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Soil Erosion on Abandoned Fields in Mediterranean Mountains - Monitoring of Processes and Development

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Abstract

Abandoned fields as a result of the land use change can frequently be found in the Mediterranean Mountains. In comparison to arable land they demonstrate heterogenic geomorphodynamic processes which vary greatly over small spaces. Their activity and development are difficult to record. Due to linear erosion between the dwarf shrubs the soil erosion patterns show big differences depending on vegetation structure and sheep trails. The study was carried out in two Mediterranean Mountain landscapes in Northeast Spain: In the Pre-Pyrenees, runoff under matorral of dense *Genista scorpius* on Hypercalcic Calcisols with rock fragment cover remains high (runoff coefficients up to 62%). Soil erosion rates are scattered (1 g m^{-2} up to 29 g m^{-2}/ 30 min simulated rainfall). In the Flysch-Area of the Central Pyrenees (dense matorral of *Genista scorpius*, dense herbaceous cover of *Brachypodium*, Stagnic Regosols with stone cover of siltstone fragments), runoff coefficients are lower (up to 35%), soil erosion also, with rates not higher than 11 g m^{-2}. In both landscapes by far the highest values were found in sheep trails (up to 66%, 334 g m^{-2}). In order to examine the interdependence of vegetation dynamics and soil erosion a large-scale testplot monitoring is used to document the factors of vegetation cover and process activity. Short-term changes can be recorded and relationship in the development made clear. It can be shown that the increase or decrease in vegetation cover does not generally lead to stabilisation or intensification of soil erosion. Only a dense vegetation cover above 60% correlates with stability in the process activity although linear erosion forms are still active.

Introduction and Questions

Abandoned fields are widely found in the Mediterranean Mountains as a result of the land use change. In comparison to arable land they demonstrate heterogenic geomorphodynamic processes which vary greatly over small spaces. José María García Ruiz made more than 10 years ago this statement in a fundamental article about Soil Erosion in Spain.

"[...] many fields will be abandoned in the near future and the ecological and geomorphological consequences of this generalized process are not well known. What happens 0in an abandoned field? After many years of cultivation, an abandoned field is a natural, uncommonly complex laboratory [...]." (García-Ruiz et al. 1991: 98)

The classical vegetation cover/soil erosion-relation implies a clear reduction in soil loss due to increasing cover (Fig. 1). Molinillo et al. (1997) and other researchers from the Instituto Pirenaico de Ecología observed an increase in runoff and soil erosion up to 60% shrub-cover and only above the reduction of these processes (Fig. 2). This makes clear that the classical relation does not exist under matorral. The processes are difficult to document and their development is even more difficult to record: Due to linear erosion between the dwarf shrubs the soil erosion patterns show big differences depending on vegetation structure and sheep trails (Ries et al. 2000a, Ries et al. 2003). Though soils demonstrate the spatial differences of the erosion processes after abandonment on a midterm time scale (Seeger, Errea & Lana-Renault in this issue), temporal and spatial heterogeneity of the processes imply, that for this, the following questions have to be answered:

How high are the rates of runoff and soil erosion?

Is there an interdependence of vegetation cover and morphodynamic activity?

What is the influence of sheep grazing?

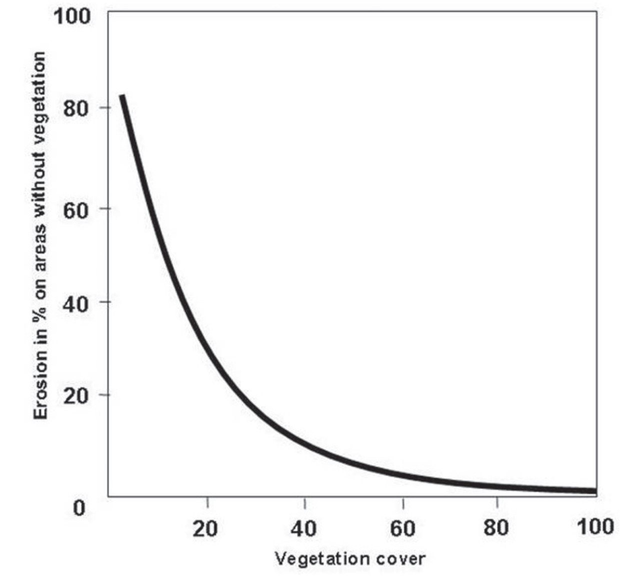


Fig. 1: Soil erosion and vegetation cover (acc. to Elwell & Stocking 1974)

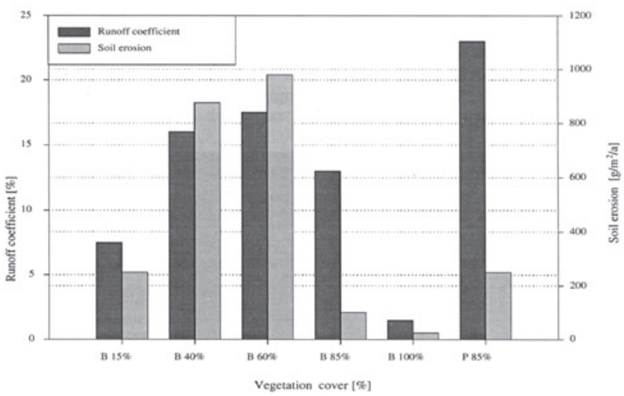


Fig. 2: Runoff and soil erosion on matorral in the upper Aisa-Valley according to Molinillo et al. (1997: 595, Fig. 6), changed

Test Area

The study was carried out in two Mediterranean Mountain landscapes. In Arnás in the Flysch-Area of the Central Pyrennees, with a subhumid climate, and in Sabayés on the southern slope of the Sierras Exteriores, with a semiarid climate and a already negative soil water balance (Fig. 3).

In Sabayés a 40 years old matorral of dense *Genista scorpius* with some *Quercus rotundifolia* on the terrace edges was observed. Hypercalcic Calcisols were found with a dense rock fragment cover. The terraces of the old vineyard are deteriorated mainly by slope sliding and grazing sheeps.

