LIFE PASTORALP

LIFE16 CCA/IT/000060

Pastures vulnerability and adaptation strategies to climate change impacts in the Alps

Deliverable C2

Pastures typologies survey and mapping

May, 2021

LIFE PASTORALP

Pastures vulnerability and adaptation strategies to climate change impacts in the Alps

Acknowledgements

This report was produced under co-finance of the EC LIFE programme for the Environment and Climate Action (2014-2020), in the framework of Action C.2 “Pastures typologies survey and mapping” of the project LIFE PASTORALP (LIFE16 CCA/IT/000060) “Pastures vulnerability and adaptation strategies to climate change impacts in the Alps”.

The project is being implemented by the following beneficiaries:

University of Florence – UNIFI

Agenzia Regionale Protezione Ambiente - Aosta Valley - ARPA VDA

Centre National de la Recherche Scientifique - CNRS

Institut Agricole Régional – IAR

Institut National de la Recherche pour l’Agriculture, l’Alimentation et l’Environnement – INRAE

Parc National des Écrins – PNE

Ente Parco Nazionale Gran Paradiso – PNGP

Authors

Author(s)	Organisation(s)	E-mail (s)
Mauro Bassignana Anaïs Piccot	Institut Agricole Régional - IAR - Aosta (Italy)	m.bassignana@iaraosta.it a.piccot@iaraosta.it
Edoardo Cremonese Gianluca Filippa Marta Galvagno	Agenzia Regionale Protezione Ambiente - Valle d'Aosta - ARPA VDA (Italy)	e.cremonese@arpa.vda.it gian.filippa@gmail.com m.galvagno@arpa.vda.it
Philippe Choler Arthur Bayle	Centre National de la Recherche Scientifique – CNRS (France)	philippe.choler@univ-grenoble-alpes.fr arthur.bayle@univ-grenoble-alpes.fr
Laura Poggio	Ente Parco Nazionale Gran Paradiso - PNGP (Italy)	laura.poggio@pngp.it

The authors would like to recognise the contribution of PNE colleagues and IAR and PNGP consultants, expert pastoralists, who carried out the vegetation survey in the field and produced the maps of pasture types in the Gran Paradiso National Park and the Ecrins National Park:

- Valentina Andreo;
- Roberta Benetti;
- Giampaolo Bruno;
- Mauro Coppa;
- Maurizio Odasso;
- Camilla Scalabrini;
- Muriel Dellavedova;
- Hermann Dodier;
- Ariane Silhol;
- Simon Vieux.

Contents

Acknowledgements 2
Authors 3
Contents 4
Executive summary 5
1) Methodological approaches: harmonizing pasture classifications 6
2) Field mapping of pasture types in PNGP 10
Materials and methods 10
Subdivision of the PNGP territory in Pasture districts 10
Base cartography 11
Photo-interpretation and initial identification of alpine pastures 12
Field validation 14
Identification of the pasture type 15
Pasture districts 18
Pasture district n. 101 Agnel 18
Pasture district n. 102 Alto Vallone di Campiglia 22
Pasture district n. 103 Bardoney 26
Pasture district n. 104 Bastalon 30
Pasture district n. 105 Benevolo 33
Pasture district n. 106 Djouan-Orvieilles 36
Pasture district n. 107 Entrelor 39
Pasture district n. 108 Gran Loson 42
Pasture district n. 109 Lago di Dres 46
Pasture district n. 110 Levionaz 48
Pasture district n. 111 Meyes 52
Pasture district n. 112 Nivolet 55
Pasture district n. 113 Noaschetta 58
Pasture district n. 114 Punta dell'Orletto 61
Pasture district n. 115 San Besso 65
Pasture district n. 116 Urtier 68
Pasture district n. 117 Vallone di Piamprato 72
Pasture district n. 118 Vallone Ciamoseretto 76
Pasture district n. 119 Vallone di Forzo 79
Pasture district n. 120 Vallone di Piantonetto 82
Pasture district n. 121 Vallone Roc 85
Pasture district n. 122 Vaudala 88
Pasture district n. 123 Vaudaletta 90
Outcomes 93
3) Remote sensing and development of modelling approaches 98
3.1 Modelling the distribution of pasture types using random forest models 98
Modelling pasture distribution in PNGP 103
3.2 Predicting the distribution of pasture types in PNE using a simple decision tree 113
Methods 114
Remote sensing data and climate variables 116
Decision tree and predictive mapping of pasture types 119
Discussion & perspectives 123
Prospects and future 123
References 124

EXECUTIVE SUMMARY

With the aim of obtaining an updated cartography of the PNGP and PNE pasture vegetation, the grassland types have been inventoried integrating field surveys and remotely sensed data. The cartography will be the reference for further analysis of land cover dynamics related to climate and land use changes.

The pasture mapping activity involved the PNE and PNGP territories differently.

In the PNE, some pasture maps produced under the "Alpages Sentinelles" programme were already available. The field work allowed to add six more pasture maps and to resurvey for a total of 2563 ha mapped.

In the PNGP, on the other hand, the surveys and mapping activities were done *ex novo*. All mountain pastures of PNGP and closest surroundings, for a total of about 8000 ha, were involved.

The action was developed in 3 steps:

1) In order to conform methodologies of pasture mapping between the partners a coordination phase was essential. Meetings and field tours were therefore organised in PNE and PNGP.

The territories of the two Parks lie in the validity zones of three different vegetation typologies, which classify the main plant communities that can be found in subalpine and alpine pastures in French Southern Alps (Jouglet, 1999), Vanoise and Aosta Valley (Bornard et al., 2007) or Piedmont (Cavallero et al., 2007). Categorization criteria were harmonised between the three classifications and common 13 pasture categories were developed.

This common and shared methodology is not only deployed throughout the project lifetime, but that can also be used in the future in these areas and potentially extended to the whole western Alps.

2) The mountain grassland types have been identified by field visual assessments, and mapped according to the existing pasture typologies. This action was implemented in the territories of PNGP and closest surroundings (Orco, Cogne and Rhêmes Valleys) as well in targeted pastoral units of PNE.

3) We used existing and new remote sensing data to implement innovative ways of mapping the main types of mountain pastures at a relevant scale for pastoral management. Whenever feasible, a special attention was paid to the cross-validation between field and satellite data. This result was achieved through these steps: a) identification and characterization of a number of properly representative surfaces to cover the range of variation in representative plots; b) processing and analysis of remotely sensed data to select the spectral indices capable of best discriminating the different vegetation types; c) validation of the detection algorithms through the comparison of results derived from satellite imagery with real vegetation on the ground.

At all stages of this working flow, there has been an exemplary cooperation between Italian and French beneficiaries - including academics and protected areas. The result is an agreed typology of mountain pastures that will be of high relevance for pastoral management and the sharing of data, methods and field experience to map mountain vegetation.

1) METHODOLOGICAL APPROACHES: HARMONIZING PASTURE CLASSIFICATIONS

With the aim of sharing the methodological approach carried out for pasture mapping, technical meetings and field surveys were done both in PNE and in PNGP.

PASTORALP researchers and consultants followed a common protocol of pasture classification widely discussed and agreed especially with IAR, PNGP and PNE. Exchange visits and remote technical meetings as well face-to face have been organized to this aim:

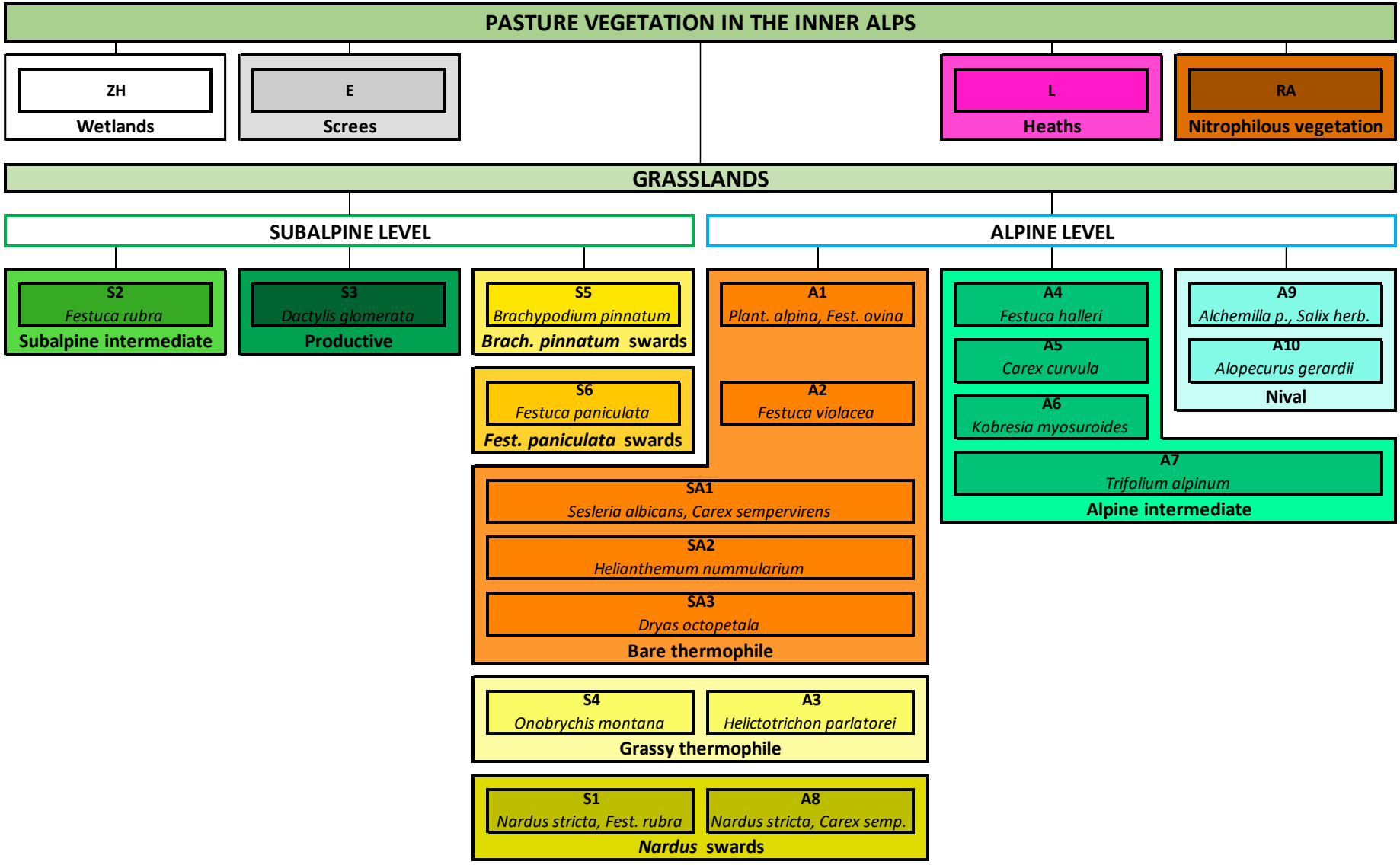
- 17-18 July 2018 PNE and INRAE-Ecodev visited the pasture areas of PNGP;
- 3-4 September 2018 an Italian delegation IAR and PNGP and representatives of INRAE-Ecodev visited mountain pasture areas of Tramouillon and Crouzet, Les Lauzes in PNE;
- 15 January 2019 a technical meeting was organized in Grenoble with IAR, CNRS, INRAE-IRSTEA, and the Laboratoire d'Écologie Alpine to examine the difficulties encountered in relation to the typological approach, evaluate and review the contribution of remote sensing to diagnosis and mapping of mountain pastures;
- 26th February 2019 among ARPA VdA, IAR and CNRS at PNGP;
- June 19th and 20th 2019, IAR and PNGP researchers and consultants received the PNE botanists on the mountain pastures of Ceresole Reale and Cogne.

In order to accurately represent the grasslands cover of the ground, three different vegetation typologies were used for mapping highland pastures. These typologies classify the main pasture plant associations in the validity zones of Vanoise and Aosta Valley (Bornard et al., 2007), Piedmont (Cavallero et al., 2007) and French Southern Alps (Jouglet, 1999).

A coordination phase made it possible to harmonise the three classifications and define 13 common pasture categories from the Aosta Valley typology:

- **Productive**: vegetation in flatlands and low slopes of the subalpine level with rich soil. Very tall (over 50 cm) and very dense vegetation dominated by broad-leaved graminaceae.
- **Subalpine intermediate**: vegetation in flatlands and low slopes of the subalpine level with medium-rich soil. 30 to 50 cm high, dense grassy patches dominated by fine to medium-leaved graminaceae.
- **Nardus swards**: on lowlands and slopes in the subalpine or alpine level, vegetation of medium height (20-30 cm), not very dense, dominated by *Nardus stricta*.
- **Grassy thermophile**: on medium and steepy sunny slopes in the subalpine and alpine level, on dry and fairly deep soil. 30 to 50 cm high, very dense vegetation with almost total herbaceous cover.
- **Festuca paniculata swards**: on medium sunny slopes in the subalpine level, vegetation very tall (over 50 cm), very dense, dominated by graminaceae with long, thick leaves, especially *Festuca paniculata*.
- **Brachypodium pinnatum swards**: on medium sunny slopes in the subalpine level, vegetation of medium height (20-30 cm), dense, dominated by *Brachypodium pinnatum*.
- **Bare thermophile**: medium to steep south-facing slopes in the subalpine and alpine level with dry soil.
- **Alpine intermediate**: sparse vegetation on medium to moderate slopes, windy ridges and bumps in the alpine level.
- **Nival**: sparse vegetation in snow combes and moderate slopes in alpine and nival environment.
- **Heaths:** vegetation with a shrub and herb layer in the subalpine and alpine environment.

- **Nitrophilous vegetation**: in flatlands and moderate slopes of the subalpine level; these herbaceous formations, dominated by nitrophilous species, develop in areas of accumulation and excess of manure.
- **Screes:** areas with more than 50% of the surface occupied by stones and rocks, on steep slopes, located under ridges or rock bars.
- **Wetlands:** very wet areas with temporary or permanent excess of water.


PASTURE VEGETATION IN THE INNER ALPS
ZH
Wetlands
E
Screes
L
Heaths
RA
Nitrophilous vegetation
GRASSLANDS
SUBALPINE LEVEL
ALPINE LEVEL
S2
Festuca rubra
Subalpine intermediate
S3
Dactylis glomerata
Productive
S5
Brachypodium pinnatum
Brach. pinnatum swards
S6
Festuca paniculata
Fest. paniculata swards
A1
Plant. alpina, Fest. ovina
A2
Festuca violacea
SA1
Sesleria albicans, Carex sempervirens
SA2
Helianthemum nummularium
SA3
Dryas octopetala
Bare thermophile
S4
Onobrychis montana
A3
Helictotrichon parlatorei
Grassy thermophile
S1
Nardus stricta, Fest. rubra
A8
Nardus stricta, Carex semp.
Nardus swards
A4
Festuca halleri
A5
Carex curvula
A6
Kobresia myosuroides
A7
Trifolium alpinum
Alpine intermediate
A9
Alchemilla p., Salix herb.
A10
Alopecurus gerardii
Nival

A great deal of work was carried out by IAR, PNGP and PNE to determine correspondences between the three vegetation typologies used.
As far as the Piedmontese types are concerned, only the pasture types found in PNGP field surveys were classified as they were the only ones of interest for the purposes of the pasture mapping work.
The pasture types of the three typologies were then classified into the 13 identified categories:

PASTURE CATEGORY	AOSTA VALLEY - VANOISE TYPES	PIEDMONT TYPES	FRENCH SOUTHERN ALPS TYPES
Productive	S3	8, 56, 57, 59	
Subalpine intermediate	S2	52, 53, 54, 60, 64,	PI3
Nardus swards	S1, A8	29, 30, 32, 41, 47, 48, 49, 61	PI2, PI4
Grassy thermophile	A3, S4	11, 40	PT1
F. paniculata swards	S6	26	PI6, PI7
B. pinnatum swards	S5	3, 25	PT2, PI5
Bare thermophile	SA1, SA2, SA3, A1, A2	13, 17, 19, 24, 46, 50	PT3, PT4, PI1
Alpine intermediate	A4, A5, A6, A7	21, 22, 33, 35, 36, 37	PT5
Nival	A9, A10	72, 74, 75, 76, 77, 79	PN1, PN2, PN3, PN4
Heaths	L1, L2, L3	90, 91, 92	F1, F2, F3, F4
Nitrophilous vegetation		67, 69	RA1, RA2
Screes	E	70	E1, E2
Wetlands	ZH	81, 86	ZH1, ZH2

Table 1. Pasture type correspondences between the three vegetation typologies of the study area.

The above classification was used for the recognition and mapping of pasture types in PNGP, as described below.

2) FIELD MAPPING OF PASTURE TYPES IN PNGP

Materials and methods

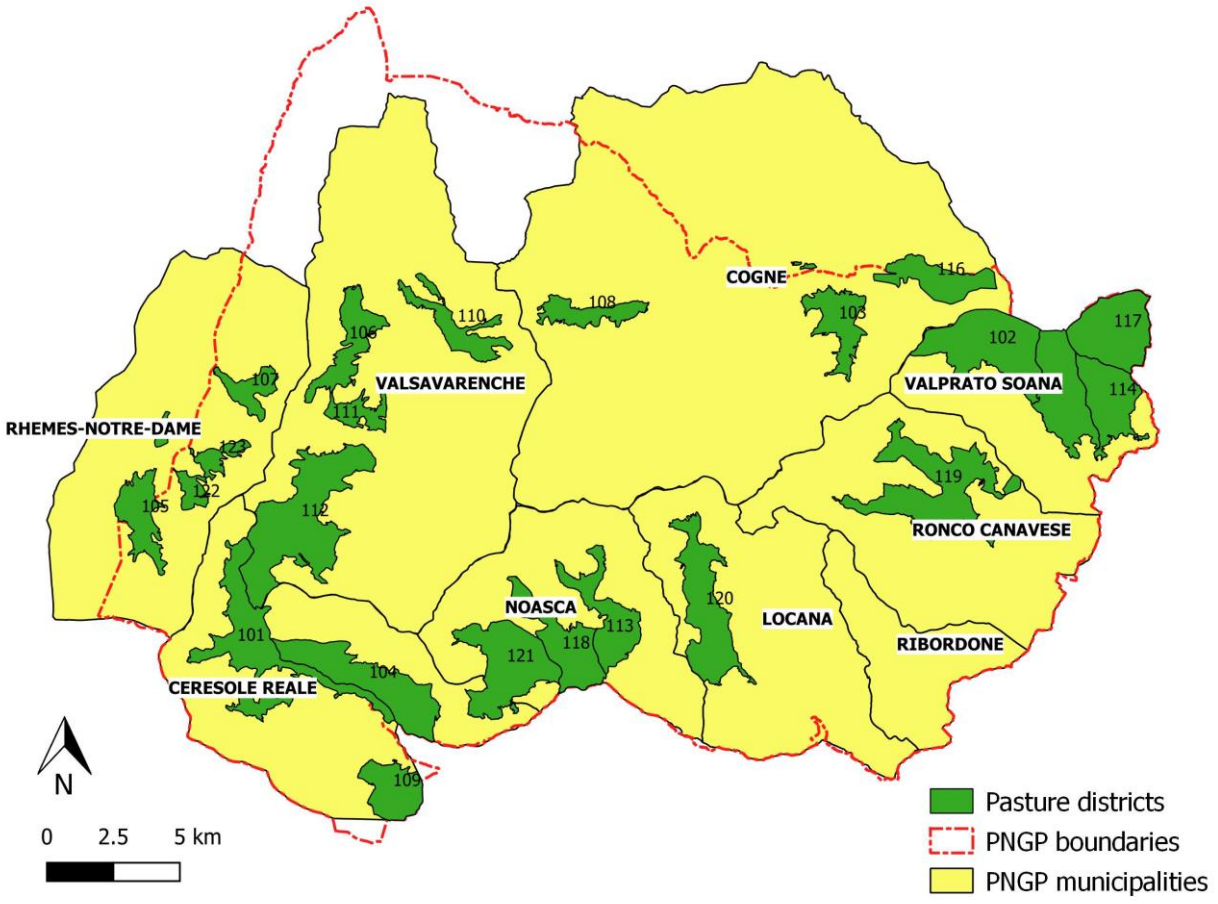
Subdivision of the PNGP territory in Pasture districts

The activity of surveying and cartographic restitution of pasture types was carried out on all the alpine grasslands in PNGP, whose territory extends over two regions: Aosta Valley and Piedmont.

In Aosta Valley the alpine pasture vegetation in PNGP involved the municipalities of Cogne, Rhêmes Notre-Dame and Valsavarenche. On the Piedmont side of the park, the activity involved the municipalities of Ceresole Reale, Locana, Noasca, Ronco Canavese and Valprato Soana.

The grasslands have been subdivided into Pasture districts whose names roughly correspond to the main valleys or localities in which they fall.

In the Orco, Rhêmes and Cogne valleys the survey of pasture types involved some areas located just outside the Park boundaries, in order to include and guarantee the continuity of the whole pasture system named “alpeggio”. For example, in the case of the Benevolo district (Val di Rhêmes), the Fond alpine pasture is only partly included in the park, so the remaining part of the pastures, which in any case fall within the SCI "Ambienti calcarei d'alta quota della Valle di Rhêmes", and the lower Fos pasture were included. In the Bardoney district (Cogne), pasture areas detached from the Bardoney alpine pasture have been included, as these are pastures (Goilles, Etzelley) of the same mountain pasture line; Goilles and Etzelley are also located in protected areas: the SCI "Vallone dell'Urtier" and the SPA "Mont Avic and Mont Emilius".



The following table shows the name and the code of Pasture districts and the municipality and region in which they are located. The district codes have been allocated in predominantly alphabetical order.

Pasture district code	Pasture district name	Municipality	Region
101	Agnel	Ceresole Reale (TO)	Piedmont
102	Alto vallone di Campiglia	Valprato Soana (TO)	Piedmont
103	Bardoney	Cogne (AO)	Aosta Valley
104	Bastalon	Ceresole Reale (TO)	Piedmont
105	Benevolo	Rhêmes Notre-Dame (AO)	Aosta Valley
106	Djouan	Valsavarenche (AO)	Aosta Valley
107	Entrelor	Rhêmes Notre-Dame (AO)	Aosta Valley
108	Gran Loson	Cogne (AO)	Aosta Valley
109	Lago di Dres	Ceresole Reale (TO)	Piedmont
110	Levionaz	Valsavarenche (AO)	Aosta Valley
111	Meyes	Valsavarenche (AO)	Aosta Valley
112	Nivolet	Valsavarenche (AO)	Aosta Valley
113	Noaschetta	Noasca (TO)	Piedmont
114	Punta dell'Orletto	Valprato Soana (TO)	Piedmont
115	San Besso	Valprato Soana (TO)	Piedmont
116	Urtier	Cogne (AO)	Aosta Valley
117	Valle di Piamprato	Valprato Soana (TO)	Piedmont
118	Vallone Ciamoseretto	Noasca (TO)	Piedmont
119	Valle di Forzo	Ronco Canavese (TO)	Piedmont
120	Vallone di Piantonetto	Locana (TO)	Piedmont
121	Vallone Roc	Noasca, Ceresole Reale (TO)	Piedmont
122	Vaudala	Rhêmes Notre-Dame (AO)	Aosta Valley
123	Vaudalettaz	Rhêmes Notre-Dame (AO)	Aosta Valley

Table 2. List of Pasture districts.

The high grasslands of PNGP were subdivided into 23 Pasture districts for a total surveyed surface of 8022 ha.

Considering the vast extension of the territory and the very short vegetation season at high altitudes, PNGP and IAR commissioned six consultants to recognize the pasture types and draw up the pasture maps.

The consultants were chosen by IAR and PNGP through a call for tenders to select pasture experts. Six professionals, either agronomists or foresters, who normally work in the western Italian Alps were therefore recruited.

These activities were carried out and completed over the course of two years (2018, 2019).

Base cartography

Prior to the fieldwork, the consultants carried out a first definition of mountain pastures and their delimitation into homogeneous areas by photo-interpretation. The following base cartography was used, distinguished in the two Regions on which PNGP insists:

- DTM with 5 m pitch (Piedmont Region, 2009-2011) and 2 m pitch (Autonomous Region of Aosta Valley, 2008);
- Orthophotos (year of shooting 2012), WMS service of the National Cartographic Portal of the Ministry for the Environment, Land and Sea;

- Orthophotos of Piedmont Region (2010) and Autonomous Region of Aosta Valley (2012).
- CTRN for the Autonomous Region of Aosta Valley (year 2003) and BDTRE for Piedmont Region (year 2018);
- ICE aerial photography for the Piedmont Region (year 2009-2011) and infrared aerial photography (provided by PNGP, year 2012).

The two regions use different coordinate systems for cartography: Piedmont adopts the WGS 84 / UTM zone 32N while Aosta Valley ED50 / UTM zone 32N.

For the cartography in question it was decided to adopt a univocal coordinate reference system for the entire park territory, i.e. WGS 84 / UTM zone 32N (EPSG: 32632).

Photo-interpretation and initial identification of alpine pastures

An initial analysis of the grasslands was carried out starting from the PNGP Habitat Map, a fundamental annex to the Management Plans for Sites of Community Importance (SCI) and Special Protection Areas (SPA). The Habitat Map was produced by interpreting aerial photographs (2005) and other supporting cartography (geological map, map of forest types) at a scale of 1:10.000 with in-depth studies also at a larger scale, therefore not by means of vegetation surveys carried out in the field. This cartography cannot therefore constitute a faithful representation of all the habitats but, for the work on Pastoralp, it constituted a good starting point.

The areas classified in group 7 "Grasslands" were taken into consideration and are further subdivided into the following subgroups in the habitat map:

- 7a "Alpine tall herbs".

Herbaceous formations dominated by grasses typical of sunny slopes, in areas with high rainfall and above the forest line.

- 7b "Subalpine and alpine acidophilic grasslands".

Alpine and subalpine pastures on acidic soils.

- 7c "Subalpine and alpine calcicole grasslands".

Alpine and subalpine grasslands on basic soils.

- 7d "Arid and thermophilic grasslands".

Arid rupestral grasslands widespread mainly in the hills and mountains, more sporadically in the sub-alps.

- 7e "Mountain grasslands"

These correspond in most cases to grasslands where cultivation practices such as mowing, irrigation and fertilisation are still carried out.

- 7f "Low-altitude grasslands".

These correspond in most cases to mown and fertilised grasslands of low and medium altitude (*Arrhenatherion*).

Starting from the herbaceous areas of group 7, photo-interpretation was used to confirm the polygons and add or remove any herbaceous areas that differed from the Habitat Map.

Then, for each polygon, the homogeneous surfaces were identified on the basis of differences perceptible from orthophotos (quantity and quality of the tare, colour and density of the plot, etc.) and finally an initial estimate of the tares was made.

The criteria for the identification of net grazing areas were therefore:

a) Percentage of net grass cover and characterisation of tares:

Tares were coded and grouped in order to make the information collected homogeneous and comparable. The net grazing area was obtained by subtracting from the gross area of the polygon the unproductive tares

(rocks and boulders, watercourses, buildings) and the diffuse tares within the grassy polygons (rocks and boulders outcropping, bushy and/or tree areas).
In particular, the following classes were adopted for the quantification of tares:

Percentage of the grass cover	Applied class of tare
Between 95% and 100%	0%
Between 80% and 95%	20%
Between 50% and 80%	50%
Between 50% and 20%	80%
Less than 20%	100%

Table 3. Tare classes adopted.

Tare type	***Description***
Water	Lakes and rivers
Trees and shrubs	For areas with diffuse tares (<100%)
Other	Ex. anti-avalanche barriers with vegetation, but not accessible to the herds, grassy areas too steep for grazing animals
Shrublands	Ungrazeable (tare=100%) The areas with the presence of shrubs, but suitable for grazing, fall into the category PASTURE and a percentage of tare of the category "Trees and shrubs" was estimated
Forest	Ungrazeable; the wooden pastures, where grazing is still possible, were included in the Pasture category (pasture types depending on the dominant herbaceous species) and a percentage of tare of the category "Trees and shrubs" was estimated.
Artifacts	Slurry pits, buildings, parkings, farms,tracks and ruins
Ski runs	Grazed; sown species
Rocks and screes	They include rocks and screes poorly colonized, with little vegetation covering (<20%)
VNP	Ungrazeable herbaceous vegetation (nitrophilous species, tall herbs, *Veratrum*…).

Table 4. Tare typology.

b) Surface steepness: the analysis of the digital terrain model (DTM) excluded areas that, although grassed, present a slope that does not allow grazing by domestic herbivores.
c) Accessibility by domestic herbivores: exclusion of grassy areas that can potentially be grazed but cannot be reached by this category of animals.
From the results of these initial surveys, net grazing areas were obtained, subdivided into homogeneous areas, which were subsequently used for field validation.
For each single polygon the data visible in the table below, agreed by the IAR and PNGP with the consultants in charge, were matched.

Field name	***Description***
CP_COD	Pasture district code
CP_DES	Pasture district name
ANNO	Most recent year of field survey
PASCOLO	Grazeable or not
TIPO_1	Code of the dominant pasture code
%_TIPO_1	% of type 1 coverage
TIPO_2	Code of the secondary type, if any
%_TIPO_2	% of type 2 coverage
TARA	Tare extent: 0, 20, 50, 80, 100%

TARA_1_DES	Description of the tare typology
TARA_2_DES	Further description of the tare typology
CATEGORIA	Name of the pasture category
HA_LORDI	Gross area
HA_NETTI	Net area (gross area – tare)
ELEV_MEAN	Average pasture elevation
ELEV_MIN	Minimum pasture elevation
ELEV_MAX	Maximum pasture elevation
REGIONE	Region
NOTES	Space for notes

Table 5. Table of attributes related to polygons of the pasture types file.

Field validation

For the field surveys, each professional used his or her own working method, making use of auxiliary and support tools, both digital (tablets, GPS, mobile phones) and paper-based (various types of maps, books and publications).

One or more inspections were carried out for each Pasture district investigated over the course of two mountain pasture seasons (2018-2019), each time assessing the optimal conditions of the plot, linked to both the phenological stage and grazing activity.

The areas of the polygons were covered on foot, sometimes encountering difficulties related to accessibility due to steepness, rock jumps, low density of paths or walkways. In these cases, remote observations were carried out with the aid of binoculars.

In the field, the data entered by remote photo-interpretation were verified, such as the actual use of the land for grazing, the correctness of the geometry, % and quality of the tare as well as the actual accessibility and usability by domestic herbivores. In addition, the surveys allowed the identification and assignment of the correct pasture type for each polygon.

This information was noted and recorded using different methods at the consultant's discretion:

- On field cartography and subsequently digitised, also making use of GPS on a mobile phone which allows precise location and identification of the correct polygon.
- On a cartographic project using the Qfield application on a tablet. The project allowed themes of interest to be uploaded and masks supported by drop-down menus to facilitate data entry. In addition, individual polygons appeared with a coloured background only when they were typed in, avoiding the possibility of forgetting any. The use of the tablet in the field entails a slightly more onerous task in the preparation phase of the surveys and also the compilation in the field takes considerably longer, but is subsequently much more efficient: both because the information collected is reported directly on digital media, thus reducing not only the transposition time but also the possibility of error; and because the GPS on board the tablet allows the surveyor to be located precisely at all times, so that he can better orientate himself and verify the correctness of the photo-interpretation as well as obviously identifying the pasture type.

