BUCEGI MOUNTAINS BETWEEN DEVELOPMENT OF NEW SKI AREAS AND PRESERVATION OF NATURAL HERITAGE – ANALYSIS OF SNOW RELATED PARAMETERS IN THE CONTEXT OF CLIMATE CHANGE

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ABSTRACT *The Bucegi Mountains and the Prahova Valley host the most renowned ski resorts in Romania. Thus local stakeholders will try to develop the existing ski resorts or build new ones in the area benefiting from the already acknowledged brand "Prahova Valley". Development projects have already chosen different sites based on infrastructure proximity, geomorphologic features, land ownership, and on climatic data, but restricted to a very short acquisition period (10 years or less).*
Recent climatic changes related to an observed decrease in the snow cover and snow depth in mountain areas require a more detailed analysis of local climate and more importantly of its trend, so that decisions can be made regarding the benefits of such an investment in the present climatic setting.
In this context, meteorological data sets belonging to different weather stations within the Bucegi Mountains with more than 50 years of observation have been processed. And for certain key parameters such as snow cover and, snow depth they have been modelled and compared with the NDSI (Normalized Difference Snow Index) resulted from processing Landsat satellite images with different acquisition dates throughout one winter season.
Results show that most of the proposed sites would not be viable in a medium term plan, even with snow cannons involved. Moreover a conflict situation arises between development and conservation, for most of these areas are part of the Bucegi Natural Park and thus it is important that these should be preserved for other more durable activities, even tourist ones if they belong to green tourism.

Keywords: *NDSI, climate change, conservation, Southern Carpathians.*

INTRODUCTION

Winter sports, as recreational activities are popular all over the world ever since the mid 1800s, when Sondre Norheim has transformed skiing, which used to be a means of transport during the long winter months, into one of today's favourite pastimes during the cold season [1]. Since those days up to current times the sport itself has evolved as has the dedicated tourism. From the 1st generation to the 4th generation of ski resorts [2] which reclaimed going back to more natural planning of the resort itself, all rely mostly on one important climatic parameter: snow. As the number of winter-sports consumers grew so have the number of resorts all over the world [3], until the turn of the century when they found themselves in a challenging situation due to the diminishing snow pack, related to the global climate change [4][5][6]. The majority of ski resorts all over the world started mitigating the consequences of the climate change [7] [8]. But in other countries, especially where the market economy has latency close to half a century due to totalitarian regimes such as communism, winter sport tourism has boomed just around the turn of the century.

In 2003, in Romania, a programme called Superski in the Carpathians ("Superschi în Carpaţi") was developed [9], based on the Italian model Dolomiti Superski, which was supposed to increase the ski area, nation-wide, from around 100 km, existing in the years 2000 to 1500-2000km at the end of the programme [10],[11]. After a slow start and changing of the law that regulated the programme, at the end of 2011, 116 km of ski pistes were homologated, most of them constructed for the European Youth Olympic Winter Festival 2013. Since then rather little was done, but with little political stability and with the changing of the ministry of tourism, one can never know when the investments will restart. The purpose of this study is to draw attention to the proposed development of ski areas in the Bucegi Mountains, such as they appear in the above mentioned programme in relation to the

consequences of climate change at local and regional scale, and also to the fact that the Bucegi Mountains are included in the Bucegi Natural Park.
The objectives of the study are to analyze the main snow related parameters and their trends in the last 50 years to assess the suitability of the proposed ski sited in the context of climate change and moreover in the setting of a protected area.

STUDY AREA

The Bucegi Mountains are located in the eastern part of the Southern Carpathians (fig. 1), within the mountain group that bears the same name.