In Sabayés a high state of soil degradation can be observed (Seeger 2001):

The runoff coefficients, measured by rainfall simulation with a small jet-noozle rainfall simulator (Ries et al 2000b, Ries and Langer 2002a) show, according to the different parameters a broad variety between 0 and 62%. Some values are very high and extreme high up to 96% (Fig. 4a). At the same time, only middle to low infiltration capacities, measured with a single ring infiltrometer with a final rate about 7.5

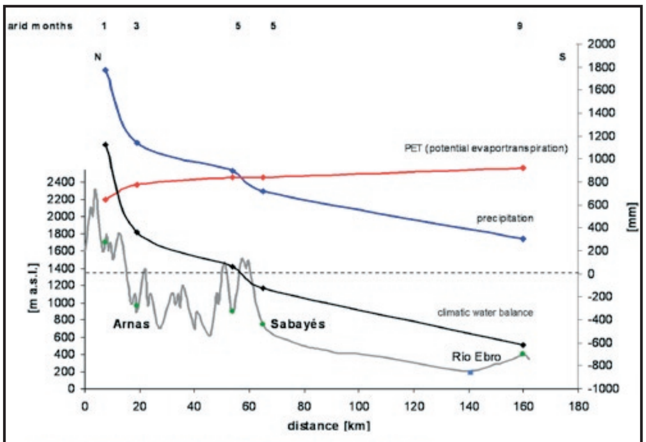


Fig. 3: Transect from the High Pyrenees to the Ebro Basin

mm h^{-1} could be recorded (Fig 5). The soil erosion rates are high and scattered, too. Rates from 1 g m^{-2} up to 29 g m^{-2} on grass and stone cover were quantified (Fig. 4b). By far the highest values were found on sheep trails: The erosion can reach here rates up to 334 g m^{-2} which is ten times higher as the maximum. The runoff coefficients in these trails are also very high, up to 66%.

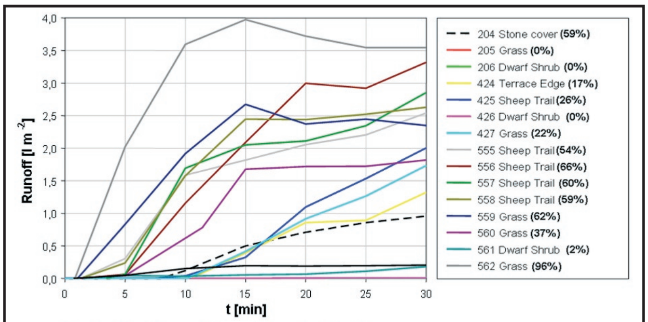


Fig. 4a: Runoff on a 40-year old matorral in Sabayes

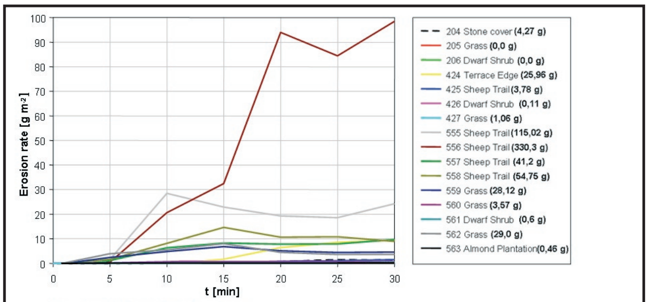


Fig. 4b: Soil erosion in Sabayes

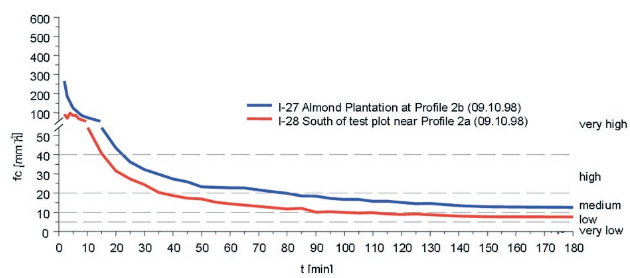


Fig. 5: Infiltration rates in Sabayes

In Arnás the 30 year old abandoned field is covered by a dense matorral of *Genista scorpius* and a dense grass cover of *Brachypodium retusum* on a Stagnic Regosol with stone

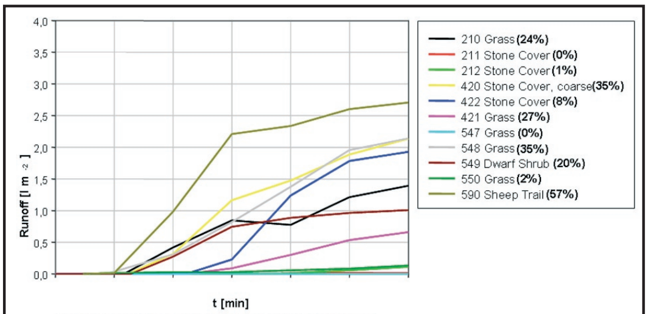


Fig. 6a: Runoff on a 40-year old matorral in Arnas

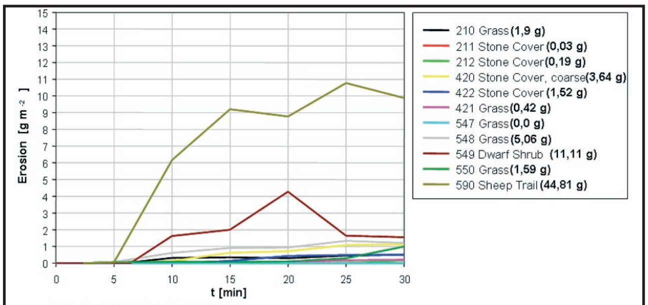


Fig. 6b: Soil erosion in Arnas

cover of siltstone fragments. The runoff coefficients are lower than in Sabayés, only up to 35% which is, nevertheless, a high value (Fig. 6a). Astonishingly, considerably lower infiltration capacities with end rates between 3.7 and 4.6 mm h^{-1} were recorded (Fig. 7). The swelling of the clays reduces the

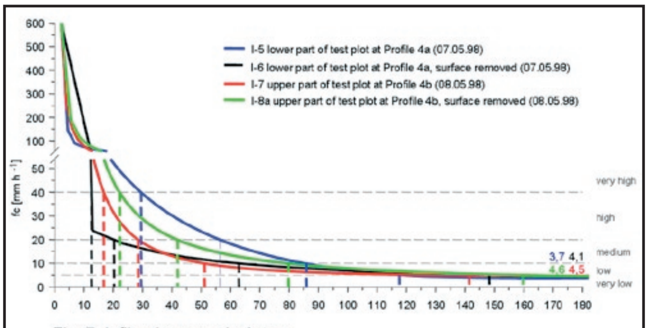


Fig. 7: Infiltration rates in Arnas

infiltration capacity during infiltration measurement using ring infiltrometers, contrarily the macropores are still active under rainfall simulation conditions. The erosion rates are medium with values not higher than 11 g m^{-2} (Fig. 6b). And again, the sheep trails produce here the highest values up to 40 g m^{-2}. In these trails a residual accumulation of large rock fragments can be observed.

