FREPPAZ MICHELE[1]
FILIPPA GIANLUCA[2]
CAIMI ANGELO[3]
ZANINI ERMANNO[4]

SUSTAINABLE TOURISM IN NORTHWESTERN ALPS: WINTER SPORTS IMPACT ON PASTURE LANDS

Abstract

Tourism has many potential benefits for rural areas, being an important source of jobs for nonmetro communities, especially for those that are economically underdeveloped. The traditional use of lands in mountain regions is combined nowadays with surfaces devoted to recreational activities because of increasing tourist demand for winter sports. Winter-based ski tourism is a major human use of many mountain regions, with large-scale ski resorts in Europe, Asia, North and South America, New Zealand and Australia. The Alps have become increasingly developed to cater to tourist activities beginning in the '50s. This was partly an outcome of traditional practices (livestock, agriculture, forestry), which were unable to generate enough income to maintain farms and the social structure. As with many human activities, the development of winter sport resorts may impact mountain landscapes and environments. In general, ski run construction and management have a great impact on the soil properties and other environmental factors, sometimes influencing traditional rural activities such as the management of pasture lands. Therefore, it could be recommended that environmental goals in ski resort management should be established and respected. In particular, we recommend carefully recording the vegetation and soil characteristics in a specific area before any intensification of use as ski slope, and complete avoidance of areas with soil and vegetation of particularly high conservation value.

Key words: *Ski slopes, grazing, soil, winter tourism*

1. Introduction

As many human activities, the development of winter sport resorts caused a strong impact on the mountain landscapes and environments. The traditional use of lands in mountain regions, in fact, is combined nowadays with surfaces devoted to recreational activities because of increasing tourist demand for winter sports. Construction and persistence of ski runs and lifts have a particular impact on high-altitude

[1] Università degli Studi di Torino, DIVAPRA - Chimica Agraria e Pedologia - Italy
44, Via Leonardo da Vinci, 10095, Grugliasco (TO), Italy, *e-mail:* michele.freppaz@unito.it
[2] Università degli Studi di Torino, DIVAPRA - Chimica Agraria e Pedologia - Italy
44, Via Leonardo da Vinci, 10095, Grugliasco (TO), Italy, e-mail: gianluca.filippa@unito.it
[3] Università degli Studi di Torino, DIVAPRA - Chimica Agraria e Pedologia - Italy
44, Via Leonardo da Vinci, 10095, Grugliasco (TO), Italy, e-mail: angelo.caimi@unito.it
[4] Università degli Studi di Torino, DIVAPRA - Chimica Agraria e Pedologia - Italy
44, Via Leonardo da Vinci, 10095, Grugliasco (TO), Italy, e-mail: ermanno.zanini@unito.it

An. Inst. cerc. ec. "Gh. Zane", t. 19, Iaşi, 2010, p. 79–93

ecosystems and soil resilience because their building induces many environment transformations such as: tree-clearing, removal of the soil and vegetation cover, surface corrections, road construction and artificial snowing. All these operations may induce geomorphologic hazards, increase of flow and sediment loads (David et al. [8]), soil erosion and interference with flora and fauna that lead to loss, deterioration and fragmentation of the ecosystems and consequent modifications in animal behaviour (Geneletti [15] ; Geneletti and Dawa [16]; Negro et al. [31]; Arrowsmith and Inbakaran [2]). In spite of these threats, ski resorts are widespread all around the World where latitude and/or altitude are suitable. In this paper, we report of the modifications occurred on the pasture lands and soils because of the construction, presence and managing of ski resorts and runs.

2. Effects of ski resort construction on ecosystem compartments

The construction of ski resorts and slopes may interfere at various extent with many ecosystems components. At each place, prevailing site conditions in terms of geology, geomorphology, climate, soil, vegetation, flora and fauna determine the degree and type of interference.

