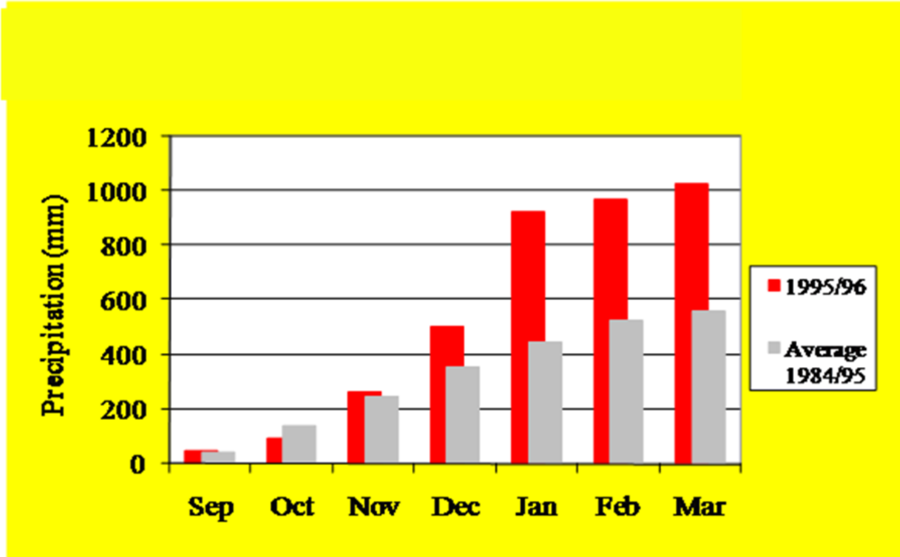

Figure 3*: Precipitation accumulated since summer dry period at Bragança: year of severe gullying compared with the average year.*

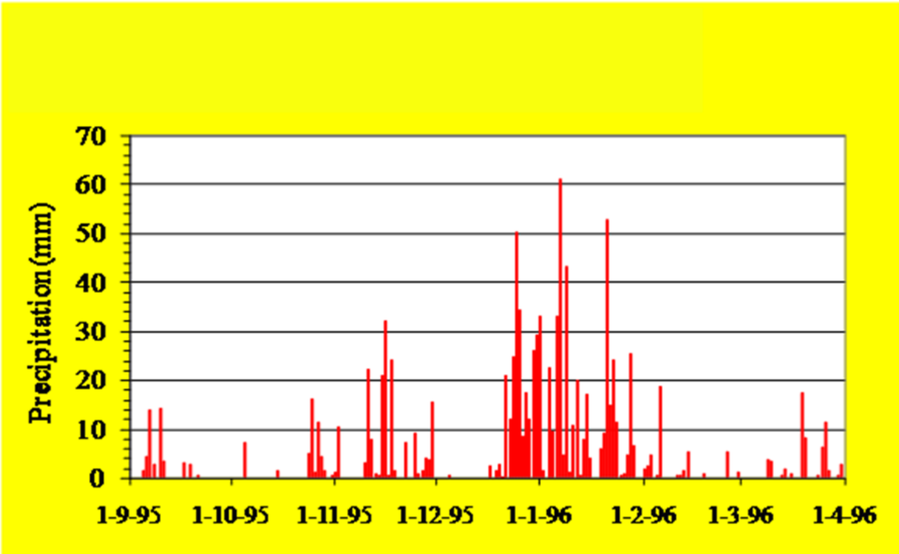

Figure 4*: Daily Precipitation through Fall and Winter in the year of severe gullying in Bragança area.*

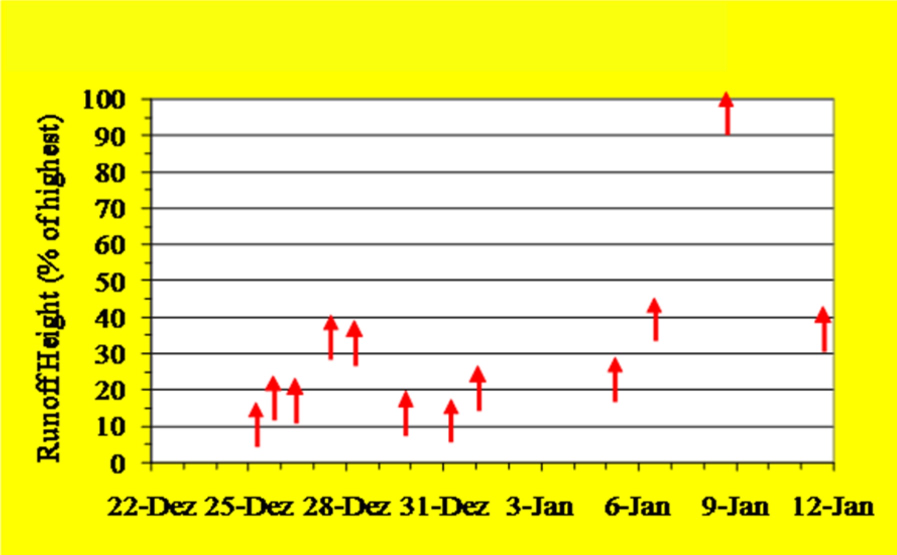

Figure 5*: The limnigraph peaks in a stream in Bragança, during the period of heavier rainfalls*

1. Field work

Sites were selected among the most affected by linear erosion, after a reconaissance survey when rainfalls ceased in the area. Selected catchments have planar or hollowed surface shapes and either convergent (draining to a main gully) or parallel incisions networks. Contour-tillage was evident in all selected fields. Catchments area range from 0.5ha to 4ha and average slope gradients from 10 to 20%.