Methods

In order to examine the interdependence of vegetation dynamics and soil erosion, a large-scale testplot monitoring was performed to document the factors vegetation and the geomorphic process activity. The five vegetation classes

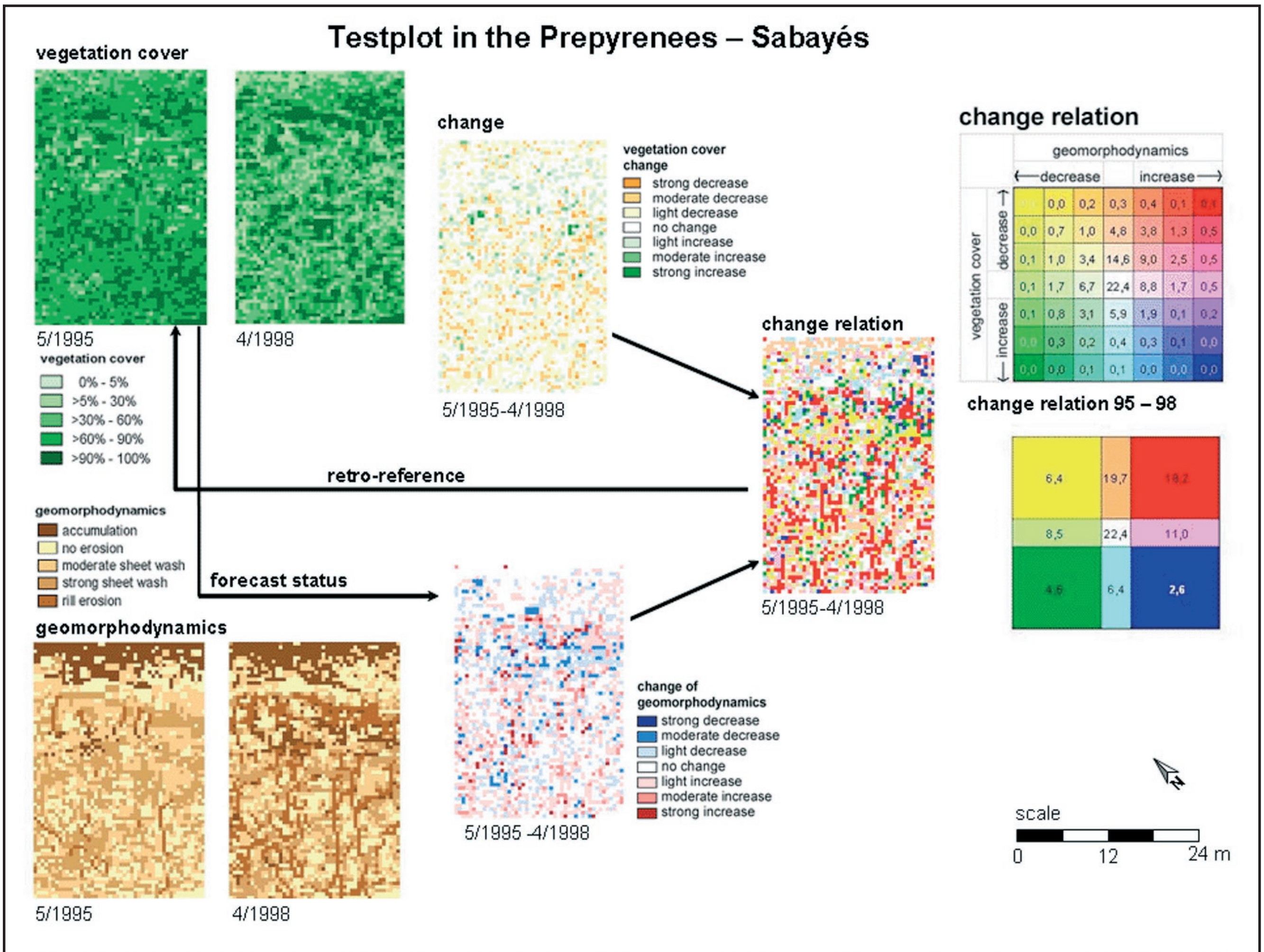


Fig. 8: Vegetation cover and geomorphodynamics, status and changes, and change relation on the testplot on an abandoned field in Sabayes in the Prepyrenees

range from 'no vegetation' (0-5%), 'low vegetation cover' (>5-30%), 'patchy vegetation cover' (>30-60%), 'dense vegetation cover' (>60-90%) up to 'complete vegetation cover' (>90-100%) according to Dierschke (1994). The classes of the geomorphic process activity range from 'accumulation', 'no erosion', 'moderate' and 'strong sheet wash' up to 'rill erosion' according to DVWK (1996) and Mäckel & Walther (1994, 1984). Figure 8 shows the monitoring period from May 1995 to April 1998. The ground resolution is a square of 50 by 50 cm.

With a simple difference of both pictures, change maps with 7 categories of change can be calculated. A strong decrease in the average vegetation cover, from 73% to 61%, and correspondingly an increase in geomorphic activity can be recognized. This occurs in a closed neighbourhood of small patchy patterns of opposite developments of 'light' and 'moderate' 'increase' and 'decrease'. The extreme increase of rill erosion from 3% to 19% is striking (middle brown): The rills up to 16 m length begin often in the diagonal running sheep trails and break out in the direction of the slope gradient. In these sheep trails, the very high erosion rates of more than 300 g m^{-2} were recorded.

