Relative soil vulnerability and patterns of erosion during the muddy floods of 2000-2001 on the South Downs, Sussex, UK

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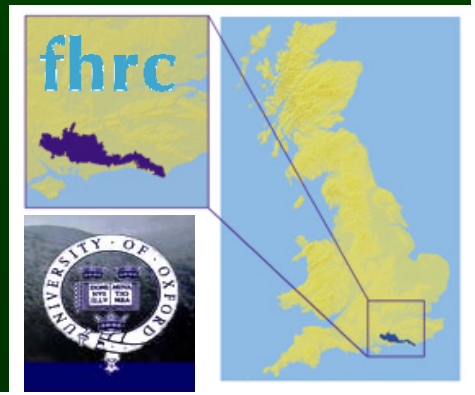
&

John Boardman



South Downs

East Sussex

Due to a long history of research interest, a rich database exists on the local erosional history

The study area is around 11 Km by 11 Km and covers the east end of Brighton, Lewes, Rottingdean, Woddingdean and Peacehaven. The coordinates (OSGB 1936) of the corners are:

Corner	*Easting (m)*	*Northing (m)*
Top left	533,000	112,000
Top right	544,000	112,000
Bottom left	533,000	101,000
Bottom right	544,000	101,000

The South Downs soils

particularly vulnerable to erosion

- typically less than 25cm thick
- >70% loessial silt
- prone to crusting

continuing erosion means that they become stonier, more droughty and less easier to work.

rates of erosion are relatively low but during extreme events soils are vulnerable

Soil Erosion

← on-site erosion

↓ and off-site erosion

…….both represent a current and long-term risk

Muddy flooding

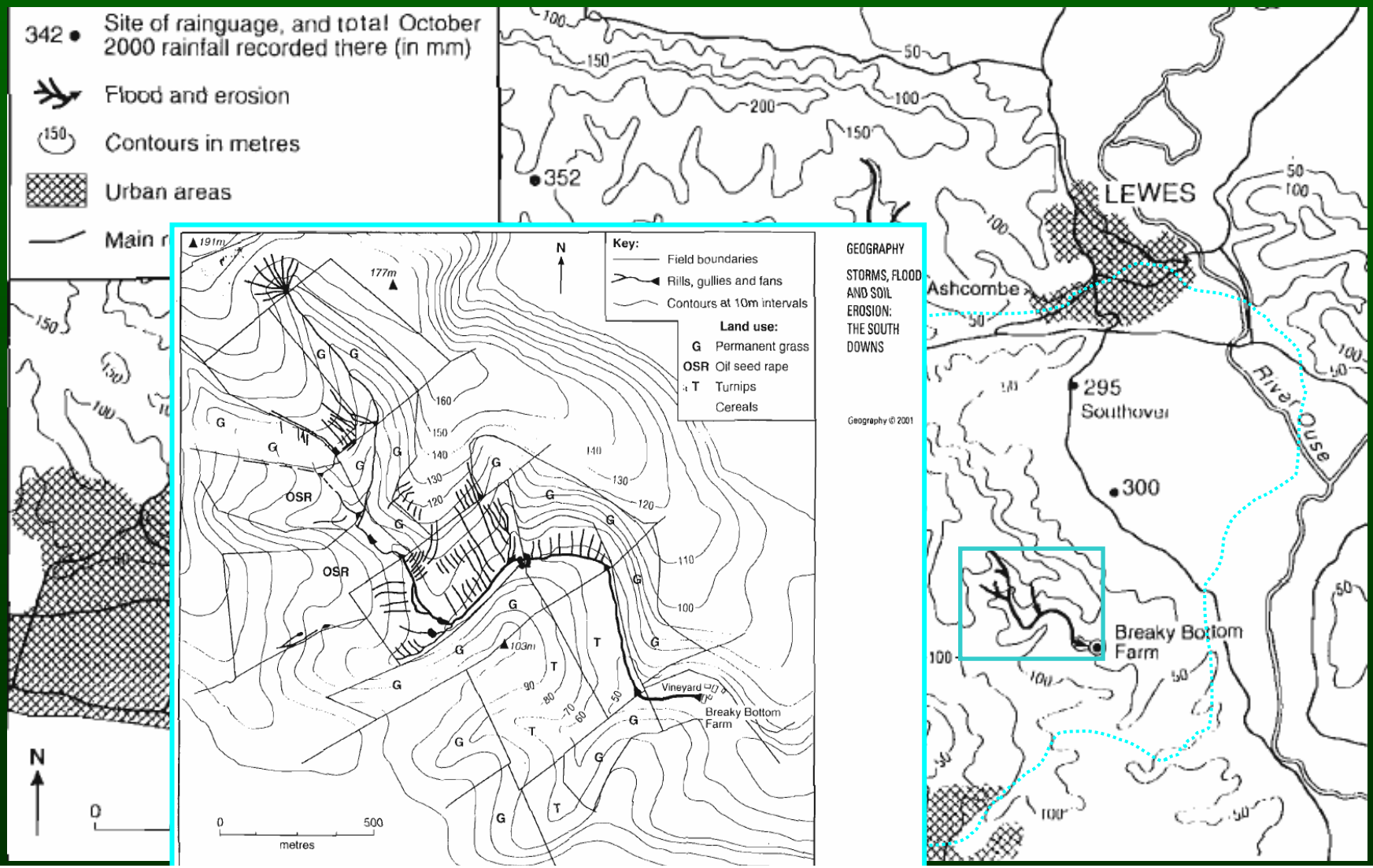
Property damage is of particular concern

(Boardman, 2003)

The winter of 2000-2001

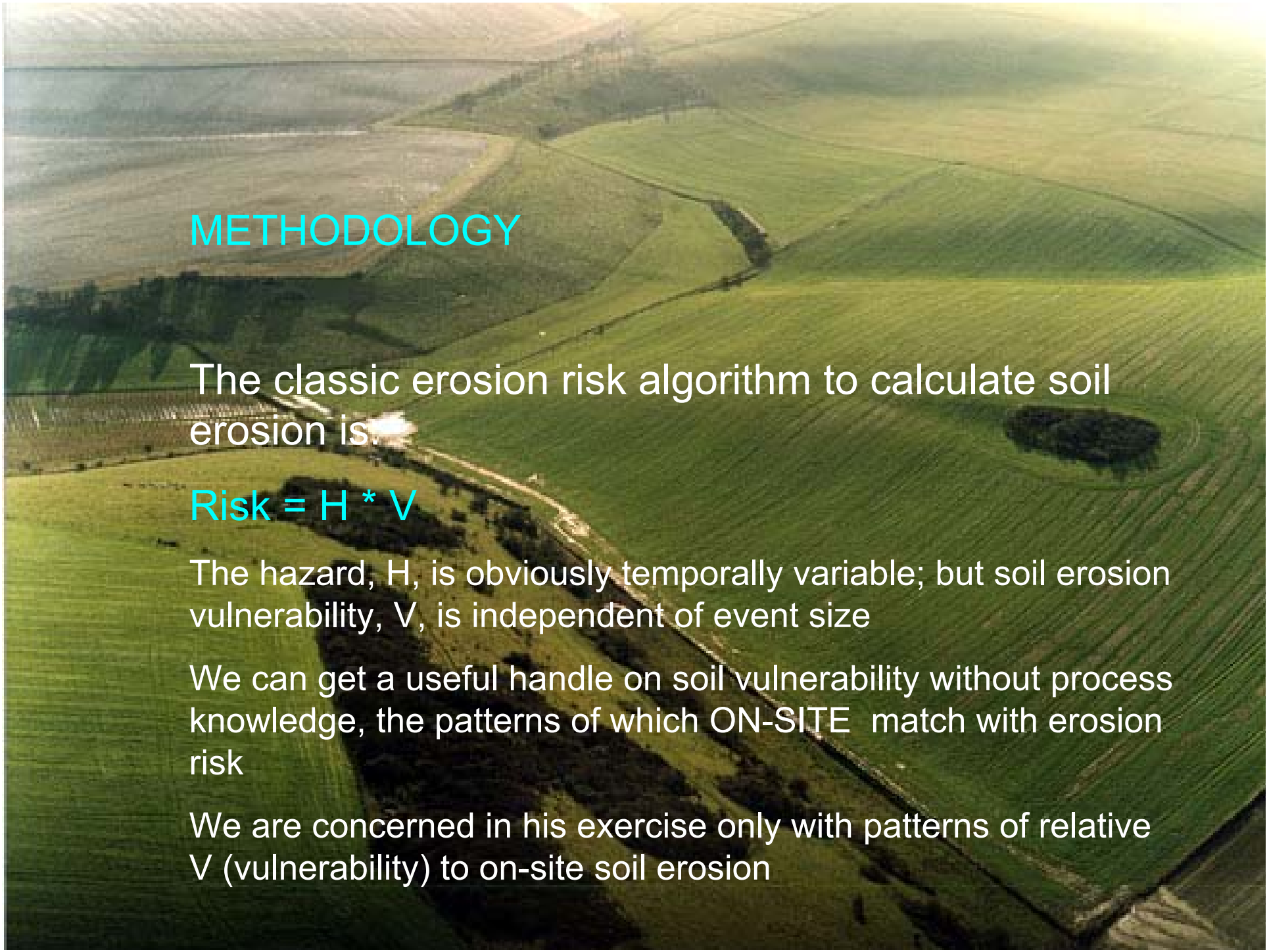
Hortonion overland flow was common and was particularly intensive on certain crop types.