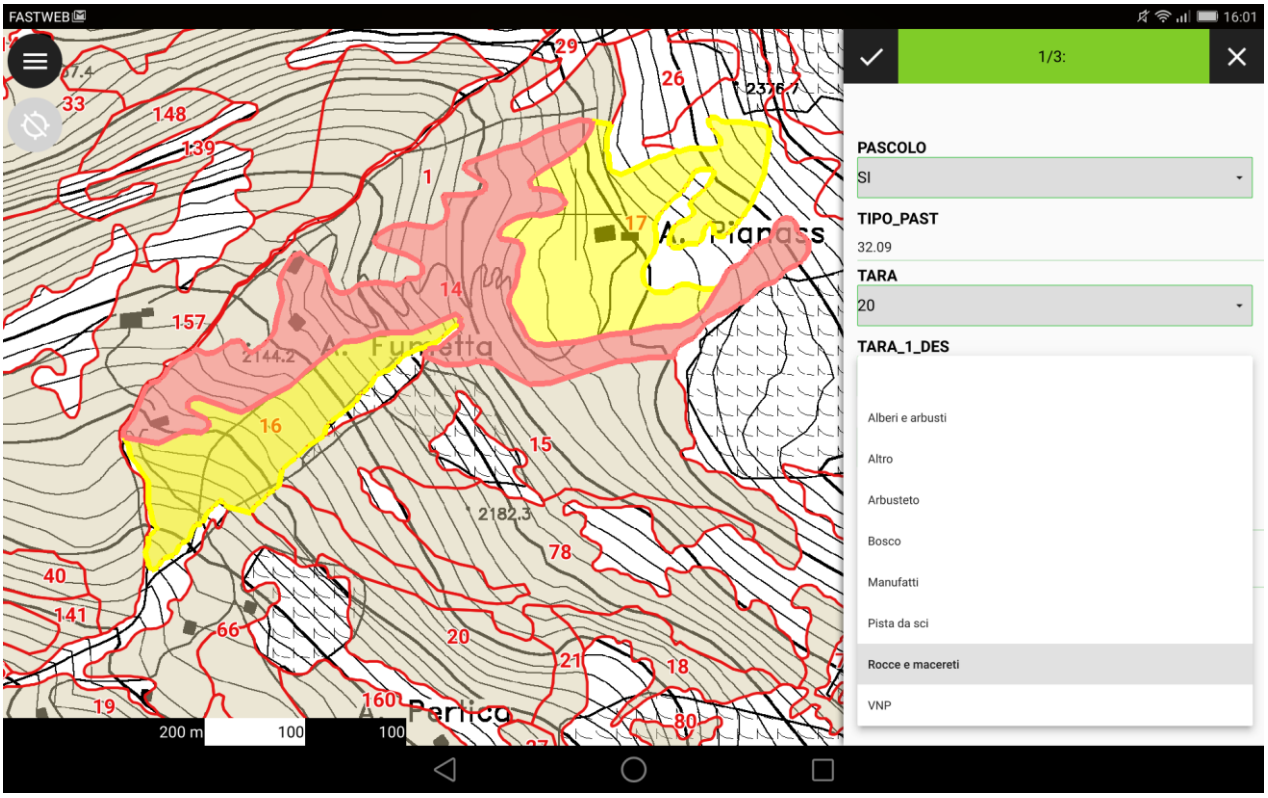


Figure 1 - Screenshot of the project. In red the polygon to which it refers the data entry mask positioned on the right.

Identification of the pasture type

The identification of the facies or pasture types was carried out on the basis of the following bibliographic tools:

- “Tipologia agroecologica delle vegetazioni d’alpeggio in zona intra-alpina nelle Alpi nord-occidentali” (Bassignana M., Bornard A., 2001, compiled within the framework of the Italy-France Interreg Project No. 110);
- “I Tipi pastorali delle Alpi piemontesi” (Cavallero et al., 2007, Alberto Perdisa Editore);
- “Les végétations d'alpage de la Vanoise - Description agro-écologique et gestion pastorale” (A. Bornard, M. Bassignana, C. Bernard-Brunet, S. Labonne, P. Cozic, 2006, Quae éditions).

During several meeting and field surveys, IAR and PNGP agreed with the consultants on the preference for the attribution of facies and pasture types related to the Aosta Valley typology, i.e. referring to the Agro-ecological typology of pasture vegetation in the inner north-western Alps.

Only when there was no correspondence with the Aosta Valley typology, the "Pasture types of the Piedmontese Alps” or "Les végétations d'alpage de la Vanoise" were taken as reference.

The identification of the pasture types in the field was carried out using a visual method of plant association detection, which is clearly more expeditious than the classic floristic method of linear survey according to Daget and Poissonet (1971), which is not applicable on such large areas and for the purposes of this work.

The first three criteria for the determination of the Aosta Valley types allow three easily recognisable environments to be identified: screes, wetlands and heaths for a total of 5 types and 7 facies. Altitudinal, topographical, physiognomic and ground cover criteria were then taken into account to distinguish the pasture types. The recognition of dominant or indicator species led to the recognition of the pasture type.

The "agro-ecological typology of alpine pasture vegetation in the intra-alpine zone in the north-western Alps" distinguishes 23 pasture types and 43 sub-types or facies among the alpine pastures.
Wherever possible, correspondence was attributed at facies level, otherwise the pasture type code was attributed. In case of coexistence of more than one pasture type which cannot be mapped individually due to particular stationary, morphological and/or management conditions, the two most present types and the percentage of coverage of each within the polygon have been indicated.
It is possible to find in the notes some annotations concerning specifications on the facies or types attributed, for example species present in % different from those indicated in the bibliography or not described or absent.
In two Pasture districts on the Aosta Valley side of PNGP, Levionaz (code no. 110) and Djouan-Orvieilles (code no. 106), the information contained in a previous pasture study "La vegetazione di Orvieille e Levionaz: individuazione dei tipi di pascolo e relativa cartografia tematica" (The vegetation of Orvieille and Levionaz: identification of pasture types and related thematic mapping) was used. This study was made by Dr. Barbara Martinasso in the framework of "Interreg-GREAT Large Herbivores in Transforming Alpine Ecosystems Project" (the work was made available by PNGP).
This work was used as a starting point and then adapted to the Pastoralp methodology:
- The pasture types and facies were recoded according to the bibliographic references of Pastoralp;
- The perimeter of the polygons was modified where necessary, thanks to the use of more recent orthophotos and field rectification surveys.

The cartography of the pasture types of PNGP was obtained after a long work that included:
- Surveys of alpine pasture vegetation, determination of pasture types and restitution of data in a cartographic shape using the open-source software QGIS.
- Harmonisation of collected data and creation of a common cartographic project.
In PNGP, 8022 ha of mountain pastures were surveyed, corresponding to 4596 ha of net surface. The table below shows the gross and net areas divided by Pasture districts:

Pasture district code	***Pasture district name***	***Gross area (ha)***	***Net area (ha)***
101	Agnel	527.85	402.38
102	Alto vallone di Campiglia	546.59	245.44
103	Bardoney	201.99	125.68
104	Bastalon	421.37	176.18
105	Benevolo	358.07	269.56
106	Djouan	412.90	259.68
107	Entrelor	175.19	126.23
108	Gran Loson	207.25	162.04
109	Lago di Dres	124.77	44.20
110	Levionaz	261.53	172.92
111	Meyes	205.54	91.80
112	Nivolet	726.04	556.35
113	Noaschetta	362.84	115.12
114	Punta dell'Orletto	373.73	249.21
115	San Besso	483.66	242.44
116	Urtier	319.43	237.75
117	Valle di Piamprato	449.69	289.12
118	Vallone Ciamoseretto	254.94	107.1
119	Valle di Forzo	509.92	203.69

120	Vallone di Piantonetto	383.83	160.4
121	Vallone Roc	549.25	242.96
122	Vaudala	80.94	56.69
123	Vaudalettaz	84.79	58.98
Total areas (ha)		**8022.11**	**4595.93**

Table 6. Gross area and net area of Pasture districts.

In this chapter we describe each Pasture district, analysing the results for the pasture types and finally giving some management comments. A map of pasture types has been produced for each Pasture district and can be consulted in the annexes n. 01-23.
The overall outcomes for the whole Park territory are presented in the next section.

Pasture districts

Pasture district n. 101 Agnel

Municipality	Ceresole Reale (TO)
Surface	Total (gross area): 528 ha Pasture (net area): 402 ha
Elevation	1585 m – 2858 m a.s.l.
Aspect	Variable with wide plateaus
Slope	Low along the valley floor and at higher altitudes where there are several plateaus

Territorial overview

The Agnel Pasture district belongs to the municipality of Ceresole Reale (TO) and includes the upper part of the Orco Valley. The lowest pastures are close to Borgata Villa (1580 m), on the edge of the Ceresole lake; the border then climbs the Valley proceeding east to west, covering the bottom of the Valley and a narrow strip of the mountainside (mainly on the orographical left of Orco creek) up to the crossroad between the road to the Nivolet pass and the track leading to Vallone del Carro. In this place the valley splits in two: the branch heading south becomes Vallone del Carro, the northern branch leads to the Nivolet pass. On the road to the Nivolet pass lie the Serrù and Agnel lakes, with large pastures on gentle slopes. The northern branch reaches Nivolet pass (2625 m) and includes pastures of Pian Rosset with the Rosset and Leytà lakes, on the border with Aosta Valley (and with the Nivolet Pasture district). The highest pastures, close to the Rosset lake, reach the elevation of 2850 m a.s.l. The part of the Pasture district running at the bottom of the main valley borders north on the Bastalon Pasture district.

Pasture surfaces

The net grazing surfaces of the Pasture district are described by tare classes in *Table 101.1.*

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	206.64	39.14%	206.64	51.35%
20	165.14	31.29%	132.16	32.84%
50	107.42	20.35%	53.85	13.38%
80	48.65	9.22%	9.73	2.42%
Total	**527.85**	**100.00%**	**402.38**	**100.00%**

Table 101.1. Total and net area in the Pasture district by tare class.

There are nearly 528 ha of gross surfaces, corresponding to 402 ha of net grazing surfaces. Half of the pastures (located at the bottom of the main valley, between Serrù and Agnel lakes and Pian Rosset), is free from tares. A third of the pastures has a 20% tare (those mainly being slopes on the orographical left with emerging rocks and stones), while the remaining grazing surface has a 50% tare (due to shrub encroachment of the alpine grasslands). 2% of the surface has 80% tare, representing *Vaccinium* and *Rhododendron* formations on the north aspect. The green alder (*Alnus viridis*) encroached some pasture sectors, expecially along the streams in the upper subalpine level.

Pasture types

The pasture types identified on the Pasture district are given in *Table 101.2* and reported in *Figure 101.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Carex curvula	37 + A5	95.00	18.00%	63.60	15.81%
Festuca scabriculmis	24	75.50	14.30%	57.50	14.29%
Dactylis glomerata	S3	58.60	11.10%	56.20	13.97%
Alopecurus gerardi	76 + A10	35.50	6.73%	33.30	8.28%
Festuca gr. violacea	46 + A2	36.70	6.95%	31.00	7.70%
Nardus stricta and *Carex sempervirens*	A8	26.50	5.02%	22.50	5.59%
Festuca rubra	S2	18.30	3.47%	15.50	3.85%
Poa alpina	61	15.20	2.88%	15.20	3.78%
Alchemilla pentaphyllea and *Salix herbacea*	A9	16.50	3.13%	13.60	3.38%
Rhododendron ferrugineum and *Vaccinium uliginosum*	L3	44.60	8.45%	12.30	3.06%
Kobresia myosuroides	A6	12.70	2.41%	9.00	2.24%
Ligusticum mutellina	74	8.90	1.69%	8.90	2.21%
Nardus stricta and *Festuca rubra*	S1	8.60	1.63%	8.30	2.06%
Festuca gr. ovina	19	9.70	1.84%	6.90	1.71%
Plantago alpina and *Festuca ovina*	A1	8.60	1.63%	6.90	1.71%
Nardus stricta	30	7.00	1.33%	5.80	1.44%
Phleum alpinum	60	5.80	1.10%	5.40	1.34%
Arctostaphylos uva-ursi, Juniperus nana and *Vaccinium uliginosum*	L2	11.00	2.08%	4.80	1.19%
Trifolium alpinum	A7	4.70	0.89%	4.70	1.17%
Rumex alpinus	69	4.20	0.80%	4.00	0.99%
Helictotrichon parlatorei	11	4.40	0.83%	3.60	0.89%
Agrostis schraderana	50	3.20	0.61%	2.60	0.65%
Loiseleuria procumbens and*/or Vaccinium uliginosum*	L1	4.70	0.89%	2.30	0.57%
Veratrum album	54	3.50	0.66%	2.20	0.55%
Carex foetida	79	2.70	0.51%	1.80	0.45%
Poa violacea	29	1.50	0.28%	1.50	0.37%
Carex sempervirens	32	2.60	0.49%	1.50	0.37%
Salix retusa and *Salix reticulata*	70	0.90	0.17%	0.90	0.22%
Vaccinium gaultherioides	91	0.70	0.13%	0.40	0.10%
Total		**527.85**	**100.00%**	**402.38**	**100.00%**

Table 101.2. Pasture surface divided by pasture type.

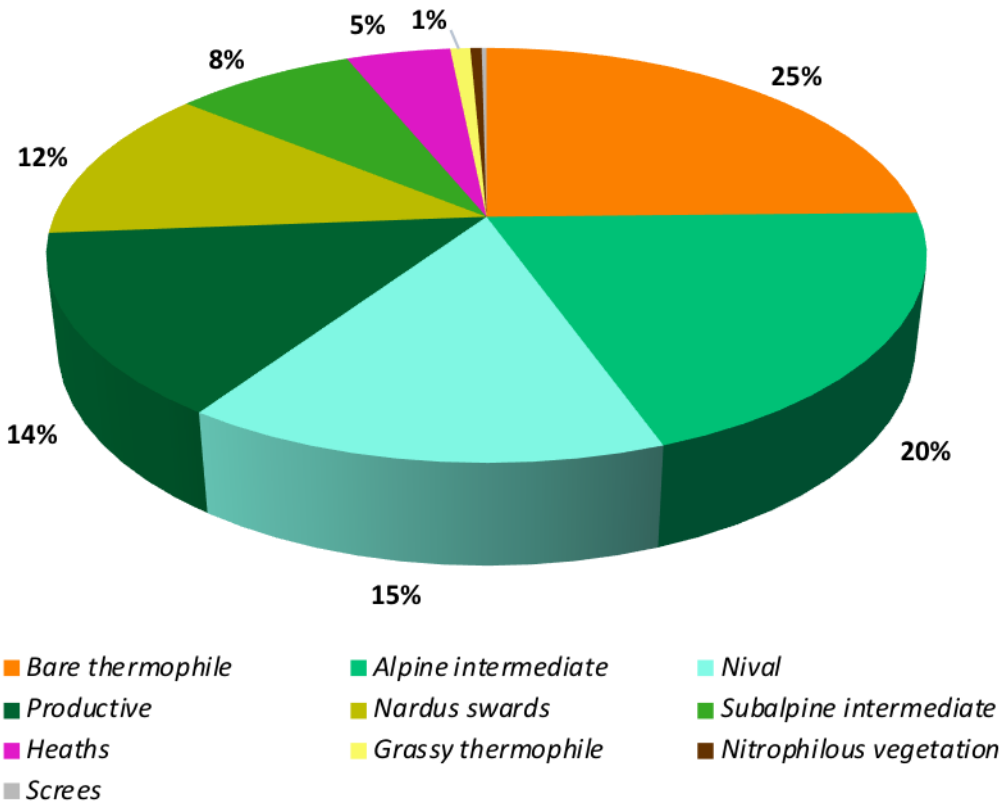


Figure 101.1. Pasture net surface divided by pasture category.

29 Pasture types and 47 facies have been described. Types belonging to intermediate conditions are prevailing (with 60% of net surface, 290 ha of gross surface). Thermic formations are set on about 102 gross hectares on steep, sunny slopes and on windy ridges while in the snowbeds, where the snow cover lasts longer, formations of nival conditions can be found (73 gross hectares). Formations with shrub encroachment (but less than 80% tare) occupy about 11% of the gross grazing surface (61 gross hectares). Hydromorphic formations of Pian Rosset have been excluded from the grazing surfaces since, being a peat bog, grazing is forbidden. Pastures under larch canopies have a minor extent and are located in the lower part of the grazing area.

The *Carex curvula* type prevails, with nearly 64 hectares split in 3 facies on the Nivolet pass in the upper parts of Vallone del Carro. The most extensive facies are those with *Carex curvula, Avenula versicolor* and *Potentilla aurea* and those with *Trifolium alpinum*, *Carex curvula*, *Festuca halleri* and *Avenula versicolor*. Then the *Festuca scabriculmis* type, with 57.50 net hectares set on steep and sunny slopes (mostly on the sides of the old Royal Road to the Nivolet pass) with a total of 6 facies, of which the most abundant is the one with the key species as a dominant; the valley floor, in the former crops and hay meadows, consists of the *Dactylis glomerata* eutrophic type with *Trisetum flavescens, Dactylis glomerata* and *Agrostis capillaris* facies (56 hectares).

There are then, in descending order of extension, the *Alopecurus gerardi* type (3 facies, the largest of which is close to the Agnel lake), as well as the *Festuca violacea* type (4 facies mostly close to Serrù lake) and the *Nardus stricta* and *Carex sempervirens* type (2 facies, with cores in the lower alpine belt).

Grazing management notes

In the Agnel Pasture district the following main mountain pastures (called “Alpeggi” in Western Alps) can be found, of which buildings and pastures are used:

- Serrù (2406 m), located between the lake of the same name and the Agnel lake, accessible with a dirt track starting from Alpe dell'Agnel. It has houses and stables in good conditions. A few dozen of dry, crossbred cattle graze on it with rotational grazing technique; the pastures are bounded by electrified mobile fences.
- Agnel (2337 m) located in the plain of the homonymous Lake next to the road to the Nivolet. The Alpeggio has a house, a dairy and a stable in good condition. Some dozens of crossbred cattle (some of which are milked) are kept there, managed with rotational grazing, the pasture sectors are delimited by mobile electrified fences.
- Cernera (2218 m) set in the Vallone del Carro, accessible by a dirt track. The Alpeggio has a house and stable in fair condition. A few dozens of dry, crossbred cattle graze on it with rotational grazing, the pasture sectors are delimited by mobile electrified fences.

In the Pasture district the same farmers handling the aforementioned mountain pastures use some lower altitude sections at the beginning and at the end of the summer period, stopping for a few weeks in the buildings of the following mountain pastures (located along the road to the Nivolet pass): Renarda (2130 m), Brangie (1976 m), Sansuera (or Sansuero, at the beginning of Vallone del Carro, 1919 m); Pilocca (1870 m); Chiapili superiore (1667 m); Chiapili inferiore (1664 m); Mua (1597 m); Villa (1583 m).

The pastures at the entrance to the Vallone del Carro (Sansuero, Trumajet) are used by a herd of about 50 Piedmontese breed cattle.

Two transhumant flocks can be found in the area during the months of July and August: one is formed by a few hundred sheep and goats grazing pastures not suitable for cattle below Lago del Serrù; the other flock, also made up of a few hundred heads, graze near the Colle del Nivolet and in the Piedmont area of Pian Rosset. During the night flocks are closed in electric fences, and grazing is guided. The sheep are mainly of Biellese breed.

The buildings of the following Alps are no longer viable: Trumajet (at the entrance to the Vallone del Carro, 1900 m); Peretti (on the shore of Lake Agnel, 2370 m), Pratorotondo (below the Serrù dam, 2166 m), Buffà (aong the old Royal Road, 2272 m); Alpe Mandette (Vallone del Carro, 2158 m); Rocce Piccole (on the upper mountainside on the orographic left of the Vallone del Carro, 2495 m); Rocce Grandi (near the previous one, 2405 m), Alpe Gias (near Alpe Cernera, 2262 m).

In the valley floor and in the easily accessible areas, the load of cattle is balanced with the pasture supply, while in the inaccessible areas the pastures are slightly under-loaded, expecially in the high elevation and inaccessible ones suitable for sheep and goats. The pastures of Rocce Piccole and Rocce Grandi have not been grazed for about ten years.

Pasture district n. 102 Alto Vallone di Campiglia

Municipality	*Valprato Soana (TO)*
Surface	*Total (gross area): 547 ha* *Pasture (net area): 245 ha*
Elevation	*1540 m – 2812 m a.s.l.*
Aspect	*South-south-east* and *south-south-west; in the Vallone del Rancio east* and *north-east*
Slope	*Weak to medium along the valley floor, in the Vallone del Rancio* and *in the Grande Arietta pastures. Strong gradients along the slopes*

Territorial overview

The Pasture district Alto Vallone di Campiglia is composed by the terminal valley of Campiglia, oriented from south-east to west, neighbouring in the eastern side with the San Besso valley, in the northern and north-western side with the Aosta Valley, and in the southern and south-western side with the Forzo Valley. In its upper part, the main Campiglia valley is divided in two sub-valleys: the principal one and the Rancio valley that is a lateral sub-valley south-southeast oriented and named. The pastures are mainly located on the left orographic side of the Campiglia River and range from 1540 m a.s.l. near Azaria, up to the 2880 m of the Bocchetta del Rancio and of the Colle dell'Arietta. The main pasture aspect range from south-south-east to south-south-west, except for the Rancio sub valley, in which pastures are oriented from east to northeast.

Pasture surfaces

The net grazing area of the pasture district, are given by tare classes, in *Table 102.1*:

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	95.73	17.51%	95.73	39.00%
20	115.35	21.10%	92.24	37.58%
50	105.86	19.37%	53.35	21.74%
80	20.45	3.74%	4.12	1.68%
100	209.20	38.27%	0.00	0.00%
Total	**546.59**	**100.00%**	**245.44**	**100.00%**

Table 102.1 Total and net area in the Pasture District by tare class.

In the examined Pasture district, there are about 245 ha of net grazing area. About the 40% of the net grazing area is characterized by the absence of diffused tares, whereas about another 38% of the net grazing area is characterized by the 20% of diffused tares, as well as about the 22% of the net grazing area showed the 50% of diffused tares. Concerning the ungrazeable areas, about 168 ha of gross area (about the 80% of gross ungrazeable surfaces) are characterized by grass cover zone that are almost inaccessible, except for small flocks (100-150 heads) of small ruminants (sheep or goats). As their high slope and complex morphology do not facilitate the flock management and movements, it would not be possible to safely exploit such areas by large flock. Furthermore, these areas are inaccessible by cattle.

Pasture types

The pasture types identified on the Pasture district are given in *Table 102.2* and reported in *Figure 102.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	156.10	46.27%	115.14	46.91%
Dactylis glomerata	57	33.20	9.84%	25.30	10.31%
Brachypodium rupestre	25	35.10	10.40%	22.10	9.00%
Nardus stricta and Carex sempervirens	A8	25.10	7.44%	19.20	7.82%
Festuca gr. rubra	S2	15.20	4.51%	13.70	5.58%
Poa alpina	61	13.19	3.91%	9.30	3.79%
Helianthemum nummularium	SA2	9.00	2.67%	7.30	2.97%
Geum montanum	47	8.60	2.55%	6.30	2.57%
Festuca gr. violacea	46	7.00	2.07%	5.20	2.12%
Poa violacea	29	5.70	1.69%	4.90	2.00%
Festuca gr. quadriflora	21	12.20	3.62%	4.30	1.75%
Trifolium alpinum	A7	3.30	0.98%	2.70	1.10%
Phleum alpinum	60	2.90	0.86%	2.10	0.86%
Carex fusca	ZH2	2.70	0.80%	1.80	0.73%
Trisetum flavescens	59	1.60	0.47%	1.60	0.65%
Deschampsia caespitosa	53	1.70	0.50%	1.40	0.57%
Poa pratensis	56	1.20	0.36%	1.20	0.49%
Subalpine nitrophilous vegetation	RA1	1.20	0.36%	0.80	0.33%
Kobersia myosuroides	A6	1.30	0.39%	0.50	0.20%
Nardus stricta and Festuca gr. rubra	S1	0.40	0.32%	0.40	0.16%
Salix retusa and Salix reticulata	70	0.50	0.15%	0.20	0.08%
Carex foetida	79	0.20	0.06%	0.00	0.00%
Total		**337.39**	**100.00%**	**245.44**	**100.00%**

Table 102.2. Pasture surface divided by pasture types.

Pastures are largely dominated by the *Festuca scabriculmis* type that share about the 47% of the net grazing areas. This type is represented by two facies: the first, in the minority (about the 0.2% of net grazing area) represent the transition to the *Brachypodium rupestre* type (facies 24.04 - *Festuca scabriculmis* and *Brachypodium rupestre*); the second dominant one, is the typical facies (facies 24.05 - *Festuca scabriculmis*), that cover almost all the wide slopes of the grazing areas. The 24.05 facies cover also about the 80% of the gross ungrazeable grass-covered areas, exploitable by a small flock only. The second type for surface share is the type 57 - *Dactylis glomerata* that cover a little more than the 10% of the net grazing area and that is located in the fertile and flat zones between the Campiglia river and the summer barns at the lower altitude (Grange Azaria and Barmaion). This type is represented by two facies: the typical one 57.22 - *Dactylis glomerata, Agrostis tenuis* and *Festuca* gr. *rubra* (about the 4% of the net grazing area) and the facies 57.27 - *Dactylis glomerata* and *Polygonum bistorta* that cover about the 6% of the net grazing area, almost near Grange Azaria. The third type for surface is the type 25 - *Brachypodium rupestre* (9% of net grazing area) that substitute the *Festuca scabriculmis* type in the slopes at a lower altitude and in more thermic conditions. This type is represented by two facies: the typical one 25.11 that characterise all the grazeable *Larix decidua* forests (and about the 20% of gross ungrazeable grass covered areas, exploitable only by a small flock), the other, the facies 25.16 - *Brachypodium rupestre*, *Carex sempervirens* and *Festuca* gr. *ovina*, represent the involution of the *Festuca* gr. *ovina* in thermic condition due to an underutilisation. This facies is located mainly over the Alpe Barmaion. The fourth type for surface share is the type A8 -

Nardus stricta and *Carex sempervirens* (7.8% of the net grazing area), particularly represented by the sub-type A8.1 a *Nardus stricta, Trifolium alpinum* and *Carex sempervirens* (about the 5% of the net grazing area) and mainly located near the Alpe del Rancio. Among the other types, only the type S2 - *Festuca* gr. *rubra* still exceed (marginally) the 5% of the net grazing area (in particular the facies S2.2 - *Festuca* gr. *rubra*, *Agrostis capillaris, Phleum alpinum* and *Alchemilla xanthochlora*). Non negligible is anyway the surface share of the types 29 - *Poa violacea*, 46 - *Festuca* gr. *violacea*, 47 - *Geum montanum*, 61 - *Poa alpina* and SA2 *Helianthemum nummularium*, that range between the 2 and the 4 % of the net grazing area.

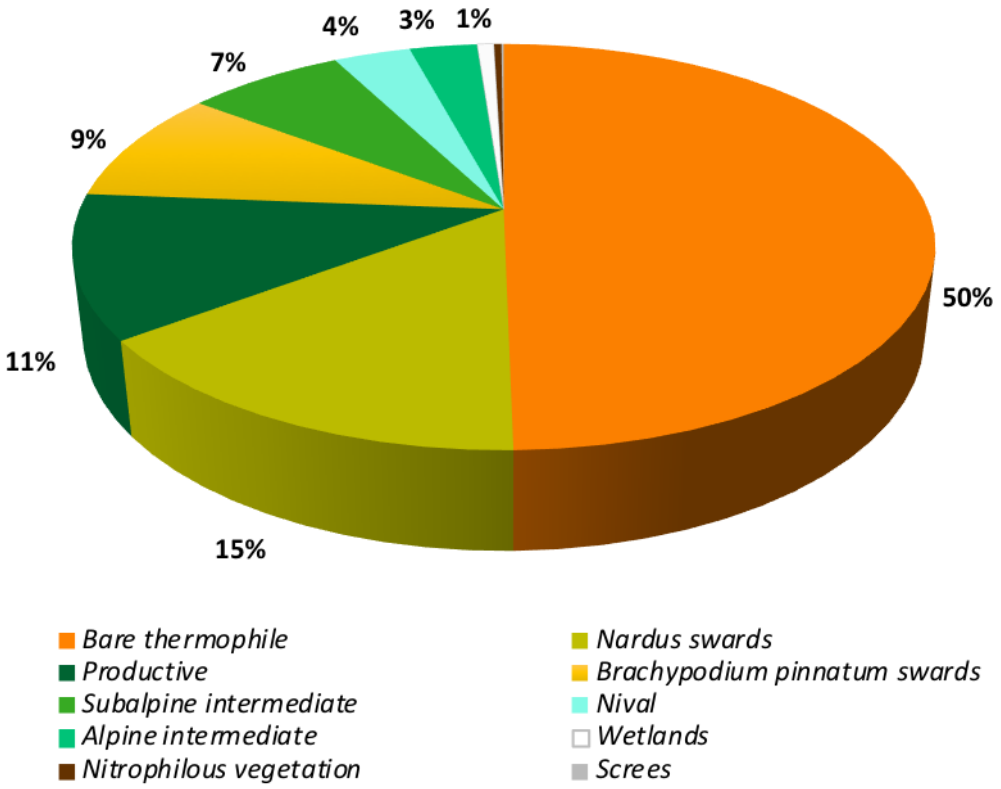


Figure 102.1. Pasture net surface divided by pasture category.

Grazing management notes

Two different farmers manage the grazing area, thus it can be considered as subdivided into two management units.

The first one in composed by the Alpe dell'Azaria: the farmer manage the more fertile pastures, located between the barn, the hunting house of Azaria and the river, by strip grazing a dairy herd of about 60 milked cows of mixed breeds (mainly double-purpose breeds). A small flock of meat sheep and goats exploit the slopes behind the barn trough ranging grazing management. The flock is protected against wolf predation by the presence of guard dogs and the night camping in electric fences. Heifers and dry cows (about 35-40 animals) exploit the Alpe del Rancio pastures through free ranging grazing management and are visited about twice a week.

The second management unit is composed by the Alpe Barmaion (lower altitude barn) and the Grange Arietta (upper altitude barn). The almost flat and fertile pastures in front of the Alpe Barmaion are exploited through strip grazing by a dairy herd of about 50 milked cows of Aosta Red Pied breed. The same herd is moved to the less steep pastures near to Grange Arietta and managed similarly. This herd come back in the autumn to Alpe Barmaion for a second grazing cycle. Heifers and dry cows (about 25-30 animals) exploit slope over the Alpe Barmaion, from east to west by extensive rotational grazing, up to the

end of the valley. A small flock (about 120-170 sheep and goats) partially exploit the steeper and less fertile pasture over and under the Grange Arietta through guided grazing. The flock is protected against wolf predation by the presence of guard dogs and the night camping in electric fences.

Pasture district n. 103 Bardoney

Municipality	*Cogne (AO)*
Surface	*Total (gross area): 202 ha* *Pasture (net area): 126 ha*
Elevation	*Alpeggio of Bardoney: 2250 m – 2850 m a.s.l.* *Alpeggio of Goilles* and *Etzelley: 1793 m – 1949 m a.s.l.*
Aspect	*Alpeggio of Bardoney: East but considering that most of the grazed areas are flat* *Alpeggio of Goilles* and *Etzelley: South*
Slope	*Low on the Bardoney* and *Plan des Goilles plains, sustained on the slopes* *Low on the pastures of Goilles* and *Etzelley, with an average of 16°.*

Territorial overview

Located in the homonymous valley it is accessible by paved road from Lillaz, hamlet of Cogne, up to Pianes and then with about 1-hour walk (300 m altitude difference) on a smooth path. It covers the entire valley and the north, northwest east and south, sides of the peak of Bardoney and the Lake Loïe area. It also includes two small separated pastures in the localities of Goilles-dessou and Etzelley.

The prevalent exposure is east, namely the left side of the Bardoney stream on which there is the majority of the pasture surface. In the two separated zones the prevalent exposure is south.

The slopes are moderate in the valley and on the right side where the grazing areas are confined to the low side. Elsewhere they are greater, reaching values higher than 40°. The average slope of the main body is equal to 25°, of Goilles and Edzellei 16°.

Pasture surfaces

The following table shows the grazing surfaces of the district under review, divided by tare class:

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	31.98	15.83%	31.98	25.45%
20	54.60	27.03%	43.66	34.74%
50	93.23	46.16%	46.82	37.25%
80	16.11	7.98%	3.22	2.56%
100	6.07	3.01%	0.00	0.00%
Totale	**201.99**	**100.00%**	**125.68**	**100.00%**

Table 103.1. Total and net area in the Pasture district by tare class.

In the whole district of Bardoney there are about 202 ha excluding the unproductive tare (rocks and screes, waterways, buildings) and 126 ha excluding the diffuse tare, i.e. within the grassed polygons (rocks and outcropping scree, bushy and/or arboreal areas).

As part of the tares over 70% is made up of rocks and scree, slightly less of 25% by trees and shrubs and 2.5% attributed to other, which is almost always made from bare soil.