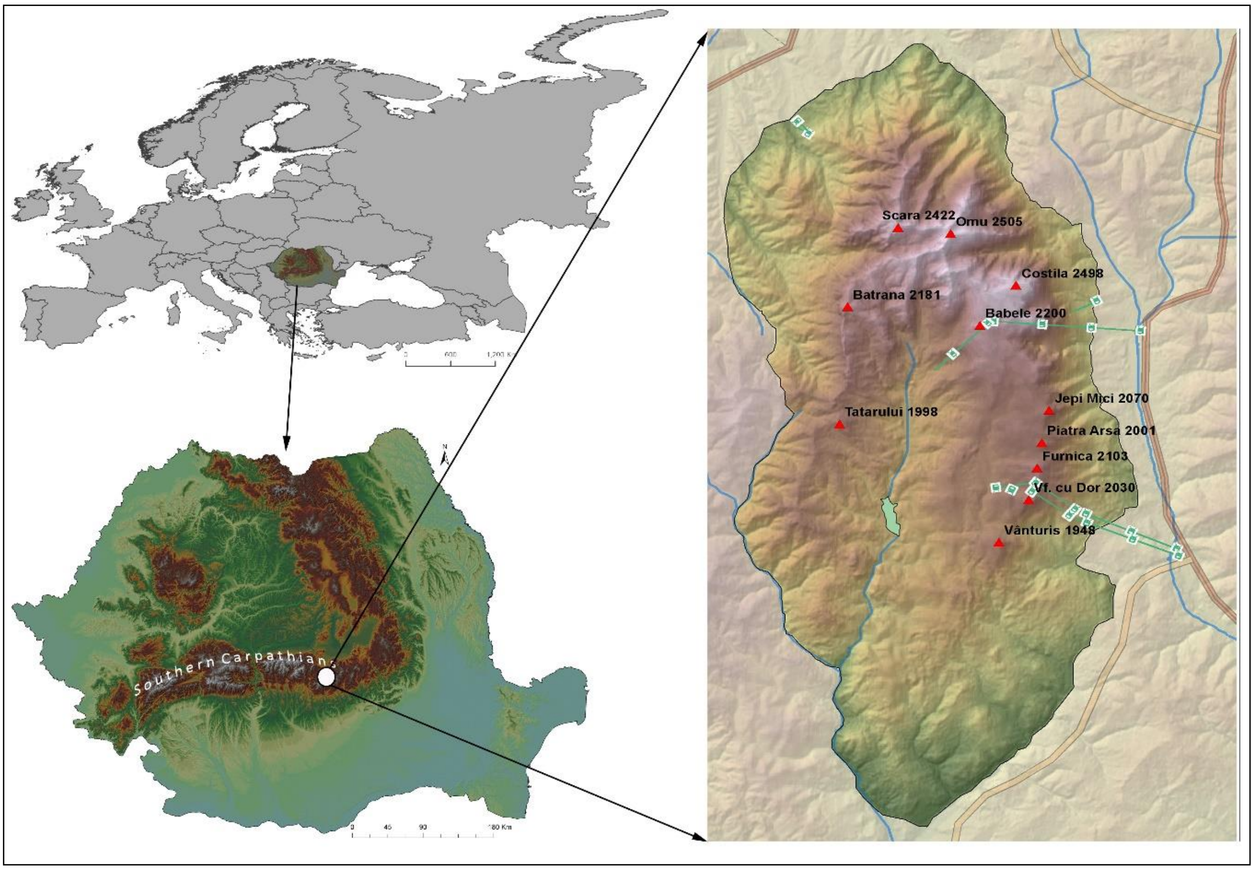

Fig. 1. Location of the study area

The Bucegi Mountains are bordered by cliffs on three sides (on the east towards the Prahova Valley, on the west towards the Rucăr-Bran-Dragoslavele Corridor and on the northern side towards the Braşov Basin) and by the Ialomiţa's Subcarpathians on the southern side. This mountain area has the shape of an amphitheatre with its opening towards the Ialomiţa Valley, to the south. The highest altitudes are concentrated in the northern part. The foremost important orographic knot is situated in the northern part and is represented by the Omu Peak-2505 m [12]. Due to their morphology, there are only 3 areas where ski areas developed [13]. The most important ski area in these mountains is located in the southern part, above the tourist resort of Sinaia and covers around 70 ha [14]. This is the only one that can be called ski resort. The other two: Buşteni and Bran are winter recreational sites since in both sites there are 3 cable transportation facilities altogether. The first one is located about 10 km north of Sinaia, but a connection between the two would be almost impossible due to the mountain's morphology and the other one is located on the northwestern side of the massif (fig.

2). For both of these areas new pistes and cable transportation have been proposed in the above mentioned programme (fig. 2). Also a new site was proposed for development, called Peştera-Padina, within the central area of the Bucegi Mountains (fig. 2).

