UNIVERSITAT DE LLEIDA
Escola Tècnica Superior d'Enginyeria Agrària
Departament de Medi Ambient i Ciències del Sòl

Suelo-Paisaje-Erosión. Erosión por cárcavas y barrancos en el Alt Penedès – Anoia (Cataluña).

Un enfoque de estudio mediante tecnologías de la información espacial: Bases de Datos, Sistemas de Información Geográfica y Teledetección.

Soil-Landscape-Erosion. Gully erosion in the Alt Penedès – Anoia (Catalonia).

A spatial information technology approach: Spatial databases, Geographical Information Systems and Remote Sensing

Memoria presentada por:

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Para optar al grado de Doctor

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El director de la tesis,

El doctorando,

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Figure 4.13. Examples of gully walls classified as Semi-active – Stable (> 60% vegetation cover).

Figure 4.14. Examples of gully walls classified as Active – Semi-active (< 40% vegetation cover).

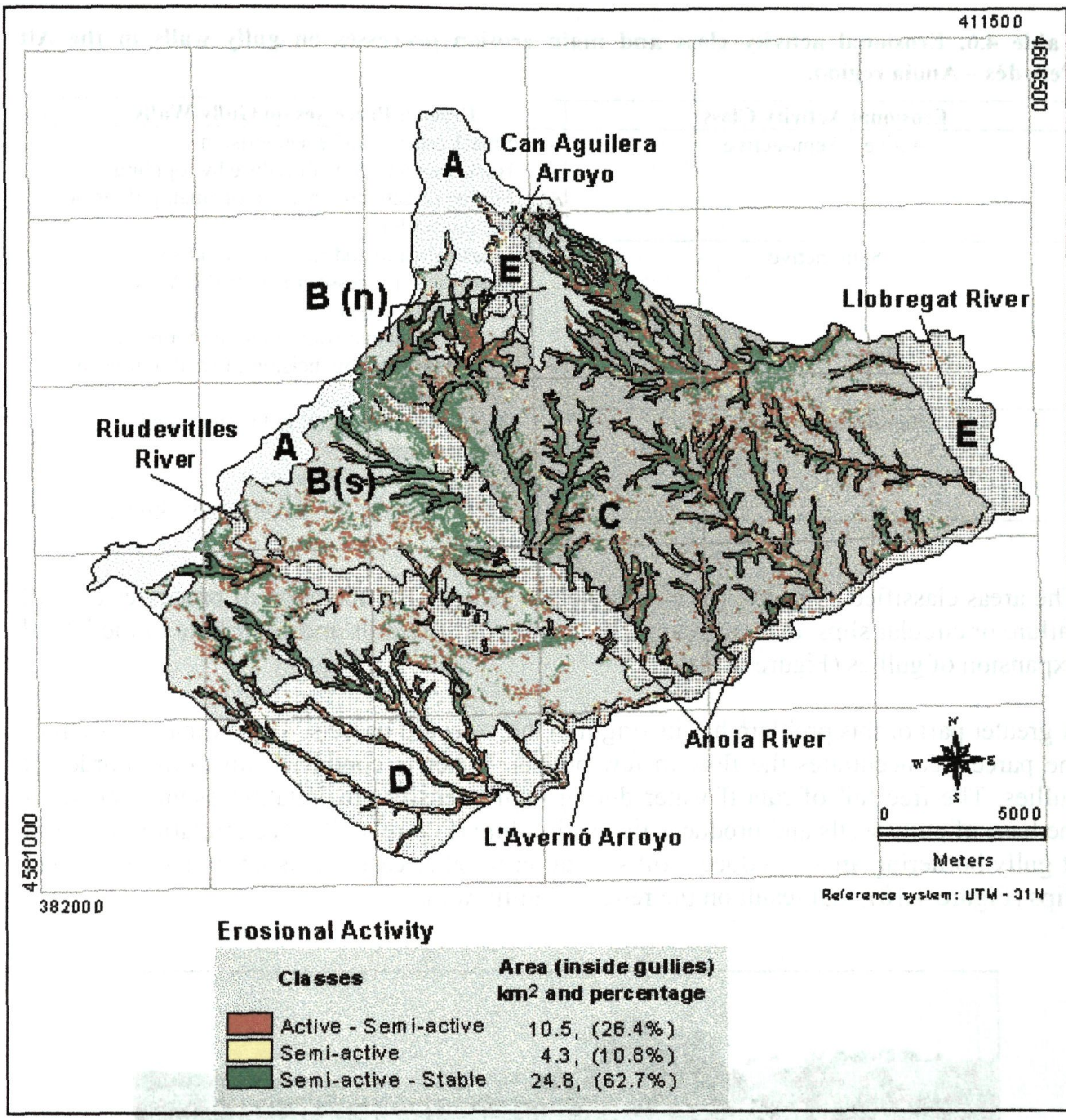

Figure 4.15. Erosional activity of gully walls and other areas >20 % slope degree.