Pasture types

The pasture types identified within the grazing area are 21. 4 of these type are related to those of the Piedmont Alps and cover a total of approximately 30 ha equal to about 24% of the net grazing surface; these are mainly *Festuca scabriculmis* pasture and other limited situations closely linked to environmental or management factors. In *Table 103.2* the identified pasture types are reported in descending order for the covered surface. As it can be observed there are 3 types that prevail and that alone occupy almost 55% of entire surface.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	47.72	23.63%	26.99	21.48%
Nardus stricta and Carex sempervirens	A8	29.67	14.69%	22.62	18.00%
Carex curvula	A5	28.04	13.88%	20.20	16.07%
Plantago alpina and Festuca ovina	A1	13.98	6.92%	9.59	7.63%
Arctostaphylos uva-ursi, Juniperus nana and Vaccinium uliginosum	L2	23.51	11.64%	8.79	6.99%
Festuca violacea	A2	11.62	5.75%	7.97	6.34%
Dactylis glomerata	S3	4.41	2.18%	4.21	3.35%
Festuca halleri	A4	5.93	2.94%	3.98	3.17%
Loiseleuria procumbens and/or Vaccinium uliginosum	L1	7.74	3.83%	3.89	3.10%
Trifolium alpinum	A7	5.07	2.51%	3.43	2.73%
Rhododendron ferrugineum and Vaccinium uliginosum	L3	6.76	3.35%	2.81	2.24%
Alchemilla pentaphyllea and Salix herbacea	A9	3.57	1.77%	2.67	2.12%
Festuca rubra	S2	3.26	1.61%	2.61	2.08%
Agrostis schraderana	50	2.97	1.47%	1.97	1.57%
Brachypodium pinnatum	S5	1.35	0.67%	1.10	0.88%
Poa supina/annua	67	1.06	0.52%	1.06	0.84%
Screes	E	3.19	1.58%	0.85	0.68%
Kobresia myosuroides	A6	1.49	0.74%	0.75	0.60%
Deschampsia caespitosa	53	0.16	0.08%	0.16	0.13%
Wetlands	ZH	0.095	0.05%	0.02	0.02%
Dryas octopetala	SA3	0.39	0.19%	0.00	0.00%
Total		**201.99**	**100.00%**	**125.68**	**100.00%**

Table 103.2. Pasture surface divided by pasture type.

In *Figure 103.1* the pasture types are represented with the reference colors.

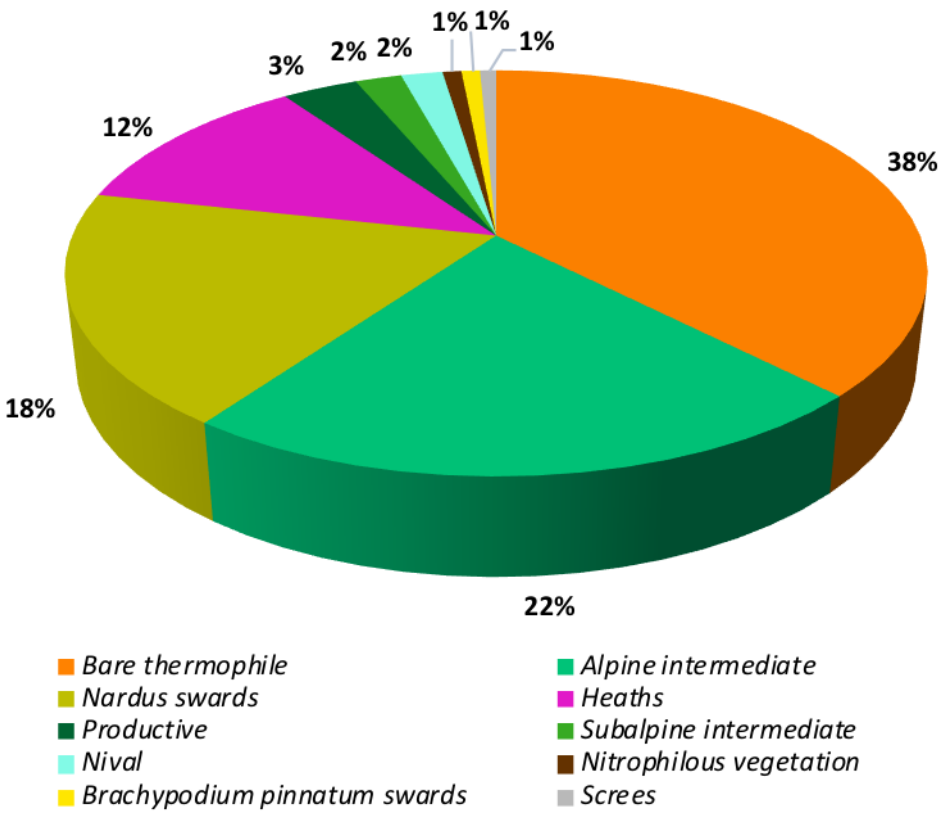


Figure 103.1. Pasture net surface divided by pasture category.

Management notes

The district is currently partially used from a herd of lactating bovines Aosta Red Pied, Aosta Black Pied or Aosta Chestnut. which are regularly milked to produce Fontina PDO and other cheeses and dairy products. The animals are collected in the barn at night and during the middle of the day. The most inaccessible areas are unused and not suitable for cattle and far from the pastureland in particular the upper part of the left side and the areas towards the lake of Loie.

The buildings are newly renovated and adjusted, while the farmer complains about the lack of a track that allows access by motorized vehicles (for example a quad).

The areas trampled by animals grazing, appear to be used correctly and in a uniform manner, although in the most low-lying areas and nearby pasture, the wide diffuse and high presence of nard may indicate a localized over-use, while in the peripheral and more steep zones there are shrubs and trees, sign of too extensive pasture.

Picture 103.1. View of the pasture from the top of Bardoney.

Picture 103.2. The pastures to Lake Loie.

The objectives and the attention elements with respect to the influence of the management aspects on the vegetation of the district are:

- Uniform utilization of all grazing surfaces in order to oppose the advance of trees and shrubs species already present in the steeper sections and far from the main pastures and maintain a good quality of the grassy turf.
- More uniform and diffused distribution of stable slurry, in order to avoid excessive concentrations in some areas and impoverishment of others;
- Mantaining of the *Trifolium alpinum* (A7) and, *Nardus stricta*, *Trifolium alpinum* (A8.1) facies through an involving balanced refunds and relatively late utilization to promote the dissemination of *Trifolium alpinum*.
- Greater attention to the phenological stages in relation to the use trying to anticipate the grazing in the *Nardus stricta* areas using them in the first sprouts when the ears, in the bulge of the sheaths, are not aggressive yet.
- Improvement of the areas with the presence of *Festuca scabriculmis* through early uses made with regularity and balanced loads.

Pasture district n. 104 Bastalon

Municipality	*Ceresole Reale (TO)*
Surface	*Total (gross area): 421 ha* *Pasture (net area): 176 ha*
Elevation	*1650 m – 2640 m a.s.l.*
Aspect	*South* and *south-west*
Slope	*Average slope of 59°, rarely less than 30°.*

Territorial overview

Located on the left hydrographic side of the Orco river, upstream of the Ceresole Lake, it extends on the medium-low side from Ceresole Reale to Chiapili di Sopra. Access is from the Provincial Road N. 50 and then with the trails that start in Ceresole Reale, in the village of Muà, Chiapili di Sopra and from Alpe Renalda. The travel time on foot to reach the pastures varies from 1 to 2 hours, the paths from Ceresole and Muà have traits with high slope and are not accessible with pack animals.

Pasture surface

Table 104.1 show the surfaces of the Pasture district, divided by tare class.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	0.00	0.00%	0.00	0.00%
20	111.75	26.52%	89.40	50.74%
50	159.43	37.84%	79.89	45.35%
80	34.49	8.19%	6.89	3.91%
100	115.70	27.46%	0.00	0.00%
Totale	**421.37**	**100.00%**	**176.18**	**100.00%**

Table 104.1. Total and net area in the Pasture district by tare class.

In the whole district of Bastalon there are about 421 ha excluding the unproductive tare (rocks and scree, waterways, buildings) and 176 ha excluding the diffuse tare, i.e. within the grassed polygons (rocks and outcropping scree, bushy and / or arboreal areas).
As part of the tares over 89% is made up of rocks and scree, about 8% by trees and shrubs, slightly less than 2% attributed to other, which is almost always made from bare soil and 0.5 % by non-pasture vegetation.

Pasture types

The pasture types identified within the grazing area are 11. 8 of these types are related to those of the Piedmont Alps and cover a total of approximately 216 ha equal to about 98% of the net grazing surface: these are mainly *Festuca scabriculmis* pasture. The other pasture types, with the exception of the lands predominantly covered by a shrubby vegetation, are located almost exclusively around the huts almost abandoned.
In *Table 104.2* the identified pasture types are reported in descending order for the covered surface. As it can be observed the type that prevails the most is the *Festuca scabriculmis* which alone occupies more than 78% of the entire surface.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	349.34	82.91%	138.16	78.42%
Nardus stricta	30	21.21	5.03%	14.2	8.06%
Juniperus nana	90	17.89	4.25%	5.88	3.34%
Arctostaphylos uva-ursi, Juniperus nana and *Vaccinium uliginosum*	L2	10.00	2.37%	3.83	2.17%
Vaccinium myrtillus	92	8.43	2.00%	3.77	2.14%
Carex sempervirens	32	4.71	1.12%	3.77	2.14%
Festuca gr. ovina	19	4.44	1.05%	2.63	1.49%
Carex fusca	86	3.02	0.72%	2.25	1.28%
Festuca gr. rubra and *Agrostis tenuis*	52	0.93	0.22%	0.74	0.42%
Alopecurus gerardii	A10	0.84	0.20%	0.67	0.38%
Dactylis glomerata	S3	0.56	0.13%	0.28	0.16%
Total		**421.37**	**100.00%**	**176.18**	**100.00%**

Table 104.2. Pasture surface divided by pasture type.

In *Figure 104.1* the pasture categories are represented with the reference colors.

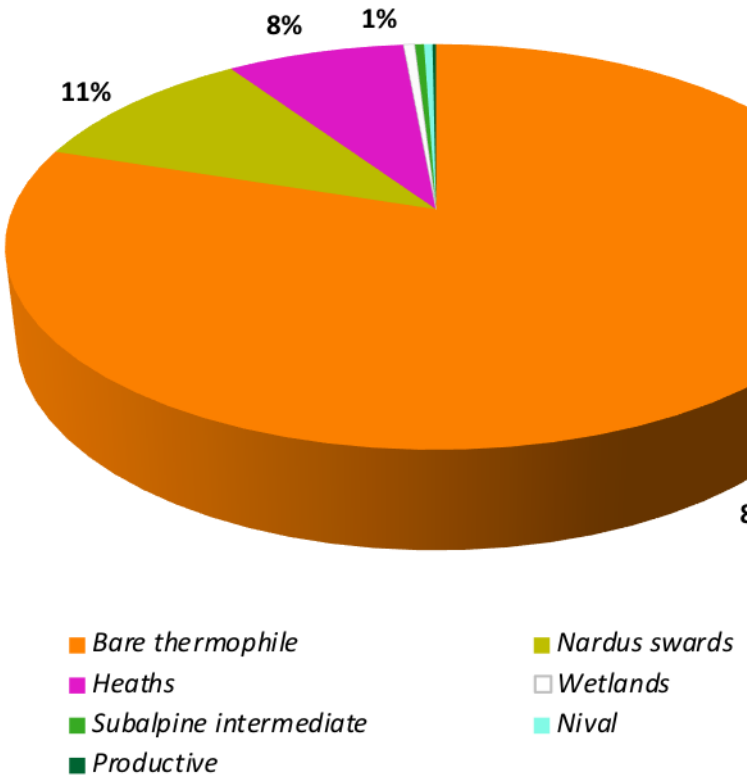


Figure 104.1. Pasture net surface divided by pasture categories.

Management notes

In the Pasture district, no traces of recent uses have been found except in the west, towards the Nivolet, in Alpe Moncialet and Alpe Combetta, where few flocks, consisting mainly of sheep, graze.

Picture 104.1. Alpe Moncialet m 2.320 a.s.l.

Picture 104.2. Alpe Combetta m 2.420 a.s.l.

Infrastructures are lacking both for buildings and for the access to grazing areas.

It should be noted that during the surveys it was observed in the more acclaimed and better exposed slopes a wide diffuse erosion caused by the early melting of the snowpack. In winters with occasional snowfall, in fact, in spring, the snowpack in these areas melts prematurely making to lack the frost protection to the turf below, that dies, leaving areas of bare soil which inevitably trigger the erosion of the most fertile part of the soil.

Morphological and vegetation conditions of the area make it very difficult to recover his farming purposes. However, in the still used areas, the main objectives to be pursued under the pasture management are:

- Contrast the dropping-out of grazing activities;
- Improvement of the areas with the presence of *Festuca scabriculmis* through early use made with regularity and balanced loads.

Pasture district n. 105 Benevolo

Municipality	*Rhêmes-Notre-Dame (AO)*
Surface	*Total (gross area): 358 ha* *Pasture (net area): 270 ha*
Elevation	*1919 m – 2725 m a.s.l.*
Aspect	*East and southeast in the alpine pastures of Fos; very changeable in Fond.*
Slope	*Low to medium.*

Territorial overview

The Pasture district of Benevolo is at the head of Rhêmes Valley, oriented from north to south, between 1900 m a.s.l. and 2700 m a.s.l., in the subalpine and alpine level.

The Pasture district is divided into two separate grazing sectors: Fos alpine pasture, at lower altitudes, and Fond alpine pasture, which is more extensive and located at higher altitudes. Only part of the Fond pastures are included in the PNGP.

The morphology is very changeable (flat areas, slopes, rocky walls). Wide pasture areas are below 20°, or between 20° and 30°. The substrate consists of gneisses, limestones, calcschists, glacial moraine deposits.

The exposures are changeable. In Fond there are two main opposite sides with exposure to west (the main) and to east; a central sector with exposure to north; little portions to south. In the Fos alpine pastures the main aspects are east and southeast.

The Pasture district can be reached by a dirt road (restricted access), from Thumel to Benevolo Mountain Hut (2285 m a.s.l.) and Alpe Fond (2325 m a.s.l.), or by footpath from Thumel.

Pasture surfaces

The net grazing areas, divided by tare classes, are represented in Table 105.1:

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	22.91	6.40%	22.91	8.50%
20	266.21	74.35%	212.96	79.00%
50	66.15	18.47%	33.13	12.29%
80	2.80	0.78%	0.56	0.21%
Total	**358.07**	**100.00%**	**269.56**	**100.00%**

Table 105.1. Total and net area in the Pasture District divided by tare class.

In the examined pasture district there are about 358 ha of grassland and 270 ha of net grazing area.

As the figure shows, about the 9% of the net grazing area is characterized by the absence of diffused tares, whereas about 79% of the net grazing area is characterized by the 20% of diffused tares, and about the 12% of the net grazing by the 50% of diffused tares.

The main tare are rocks and screes, that also includes the uncovered ground.

Main shrubs, in the lower areas, are *Rhododendron ferrugineum, Vaccinium* spp., *Juniperus nana*, *Salix* spp.

Pasture types

The pasture types identified on the pasture area are represented in *Table 105.2* and reported in *Figure 105.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Nardus stricta and *Carex sempervirens*	A8	131.49	36.72%	103.79	38.48%
Festuca rubra	S2	27.96	7.81%	24.19	8.97%
Kobresia myosuroides	A6	30.58	8.54%	21.70	8.05%
Sesleria albicans and *Carex sempervirens*	SA1	27.89	7.79%	17.86	6.62%
Festuca violacea	A2	25.19	7.04%	17.82	6.61%
Nardus stricta and *Festuca rubra*	S1	15.65	4.37%	13.15	4.88%
Carex curvula	A5	15.55	4.34%	10.42	3.86%
Helianthemum nummularium	SA2	10.64	2.97%	8.20	3.04%
Carex sempervirens	32	13.01	3.63%	7.32	2.71%
Geum montanum	47	11.97	3.34%	9.58	3.55%
Festuca gr. ovina	19	10.10	2.82%	8.19	3.04%
Wetlands	ZH	9.33	2.61%	5.75	2.13%
Dactylis glomerata	S3	5.78	1.61%	4.77	1.77%
Festuca gr. violacea	46	5.50	1.54%	3.44	1.28%
Helictotrichon parlatorei	A3	3.86	1.08%	3.09	1.14%
Plantago alpina	75	1.36	0.38%	0.78	0.29%
Carex curvula	37	2.20	0.61%	1.42	0.53%
Poa alpina	61	1.96	0.55%	1.92	0.71%
Dryas octopetala	SA3	1.48	0.41%	1.41	0.52%
Plantago alpina	75	0.97	0.27%	0.77	0.29%
Brachypodium pinnatum	S4	0.81	0.23%	0.70	0.26%
Festuca gr. rubra and *Agrostis tenuis*	52	0.81	0.23%	0.65	0.24%
Nardus stricta	30	0.62	0.17%	0.62	0.23%
Alchemilla pentaphyllea and *Salix herbacea*	A9	1.20	0.34%	0.60	0.22%
Rumex alpinus	69	0.57	0.16%	0.53	0.20%
Trifolium badium	72	0.51	0.14%	0.41	0.15%
Deschampsia caespitosa	53	0.48	0.13%	0.29	0.11%
Plantago alpina and *Festuca ovina*	A1	0.33	0.09%	0.26	0.10%
Screes	E2	0.27	0.08%	0.05	0.02%
Total		**358.07**	**100.00%**	**269.56**	**100.00%**

Table 105.2. Pasture surface divided by pasture type.

There are 29 pasture types in the Pasture district. The most represented type is *Nardus stricta* and *Carex sempervirens* type, with *Trifolium alpinum* (cod. A8.1), of intermediate ecological conditions, in wide portions mainly far from the Alpe Fond. The main three species may have different percentages, according to the zone. Also well represented basic meadows like *Kobresia myosuroides* type and *Sesleria varia* type, of termic ecological conditions, on slopes, crests and the *Festuca violacea* type of intermediate or thermic ecological conditions.

The most fertile type is *Festuca* gr. *rubra*, well represented in Fos but also in Fond, thanks to fertigation, at the lower altitude, in the areas near the mountain pasture buildings (only one still used), with low slopes.

The *Nardus stricta* and *Festuca* gr. *rubra* type receives less fertility. At the higher altitudes there is *Carex curvula* type, sometimes with little snowbed communities with *Alchemilla pentaphyllea, Salix herbacea, Carex foetida*. Several wetlands with *Carex* sp.pl, *Juncus* spp. and *Eriophorum* spp. often forming mosaics with other pasture types.

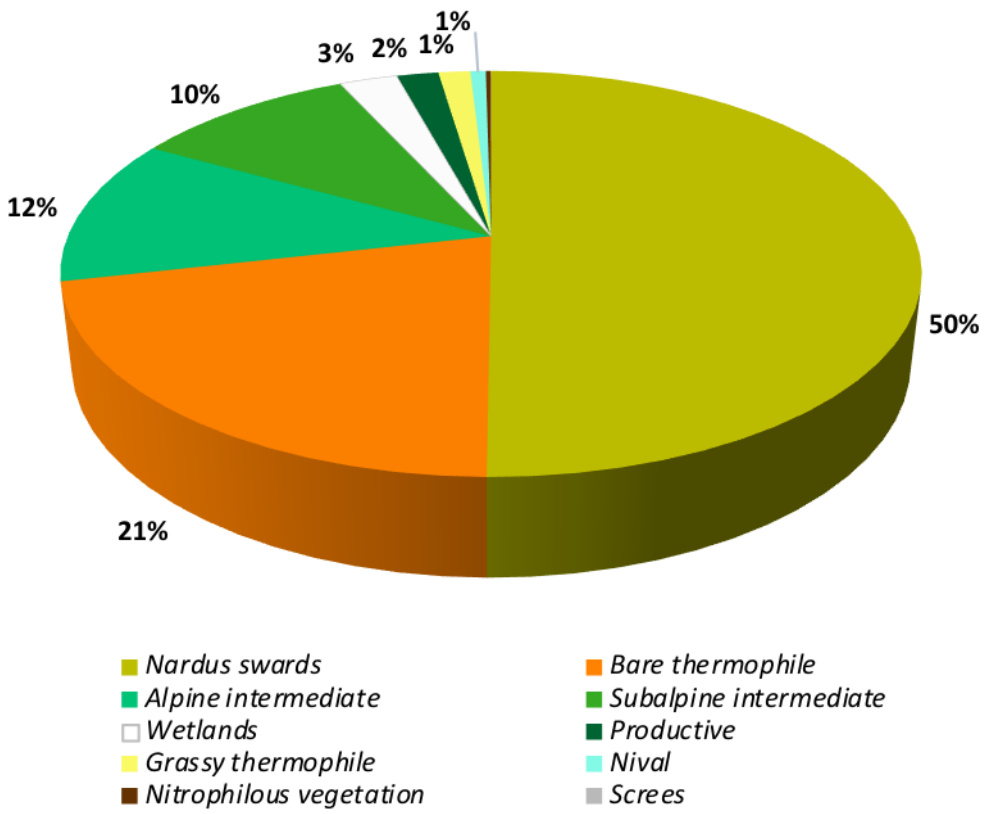


Figura 105.1 Pasture net surface divided by pasture category.

Grazing management notes

The Pasture district is managed by one farmer with two herds of about 115 cows and 106 Livestock Units (LSU) (2017 data): one of dairy cows (the largest, 90 cows) and one of heifers and dry cows. The first herd grazes the most accessible pastures with strip grazing; the second one grazes the farthest meadows mainly on the hydrographic right.

Dairy cows are sheltered in the barn of Alpe Fos and Alpe Fond nightly and during the central hours of the day; then the dejections are distributed on a part of the pastures, through fertigation.

The grazing season lasts from end of June to end of September.

Pasture district n. 106 Djouan-Orvieilles

Municipality	*Valsavarenche (AO)*
Surface	*Total (gross area): 413 ha* *Pasture (net area): 260 ha*
Elevation	*1893 m – 2869 m a.s.l.*
Aspect	*East, south-east*
Slope	*Slopes of between 10°* and *30° on the most attractive pasture areas; slopes increase in areas at higher altitudes.*

Territorial overview

The Pasture district of Djouan-Orvieilles is on the hydrographic left side of Valsavarenche between 1900 m a.s.l. and 2900 m a.s.l., in the subalpine and alpine altitudinal level. The morphology is characterized by prevailing slopes (10°-30°) and not very large flat areas. The substrate is changeable: glacial moraine deposits, calcschists, metabasalts, gneisses, sloap coarse deposits.

The prevailing exposure is east, south-east, with little sectors to south and north.

The Pasture district can be reached by a dirt road with little vehicles, from Vers Le Bois to Orvieille Royal hunting house and Alpe Djouan (2230 m a.s.l.), or by footpaths from Creton or Eaux Rousses.

Pasture surfaces

The net grazing areas, divided by tare classes, are represented in *Table 106.1*:

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	111.55	27.02%	111.55	42.96%
20	117.84	28.54%	94.27	36.30%
50	91.79	22.23%	45.96	17.70%
80	39.62	9.60%	7.90	3.04%
100	52.10	12.62%	0.00	0.00%
Total	**412.90**	**100.00%**	**259.68**	**100.00%**

Table 106.1. Total and net area in the Pasture district by tare class.

In the examined Pasture district there are about 413 ha of grassland and about 260 ha of net grazing area.

About the 43% of the net grazing area is characterized by the absence of diffused tares, whereas about 36% of the net grazing area is characterized by the 20% of diffused tares, about the 18% of the net grazing by the 50% of diffused tares, and about the 3% of the net grazing by the 80% of diffused tares.

The main tares are rocks and screes, that also includes the uncovered ground and trees and shrubs, mainly *Rhododendron ferrugineum, Vaccinium* spp. and *Juniperus nana*.

Pasture type

The pasture types identified on the pasture district are represented in *Table 106.2* and reported in *Figure 106.1.*

The identification of pasture vegetation communities was based on the work “La vegetazione di Orvieille e Levionaz: individuazione dei tipi di pascolo e relativa cartografia tematica” by Dr. Barbara Martinasso, adapting it to the methodology of the present work.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Nardus stricta and *Carex sempervirens*	A8	92.81	25.72%	81.24	31.29%
Festuca gr. violacea	46	56.43	15.64%	31.01	11.94%
Carex curvula	A5	48.04	13.31%	30.49	11.74%
Plantago alpina and *Festuca ovina*	A1	27.26	7.56%	21.16	8.15%
Carex sempervirens	32	27.05	7.50%	16.27	6.27%
Festuca violacea	A2	26.82	7.43%	14.48	5.58%
Dactylis glomerata	S3	24.58	6.81%	24.09	9.28%
Kobresia myosuroides	A6	11.25	3.12%	6.94	2.67%
Helictotrichon parlatorei	A3	10.57	2.93%	7.02	2.70%
Festuca rubra	S2	8.72	2.42%	8.29	3.19%
Festuca scabriculmis	24	8.31	2.30%	3.91	1.51%
Nardus stricta and *Festuca rubra*	S1	6.58	1.82%	4.78	1.84%
Rhododendron ferrugineum and *Vaccinium uliginosum*	L3	2.34	0.65%	2.34	0.90%
Trifolium alpinum and *Carex sempervirens*	33	2.22	0.62%	1.11	0.43%
Phleum alpinum	60	1.99	0.55%	1.94	0.75%
Poa alpina	61	1.89	0.52%	1.89	0.73%
Festuca paniculata	S6	1.03	0.29%	0.92	0.35%
Brachypodium pinnatum	S5	0.90	0.25%	0.45	0.17%
Nardus stricta	30	0.80	0.22%	0.64	0.25%
Dryas octopetala	SA3	0.74	0.21%	0.23	0.09%
Trisetum flavescens	59	0.33	0.09%	0.33	0.13%
Wetlands	ZH	0.14	0.04%	0.14	0.05%
Total		**360.80**	**100.00%**	**259.68**	**100.00%**

Table 106.2. Pasture surface divided by pasture type.

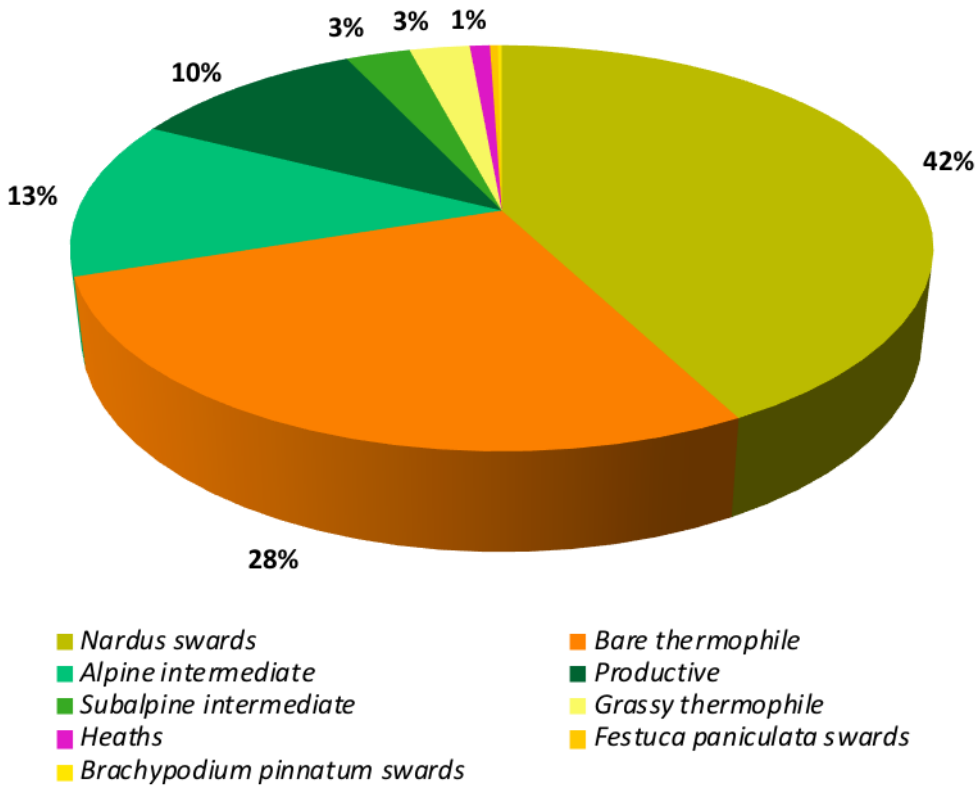


Figura 106.1. Pasture net surface divided by pasture category.

There are 22 pasture types and 29 facies.
The most represented type is *Nardus stricta* and *Carex sempervirens* type, with *Trifolium alpinum* (cod. A8.1), of intermediate ecological conditions, in wide portions mainly far from the Alpe Djouan. The main three species may have different percentages, according to the zone. *Festuca violacea* type of intermediate or thermic ecological conditions is also well represented on slopes, while at higher altitude *Carex curvula* formations are well represented, sometimes forming mosaics with *Kobresia myosuroides* type on slopes and crests and sometimes present in the *Trifolium alpinum* facies.
Then there are *Plantago alpina* and *Festuca ovina* formations of thermic ecological conditions, on slopes from east to south and the *Carex sempervirens* type with *Plantago alpina, Sesleria varia* and *Festuca ovina*, on slopes to east.
The richest formations are *Trisetum flavescens*, *Festuca* gr. *rubra, Agrostis tenuis* and *Dactylis glomerata* ones and *Festuca* gr. *rubra* ones, at the lower altitude, between Ruyaz, Ploriond and Alpe Djouan.

Grazing management notes

The Pasture district is managed by two farmers with two herds; the first is a dairy cows herd of about 66 cows and 19 heifers equal to 82 LSU (2017 data), that grazes the northern pastures of the area from Djouan to Tramouail, with strip or guided grazing. The grazing season lasts from mid/end of June to the end of September.
The second is a heifers and dry cows herd of about 54 elements equal to 40 LSU (2017 data), that grazes the sector from Tramouail to Djouan lakes, with free grazing. The grazing season in this area lasts from the second half of July to the end of September.

Pasture district n. 107 Entrelor

Municipality	*Rhêmes-Notre-Dame (AO)*
Surface	*Total (gross area): 216 ha* *Pasture (net area): 126 ha*
Elevation	*2025 m – 2761 m a.s.l.*
Aspect	*West and north*
Slope	*Low in the lower part of the district* and *medium to steep at higher altitudes*

Territorial overview

The Pasture district of Entrelor occupies the Entrelor hanging valley, on the hydrographic right side of Rhêmes Valley, and a part of the neighboring Sort valley, between 2025 m a.s.l. and almost 2800 m a.s.l., in the subalpine and alpine altitudinal level; the total surface district is about 216 ha.

The morphology is characterized by an alternation of flat areas and slopes from 10° to 30° with exposure to north-west, in the main valley; by slopes from 10° to 40° with exposure to west and south west, under Gollien pass; by slopes from 10° to 40° with exposure to north, north west, in the Sort valley.

The substrate is changeable: calcschists, metabasalts, gneisses, glacial moraine deposits.

The Pasture district can be reached by footpath from Chaudanne.

Pasture surfaces

The total and net areas, divided by tare classes, are represented in *Table 107.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	11.81	5.46%	11.81	9.36%
20	113.42	52.41%	90.74	71.88%
50	45.51	21.03%	22.79	18.05%
80	4.45	2.06%	0.89	0.71%
100	41.20	19.04%	0.00	0.00%
Totale	**216.49**	**100.00%**	**126.23**	**100.00%**

Table 107.1. Total and net area in the Pasture district by tare class.

In the examined Pasture district there are about 216 ha of grassland and 126 ha of net grazing area.

About the 9% of the net grazing area is characterized by the absence of diffused tares, whereas about 72% of the net grazing area is characterized by the 20% of diffused tares, about the 18% of the net grazing by the 50% of diffused tares, and about the 1% of the net grazing by the 80% of diffused tares.

The main tare are rocks and screes, that also includes the uncovered ground. Main shrubs, in the lower areas, are *Rhododendron ferrugineum, Vaccinium* spp., *Juniperus nana*.

Pasture types

The pasture types identified on the pasture district are represented in *Table 107.2* and reported in *Figure 107.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Carex curvula	A5	34.42	19.65%	23.04	18.25%
Kobresia myosuroides	A6	33.22	18.96%	19.80	15.69%
Nardus stricta and *Carex sempervirens*	A8	15.14	8.64%	12.11	9.59%
Plantago atrata	49	14.73	8.41%	10.96	8.68%
Festuca rubra	S2	11.44	6.53%	10.71	8.48%
Festuca gr. violacea	46	12.79	7.30%	9.74	7.72%
Nardus stricta and *Festuca rubra*	S1	12.05	6.88%	8.69	6.88%
Plantago alpina	75	10.49	5.99%	8.39	6.65%
Trifolium alpinum and *Carex sempervirens*	33	10.24	5.85%	8.19	6.49%
Rhododendron ferrugineum and *Vaccinium uliginosum*	L3	7.74	4.42%	5.83	4.62%
Dactylis glomerata	S3	5.14	2.93%	4.10	3.25%
Plantago alpina and *Festuca ovina*	A1	4.25	2.43%	3.40	2.69%
Screes	E	2.39	1.36%	0.48	0.38%
Juniperus nana	L2	0.53	0.30%	0.48	0.38%
Alchemilla pentaphyllea and *Salix herbacea*	A9	0.62	0.35%	0.31	0.25%
Totale		**175.19**	**100.00%**	**126.23**	**100.00%**

Table 107.2. Pasture surface divided by pasture type.