The gullies and rills formed by runoff were mapped *(Boardman, 2001)*



Validation of the scheme

the pattern of features mapped by John Boardman in 2001 has been used to validate a soil erosion vulnerability model based on orthorectified , geocorrected aerial imagery flown the previous summer.



METHODOLOGY

The classic erosion risk algorithm to calculate soil erosion is:

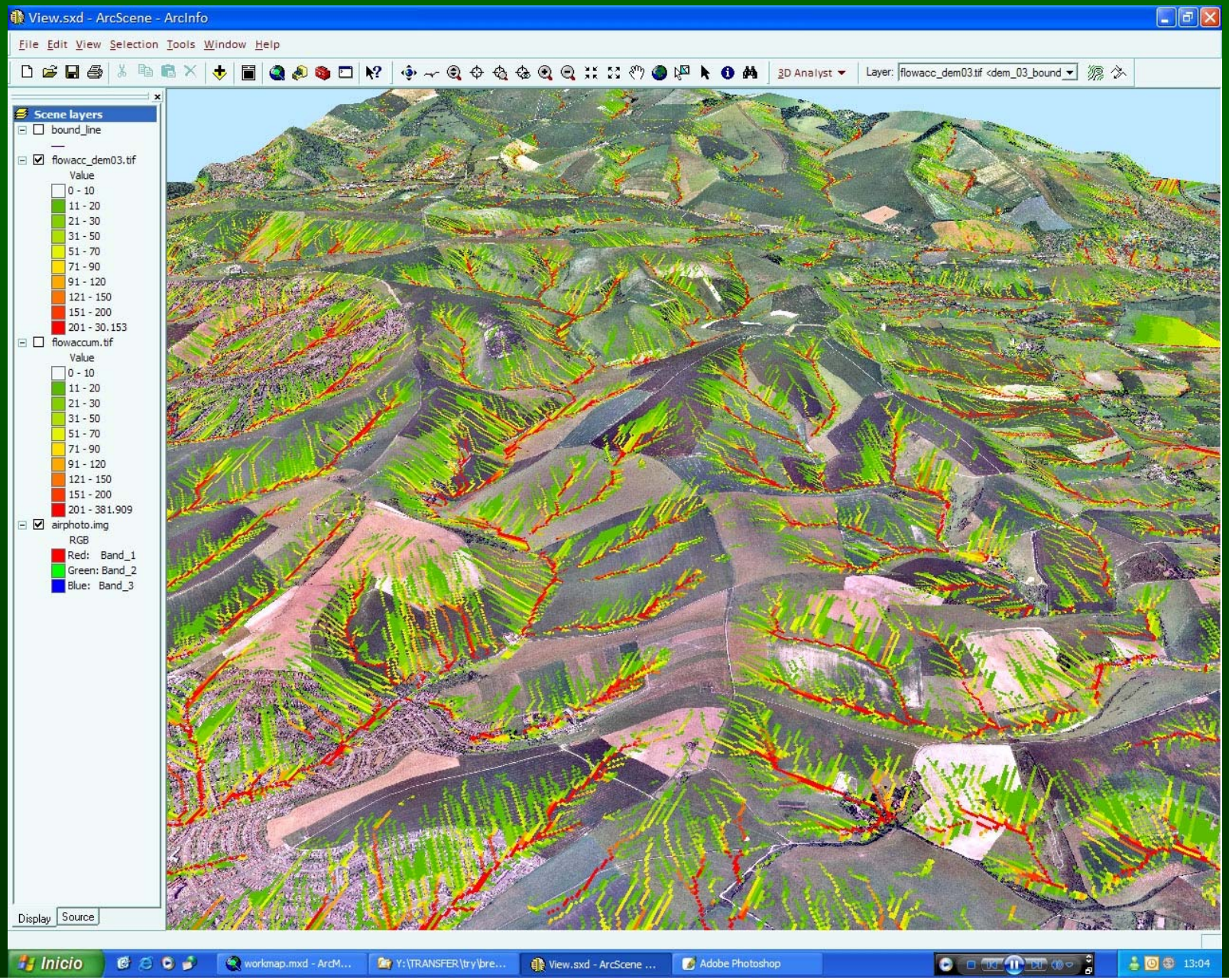
Risk = H * V

The hazard, H, is obviously temporally variable; but soil erosion vulnerability, V, is independent of event size

We can get a useful handle on soil vulnerability without process knowledge, the patterns of which ON-SITE match with erosion risk

We are concerned in his exercise only with patterns of relative V (vulnerability) to on-site soil erosion

How to maximise the power of the ArcGIS function, “Flow Accumulation” FA?



SOLUTION…

Instead of accumulating numbers of pixels above any one given pixel, we created a method of accumulating the result of multiplying slopeclass weighting (S_p) * Land Cover class weightings (LC_p) to the limit of the FA class for that pixel.

$$\textbf{Erosion vulnerability, } V_p = \log_{10}\left[\int_{P=0}^{P=FA} (S_p * LC_p)\right]$$

Where FA is the ArcGIS © function "Flow Accumulation"

NB Slope (S_p) **and** Land Cover class weightings (LC_p) run from 1 to 5 in relation to the expert's perceptions of the vulnerability that class represented

http://www.enviria.com/English/z_eng_download.htm

The GIS

We used a multiplicative weighted GIS with ARCGIS flow accumulation algorithm was used Slide 10

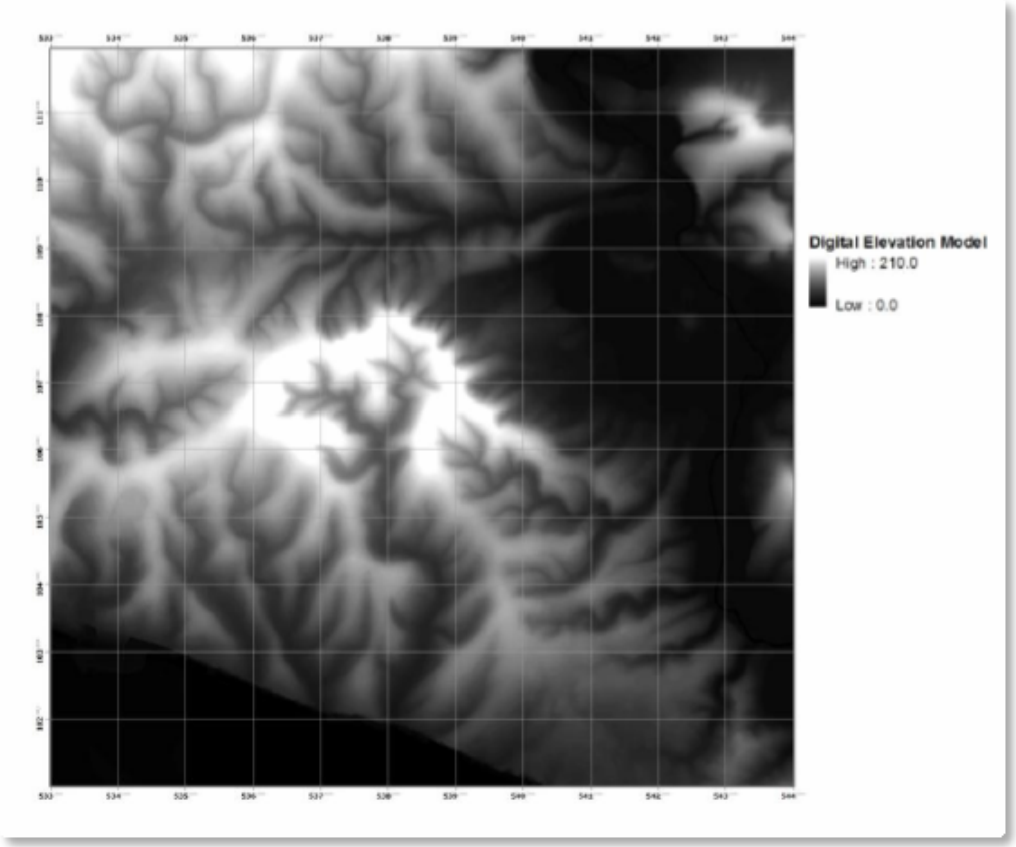
Layers created were:

