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A SOLAR RADIATION MODEL FOR IBEX RELOCATION PROGRAMS

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This paper is dedicated to the memory of our friend
Gerbrandt Wiersema, who died in the Gran Paradiso National Park
while on field work for his "Project Ibex".

ABSTRACT

A SUN/LAND program (solar radiation calculated from a digital elevation model) was tested as a practical and time-saving means of evaluating suitability of mountain slopes as wintering sites for the establishment of new ibex colonies. The test site was a protected area on the Italian Western Alps, harbouring old, numerically stable ibex population. Actual wintering areas regularly overlapped well defined patches of territory receiving high incoming solar radiation (minimum value: 1800 Wh/m^2 on January 15 map); habitat corridors for late spring migration were also represented. Limitations and management implications of this method are discussed.

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INTRODUCTION

In 1821 Alpine ibex (Capra ibex ibex L. 1758) were close to extinction with only 100 animals surviving in the Massif of Gran Paradiso in Northwestern Italy (Couturier, 1962). After 160 years of protection and reintroductions carried out in the 7 Alpine countries (natural recolonization by ibex is limited), the present stock is over 18,000 head (Tosi 1983).

However, historical distribution of this ungulate (Couturier 1962) and the human cause of its former local extinctions (uncontrolled hunting), suggest that much unexploited habitat remains. Consequently, the demand to establish new colonies is still high.

On the other hand, ibex reintroductions are expensive and delicate operations; a third of the colonies harbour stagnant or declining small stocks (Wiersema 1983a) and complete failures are also frequent (4 out of 9 on the Italian side of the Western Alps).

Recently, habitat evaluation models were developed so future reintroductions could be planned on a more objective ecological basis (Elsner-Schack 1982; Wiersema 1983b; Apollonio and Grimod 1984; Tosi et al. 1985; Rossi et al. 1986). According to these studies, the presence of suitable winter ranges appears to be the main factor for the success of an ibex colony. Habitats with high incoming solar radiation and steep slopes allow access to forage through fast snow melting/sliding, giving ibex the possibility of surviving during the harsh Alpine winter. As such sites are usually localized and difficult to reach in winter, their identification over a large territory, through field searches and/or low level flights, would require high personnel involvement and economic cost.

The aim of this study is to test whether the computing and mapping of solar radiation, using a procedure already developed for other purposes, may facilitate detection of suitable wintering areas and habitat evaluation for ibex relocation programs [(2)].

STUDY AREA

The 42,000 ha study area is encompassed by the following coordinates:
NE angle latitude 45°51' longitude 5°00'
SW angle latitude 45°38' longitude 5°35'.

It comprises the middle and high Orco Valley (Italian Western Alps), with a major east-west orientation. The head and north side of Orco Valley

(2) When the research was over, we knew that a similar survey, though performed with different methods, was carried out by Stefanovic and Wiersema. Their paper is in press in the ITC Journal (1985-3).

represent the southernmost part of the Gran Paradiso National Park (G.P.N.P.). Wide lateral valleys obliquely entering the main glacial valley characterize the landscape. Altitudes range from 650 to 3,642 m (Mt. Ciarforon).

Ground cover is generally poor on the south slopes with broadleaf trees at low elevation and larches (Larix decidua) higher up. Rich and dense spruce (Picea picea) and larch forests exist on the exposed northern side. Alpine grassland extends as far as 2,800-3,200 m.

The climate is of the continental type (highest precitipitation rates occur in summer and are minimal in winter) and is typical of the xeric inneralpine valleys. Total annual precipitation reaches 997.5 mm in the heart of the study area (Ceresole Reale, 1,582 m).

Ibex living in the study area belong to the only autochthonous population of this ungulate. On average 250 ibex have been observed since 1950 during summer ground counts; winter stock is higher (585 ibex in winter 1984-85) because of migration from the neighbouring valleys.

The long term stability of this protected population suggests that the carrying capacity of the study area has likely been reached, supporting the hypothesis that all or at least most of the suitable wintering areas have been colonized.

METHODS

Ibex winter distributions (Fig. 1) were compared with thematic maps of daily solar radiation (Fig. 2-6).