2.1. Effects on flora and fauna

In the European Alps, ski runs are constructed mainly on pastures and heaths (Figure 1), and this has led to ecological damages such as reduction in the number of species of some vegetal population (Bayfield [4]; Stern [44]; Watson [53]; Haimayer [21]). Other studies have documented changes in plant biomass, and plant species composition and colonisation due to ski run construction (Titus and Tsuyuzaki [46]; Ruth-Balaganskaya and Myllynen-Malinen [40]).

Figure 1. Ski run construction on a pasture land
(Photo, courtesy Monterosa Ski Resort)

In other cases, it has been assessed that the creation of ski runs have often induced forest loss and/or fragmentation and upper soil layers removal (Malinen [28]; Tsuyuzaki [47], [48]; Titus and Tsuyuzaki [45]), with consequent severe impacts on plant and animal communities. The vegetation dynamics and the success of re-vegetation decline with altitude (Urbanska [50]), also because of the deterioration of the soil physico-chemical properties (Gros et al. [18]).

In the alpine environment, also because of the harsh climate conditions and steep slopes, former run construction and earth moving needed for topographic adjustment led to site degradation, vegetation removal and soil erosion. In these areas, recurrent rainfalls caused seed runoff, which is one of the main factors hindering vegetation recovery. According to Urbanska [49], Titus and Tsuyuzaki [46] and Ruth-Balaganskaya and Myllynen-Malinen [40], ski run construction is able to induce different soil nutrient status and change plant species composition and colonization.

In fact, to prevent erosion and improve the quality of the landscape, ski runs are often re-vegetated with non native grass species as they are less expensive than native plants and have the ability to quickly establish a sufficient vegetation cover.

Thus, the vegetation composition and colonization is also affected by fertilization and artificial snow (Kammer [23]) and complicated by the use of salts in the snow that can result in environmental impacts that are still not recognized (Rixen et al. [36]).

The construction of ski resorts and slopes and the consequent environmental changes can influence animals ecology and behaviour because of the disappearance of one or more of the factors necessary for their survival.

The most affected animals are those feudatory to soil, in particular small mammals, some bird and mesofauna (arthropods). For example, Menoni and Magnani [30] and Zeitler and Glanzer [55] observed that the expansion of ski resorts caused damages to local population of black grouse (*Tetrao tetrix*), which also suffer mortality induced from collision with cable wires (OGM [33]).

Laiolo and Rolando [27] described negative edge effect on bird species richness and diversity in forests crossed by ski runs, while Amo et al. [1] reported that ski run construction increases the predation risk for lizards, and consequently affects their body condition, because of the elimination of rocks and bushes which favour lizards aggregation (Martin and Salvador [29]). Some authors (Hadley and Wilson [19]; Sanecki et al. [42]) investigated short-term effects of ski runs on the dynamics of small mammal populations in a ski area located in Colorado (USA) and in Kosciuszko National Park (Australia).

Ski resorts and associated infrastructure have the potential power to adversely affect small mammals (*Antechinus swainsonii* and *Rattus fuscipes*) that over-winter in the sub-nivean space (Sanecki et al. [42]).

These winter-active small mammals are dependent on the formation of a sub-nivean space, which occurs under Australian snow conditions only if structural features such as vegetation, boulders and microtopography are present. Negro et al. [31] pointed out the severe impacts of the ski runs in north-western Italian Alps, with negative effects on small mammals and ground animal communities such as spiders and carabids.

2.2. Effects on soil

The soil provides resources such as nutrients and oxygen for the development and growth of vegetation, and is a habitat for organisms, which are important elements in the pedogenesis. Human impact in mountain ecosystems may produce soil quality shifting whose direction and degree of changing depend on climate, soil conditions, and land use.

Because of the multi-factorial nature of the ecosystem, human pressure on mountain environments has modified the land use toward productive systems that resulted in unknown ecological effects. Ecological sustainability of land use requires that soil functions such as biogeochemical cycling, portioning of water, storage and release of nutrients, buffering and energy partitioning be maintained (Sanchez-Maranon et al. [41]).