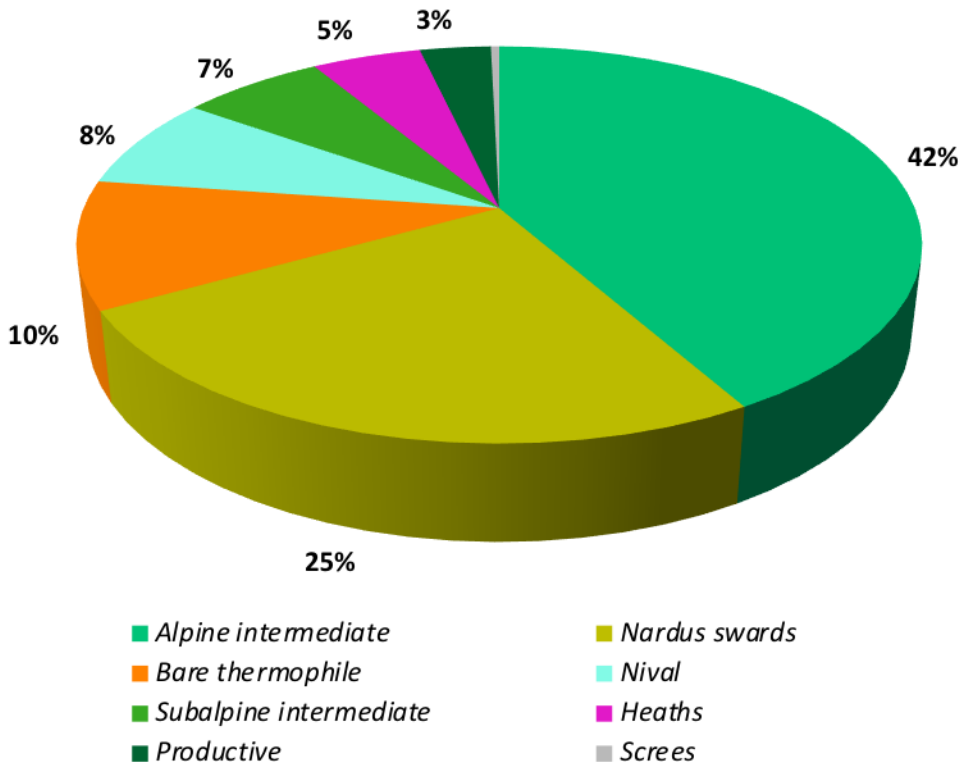


Figure 107.1. Pasture net surface divided by pasture category.

There are 15 pasture types and 19 facies.
The most represented type is the *Carex curvula* one, at the higher altitudes, forming mosaics sometimes with little snowbed communities with *Alchemilla pentaphyllea, Salix herbacea, Carex foetida*, but mostly with *Kobresia myosuroides* type, on slopes and crests. Always at the higher altitudes there are *Plantago atrata* formations with *Poa alpina, Geum montanum* and *Festuca violacea*, sometimes forming mosaics with *Kobresia myosuroides* type.
The *Nardus stricta* and *Carex sempervirens* type, with *Trifolium alpinum* (cod. A8.1), of intermediate ecological conditions, is far from the Alpe Entrelor; the main three species may have different percentages, according to the zone.
At the lower altitude, in the areas with low slopes, there are the *Nardus stricta* and *Festuca* gr. *rubra* type, receiving less fertility, and the *Festuca* gr. *rubra* type and the *Trisetum flavescens*, *Agrostis tenuis, Festuca* gr. *rubra, Polygonum bistorta* formations, receiving higher levels of fertility.
Above the cow-shed, a *Plantago alpina* type, with *Plantago atrata* and *Festuca* gr. *rubra,* was indicated.

Grazing management notes

The Pasture district is managed by two farmers with a meat cows herd of about 30 elements equal to 22 LSU and a sheep flock of about 900 elements equal to 135 LSU.
The herd exploits the lowest pastures, downstream of Alpe Entrelor, managed with strip grazing; the flock exploits pastures above Alpe Entrelor, with guided grazing and is nightly closed in electric fences, to be protected against wolf predation.
The grazing season lasts from mid-end July to mid-September.
Previously (from 1999 to 2016) the area was managed with a dairy cows herd (about 60 elements), with night and day strip grazing; cows were milked on the pasture, using a self-moving milking machine.
Sort valley has not been used for decades.

Pasture district n. 108 Gran Loson

Municipality	*Cogne (AO)*
Surface	*Total (gross area): 207 ha* *Pasture (net area): 162 ha*
Elevation	*1672 m – 2999 m a.s.l.*
Aspect	*North* and *south-east*
Slope	*Good gradients with an average of 26°*

Territorial overview

The Pasture district Gran Loson is located in the homonymous valley; it is accessible by a paved road from Valnontey and then with about 1.5-2 hour walk (900 m altitude difference) on a smooth path. It covers the central part of the valley and the low slopes both on the right and left bank of the stream. In the head of the valley the border is defined by the presence of pasture vegetation. The district also includes two-grass pastures in separated locations Leuttaz and Tsantelet next to Valnontey.

As the valley has a course east-west, the exposures that prevail are the north, north-east and south, southeast. In the two separate zones there isn't a clearly prevalent exposure because it consists of flat surfaces, the prevailing trend, however, is oriented to the south-east.

The morphology is wavy at the center of the valley while on the sides it partially goes up, the slopes are fairly small, the left side is steeper, next to the stream there are cracks but they are suitable for grazing. The average slope of the main body is equal to 26°, of the Leuttaz and Tsantelet 19° lawns.

Pasture surfaces

The following table shows the grazing surfaces of the district under review, divided by tare class.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	83.75	40.41%	83.75	51.68%
20	70.28	33.91%	56.20	34.68%
50	42.21	20.37%	21.13	13.10%
80	4.28	2.07%	0.86	0.53%
100	6.73	3.25%	0.00	0.00%
Totale	**207.25**	**100.00%**	**162.04**	**100.00%**

Table 108.1. Total and net area in the Pasture district by tare class.

In the whole Grand Loson Pasture district there are about 207 ha excluding the unproductive tare (rocks and scree, waterways, buildings) and 162 ha excluding the diffuse tare, i.e. within the grassed polygons (rocks and outcropping scree, bushy and / or arboreal areas).

As part of the tares over 84% is made up of rocks and screes, about 3% by trees and shrubs, 2.5% attributed to other, which is almost always made from bare soil and other categories which have insignificant surfaces.

Pasture types

The pasture types identified within the grazing area are 25: 6 are related to those of the Piedmont Alps and cover a total of approximately 20 ha equal to about 12% of the net grazing surface. These are mainly *Festuca scabriculmis* and *Poa violacea* formations. In *Table 108.2* the identified pasture types are reported in descending order for the covered surface. As it can be observed there are 4 types that prevail and that alone occupy half of the entire surface.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Carex curvula	A5	40.02	19.31%	32.90	20.30%
Festuca halleri	A4	27.45	13.24%	22.71	14.01%
Festuca violacea	A2	21.13	10.20%	15.96	9.85%
Festuca scabriculmis	24	17.49	8.44%	13.31	8.21%
Helianthemum nummularium	SA2	14.01	6.76%	13.41	8.28%
Nardus stricta and *Carex sempervirens*	A8	17.25	8.32%	11.54	7.12%
Plantago alpina and *Festuca ovina*	A1	13.63	6.58%	10.75	6.63%
Kobresia myosuroides	A6	14.43	6.96%	10.42	6.43%
Dactylis glomerata	S3	9.30	4.49%	8.89	5.49%
Alchemilla pentaphyllea and *Salix herbacea*	A9	11.43	5.51%	5.58	3.44%
Nardus stricta and *Festuca rubra*	S1	4.17	2.01%	3.63	2.24%
Festuca rubra	S2	3.38	1.63%	3.19	1.97%
Poa violacea	29	2.87	1.38%	2.34	1.44%
Nardus stricta	30	2.87	1.38%	2.32	1.43%
Geum montanum	47	1.84	0.89%	1.84	1.14%
Trifolium alpinum	A7	1.56	0.75%	1.56	0.96%
Brachypodium pinnatum	S5	0.62	0.30%	0.62	0.38%
Loiseleuria procumbens and/or *Vaccinium uliginosum*	L1	0.48	0.23%	0.38	0.23%
Festuca quadriflora	21	0.27	0.13%	0.27	0.17%
Deschampsia caespitosa	53	0.25	0.12%	0.25	0.15%
Helictotrichon parlatorei	A3	0.19	0.09%	0.10	0.06%
Rhododendron ferrugineum and *Vaccinium uliginosum*	L3	0.16	0.08%	0.03	0.02%
Arctostaphylos uva-ursi. Juniperus nana and *Vaccinium uliginosum*	L2	0.13	0.06%	0.03	0.02%
Dryas octopetala	SA3	0.02	0.01%	0.02	0.01%
Screes	E2	2.02	0.97%	0.00	0.00%
Wetlands	ZH	0.29	0.14%	0.00	0.00%
Total		**207.26**	**100.00%**	**162.05**	**100.00%**

Table 108.1. Pasture surface divided by pasture type.

In the *Figure 108.1* the pasture types are represented with the reference colors.

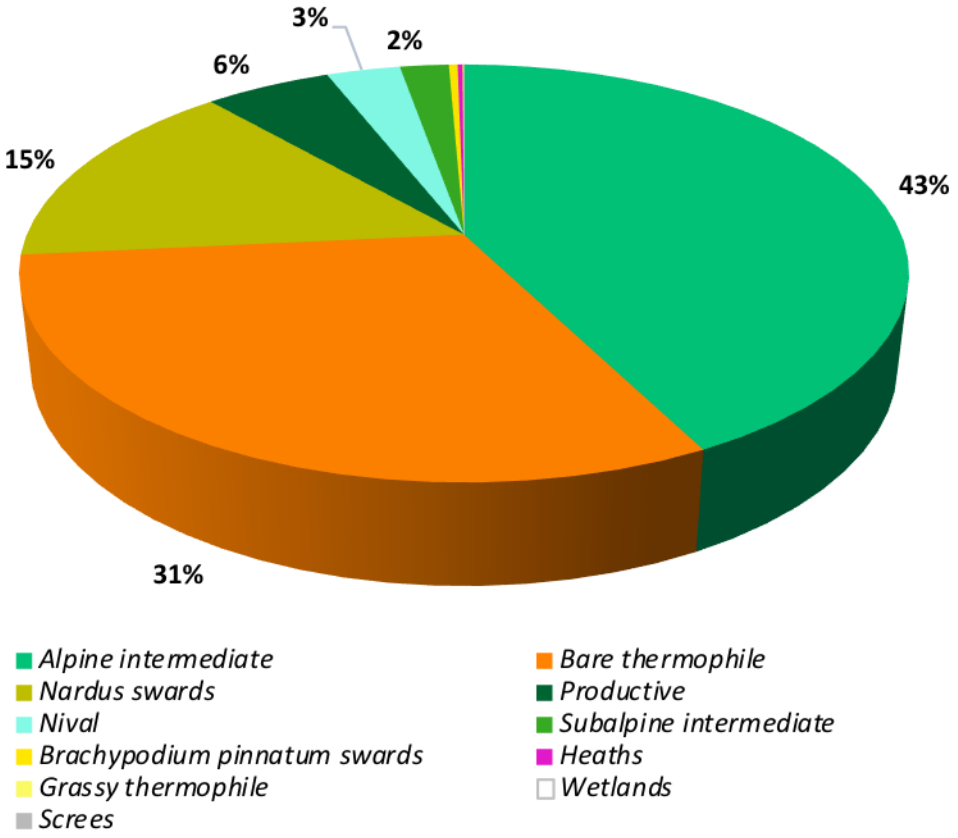


Figure 108.1. Pasture net surface divided by pasture category.

Management notes

The district is currently used by a race of Biella sheep. The utilization appears uniform over the entire surface with the exception of the low-lying areas (Thoules) which are underutilized especially in the more peripheral surfaces. In addition, the left hydrographic side downstream Gran Loson pastureland is not grazed. During the survey season, perhaps because of a summer with the very scarce rainfall, at the head of the valley (2600-2700 m above sea level) some erosion phenomena have been detected, especially in the screes, aggravated by the passage of animals. More generally, in the steepest slopes and at higher altitudes, the grassy turf is sparse and not very compact.

The alpine buildings have been recently renovated, tailored to the needs of the company and indeed oversized because the barn is not used.

The areas covered by animals grazing appear used correctly and consistently, particular care should be taken by moving frequently, once every 2-3 days the fence for the animals overnight.

Picture 108.1. The flock grazing in the downstream area of Cote verte.

Picture 108.2. The shepherd watches over his flock.

The objectives and the attention elements with respect to the influence of the management aspects on the vegetation of the district are:

- reduce the utilization of the high areas while increasing that in the low areas of the district anticipating, if necessary, the transhumance date;
- maintaining of the facies *Nardus stricta* and *Trifolium alpinum* (A8.1) through a management involving balanced refunds and relatively late utilization to encourage the dissemination of *Trifolium alpinum* very early when the leaves of the clover are still too small to be browsed and young sprouts of nardeto are more attractive;
- preservation of the facies *Carex curvula* through well calibrated uses in relation to the offer and trying to reduce as much as possible the displacement of the animals;
- improvement of fodder value in the facies *Poa violacea* or where its presence is significant, by means of early uses with loads that can be locally high in order to reduce the selection on the species and provide higher refunds;
- improvement of the zones with the presence of *Festuca scabriculmis* through early uses made with regularity and balanced loads.

Pasture district n. 109 Lago di Dres

Municipality	*Ceresole Reale (TO)*
Surface	*Total (gross area): 125 ha* *Pasture (net area): 44 ha*
Elevation	*1812 m – 2458 m a.s.l.*
Aspect	*North* and *north-east*
Slope	*Generally gentle slopes of less than 20°.*

Territorial overview

The Pasture district Lago di Dres is placed in the right side of Orco Valley, just over the Ceresole Lake and is mainly oriented to the north-east. The pastures are mainly located in the areas with the lowest slope (near the Foppa, Trucco, Pian Mutta and Manda Alps), from an altitude of approximately 1800 m a.s.l. up to about 2230 m a.s.l.; only a limited pasture surface is located at higher altitudes. The main pasture exposure ranges between north and north-east. The Pasture district does not border with other investigated Pasture district.

Pasture surfaces

The net grazing area of the Pasture district, are given by tare classes, in *Table 109.1:*

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	25.51	18.04%	25.51	57.70%
20	9.22	7.39%	7.38	16.69%
50	16.95	13.58%	8.48	19.18%
80	14.19	11.37%	2.84	6.42%
100	58.90	47.21%	0.00	0.0%
Total	**124.77**	**100.00%**	**44.21**	**100.00%**

Table 109.1. Total and net area in the Pasture District by tare class.

In the examined pasture district, there are about 44 ha of net grazing area. About the 58% of the net grazing area is characterized by the absence of diffused tares, whereas about another 17% of the net grazing area in characterized by the 20% of diffused tares, as well as about the 19% of the net grazing area showed the 50% of diffused tares. The areas that cannot be grazed correspond to about 59 ha of gross area (about the 47% of gross ungrazeable surfaces).

Pasture types

The pasture type identified on the pasture district are given in *Table 109.2* and reported in *Figure 109.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca gr. *rubra*	S2	36.03	54.70%	29.96	67.78%
Nardus stricta and *Carex sempervirens*	A8	24.06	36.53%	9.24	20.91%
Carex fusca	ZH2	5.17	7.85%	4.40	9.95%
Subalpine nitrophilous vegetation	RA1	0.61	0.93%	0.61	1.38%
Total		**65.87**	**100.00%**	**44.20**	**100.00%**

Table 109.2. Pasture surface divided by pasture type.

Pastures are largely dominated by the *Festuca* gr. *rubra* type that share about 68% of the net grazing areas. The second type for surface share is the type A8-*Nardus stricta* and *Carex sempervirens*, that cover just over 9 ha, corresponding to about 21% of the net grazing areas.

This type is represented by two facies, the first, less wide (about 2.4% of net grazing area) is the variant with *Trifolium alpinum* (cod. A8.1 with *Nardus stricta, Trifolium alpinum* and *Carex sempervirens*), the second one, dominant, is with *Nardus stricta*, *Carex sempervirens* and *Festuca* gr. *rubra* (code A8.2), that cover a net area of about 8 ha, corresponding to 18.5% of the total net grazing areas. The third type for surface share is the *Carex fusca* type, which makes up 10% of the grazing net areas in the pasture district and is located near the extensive wetlands. The remaining area (for an extension of just over half a hectare) is taken by the Subalpine nitrophilous vegetation, which characterize the surfaces near the mountain pastures buildings.

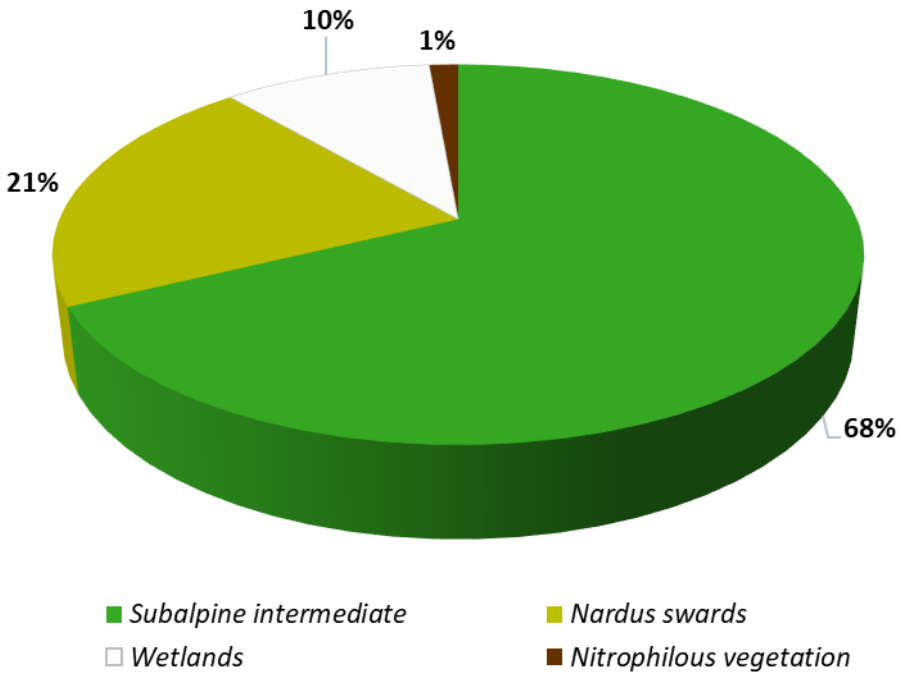


Figure 109.1. Pasture net surface divided by pasture category.

Grazing management notes

Two different farmers manage the grazing area, but no separation of management units are evident.

The first farm manages the more fertile flat pastures, located between the barn, by free ranging with a cattle herd of about 25-40 heads of Piedmontese breed. The farmer does not stay continuatively at the pasture area.

The second farm manage the steeper and farer areas, not accessible by cattle, with a large free ranging sheep flock. The flock also graze on the refusal on the other pasture surface after cattle exploitation.

Pasture district n. 110 Levionaz

Municipality	*Valsavarenche (AO)*
Surface	*Total (gross area): 262 ha* *Pasture (net area): 173 ha*
Elevation	*1557 m – 3000 m a.s.l.*
Aspect	*West and, within the valley, west and south-east*
Slope	*Low along the valley floor and higher on the slopes in the Levionaz valley*

Territorial overview

The Pasture district of Levionaz is located in the municipality of Valsavarenche (AO) and includes the entire Vallone di Levionaz, located on the oroghraphic right of the main axis of the Valley. The Pasture district is crossed by the Levionaz creek which flows from east to west. The grasslands extend from 1550 m a.s.l. (Frazione Tignet) up to 3000 m a.s.l. covering the lower subalpine, upper subalpine and alpine (lower and upper) belts.

Near the crumbling buildings of the Alpe Levionaz du Milieu the valley splits into two branches, the one on the north leads to Lauson (or Loson) pass, the southern one splits again further near Alpe Levionaz Damon into two valleys: to the north the Vallon d'Enfer, to the south the Vallon de Timorion. An offshoot of the Pasture district (Le Tour) belongs to the river basin of the Vallone di Pessin.

The lower part of the Pasture district includes former crops (as evidenced by stone walls and terracing).

Pasture surfaces

The net grazing area of the Pasture district, are given by tare classes, in *Table 110.1*:

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	59.37	22.70%	59.37	34.33%
20	80.64	30.83%	64.50	37.30%
50	82.07	31.38%	41.18	23.81%
80	39.45	15.08%	7.87	4.55%
Total	**261.53**	**100.00%**	**172.92**	**100.00%**

Table 110.1. Total and net area in the Pasture district by tare class.

There are about 262 gross grazing hectares in the pasture area, corresponding to 173 net grazing hectares. Surfaces with a 20% tare mainly consisting of stones are prevalent, followed by portions without tare (located in the lower part of the Pasture district and on the slopes of the Levionaz plain). The presence of pastures with a 50% tare is significant especially in the alpine belt due to the rocks and bare soil. Tares caused by shrubs and tree species renovation are negligible throughout the Pasture district.

Pasture types

The pasture type identified on the Pasture district are given in *Table 110.2* and reported in *Figure 110.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca violacea	A2	48.13	18.40%	32.90	19.03%
Elyna myosuroides (= Kobresia m.)	22 + A6	56.30	21.53%	26.82	15.51%
Helianthemum nummularium	17 + SA2	28.30	10.82%	25.30	14.63%
Nardus stricta and *Carex sempervirens*	A8	21.40	8.18%	16.30	9.43%
Bromus erectus	8	15.80	6.04%	15.80	9.14%
Carex curvula	A5	19.60	7.49%	11.40	6.59%
Festuca gr. halleri	35 + A4	21.60	8.26%	11.20	6.48%
Sesleria varia	13	9.90	3.79%	8.10	4.68%
Stipa pennata	3	7.40	2.83%	5.90	3.41%
Brachypodium rupestre	25	6.50	2.49%	5.20	3.01%
Dryas octopetala	SA3	7.70	2.94%	3.30	1.91%
Festuca scabriculmis	24	3.60	1.38%	1.80	1.04%
Carex sempervirens	32	2.40	0.92%	1.90	1.10%
Rhododendron ferrugineum and *Vaccinium uliginosum*	L3	4.20	1.61%	1.50	0.87%
Helictotrichon parlatorei	A3	2.60	0.99%	1.40	0.81%
Festuca gr. rubra and *Agrostis tenuis*	52	1.20	0.46%	1.20	0.69%
Salix retusa and *Salix reticulata*	70	1.90	0.73%	0.90	0.52%
Plantago alpina	75	0.90	0.34%	0.90	0.52%
Salix herbacea	77	1.10	0.42%	0.50	0.29%
Alchemilla pentaphyllea and *Salix herbacea*	A9	0.90	0.34%	0.50	0.29%
Carex fusca	86	0.10	0.04%	0.10	0.06%
Total		**261.53**	**100.00%**	**172.92**	**100.00%**

Table 110.2. Pasture surface divided by pasture type.

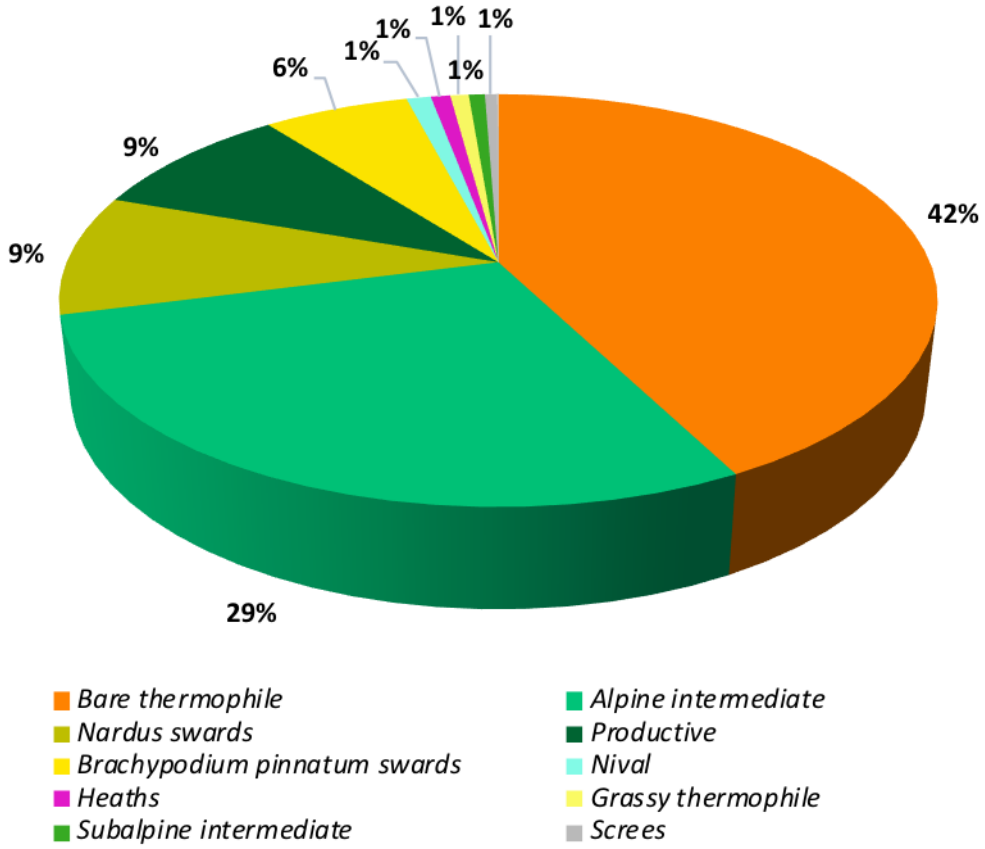


Figure 110.1. Pasture net surface divided by pasture category.

21 Pasture types and 25 facies were found: this is a significant heterogeneity, in relation to the small surface of the Pasture district, and it is due to the considerable altitudinal extension, the diversified aspects of the Vallone and the various lithology.

Overall the types referable to formations of thermal conditions prevail (138 gross hectares), located mostly on the south-west facing slopes, followed by the formation of intermediate conditions (114 gross hectares), while snowbed formations is have limited input (about 4 gross hectares) and the formation of hydromorphic conditions and shrub encroachment is negligible. There are no pastures under tree cover.

The largest pasture type in terms of net area is the *Festuca violacea* one (19% of the net surface area, above all on skeleton-rich soils) with a single facies composed by *Festuca violacea, Carex sempervirens, Festuca rubra* and *Potentilla grandiflora*.

The *Elyna myosuroides* (= *Kobresia* m.) one is the following type. It is located in thermic conditions and on poorly developed calcareous soils, on the bumps and on the windy ridges occupying 15.5% of the surface; it includes 3 facies of which the most extensive one includes *Elyna myosuroides* and *Salix serpyllifolia*. In case of considering the gross surface instead of the net surface, the *Elyna* type would be the largest since the formation is characterized by abundant presence of bare soil and / or rock.

The *Helianthemum nummularium* type was then described (occupies 14.6% of the surface), located on the sunny slopes with 2 facies of which the largest is the *Helianthemum nummularium, Sesleria varia* and *Festuca* gr. *ovina*.

Last are *Nardus stricta* and *Carex sempervirens* type, on flat terrain, and the *Bromus erectus* type in the former cultivations (both with an extension of 9%).

Grazing management notes

The *Bromus erectus* grasslands of the Pasture district, which are located below 2000 m a.s.l., are partly forage harvested and partly (prevalent) grazed; those related to the *Brachypodium rupestre* pasture type are managed with grazing. Mowed grasslands are not irrigated and fertilized with manure. These grasslands are grazed by Valdostana breed cattle at the beginning and at the end of the pasture season (regrowth), with a turned grazing technique and electrified mobile fences.

The high grasslands of the Pasture district (located above the 2000 m a.s.l.) of Levionaz have no longer been destined for the grazing of domestic animals for several decades, in accordance with the addresses of PNGP (surely the mountain pasture was no longer utilized as early as 1999). Since these are pastures that can potentially be used by domestic livestock, they have been marked in the database as "suitable for grazing": this classification procedure has been agreed with PNGP. The Alpe di Levionaz Dessous buildings were used as Park Ranger's Cabin, those of Levionaz du Milieu collapsed, while those of Levionaz Damon (distinguished by their considerable size and with a valuable stone vault) are in fairly good condition, albeit unused.

The upper part of the Pasture district can be reached through two paths: one starts from Tignet and one, wider and with milder slope by Eaux Rousses (suitable for the passage of cattle), both reaching Levionaz Dessous; beyond that the valley is crossed by the track leading to Col Lauson, easily accessible by cattle.

The portion of the Pasture district called La Tour would, in any case, be difficult to access by the livestock from the Levionaz valley because the only way is along an exposed and slippery path: access would be easier from the parallel valley of Torrente Pessin (mainly *Elyna myosuroides* formations with poor pabular value).

Theoretically, given the current grazing ban in that part of the Pasture district, the most productive areas of the pasture, easily accessible and with a gentle slope, could be destined to milking cows grazing while the less productive pasture types would be assigned to young or dry cattle and the parts with a though access, very steep or at high elevation, would be grazed by sheep.

Pasture district n. 111 Meyes

Municipality	*Valsavarenche (AO)*
Surface	*Total (gross area): 206 ha* *Pasture (net area): 92 ha*
Elevation	*2000 m – 2825 m a.s.l.*
Aspect	*East and south*
Slope	*Extensive plateaus in the upper part of the district and slopes with changeable gradients in the lower part*

Territorial aspects

The Pasture district of Meyes is on the hydrographic left side of Valsavarenche Valley, between 2000 m a.s.l. and 2800 m a.s.l., in the subalpine and alpine altitudinal zones.
The morphology is characterized by versants from moderate to high slope, flat areas or faint slopes, mostly in the higher altitudinal zone. The main exposures are to east and south, south-east, with little sectors to west and north.
The substrate consists of orthogneisses, glacial moraine deposits.
The Pasture district can be reached by a dirt road (restricted access), from Pont almost to Alpe Meyes desot (2280 m s.l.m.), or by footpath from regional road n.23 between Eaux rousses and Pont.

Pasture surfaces

The net grazing areas, divided by tare classes, are represented in *Table 111.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	11.39	5.54%	11.39	12.41%
20	47.97	23.33%	38.38	41.81%
50	80.66	39.23%	40.36	43.97%
80	8.32	4.05%	1.67	1.82%
100	57.20	27.82%	0.00	0.00%
Total	**205.54**	**100.00%**	**91.80**	**100.00%**

Table 111.1. Total and net area in the Pasture district by tare class.

In the examined pasture area there are about 148 ha of grassland and 92 ha of net grazing area.
As the figure shows about the 12% of the net grazing area is characterized by the absence of diffused tares, whereas about 42% of the net grazing area is characterized by the 20% of diffused tares, about the 44% of the net grazing by the 50% of diffused tares, and about the 2% of the net grazing by the 80% of diffused tares.
The main tare are rocks and screes, that also includes the uncovered ground. Main shrubs, in the lower areas, are *Juniperus nana, Rhododendron ferrugineum, Vaccinium* sp. pl.