According to different authors (Ireland *et al.* 1939, Morgan 1979, Bergsma 1982, Crouch and Blong 1989) gullies can be considered as stable when, after a period of remoulding of the walls by slope wash and mass movements, walls reach partially or fully vegetated. In the present case study, this is for sure one of the first conclusions one can arrive to from the above mentioned results: the major part of the gully-eroded areas are stable or tend to the stabilisation. However, several types of erosion processes were identified during the field work and were associated with the different erosional activity classes (Table 4.6).

Table 4.6. Erosional activity class and main erosion processes on gully walls in the Alt Penedès – Anoia region.

Erosional Activity Class	Erosion Processes on Gully Walls
Active – Semi-active	- Splash erosion and sheet erosion - Bank erosion and wall failure by toppling - Fluting (created by incision of small gullies on the sidewalls)
Semi-active	- Splash erosion and sheet erosion (lower intensity of processes than for the Active – Semi-active class) - Bank erosion and wall failure by toppling - Fluting (created by incision of small gullies on the sidewalls)
Semi-active - Stable	- Bank erosion and wall failure by toppling - Circular slips - Caving due to soil saturation - Undercutting by parcels' drainage flows

The areas classified as Semi-active – Stable are liable to the actuation of processes as wall failure or circular slips, that can reactivate erosion on sidewalls and contribute to the lateral expansion of gullies (Figure 4.16).

A greater part of this problem has its origin in the vineyard parcels. The drainage system of the parcels concentrates the flow in few outlets. Water is conducted up to the border of gullies. The free fall of runoff water during high intensity precipitation events undercuts the base of gully walls and produces the wall failure (Figure 4.17). Accumulation of runoff at gully bordering areas produces soil saturation in other cases. This later favours circular slips (Figure 4.18), that result on the retreat of gully walls.

Figure 4.16. Processes in the gully borders that contribute to the lateral retreat of gullies. Example of a circular slip.

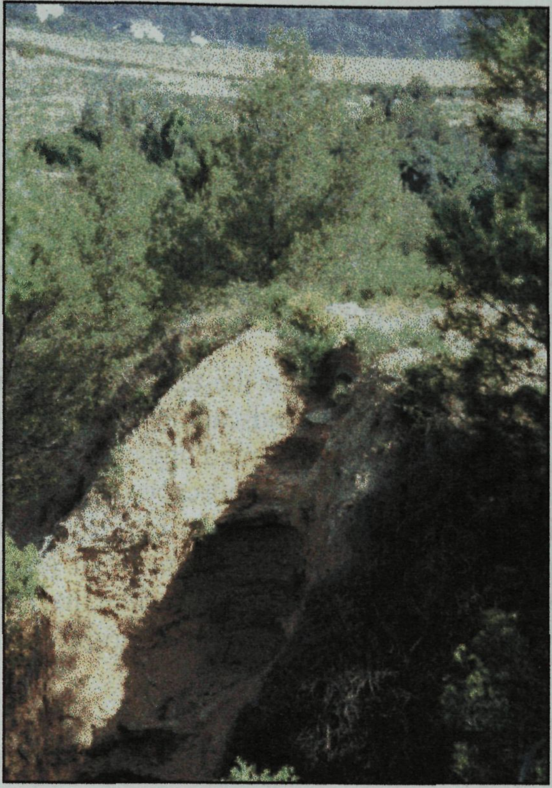

Figure 4.17. Outlet of a drainage channel in a vineyard parcel that has produced a retreat of the gully wall by direct impact of water flow and undercutting of the wall.

Figure 4.18. Left: Fissure produced in border between a parcel and a gully. Right: Slip that produces gully wall retreat.