Mountain soils can be affected by ski slope construction with rocks removal, machine-grading and levelling of the surface.

These operations are carried out mainly during summer months, sometimes by the same operators which are responsible of ski runs management (e.g. snow grooming) during the winter season. Also the snow management during the ski season may strongly influence the soil characteristics of the ski slopes, by snow density changes due to grooming and use of artificial snow. The construction and maintenance of ski runs involves the use of heavy earth-moving machinery to level slopes, provide drainage and create retaining walls that may have strong impacts on the soil.

Impacts may be several and able to strongly affect different soil properties.

2.2.1. Soil structure and texture

Because of the construction of ski runs, the original soil thickness can be reduced, with the loss of the previous soil stratification and resulting in a disordered topsoil. After reduction of soil thickness, the natural watershed may be destroyed and wet zones may begin to occur at the foot of the slope. Then, also soil erosion may become a serious threat as top-soil, rich in gravel, is covered with sparse vegetation.

Descroix and Mathys [10] evaluated the influence of mountain management on alpine erosion, finding that gully erosion and solifluction were sometimes provoked by the development of ski resorts in the Northern Alps (Eglise and Ravoire Torrents downstream of Les Arcs resort, in the upper Isère valley, Savoie as well as in the Southern Alps, for example in Vars).

Slopes that have been disturbed through roadway, ski runs or other constructions often produce more sediments than less disturbed sites, with the loss of nutrient-containing topsoil essential for plant growth (Grismer and Hogan [17]).

The extremely scarce development of the ski slopes soils involves an almost complete lack of structure with subsequent problems of soil compaction and reduction of water and air permeability (Tsuyuzaki [48]). A consequent control of the incipient soil erosion on ski runs was pursued through artificial seeding (Siniscalco et al. [43]; Urbanska et al. [51]) (Figure 2).

Soil aggregation is important because it affects infiltration capacity, hydraulic conductivity, water retention capacity, gas exchange, decomposition of organic material and resistance to erosion (Delgado et al. [9]). Barni et al. [3] found a significant decrease of water aggregate stability in sky runs constructed above timberline and hydro-seeded at different times (4-12 years).

In the same work the soil aggregate breakdown was inversely correlated with the organic matter content. Soil aggregates of the upper soil layer contain fine material, organic substances and soil organisms and they are well known for their high water holding capacity. The destruction of aggregates decreases the soil water retention and therefore the plant-available water, and it encourages a rapid drainage to the underground (Freppaz et al. [11]). As water availability is one of the most important factors for plant growth, and soil hydrological functions (e.g. soil ability to hold certain amount of water to a certain depth) are controlled by soil aggregation, this latter is among the first factors to take into consideration for successful re-vegetation process of a levelled ski slope (Pintar et al. [34]).

Figure 2. Artificial seeding at the end of a ski run construction (Photo, courtesy Monterosa Ski Resort)

Disturbances due to ski run construction also resulted in great changes in particle size distribution and amount of carbon, so influencing aggregate stability and porosity. The soils of ski runs were characterised by the abundance of rock fragments; in fact, the increase rock fragments and sand particles resulted from the mechanical crushing of stones during the ski runs establishment (Gros et al. [18]).

In natural soils of the Sierra Nevada, a significant decrease in clay and organic C content with increasing altitude was found. This tendency was not found in the ski run soils where the influence of management seemed greater than that of the environmental factors (Delgado et al. [9]).

2.2.2. Soil content of nutrients

The soil of the ski runs is subjected to more intense freezing, higher CO_2 content, and changes in pH and nitrogen fixation. Kangas et al. [24] found that both pH and conductivity were significantly higher in ski-runs than in the forests. Similarly, concentrations of K, Mg, Ca were significantly higher on the ski-runs soil than in the forest soil, while the concentration of P tended to be higher on the ski runs than in the forests.

