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# TEMPORAL OCCURRENCE AND FORECASTING OF LANDSLIDING IN THE EUROPEAN COMMUNITY

## INTRODUCTION

In the frame of the general «Epoch» programme of the EC DG XII, the research programme «Temporal occurrence and Forecasting of landsliding in the European Community» was carried out by nine contractors and subcontractors on the network of the European Centre for Geomorphological Hazards from 1991 to 1993. Its effective European dimension was assured

1. By the number of participants and countries

- 6 European countries (England, France, Germany, Italy, the Netherlands, Spain), 26 Universities and National research centres, 86 researchers: G. Abele (Innsbrück), J. Agili, C. Baera, J. Corominas, J. Moya, J.M. Vilaplana (Catalunya), V. Agnesi, C. Di Maggio, C. Gagliano, M. Macaluso, S. Monteleone, G. Pipitone (Palermo), E.J. Anthony, M. Julian (Nice), L. Antronico, E. Catalano, E. Filice, G. Gulla, L. Merenda, O. Petrucci, M. Sorriso-Valvo, C. Tansi (Cosenza), D. Barsch, R. Dikau, J. Jăger (Heidelberg), E. Bibus, I. Fleig, E. Jacobs, S. Wiesel (Tübingen), C. Bisci, F. Dramis, F. Eusebio, B. Gentili, G. Pambianchi (Camerino), D. Brundsen, M. Ibsen (London), A. Cavallin, B. Floris, M. Marchetti (Milano), A. Cendrero, J.R. Diaz de Teran, A. Gonzales-Diez, A.L. Salas (Cantabria), E. Cliquot, R. Ingonacka, P. Lahousse (Lille), B. Dumas (Paris XII), P. Farias, Fernandez-Menedez, M. Jmenez, J. Marquinez, R. Menendez Duarte (Oviedo), G. Furdada, D. Serrat, J.M. Vilaplana (Barcelona), J.C. Flageollet, O. Maquaire, B. Martin, D. Weber (Strasbourg), A. Galgaro, G.B. Pellegrini, N. Surian, R. Zambrano (Padova), P. Gasparetto, L. Marchi, S. Pasuto, S. Silvano (Padova), R. Glaser, H. Hagedorn, S. Helzel, B. Sponholz (Würzburg), P. Gueremy, A. Marre, E. Seve-Maure (Reims), R. Lhenaff (Savbie), E.F. Mantovani (Ferrara), M. Panizza, M. Soldati (Modena), G. Rodolfi (Firenze), R. Soeters, K. van Vesten (Enschede), T.W.J. van Asch, H.M. Blijenberg, R. Lammers, D. Nieu Wenhuis, H. van Steijn, K. Towen, E.E.J. Weiss (Utrecht).

2. By the structure of its management team

- 1 coordinator, 4 contractors and 4 sub-contractors, of different countries: *Coordinator*: J.C. Flageollet (University Louis Pasteur, Strasbourg, France); *Contractors*: D. Brunsden (King's College, United Kingdom), R. Dikau (Universität Heidelberg, Deutschland), T.W.J. van Asch (Rijk's Universiteit Utrecht, the Netherlands), M. Sorriso-Valvo (Consiglio Nazionale Ricerche Cosenza, Italia); *Associated contractors*: A. Cendrero (Universidad de Cantabria, Santander, Espana), R. Lhenaff (Université des Sciences et Techniques, Lille, France), M. Panizza (Università degli Studi, Modena, Italia), J. Corominas (Universidad Politecnica de Catalunya, Barcelona, Espagna).

3. By the diversity of test sites

- 21 test sites, of small dimension, of different geological, geomorphological and human features, distributed in four main regions, representative of different climatic regimes;
- Ocean climate areas, Northern area of the Alps, Southern face of the Alps, Peninsular Mediterranean areas.