The assessment of the erosional activity on the basis of vegetation cover on gully walls can produce in these cases default results. The existence of vegetation cover mainly avoids sheet erosion, so soil losses decrease on sidewalls, but it does not imply gullies stop growing and branching since other processes occur. Those processes could not be detected from medium resolution remotely sensed data (Landsat TM data), nor inferred from the image. Complementary field observations were necessary to detect them. The applied method was nevertheless useful to locate the areas of highest sheet erosion on gully walls activity: badlands and non-vegetated sidewalls (Figure 4.15).

Significant differences (P< 0.01) were found in the test of the spatial distribution of the erosional activity classes with respect to the landscape units (Table 4.7). The walls of the gullies cutting the Piedmont landscape unit presented higher proportion of the Semi-active – Stable class (particularly in the sourthern sub-landscape unit). On the contrary, the Low dissected valley-glacis unit presented the major proportion of areas classified as Active – Semi-active. This is interpreted as a relative higher activity of gully erosion in this unit, that agrees with the relative high density of incipient gullies that was measured and with the gully growth in infilled valleys observed during field work.

Table 4.7. Chi Square (X^2) test between erosional activity classes and landscape units. Differences between the distribution of observed and expected frequencies.

	Landscape Unit			
Erosional Activity Class	Piedmont	High dissected valley-glacis	Low dissected valley-glacis	Valleys
Active – Semi-active	-6.57	-1.58	7.18	0.96
Semi-active	-4.88	-4.16	7.89	1.16
Semi-active – Stable	11.45	5.74	-15.08	-2.12
X^2 value = 17.93 X^2 (P = 0.05) = 12.59 X^2 (P= 0.01) = 16.81	Significant differences exist with P<0.01.			

The analysis between the erosional activity classes and topographical variables (slope and exposition) in the gully eroded areas showed a lack of significant relationships (Table 4.8).

Table 4.8. Relationships between the erosional activity classes and topographical variables in the gully eroded areas.

	Gully wall erosional activity	Landscape unit	Slope degree
Gully wall erosional activity	—	—	—
Landscape unit	X^2 value = 17.93 ** X^2 (P = 0.05) = 12.59 X^2 (P = 0.01) = 16.81 Piedmont has higher relative % of SA – S class. Low dissected has higher relative % of A – SA class.	—	—
Slope degree	X^2 value = 9.54 X^2 (P = 0.05) = 15.50 X^2 (P = 0.01) = 20.09 Tendencies: Slopes >40% ⇒ SA - S Slopes <20% ⇒ A - SA	X^2 value = 46.47 ** X^2 (P = 0.05) = 21.02 X^2 (P = 0.01) = 26.21 Piedmont and High dissected has higher slope degrees. Low dissected has lower slope degrees.	—
Exposition	X^2 value = 4.43 X^2 (P = 0.05) = 12.59 X^2 (P= 0.01) = 16.81 Tendencies: A – SA, SA ⇒ South SA – S ⇒ Noth	X^2 value = 12.40 X^2 (P = 0.05) = 16.91 X^2 (P= 0.01) = 21.66 Tendencies: High dissected ⇒ North Low dissected ⇒ West Valley ⇒ East	X^2 value = 7.23 X^2 (P = 0.05) = 21.02 X^2 (P = 0.01) = 26.21 Tendencies: Slope <10% ⇒ South Slope >40% ⇒ North

** Significant with a P<0.01; SA – S: Semi-active – Stable; A – SA: Active – Semi-active

The lack of a logical and expected relationship between the activity classes and variables as the slope degree or the exposition of the eroded areas is be interpreted as gully growth is an active and dynamic process in the study area. The most stable walls usually present a stability that can be broken in a given moment by wall failures, circular slips, undercutting of the walls, etc. This does not depend on the vegetation cover or topographic characteristics as much as erosional processes that are originated by the type of use of the neighbour agricultural parcels (crops, management practices and erosion control measures).

4.3.2. Gully change analysis and estimation of erosion rates at sub-catchment scale

4.3.2.1. Changes in small and medium-size gullies: 1957 – 1993

The results of the change analysis of small and medium-size gullies in the period 1957 – 1993 in the Rierusa catchment show an apparent reduction of 9 km in the total mapped length of gullies (Figure 4.19). Without any other knowledge about the study area, it could be interpreted as gullied areas had been regenerated. The reality is however quite different. Two are the main reasons for this apparent regeneration. One of them is the lateral retreat of some small and medium-size gullies, which in the 1993 situation were mapped as area features (Figure 4.20). This supposes a reduction of 3.6 km of the total mapped length. But the main reason is the filling of gullies by farmers as a consequence of levelling and soil movements produced to achieve bigger parcels (Figure 4.21). The total length of filled gullies is difficult to estimate, since also new gullies appeared.