In soil of ski-runs, Delgado et al. [9] found an electrical conductivity value and a calcium carbonate equivalent equal to 0.65 dS m^{-1} and 8.2%, respectively. These values are not normal for soils on felsic rocks under a mean annual precipitation between 970 and 1270 mm, and the apparent discrepancy was found to be due to the application of dolomite, additives for artificial snow production, salts to harden the snow in race runs and fertilizers for grass growth.

An unexpected finding was the relatively high exchangeable sodium percentage (ESP) measured in the soil of ski-runs, although these soils did not display serious sodicity problems. The ESP values ranged between 5.5 and 8.0%, even in soils not managed directly, implying a diffuse contamination with Na caused by the treatment of runs with Na-containing products and by salting of roads.

Downhill movement of the soil solution, continuous reworking of the runs, and wind would have contributed to the contamination. The same authors also noted the lack of correlation between organic carbon content and other properties of the run soils.

When the data of the undisturbed site were excluded, cation exchange capacity, water retention at 33 and 1500 kPa, total N and exchangeable K were positively correlated with the clay content, but not with organic C.

Thus, it seemed that the effect of organic material on water retention and ion adsorption had been reduced by ski runs preparation. In that case, the soils of the ski runs showed a low organic matter content, but the degree of humification of the soil organic matter, as indicated by the C:N and humic: fulvic ratios, was similar to that of the natural soils because of the climatic and pedogenic factors, similar in both natural and disturbed soils.

2.2.3. Soil as habitat for microorganisms

Gros et al. [18] observed that ski runs are degraded ecosystems which need to restore relationships between soil physico-chemical properties, plant colonization and soil microbial activity. In fact, along a chronosequence of restored alpine grasslands they observed that recurrent changes in microbial habitats, such as aggregate-size habitats and rhizosphere soil, and heterogeneous resource input, had initiate shifts in the structure of the microbial community.

In this case study, microbial communities resulted very unstable during the early stage of ski run operation (<13 years) and ski run construction and rehabilitation processes induced wide and long lasting changes of soil microbial life.

As ski run construction promotes aggregate breakdown, it may induce the release and subsequent degradation of previously protected organic matter. Potential N_2 fixation slightly increased during the first year of restoration, to strongly increased in the successive stages. Soil respiration in these runs was also low, indicating that 13–14 years is a too short time for the stabilization of biological activity in these soils.

3. Effect of snowpack management on soil

During the ski season, snow-management vehicles and skiers compact the snow, alter the depth and density of the snowpack, increase thermal conductivity and duration of the snow and decrease gas exchange between the snow surface and the base. Vegetation and soil are likely to be degraded by these processes (Wood [54]; Rixen et al. [36]).

In Scotland, Bayfield [5] reported little subsequent disturbance of the seeded ground as winter damage by skiing was largely prevented by the cushioning effect of snow, while in summer most damage from walkers was minimized by canalizing use along gravel-surfaced vehicle trails and footpaths.

In particular, the mechanical impact on the soil surface by skiers and snow-grooming vehicles is likely higher on runs with natural snow than with artificial snow (Rixen et al. [36]; Rixen et al. [38]). However, the groomed snow on ski slopes has a reduced insulation capacity and the ground may freeze, with subsequent effects on soil nutrient dynamics and plant development.

On ski runs, Newesely [32] found indications that the increased thermal conductivity of compacted snow can cause severe frost in the soil.

Rixen et al. [39], in a snow density manipulation study, found that a denser and thinner snow cover led to reduced soil insulation and lower soil temperatures, which consequently increased net N mineralization. On ski runs, Newesely [32] found indications that the increased thermal conductivity of compacted snow can cause severe frost in the soil. A denser snow cover furthermore resulted in a delay in plant phenology of up to five weeks after melt-out.

With the ongoing intensification of ski resorts, the use of artificial snow will become more prevalent (Freppaz et al. [13]) and the vegetation will change over an increasing area. The use of artificial snow has a considerable effect.