The research programme, agreed with and sponsored by the European Communities'DG XII had four main objectives: 1) to describe: the frequency and magnitude of

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events and of different types of landslides; 2) to describe: the current statistical distribution of European landslides in the context of historical records and, as far as possible, in the context of the time scales of global environment change; 3) to assess: the external causal factors of landsliding (human, climatic and tectonic), their temporal properties and the degree of which they explain the temporal variations in landslide activity; 4) to use: the empirical data to establish predictive models of landslide occurrence.

The scientific results of this collective research cannot be presented here in some words, and for a complete view, you are invited to consult the two volumes of the publication, which includes, in 960 pages, 28 partial reports, 375 figures, 82 tables, 91 maps, 19 colour plates and 37 photographs.

Some main results are just evoked here.

## INVENTORIES OF LANDSLIDES

– *Chronologies* are reliable when they are directly set up on absolute data by $^{14}C$, but extrapolations or indirect datations depending on geomorphological relation between remnants of landslides and geomorphological elements like fluvial terrace, are less precise.

– For historical periods covering the last 200 years, inventories are supported on:

– *Natural archives*, like dendrochronology, in the French Alps and part of the Pyrenees. They give precise data on the frequency of landsliding, they can identify actual years as well as wet periods and landslide episodes.

– Researchers largely appealed *Human archives*, newspapers, documents, technical reports, but all have underlined the encountered difficulties: uncompleted series, uncertainty on the type of landslide, date not indicated etc...

Nevertheless, every team succeeded in dressing an historical inventory in their area. The recording of landslides arising or recurring in the last two centuries is impressive, considering the surface areas involved: 423 in the last century in the 560 km of the coast of Kent, 320 in the pays d'Auge in Normandy between 1885 and 1985, 750 in Rheinhessen; 300 landslides of various types in the two hundred years over the 9000 ha of the commune of Vars in the French Alps etc...

## MAIN PERIODS OF LANDSLIDE ACTIVITY

– Traces of *Pleistocene* movements were found in several regions, for example in some regions of Cantabria as well in the Lower Pleistocene period as well as the recent Pleistocene period, without the possibility to be more precise (tab. 1).

Four main phases of landslide activity are assumed during the Pleistocene in England.

TABLE 1

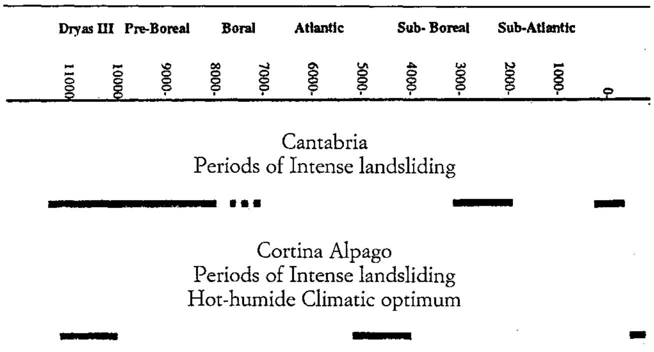
| Upper Pleistocene | Middle Pleistocene | Lower Pleistocene |
|---|---|---|
| 10,000<br>100,000 | 100,000<br>700,000 | 700,000<br>2,000,000 |
| Magdalena Region<br>24 | Magdalena Region<br>22<br>Nalon Somiedo Leitariegos<br>66 | |

– The *Pleistocene-Holocene* limit is noted as favourable to landsliding

– in the Dolomites because of the effects of the postglacial détente release in glacial confluence sectors where the rocks have been subject to considerable pressure;
– in the Guisane valley also;
– in northern Europe, throughout the late Devensian due to the proximity to the ice front, deglaciation and periglacial activity.

– The late *Boreal-early Atlantic* (7500-6000 BP) warmer and wetter , is considered as very favourable to landslide activity in the northern Europe and in the Cortina basin but, for example in Cantabria (tab. 2), the climatic conditions were different : the average temperature in the mountains of this area were some 2 to 3° higher than at present, but the climate was also drier, with an average rainfall 300 to 400 mm lower than it is today. There was also deforestation and grazing following a significant increase in Neolitic populations, and these natural and anthropic conditions were more favourable to fluvial and rainfall erosion.