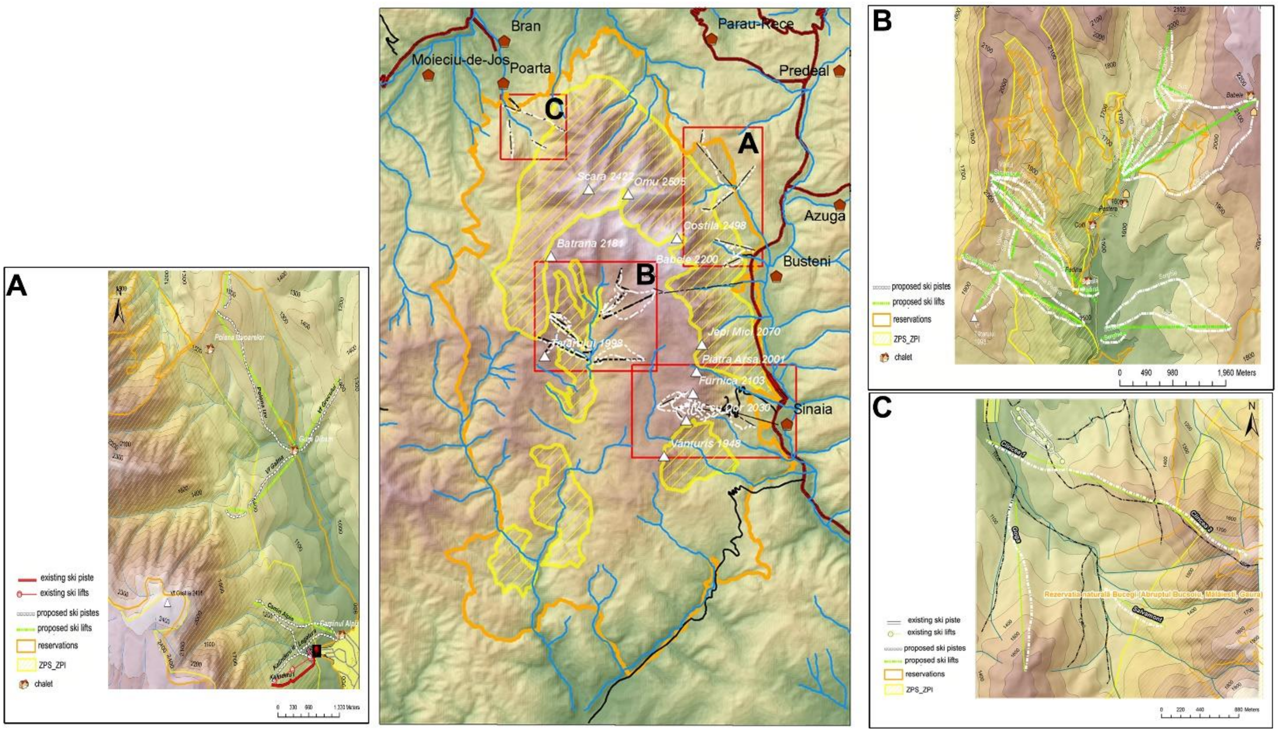

Fig. 2. Location of the proposed ski sites within the Bucegi Mountains: Buşteni site (A) Peştera-Padina site (B) Bran site (C) (Data source of the features of the proposed ski areas: National Institute for Research and Development in Tourism (INCDT))

The Bucegi Mountains have become a Natural Park in 2000 and was integrated in the international network of Natura 2000 sites [15]. The protected area has a specific zoning strategy inside the park which includes Areas with Integral Protection (ZPI_ZPS marked on the map – fig. 2) where no exploitation of natural resources is allowed or any other activity that contravenes with the scope of protection [16].

MATERIALS AND METHODS

Cable infrastructure data and ski trails data was rendered on site using a GPS device, and further integrated in a GIS database. Other infrastructure data (road network, settlements) were acquired courtesy of the Digital Map of Romania project. The vector data with the integral protection zones within Bucegi Natural Park were provided by the National Ministry for Environment, Waters and Forests [17].

For the climatic trend analysis we used meteorological data: monthly values (temperature, number of days with snowfall, snow depth) for the winter months of 1961-2014, courtesy of the NMA (National Meteorological Administration). Full series of data were used for 3 meteorological stations: Omu, Sinaia, Predeal. For Fundata weather station the data were provided until 2007 (table 1). Additional climatic data from other meteorological stations outside the study area were used to interpolate snow depth values for the snow depth model of Bucegi Mountains throughout a winter season.

Table.1. Characteristics of the weather stations used for this study

Weather station altitude (m.a.s.l.)	Geographical coordinates		Climatic influence	Air temperature (0ºC)		Total precipitation (mm)		Snow depth (cm)
	Latitude	Longitude		annual	winter season	annual	winter season	
Vf. Omu - 2505	45°27′	25°27′	eastern	-2.5	-9.7	995.7	428.3	34.5
Sinaia - 1500	45°23′	25°30′	eastern	3.7	-4.5	1057.4	380.7	47.6
Predeal -1030	45°30′	25°33′	eastern	4.9	-1.3	942.5	315.2	34
Fundata - 1371	45°26′	25°16′	western	4.6	-3.5	898.7	299.2	12.8