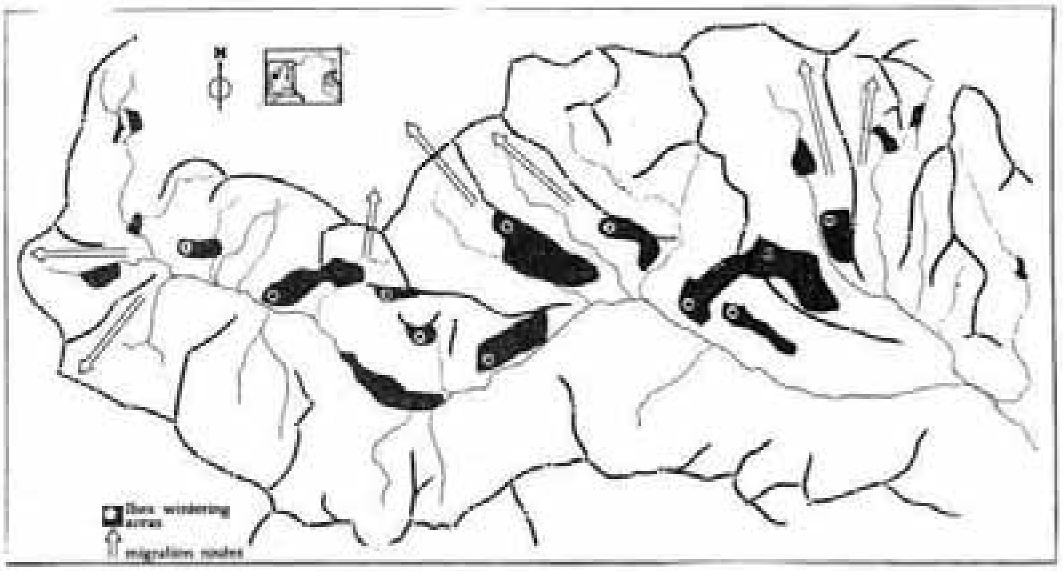


Fig. 1 - Winter distribution and main migration routes of ibex in the middle and high Orco Valley.

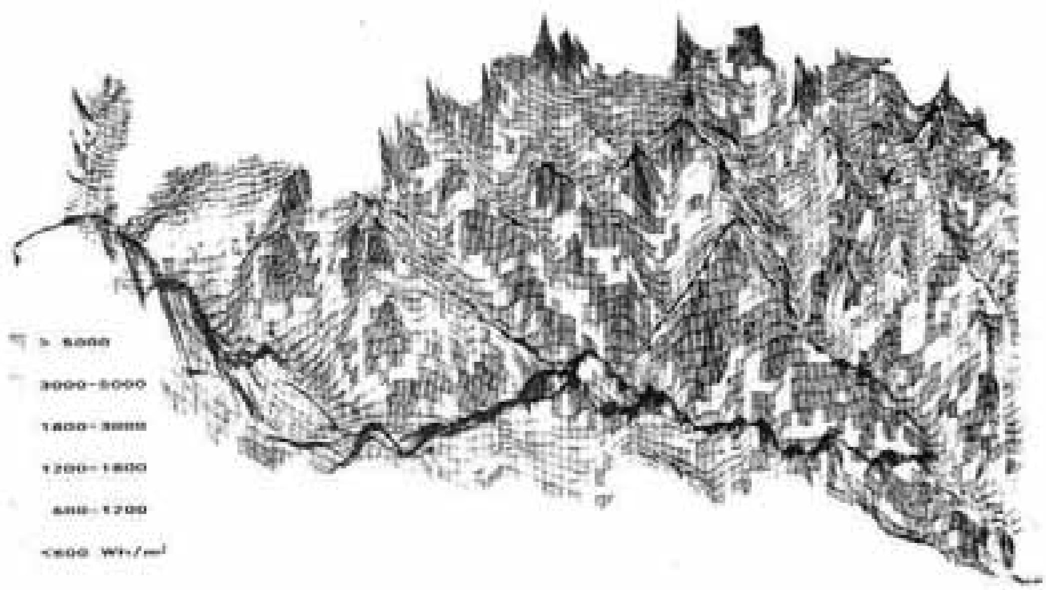


Fig. 2 - Solar radiation map of the middle and high Orco Valley on January 15 (isometric view).