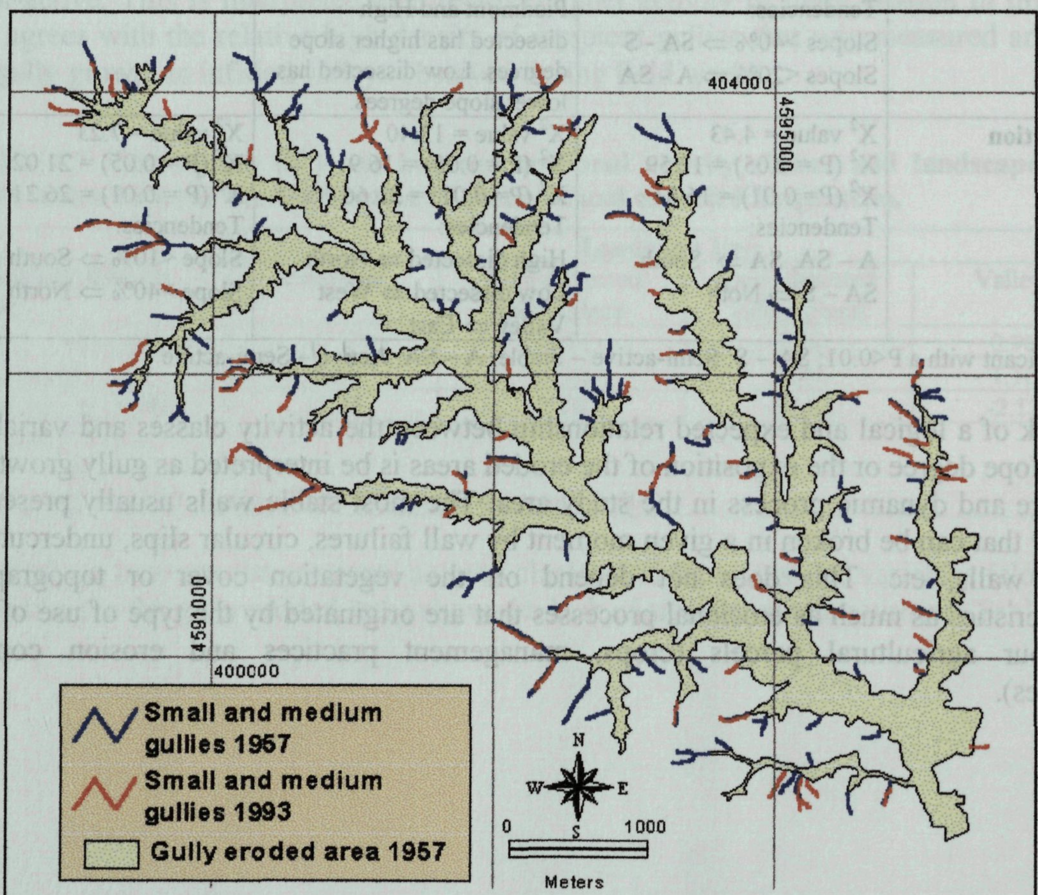

Figure 4.19. Small and medium-size gullies in the Rierusa catchment: 1957 and 1993 situations.

Figure 4.20. Example of lateral retreat of a gully that makes the gully is represented as an area feature in the 1993 situation.