Catchment area and geometry were assessed stepping upstream along the main gully axis (or a reference direction), stopping at regular distances (10m intervals) and stepping again in perpendicular direction, along a transect up to catchment divides. Therefore, catchments were divided in rectangular trapezoidal areas and their sizes measured by stepping. At each stopping point slope was measured with a clinometer, towards the catchment outlet (thalweg slope) and towards the divides (transect slope). Catchment divides were visually determined in the field, taking into account also micro-topographical features affecting runoff paths, such as tillage ridges or tractor tyre tracks.

Along the transects all incisions (rills and gullies) were identified and their cross-sectional areas estimated, measuring width and depth of incisions

and visually assessing cross-section shape (semicircular, triangular or rectangular). Eroded volumes were estimated by integration of cross-sectional areas along the incisions' axis. Gully erosion volumes were estimated from incision volumes corresponding to cross-sectional areas higher than 900cm2 (1ft2 arbitrarily taken as gully lower size limit). Total eroded volumes correspond to the volume of all measured incisions.

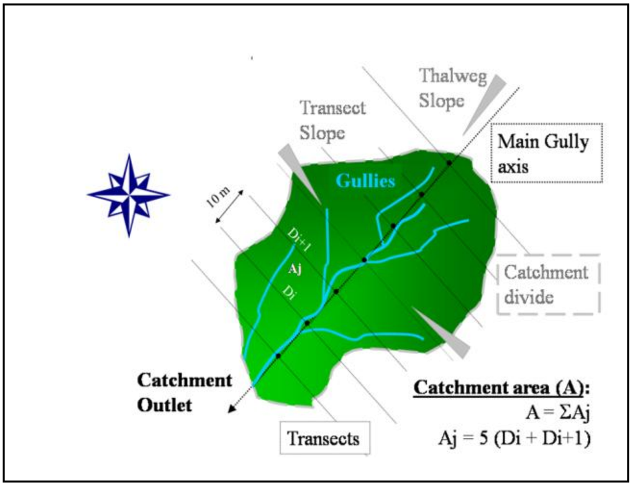

Figure 6*: Field measurements for estimating catchment geometry.*

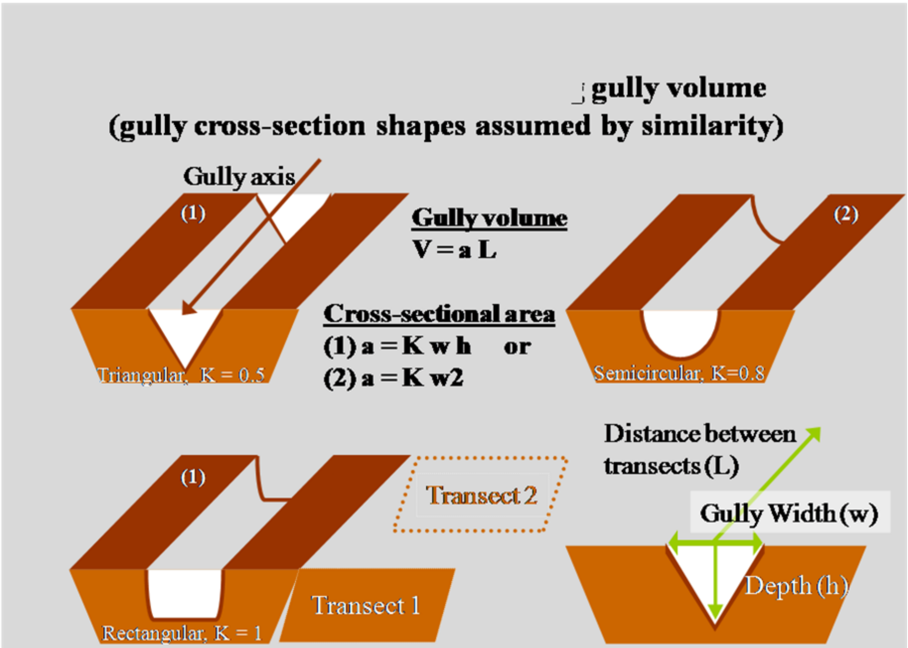

Figure 7*: Field measurements for estimating gully volumes.*

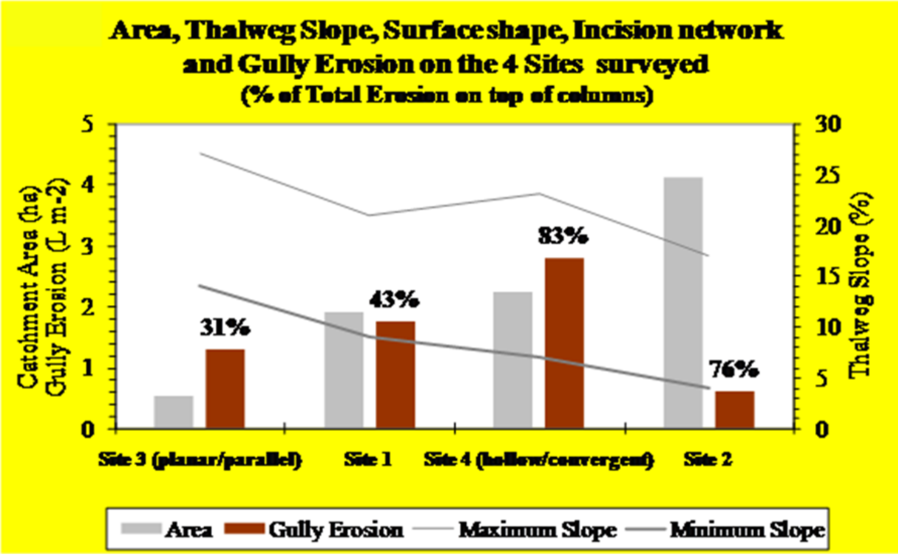

***Figure 8**: Catchment characteristics and gully volumes estimated.*

Results and discussion

Results show erosion volumes ranging from 6 to 28 m3 ha-1 in a single season. These are far higher values than those observed under interrill erosion conditions, as annual average interrill erosion rates measured at plot scale in the region are lower than 0.5 ton ha-1. Values found are also 5 to 6 times higher than annual gully erosion rates estimated for Alentejo, Southern Portugal (Vandaele et al., 1996).

Contributions of gully erosion to total erosion ranged from 31 to 83%, falling below values obtained for Southern Portugal (81 to 84%, Vandaele et al., 1996). Total erosion in the paper mentioned included also interrill erosion rates, which were not accounted for in results being presented. The contribution of gully erosion to total erosion tends to increase with the increase of catchment size and with the decrease of catchment slope.