Nonetheless meteorological data is punctual and cannot be generalized to a larger area such as the Bucegi Mountains. In order to show that the extent of snow covered area throughout the winter season is even smaller then in a continuous snow model of meteorological data, we used Landsat images throughout one winter season and the NDSI was derived. The NDSI was introduced by Dozier in 1989 as a ratio between the bands 2 (0.52-0.60 μm) and 5 (1.55 1.75μm) of the Landsat Thematic Mapper TM. Today this index is much associated with MODIS (Moderate Resolution Imaging Spectroradiometer) images acquired by two satellites AQUA and TERRA, the National Snow and Ice Data Center (NSIDC), providing either 8-day composite images or daily images of the derived snow and ice covered surfaces. Even though MODIS images have a high temporal resolution (1-2 days), the spatial resolution is low (250 - 1000m) and they need to be calibrated with finer resolution data, either remotely sensed ASTER data [18] or Landsat data which is called "the truth" in this respect [19],[20] or with field data. For this study, a series of Landsat images were chosen, for the most tourist sensitive months: December, January and April. For all of the Landsat images, the area covered by snow in all winter months from the season 1987-1988 was derived and correlated to the data for snow depth model derived from meteorological measurements.

RESULTS

First of all we would like to draw the attention to the fact that some of the ski pistes proposed within the "Schi in Romania" project fall within the integral protection zones of the Bucegi Natural Park (fig. 2). Though it was done before- changing the protected status of that particular area so that the development can take place –for these particular sites would not be reasonable at all since the exploitation of that development can only be done on short term as it will be further discussed.

The most important climatic parameter for the development of ski resorts is snow and its characteristics: snow cover duration, snow depth, number of days with snow fall. Snow is a function of temperature and precipitation, consequently there parameters are also important when studying snow and snow cover.

Regarding climate change within the Carpathians, recent studies have shown a general rise of temperature with 0.3-0.5 °C in the Southern Carpathians [21]. Regarding the winter months, some authors have found that for 40% of the weather stations within the Carpathians (including the weather stations used in the present study) the mean, maximum and minimum temperatures are rising [22]. Proxy information, such as an increase in the elevation of timberline and the replacement of coniferous forests with mixed ones, confirms also the warming trend in the Southern Carpathians [23].

Temperature is important for precipitation in solid state, but nowadays, for winter sports, the natural solid precipitation is sometimes replaced by artificial snow when precipitations are scarce. In order to produce good quality artificial snow, negative temperatures are necessary, the following conditions being ideal: -7°C and 60% humidity. Due to rising temperatures in many resorts, they have succeeded in rising the ideal temperature to -3.8°C, with the help of organic or chemical additives [24]. Snow cannons work even at positive temperatures but the quality of the snow is precarious and its impact upon the environment significant.

Even if resorts do not rely on natural snowfall, it is clear that they rely on negative temperature. As shown in fig. 3, in all winter months the temperatures are rising. The most important rise is registered for January (fig. 3b), almost 2° C, at almost all weather stations – especially at those situated at 1500 m.a.s.l. or under this threshold, in 50 years of observation. It is then followed by February (fig. 3c)) as a general trend, and by the March for the weather stations located at 1500 m.a.s.l. or below. December on the other hand shows a slight rising trend at higher altitudes (fig. 3a). We have chosen the month of April for our study as well since the main rule for a profitable ski resort is the persistence a continuous layer of minimum 30 cm, for 100 days between December 1st and the month of April when the season closes around the Easter Holidays [25].