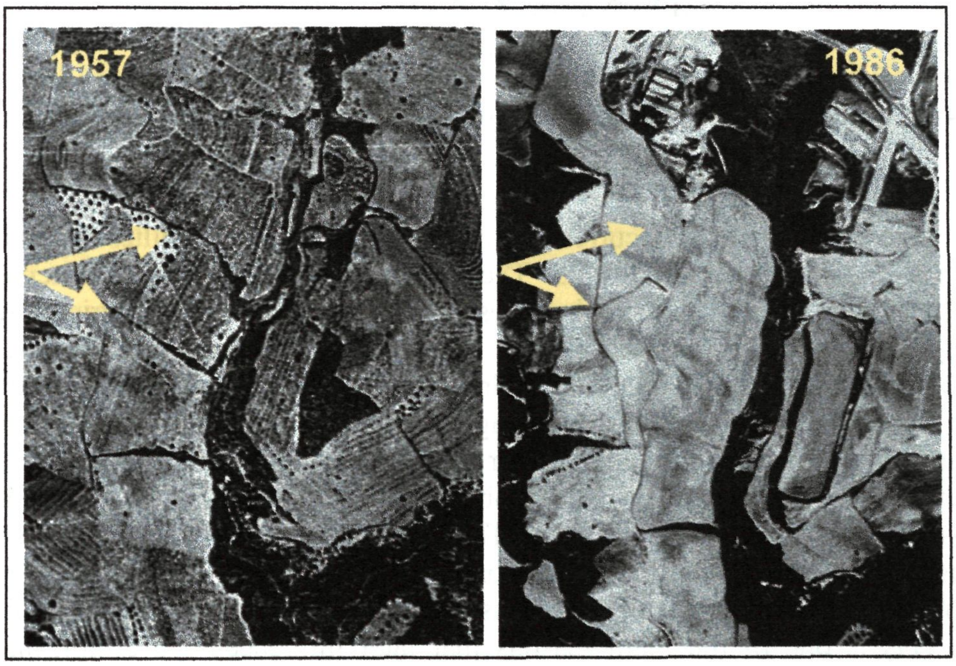

Figure 4.21. Filling of gullies as consequence of the levelling of the parcel.

In the studied period, the most active areas were the main head of the Rierusa gully, the area of the Maset – Mas Bernich, the area of Torrentfondo – Cal Pujades and the area of Sant Joan Samora (Figure 4.22). Of those, the area of Torrentfondo – Cal Pujades experimented one of the most significant changes. This gully is capturing the neighbour catchment to its west and presented a fast linear retreat. In the middle term, it makes this area presents one of the highest degrees of erosion risk.