Previous studies conducted in Bragança area (Vandekerckhove et al., 1998) showed that gully initiation depended to some extent on topographical thresholds, such as local slope and catchment area upslope the initiation cross-section. A slope-area (S – A) relationship was derived from measurements in 50 catchments ($S = 0.102\ A^{0.226}$, S in m m-1 and A in ha). Hence, for a given slope, the Minimum Catchment Area for Gully Initiation can be calculated. Catchment area exceeding this critical value should relate with gully extension and, therefore, with gully eroded volumes. Applying the S – A relationship with the 4 catchments "average" slope (average of maximum and minimum thalweg slopes) a Minimum Catchment Area for Gully Initiation was obtained for each site. The difference between catchment area and that value is Catchment Area Exceeding Minimum for Incision. As catchment area is a surrogate of erosive overland flow concentration, this index represents the area contributing to gully extension. Actually, gully eroded volumes, expressed in % of total erosion, are proportional to the square root of Exceeding Area, suggesting that gully extension is related to a linear topographical feature. Yet, the relationship obtained is not statistically significant due to the small sample size ($r = 0.862$, $N = 4$, $P = 0,138$).

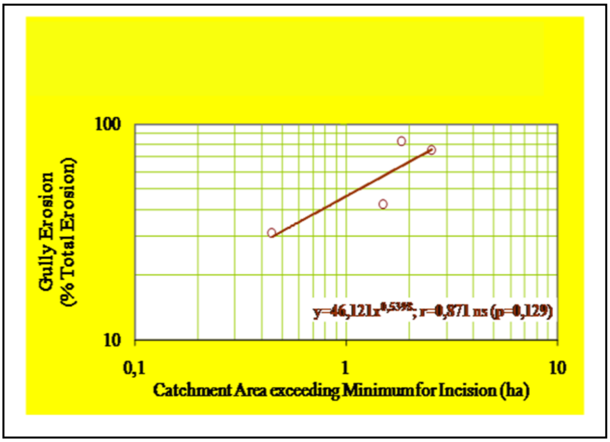

Figure 9*: Gully erosion (% of total erosion) as related to catchment area exceeding minimum for incision (based on thalweg slope and slope-area relationship).*

Conclusions

These results highlight the regional importance of gully erosion. The combination of low crop cover status with heavy rainfalls allowed the concentration of erosive overland flow, generating linear erosion features all over the Bragança area. Results address the attention to the need of conservation measures specifically coping with this problem.

References

Vandekerckhove, L., Poesen, J., Oostwoud-Wijdenes, D. & Figueiredo, T. de., 1998:. Topographical thresholds for ephemeral gully initiation in intensively cultivated areas on the Mediterranean, Catena 33, pp.271-292.

Vandekerkchove, L., Poesen, J., Oostwoud-Wijdenes, D., Nachtergaele, J., Kosmas, D., Roxo, M. J. & Figueiredo, T. de., 2000: Thresholds for gully initiation and sedimentation in Mediterranean Europe, Earth Surface Processes and Landforms 25, pp.1201–1220.