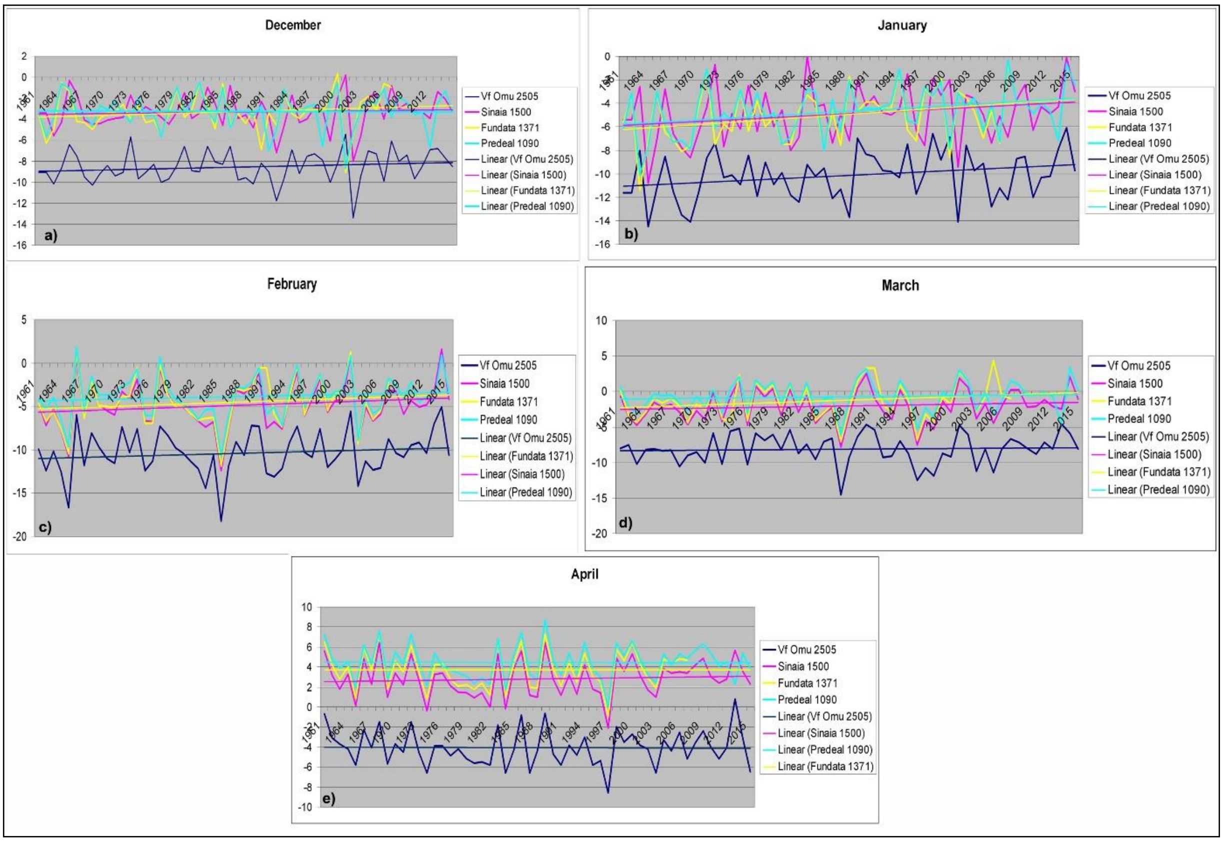

Fig. 3. Mean temperature evolution within the Bucegi Mountains in winter season between 1961-2015
(Data source: NMA Archives)

Some authors reported a decrease in the amount of the winter precipitation in Romania (1961–1996) [26]. The importance of precipitation in our present study is related to the number of days with snowfall. Recent studies in Romania show that a decreased frequency of the snowfalls defines the period 1961–2003 [27].

Although we only have continuous data with number of days with snowfall from 1961-2007 (fig. 4), it is clear that these data show an important decrease at higher altitudes and a slight increase at lower altitudes.

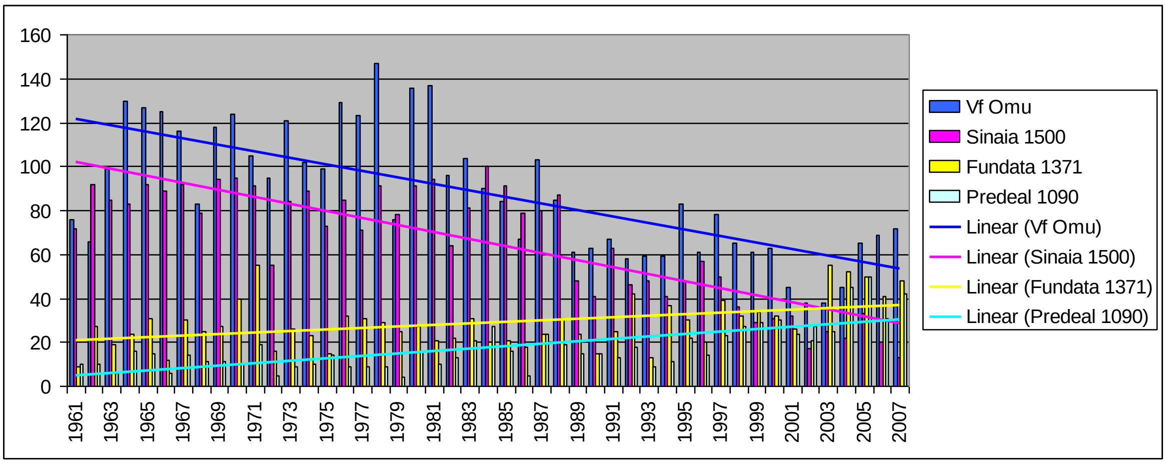

Fig. 4. Number of days with snowfall within the Bucegi Mountains between 1961-2015 (Data source: NMA Archives)

More important than the number of days with snowfall is the period with snow-covered surface. This parameter shows an important decreasing trend especially at higher altitudes, but also at 1500 m.a.s.l. and below (fig. 5).