Pasture types

The pasture types identified on the Pasture district are represented in *Table 111.2* and reported in *Figure 111.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Carex curvula	A5	57.12	38.51%	34.43	37.51%
Festuca scabriculmis	24	42.57	28.70%	21.86	23.81%
Nardus stricta and *Carex sempervirens*	A8	10.90	7.35%	7.97	8.68%
Poa alpina	61	4.76	3.21%	4.76	5.19%
Plantago alpina and *Festuca ovina*	A1	5.16	3.48%	4.23	4.61%
Trifolium alpinum and *Carex sempervirens*	33	6.01	4.05%	3.01	3.28%
Alchemilla pentaphyllea and *Salix herbacea*	A9	4.35	2.93%	2.75	2.99%
Festuca rubra	S2	3.118	2.10%	2.63	2.86%
Kobresia myosuroides	A6	4.97	3.35%	2.49	2.71%
Carex sempervirens	32	3.12	2.10%	2.2	2.40%
Nardus stricta and *Festuca rubra*	S1	1.79	1.21%	1.79	1.95%
Festuca violacea	A2	2.11	1.42%	1.69	1.84%
Trifolium badium	72	1.53	1.03%	1.22	1.33%
Deschampsia caespitosa	53	0.74	0.50%	0.7	0.76%
Wetlands	ZH	0.08	0.06%	0.07	0.08%
Total		**148.34**	**100.00%**	**91.80**	**100.00%**

Table 111.1. Pasture surface divided by pasture type.

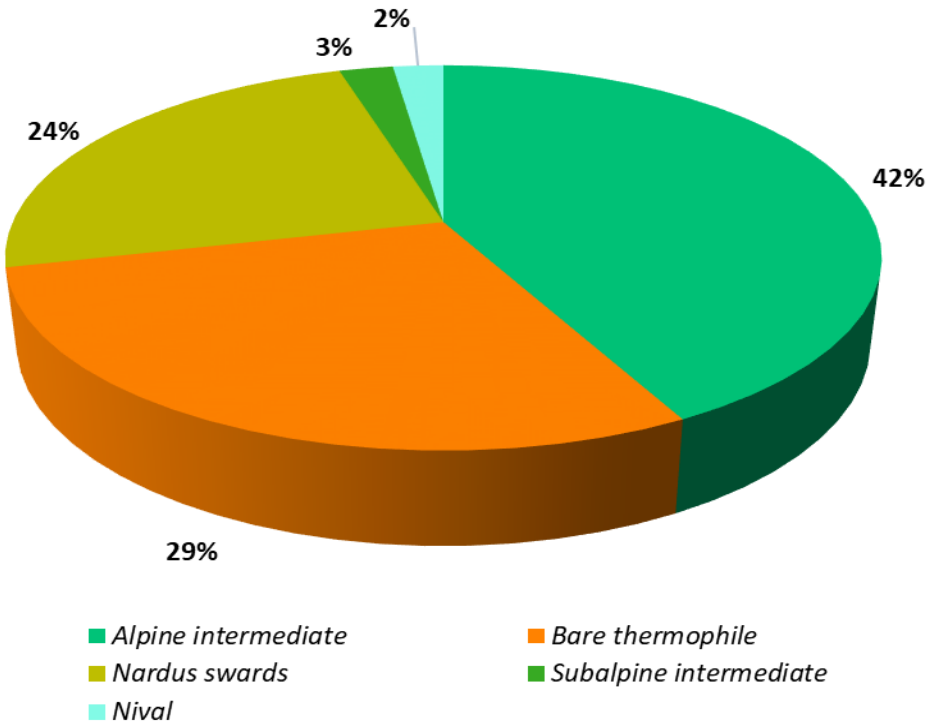


Figure 111.1. Pasture net surface divided by pasture category.

There are 15 pasture types and 21 facies.
As the widest pastures are in the higher altitudinal zone, the main type is the *Carex curvula* one, also in the facies A5.2 (with *Trifolium alpinum*), sometimes forming mosaics with little snowbed communities with *Alchemilla pentaphyllea, Salix herbacea, Carex foetida.*
In the higher zone there are also *Trifolium alpinum* and *Carex sempervirens* formations. *Festuca scabriculmis* type is widespread on slopes from south to east, in thermic ecological conditions.

Then there are *Nardus stricta* and *Carex sempervirens* formations of both facies (A8.1 with *Trifolium alpinum* and A8.2 with *Festuca* gr. *rubra*), in the middle altitudinal zone.
In the lower altitudinal zone there are *Plantago alpina* and *Festuca ovina* thermic formations, on medium slopes with exposure from south-east to east. The most fertile formations of *Festuca* gr. *rubra* types are located around Alpe Meyes Desot.

Grazing management notes

The pasture district has not been used for decades, since the early 1980s of the last century, when it was grazed by cows.

Pasture district n. 112 Nivolet

Municipality	*Valsavarenche (AO)*
Surface	*Total (gross area): 726 ha* *Pasture (net area): 556 ha*
Elevation	*2168 m – 3041 m a.s.l..*
Aspect	*No prevailing aspect*
Slope	*Low along the valley floor and at higher altitudes, where there are several plateaus.*

Territorial overview

The Pasture district of Nivolet falls within the municipality of Valsavarenche (AO) and includes the entire Vallone del Nivolet placed at the head of Valsavaranche. The most interesting grasslands spread from 2160 m a.s.l. to the Croix de la Roley and reach, near the Col Leynir, 3000 m s.l.m. involving lower alpine and upper alpine belts; the Pasture district ends at the Colle del Nivolet, on the border with Piedmont (and with the Agnel pastures). The Pasture district is crossed by the Doire del Nivolet which runs south-west to north-east along the huge Grande Plan de Nivolet.

The pastures occupy a large portion of the Piana del Nivolet while the remaining part is occupied by a large peat bog (excluded from grazing). Large grasslands are present on the mountainside on the hydrographic left and on the grassy plateaux surrounding the Trebecchi lakes and Lake Noir (or Leynir). On the hydrographic left, above the Alp Turin, the valley of Plan Borgnoz branches off. On the right bank the Gran Collet, Torrent Gran Ferrand and Torrent Petit Ferrand pastures are interspersed with rocky outcrops.

Pasture surfaces

The net grazing area of the Pasture district, is given by tare classes, in *Table 112.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	306.76	42.25%	306.76	55.14%
20	141.10	19.43%	112.91	20.29%
50	269.67	37.14%	134.98	24.26%
80	8.51	1.17%	1.70	0.31%
Total	**726.04**	**100.00%**	**556.35**	**100.00%**

Table 112.1. Total and net area in the Pasture district by tare class.

There are approximately 726 gross hectares of grazing surface in the Pasture district, corresponding to 556 net grazing hectares. More than half of the pastures, located on the valley floor and the plains, is free from tare; a fourth of the surface has a 50% tare and the remaining grazing surface has a 20% tare. Tares mostly consist in rocks and bare soil and, just locally, from alpine shrubs. In the whole Pasture district, tares deriving from shrubs and tree renovation are generally negligible, due to the high elevation.

Pasture types

The pasture types identified on the Pasture district are given in *Table 112.2* and reported in *Figure 112.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Carex curvula	37 + A5	194.90	26.84%	138.6	24.91%
Festuca scabriculmis	24	167.14	23.02%	110.35	19.83%
Nardus stricta and *Carex sempervirens*	A8	100.30	13.81%	89.60	16.10%
Trifolium alpinum	A7	86.20	11.87%	73.60	13.23%
Alch. pentaphyllea and *Salix herbacea*	A9	50.00	6.89%	38.60	6.94%

Festuca gr. violacea	46 + A2	51.30	7.07%	37.20	6.69%
Alopecurus gerardi	76 + A10	35.20	4.85%	34.80	6.26%
Phleum alpinum	60	9.20	1.27%	9.20	1.65%
Carex foetida	79	8.50	1.17%	7.30	1.31%
Festuca halleri	A4	7.70	1.06%	50	0.90%
Trifolium alpinum and *Carex sempervirens*	33	3.30	0 .45%	3.30	0.59%
Kobresia myosuroides	A6	3.70	0.51%	3.20	0.58%
Rumex alpinus	69	1.90	0.26%	1.90	0.34%
Nardus stricta	30	1.60	0.22%	1.60	0.29%
Festuca rubra	S2	2.80	0.39%	1.40	0.25%
Loiseleuria procumbens and/or *Vaccinium uliginosum*	L1	2.00	0.28%	0.40	0.07%
Salix retusa and *Salix reticulata*	70	0.30	0.04%	0.30	0.05%
Total		**726.04**	**100.00**	**556.35**	**100.00**

Table 112.2. Pasture surface divided by pasture type.

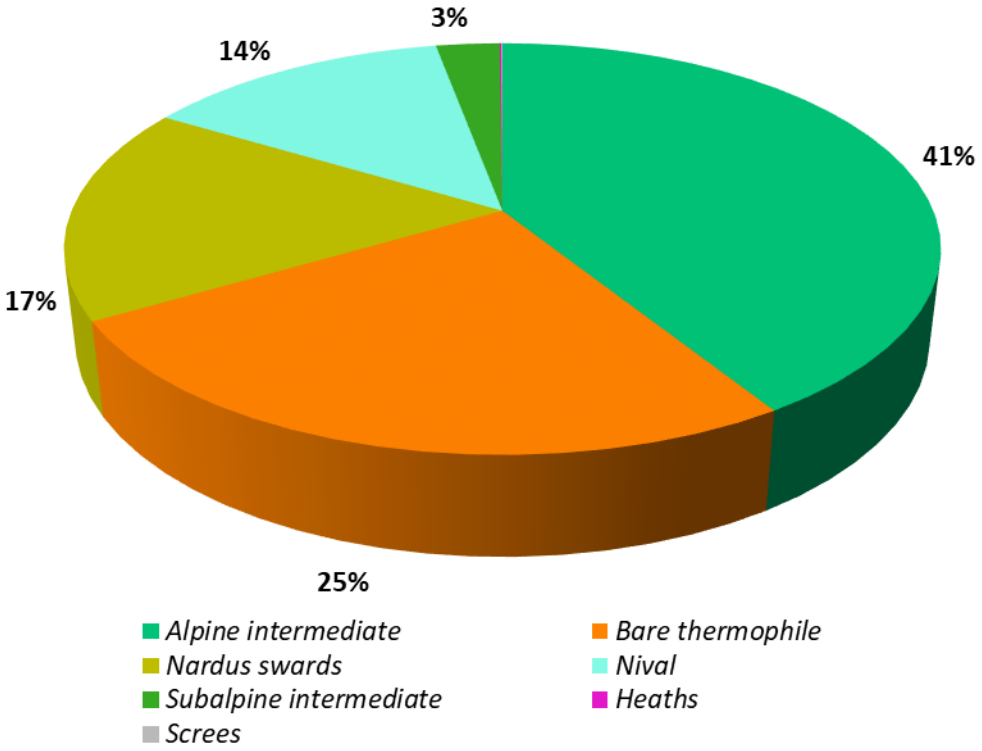


Figure 112.1. Pasture net surface divided by pasture category.

17 pasture types and 35 facies were found. Overall, the types attributable to the formation of intermediate conditions are clearly prevalent (65% of the net area, 459 hectares gross); the thermal formations are found on about 110 net hectares of steep and sunny slopes and on the windy hills, while in the valleys, where the snow lasts a long time, there are the formations of the snow conditions (94 gross hectares). The hydromorphic formations have been excluded from the grazing surfaces because, being peat bogs, grazing is forbidden. There are no pastures under tree cover.

The pasture type prevails at *Carex curvula* with about 140 net hectares divided into 3 facies located on the slopes in the Lakes area and at the upper limits of the herbaceous vegetation of Ferrand. The most

extensive facies are those with *Carex curvula, Avenula versicolor* and *Potentilla aurea* and that with *Trifolium alpinum*, *Carex curvula, Festuca halleri* and *Avenula versiclor*.
The *Festuca scabriculmis* type follows, with 110 net hectares positioned on the steep and sunny sides (es. Coast Lombarda) with 7 facies: the facies prevail with the dominant guide species and that to *Festuca scabriculmis, Festuca violacea* and *Avenella flexuosa*.
Then there are, in descending order of extension, the *Nardus stricta* and *Carex sempervirens* type (2 facies, present in the plain of the Nivolet and on the slightly steep slopes in the hydrographic right) and that of *Trifolium alpinum* (1 facies present near the Alpe Rivaz - Pian Rosset and on the right hydrographic side above the Alpe Nivolet).
Also worth mentioning for their extension are the types with *Alchemilla pentaphyllea* and *Salix herbacea* (2 facies, particularly widespread in Plan Borgnoz), that of *Festuca violacea* (4 facies, on steep and difficult to access slopes for livestock) and the *Alopecurus gerardi* type (4 facies, the largest of which is found on the slopes below the Alpe Rivaz).

Grazing management notes

In the Nivolet Pasture district, only the Rivaz mountain pasture is regularly grazed (it is located at 2610 m a.s.l., just above the Chivasso mountain hut). The building has recently been improved and is equipped with 2 stables, a dwelling and a dairy and can be reached from the mountain hut with a dirt road. In the period between the first ten days of July and mid-September, 110 Aosta Chestnut breed cows (about 80 LU) and about 20 sheep and goats from the Aosta Valley are taken on the pastures. Part of the cows is milked. Cattle grazing is guided and the cows mainly use the pastures near the barn. In the period 1999-2003, on the mountain pasture, an average of 95 LU, belonging to the same farm that currently uses the pasture, were kept, but the dairy cattle were more abundant.
During some summers at Plan Borgnoz a flock of several hundred sheep graze, remaining for a short lapse of time.
The buildings of the Alps of Nivolet, Grand Collet, Turin (or Teureun), Plan Borgonz and Aouille are unused (many of the buildings are in a poor condition or in ruins).
The pastures are accessible by tracks that can be easily followed by cattle, with just some areas difficult to reach for livestock (such as herbaceous formations near the Col Leynir). The Colle del Nivolet road continues as a dirt road and enters the orographic left side of the Plain for almost 6 km, but does not directly reach any mountain pasture.
Overall, the Pasture district is under-utilized compared to the potential of the forage resources found, in particular there are large portions of pasture which are completely unused and could be allocated for cattle (restock or dry) and for sheep and goats.

Pasture district n. 113 Noaschetta

Municipality	*Noasca (TO)*
Surface	*Total (gross area): 363 ha* *Pasture (net area): 115 ha*
Elevation	*1446 m – 2874 m a.s.l.*
Aspect	*South-east to south-west*
Slope	*Low along the valley floor and at higher altitudes; medium to high in the middle part of the district and along the slopes.*

Territorial overview

The Pasture district of Noaschetta is characterized by a long valley developing from just slightly over Noasca along the Noaschetta river, up to an altitude of about 2800 m a.s.l. In the final part, over the Alpe la Bruna, the valley it is divided into two parts, the first in the direction of the Alpe di Gol, which ends near Lake Gol, the second in the direction of Alpe la Motta which ends at an altitude of about 2800 m a.s.l. The valley is oriented in the first part from south-west to north-east; near the Alpe Brengi it turns in direction north-west, and then is divided into the terminal portion over of the Alpe la Bruna towards the Gol Lake (oriented north-west) and the Alpe la Motta (oriented north-east). The pasture surfaces are distributed both on the left and on the right side of the Noaschetta river and ranges from an altitude of about 1450 m a.s.l., near the Alpe Scialier, up to about 2800 m a.s.l. The exposure of the pastures is very heterogeneous (depending on the direction of the valley), with a prevalence of south-east to south-west aspect.

The area of pasture of Noaschetta borders, in the western area near Monte Castello, with the Vallone Ciamoseretto Pasture district.

Pasture surfaces

The net grazing area of the Pasture district, are given by tare classes, in *Table 113.1.*

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	12.09	3.33%	12.09	10.50%
20	36.49	10.06%	29.19	25.36%
50	105.63	29.11%	52.82	45.88%
80	105.13	28.97%	21.02	18.26%
100	103.50	28.52%	0.00	0.00%
Total	**362.84**	**100.00%**	**115.12**	**100.00%**

Table 113.1. Total and net surface in the Pasture district divided by tare class.

In the examined Pasture district there are about 115 ha of net grazing area. About the 11% of the net grazing area is characterized by the absence of diffused tares. About 25% of the net grazing area is characterized by the 20% of diffused tares, whereas about the 46% of the net grazing area showed the 50% of diffused tares. Around 18% of the net grazing area is characterized by the 80% of diffused tares. Concerning the ungrazeable areas, about 43 ha of gross area (about the 41 % of gross ungrazeable surfaces) are characterized by grass cover zone that are almost inaccessible, except for small flocks (100-150 heads) of small ruminants (sheep or goats). As their high slope and complex morphology do not facilitate the flock management and movements, it would not be possible to safely exploit such areas by large flock. Furthermore, these areas are inaccessible by cattle.

Pasture types

The pasture types identified on the Pasture district are given in *Table 113.2* and reported in *Figure 113.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	104.24	40.19%	49.50	43.00%
Kobresia myosuroides	A6	67.83	26.15%	17.01	14.78%
Nardus stricta and *Carex sempervirens*	A8	29.22	11.27%	14.62	12.70%
Carex fusca	ZH2	14.35	5.53%	8.53	7.41%
Poa alpina	61	7.10	2.74%	5.76	5.00%
Festuca gr. quadriflora	21	13.24	5.11%	4.23	3.68%
Festuca gr. rubra	S2	5.12	1.97%	3.73	3.24%
Brachypodium rupestre	25	5.04	1.94%	2.87	2.49%
Alchemilla pentaphyllea and *Salix herbacea*	A9	5.28	2.04%	2.54	2.21%
Reposoirs subalpini	RA1	2.40	0.93%	2.01	1.75%
Deschampsia caespitosa	53	1.70	0.6%	1.3	1.10%
Dactylis glomerata	S3	1.45	0.56%	1.05	0.91%
Phleum alpinum	60	0.71	0.27%	0.36	0.31%
Total		**259.34**	**100.00%**	**115.12**	**100.00%**

Table 113.2. Pasture surface divided by pasture type.

Pastures are largely dominated by the *Festuca scabriculmis* type that share about the 43% of the net grazing areas. This type is represented by the typical facies 24.05 a *Festuca scabriculmis*, that cover almost all the wide slopes of the grazing areas, particularly in the south, south-east and south-west exposures of the slopes of Monte Castello, of the Ruine and of the Alpe Gorgi and the steepest portions of the slope near Lake Gol. *Festuca scabriculmis* type cover also the gross ungrazeable grass-covered areas, exploitable by a small flock only. The second type for surface share is the type A6 - *Kobresia myosuroides* (about the 15% of the net grazing area) principally represented by the sub-type A6.2 a *Kobresia myosuroides* and *Avenula versicolor* mainly located in the upper part of the valley, in the areas near Alpe di Gol, Lago di Gol, Alpe la Motta and in the flat areas surrounding the Ivrea Refuge. The third type for surface share is the type A8- *Nardus stricta* and *Carex sempervirens* (12.7% of the net grazing area) mainly represented (about 9% of the net grazing area) by the sub-type A8.1 - *Nardus stricta, Trifolium alpinum* and *Carex sempervirens* and secondly (3.5% of the net grazing area) by the sub-type A8.2- *Nardus stricta*, *Carex sempervirens* and *Festuca* gr. *rubra.* This type covers in a more or less widespread way the whole valley, but have a greater extension in the upper part of the valley, interposing itself to the *Kobresia myosuroides* type in the less steep areas. The *Carex fusca* type follows by extension and shares about the 7% of the net grazing areas of the pasture district. Thys type is more widespread in the upper part of the valley, in hydromorphic conditions. The fifth type for surface share (5% of the net grazing areas) is the *Poa alpina* type (cod. 61) located for the most part of the surface, near Alpe la Bruna in the flat or less steep areas. Non negligible is the surface share of the types 21 - *Festuca* gr. *quadriflora*, 25 - *Brachypodium rupestre*, 57 - *Dactylis glomerata*, A9 - *Alchemilla pentaphyllea* and *Salix herbacea*, S2 - *Festuca* gr. *rubra*, that range between the 2 and the 4% of the net grazing area.

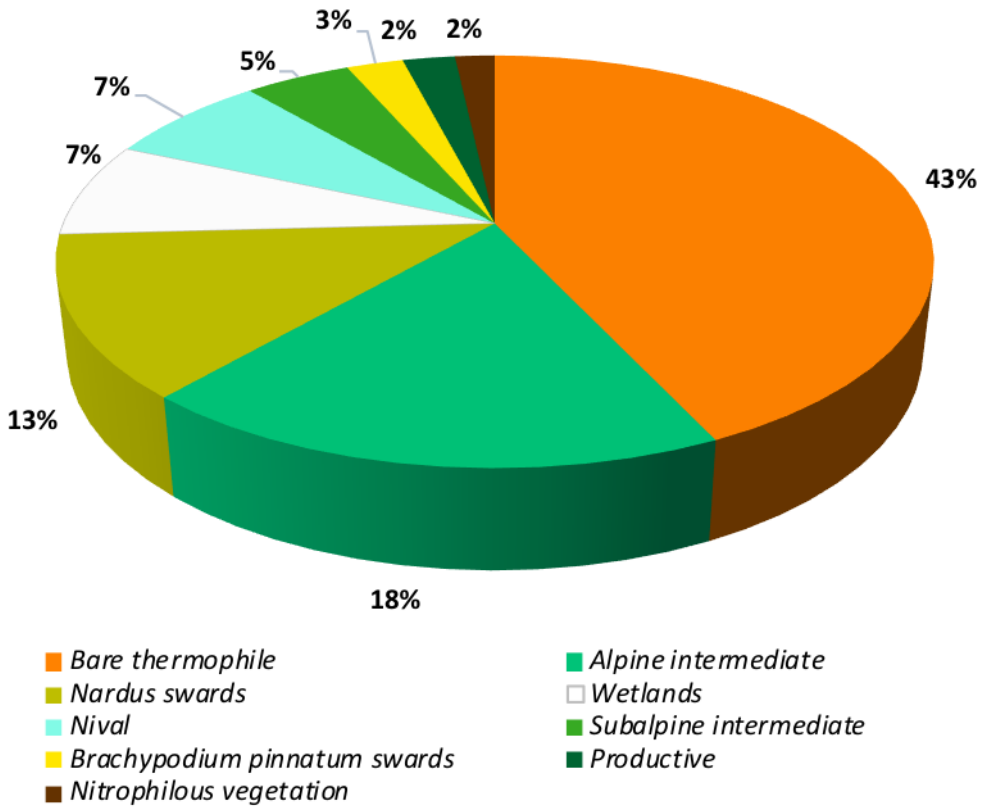


Figure 113.1. Pasture net surface divided by pasture category.

Grazing management notes

Only the portion at a lower altitude of the Pasture district, located near Pian Sengio, Alpe Lavassai and Betasse is managed by a small flock of about 30 sheep under rotational grazing. In the upper part of the Pasture district, only marginal ancient exploitation signs are present up to Pian dell'Alpe. The last part of the valley in unexploited since long time.

Pasture district n. 114 Punta dell'Orletto

Municipality	*Valprato Soana (TO)*
Surface	*Total (gross area): 374 ha* *Pasture (net area): 249 ha*
Elevation	*1562 m – 2735 m a.s.l.*
Aspect	*South-east and east*
Slope	*Medium - high*

Territorial overview

The Pasture district Punta dell'Orletto is composed by two sub valleys oriented respectively south-southeast (Civetto sub-valley) and east (Borra sub-valley), culminating both to the Orletto mountain. Both sub-valleys neighbor on the western side with the S. Besso and Fanton sub-valleys, with the Piamprato valley on the southern and eastern sides and with the upper part of the Piamprato valley on the northern side. The pastures are located on both orographic side of Civetto river and on the left side of Piamprato river and their altitude distribution ranges from 1580 m a.s.l. near the Brenvetto urban settlement and Grange Prariond up to about 2500 m of the Orletto Mountain and up to 2650 m of the Punta della Borra tops. The main pasture exposure ranges from south-east to west for the Civetto sub-valley and from east to south-east for the Borra sub-valley.

Pasture surfaces

The net grazing areas of the Pasture district, are given by tare classes, in *Table 114.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	190.69	51.02%	190.69	76.52%
20	37.26	9.97%	29.84	11.97%
50	47.25	12.64%	23.80	9.55%
80	24.23	6.48%	4.88	1.96%
100	74.30	19.88%	0.00	0.00%
Total	**373.73**	**100.00%**	**249.21**	**100.00%**

Table 114.1. Total and net area in the Pasture district by tare class.

In the examined Pasture district, there are about 249 ha of net grazing area. About the 77% of the net grazing area is characterized by the absence of diffused tares, whereas about another 12% of the net grazing area in characterized by the 20% of diffused tares, as well as about the 10% of the net grazing area showed the 50% of diffused tares. Concerning the ungrazeable areas, about 46 ha of gross area (about the 62% of gross ungrazeable surfaces) is characterized by grass cover zone that are almost inaccessible, except for small flocks (100-150 heads) of small ruminants (sheep or goats). As their high slope and complex morphology do not facilitate the flock management and movements, it would not be possible to safely exploit such areas by large flock. Furthermore, these areas are inaccessible by cattle.

Pasture types

The pasture types identified on the pasture district are given in *Table 114.2* and reported in *Figure 114.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	135.27	45.18%	117.41	47.11%
Nardus stricta and *Carex sempervirens*	A8	28.77	9.61%	26.86	10.78%
Brachypodium rupestre	25	33.51	11.19%	25.04	10.05%
Festuca gr. rubra	S2	23.57	7.87%	22.29	8.94%
Dactylis glomerata	57	16.54	5.52%	15.74	6.32%
Nardus stricta and *Festuca gr. rubra*	S1	15.71	5.25%	9.7	3.89%
Poa alpina	61	6.78	2.26%	6.65	2.67%
Poa violacea	29	6.73	2.25%	6.45	2.59%
Helianthemum nummularium	SA2	6.02	2.01%	5.1	2.05%
Plantago alpina	75	12.66	4.23%	3.9	1.56%
Kobersia myosuroides	A6	2.17	0.72%	2.17	0.87%
Subalpine nitrophilous vegetation	RA1	2.1	0.70%	1.8	0.72%
Festuca gr. violacea	46	1.52	0.51%	1.5	0.60%
Festuca gr. quadriflora	21	2.2	0.73%	1.1	0.44%
Calamagrostis villosa	40	2.13	0.71%	1.08	0.43%
Alchemilla pentaphyllea and *Salix herbacea*	A9	1.05	0.35%	0.9	0.36%
Salix retusa and *Salix reticulata*	70	1.26	0.42%	0.63	0.25%
Alchemilla gr. alpina	48	1.1	0.37%	0.55	0.22%
Deschampsia caespitosa	53	0.34	0.11%	0.34	0.14%
Total		**299.43**	**100.00%**	**249.21**	**100.00%**

Table 114.2. Pasture surface divided by pasture type.

Pastures are largely dominated by the *Festuca scabriculmis* type that share about the 47% of the net grazing areas. This type is represented by two facies: the first, in the minority (about the 7% of net grazing area) represent the transition to the *Brachypodium rupestre* type (facies 24.04 - *Festuca scabriculmis* and *Brachypodium rupestre*); the second dominant one, is the typical facies (facies 24.05 - *Festuca scabriculmis*), that cover almost all the wide slopes of the grazing areas. The 24.05 facies cover also about the 87% of the gross ungrazeable grass-covered areas, exploitable by a small flock only.

The second type for surface share is the A8 - *Nardus stricta* and *Carex sempervirens* that cover a little more than the 10% of the net grazing area and in particular with the more diffused A8.1 - *Nardus stricta, Trifolium alpinum* and *Carex sempervirens* sub-type that is located over the upper Grange Civetto and near Grange della Borra on their northern side. The third type for surface share is the type 25 - *Brachypodium rupestre* (10 % of net grazing area) that substitute the *Festuca scabriculmis* type in the slopes at a lower altitude and in more thermic conditions. This type is represented by two facies: the typical one 25.11 that characterise all the grazeable *Larix decidua* forests below grange Vandilliana and Orletto, the other, the facies 25.16 a *Brachypodium rupestre*, *Carex sempervirens* and *Festuca* gr. *ovina*, represent the involution of the *Festuca* gr. *ovina* in thermic condition due to an underutilisation. This facies is located mainly at the lower altitude of the Civetto sub-valley. The fourth type for surface share is the type S2 - *Festuca* gr. *rubra* (9% of the net grazing area), mainly located in the fertile areas below the lower and upper Grange Civetto and below Grange Orletto. This type is represented by two sub-types: S2.2 *Festuca* gr. *rubra*, *Agrostis capillaris*, *Phleum alpinum* and *Alchemilla xanthochlora* (about the 6% of the net grazing area) and S2.1 - *Alchemilla xanthochlora, Festuca gr. rubra* and *Agrostis capillaris* that cover about the 3% of the net grazing area. Among the other types, only the type 57 - *Dactylis glomerata* still exceed (marginally) the 5% of the

net grazing area (in particular the facies 57.22 - *Dactylis glomerata, Agrostis tenuis* and *Festuca* gr. *rubra*). Non negligible is anyway the surface share of the types 29 - *Poa violacea*, 61 - *Poa alpine,* S1 - *Nardus stricta* and *Festuca* gr. *rubra* and SA2 *Helianthemum nummularium*, that range between the 2 and the 4 % of the net grazing area.

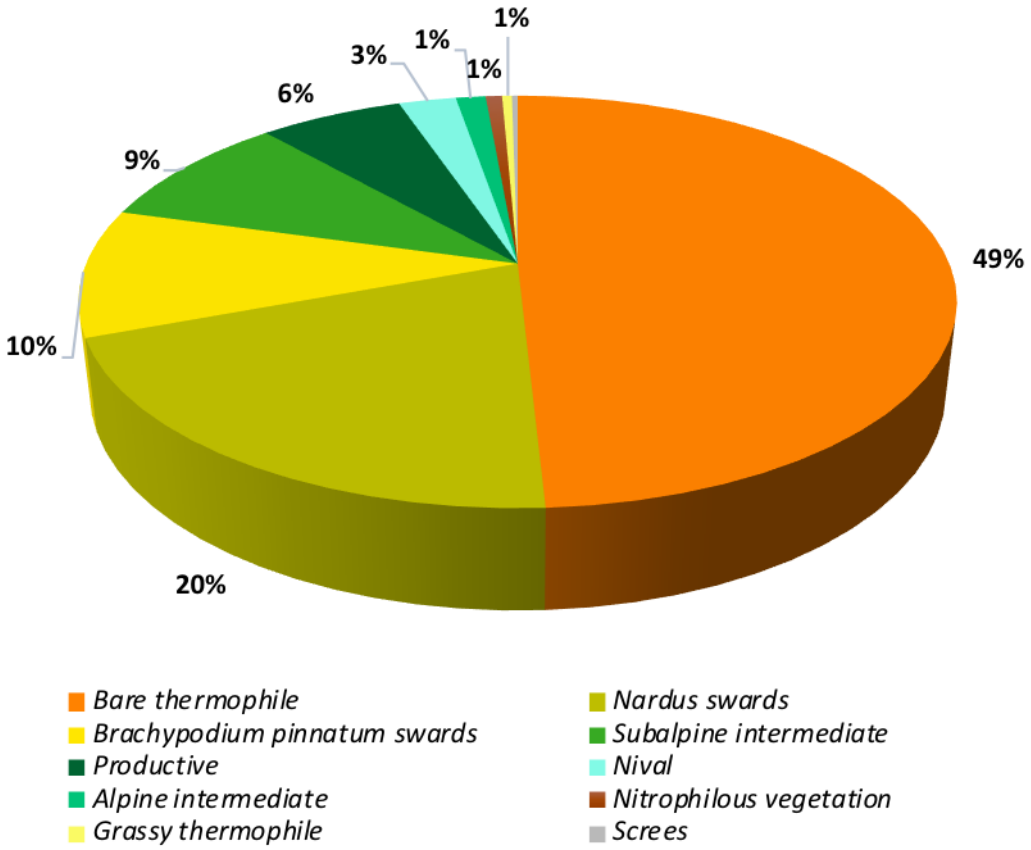


Figure 114.1. Pasture net surface divided by pasture category.

Grazing management notes

Four different farmers manage the grazing area. It can be considered as subdivided into two full management units to which a small part of two other management units, located in the Piamprato Valley pasture district, are added.

The first management unit in composed by the Alpe Civetto (upper and lower), which farmer manage the more fertile pastures, located near the barns and on the orographic right side of the Civetto River, by strip grazing a dairy herd of about 30 milked cows of mixed breeds (mainly double-purpose breeds). Heifers and dry cows (about 30-35 animals) exploit the pastures farer form the barn and mainly located on the left orographic side of the Civetto river through extensive rotational grazing management.

The second management unit is composed by the Alpe Vandilliana and Grange Orletto (lower altitude barn) and the Grange della Borra (upper altitude barn). The fertile pastures in front of the Alpe Vandilliana are exploited through strip grazing by a dairy herd of about 50 milked cows of Aosta Red Pied breed. The same herd is moved to Grange Orletto thereafter and come back to Alpe Vandilliana in the autumn. The less fertile and farer pasture are exploited by a herd of heifers and dry cows (about 25-30 animals) through extensive rotational grazing. The same herd exploit the Grange della Borra upper part of this management unit, in which there is any barn or farmer house.