On runs with natural snow, the thin and compacted snow cover led to severe and long lasting seasonal soil frost. Winter soil temperature regime can directly affect soil nutrient status (Freppaz et al. [12], b; Freppaz et al. [14]). Microbes can be active below 0°C (Brooks et al. [6]) and thus have an impact on the N cycling in the soil (Brooks and Williams [7]) and the N availability for plants even during the winter.

Hence, preventing frost in soils that are usually not exposed to temperatures much below freezing can be considered as beneficial. Interestingly, the ground temperatures on runs with naturals snow showed parallel characteristics to those from permafrost sites (Haeberli [20]).

The ground cooling in the ski runs may, in the long run, change the runs into slopes of coarse debris (Haeberli [20]), with considerably increased erosion problems. If permafrost is induced on a ski run, feedback mechanisms like increased lateral runoff can further enhance erosion. However, it has still to be proved that permafrost can be introduced by ski run preparation (Rixen et al. [37]).

On runs with artificial snow, soil frost occurred less frequently because of increased insulation due to the greater snow depth. However, due to the greater snow mass, the beginning of the snow-free season was delayed by more than 2 weeks (Rixen et al. [37]; Keller et al. [25]).

The late melting of the artificial snow can additionally increase the erosion risk in the warm season.

The impact on soil from the addition of water, ions, bacteria and salts through artificial snow production is unclear (Rixen et al. [36]). In soils down to a depth of 15 cm, Kammer and Hegg [22] recorded significantly higher pH-values on snowed runs compared to control plots.

They attributed the differences to the high pH of the river water that was used for snow production. Salts are used for ski run preparation, especially on race runs, to improve the snow quality for skiing purposes, for example, if snow is too cold, too sticky or hard ice (USSA [52]; Raguso [35]).

Comparable to salts used on roads, the chemicals used on ski runs melt the uppermost layer of the snowpack and thus change the snow quality (Kobayashi et al. [26]).

4. Conclusions

Ski recreation represents an intensive form of land use that has considerable impacts on mountain ecosystems. In general, ski run construction and management have a greater influence on the soil properties than other environmental factors.

With the ongoing intensification of ski resorts, the use of artificial snow will become more prevalent and the vegetation will change over an increasing area. Moreover, impacts of artificial snowing are cumulative and will become even more pronounced in the long term.

In summary, mountain regions with a high proportion of areas with extensive outdoor recreation activities, like the European Alps, are facing continuous change of their traditional unique environment and vegetation.

Therefore, it could be recommended that environmental goals in ski resort management should be established and respected. In particular, we recommend carefully recording the vegetation and soil characteristics in a specific area before any intensification of use as ski run, and complete avoidance of areas with vegetation of particularly high conservation value.

Acknowledgments

The chapter was written in the framework of the “Progetto di Rilevanza Nazionale (PRIN 2007) *Impatto delle piste da sci sulla temperatura e la dinamica dell’azoto nel suolo*. Thanks for the technical and logistic support to Monterosa 2000, Monterosa SpA and Sagit SpA (Monterosa Ski Resort).