Combining these change maps, the spatial relation of vegetation cover change and change of erosion can be statistically analyzed and visualized. Resulting from the number of 7 change categories, a cross table is created with 49 cells generalized into 9 groups. In this square of change relation the rows show the categories of cover change, increase up and decrease down. The columns show the categories of change of the erosion activity, increase to the right and decrease to the left (Fig. 9).

The square of change relation can be subdivided into the

- red group, top right, in which erosion increases with decreasing cover,
- green group, bottom left, in which the erosion decreases with increasing cover,
- yellow group, top left, in which the erosion decreases with decreasing cover,
- blue group, bottom right, in which erosion increases despite of increasing cover.

The green and the red groups reflect the change relation that may be expected for a simple direct causal connection: Within the red group it is possible to speak of classic degradation.

The green group should represent regradation or rehabilitation which is expected to include abandoned fields with a progressive vegetation succession and a reduced geomorphic activity. The yellow group shows that both factors have decreased, on the other hand, the blue group shows an apparently unexpected development, which is often related to torrential rainfall. Between these groups, there are the groups with the secondary colours, orange, pink, light blue and light green, in which one factor changes while the other does not change. In the centre of the change relation square, the white group indicates 'no change'. This square forms the legend to the maps of change relation (Fig. 8, Fig. 10).

Results

The change relation in Sabayés shows an area of 80% which has changed (Fig. 8). This is a surprisingly high percentage for such an old matorral. The change relation shows a great heterogeneity: A colourful picture of all groups in a small scale patchwork. A lot of contradictory change relations in immediate vicinity can be recognized. The red group of degradation is with 18% high and can only be explained by grazing effects. The increase in rill erosion can be observed even under 'dense vegetation cover' (60% - 90%). The following conclusion has to be made: on abandoned fields the geomorphic activity of linear forms, once it started, can not be stopped, even under vegetation cover of more than 60%.