A small flock (about 250-300 sheep and goats) partially exploit the steeper and less fertile pasture below Alpe Vandilliana and Orletto and on the left orographic side of della Borra river through guided grazing. The

flock is protected against wolf predation by the presence of guard dogs and the night camping in electric fences.
The fertile pastures at the bottom part of the slope of the right side of the della Borra river are exploited through strip grazing by a dairy herd which belong to a farmer which barn is located at Alpe Prariond, on the right side of the Piamprato river, at the neighbour between the present Pasture district and the Valle di Piamprato one. The herd is mainly composed by of Aosta Red Pied dairy cows.
Finally, a fourth dairy herd exploit the bottom part of the slope of the left side of della Borra river. This herd moves daily from the barn located in Grange Pontet and Cavanessa, both on the right side of the Piamprato river, at the neighbour between the present Pasture district and the Valle di Piamprato one.

Pasture district n. 115 San Besso

Municipality	*Valprato Soana (TO)*
Surface	*Total (gross area): 439 ha* *Pasture (net area): 242 ha*
Elevation	*1309 m – 2801 m a.s.l.*
Aspect	*South, south-east and south-west*
Slope	*Low along the valley floor and moderate along the slopes*

Territorial overview

The Pasture district San Besso is composed by the sub-valley of San Besso and the neighbour and parallel sub-valley of the Fanton river, both north-south oriented. The Pasture district borders with the Campiglia valley on the western side (Azaria and Grange Arietta), with the Aosta Valley on the northern side, with the Borra and Civetto valleys on the eastern side and with the valleyfloor of the Campiglia valley on the southern and south-western side. The pastures are mainly located on along the Campiglia river, in the valleyfoor, and on the orographic left side of the Fanton river and in the upper portion of Fanton and San Besso sub-valleys and their altitude distribution ranges from 1330 m a.s.l. near the Campiglia Soana urban settlement up to about 2830 m of Colle della Rosa. The main pasture exposure ranges from south-southeast to south-southwest.

Pasture surfaces

The net grazing areas of the Pasture district, are given by tare classes, in *Table 115.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	133.88	30.52%	133.88	55.10%
20	83.71	19.08%	66.96	27.60%
50	77.62	17.47%	38.60	16.00%
80	15.05	3.43%	3.00	1.20%
100	129.40	29.50%	0.00	0.00%
Total	**439.66**	**100.00%**	**242.44**	**100.00%**

Table 115.1. Total and net area in the Pasture district by tare class.

In the examined Pasture district, there are about 242 ha of net grazing area. About the 55% of the net grazing area is characterized by the absence of diffused tares, whereas about another 28% of the net grazing area in characterized by the 20% of diffused tares, as well as about the 16% of the net grazing area showed the 50% of diffused tares. Concerning the ungrazeable areas, about 99 ha of gross area (about the 76% of gross ungrazeable surfaces) are characterized by grass cover zone that are almost inaccessible, except for small flocks (100-150 heads) of small ruminants (sheep or goats). As their high slope and complex morphology do not facilitate the flock management and movements, it would not be possible to safely exploit such areas by large flock. Furthermore, these areas are inaccessible by cattle.

Pasture types

The pasture types identified on the pasture district are given in *Table 115.2* and reported in *Figure 115.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	142.83	46.18%	115.37	47.59%
Dactylis glomerata	57	28.04	9.07%	25.19	10.39%
Festuca gr. rubra	S2	28.12	9.09%	23.13	9.54%
Brachypodium rupestre	25	39.51	12.78%	22.65	9.34%
Helianthemum nummularium	SA2	22.87	7.40%	17.64	7.28%
Poa violacea	29	10.91	3.53%	10.49	4.33%
Nardus stricta and *Carex sempervirens*	A8	13.63	4.41%	10.36	4.27%
Poa alpina	61	7.72	2.50%	6.17	2.54%
Poa pratensis	56	4.07	1.32%	2.96	1.22%
Trisetum flavescens	59	2.52	0.81%	2.45	1.01%
Nardus stricta and *Festuca gr. rubra*	S1	1.83	0.59%	1.72	0.71%
Geum montanum	47	1.52	0.49%	1.15	0.47%
Festuca gr. quadriflora	21	3.48	1.13%	1.08	0.45%
Trifolium alpinum	A7	0.55	0.18%	0.55	0.23%
Carex fusca	ZH2	0.6	0.19%	0.55	0.23%
Carex foetida	79	0.32	0.10%	0.32	0.13%
Subalpine nitrophilous vegetation	RA1	0.29	0.09%	0.29	0.12%
Deschampsia caespitosa	53	0.24	0.08%	0.24	0.10%
Phleum alpinum	60	0.21	0.07%	0.13	0.05%
Total		**309.26**	**100.00%**	**242.44**	**100.00%**

Table 115.2. Pasture surface divided by pasture type.

Pastures are largely dominated by the *Festuca scabriculmis* type that share about the 47% of the net grazing areas. This type is represented by two facies: the first, in the minority (about the 2.5% of net grazing area) represent the transition to the *Brachypodium rupestre* type (facies 24.04 - *Festuca scabriculmis* and *Brachypodium rupestre*); the second dominant one, is the typical facies (facies 24.05 - *Festuca scabriculmis*), that cover almost all the wide slopes of the grazing areas. The 24.05 facies cover also about the 89% of the gross ungrazeable grass-covered areas, exploitable by a small flock only. The second type for surface share is the type 57 - *Dactylis glomerata* that cover a little more than the 10% of the net grazing area and that is located in the fertile and flat zones between the Campiglia river and the summer barns at the lower altitude (Grange Cugnona, Ciavanis, Alpe Fanton). It is exclusively represented by the typical facies 57.22 - *Dactylis glomerata, Agrostis tenuis* and *Festuca* gr. *rubra*. The third type for surface share is the type S2 - *Festuca* gr. *rubra* (about the 9.5% of the net grazing area) and mainly located near the fertile areas near the upper summer barns (Alpe la Balma, Grangia Ciavanis, Alpe Fanton). This type is represented by two subtypes: type S2.2 *Festuca* gr. *rubra*, *Agrostis capillaris, Phleum alpinum* and *Alchemilla xanthochlora* is dominant (about the 7% of the net grazing area), compared to the second sub-type (S2.1 a *Alchemilla xanthochlora*, *Festuca* gr. *rubra* and *Agrostis capillaris*). The fourth type for surface share is the type 25 - *Brachypodium rupestre* (9 % of net grazing area) that substitute the *Festuca scabriculmis* type in the slopes at a lower altitude and in more thermic conditions. This type is represented by two facies: the typical one 25.11 that characterise all the grazeable *Larix decidua* forests (and about the 10% of gross ungrazeable grass covered areas, exploitable only by a small flock), the other, the facies 25.32 - *Brachypodium rupestre* and *Dactylis glomerata*, represent the involution of the *Dactylis glomerata* in thermic condition due to an underutilisation, mainly located near the intermediate areas historically cut or hay-making. The fifth type

for surface share is the type SA2 *Helianthemum nummularium* (7.2% of the net grazing area), particularly represented by the sub-type SA2.1 a *Carex sempervirens, Helianthemum nummularium* and *Plantago alpina* (about the 6% of the net grazing area) and mainly located above the Alpe della Balma. Non negligible is anyway the surface share of the types 29 - *Poa violacea*, 61 - *Poa alpina* and A8 - *Nardus stricta* and *Carex sempervirens*, that range between the 2 and the 4% of the net grazing area.

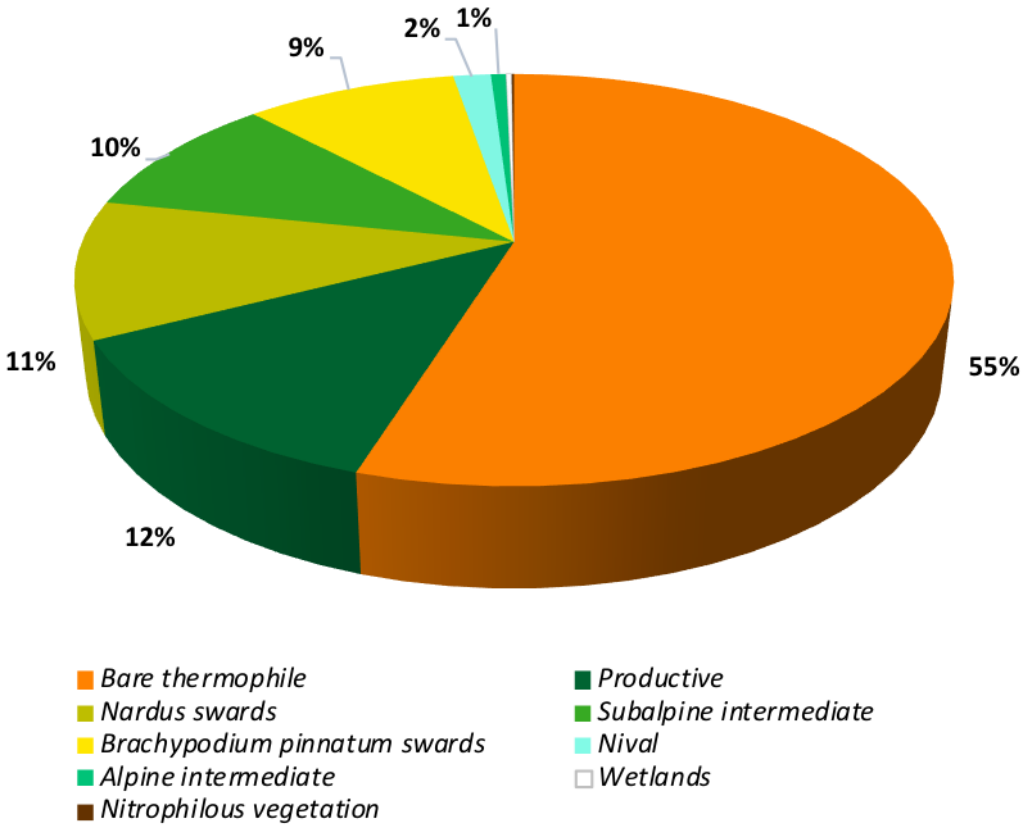


Figure 115.1. Pasture net surface divided by pasture category.

Grazing management notes

Two different farmers manage the grazing area, thus it can be considered as subdivided into two management units.

The first one is composed by the valleyfloor of Campiglia valley, by the Grange Ciavanis and by the Alpe della Balma, which farmer manage the more fertile pastures on the valleyfloor and between the upper barn Alpe della Balma and the San Besso church by strip grazing through a dairy herd of about 60 milked cows of Aosta Red Pied breed. Heifers and dry cows (about 35-40 animals) exploit the Grange la Posa and Grangia Pugnon pastures through extensive rotational grazing management. Both herds come back in the autumn lower altitude pasture for a second grazing cycle.

The second management unit is composed by the Grangia Pugnon (lower altitude barn) and the Alpe Fanton (upper altitude barn). All the pastures are exploited by extensive rotational grazing management through about 55-60 cattle herd of Piedmontese breed.

Pasture district n. 116 Urtier

Municipality	*Cogne (AO)*
Surface	*Total (gross area): 319 ha* *Pasture (net area): 238 ha*
Elevation	*2224 m – 2757 m a.s.l.*
Aspect	*No prevailing aspect*
Slope	*Medium, rarely exceeding 40°. The average slope is 19°.*

Territorial overview

Located in the homonymous valley accessible by paved road from Lillaz hamlet of Cogne, it occupies large areas showing a little steep with an undulating morphology between Torrents Urtier, Péradza and La Nouva and Broillot which becomes in the upper part Miserin as it is named after the lake from which it originates.
There are no clearly prevalent exposures.
The slopes are always moderate, only in some short stretches the slope exceeds 40°. The average slope is equal to 19°.

Pasture surfaces

The following table shows the grazing surfaces of the Pasture district under review, divided by tare class.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	94.06	29.46%	94.06	55.10%
20	133.31	41.75%	106.65	27.60%
50	70.74	22.15%	35.49	16.00%
80	7.78	2.44%	1.55	1.20%
100	13.44	4.21%	0.00	0.00%
Total	**319.33**	**100.00%**	**237.75**	**100.00%**

Table 116.1. Total and net area of the Pasture district by tare class.

In the whole district of Urtier there are about 319 ha excluding the unproductive tare (rocks and scree, waterways, buildings) and 238 ha excluding the diffuse tare, i.e. within the grassed polygons (rocks and outcropping scree, bushy and / or arboreal areas).
As part of the tares over 62% is made up of rocks and screes, about 13% by trees and shrubs, 5% by non-grazeable vegetation, slightly less than 1.5% attributed to other, which is almost always made from bare soil and an insignificant proportion of 0.04% by buildings, i.e. some ruins in the left bank of Broillot river up to the homonymous “alpeggio”.

Pasture types

The pasture types identified within the grazing area are 27. 9 of these are related to those of the Piedmontese typology and cover a total of approximately 23 ha equal to about 9% of the net grazing surface, these are mainly festuceti *Festuca scabriculmis* and other limited situations linked to environmental or management factors. In *Table 106.2* the identified pasture types are reported in descending order for the covered surface. As it can be observed there are 3 types that prevail and that alone occupy almost 70% of the entire surface.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Nardus stricta and *Carex sempervirens*	A8	62.39	19.54%	52.49	22.08%
Carex curvula	A5	64.64	20.24%	51.65	21.72%
Trifolium alpinum	A7	34.86	10.92%	29.48	12.40%
Festuca violacea	A2	26.16	8.19%	21.32	8.97%
Plantago alpina and *Festuca ovina*	A1	17.96	5.62%	15.42	6.49%
Alchemilla pentaphyllea and *Salix herbacea*	A9	13.47	4.22%	10.73	4.51%
Festuca scabriculmis	24	14.08	4.41%	8.24	3.47%
Kobresia myosuroides	A6	9.68	3.03%	7.37	3.10%
Alchemilla gr. vulgaris	64	8.91	2.79%	6.60	2.78%
Festuca rubra	S2	6.78	2.12%	5.84	2.46%
Loiseleuria procumbens and/*or Vaccinium uliginosum*	L1	14.71	4.60%	5.80	2.44%
Nardus stricta and *Festuca rubra*	S1	4.42	1.38%	3.93	1.65%
Rhododendron ferrugineum and *Vaccinium uliginosum*	L3	12.34	3.87%	3.79	1.59%
Ligusticum mutellina	74	4.41	1.38%	3.52	1.48%
Dryas octopetala	SA3	3.80	1.19%	2.65	1.12%
Helianthemum nummularium	SA2	2.62	0.82%	2.10	0.88%
Festuca halleri	A4	2.58	0.81%	1.85	0.78%
Geum montanum	47	1.51	0.47%	1.48	0.62%
Screes	E	4.84	1.52%	0.77	0.32%
Helictotrichon parlatorei	A3	0.79	0.25%	0.75	0.32%
Carex foetida	79	0.47	0.15%	0.47	0.20%
Sesleria varia	13	0.78	0.24%	0.39	0.16%
Arctostaphylos uva-ursi, Juniperus nana and *Vaccinium uliginosum*	L2	1.89	0.59%	0.32	0.13%
Onobrychis montana	S4	0.64	0.20%	0.32	0.13%
Plantago alpina	75	0.28	0.09%	0.24	0.10%
Deschampsia caespitosa	53	0.46	0.14%	0.10	0.04%
Wetlands	ZH	3.82	1.20%	0.08	0.03%
Rumex alpinus	69	0.05	0.02%	0.05	0.02%
Total		**319.34**	**100.00%**	**237.75**	**100.00%**

Table 116.2. Pasture surface divided by pasture type.

In the *Figure 116.1.* the pasture categories are represented with the reference colors.

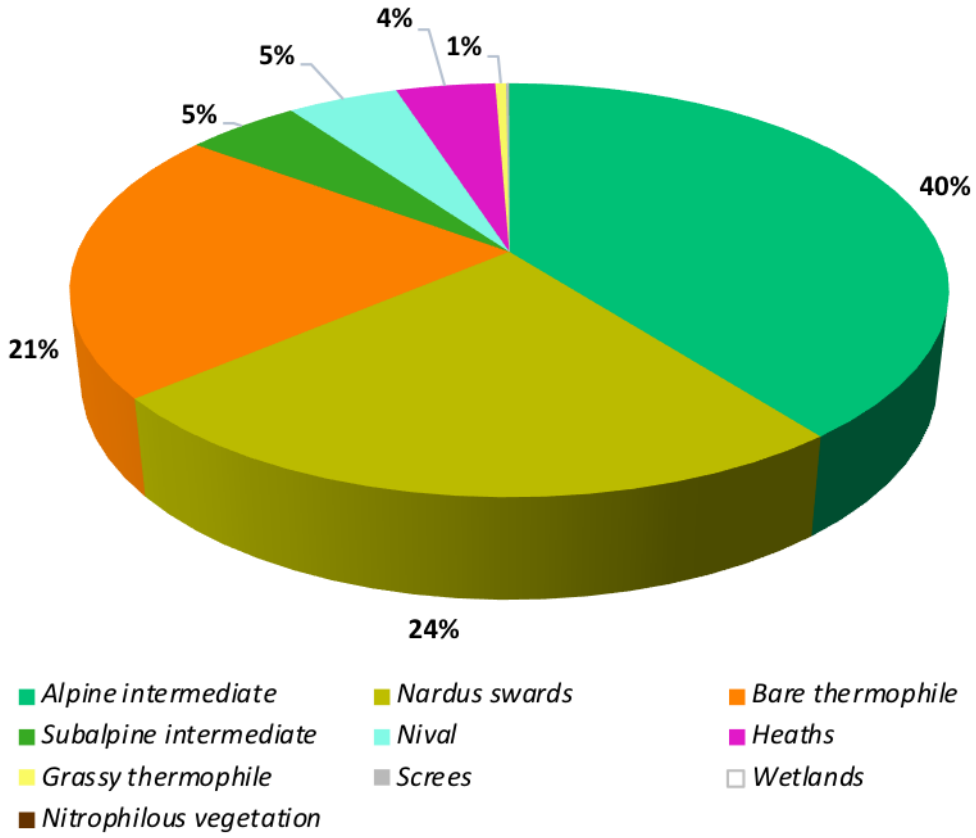


Figure 116.1. Net pasture surface divided into pasture categories.

Grazing management notes

The district i.e. the whole area south of the Péradza, Chavanis and Broillot huts, is currently mostly used from a herd of lactating bovines Valdostan breed spotted black / brown and red which are regularly milked to produce Fontina and other cheeses and dairy products. The animals are collected in the barn at night and during the middle of the day. The remaining part, Mandaz hut is grazed by a herd of brown cows for the production of meat, always kept outdoor.

The head of the valley, roughly upstream the Lodge Sogno di Berdzè is not grazed.

Overall the pasture appears correctly and uniformly used, just locally some types are strongly influenced by management procedures such as that to *Alchemilla gr. vulgaris*, which highlights an excessive fertilization, located near the Broillot “alpeggio”, in some flat areas intensively used also for the overnight stay of the animals in the right bank of Peradzà river. The presence of locally abundant *Geum montanum* can be interpreted as an effect partly due to intensive trampling by animals.

Picture 116.1. *Trifolium alpinum* type full bloom.

Picture 116.2. *Alchemilla gr. vulgaris type* under the Broillot hut.

The objectives and the attention elements with respect to the influence of the management aspects on the vegetation of the district are:

- Maintaining of *Trifolium alpinum* (A7), *Nardus stricta*, *Trifolium alpinum* (A8.1) facies through a management involving balanced refunds and relatively late utilization to promote the dissemination of *Trifolium alpinum*.
- Uniform utilization of all grazing surfaces in order to oppose the advance of trees and shrubs species already present in the steeper sections and far from the pastureland.
- Control of the locally abundant ungrazeable vegetation, such as *Pulsatilla alpina*, preventing its dissemination.
- Improvement of the zones with the presence of *Festuca scabriculmis* through early uses made with regularity and balanced loads.

Pasture district n. 117 Vallone di Piamprato

Municipality	*Valprato Soana (TO)*
Surface	*Total (gross area): 450 ha* *Pasture (net area): 289 ha*
Elevation	*1598 m – 2857 m a.s.l.*
Aspect	*South to east*
Slope	*Very variable*

Territorial overview

Piamprato Valley has a north-south course (NNO-SSE) and borders with the ridges of Aosta Valley (Champorcher Valley and Mont Avic Natural Park for a short stretch in the northwest corner) to the north, with the area of lakes La Reale and Santanel (below Mont Noir, outside PNGP) to the east, with Valle di Campiglia to the west and it flows into Val Soana to the south.

Plamprato's pastures cover the head of the valley, on an area approximately shaped like a sector of an amphitheatre (a quarter of a circle). The main exposures rotate from south to east. Coming from the bottom of the valley, at an altitude of about 1700 m a.s.l., the amphitheatre opens like a fan starting from the basal pastures located near Prariond and Ciavanessa Granges (connected by a small chairlift system). From this point the slopes rise steeply up to a large central basin located around 2000-2200 m a.s.l., from which originates the torrent Rio del Becco. Becco Grande and La Reale Granges are located on this interruption of the slope.

Above this flat area, the amphitheatre formed by the slopes continues to rise (with more or less steep sectors) up to the upper limit of the pastures, located at over 2700 m a.s.l.

The slope near the western border of the area becomes steeper and more continuous; from here originates torrent Rio delle Fontane. In the northeastern corner of the area (beyond Cima del Rospo) the morphology becomes more complex: a counter-sloping stretch encloses a narrow valley suspended at about 2500 m a.s.l. and opened to east. This small valley is crossed by torrent Rio della Reale, which, downstream, turns south and forms the eastern border of the study area.

Pasture surfaces

The surface of net pasture covers about 289 ha out of 450 ha of total gross area, corresponding to an average tare of about 40%.

The incidence of tares is slightly lower than in other grazing districts in the area. More than half of the pasture surface is affected by tares up to a maximum of 20%. The largest zones with low tares correspond to the wide central basin located at an altitude of 2000-2200 m a.s.l., where Becco Grande and La Reale Granges are located. Other areas are found around the Granges on the valley floor (Prariond and Ciavanessa) or even at higher altitude on not very steep portions of grassland.

The grazing areas with tares higher than 20% are located for a small part in the steep basal belt (shrubby or even partly wooded slopes), but above all they occupy the highest pastures, close to the rocky ridges, where the rocky surface increases and the grazing areas are fragmented.

The net grazing area of the Pasture district, are given by tare classes, in *Table 117.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	21.82	4.85%	21.82	7.55%
20	206.30	45.88%	165.00	57.07%
50	194.93	43.35%	97.94	33.88%
80	21.77	4.84%	4.36	1.51%
100	4.87	1.08%	0.00	0.00%
Totale	**449.69**	**100.00%**	**289.12**	**100.00%**

Table 117.1. Total and net area in the Pasture district divided by tare class.

Pasture types

The pasture type identified on the Pasture district are given in *Table 117.2* and reported in *Figure 117.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Helianthemum nummularium	SA2	67.04	14.91%	42.17	14.59%
Trifolium alpinum	A7	47.94	10.66%	35.15	12.16%
Plantago alpina and Festuca ovina	A1	47.89	10.65%	28.70	9.92%
Festuca rubra	S2	32.50	7.23%	25.43	8.80%
Nardus stricta and Carex sempervirens	A8	31.02	6.90%	20.01	6.92%
Festuca scabriculmis	24	26.15	5.82%	15.64	5.41%
Alchemilla pentaphyllea and Salix herbacea	A9	32.67	7.26%	15.61	5.40%
Sesleria albicans	SA1	18.44	4.10%	14.60	5.05%
Nardus stricta and Festuca rubra	S1	18.31	4.07%	12.91	4.47%
Helictotrichon parlatorei	A3	19.64	4.37%	10.88	3.76%
Kobresia myosuroides	A6	20.46	4.55%	10.73	3.71%
Carex curvula	A5	16.01	3.56%	10.09	3.49%
Poa violacea	29	11.09	2.47%	9.32	3.22%
Dactylis glomerata	S3	11.61	2.58%	9.08	3.14%
Dactylis glomerata	57	9.47	2.11%	7.67	2.65%
Festuca violacea	A2	11.18	2.49%	7.42	2.57%
Brachypodium pinnatum	25	8.28	1.84%	4.67	1.62%
Loiseleuria procumbens and/or Vaccinium uliginosum	L1	8.50	1.89%	4.22	1.46%
Wetlands	ZH	5.01	1.11%	3.29	1.14%
Subalpine nitrophilous vegetation	RA	2.78	0.62%	1.44	0.50%
Arctostaphylos uva-ursi, Juniperus nana and Vaccinium uliginosum	L2	3.71	0.83%	0.11	0.04%
Total		**449.70**	**100.00%**	**289.12**	**100.00%**

Table 117.2. Pasture surface divided by pasture type.

The table show a complex and articulated vegetational context, which indicates a high level of biodiversity. This high level of biodiversity is due to the difference in soil conditions, which are created by the specific geological substratum (calcescisti). None of the pastures types clearly prevails, but in relative terms the grasslands with *Nardus stricta* and *Carex sempervirens* (type A8) represent the most important group, not only for their extension but also for their good fertility. These grasslands are located in not very sloping stations of the alpine altitudinal belt, above the Granges and the rich pasture areas surrounding them. The upper part of the A8 grasslands borders with many other different types of alpine grassland and includes a wide area of peat bog with *Carex fusca* (ZH). The main part of the peat bog, covering about two hectares, is located in the middle of the plateau just above Becco Grande Grange, at an altitude of 2200 m a.s.l. On the wavy ground surrounding this plateau, the grassland is enriched in several points by *Trifolium alpinum*, which in some places becomes the main species (A7). On the edge of the pasture there are some invasions of *Rhododendrum ferrugineum* (L3).

The steep slopes above the plateau are covered by poor alpine calcareous grasslands, with *Helianthemum nummularium* and *Sesleria* (type SA2): there are some transitions (perhaps where there is a more acid soil) towards the meadow of *Festuca scabriculmis* (type 24). The alpine calcareous grasslands occupy about 20% of the grazeable area. At a higher altitude, the steep slopes are occupied by a low and discontinuous herbaceous vegetation, composed by small species, such as *Agrostis rupestris, Deschampsia flexuosa, Festuca ovina, F. violacea, F. halleri, Plantago alpina, Sempervivum* sp., etc. (type A1, also in transition to

type A2). In less steep areas, the *Carex curvula* type (A5) is prevalent, and it is often mixed with snow-beds vegetation (A9) in the hollow and with swards of *Kobresia* type (A6) on the bumps. Some areas with a wavy topography are very characteristic; in these areas the vegetation of types A6 and A9 composes a tangled mosaic, made even more complex by the presence of heaths of *Loiseleuria* (L1) on the most prominent bumps.

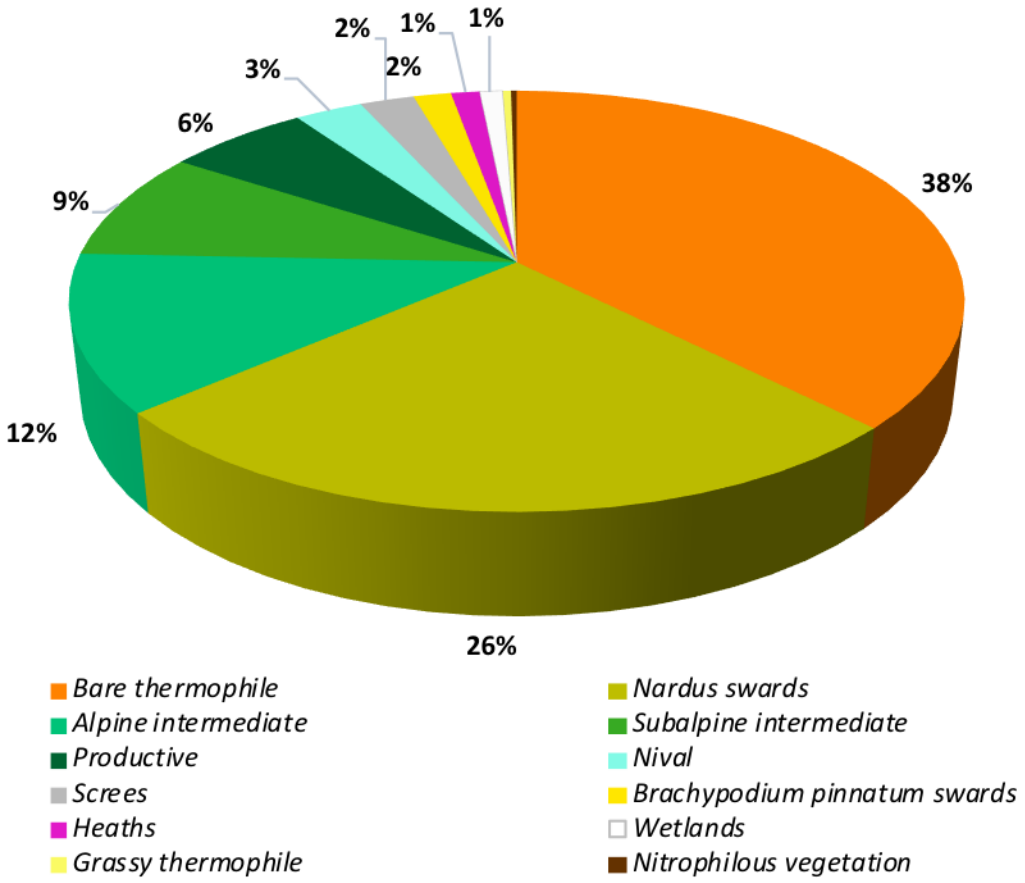


Figure 117.1. Pasture net surface divided by pasture category.

The subalpine environment starts from the area of Becco Grande and La Reale Granges down. Some small areas with nitrophilous species (RA) are located near the Granges and are surrounded by wide rich pastures of *Festuca rubra* type (S2). The more peripheric and rather steep portions are occupied by *Nardus stricta* type (S1). Below the main pastures of the Granges, the presence of a rather steep but not so poor pasture belt is interesting, in which the S1 and S2 species are associated with a good amount of *Poa violacea* (type 29).
Further down the slope becomes very steep and sunny; here rocky surfaces, patches of dwarf juniper (L2) and meadows are scattered. The meadows of *Festuca scabriculmis* and, in some places, *Helictotrichon parlatorei* (A3) are mixed.
Rich pastures are widespread at the bottom of the valley, at the edges of which there are some areas with *Brachypodium rupestre* type (25), near the wooded zones or in the erosion of the torrent. Around Prariond and Ciavanessa Granges (at low altitude) the pastures belong to *Dactylis glomerata* type (S3).

Grazing management notes

The two lower pasture units (Prariond and Ciavanessa Granges) have a strong productive vocation, and are regularly grazed by cattle. The road makes it easy to manage, with the possibility of milk production. A solid bridge (across Rio della Reale) connects the Ciavanessa pastures to the rich meadows at the base of the

slope next to Pontet Grange. Furthermore, for this area there are no technical restrictions for the production.
Higher up, in the middle of the survey area, also Becco Grande and La Reale Granges are regularly loaded. The pastures of these two Granges, although contiguous, are divided by the deep engraving of torrent Rio del Becco. Even the high pastures, far over the central plain, show frequent signs of use, although in a more extensive way.
The grazing animals are very numerous, and they spread on all the pasture district, divided into at least 3 or 4 large groups of several dozen (up to a hundred) heads each. The most intensively grazed areas are the surroundings of La Reale Grange and the plain surrounding the peat bog. In these areas with more intensive grazing, some lines of electrified wire are in use.
In the area at the north of the Grange, on the banks of Rio della Reale, a small flock of sheep has also been observed (about one hundred animals). The pasture in this district also extends beyond the borders of the Park (outside the investigated area) for a fringe surface of about ten hectares.

Pasture district n. 118 Vallone Ciamoseretto

Municipality	*Noasca (TO)*
Surface	*Total (gross area): 255 ha* *Pasture (net area): 107 ha*
Elevation	*1116 m – 2537 m a.s.l.*
Aspect	*South to west*
Slope	*Generally low-medium*

Territorial overview

The Pasture district of Ciamoseretto is characterised by the valley of the homonymous river oriented from south-east to north-west, bordering to the east with the Pasture district of Noaschetta, to the west with Pasture district of Vallone del Roc, to the south with the road leading to Colle del Nivolet and finishing in the north part at an altitude of about 2850 m a.s.l. The pasture surfaces are distributed along the whole valley, but concentrated mainly in the middle part and extend from Balmarossa to an altitude of 1190 m a.s.l. up to 2500 m a.s.l. of the Laghetti passing through the alps of Ramajot, Gran Pra and the Alpe Gran Piano. The main exposure of pastures varies between south-southeast and south-southwest.