References

1. *Amo, L., P. López, Martín, J. (2007). .Habitat deterioration affects body condition of lizards: a behavioral approach with Iberolacerta cyreni lizards inhabiting ski resorts. Biol. Conserv. 135:77–85.*
2. *Arrowsmith, C. and Inbakaran, R. (2002). .Estimating environmental resiliency for the Grampians National Park, Victoria, Australia: a quantitative approach. Tour Manag. 23:295–309.*
3. *Barni, E., Freppaz, M.,and Siniscalco, C. (2007).* **.***Interactions between vegetation, roots and soil stability in restored high altitude ski runs on the Western Alps, Italy. Arctic Antarctic and Alpine Research 39:25-33.*
4. *Bayfield, N. G. (1980). .Replacement of vegetation on disturbed ground near ski lifts in the Cairngorm Mountains, Scotland. Journal of Biogeography 7:249–260.*
5. *Bayfield, N. G. (1996).* **.***Long-term changes in colonization of bulldozed ski runs at Cairn Gorm, Scotland. Journal of Applied Ecology 33:1359-1365.*
6. *Brooks, P. D., Williams, M. W.,and Schmidt, S. K. (1996). .Microbial activity under alpine snowpacks, Niwot Ridge, Colorado. Biogeochemistry 32:93–113.*
7. *Brooks, P. D. and Williams, M. W. (1999). .Snowpack controls on nitrogen cycling and export in seasonally snow-covered catchments. Hydrological Processes 13:2177–2190.*
8. *David G. C. L., Bledsoe B. P., Merritt D. M., Wohl E. (2009). .The impacts of ski slope development on stream channel morphology in the White River National Forest, Colorado, USA. Geomorphology 103:375–388.*
9. *Delgado R., Sanchez-Maranon M., Martin-Garcia J. M., Aranda V., Serrano-Bernardo F., Rosua J. L. (2007). .Impact of ski runs on soil properties: a case study from a mountainous area in the Mediterranean region. Soil Use and Management 23:269-277.*
10. *Descroix, L. and Mathys, N. (2003).* **.***Processes, Spatio-temporal factors and measurements of current erosion in the French Southern Alps: a review. Earth Surface Processes Landforms 28:993–1011.*

11. *Freppaz M., Lunardi S., Bonifacio E., Scalenghe R.,and Zanini E. (2002).* **.***Ski slopes and stability of soil aggregates. In: Pagliai M., Jones R. (Eds.) Advances in GeoEcology 35, Sustainable Land Management-Environmental Protection, Catena Verlag, Reiskirchen, Germany, pp.125-132.*
12. *Freppaz M., Williams B.L., Edwards A.C., Scalenghe R.,and Zanini E. (2007).* **.***Labile nitrogen, carbon, and phosphorus pools and nitrogen mineralization and immobilization rates at low temperatures in*

seasonally snow-covered soils,. Biology and Fertility of Soils 43:519-529.

13. *Freppaz M., Filippa G., Francione C., Cucchi M., Colla A., Maggioni M., and Zanini E. (2008). .Artificial snow production with respect to the altitude: a case study in the Italian Western Alps. Geophysical Research Abstracts, Vol. 10, EGU 2008-A-9801, 2008. EGU General Assembly 2008.*
14. *Freppaz M., Icardi M., Filippa G.,and Zanini E. (2009). .Soil nitrogen dynamics in high-altitude ski runs during the winter season (Monterosaski - Vallée d'Aoste – Italy). Geophysical Research Abstracts, Vol. 11, EGU 2009-9065, 2009. EGU General Assembly 2009.*
15. *Geneletti, D. (2008). .Impact assessment of proposed ski areas: A GIS approach integrating biological, physical and landscape indicators. Environmental Impact Assessment Review 28:116–130.*
16. *Geneletti, D., and Dawa, D. (2009). .Environmental impact assess,emt of mountain tourism in developing regions: a study in Ladakh, Indian Himalaya. Environmental Impact assessment Review 29:229-242.*
17. *Grismer, M. E. and Hogan, M. P. (2005). .Simulated rainfall evaluation of revegetation/mulch erosion control in the lake Tahoe basin: 2. bare soil assessment. Land degradation and development 16:397-404.*
18. *Gros R., Monrozier L. J., Bartoli F., Chotte J. L., Faivre P. (2004). .Relationships between soil physico-chemical properties and microbial activity along a restoration chronosequence of alpine grasslands following ski run construction. Applied Soil Ecology 27:7-22.*
19. *Hadley, G. L. and Wilson, K. R. (2004). .Patterns of density and survival in small mammals in ski runs and adjacent forest patches. Journal od Wildl. Manage. 68:288-298.*
20. *Haeberli, W. (1992). .Construction, environmental problems and natural hazards in periglacial mountain belts. Permafrost and Periglacial Processes 3:111-124.*
21. *Haimayer, P. (1989). .Glacier-skiing areas in Austria: a socio-political perspective. Mountain Research and Development 9:51–58.*
22. *Kammer, P., Hegg O. (1990). .Auswirkungen von Kunstschnee auf subalpine Rasenvegetation. Verhandlungen der Gesellschaft für Ökologie 19:758–767.*
23. *Kammer P. M. (2002). .Floristic changes in subalpine grasslands after 22 years of artificial snowing. Journal of Nature Conservation 10:109–123.*