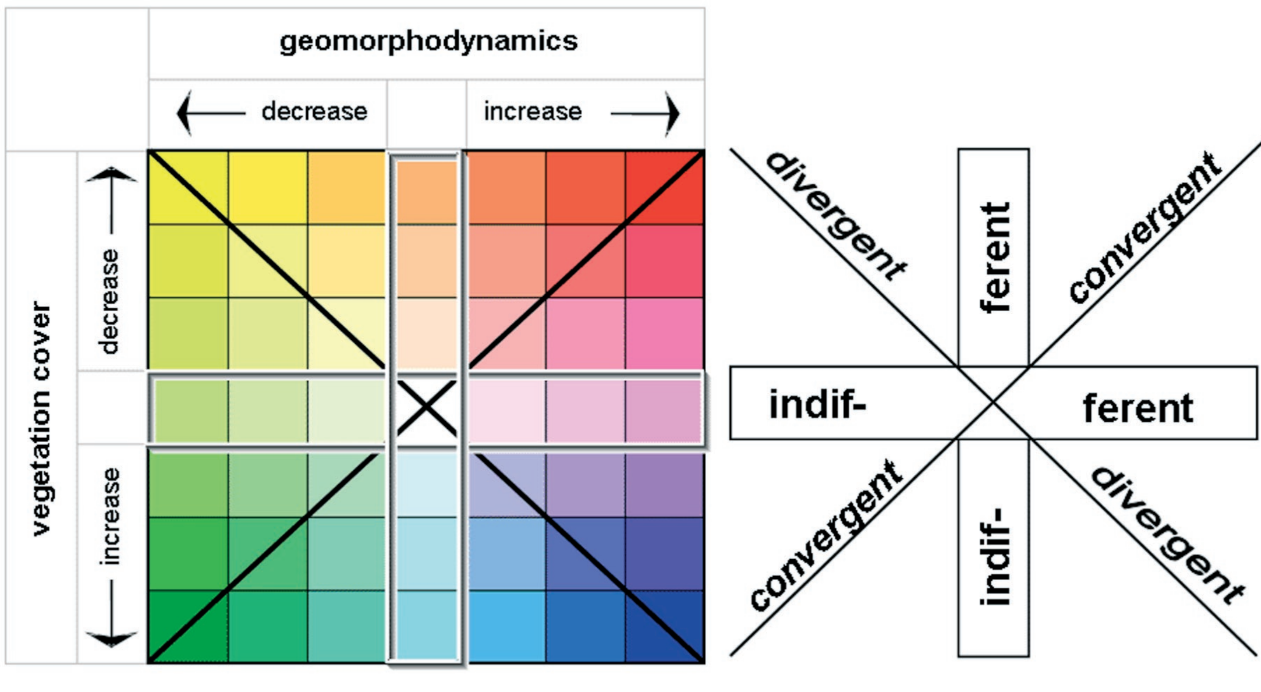


Fig. 9: Change relation

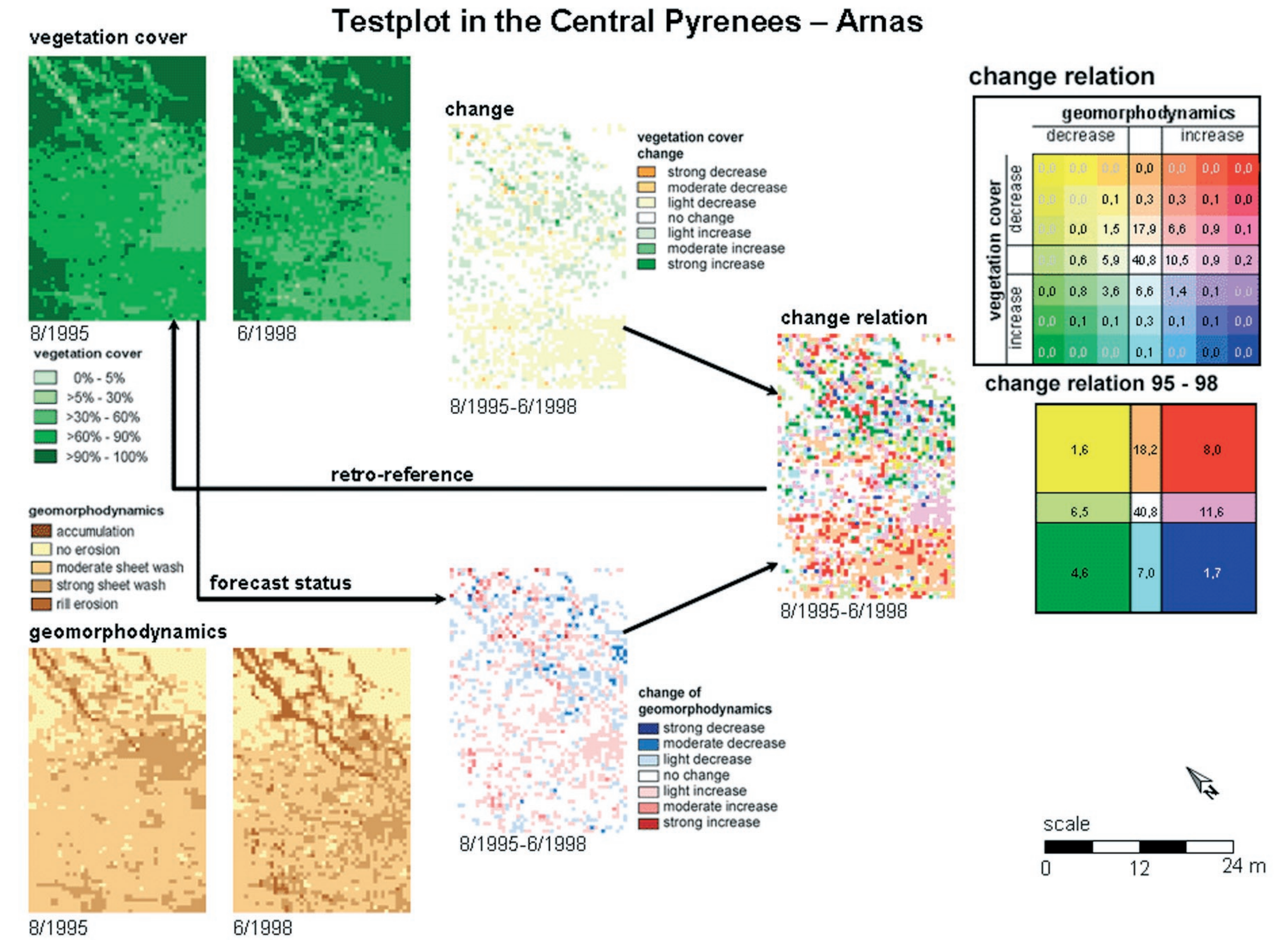


Fig. 10: Vegetation cover and geomorphodynamics, status and changes, and change relation on the testplot on an abandoned field in Arnas in the Central Pyrenees

The field in the Central Pyrenees shows a differentiated change relation (Fig. 10). The plot in Arnás is divided in an upper part with a dense matorral and mainly 'no erosion' except in some trails and a down part with 'dense grass cover' and 'moderate sheet wash'. Even here, the 'rill erosion' in and along the trails is increasing over the three years from 1.5% to 7.5%. We can observe the following change relation pattern:

- The down part, which is heavily grazed, shows continuously decreasing vegetation cover with 'unchanged' or 'increasing' erosion (orange group, red group, pink group).
- Inside the matorral, a general increase of vegetation cover with conflicting development side by side can be observed.
- The trails show progressive degradation (red group), the portions with 'dense vegetation cover' further regradation (green group).

In a last step an idea is presented to create a scenario for future development:

Comparing the initial vegetation cover with the change relation, the influence of vegetation cover to the change relation can be statistically analyzed. This procedure is called retro-reference. For this, the nine groups of the change relation are combined with the five vegetation cover classes in a correspondence analysis based on a cross table (Tab. 1, Tab. 2). On the basis of the χ^2, which indicates the ratio of expected to actual frequency in each cell, each vegetation cover class can be allocated to a change relation as the most likely development according to the empirical results. The cell with a significant high χ^2 for each vegetation class shows the development of the geomorphodynamics in this vegetation cover class and is shaded in the cross-table.

Assuming that the time period used is representative regarding precipitation and grazing, a forecast for the recent geomorphodynamics can be derived from this retro-reference.

The following questions, which have to be solved for efficiently combating erosion, can be answered:

- Which degree of vegetation cover must be exceeded for a reduction in erosion?
- At which degree of vegetation cover does its reduction lead to an increase in erosion?

And the reference to vegetation cover also allows the results to be transferred from the testplots to smaller scales: For small-scale land degradation studies on the basis of aerial photographs and satellite images the vegetation cover remains the most easily detectable factor from which conclusions can be drawn about the geomorphological processes. For that, the testplot results are combined with large scale aerial photographs, which were taken from a remote controlled hot air blimp (Ries and Marzolff 2002b).

For Arnás the scenario is: Unchanged and decreasing vegetation cover will result on increasing soil erosion in all vegetation classes up to 90% cover. Only the complete vegetation cover in the areas of *Genista scorpius* are stable

Tab. 1: Cross table for retro-reference to the vegetation cover at the first monitoring date on the testplot on an abandoned field in the Central Pyrenees (yellow group: decreasing vegetation cover & decreasing geomorphodynamic activity, orange group: decreasing vegetation cover & unchanged geomorphodynamic activity, red group: decreasing vegetation cover & increasing geomorphodynamic activity, light green group: unchanged vegetation cover & decreasing geomorphodynamic activity, white group: no changes at all, pink group: unchanged vegetation cover & increasing geomorphodynamic activity, green group: increasing vegetation cover & decreasing geomorphodynamic activity, light blue group: increasing vegetation cover & unchanged geomorphodynamic activity, blue group: increasing vegetation cover & increasing geomorphodynamic activity).

frequency (50 cm by 50 cm grid point)

expected frequency

% of complete testplot

cell-χ^2 (*significant)