- topography,
- field boundaries
- slope% class;
- land cover, class
- land cover weightings,
- flow accumulation,
- digimap

•NB All lithological variations are assumed unimportant on the all-chalk study area

The Digital Elevation model

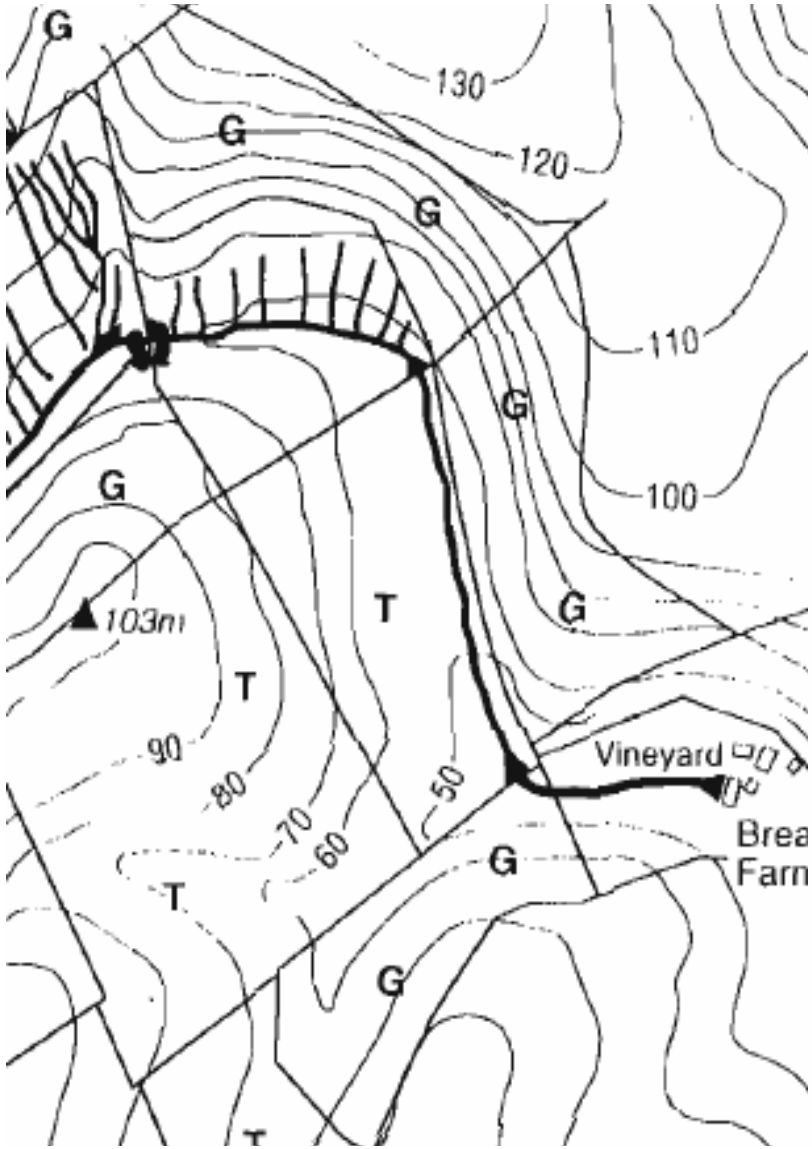
The Digital Elevation Model (DEM) is a raster dataset that represents the height of the terrain. The spatial resolution of this layer is 10 by 10 meters, meaning that every cell (pixel) of the image has an area of 100 square meters. The vertical resolution is infinite as it has been interpolated from discrete values when the dataset was created (vertical precision is not known but higher than 30 cm). Height is represented continuously as a level of grey, from a value of 0 meters (black) to a maximum of 210 meters (white) as shown.

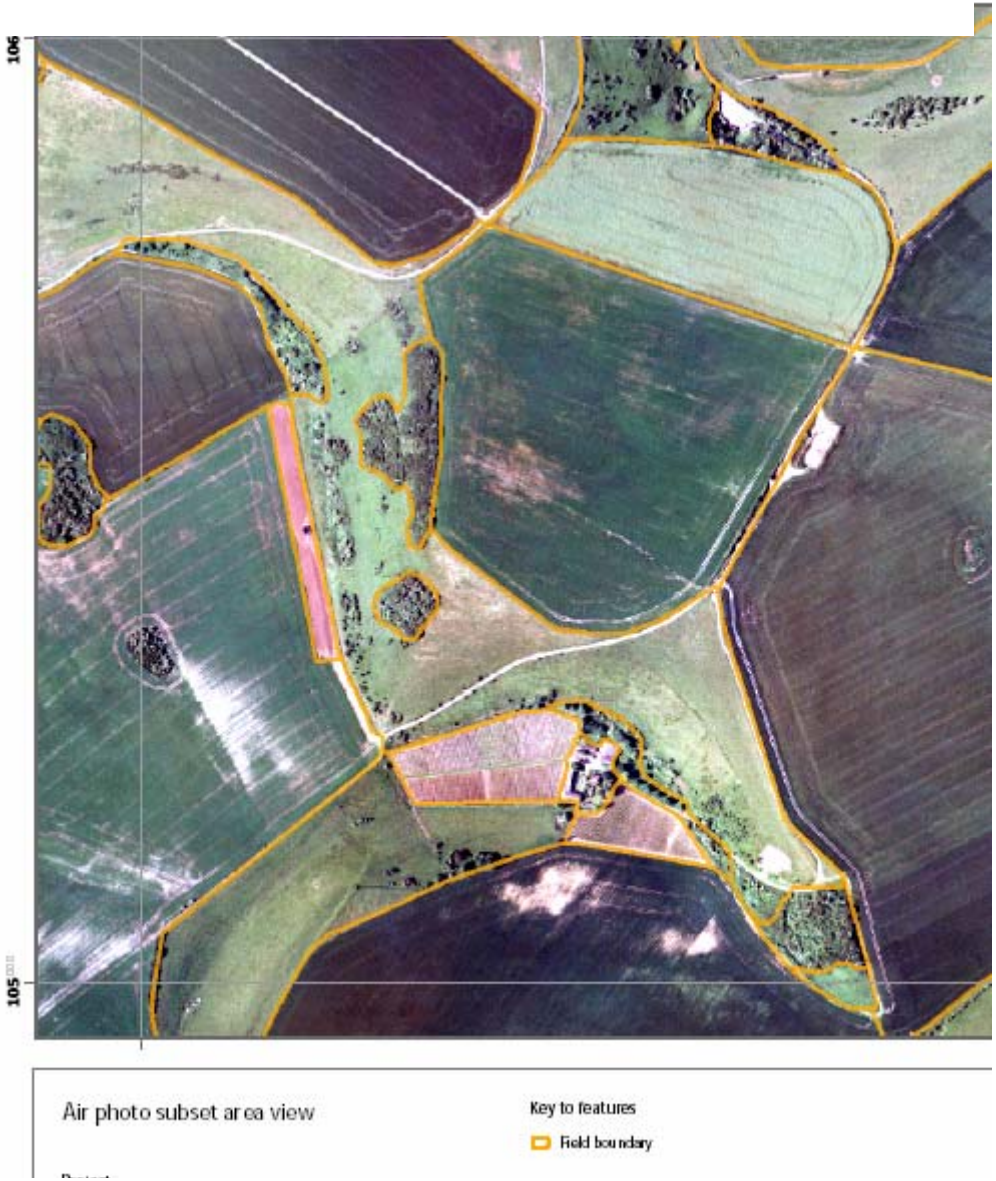


This layer is the base for other factors to extract and operate with topographic information.