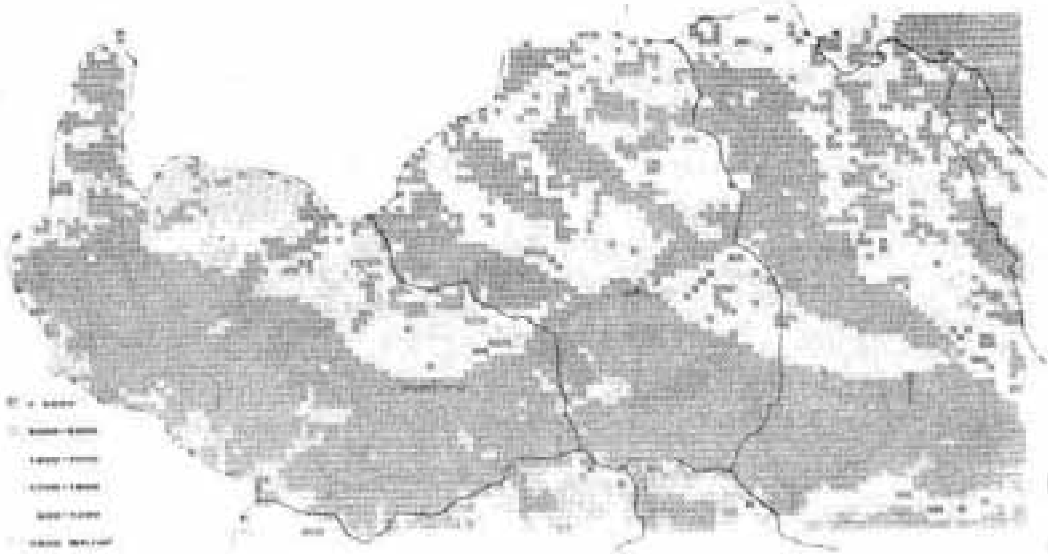


Fig. 3 - Solar radiation map of the middle and high Orco Valley on January 15.

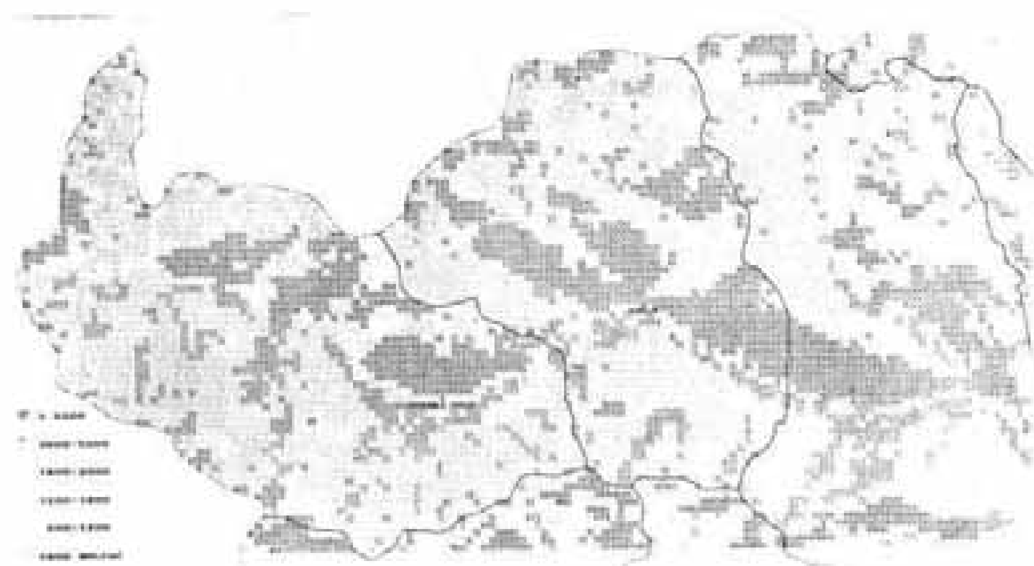


Fig. 4 - Solar radiation map of the middle and high Orco Valley on February 15.