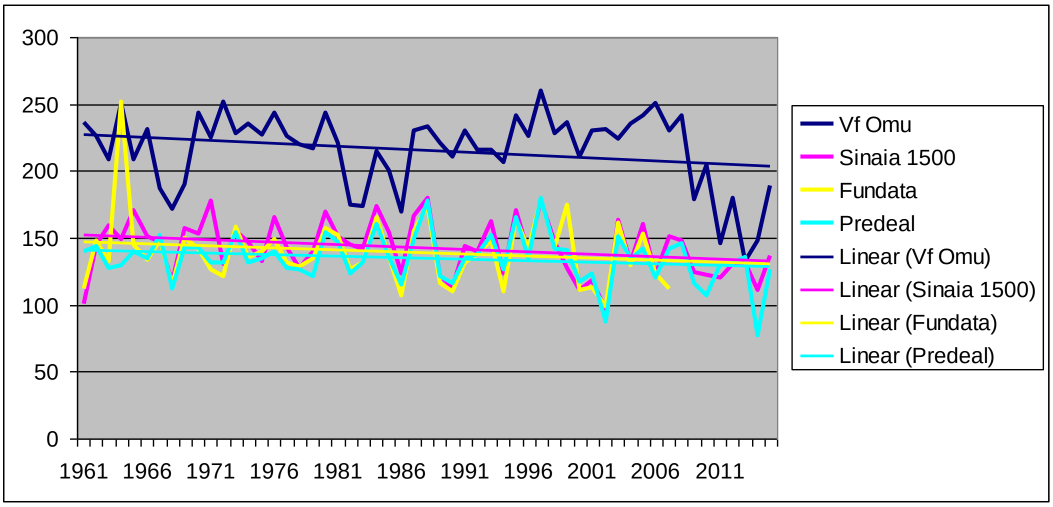

Fig.5. Number of days with snowcover within the Bucegi Mountains between 1961-2015 (Data source: NMA Archives)

Nonetheless these measurements show the presence of the snow layer, but do not reflect its depth, which is an important parameter and dedicated literature [24] reclaims a layer of at least 30 cm or with today's technology of slope preparation before the season, of 20 cm.

Recent studies have shown that in the Carpathian mountain region, snow depth values are decreasing over quite many areas, mainly in January–February, but also in December and March [28]. As shown in fig. 6 a)-e), snow depth reveals great variability between years. At higher altitudes (i.e. at Omu weather station 2505m), all throughout the winter season, the trendline shows an increase. At Sinaia weather station, 1000 m lower, an increasing trend for the dedicated winter months (December-February) can be observed. Below 1500 m.a.s.l., a general decreasing trend is characteristic, especially for the dedicated winter months, as documented in other mountain areas [29].

The proposed ski areas consider important surfaces located below 1500 m.a.s.l.: more than 50% of the proposed investment for Bran, close to 100% for Buşteni and around 30% for the Peştera area as it can be seen in fig. 2 b),d),f), where the most important decrease of snow depth and of snow cover are registered,

Furthermore we need to consider the fact that these measurements have a low spatial resolution and cannot be considered equal at similar altitudes. Snow cover and snow depth are also influenced by other parameters such as local topography, slope aspect, landcover etc., therefore a more detailed analysis of snow related parameters needs to be done. In the same time, a valuable source of data is satellite images, i.e. Landsat series, with more than 40 years archive of imagery.