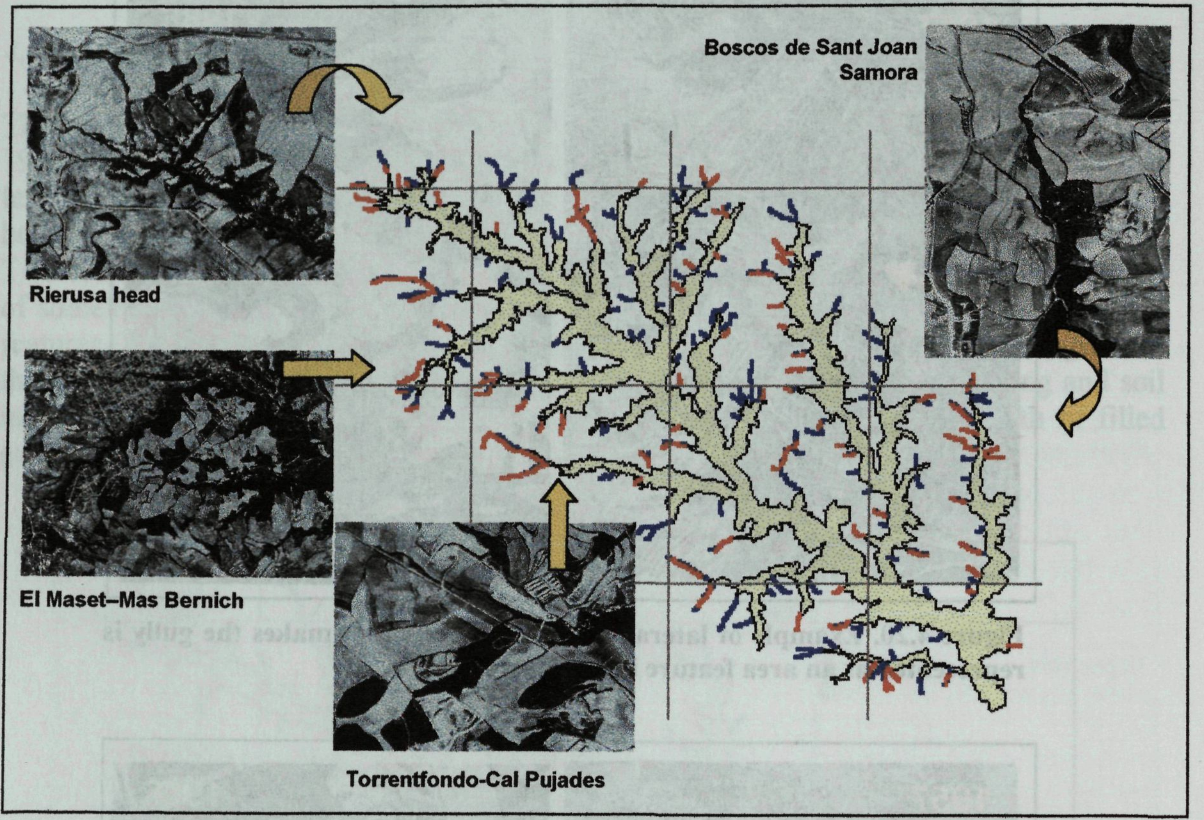

Figure 4.22. Main active areas of gully erosion (small and medium-size gullies) in the studied period.

The mapping of the changes occurred on small and medium-size gullies in the considered period has given unexpected results. These mainly attend to human intervention. At present, it is quite rare to find small gullies as permanent features in agricultural parcels. After high intensity precipitation events, ephemeral gullies, that are formed wherever runoff is concentrated (artificial terraces, drainage channels or small concave areas within parcels), are immediately removed by tillage operations. Gully erosion exist, new gullies would grow but farmers usually avoid their establishment as permanent features. This also has been argued by other authors as a problem to monitor the growth of small gullies in agricultural parcels (Thomas *et al.* 1986). Therefore, the monitoring of gully erosion in the study area, with an intensive mechanisation, is a difficult task and it makes no sense to predict ratios of linear retreat of gullies as a tool for decision making on gully erosion control. This is one of the main reasons that later influenced the establishment of an approach for gully erosion modelling at parcel level on the basis of the probability gully erosion occurs in a parcel above the prediction of retreat of existing small gullies.

Provided that farmers only use to remove ephemeral gullies within their own parcels, gullies take advantage of no-man's land to grow, where the runoff of the parcels is often concentrated,. Then, boundaries between parcels or properties or between parcels and pathways are places where gullies growth, without very much man intervention. At present, these places constitute the main ways of linear retreat of the gully network (Figure 4.23).

Figure 4.23. Left: ephemeral gully formed during a high intensity precipitation event and that is later removed by tillage operations. Right: Gully developed in the border of a parcel that is periodically filled.

4.3.2.2. Changes in large gullies and rate of gully wall retreat (1957 – 1993)

As result of the interpretation of aerial photographs of the two situations, each land cover/use maps were produced (Figure 4.24). These maps show important changes have occurred in the inside gullied areas during the considered period. The most important changes were the increasing of the vegetation cover and the abandon of agricultural uses on high slope degree areas. The overlay of the land cover/use maps of the inside gully areas in the 1957 and 1993 situations allowed the spatial analysis of changes. The results of the analysis are summarised in the matrix of changes (Table 4.1).