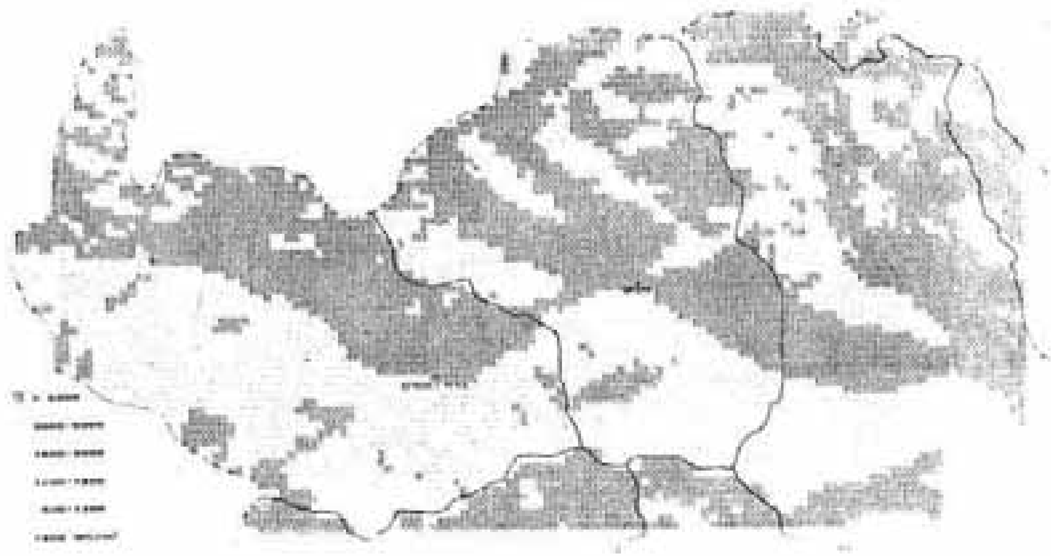


Fig. 5 - Solar radiation map of the middle and high Orco Valley on March 15.

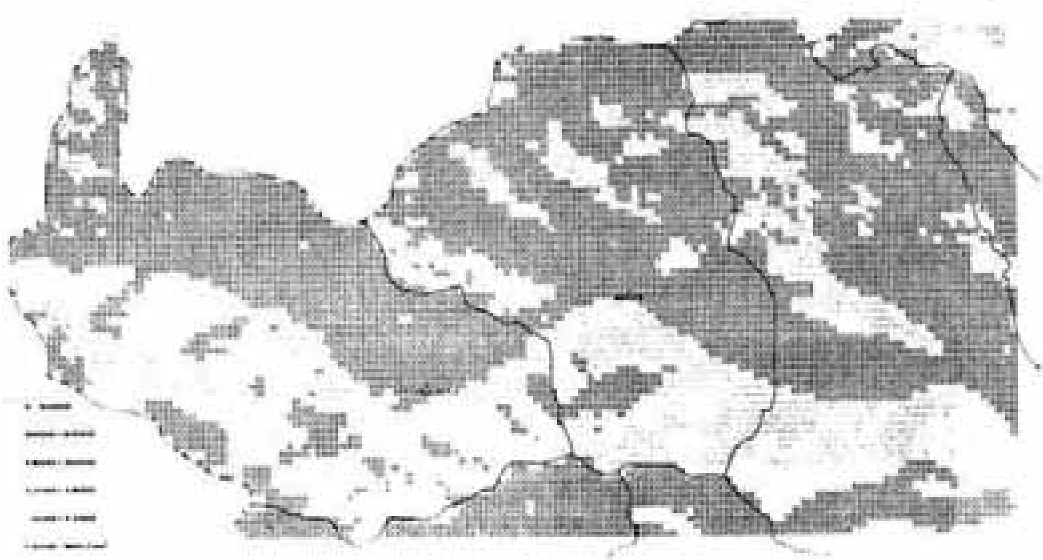


Fig. 6 - Solar radiation map of the middle and high Orco Valley on April 15.