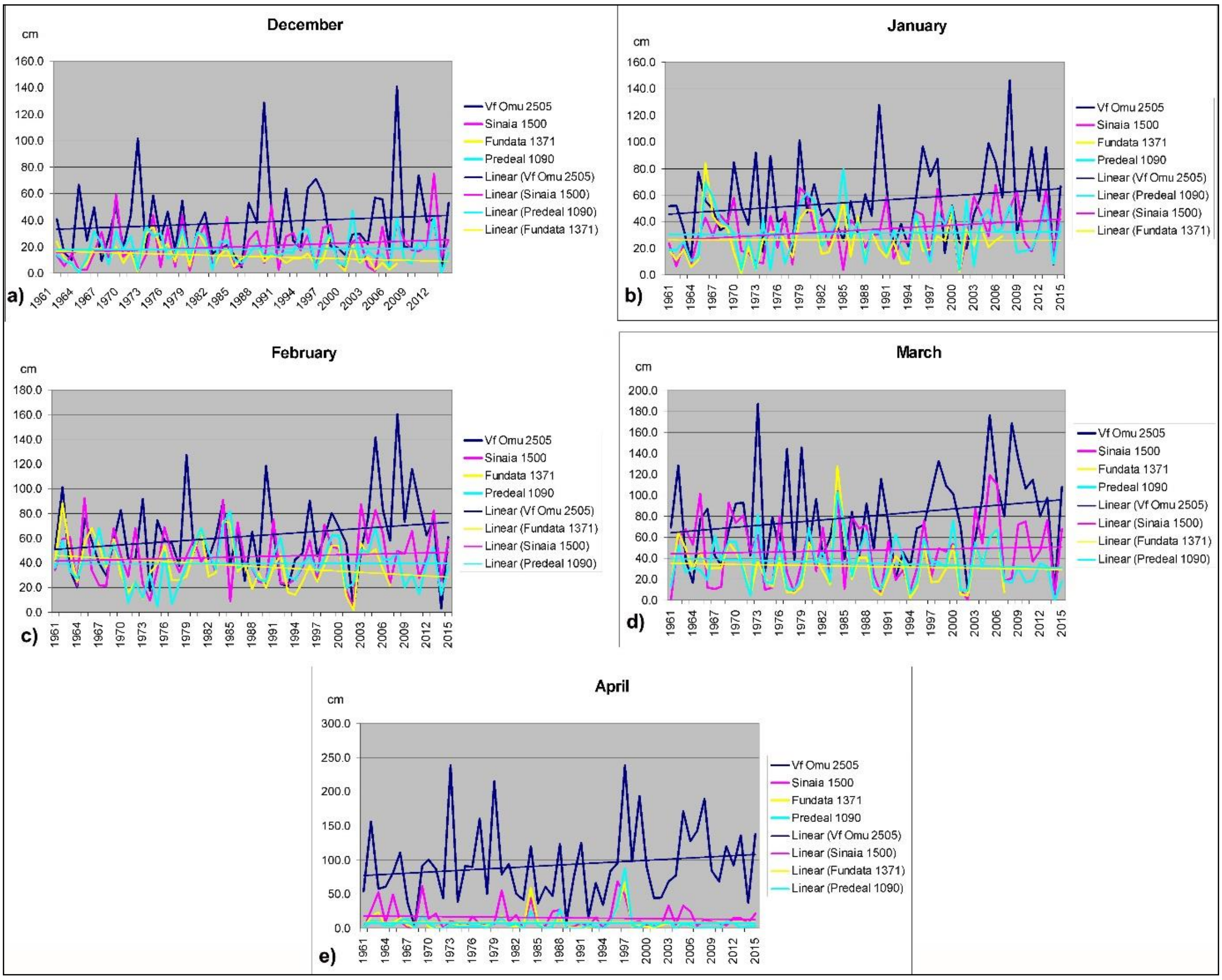

Fig. 6. Snow depth's evolution within the Bucegi Mountains between 1961-2015
(Data source: NMA Archives)

In this context, to correlate the climatic data with information extracted from satellite images we calculated the NDSI using several Landsat images of the Bucegi Mountains and we used as an example the 1987-1988 winter season, and compared it with the models of the snow cover using snow depth data from the same monthly decade as the acquisition date of the Landsat images.

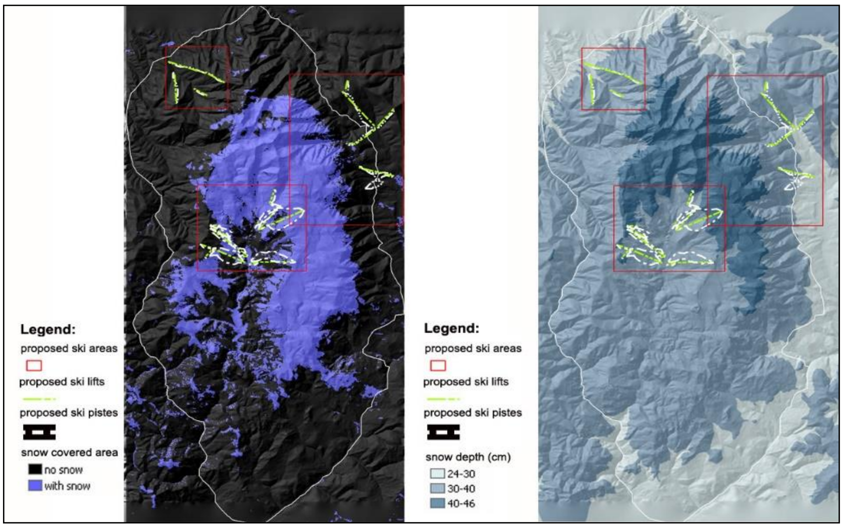

Fig. 7. Snow covered surfaces, extracted from NDSI (left) and snow covered surfaces based on climatic model of snow-depth for the 2nd decade of December 1987 (right) (Data sources: Lansat7, courtesy of USGS and climatic data from NMA Archives)

In all figures (7, 8, 9) we can notice the differences between the snow-covered surfaces extracted from NDSI as compared to the climatic models. For the month of December the climatic model shows 30-40 cm of snow, where in fact there was no snow at all. This result is of great importance for the Bran and Buşteni sites which appear to be covered with a sufficient snow cover for winter actives when in fact, on the satellite image appear to be free of snow.

For January we can notice the same results with the mention that in the north-eastern area there was cloud coverage that was not fully filtered.