24. *Kangas K., Tolvanen A., Kälkäjä T., Siikamäki P. (2009). .Ecological impacts of revegetation and management of ski slopes in northern Finland. Environmental Management 44:408–419.*
25. *Keller, T., Pielmeier, C., Rixen, C., Gadient, F., Gustoffson, D.,and Stahli, M. (2004). .Impact of artificial snow and ski-slope grooming on snowpack properties and soil thermal regime in a sub-alpine ski area. Annals of Glaciology 38:314-318.*
26. *Kobayashi T., Endo, Y., and Nohguchi, Y. (2000). .Hardening of snow surface – 'natural/artificial'. In: Proceedings of the fourth International Conference on Snow Engineering: Snow Engineering: Recent Advances and Developments, E. Hjorth- Hansen, I. Holand, S. Löset and H., Norem (eds.), pp. 99–103, Trondheim, Norway.*
27. *Laiolo P. and Rolando A. (2005). .Forest bird diversity and ski runs: a case of negative edge effect. Animal Conservation 8:9–16.*
28. *Malinen, K. (1991). .Ympäristön kunnostuksen näkökulma laskettelurinteiden kasvillisuuden palautamiseen pohjois-suomessa. Acta Universitatis Ouluensis C97:305-317.*
29. *Martin, J. and Salvador, A. (1995). .Microhabitat selection by the Iberian rock lizard Lacerta monticola: effects on density and spatial distribution of individuals. Biological Conservation 79:303-307.*
30. *Menoni, E. and Magnani, Y. (1998). .Human disturbance of grouse in France. Grouse News 15:4-8.*
31. *Negro M., Isaia M., Palestrini C., and Rolando A. (2009). .The impact of forest ski-runs on diversity of ground-dwelling arthropods and small mammals in the Alps. Biodivers. Conserv. 18:2799–2821.*
32. *Newesely, C. (1997). .Auswirkungen der kiinstlichen Beschneiungv on Schirunn auf Aufbau, Struktur und Gasdurchlassigkeit der Schneedecke, sowie auf den Verlauf der Bodentemperaturun das Auftreten von Bodenfrost. Ph. Dissertation, Naturwissenschaftliche Fakultit, Leopold Franzens Universitait, Innsbruck. 239 pp.*
33. *OGM [Observatoire de Galliformes de Montagne]. (2006). .Percussion dex oiseux dans le cáble áeriens des domaines skiables. Report n°4.*
34. *Pintar M., Mali B.,and Kraigher H. (2009). .The impact of ski slopes management on Krvavec ski resort (Slovenia) on hydrological functions of soils. Biologia 64:639-642.*
35. *Raguso, V. (2000). .Alpine Education Guidebook. Alpine ski racing education series. New York State Ski Racing Association (NYSSRA).*
36. *Rixen, C., Stoeckli, V. and Ammann, W. (2003). .Does artificial show production affect soil and vegetation of ski runs? A review. Perspectives in Plant Ecology, Evolution and Systematics 5, 219– 230.*
37. *Rixen, C., Casteller, A., Schweingruber, F. H., and Stoeckli, V. (2004a). .Age analysis helps to estimate plant performance on ski runs. Botanica Helvetica 114:127-138.*