Figure 1 was drawn from observations of the wardens of the G.P.N.P., collected over a 5-year period. Data were recorded on a 1:50,000 scale map. Eleven wintering sites were mapped (Table 1).

Moreover, main migration routes of some ibex herds from their wintering sites were drawn (Fig. 1).

Table 1 - Topographic features of actual wintering sites of ibex in the middle and high Orco Valley.

wintering area	elevation (meters)	average slope	aspect
1	2400 - 2000	30°-45°	S
2	2600 - 1700	30°-45°	S
3	3000 - 2400	30°-45°	S
4	2500 - 2200	30°-45°	S
5	2200 - 1500	30°-45°	S
6	2700 - 1400	30°-45°	S
7	2700 - 1600	30°-45°	S
8	2900 - 1400	30°-45°	SW
9	2200 - 1700	30°-45°	SW
10	2900 - 1500	30°-45°	E
11	2700 - 1900	30°-45°	SW

Solar radiation was mapped using software (SUN/LAND) developed by Grosso et al. (1983). This program, supplied by C.S.I.-Piemonte (a public service documentation and computing Center), is available on request.

Briefly, the SUN/LAND is made up of the following stages:

- constructing a digital elevation model representing the outline of the sample area;
- computing insolation through a model giving the instantaneous and daily evaluation of sunlit and shaded zones;
- computing ground position;
- computing solar radiation through a model based on unitary radiation values on the horizontal plane and including the instantaneous and daily radiation values for each node of the elevation model.

The study area was digitally represented by a 200 x 200 m grid (7,418 meshes total) to optimize the 1:100,000 plotted orographic data stored in the CSI-Piemonte archives.

Seven thematic colour maps were drawn [3], representing solar radiation on January 15, February 1 and 15, March 1 and 15, April 1 and 15 (Figs. 3-6). An isometric solar radiation map was also drawn for January 15 (Fig. 2). Mapping was started on January 15, because by this time regular rutting is over and ibex have reached their winter range.

Solar radiation values (Wh/m^2) were grouped in six classes (Table 2); the percentage of grid meshes in each class were determined from the thematic maps (Table 3).

Table 2 - Solar radiation classes used and their associated solar radiation values.

Class	Wh/m^2
1	> 5000
2	3000-5000
3	1800-3000
4	1200-1800
5	600-1200
6	< 600

Table 3 - Distribution of solar radiation values on the thematic maps of the middle and high Orco Valley.

	% of grid meshes from each energy class						
Class	Jan 15	Feb 1	Feb 15	Mar 1	Mar 15	Apr 1	Apr 15
1	2.3	11.0	22.0	35.7	48.4	56.7	59.5
2	8.8	10.1	9.8	9.1	7.1	7.3	9.5
3	8.0	8.1	8.2	6.3	5.7	6.4	7.8
4	5.7	5.7	5.0	5.2	5.2	7.5	17.7
5	15.8	34.6	45.7	42.1	33.6	22.1	5.5
6	59.4	30.5	9.3	1.6	0	0	0

(3) Following Editor's instructions, black and white prints of original colour maps are presented.

Ten man-days of a CSI computer operator were needed to adapt the SUN/LAND program to our requirements and to check the results. Each thematic map required approximately 30 minutes of CPU time on a OH 5560 computer with an operative system MVS/TSO and 45 minutes on a Calcomp 1039 plotter. Total cost of the operations was about 2 million Italian Lire (~1,300 US$).