% of cell-χ^2 of total-χ^2

% of cell-χ^2 of χ^2 of the vegetation cover class

italic: underrepresented cells

bold: overrepresented cells with a significant cell-χ^2

(grey box): cell-χ^2 is the base for the forecast status

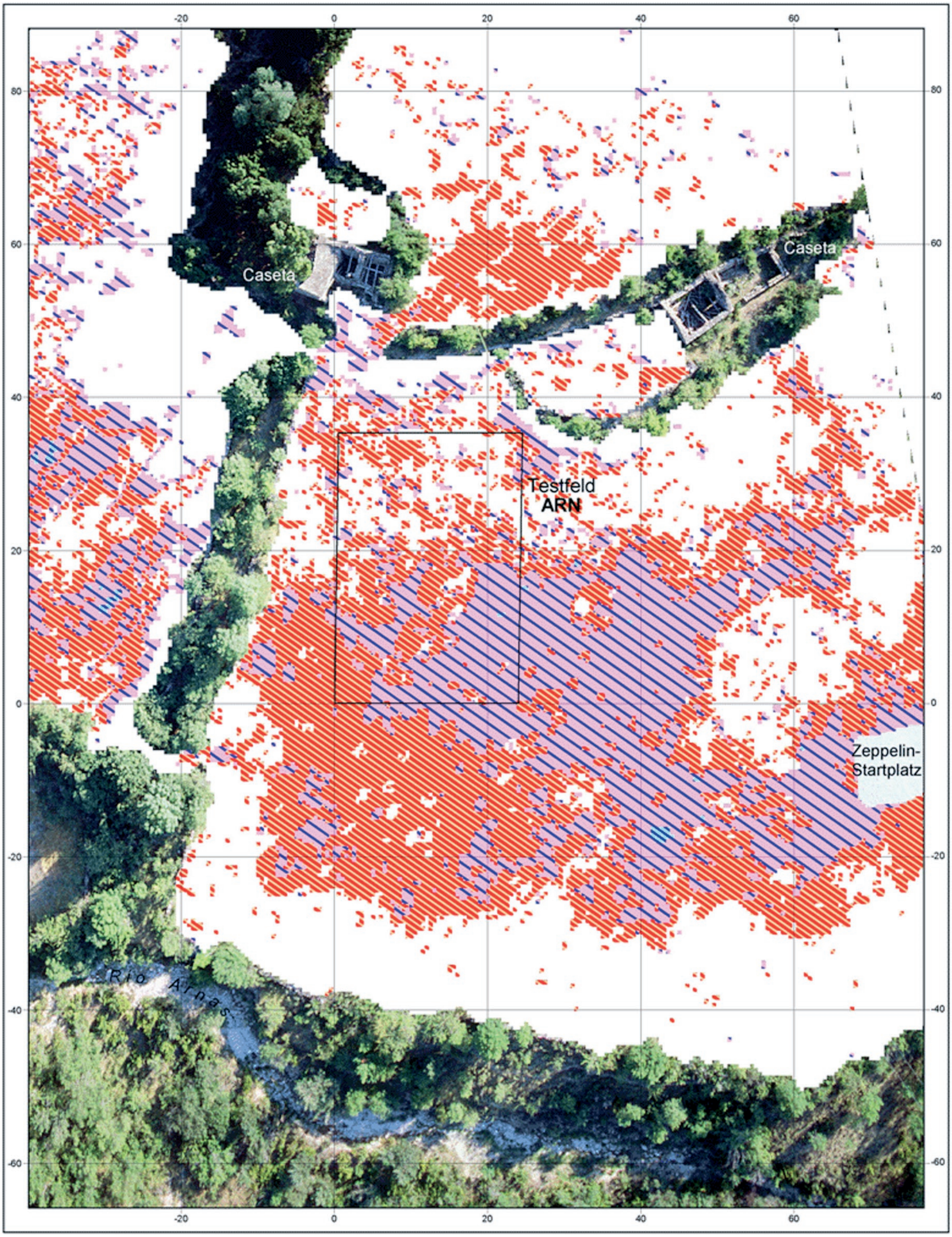
ARNAS χ^2: 1013,72 Cramers`V: 0,313	1 yellow V-G-	2 orange V-	3 red V-G+	4 light green G-	5 white no change	6 pink G+	7 green V+G-	8 light blue V+	9 blue V+G+	
1 no vegetation 0-5%	-	-	-	-	-	-	-	-	-	-
2 low vegetation cover >5-30%	*0* *0,47* *0,00%* *0,47* *0,05%* *0,51%*	*0* *5,30* *0,00%* *5,30* *0,52%* *5,73%*	*0* *2,29* *0,00%* *2,29* *0,23%* *2,47%*	*0* *1,90* *0,00%* *1,90* *0,19%* *2,05%*	*9* *11,82* *0,26%* *0,67* *0,07%* *0,73%*	4 3,36 0,12% 0,12 0,01% 0,13%	*0* *1,35* *0,00%* *1,35* *0,13%* *1,46%*	11 2,01 0,32% 40,34 3,98% 43,56%	5 0,50 0,14% 40,16 3,96% 43,36%	29 29,00 0,84% 92,61 * 9,14% 100,00%
3 patchy vegetation cover >30-60%	*1* *9,63* *0,03%* *7,73* *0,76%* *1,96%*	*10* *108,63* *0,29%* *89,55 ** *8,83%* *22,75%*	*22* *46,92* *0,64%* *13,24* *1,31%* *3,36%*	42 38,84 1,22% 0,26 0,03% 0,07%	*188* *242,17* *5,44%* *12,12* *1,20%* *3,08%*	**178** **68,75** **5,15%** **173,61 *** **17,13%** **44,11%**	38 27,67 1,10% 3,85 0,38% 0,98%	81 41,08 2,34% 38,80 3,83% 9,86%	**34** **10,31** **0,98%** **54,41 *** **5,37%** **13,83%**	594 594,00 17,19% 393,56 * 38,82% 100,00%
4 dense vegetation cover >60-90%	42 31,76 1,22% 3,30 0,33% 2,33%	481 358,43 13,92% 41,92 4,14% 29,59%	222 154,83 6,42% 29,14 2,87% 20,58%	*117* *128,17* *3,39%* *0,97* *0,10%* *0,69%*	*607* *799,09* *17,56%* *46,17* *4,55%* *32,60%*	*200* *226,85* *5,79%* *3,18* *0,31%* *2,24%*	123 91,31 3,56% 11,00 1,09% 7,77%	147 135,54 4,25% 0,97 0,10% 0,68%	*21* *34,03* *0,61%* *4,99* *0,49%* *3,52%*	1960 1960,00 56,71% 141,65 * 13,97% 100,00%
5 complete vegetation cover >90-100%	*13* *14,15* *0,38%* *0,09* *0,01%* *0,02%*	*141* *159,65* *4,08%* *2,18* *0,21%* *0,56%*	*29* *68,96* *0,84%* *23,16* *2,28%* *6,00%*	67 57,09 1,94% 1,72 0,17% 0,45%	**605** **355,92** **17,51%** **174,31 *** **17,20%** **45,17%**	*18* *101,04* *0,52%* *68,25 ** *6,73%* *17,69%*	*0* *40,67* *0,00%* *40,67* *4,01%* *10,54%*	*0* *60,37* *0,00%* *60,37 ** *5,96%* *15,64%*	*0* *15,16* *0,00%* *15,16* *1,50%* *3,93%*	873 873,00 25,26% 385,91 * 38,07% 100,00%
	56 56,00 1,62% 11,59 1,14% 1,14%	632 632,00 18,29% 138,94 * 13,71% 13,71%	273 273,00 7,90% 67,83 * 6,69% 6,69%	226 226,00 6,54% 4,85 0,48% 0,48%	1409 1409,00 40,77% 233,28 * 23,01% 23,01%	400 400,00 11,57% 245,16 * 24,18% 24,18%	161 161,00 4,66% 56,88 * 5,61% 5,61%	239 239,00 6,92% 140,48 * 13,86% 13,86%	60 60,00 1,74% 114,71 * 11,32% 11,32%	3456 3456,00 100,00% 1013,72 * 100,00% 100,00%