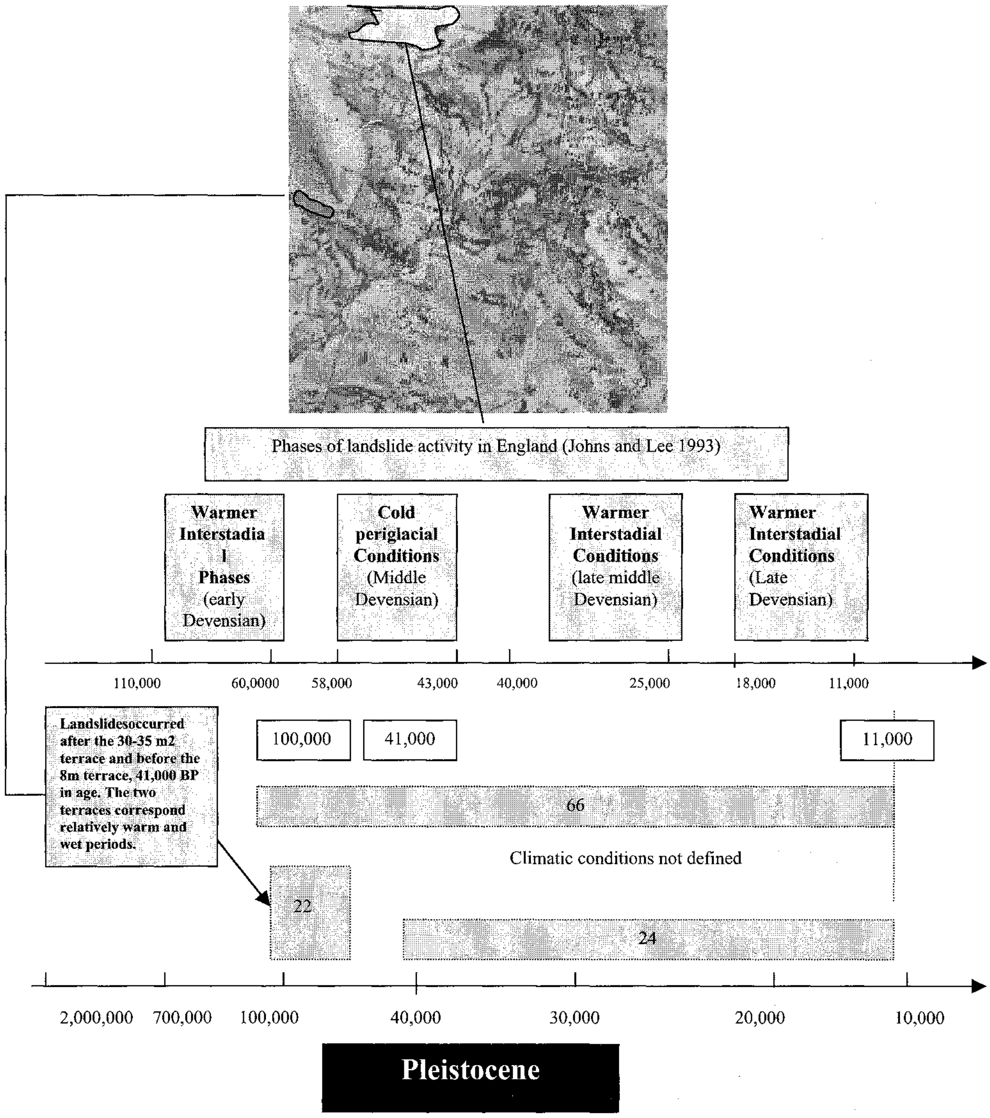
TABLE 2




– The *Sub-Boreal* (5500-3000 BP): the UK, Alpine and Pyrenean data emphasise the Sub-Boreal and the early sub-Atlantic as a time of increased activity

– During the *Little Ice Age* (1550-1850) the climatic deterioration was the cause of a great number of landslides in many places, and even in the Marche region, in Italy, it is assumed that many of the movements which are active or dormant at present started in the Little Ice Age.