Field boundaries

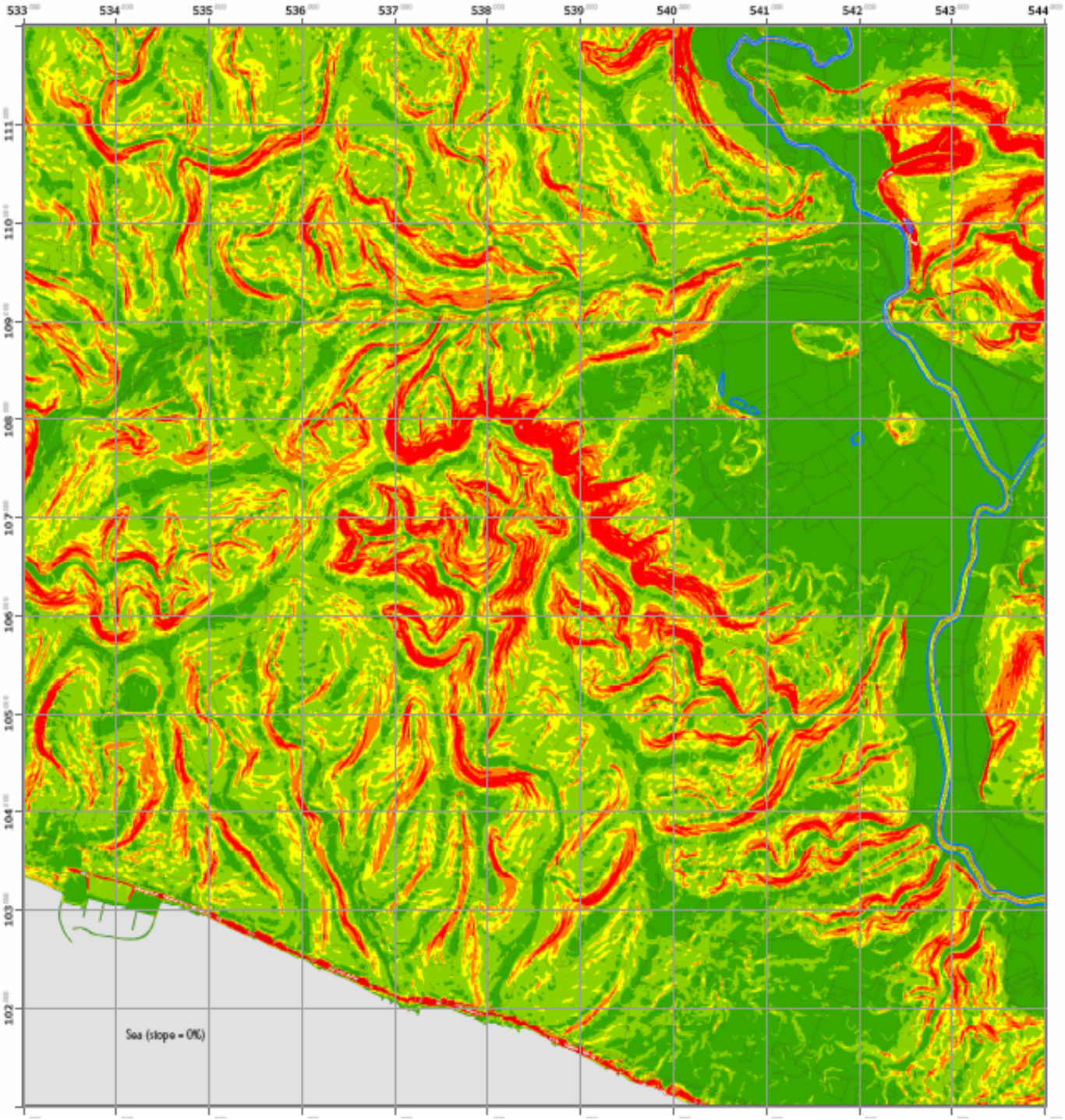
The mapped distribution of rills and gullies following the winter events of 2000/1 are compared to the model predictions, to validate the predictive efficacy the algorithm used.





Slope classes

Slope (%) classes are positively related to on-site effects – weighted 0-5



Slope hazard map

(percentage slope)

Project
Farmer's attitude against soil erosion
in the South Downs, UK

Key to features

Hydrology

Field boundary

Slope Classes

- (2) 0 - 6.30%
- (4) 6.31 - 13.33%
- (6) 13.34 - 18.50%
- (8) 18.51 - 28.60%
- (10) 28.61 - 100%

0 500 1.000 2.000 Meters

Date
October 2006

www.enviria.com

Land-cover weighting

The soil vulnerability mapping wasweighted for land-use by the experts (JB,RE).

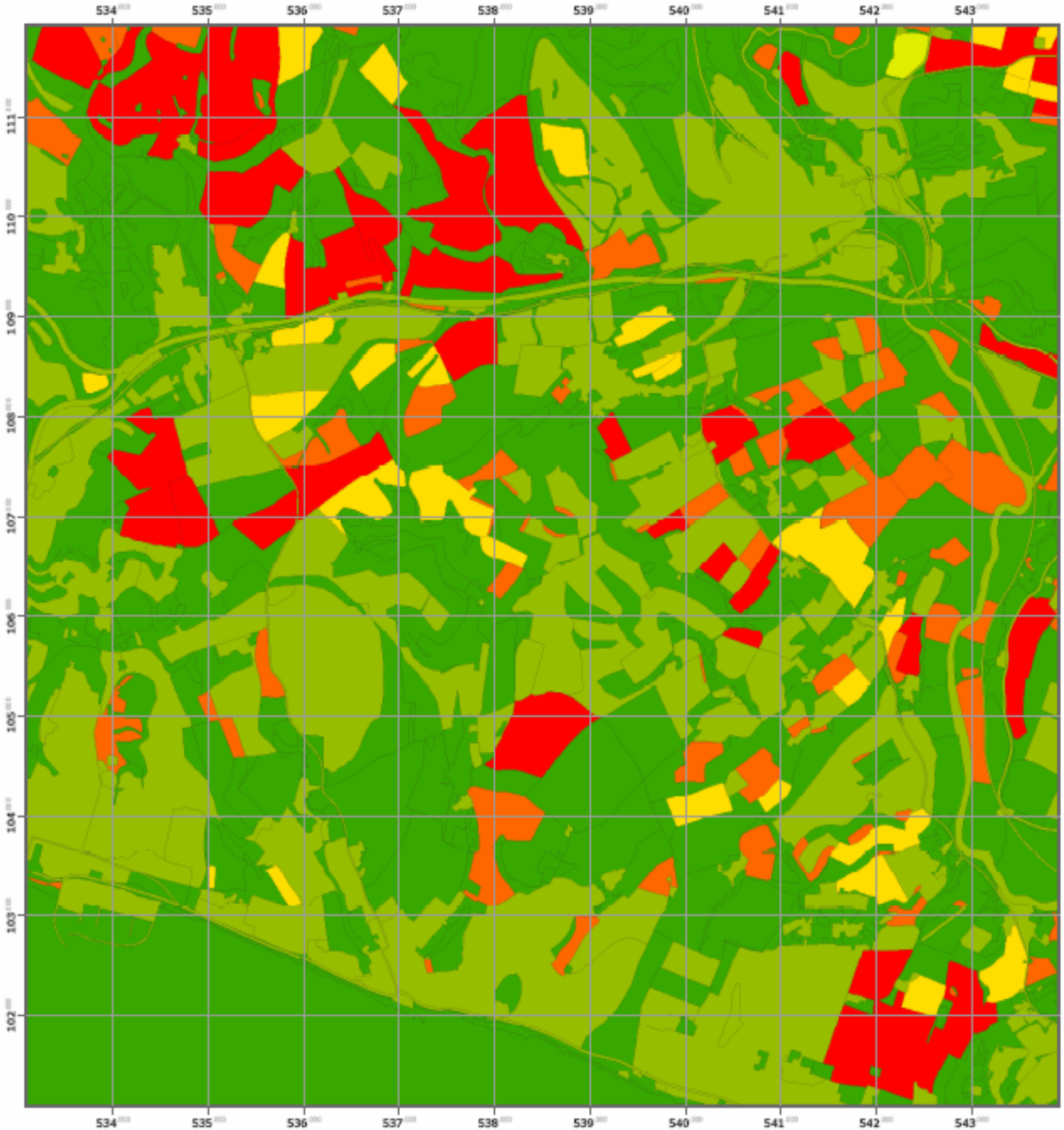
The land-use may have changed in the intervening three months prior to the storm period, but no more up to date images were available for the whole area