Tab. 2: Cross table for retro-reference to the vegetation cover at the first monitoring date on the testplot on an abandoned field in the Prepyrenees (yellow group: decreasing vegetation cover & decreasing geomorphodynamic activity, orange group: decreasing vegetation cover & unchanged geomorphodynamic activity, red group: decreasing vegetation cover & increasing geomorphodynamic activity, light green group: unchanged vegetation cover & decreasing geomorphodynamic activity, white group: no changes at all, pink group: unchanged vegetation cover & increasing geomorphodynamic activity, green group: increasing vegetation cover & decreasing geomorphodynamic activity, light blue group: increasing vegetation cover & unchanged geomorphodynamic activity, blue group: increasing vegetation cover & increasing geomorphodynamic activity).

frequency (50 cm by 50 cm grid point)
expected frequency
% of complete testplot
cell-χ^2 (*significant)
% of cell-χ^2 of total-χ^2
% of cell-χ^2 of χ^2 of the vegetation cover class

italic: underrepresented cells
bold: overrepresented cells with a significant cell-χ^2
[grey box]: cell-χ^2 is the base for the forecast status

SABAYES χ^2: 583,055 Cramers`V: 0,205	1 yellow V-G-	2 orange V-	3 red V-G+	4 light green G-	5 white no change	6 pink G+	7 green V+G-	8 light blue V+	9 blue V+G+	
1 no vegetation 0-5%	*0*	*0*	*0*	*0*	*0*	*0*	2	3	*0*	5
	0,32	*0,98*	*0,91*	*0,43*	*1,12*	*0,55*	0,23	0,32	*0,13*	5,00
	0,00%	*0,00%*	*0,00%*	*0,00%*	*0,00%*	*0,00%*	0,06%	0,09%	*0,00%*	0,14%
	0,32	*0,98*	*0,91*	*0,43*	*1,12*	*0,55*	13,41	22,22	*0,13*	40,07
	0,06%	*0,17%*	*0,16%*	*0,07%*	*0,19%*	*0,09%*	2,30%	3,81%	*0,02%*	6,87%
	0,81%	*2,46%*	*2,28%*	*1,07%*	*2,79%*	*1,37%*	33,46%	55,45%	*0,32%*	100,00%
2 low vegetation cover >5-30%	*0*	*1*	*0*	15	48	20	17	**37**	15	153
	9,87	*30,10*	*27,93*	13,06	34,27	16,78	7,13	**9,87**	3,98	153,00
	0,00%	*0,03%*	*0,00%*	0,43%	1,39%	0,58%	0,49%	**1,07%**	0,43%	4,43%
	9,87	*28,14*	*27,93*	0,29	5,51	0,62	13,67	**74,54 ***	30,45	191,03 *
	1,69%	*4,83%*	*4,79%*	0,05%	0,94%	0,11%	2,35%	**12,78%**	5,22%	32,76%
	5,17%	*14,73%*	*14,62%*	0,15%	2,88%	0,32%	7,16%	**39,02%**	15,94%	100,00%
3 patchy vegetation cover >30-60%	*18*	*85*	*54*	*37*	*105*	67	34	51	30	481
	31,04	*94,64*	*87,82*	*41,06*	*107,72*	52,75	22,41	31,04	12,53	481,00
	0,52%	*2,46%*	*1,56%*	*1,07%*	*3,04%*	1,94%	0,98%	1,48%	0,87%	13,92%
	5,48	*0,98*	*13,03*	*0,40*	*0,07*	3,85	6,00	12,84	24,38	67,02 *
	0,94%	*0,17%*	*2,23%*	*0,07%*	*0,01%*	0,66%	1,03%	2,20%	4,18%	11,49%
	8,17%	*1,47%*	*19,44%*	*0,60%*	*0,10%*	5,75%	8,95%	19,16%	36,37%	100,00%
4 dense vegetation cover >60-90%	143	392	408	*154*	*301*	241	108	132	45	1924
	124,15	378,56	351,29	*164,23*	*430,90*	210,99	89,63	124,15	50,10	1924,00
	4,14%	11,34%	11,81%	*4,46%*	*8,71%*	6,97%	3,13%	3,82%	1,30%	55,67%
	2,86	0,48	9,16	*0,64*	*39,16*	4,27	3,76	0,50	0,52	61,34 *
	0,49%	0,08%	1,57%	*0,11%*	*6,72%*	0,73%	0,65%	0,09%	0,09%	10,52%
	4,67%	0,78%	14,93%	*1,04%*	*63,84%*	6,96%	6,14%	0,81%	0,85%	100,00%
5 complete vegetation cover >90-100%	62	202	169	89	**320**	*51*	*0*	*0*	*0*	893
	57,62	175,71	163,04	76,23	**199,99**	*97,93*	*41,60*	*57,62*	*23,26*	893,00
	1,79%	5,84%	4,89%	2,58%	**9,26%**	*1,48%*	*0,00%*	*0,00%*	*0,00%*	25,84%
	0,33	3,93	0,22	2,14	**72,01 ***	*22,49*	*41,60*	*57,62 **	*23,26*	223,60 *
	0,06%	0,67%	0,04%	0,37%	**12,35%**	*3,86%*	*7,14%*	*9,88%*	*3,99%*	38,35%
	0,15%	1,76%	0,10%	0,96%	**32,20%**	*10,06%*	*18,60%*	*25,77%*	*10,40%*	100,00%
	223	680	631	295	774	379	161	223	90	3456
	223,00	680,00	631,00	295,00	774,00	379,00	161,00	223,00	90,00	3456,00
	6,45%	19,68%	18,26%	8,54%	22,40%	10,97%	4,66%	6,45%	2,60%	100,00%
	18,87	34,51	51,25 *	3,89	117,86 *	31,77	78,44 *	167,72 *	78,74 *	583,06 *
	3,24%	5,92%	8,79%	0,67%	20,21%	5,45%	13,45%	28,77%	13,50%	100,00%
	3,24%	5,92%	8,79%	0,67%	20,21%	5,45%	13,45%	28,77%	13,50%	100,00%