FIG. 1




– *19th and 20th centuries.*

Precision have been obtained on the frequency of landslides during the last two centuries:

In some places, a periodicity in landslide numbers can be visible;

– for exemple 30-50 years, becoming shorter towards the present, in the South Coast of England, from 1790 to 1989.

– A period of several years, 5 to 7, with major landslide activity, re-appears with a periodicity of 7-10 years in Rheinhessen from 1890 to 1990.

– In the commune of Vars, the periods with intense landslide activity last 5-7 years, but with a bigger periodicity, 15-20 years. But distribution of landslides in time is also irregular in many areas.

Many groups identify a great increase in the number of landslides in the record during the last 4-5 decades. That is probably, in part, the reflect of increasing reporting frequency due to better coverage, science, or interest in geomorphological processes in hazards.

Nevertheless, the contrary can exist, like in Vars, where for the four last decades, facilities to repair damages by using modern engines have made small landslides common events, which are no more recorded or mentioned in newspapers or technical records.

## CLIMATIC RELATIONSHIPS WITHIN THE CONTEMPORARY AND HISTORICAL DATA SETS

Rather than mean yearly rainfall, best results were obtained by using running mean, sometimes three years, sometimes more, five or even seven years. And when possible, instead of rainfall itself, it is more judicious to calculate and use effective rainfall.

The correlation is maximum in the South coast of England (fig. 2) and (fig. 3) in Rheinhessen.

In these two areas, rainfall seems to be the exclusive cause of triggering and reactivation, and there is a remarkable coincidence in dates and patterns between the occurrence of wet periods and wetter than average trends with frequency of occurrence for the recent period.

In Normandy, (fig. 2) where interior landslides are taken into account beside coastal landslides, the relationships with rainfall are not so close.

Apart from earthquake-induced landslides, Southern Italy (fig. 3) variability of landsliding is very important because, although the area may be becoming drier, the frequency of debris flow and catastrophic landslides is susceptible to go up, because their occurrence is related to extreme events.