Retrospective Land Use classification for summer 2000

LC class
& WEIGHTNGS

- **Autumn bean 1**
- **Autumn cereal 5**
- **Spring cereal 3**
- **Oil Seed Rape 3**
- **Linseed 1**
- **Woods 0**
- **Grass 0**
- **Bare 4**
- **Sports 1**
- **Farm 1**
- **residential 0**
- **Industrial 0**
- **'hydrology'**
- **Beach 0**
- **Sea 0**

process greatly assisted in by Bob Evans



Land cover hazard map

Project
Farmer's attitude against soil erosion
in the South Downs, UK

Key to features

Field boundary

Land cover classes

- (0) Grass; Woods; Beach; Sea
- (2) Autumn bean; Linseed; ... (*)
- (4) Oilseed rape
- (6) Spring cereal
- (8) Bare soil
- (10) Winter cereal

(*) ...Industrial; Residential; Hydrology; Road/ Railtrack; Farm; Sports ground

0 500 1.000 2.000 Meters

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Poor Breaky Bottom after the winter events of 2000-2001

Erosion hazard map

Multiplicative system

Project

Farmer's attitude to soil erosion in the South Downs, UK

Key to features

- Hydrology
- Field boundary

Erosion Hazard

Vulnerability Class (Log V)

- Low (0.301 - 0.602)
- Medium-low (0.603 - 0.903)
- Medium (0.904 - 1.204)
- Medium-high (1.205 - 1.602)
- High (1.603 - 3.000)

0 500 1.000 2.000 Meters

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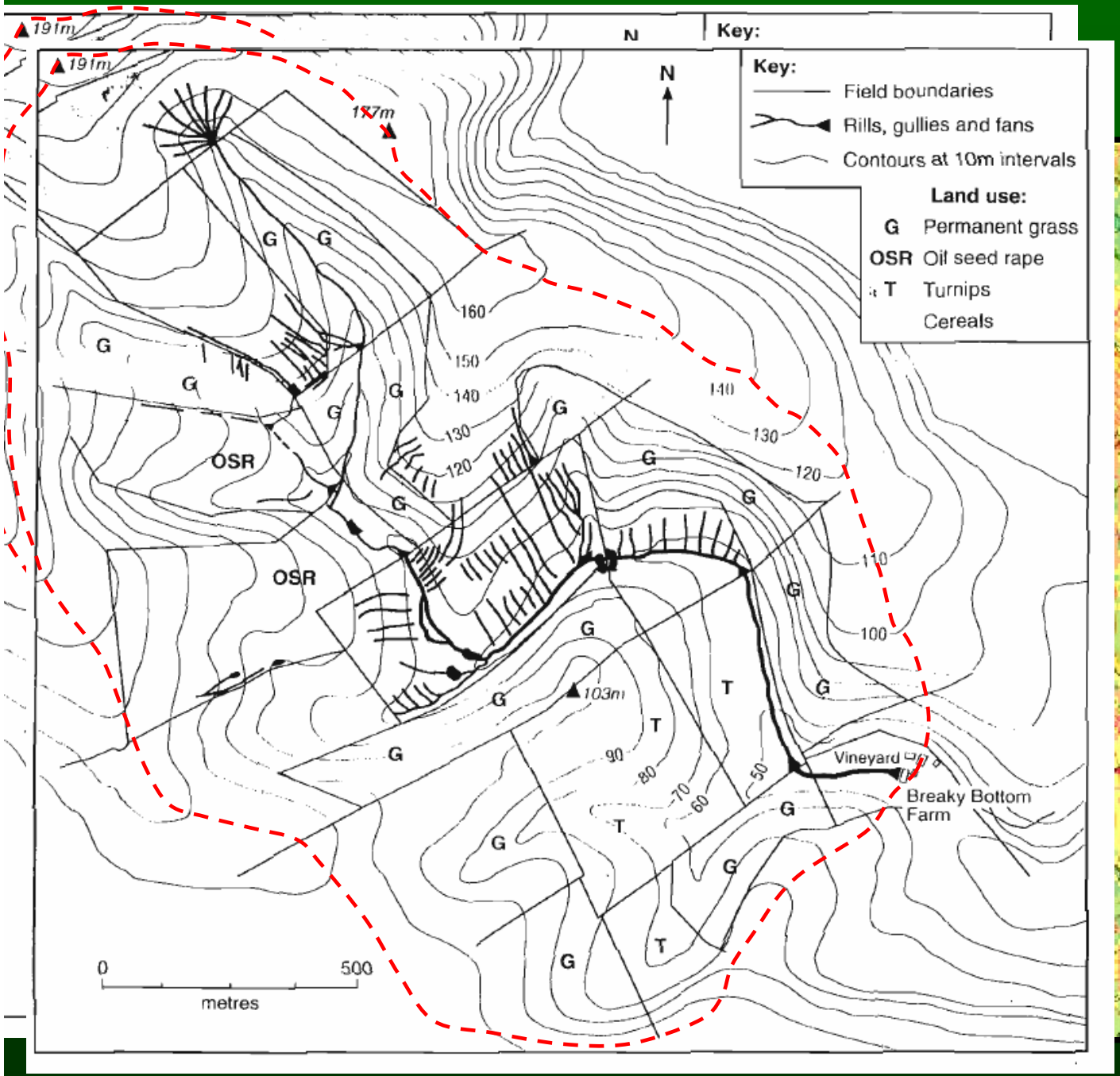
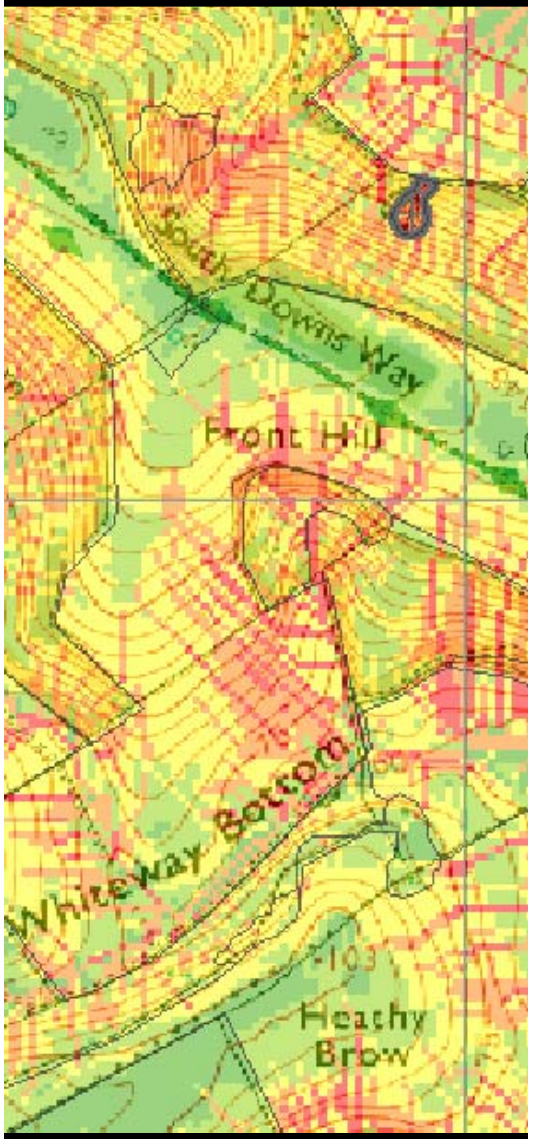
Validation


Key:
Field boundaries
Rills, gullies and fans
Contours at 10m intervals
Land use:
G Permanent grass
OSR Oil seed rape
T Turnips
Cereals
N
191m
187m
103m
160
150
140
130
120
110
100
90
80
70
60
50
OSR
Vineyard
Breaky Bottom Farm
0
500
metres


South Downs Way
Front Hill
Whiteway Bottom
Heathy Brow

Farmer's memories as validation tools

In a further survey of the utility of the map, it was discovered that farmers' recollections of the events can provide an additional useful validation tool:

Preliminary FINDINGS :