Kartengrundlage: EPRODESERT-Luftbildaufnahmen August 1998
Bildverarbeitung und Kartographie: I. Marzolff
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Maßstab 1 : 500
0 10 20 30 m

N

Lokales Koordinatensystem
Testfeldmitte bei 0°35'34" W / 42°38'40" N

Karte 7.4: Testgebiet-Entwicklungskarte Arnas / Valle de Borau, Zentrale Hochpyrenäen

Fig. 11: Scenario Arnas

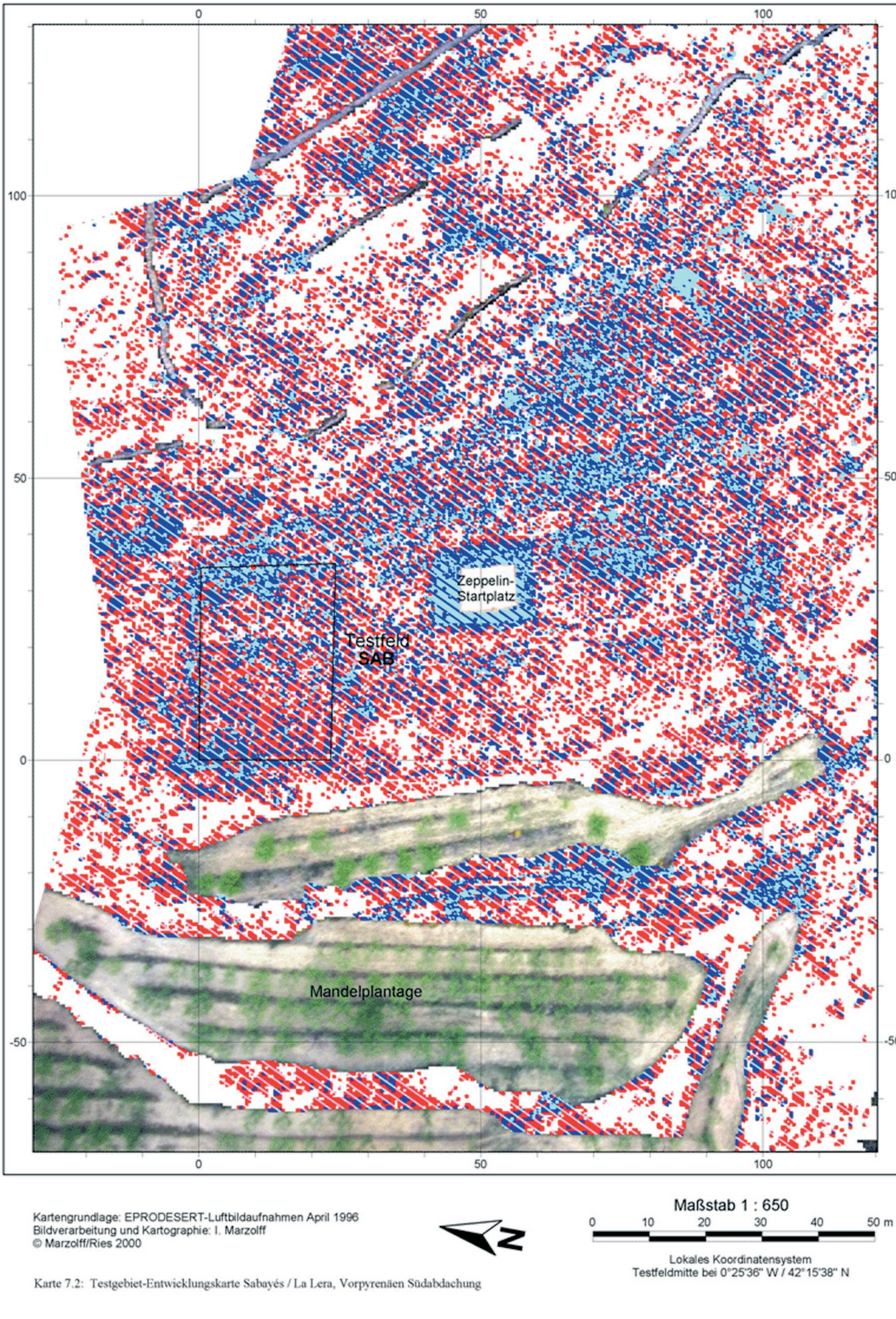

Fig. 12: Scenario Sabayes

(Fig. 11). For Sabayés it can be assumed: Vegetation cover above 60%, which decreases, will cause an increasing soil erosion, increasing 'patchy vegetation' (30%-60%) will lead to increasing soil erosion, too (Fig. 12).

Conclusions

It can be shown, that in the investigated matorral

- the increase or decrease in vegetation cover does not generally lead to stabilisation or intensification of soil erosion processes
- a closed neighbourhood of small patchy patterns of contradictory developments can be observed
- grazing on abandoned fields is the critical factor for further degradation
- only a dense vegetation cover above 60% correlates with stability of erosion processes, but linear erosion forms remain still active.

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