Pasture surfaces

The net grazing areas of the Pasture district, are given by tare classes, in *Table 118.1.*

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	56.45	22.14%	56.45	52.71%
20	29.25	11.47%	23.40	21.85%
50	49.68	19.49%	24.84	23.19%
80	12.06	4.73%	2.41	2.25%
100	107.50	42.17%	0.00	0.00%
Total	**254.94**	**100.00%**	**107.10**	**100.00%**

Table 118.1. Total and net area in the Pasture district by tare class.

In the examined Pasture district there are about 107 ha of net grazing area. About the 53% of the net grazing area is characterized by the absence of diffused tares. About the 22% of the net grazing area is characterized by the 20% of diffused tares, whereas about the 23% of the net grazing area showed the 50% of diffused tares. Concerning the ungrazeable areas, about 34 ha of gross area (about the 31% of gross ungrazeable surfaces) are characterized by grass cover zone that are almost inaccessible, except for small flocks (100-150 heads) of small ruminants (sheep or goats). As their high slope and complex morphology do not facilitate the flock management and movements, it would not be possible to safely exploit such areas by large flock. Furthermore, these areas are inaccessible by cattle.

Pasture types

The pasture types identified on the pasture district are given in *Table 118.2* and reported in *Figure 118.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	54.76	37.14%	30.66	28.63%
Brachypodium rupestre	25	34.30	23.26%	27.40	25.58%
Nardus stricta and Carex sempervirens	A8	23.43	15.89%	16.27	15.19%
Dactylis glomerata	S3	12.66	8.59%	12.22	11.41%

Festuca gr. ovina	19	7.23	4.90%	7.16	6.68%
Nardus stricta	30	5.20	3.53%	4.29	4.00%
Festuca gr. rubra	S2	2.19	1.49%	1.98	1.85%
Dactylis glomerata	57	1.97	1.34%	1.88	1.76%
Nardus stricta and *Festuca gr. rubra*	S1	2.10	1.42%	1.68	1.57%
Festuca gr. rubra and *Agrostis tenuis*	52	1.66	1.13%	1.66	1.55%
Carex sempervirens	32	1.10	0.75%	1.10	1.03%
Subalpine nitrophilous vegetation	RA1	0.51	0.35%	0.51	0.48%
Carex fusca	ZH2	0.24	0.16%	0.24	0.22%
Brachypodium rupestre	S5	0.09	0.06%	0.07	0.07%
Total		**147.44**	**100.00%**	**107.10**	**100.00%**

Table 118.2. Pasture surface divided by pasture type.

Pastures are largely dominated by the *Festuca scabriculmis* type that share about the 29% of the net grazing areas. This type is represented by two facies: the first, les extended (about the 6% of net grazing area), represents the transition to the *Brachypodium rupestre* type (facies 24.04 - *Festuca scabriculmis* and *Brachypodium rupestre*); the second dominant one (about the 22% of net grazing area), is the typical facies (facies 24.05 - *Festuca scabriculmis*), that cover almost all the wide slopes of the grazing areas. The 24.05 facies cover also the ungrazeable grass-covered areas, exploitable by a small flock only.

The second type for surface share, slightly less than the previous one, is the *Brachypodium rupestre* (type 25, about the 26% of net grazing area) that substitute the *Festuca scabriculmis* type in the slopes at a lower altitude and in more thermic conditions. This type is represented by three facies: the typical one 25.11 that characterise areas near the forests, the second (25.16) with the presence of *Festuca* gr. *ovina*, and finally the third facies 25.32 with *Brachypodium rupestre* and *Dactylis glomerata* which represent the involution of the *Dactylis glomerata* in thermic condition due to an underutilisation.

The third type for surface share is the type A8- *Nardus stricta* and *Carex sempervirens* (19% of the net grazing area) mainly represented (about 9% of the net grazing area) by the sub-type A8.1 - *Nardus stricta, Trifolium alpinum* and *Carex sempervirens* and secondly (6% of the net grazing area) by the sub-type A8.2- *Nardus stricta*, *Carex sempervirens* and *Festuca* gr. *rubra.* The *Nardus* type characterize the upper part of the valley, starting from the Gran Piano to the Laghetti.

The *Dactylis glomerata* type -57- follows by extension and share about the 11% of the net grazing areas of the Pasture district and is located in the rich and flat zones near Gran Pra, Località Pianchetti and Balmarossa. The fifth type for surface share (a little less than 7% of the net grazing areas) is the *Festuca* gr. *ovina* type (cod. 19) located in the lower slope, in the transition area from fertile type and *Brachypodium rupestre* type. Non negligible is the surface share of the types S2 - *Festuca* gr. *rubra*, that range between the 2 and the 4% of the net grazing area.

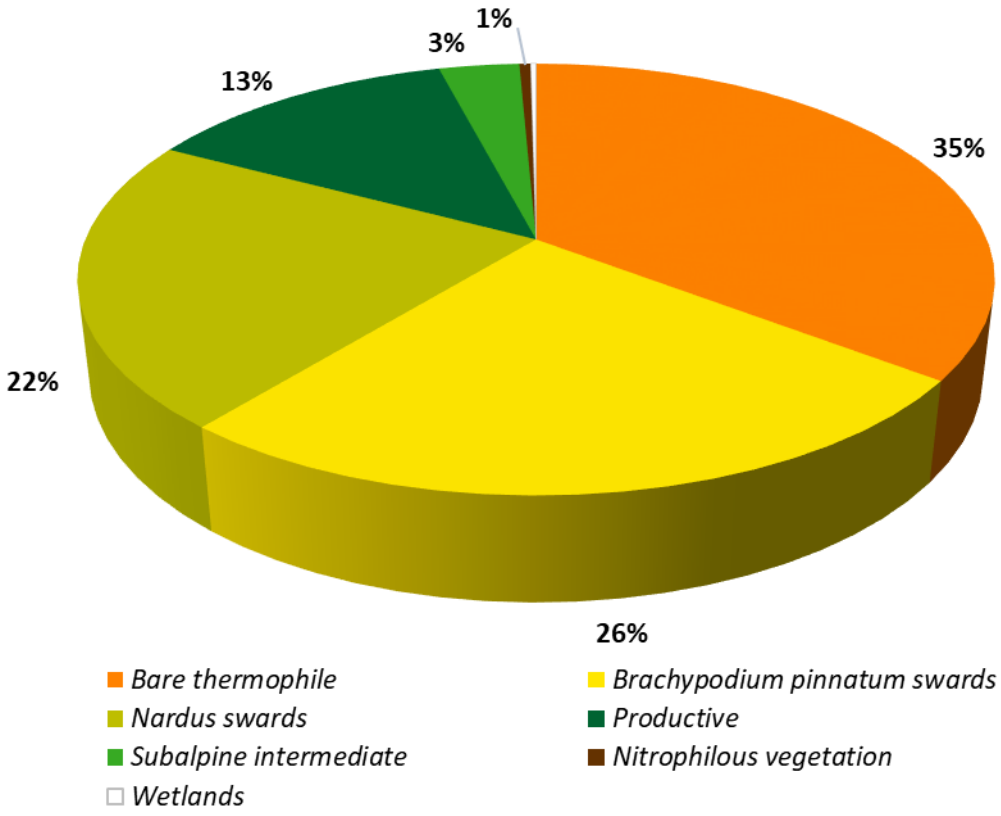


Figure 118.1. Pasture net surface divided by pasture category.

Grazing management notes

Based on the available information, two different farms manage the grazing area.

The first farm uses the grazing area at a lower altitude near Balmarossa, Ramajot at an intermediate elevation, and the Alpe Gran Pra and the portions at even higher altitudes near the Gran Piano and the Laghetti. These pastures are used through extensive rotational grazing with medium-large size plots by a herd of about 50-60 heads of Aosta Red Pied breed mainly. A second herd composed by heifers and dry cows exploit the pastures over the Gran Piano by free ranging.

The second farm manage the steeper and farer areas, not accessible by cattle, with a large free ranging sheep flock.

Pasture district n. 119 Vallone di Forzo

Municipality	*Ronco Canavese (TO)*
Surface	*Total (gross area): 510 ha* *Pasture (net area): 204 ha*
Elevation	*1069 m – 2626 m a.s.l.*
Aspect	*South, south-east*
Slope	*Low along the valley floor with steep slopes*

Territorial overview

Forzo valley has a north-west / south-east trend and it borders with the ridges of Aosta Valley (Bardoney Valley) to the north-west, with Campiglia Valley to the northeast, with the area of Valsoera Lakes to the southwest and it flows into Soana Valley to the southeast.
The pastures of Forzo cover a series of fan-shaped small valleys, whose main directions are materialized by two watercourses: the torrent Forzo (which runs through the Lavina Valley at the head of the main valley) and the torrent Pisone which flows into the orographic right (near Boschietto) going down from west to east through Pian della Valletta, Pian delle Mule and Pian Geri.
The meadows occupy three separate areas: the first includes the head of the valley and the left orographic slope of the Vallone di Lavina, with altitudes between 1700 and 2500 m a.s.l., steep slopes and prevailing exposure to the south; the second is located around the Pian delle Mule with similar altitudes, but less steep and with a prevailing exposure to east; the third is located at the bottom of the valley, close to the villages Boschettiera, Boschietto, Forzo, Molino and Marmote, at altitudes between 1000 and 1500 m a.s.l. and has very low slopes.

Pasture surfaces

The examined Pasture district covers about 204 ha net of grazeable meadows out of a total of 510 ha.
The strong diffusion of tares (especially shrubs in the lower part and rocks in the upper part) corresponds to a rather poor grassland, as well as fragmented and marginal. About 55% of net pasturable areas refers to areas with tares between 20 and 50%; another 9% results from areas with even higher tares (around 80%); only about a third of the grazing area insists on areas with scarce or limited tares (20% or less).
The best pasture areas for cattle cover about 150 hectares of gross area; they are located in relatively shallow zones at the head of the Lavina Valley (and in a smaller area near Giavino Grange on the left orographic slope), in the area of Pian dei Muli (and various other small surrounding plains) and in the valley bottom near the numerous villages.
A larger area, about 250 ha gross, is occupied by pastures of very low quality, currently (half)abandoned and potentially grazeable only with small flocks of sheep and goats. These poor pastures are located in the high and steep parts, above the timberline, on the orographic left of Lavina Valley, but also cover many steep portions of pasture on the edge of Pian dei Muli.
The net grazing area of the Pasture district, are given by tare classes, in *Table 119.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	11.18	2.19%	11.18	5.49%
20	79.17	15.53%	63.36	31.11%
50	221.06	43.35%	110.95	54.47%
80	91.01	17.85%	18.20	8.94%
100	107.50	21.08%	0.00	0.00%
Total	**509.92**	**100.00%**	**203.69**	**100.00%**

Table 119.1. Total and net area in the Pasture district by tare class.

Pasture types

The pasture types identified on the Pasture district are given in *Table 119.2* and reported in *Figure 119.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	289.64	71.86%	145.61	71.48%
Nardus stricta and Carex sempervirens	A8	39.28	9.75%	14.85	7.29%
Dactylis glomerata	S3	16.59	4.12%	13.14	6.45%
Nardus stricta and Festuca rubra	S1	11.75	2.92%	6.76	3.32%
Festuca rubra	S2	8.96	2.22%	4.70	2.31%
Deschampsia caespitosa	53	5.22	1.30%	4.44	2.18%
Carex curvula	A5	7.99	1.98%	4.00	1.96%
Alchemilla pentaphyllea and Salix herbacea	A9	7.22	1.79%	3.59	1.76%
Kobresia myosuroides	A6	3.64	0.90%	1.84	0.90%
Wetlands	ZH	4.58	1.14%	1.70	0.83%
Trifolium alpinum	A7	3.18	0.79%	1.59	0.78%
Subalpine nitrophilous vegetation	RA	2.56	0.64%	0.61	0.30%
Brachypodium pinnatum	25	0.74	0.18%	0.54	0.26%
Calamagrostis villosa	40	1.67	0.42%	0.35	0.17%
Scirpus sylvaticus	81	0.04	0.01%	0.01	0.00%
Total		**403.07**	**100.00%**	**203.69**	**100.00%**

Table 119.2. Pasture surface divided by pasture type.

The meadows of *Festuca scabriculmis* (type 24) cover all the steep slopes and are by far the most widespread, occupying about 71% of the potentially grazeable net area. These meadows are located in steep and exposed places, such as the wide slope on the left orographic side of the entire Lavina Valley or even large areas around the conch of Vassinetto and Gran Fumà Granges. These are poor grasslands, which can only be used for sheep and goat grazing (or for wild animal grazing), except for a few small areas on the edge towards less steep pastures, where the meadows of *Festuca scabriculmis* come into contact (and originate mosaics) with *Nardus stricta* and *Carex sempervirens* grasslands. In these relatively more fertile conditions, in addition to the frequent invasion of *Rhododendron ferrugineum* (considered as shrubby tare), patches of *Calamagrostis villosa* (type 40 - showing dynamic towards tree or shrub formations) can be often found in the meadow of *Festuca scabriculmis*.

In the alpine altitudinal belt type A8 - *Nardus* and *Carex sempervirens* is the most important pasture for cattle (in terms of fertility and extension, even if it occupies only 7% of the total pasture area). This pasture type is usually located in not very steep stations and it is often connected with small wetlands (ZH) or with areas of snow accumulation characterized by the presence of *Salix herbacea* (snow-beds - type A9). In the area near Muanda Grange the grassland (A8) is particularly rich in *Trifolium alpinum* (transition to A7). Above this area, going up to Lago delle Mule, the turf fragments into a complex mosaic between the types A5 - *Carex curvula*, A6 - *Kobresia myosuroiudes* and A9 - *Alchemilla pentaphyllea* and *Salix herbacea*.

At lower altitudes, around the timberline, or in clearings of subalpine larch forests, there is a series of grasslands with *Nardus stricta* (type S1) and / or *Festuca rubra* (type S2). This situation is typical of many small areas surrounding the main Granges: Lavina, Brenvei, Gran Fumà, Vallerei, Vassinetto and Bettassa (which together represent around 11% of the total pasture district). At an even lower altitude, in the valley floor zones, the rich meadows have a similar spread, and they are characterized by the abundance of *Dactylis glomerata* (type S3). All the meadows of the group "S" have many contacts with the meadows of *Festuca scabriculmis,* or with pre-nemoral situations of abandonment (type 25 - *Brachypodium rupestre*), or with relatively wet meadows with *Daschampsia caespitosa*. In the fresh and fertile areas of the valley floor, *Daschampsia caespitosa* becomes the dominant species, invading entire plots of land (type 53). In the

valley bottom there is also a large area with invasion of nitrophilous species (RA) near Boschietto, as well as a state of semi-abandonment in the meadows along the path that descends towards Forzo (even with the presence of wetlands with *Scirpus sylvaticus* - type 81).

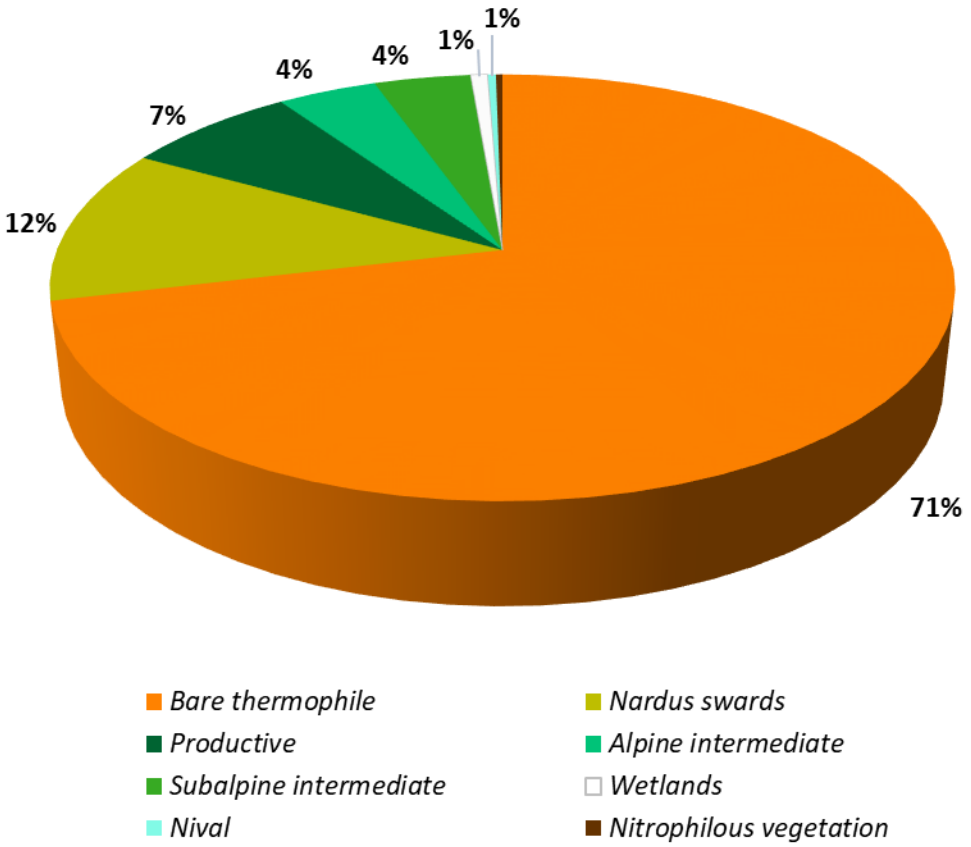


Figure 119.1. Pasture net surface divided by pasture category.

Grazing management notes

The best pastures are those belonging to Gran Fumà and Muanda Granges, still regularly grazed by cattle. The pastures of Vallerei are located just below Gran Fumà and are exploited by the same animals, but incompletely and for limited periods. Their use is so limited that there is the risk of invasion by trees and shrubs. The same risk exists for Pianass Grange, on the edge of the study area.

On the parallel ridge (further south) a discontinuous series of pastures descends from Vassinetto Grange towards Bettassa and Gran Ruina. Also these areas are only partially used and show general signs of abandonment. The presence of a small group of horses has been observed here.

Even the series of small Granges along the path that climbs north of Boschietto (Sengia, Biestan and Giavino) is now used in a partial and sporadic way.

At the head of the valley, only Lavina Grossa Grange is regularly loaded with cattle, while Lavinella and Brenvei Granges seem to be used only occasionally.

The valley floor pastures are regularly loaded and a group of cattle is located near Boschietto. In this case the pasture is guided by some lines of electrified wire. In the lower areas before Forzo there are situations of (half) abandonment, while in the area next to the carriage road the management of various plots seems to be combined, with lawn and pasture.

Pasture district n. 120 Vallone di Piantonetto

Municipality	*Locana (TO)*
Surface	*Total (gross area): 384 ha* *Pasture (net area): 160 ha*
Elevation	*1198 m – 2813 m a.s.l.*
Aspect	*East*
Slope	*Medium to high*

Territorial overview

Piantonetto valley has a north-south course and it borders with the ridges of Aosta Valley to the north (Valnontey and Valeille valleys), with Val Noaschetta to the west, with the area of the Valsoera Lakes to the east and it leads to Val Locana to the south.

Piantonetto pastures range from the head of the valley, beyond the artificial lake of Teleccio, to the steep mountain slope above the lake shore, on right hydrographic side. The swards reach an altitude of 2800 m above sea level in the innermost part of the valley (where a wide, not very steep basin extends immediately upstream of the lake), culminating at about 2500 m a.s.l. along the steep western ridge, on the orographic right. In the lower part the pasture goes down to about 1900 m a.s.l. near the lake, but downstream of the dam (and of the very steep part of the valley immediately below) it goes down more, occupying a narrow and flat strip of valley floor at about 1200 m a.s.l. The prevailing exposures vary from south (for the head and the central axis of the valley) to east, for the slope on the right bank.

Pasture surfaces

The examined Pasture district covers about 160 ha of net grazing area, out of a total of over 384 ha, which corresponds to an average tare of around 60%.

The strong diffusion of the tares (in particular shrubs in the lower part and rocks in the upper part) corresponds to the presence of poor and marginal grasslands. In particular, about 70% of the net pasture areas are burdened with tares between 20 and 50%; another 10% corresponds to even higher tares (up to 100%), while only a fifth of the pasture surface has a tare lower than 20%. The best areas that can be grazed by cattle cover just over 160 hectares; they are found in the valley bottom (and in the north-western area of the lake) and are relatively flat. A larger area, about 210 gross hectares, is occupied by very low quality pastures, currently abandoned and potentially grazeable only with small flocks of sheep and goats; they are located in a discontinuous belt that crosses all the highest and steepest rocky slopes.

The net grazing areas of the Pasture district, are given by tare classes, in *Table 120.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	4.37	1.14%	4.37	2.72%
20	34.34	8.95%	27.46	17.12%
50	222.78	58.04%	111.77	69.68%
80	83.97	21.88%	16.80	10.47%
100	38.37	10.00%	0.00	0.00%
Total	**383.83**	**100.00%**	**160.40**	**100.00%**

Table 120.1. Total and net area in the Pasture district by tare class.

Pasture types

The pasture type identified on the pasture district are given in *Table 120.2* and reported in *Figure 120.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	240.45	62.64%	106.14	66.17%
Nardus stricta and Carex sempervirens	A8	41.12	10.71%	19.48	12.14%
Festuca rubra	S2	20.28	5.28%	10.50	6.55%
Nardus stricta and Festuca rubra	S1	16.61	4.33%	9.17	5.72%
Dactylis glomerata	S3	8.28	2.16%	6.05	3.77%
Kobresia myosuroides	A6	7.21	1.88%	3.61	2.25%
Wetlands	ZH	5.75	1.50%	2.36	1.47%
Veratrum album	54	1.94	0.51%	1.38	0.86%
Carex curvula	A5	2.71	0.70%	1.36	0.85%
Subalpine nitrophilous vegetation	RA	1.26	0.33%	0.25	0.16%
Alchemilla pentaphyllea and Salix herbacea	A9	0.22	0.06%	0.11	0.07%
Rhododendron ferrugineum and Vaccinium uliginosum	L3	38.00	9.90%	0.00	0.00%
Total		**383.83**	**100.00%**	**160.40**	**100.00%**

Table 120.2. Pasture surface divided by pasture type.

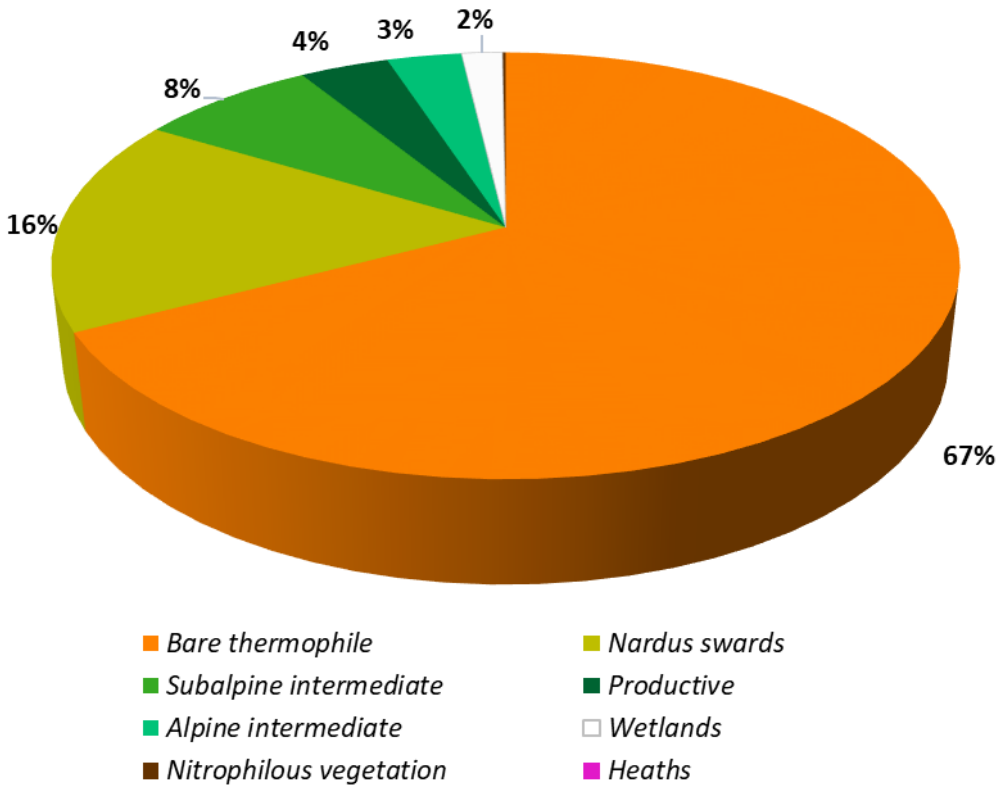


Figure 120.1. Pasture net surface divided by pasture category.

The meadows of *Festuca scabriculmis* (type 24) occupy the steepest slopes (these pastures can be grazed only by small groups of sheep and goats) and are by far the most widespread, on over 66% of the potentially grazeable net surface. This type of grassland becomes more and more widespread as we proceed towards south; the slope on the southern side of the lake does not host sites suitable for cattle, but only a series of steep and poor pastures for sheep and goats, heavily invaded by shrubs (rhododendrons) and alternated with large rocky areas or accumulations of big blocks.

Even at high altitude *Festuca scabriculmis* is common almost everywhere; only in the small valley that leads to Colle di Noaschetta there are significant surfaces (about 10 hectares) of other types of alpine swards, in particular mosaics between *Kobresia myosuroides* type (A6) and *Carex curvula* and/or *Salix herbacea* types (A5 and A9).
In the lower part of the slopes, in some areas at the edges towards more fertile pastures, the pastures with *Festuca scabriculmis* come into contact (and create mosaics) with the *Nardus* and *Festuca rubra* meadows. The pasture type composed of *Nardus stricta* and *Carex sempervirens* (A8) is the second in order of extension (12% of the net area refers to it) and is located in the large basin north of the lake and on a median belt with lower slope across the west side. These pastures are among the best ones in the area and they are still regularly grazed.
Secondary grasslands with *Nardus stricta* (S1) or more fertile meadows with *Festuca rubra* and/or *Dactylis glomerata* (types S2 and S3) are limited to the valley floor or to small and almost flat parts of the slope. Altogether they occupy 16% of the surface: among these the type with *Festuca rubra* (S2) is the most widespread in the areas located both upstream and downstream of the lake. The type S3 is limited to lower pastures. The contacts between these rich pastures and the resting areas of livestock (RH) or even with wet areas (ZH) are common and "physiological". A very large wet area (about 5 hectares) is located in the middle of the basin upstream of the lake.

Grazing management notes

The best pastures are located around Alpe Muanda; they are still regularly grazed by cattle. From Piano delle Muande the grazing cattle also move to the areas of Alpe Glafort and beyond to Alpe Mandonera (ruins). Alpe Fumietto is also grazed by cattle. In these areas there are meadows invaded by *Rhododendron* heaths (mapped as L3), which can still be restored into good grazing areas, on the edge of open grasslands.
Further south, heaths (although extended over vast areas in contact with the meadows of *Festuca scabriculmis*) are not considered potential grazing areas.
In fact, the meadows of *Festuca scabriculmis* themselves cannot be grazed except by wild animals or, potentially, by sheep and goats. The Alpi of Drosa and Fumà are abandoned or almost. Their pastures, with the exception of a very limited area near the buildings, are extremely poor and fragmented.

Pasture district n. 121 Vallone Roc

Municipality	*Noasca (TO)*
Surface	*Total (gross area): 549 ha* *Pasture (net area): 243 ha*
Elevation	*1319 m – 2700 m a.s.l.*
Aspect	*South*
Slope	*Low along the valley floor and at higher altitudes where there are several plateaus; medium-high on the slopes*

Territorial overview

The Vallone del Roc Pasture district is located in the valley that goes up to the Alpe Breullet, from Borgata Pianchetti; the valley is oriented from south-east to north-west. The Pasture district borders to east with Ciamoseretto Pasture district, defined by Ciamoseretto mountain and by the ridge that goes down towards Borgata Maison. The pastures are distributed along the whole valley, mainly concentrated on its left orographic side; they cover from 1350 m a.s.l. up to 2700 m a.s.l. The prevailing exposure of the pastures varies between south-southeast, south and south-southwest.

Pasture surfaces

The net grazing area of the Pasture district, are given by tare classes, in *Table 121.1*.

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	52.24	9.51%	52.24	21.50%
20	123.15	22.42%	98.52	40.55%
50	176.16	32.07%	88.08	36.25%
80	20.6	3.75%	4.12	1.70%
100	177.1	32.24%	0.00	0.00%
Total	**549.25**	**100.00%**	**242.96**	**100.00%**

Table 121.1. Total and net area in the Pasture district by tare class.

In the examined Pasture district there are about 243 ha of net grazing area. About the 22% of the net grazing area is characterized by the absence of diffused tares. About 41% of the net grazing area in characterized by the 20% of diffused tares, whereas about the 36% of the net grazing area showed the 50% of diffused tares. The areas that cannot be grazed correspond to about 177 ha of gross area (about the 32% of gross surface).

Pasture types

The pasture types identified on the Pasture district are given in *Table 121.2* and reported in *Figure 121.1*.

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Festuca scabriculmis	24	208.55	56.04%	134.16	55.22%
Nardus stricta and *Carex sempervirens*	A8	89.90	24.16%	58.00	23.87%
Festuca gr. *rubra*	S2	33.10	8.89%	22.30	9.18%
Dactylis glomerata	S3	15.20	4.08%	10.00	4.12%
Brachypodium rupestre	25	11.40	3.06%	8.10	3.33%
Phleum alpinum	60	5.00	1.34%	3.50	1.44%
Nardus stricta and *Festuca* gr. *rubra*	S1	2.80	0.75%	2.70	1.11%
Festuca flavescens	41	3.90	1.05%	1.90	0.78%
Carex fusca	ZH2	1.60	0.43%	1.60	0.66%
Subalpine nitrophilous vegetation	RA1	0.70	0.19%	0.70	0.29%
Total		**372.15**	**100.00%**	**242.96**	**100.00%**

Table 121.2. Pasture surface divided by pasture type.

Pastures are largely dominated by the *Festuca scabriculmis* type that share about the 55% of the net grazing areas. This type is represented by the typical facies 24.05 a *Festuca scabriculmis*, that cover almost all the wide slopes of the grazing areas.

The second type for surface share is the type A8- *Nardus stricta* and *Carex sempervirens* (24% of the net grazing area) mainly represented (about 19% of the net grazing area) by the sub-type A8.1 - *Nardus stricta, Trifolium alpinum* and *Carex sempervirens* and secondly (4.5% of the net grazing area) by the sub-type A8.2- *Nardus stricta*, *Carex sempervirens* and *Festuca* gr. *rubra.* The *Nardus* type characterises the upper part of the right orographic side of the valley and the part near Alpe di Foges and Alpe di Breuil.

The third type for surface share is the type S2 - *Festuca* gr. *Rubra* (9.2% of net grazing area) which is located in the rich and flat zones near the buildings (Mola, Cappelle, Vecchio, Roc, Alpe Pianes, La Truna, Loserai di Sotto). This type is represented by two facies: the first, dominant (about the 6% of net grazing area) represent by the sub-type S2.2 a *Festuca* gr. *rubra*, *Agrostis capillaris, Phleum alpinum* and *Alchemilla xanthochlora*; the second less extended one is the sub-type S2.1 a *Alchemilla xanthochlora*, *Festuca* gr. *rubra* and *Agrostis capillaris*.

Non negligible is the surface share of type S3 - *Dactylis glomerata* and type 25 - *Brachypodium rupestre*, that range between the 3 and the 5% of the net grazing area.