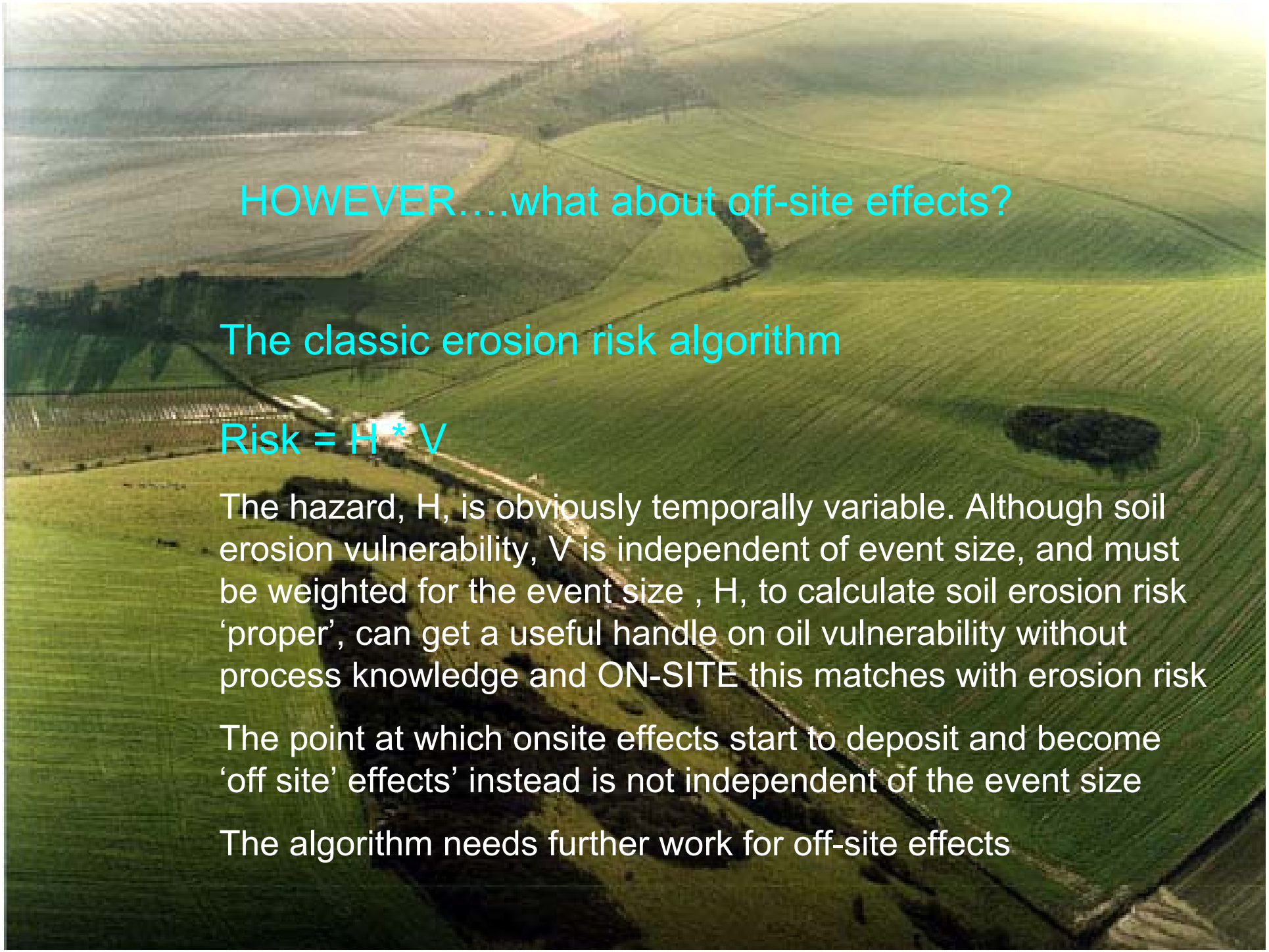
For ON-SITE predictions….

Simple approach works quite well

Land cover weightings need adjustment to optimise match between predictions and mapped erosion features

We can get help from farmers to optimise the map's match with reality

When optimise with farmer's recollections, can change land-uses in line with possible future storylines to predict future consequences or as a planning tool for farmers



HOWEVER….what about off-site effects?

The classic erosion risk algorithm

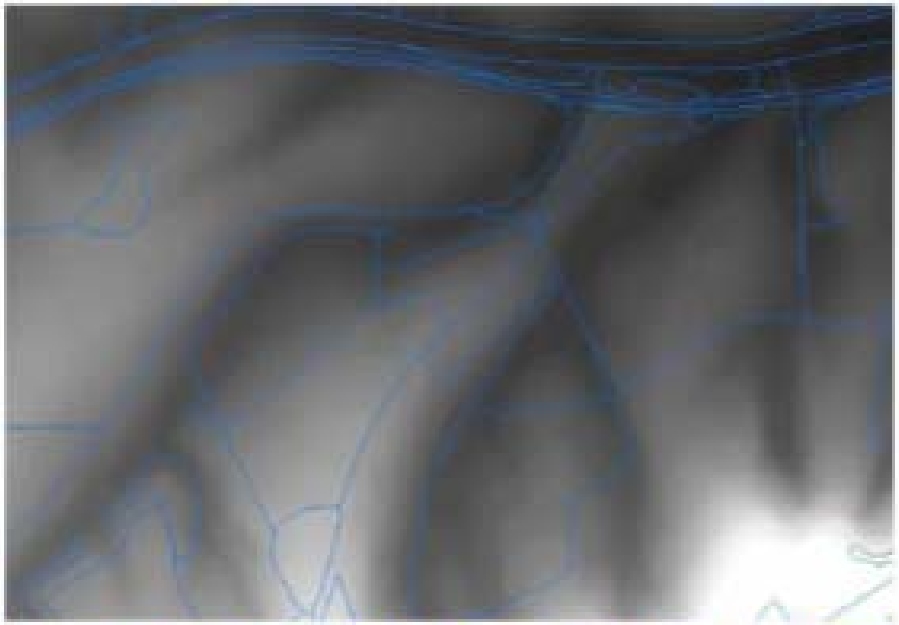
Risk = H * V

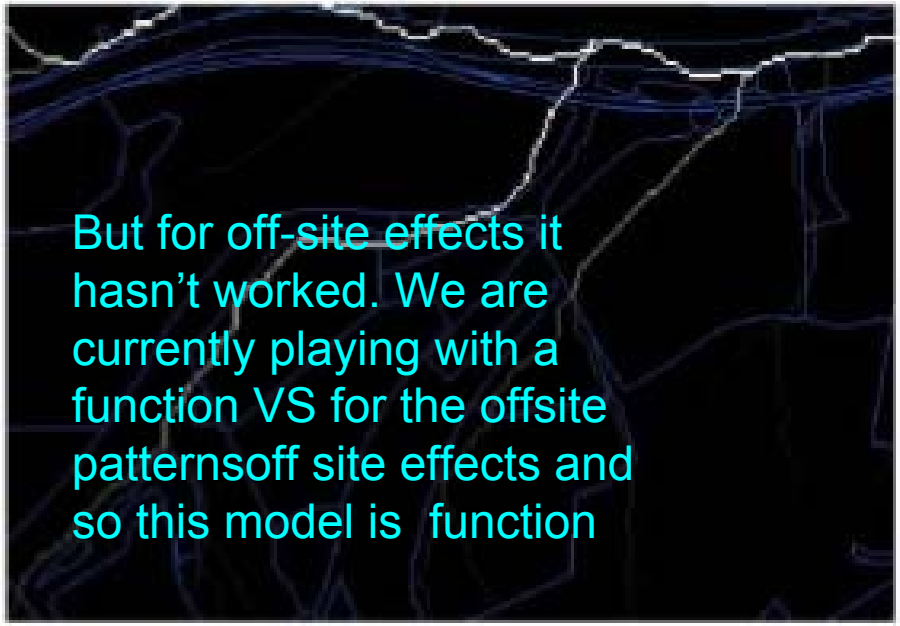
The hazard, H, is obviously temporally variable. Although soil erosion vulnerability, V is independent of event size, and must be weighted for the event size , H, to calculate soil erosion risk ‘proper’, can get a useful handle on oil vulnerability without process knowledge and ON-SITE this matches with erosion risk

The point at which onsite effects start to deposit and become ‘off site’ effects’ instead is not independent of the event size

The algorithm needs further work for off-site effects

Off-site effects not so successfully reproduced





But for off-site effects it hasn't worked. We are currently playing with a function VS for the offsite patternsoff site effects and so this model is function