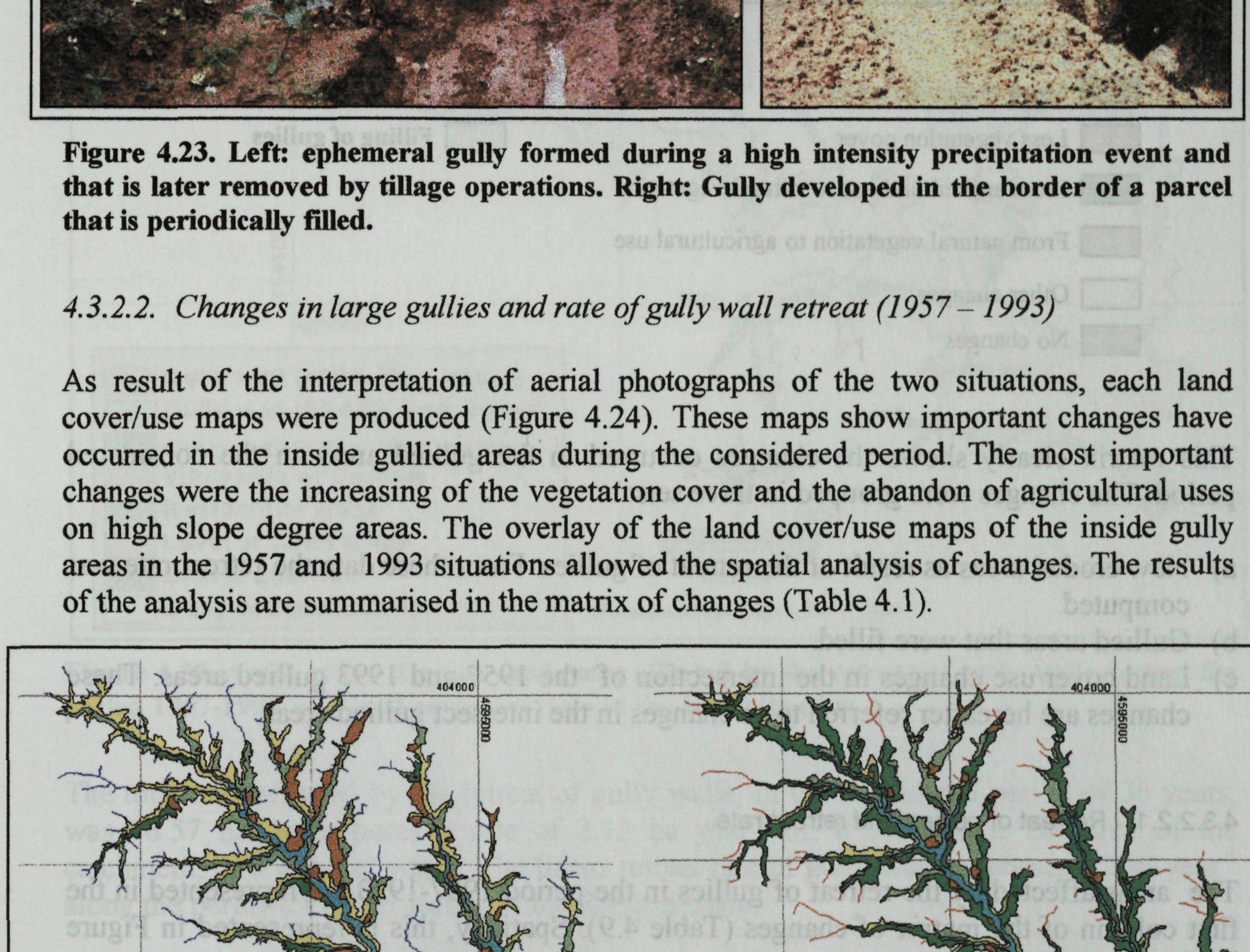

Figure 4.24. Land cover/use maps of the inside gullied area in the Rierusa catchment. Left: 1957, right: 1993.

Table 4.9. Matrix of changes occurred in the gullied areas of the Rierusa catchment in the period 1957 – 1993, (hectares).

	1957 (hectares)						
1993 (m2)	**No Eroded**	**Gully bed**	**<20% v.c.**	**20-65% v.c.**	**>65% v.c.**	**Crops**	**Total 1993**
No Eroded		0	15.52	12.49	2.72	8.08	**38.80**
Gully bed	0.80	64.96	6.31	6.53	1.86	6.12	**86.58**
<20% v.c.	5.11	0.26	33.06	3.41	0.24	2.66	**44.73**
20-65% v.c.	20.83	4.06	37.59	24.97	1.15	36.75	**125.34**
>65% v.c.	42.70	9.64	76.88	134.26	42.69	20.59	**326.77**
Crops	3.04	2.78	2.96	7.60	0.15	25.79	**42.31**
Residential	0.18	0	2.50	0	0	2.58	**5.25**
Level	2.99	0.50	1.45	3.18	0.29	1.67	**10.07**
Quarries	0.93	0	0	0	0	0	**0.93**
Total 1957	**76.58**	**82.20**	**176.25**	**192.43**	**49.10**	**104.23**	

Changes

- More vegetation cover
- Less vegetation cover
- From agricultural use to natural vegetation
- From natural vegetation to agricultural use
- Other changes
- No changes
- **Retreat of gullies**
- **Filling of gullies**

This matrix clearly shows the changes occurred in the gullied areas in the considered period. The changes were grouped in three sets:

a) New eroded areas as result of the retreat of gullies. From these data the retreat rate was computed.
b) Gullied areas that were filled.
c) Land cover/use changes in the intersection of the 1957 and 1993 gullied areas. These changes are hereafter referred to as changes in the intersect gullied areas.

4.3.2.2.1. Retreat of gullies and retreat rate

The areas affected by the retreat of gullies in the period 1957-1993 are represented in the first column of the matrix of changes (Table 4.9). Spatially, this is represented in Figure 4.25.