RESULTS

Comparison of ibex winter ranges and thematic solar radiation maps showed that:

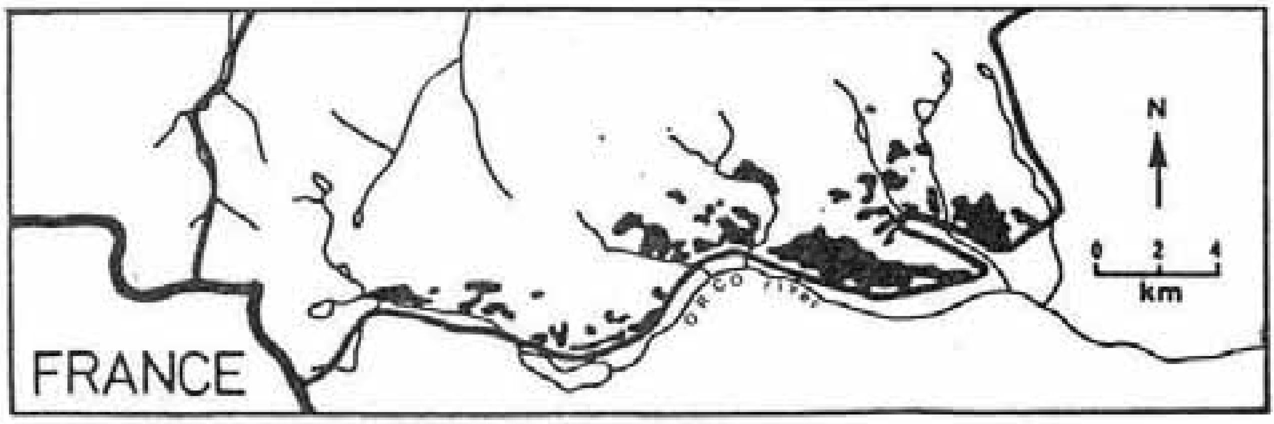
- presently utilized wintering sites overlap areas characterized by daily solar radiation values $\geqslant$1800 Wh/m^2 (except for site number 10);
- Class 1 values were found in 9 out of 11 wintering sites from the beginning of the mapping period;
- wintering sites are better recognizable on the January 15 map because on this day the ratio between the surface of areas with a daily solar radiation 1800 Wh/m^2 and the surface of known wintering sites reaches its minimum value (Table 4);
- two of the main late spring migration routes, connecting the high Orco Valley with Maurienne and Tarantaise regions, in the Vanoise National Park (westernmost arrows on Fig. 1), are clearly represented on the maps. These routes are drawn by the progressive appearance of Class 1 values along south to south-east slopes situated in a very poorly irradiated part of the sample area. The other known migration routes were not so clearly recognizable in the northern part of the study area where the high solar radiation had been homogeneously distributed since the beginning of March.

Table 4 - Predictability of ibex wintering sites location on different solar radiation maps of the middle and high Orco Valley.

Day	surface of areas with solar radiation values $\geqslant$1800 Wh/m^2 / surface of known wintering areas
Jan 15	4.62
Feb 1	7.08
Feb 15	9.74
Mar 1	12.42
Mar 15	14.85
Apr 1	16.89
Apr 15	18.68

DISCUSSION

Within the study area, which is densely populated and likely to be saturated with ibex, the solar radiation map for January 15 identified 10 out of 11 known wintering areas. These results are similar to those obtained by analysis of satellite images, which are able to furnish direct printouts of snow-free vegetation sites (Wiersema 1983b). In fact, the areas found through false colour composite of Landsat winter scenes overlap most of the sites defined on the January 15 map by a solar radiation level ≥ 1800 Wh/m^2 (Fig. 7).