38. *Rixen C., Haeberli W.,and Stoeckli V. (2004b). .Ground temperatures under ski runs with artificial and natural snow. Arctic, Antarctic and Alpine Research 36: 419-427.*
39. *Rixen C., Freppaz M., Stoeckli V., Huovinen C., Huovinen K.,and Wipf S. (2008). .Altered snow density and chemistry change soil nitrogen mineralization and plant growth. Arctic Antarctic and Alpine Research 40:568-575.*
40. *Ruth-Balaganskaya, E., and Myllynen-Malinen, K. (2000). .Soil nutrient status and revegetation practices of downhill skiing areas in Finnish Lapland-a case study of Mt. Ylläs. Landscape Urb. Plann. 50:259–268.*
41. *Sanchez-Maranon, M., Soriano, M., Delgado, G., Delgado, R. (2002). .Soil quality in Mediterranean mountain environments: effects of land use. Soil Sci. Soc. Am. J. 66:948–958.*
42. *Sanecki G. M., K. Green, Wood, H., Lindenmayer, D. (2006). .The implications of snow-based recreation for small mammals in the subnivean space in south-east Australia. Biological Conservation 129:511-518.*
43. *Siniscalco C., Barni E., Rosa A., Montacchini, F. (1997). .Vegetation dynamics after seeding in Susa Valley ski runs (W-Italian Alps). Rev. Valdotaine d'Hist. Nat. 48:307–315.*
44. *Stern, R. (1983). .Human impact on tree borderlines. In: Holzner, W.,Weger, J.A., Ikusima, I. (Eds.), Man's Impact on Vegetation. Dr. Junk Publishers, The Hague, pp. 227–236.*
45. *Titus, J. H. and Tsuyuzaki S. (1998). .Ski slope vegetation at Snogualmie Pass, Washington State, USA, and a comparison with ski slope vegetation in temperate coniferous forest zones. Ecological Research 13:97–104.*
46. *Titus, J. H. and Tsuyuzaki, S. (1999). .Ski slope vegetation of mount Hood, Oregon, USA. Arctic Antarctic Alpine Res. 13:97–104.*
47. *Tsuyuzaki, S. (1993). .Recent vegetation and prediction of successional sere on ski grounds in the higlands of Hokkaido, northern Japan. Biological Conservation 63:225–260.*
48. *Tsuyuzaki, S. (1994). .Environmental deterioration resulting from skiresort construction in Japan. Environmental Conservation 21:121–125.*
49. *Urbanska, K. M. (1995). .Biodiversity assessment in ecological restoration above the timberline. Biodiv. Conserv. 4:679–695.*
50. *Urbanska, K. M. (1997). .Restoration ecology research above the timberline: colonization of safety highlands on a machine-graded alpine ski run. Biodiv. Conserv. 6:1655-1670.*

51. Urbanska, K. M., Erdt, S., Fattorini, M. (1998). .Seed rain in natural grassland and adjacent ski run in the Swiss Alps: a preliminary report. Restor. Ecol. 6:159–165.
52. USSA, (1996). .Alpine Officials Manual, US Skiing, Chapter VII, The Race Course. US Ski and Snowboard Association (USSA).
53. Watson, A. (1985). .Soil erosion and vegetation damage near ski lifts at Cairngorm, Scotland. Biological Conservation 33:363–381.
54. Wood, T. F. (1987). .Methods for assessing relative risk of damage to soils and vegetation arising from winter sports development in the Scottish highlands. Journal of Environmental Management 25:253–270.
55. Zeitler, A. and Glanzer, U., (1998). Skiing and grouse in the Bavarian Alps. Grose News 15:8-12.

- Aiyagari,, S. R. and Wallace, N. (1991). .Existence of Steady States with Positive Consumption in Aiyagari the Kiyotaki.Wright Model,. Review of Economic Studies 58, 901.916.
- Butlin, S. J. (1968). Foundations of the Australian Monetary System 1788.1851. Sydney: Sydney Univ. Press.
- Cavalcanti, R. de O., Erosa, A., and Temzelides, T. (1997). .Private Money and Reserve Management in a Random Matching Model,. University of Western Ontario, Research Report 9715, Department of Economics.
- Diamond, P. A. (1990). .Pairwise Credit in Search Equilibrium,. Quarterly Journal of Economics 105, 285.319.