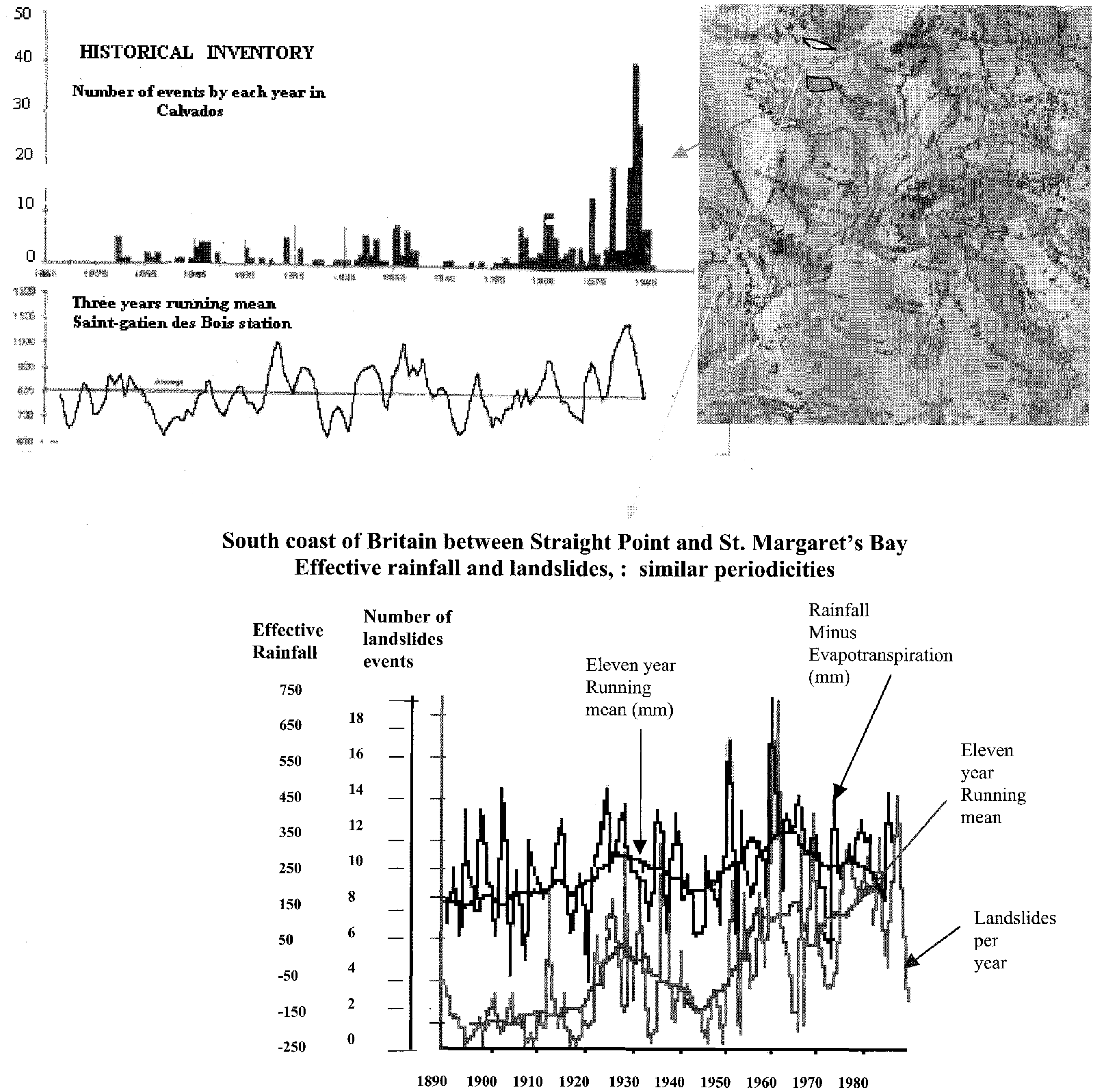



FIG. 2

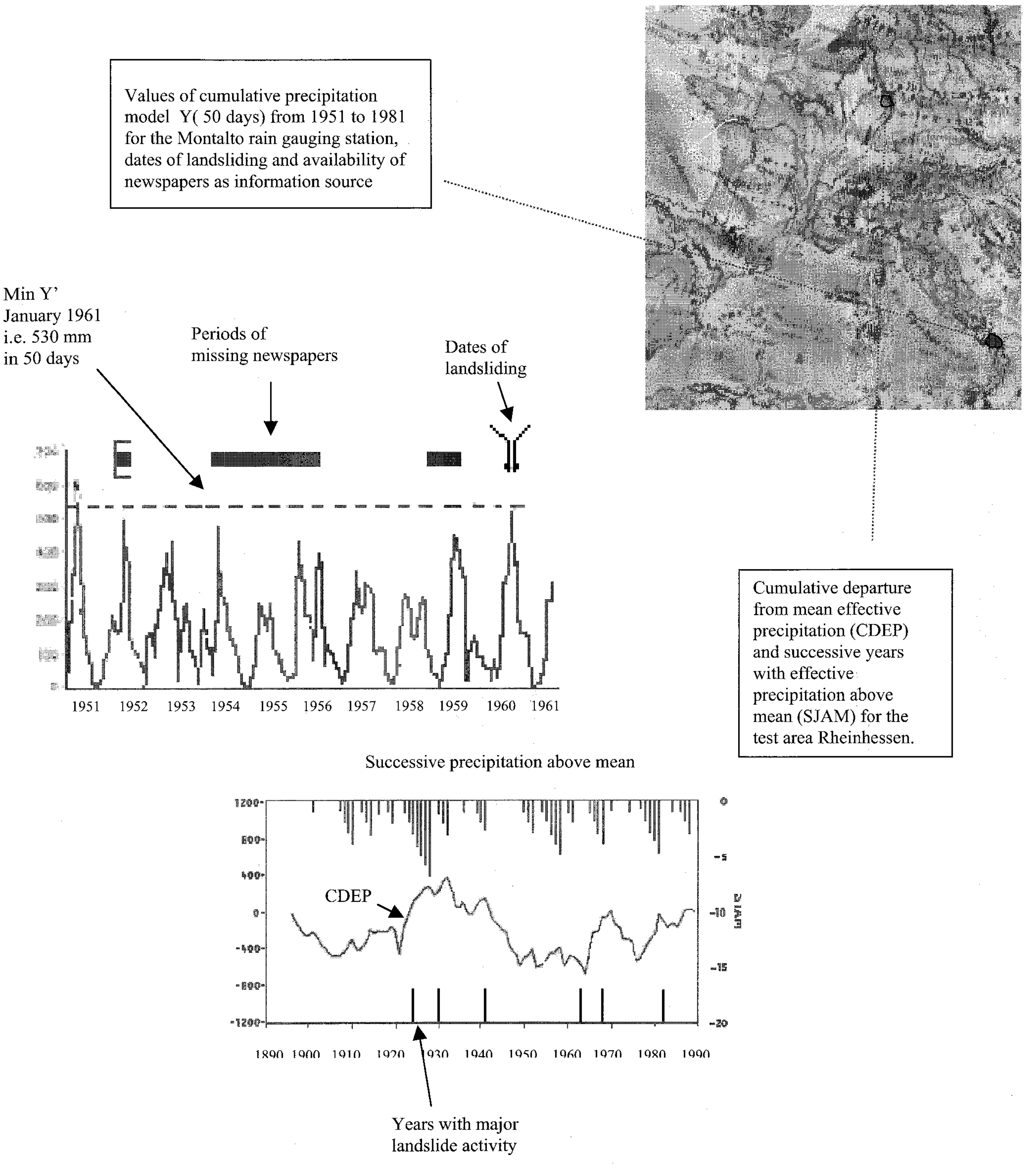

Values of cumulative precipitation model Y( 50 days) from 1951 to 1981 for the Montalto rain gauging station, dates of landsliding and availability of newspapers as information source
Min Y' January 1961 i.e. 530 mm in 50 days
Periods of missing newspapers
Dates of landsliding
1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961
Cumulative departure from mean effective precipitation (CDEP) and successive years with effective precipitation above mean (SJAM) for the test area Rheinhessen.
Successive precipitation above mean
CDEP
1200
800
400
0
-400
-800
-1200
0
-5
-10
-15
-20
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990
Years with major landslide activity

FIG. 3

In the eastern Pyrenees the heavy rainfall of the wet periods is responsible for the onset of movements and it is estimated that 200 mm over two days constitutes a frequent threshold for mudflows.

In the valley of Bachelard, the average intensity of showers provoking the onset of a debris flow was 42-47 mm/h for more than five minutes.

But, by shortening the time and spatial scale , in areas strongly affected by human activities, relationships with rainfall are less obvious, other onset factors tend to obliterate the climatic message: road-widening, abandonment or disorganization of the drainage network, ski installations etc...

## CONCLUSION

In 1993, at the end of this work, in many areas, landslides could be considered more or less as a sensitive indicator of climatic change. The results suggested to relate the data to regional aspects of the global change model predictions , and to obtain a forecasting technique of future landslide occurrence. The precipitation change models might be used to indicate how deep seated landsliding will increase across northern Europe and decrease across the Mediterranean.