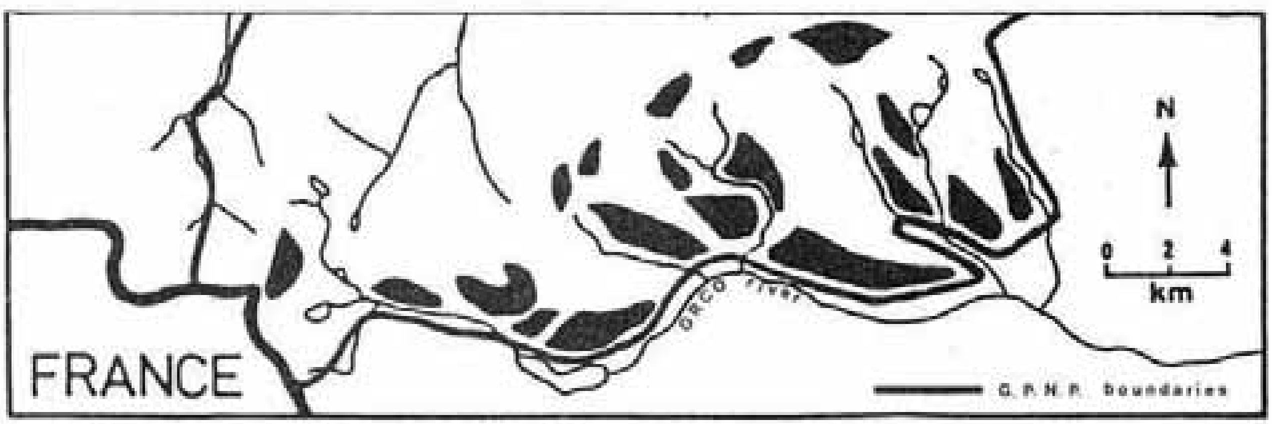


Fig. 7 - Patches of snow-free vegetation found by Wiersema (1983b) through false colour composite of a Landsat winter image of the middle and high Orco Valley (above) compared with sites of the same area receiving high solar radiation (≥ 1800 Wh/m^2) on January 15 (below).

Of course, not all sites with a high solar radiation harbour ibex herds for the following reasons:

1 - most of these sites are located at extremely high elevations (above 3,000 m);
2 - some sites are lacking necessary landscape features (steep slopes, rocky terrain interspersed with grassland, no thick forest, etc.) that can be found on topographic maps and by photointerpretation in known wintering areas (Rossi et al. 1986);
3 - a few sites have been subjected to heavy poaching in the recent past and have not yet been spontaneously recolonized.

The sensitivity of this technique could be improved by reducing the scale of the grid which defines the sample area. Consequently, this would mean input of cartographic data referring to a scale smaller than 1:100,000.

We agree with Stefanovic and Wiersema (1985) that the use of a smaller grid scale (e.g. 100 x 100 or 50 x 50 m) is advisable, at least in areas with complex topography, because in this way the computer can detect small areas that may adequately support overwintering ibex herds.

For example, as far as the study area is concerned, the exact morphology of the wintering area number 10 was seriously misrepresented due to the computer interpolation of input topographic data. This site, which actually comprises 3 narrow valleys with major east-west orientation, appeared to have a uniformly east to north-east aspect on the digital elevation model. Therefore, none of the south slopes was represented, so daily solar radiation probably had been strongly underestimated. These slopes appear as snow-free vegetation patches on the false colour composite of Landsat winter images (Wiersema 1983b).

CONCLUSIONS

Mapping of daily solar radiation, using the procedure developed by Grosso et al. (1983), can be defined as an interesting, economic and time saving possibility for dealing with the problem of planning ibex reintroductions. The screening of territory for this determining factor, not only supplies data that are valuable on their own, but also enables more detailed scale evaluations (e.g. photo-interpretation and vegetation survey) to be carried out on smaller areas through "a priori" rejections of unsuitable overshadowed sites (80.9% in the study area, though one of the most favourable for ibex).

Further studies are necessary before widespread application of this technique. In particular, a 1800 Wh/m^2 solar radiation level will be tested as the minimum requisite for predicting the locations of ibex wintering sites in homogeneous macro-climatic conditions. Thus the analysis of solar radiation will be extended to other areas harbouring:

- stable ibex colonies
- increasing ibex colonies spontaneously spread

- increasing ibex colonies recently reintroduced.

Also, an ibex reintroduction will be carried out in May '86 in an area located by the described method.

Other management implications may be foreseen through the planned development of this method. For example, recognizing possible late spring migration routes could influence the choice of the reintroduction sites, depending on the individual situations. Indeed, a policy to increase ibex on a regional level would select sites connected by corridors facilitating pioneering of vacant habitat. On the other hand isolation could control the animals' dispersal, enabling a faster establishment of the colony, and thus lower operational costs.

Finally, an analysis of the relationship between solar radiation, pasture productivity and animal biomass, could reveal interesting data correlated to the carrying capacity of an area.

Aknowledgements

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