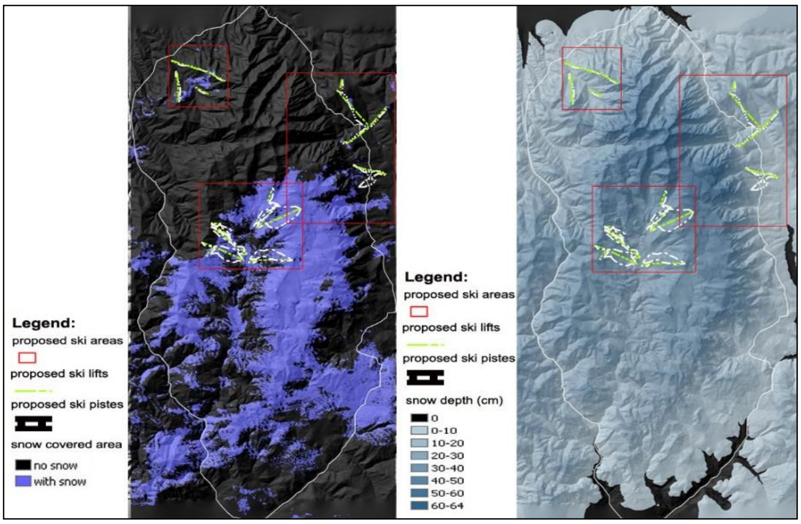

Fig. 8. Snow covered surfaces, extracted from NDSI (left) and snow covered surfaces based on climatic model of snow-depth for the 3rd decade of January 1988 (right) (Data sources: Lansat7 image courtesy of USGS, climatic data from NMA Archives)

For the month of April (fig. 9) the same difference can be observed, important for the two sites mentioned above, but also noticeable for the Peştera area, especially towards the central valley, where the lower altitudes are located. Similar situation was observed also in more recent images from years

2000-2010 and also a decreasing trend in snow covered areas at the end of the winter, thus shortening the season for winter sports.

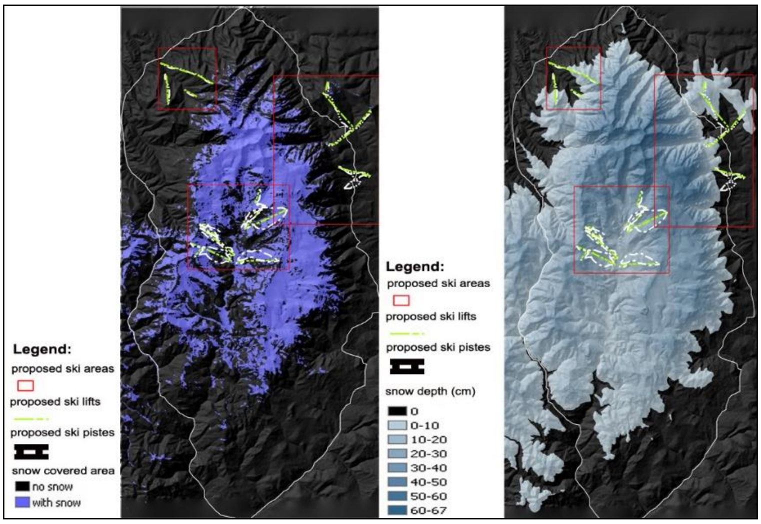

Fig. 9. Snow covered surfaces, extracted from NDSI (left) and snow covered surfaces based on climatic model of snow-depth for the 1st decade of April 1988 (right) (Data sources: Lansat 7 image, courtesy of USGS, climatic data from NMA Archives)

CONCLUSIONS

For the sites considered in this study, before analyzing the climatic data and its trend, we draw the attention to the fact that part of the proposed ski areas fall within protected areas, some even of special protection. Moreover there are an important number of wooded hectares that needed to be deforested so that that these developments could take place.

The analyzed climatic data reflect that during winter months the temperatures have an important rising trend, with a decrease in the number of days with snowfall. These higher temperatures will prevent even snow cannons to produce good-quality artificial snow. The number of days with snow-cover has a decreasing trend regardless of altitude, and snow depth has the same decreasing trend at lower altitudes where overall, more than 50% of the proposed areas are located. Moreover satellite images show that at the particular sites of our interest, there were considerable areas without snow, especially in the beginning and at the end of winter season.

Economic development is an important goal for our country, especially while we lag behind neighbouring countries. More important is to seek ways of sustainable development, learning from the experience of more developed countries, which presently chose to invest less in developing new sites dedicated to winter tourism and try to convert areas which where the revenue is turning into debt and where nature had its toll due to its intensive exploitation. These sites are located usually at lower altitudes. Furthermore it is less costly to keep the protected areas as such and develop them through green forms of tourism, and keep the special protected areas for research and study tourism.

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