View.sxd - ArcScene - ArcInfo

File Edit View Selection Tools Window Help

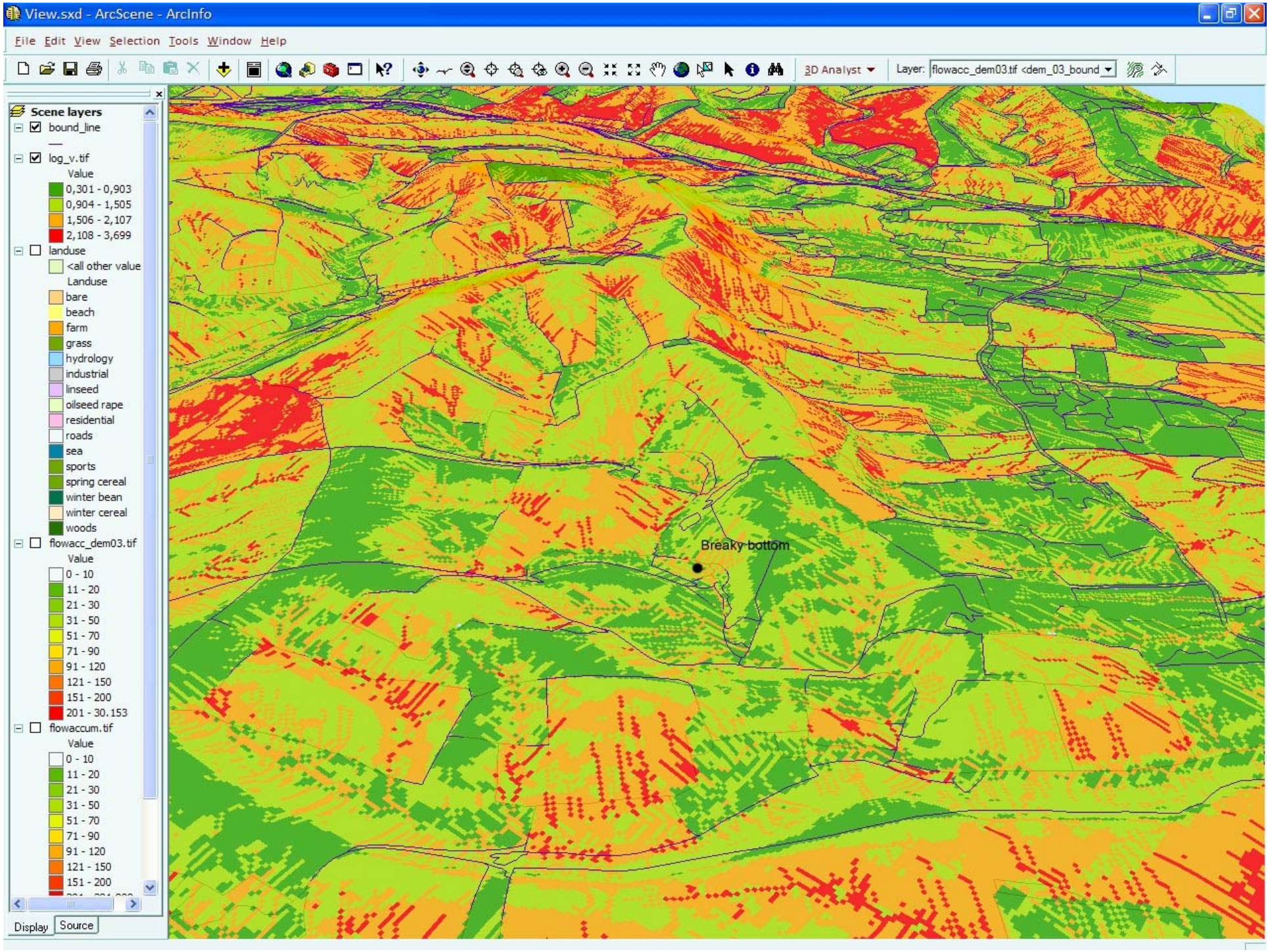
3D Analyst | Layer: flowacc_dem03.tif <dem_03_bound

Scene layers

- bound_line
- flowacc_dem03.tif
  - Value
  - 0 - 10
  - 11 - 20
  - 21 - 30
  - 31 - 50
  - 51 - 70
  - 71 - 90
  - 91 - 120
  - 121 - 150
  - 151 - 200
  - 201 - 30.153
- flowaccum.tif
  - Value
  - 0 - 10
  - 11 - 20
  - 21 - 30
  - 31 - 50
  - 51 - 70
  - 71 - 90
  - 91 - 120
  - 121 - 150
  - 151 - 200
  - 201 - 381.909
- airphoto.img
  - RGB
  - Red: Band_1
  - Green: Band_2
  - Blue: Band_3

Display | Source

Save the current scene


View.sxd - ArcScene - ArcInfo
File Edit View Selection Tools Window Help
3D Analyst
Layer: flowacc_dem03.tif <dem_03_bound
Scene layers
bound_line
log_v.tif
Value
0,301 - 0,903
0,904 - 1,505
1,506 - 2,107
2,108 - 3,699
landuse
<all other value
Landuse
bare
beach
farm
grass
hydrology
industrial
linseed
oilseed rape
residential
roads
sea
sports
spring cereal
winter bean
winter cereal
woods
flowacc_dem03.tif
Value
0 - 10
11 - 20
21 - 30
31 - 50
51 - 70
71 - 90
91 - 120
121 - 150
151 - 200
201 - 30.153
flowaccum.tif
Value
0 - 10
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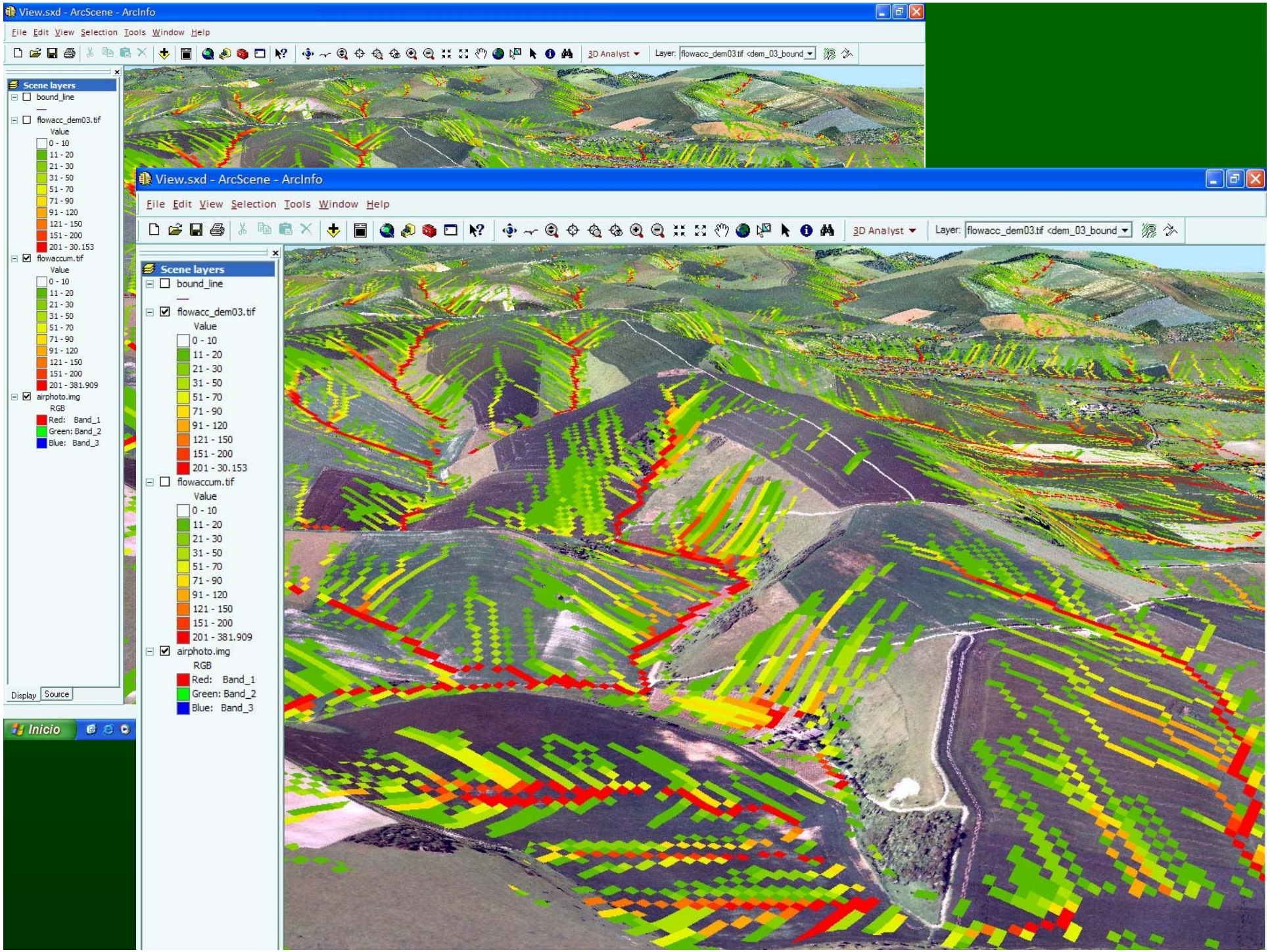
21 - 30
31 - 50
51 - 70
71 - 90
91 - 120
121 - 150
151 - 200
Display
Source
Breaky bottom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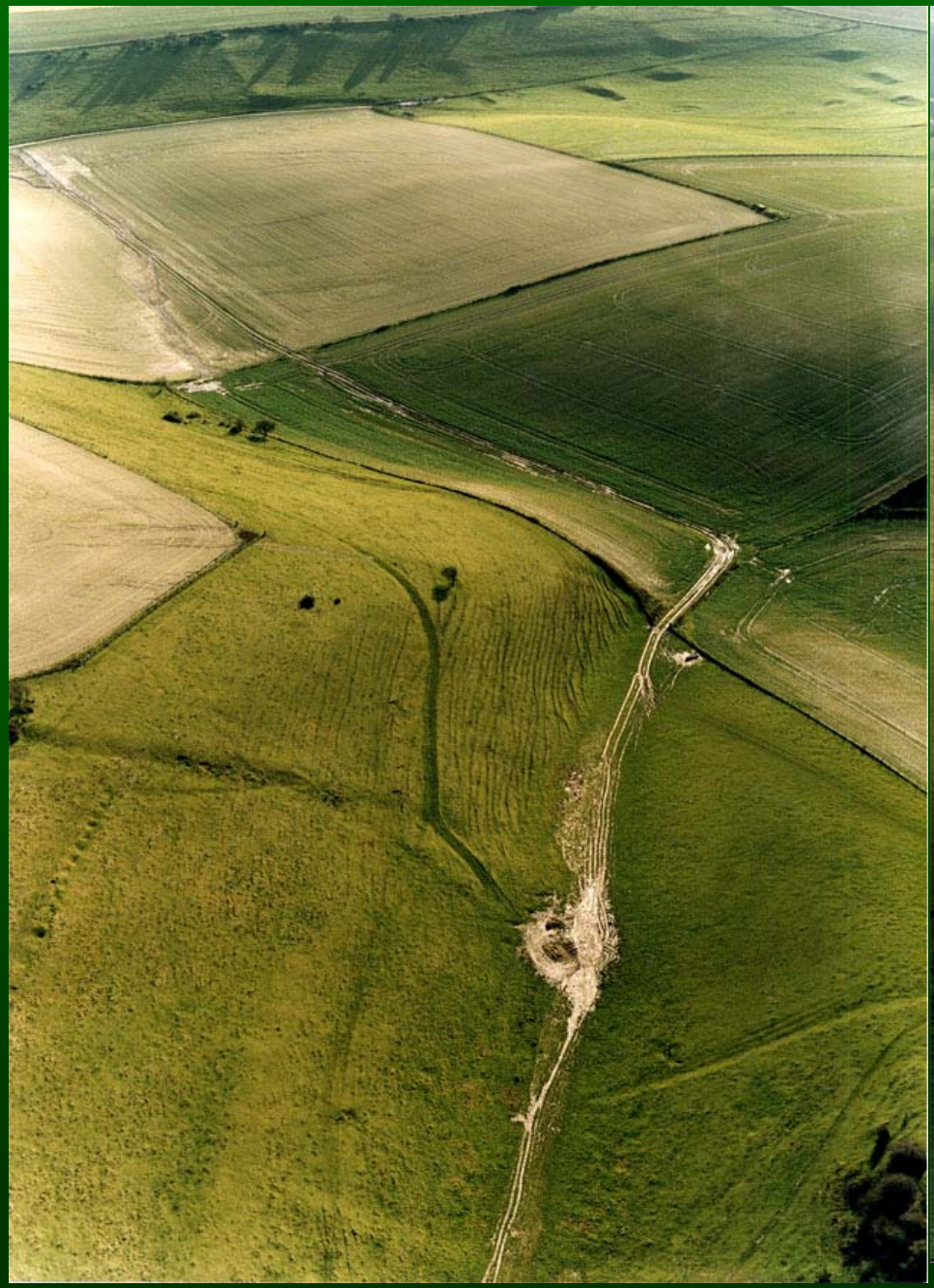
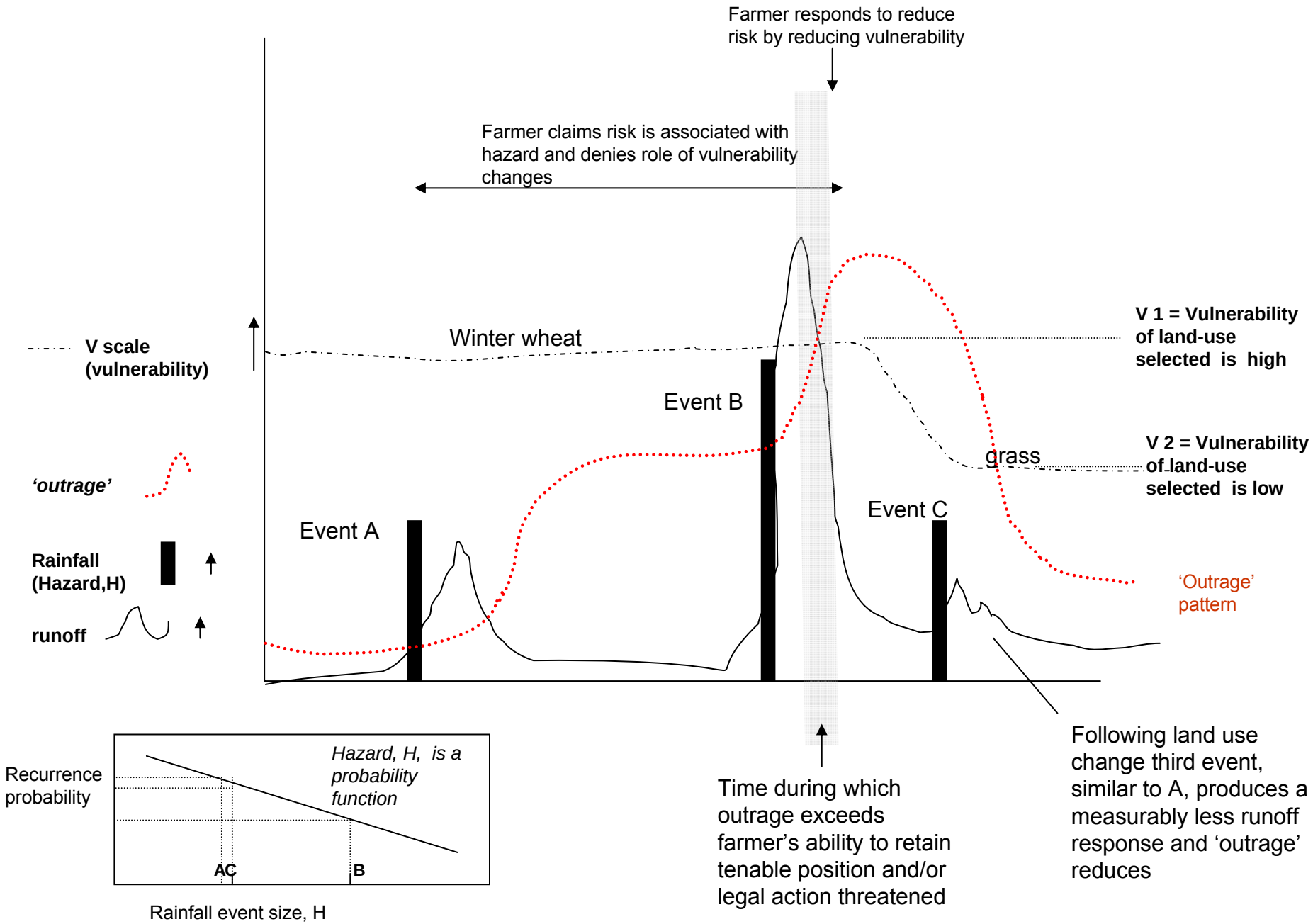
airphoto.img
RGB
Red: Band_1
Green: Band_2
Blue: Band_3
Display
Source
Inicio


Plenty more to be done with simple tools!….




Farmer responds to reduce risk by reducing vulnerability
Farmer claims risk is associated with hazard and denies role of vulnerability changes
V scale (vulnerability)
'outrage'
Rainfall (Hazard,H)
runoff
Winter wheat
Event A
Event B
Event C
grass
V 1 = Vulnerability of land-use selected is high
V 2 = Vulnerability of land-use selected is low
'Outrage' pattern
Recurrence probability
Hazard, H, is a probability function
AC
B
Rainfall event size, H
Time during which outrage exceeds farmer's ability to retain tenable position and/or legal action threatened
Following land use change third event, similar to A, produces a measurably less runoff response and 'outrage' reduces