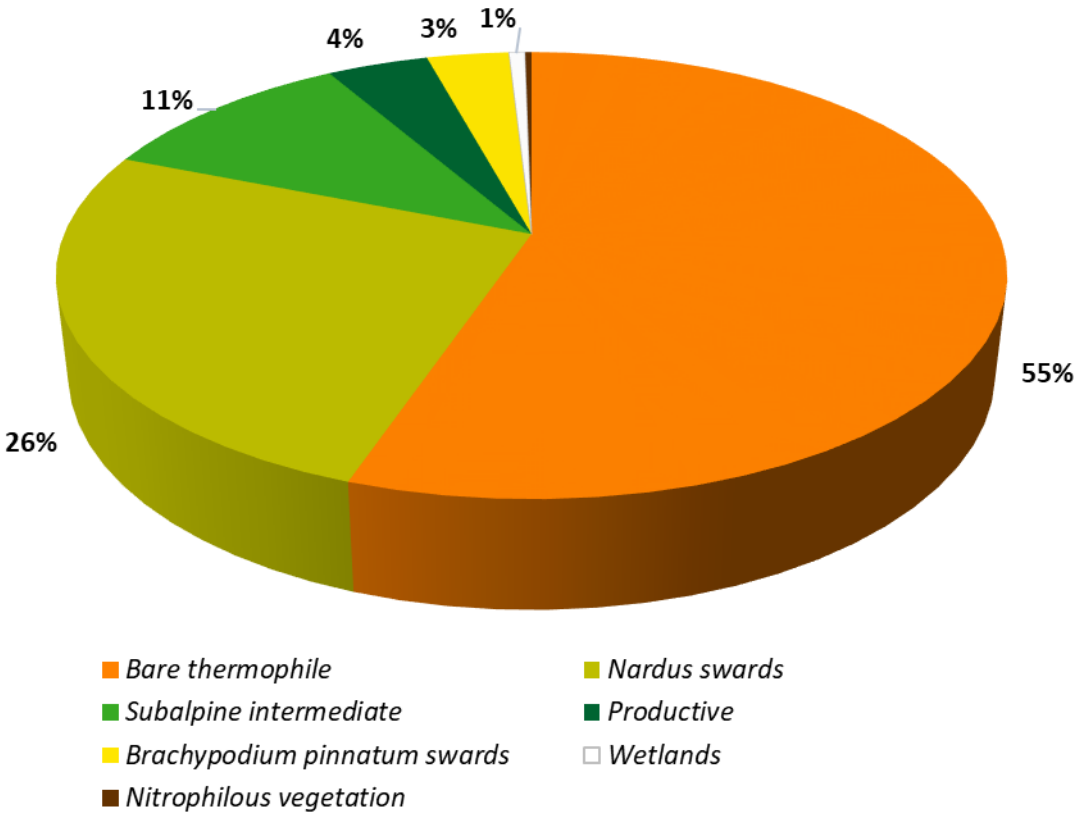


Figure 121.1. Pasture net surface divided by pasture category.

Grazing management notes

Three farms exploit the Pasture district.

The first farm exploits the pasture in the valley floor near Mola, Cappelle, Potes, and the intermediate altitude pastures near Alpe Roc, Pianes and Foges by a herd of about 60 cows of Aosta Red Pied breed and some goats by free ranging. The farmer stays in Borgata Cappelle.

The second farm exploits the pasture near C. Bianca, Pian del Brengi, Prà del Cres, Ciaplus, Loserai di Sopra and di Sotto, with a cattle herd of about 20-30 heads of Piedmontese breed and some equids by free ranging.

The third farm manage the steeper and farer areas, not accessible by cattle, with a large free ranging sheep flock.

Pasture district n. 122 Vaudala

Municipality	*Rhêmes-Notre-Dame (AO)*
Surface	*Total (gross area): 110 ha* *Pasture (net area): 57 ha*
Elevation	*2263 m – 2782 m a.s.l.*
Aspect	*No prevailing aspect*
Slope	*Mostly moderate on slopes alternating with flatlands*

Territorial aspects

The Pasture district of Vaudala is in a hanging valley, on the hydrographic right side of Rhêmes Valley, between 2300 m a.s.l. and 2800 m a.s.l., in the alpine altitudinal level.
The morphology is characterized by slopes from 10° to 30°, small flat areas, and steep slopes (30°-40°).
The main exposure is from west to north, with some small sectors south and east.
The substrate is changeable: calcescists, limestones, metabasalts, glacial moraine deposits.
The Pasture district can be reached by footpath from Thumel.

Pasture surfaces

The net grazing areas, divided by tare classes, are represented in *Table 122.1.*

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	5.48	4.98%	5.48	9.67%
20	44.99	40.92%	35.97	63.45%
50	30.47	27.72%	15.24	26.88%
100	29.00	26.38%	0.00	0.00%
Total	**109.94**	**100.00%**	**56.69**	**100.00%**

Table 122.1. Total and net area in the Pasture district by tare class.

In the examined pasture area there are about 81 ha of grassland and 57 ha of net grazing area.
As the figure shows about the 10% of the net grazing area is characterized by the absence of diffused tares, whereas about 63% of the net grazing area is characterized by the 20% of diffused tares and about the 27% of the net grazing by the 50% of diffused tares.
The main tare are rocks and screes, that also include the uncovered ground.

Pasture types

The pasture types identified on the Pasture district are represented in *Table 121.2* and reported in *Figure 121.1.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Kobresia myosuroides	A6	21.36	26.39%	14.43	25.46%
Nardus stricta and *Carex sempervirens*	A8	16.33	20.17%	13.75	24.26%
Carex curvula	A5	16.42	20.28%	8.21	14.49%
Carex curvula	37	7.81	9.65%	6.24	11.01%
Geum montanum	47	4.95	6.12%	4.17	7.36%
Festuca rubra	S2	3.56	4.40%	2.84	5.01%
Carex sempervirens	32	3.08	3.81%	2.46	4.34%
Festuca violacea	A2	3.59	4.44%	1.88	3.32%
Rhododendron ferrugineum and *Vaccinium uliginosum*	L3	1.18	1.46%	0.94	1.66%

Nardus stricta and Festuca rubra	S1	1.14	1.41%	0.91	1.61%
Festuca gr. violacea	46	1.15	1.42%	0.57	1.01%
Poa alpina	61	0.18	0.22%	0.18	0.32%
Screes	E2	0.14	0.17%	0.07	0.12%
Alchemilla pentaphyllea and *Salix herbacea*	A9	0.06	0.07%	0.03	0.05%
Total		**80.94**	**100.00%**	**56.69**	**100.00%**

Table 122.2. Pasture surface divided by pasture type.

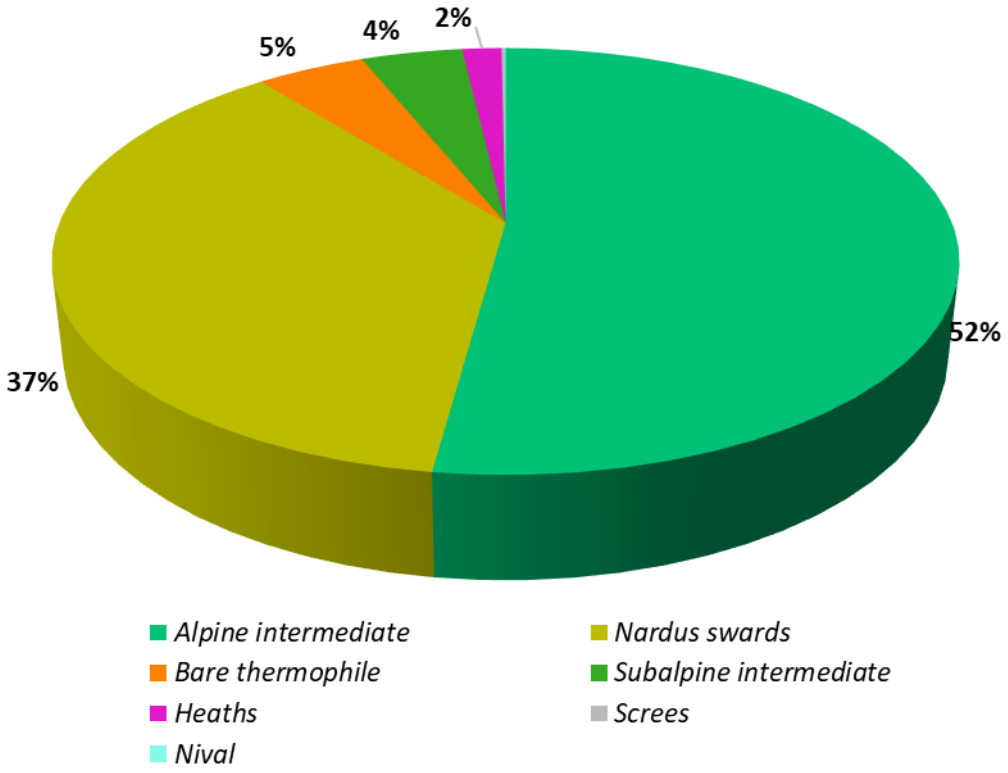


Figure 122.1. Pasture net area divided by pasture category.

There are 14 pasture types and 23 facies.
The most represented type is the *Carex curvula* one, at the higher altitudes, forming mosaics with *Kobresia myosuroides* type. These formations (*Kobresia myosuroides)*, of thermic ecological conditions, on slopes and crests, are well represented in the Pasture district, in both facies with acidophilous or calciphilous species.
The *Nardus stricta* and *Carex sempervirens* type, with *Trifolium alpinum* (cod. A8.1), of intermediate ecological conditions, is widespread in the central zone of the Pasture district; the main three species may have different percentages, according to the zone. *Geum montanum* type is also present forming mosaics with others formations.
The richest type (*Festuca* gr. *rubra*) is at the lower altitude, downstream of Alpe Gran Vaudalaz, where received fertility, also thanks to past fertigation.

Grazing management notes

The Pasture district is managed by one farmer with a herd of heifers and dry cows (about 40 elements equal to 35 LSU - 2017 data). The herd exploits the pastures with free grazing.
The grazing season lasts from the end of July to mid-September.

Pasture district n. 123 Vaudaletta

Municipality	*Rhêmes-Notre-Dame (AO)*
Surface	*Total (gross area): 127 ha* *Pasture (net area): 59 ha*
Elevation	*2302 m – 2950 m a.s.l.*
Aspect	*No prevailing aspect*
Slope	*Prevalence of medium to steep slopes*

Territorial aspects

The Pasture district of Vaudaletta is in a hanging valley, on the hydrographic right side of Rhêmes Valley, between 2250 m a.s.l. and 2950 m a.s.l., in the alpine altitudinal level.
The morphology is characterized by slopes from 10° to 30°, small flat areas, and wide steep sectors (30°-40°).
The exposure is changeable from south to west and to north.
The substrate is changeable: calcescists, metabasalts, gneisses, glacial moraine deposits, rockglaciers.
The Pasture district can be reached by footpath from Thumel.

Pasture surfaces

The net grazing areas, divided by tare classes, are represented in *Table 123.1.*

Tare class (%)	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
0	3.16	3.73%	3.16	5.36%
20	50.93	60.07%	40.74	69.07%
50	29.68	35.00%	14.88	25.23%
80	1.02	1.20%	0.20	0.34%
Total	**84.79**	**100.00%**	**58.98**	**100.00%**

Table 123.1. Total and net area in the Pasture district by tare class.

In the examined pasture area there are about 85 ha of grassland and 59 ha of net grazing area.
As the figure shows about the 5% of the net grazing area is characterized by the absence of diffused tares, whereas about 69% of the net grazing area is characterized by the 20% of diffused tares and about the 25% of the net grazing by the 50% of diffused tares.
The main tare is made up of rocks and screes, that also include the uncovered ground.

Pasture types

The pasture types identified on the Pasture district are represented in *Table 123.2.*

Pasture type	Code	Gross area (ha)	Gross area (%)	Net area (ha)	Net area (%)
Kobresia myosuroides	A6	35.64	42.04%	24.17	40.98%
Carex curvula	A5	10.73	12.66%	7.09	12.02%
Festuca quadriflora	21	8.82	10.41%	7.06	11.97%
Plantago alpina and *Festuca ovina*	A1	7.37	8.69%	5.90	10.00%
Nardus stricta and *Carex sempervirens*	A8	4.02	4.74%	3.00	5.08%
Geum montanum	47	3.40	4.01%	2.78	4.71%
Avenula versicolor	36	3.14	3.71%	2.51	4.26%
Carex sempervirens	32	3.90	4.60%	1.64	2.78%
Plantago alpina	75	2.37	2.80%	1.62	2.75%
Festuca gr. rubra and *Agrostis tenuis*	52	1.52	1.79%	0.76	1.29%
Alchemilla pentaphyllea and *Salix herbacea*	A9	1.41	1.66%	0.71	1.20%
Festuca violacea	A2	0.84	0.99%	0.67	1.14%
Elyna myosuroides	22	0.82	0.97%	0.41	0.70%
Nardus stricta	30	0.36	0.42%	0.36	0.61%
Festuca rubra	S2	0.26	0.31%	0.21	0.36%
Wetlands	ZH	0.12	0.14%	0.06	0.11%
Trifolium badium	72	0.05	0.06%	0.03	0.05%
Total		**84.78**	**100.00%**	**58.97**	**100.00%**

Table 123.2. Pasture surface divided by pasture type.

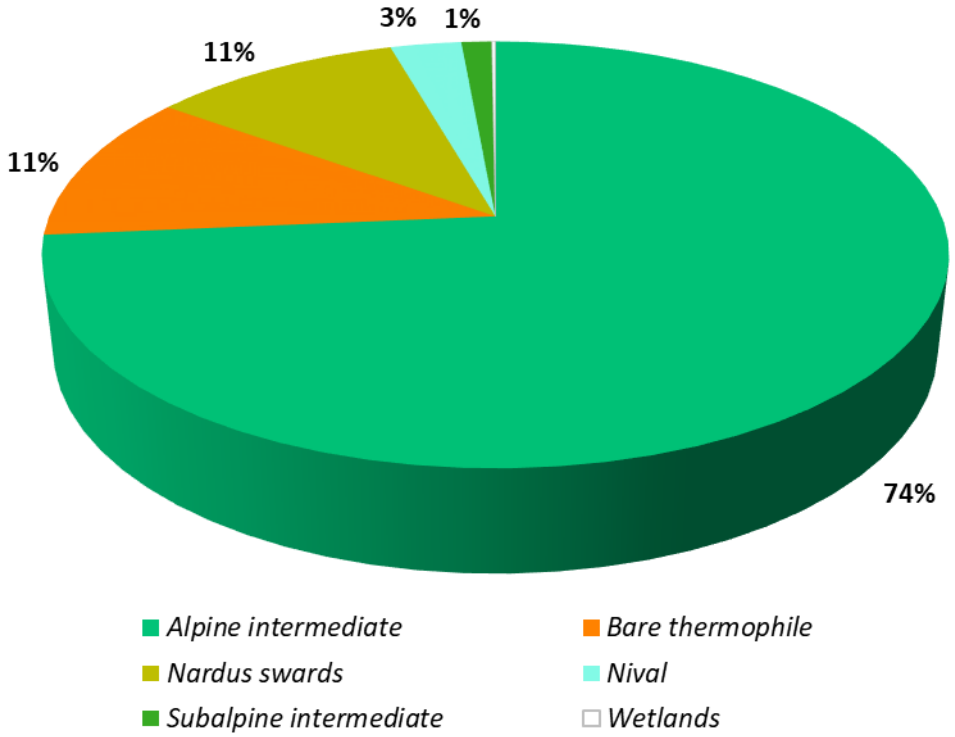


Figure 123.1. Pasture net area divided by pasture category.

There are 17 pasture types and 21 facies.
The most represented types are those of basic substrates, in particular *Kobresia myosuroides* type, often with *Sesleria varia* (but is also present the facies with acidophilous species) and then *Festuca quadriflora* type, formations of thermic ecological conditions, on slopes and crests.
The *Carex curvula* type is widespread at the higher altitudes, in low slope areas, forming mosaics with *Kobresia myosuroides* type or with little snowbed communities.
The *Plantago alpina* and *Festuca ovina* formations, of thermic ecological conditions, are on south-facing slopes in the lower zone, while the *Nardus stricta* and *Carex sempervirens* type, with *Trifolium alpinum* (cod. A8.1), is on north-facing slopes in the lower zone.

Management notes

The Pasture district was not used in the 2018 and 2019 seasons. In the previous years it was used with a small group of dry cows (6 in 2017).
The grazing season lasted from the mid-July to the beginning of September.

Outcomes

In PNGP, 8022 ha of mountain grasslands were surveyed, corresponding to 4596 ha of net pasture surface. The net area corresponds to all the part of grasslands that can be potentially reached and grazed by domestic herbivores, while the "tare" corresponds to rocks and screes, shrubs, trees or other elements that reduce the grazeable area. We found that tares are very widespread in the investigated grasslands: only 21% of the pastures have no unproductive areas. Most grasslands have tares from 20% to 50% of their surface, as shown in the table and graph below.

TARE CLASS	GROSS AREA (ha)	GROSS AREA (%)
0% tare class	1552.82	19.36%
20% tare class	2152.42	26.83%
50% tare class	2385.95	29.74%
80% tare class	623.94	7.78%
100% tare class	1306.98	16.29%
Total	**8022.11**	**100.00%**

Table 7. PNGP grassland gross area divided by tare class.

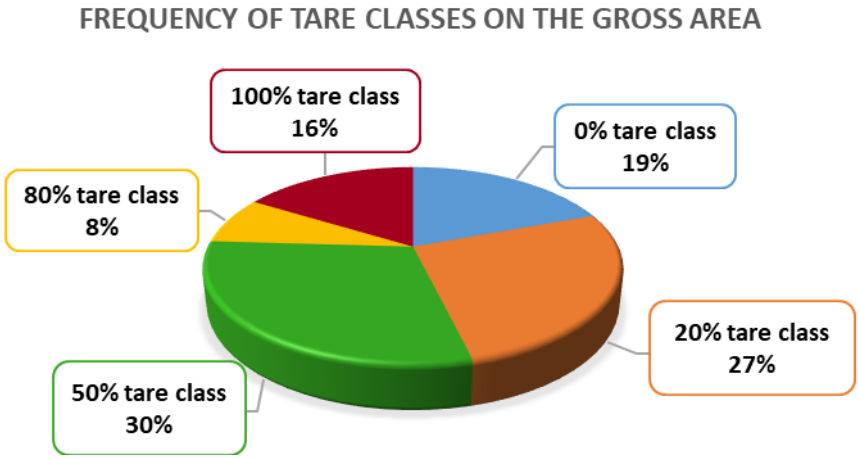


Figure 2. PNGP grassland gross area divided by tare class.

It was then studied which types of tares are present and which are the most common in the areas with tare equal to 20, 50 and 80%, totalling 5162 ha, therefore excluding:

- the areas with 100% tare because, although surveyed and included in the districts, they are not defined as pasture (1307 ha);
- the areas without tare, amounting to 1553 ha.

The table and graph below show the types of tare coded during the harmonisation phase.

TARE DESCRIPTION	SURFACE (ha)	SURFACE (%)
Rocks and screes	4208.86	81.53%
Trees and shrubs	607.8	11.77%
Shrublands	148.75	2.88%
Ungrazeable vegetation	84.41	1.64%
Bare soil	69.94	1.35%
Other	20.52	0.40%
Lakes and rivers	19.82	0.38%
Artefacts	2.21	0.04%
Total	**5162.31**	**100.00%**

Table 8. Tare percentage in the PNGP grasslands.

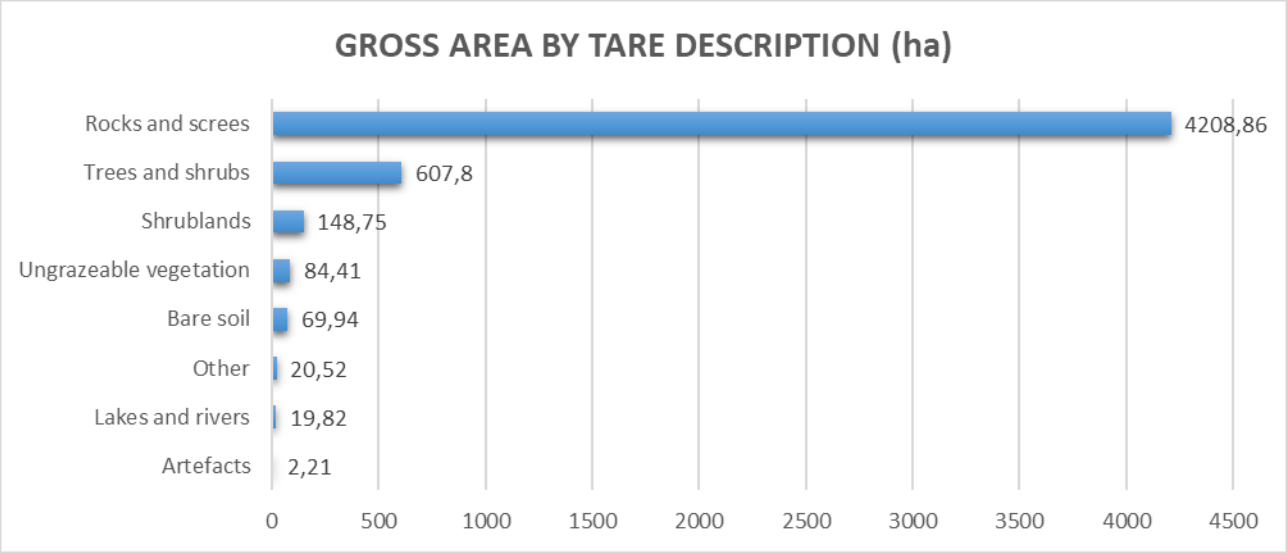


Figure 3. Tare percentage in the PNGP grasslands.

"Rocks and screes", which are poorly colonised by vegetation, represent 82% of the tares (4209 ha). As assumed, this type of tare is widespread in particular in the alpine level (>2200 m a.s.l.). At these high altitudes there is also a small fraction of tares linked to the presence of "bare soil" in the pasture (70 ha).
Below the upper treeline, "trees and shrubs" constitute the second most common type of tare (12%). The "Shrublands" category is detected at higher altitudes and includes all heaths that cannot be grazed and therefore do not fall within pasture typologies.
"Ungrazeable vegetation", on the other hand, involves herbaceous species that domestic herbivores tend to reject. This includes, for example, nitrophilous vegetation (*Rumex* in primis), infesting or tall plants (e.g. the most common *Gentiana lutea, Epilobium angustifolium*).
Finally, less than 1% of grasslands are affected by other tare categories (artefacts, lakes and rivers, etc.).

Pasture types and categories

The extensive fieldwork and mapping of pastures led to the identification of the pasture types of the grasslands of PNGP. A total of 190 different types and facies have been recognised, demonstrating a wide pasture biodiversity within the Park. The table below presents the classification of PNGP pastures by type and category, according to the harmonisation described above.

CATEGORY	AOSTA VALLEY TYPES		PIEDMONT TYPES	PNGP net surface	
	Code	Main species		(ha)	(%)
Productive	S3	*Dactylis glomerata, Trisetum flavescens, Bromus erectus*	8, 56, 57, 59	**255.95**	5.57%
F. paniculata swards	S6	*Festuca paniculata, Festuca rubra, Carex sempervirens*		**0.92**	0.02%
Subalpine intermediate	S2	*Festuca rubra, Agrostis capillaris, Phleum alpinum, Alchemilla xanthochlora*	52, 53, 54, 60, 64, 74.07	**291.64**	6.35%
Grassy thermophile	A3	*Helictotrichon parlatorei, Helianthemum spp., Festuca violacea,*	11, 40	18.45	0.40%
	S4	*Onobrychis montana, Festuca ovina, Sesleria albicans*		0.97	0.02%
	Tot. Grassy termophile			**19.42**	0.42%
B. pinnatum swards	S5	*Brachypodium pinnatum, Carex sempervirens, Festuca ovina*	3, 25	**127.27**	2.77%
Nardus swards	S1	*Nardus stricta, Festuca rubra, Plantago alpina*	29, 30.26-30.30, 30.32, 41, 48, 49	153.09	3.33%
	A8	*Nardus stricta, Carex sempervirens, Trifolium alpinum, Festuca rubra*	30, 32, 33.02, 33.06, 47, 61, 74.03	793.01	17.25%
	Tot. Nardus swards			946.10	20.59%
Bare thermophile	SA1	*Sesleria albicans, Carex sempervirens, Festuca ovina, Helianthemum*	13	41.08	0.89%
	SA2	*Helianthemum nummularium, Sesleria albicans, Festuca ovina, Carex*	17	121.16	2.64%
	A2	*Festuca violacea, Carex sempervirens, Festuca rubra, Potentilla grandiflora*	32.05, 32.08, 33.15, 46, 50	235.35	5.12%
	A1	*Plantago alpina, Festuca ovina, Potentilla grandiflora*	19	131.3	2.86%
	SA3	*Dryas octopetala, Carex sempervirens, Sesleria albicans*		7.57	0.16%
		Festuca scabriculmis	24	1211.22	26.35%
	Tot. Bare thermophile			**1747.68**	38.03%
Alpine intermediate	A7	*Trifolium alpinum*	33	127.96	2.78%
	A5	*Carex curvula, Trifolium alpinum, Avenula versicolor*	37	468.13	10.19%
	A6	*Kobresia myosuroides, Carex rosae, Avenula versicolor, Festuca*	21, 22	201.35	4.38%
	A4	*Festuca halleri, Potentilla aurea*	35.01, 74.01	45.16	0.98%
	Tot. Alpine intermediate			**842.60**	18.33%
Nival	A10	*Alopecurus gerardii, Plantago alpina, Alchemilla pentaphyllea, Ranunculus pyrenaeus, Trifolium alpinum, T. thalii, Festuca violacea*	46.14 - 46.18, 61.03, 72, 75, 76	119.26	2.59%
	A9	*Alchemilla pentaphyllea, Salix herbacea, Carex foetida, Plantago alpina*	74, 77, 79	107.84	2.35%
	Tot. Nival			**227.10**	4.94%
Heaths	L	Heaths (*Loiseleuria procumbens, Vacciunium uliginosum, Rhododendron ferrugineum, Arctostaphylos uva-ursi, Juniperus nana*)		64.87	1.41%
		Juniperus nana	90	5.87	0.13%
		Vaccinium gaultheriodes	91	0.36	0.01%
		Vaccinium myrtillus	92	3.77	0.08%
	Tot. Heaths			**74.87**	1.63%
Wetlands	ZH	*Carex spp., Eriophorum spp., Ranunculus aconitifolius, Caltha palustris*		31.59	0.69%
		Scirpus sylvaticus	81	0.01	0.00%
		Carex fusca	86	2.29	0.05%
	Tot. Wetlands			**33.89**	0.74%
Screes	E	*Achillea nana, Dryas octopetala, Salix spp., Geum reptans*		9.03	0.20%
		Salix retusa e Salix reticulata	70	2.95	0.06%
	Tot. Screes			**11.98**	0.26%
Nitrophilous vegetation	RA	*Rumex alpinus, Chenopodium bonus-henricus*		9.03	0.20%
		Poa supina/annua	67	1.06	0.02%
		Rumex alpinus	69	6.47	0.14%
	Tot. Nitrophilous vegetation			**16.56**	0.36%
Total PNGP net surface				**4595.93**	**100.00%**

Table 9. PNGP grassland net surface by pasture types and categories.

The most representative pasture types of the study area are the following:

TYPE CODE	Main species	Net surface	
		(ha)	(%)
24	*Festuca scabriculmis*	1211.22	26.35%
A8	*Nardus stricta, Carex sempervirens, Trifolium alpinum*	673.74	14.66%
A5	*Carex curvula, Trifolium alpinum, Avenula versicolor*	448.12	9.75%
S2	*Festuca rubra, Agrostis capillaris, Phleum alpinum, Alchemilla sp.*	235.14	5.12%
A2	*Festuca violacea, Carex sempervirens, Festuca rubra*	175.13	3.81%
A6	*Kobresia myosuroides, Carex rosae, Avenula versicolor*	167.90	3.65%
S3	*Dactylis glomerata, Trisetum flavescens, Bromus erectus*	154.18	3.35%
A7	*Trifolium alpinum*	119.77	2.61%
SA2	*Helianthemum nummularium, Sesleria albicans, Festuca ovina*	119.70	2.60%
25	*Brachypodium rupestre*	118.34	2.57%

Table 10. Most representative pasture types in PNGP and percentage on total net surface.

Table 10 shows the 10 most represented pasture types within the Park. It is interesting to note that the first 3 types, accounting for more than half of the net pasture area in PNGP, are quite poor grasslands.
The *Festuca scabriculmis* swards constitute about 26% of all investigated alpine pastures. It is a typical type for xero-thermic discontinuous swards on south facing slopes. The sward height is medium (20-40 cm), with the presence of bare soil or stony outcrops. This very poor type is often found in areas at the edge or outside the pastures that are regularly grazed by herds. The main species is not highly valued by domestic herbivores but can be an interesting forage resource for alpine ungulates in winter.
Two types belonging to other categories follow: type A8 with *Nardus stricta* of the homonymous category and type A5 of intermediate alpine swards.

The grassland categories that have been found in the study area are shown in *Table 11* and *Figure 4*.

PASTURE CATEGORY	Net Surface	
	(ha)	(%)
Bare thermophile	1747.68	38.03%
Nardus swards	946.10	20.59%
Alpine intermediate	842.60	18.33%
Subalpine intermediate	291.59	6.35%
Productive	255.95	5.57%
Nival	227.10	4.94%
B. pinnatum swards	127.27	2.77%
Heaths	74.87	1.63%
Wetlands	33.89	0.74%
Grassy thermophile	19.42	0.42%
Nitrophilous vegetation	16.56	0.36%
Screes	11.98	0.26%
F. paniculata swards	0.92	0.02%
Total	**4595.93**	**100.00%**

Table 11. PNGP pastures net surface divided by grassland category.

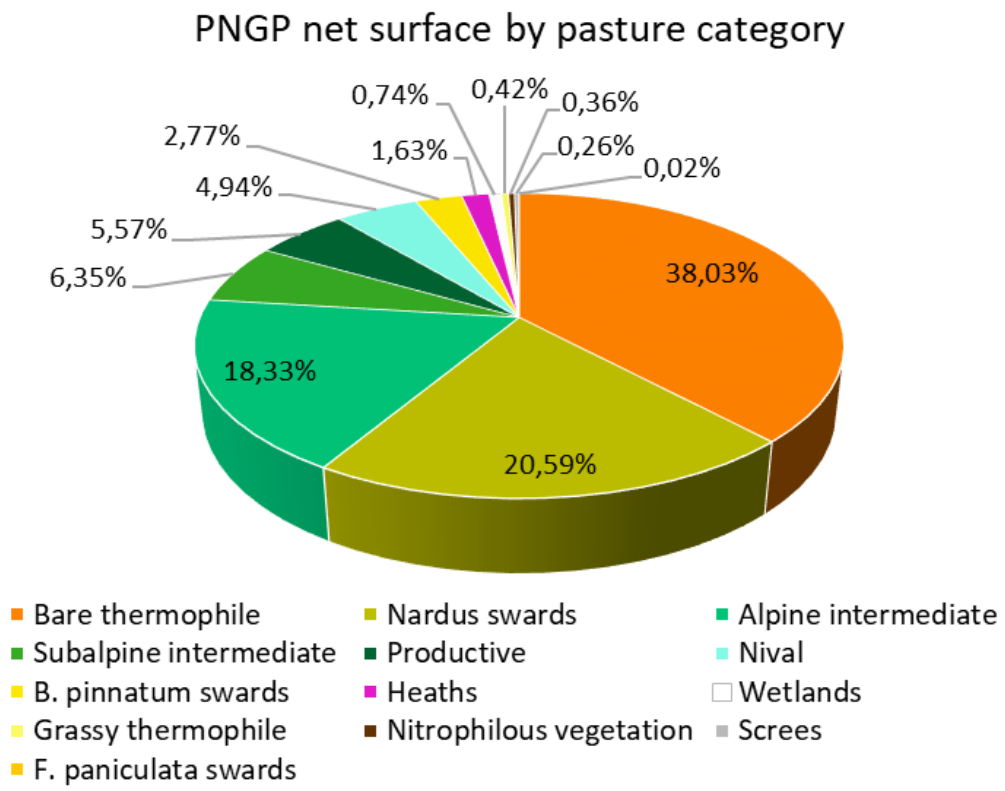


Figure 4. PNGP pastures net surface divided by pasture category.

The three prevalent categories make up about 3/4 of the total net area of the Park grasslands: bare thermophile (38%), *Nardus stricta* (21%) and alpine intermediate swards (18%).
They are followed by four categories with a much lower incidence: subalpine intermediate (6%), productive (6%), nival (5%) and *Brachypodium pinnatum* swards (3%).
Altogether, the remaining 6 categories occupy less than 4% of the Park pastures.

Finally, an analysis was carried out to detect the main differences in vegetation between the two regions of PNGP: Aosta Valley and Piedmont.
The table in *Annex 24* shows the net areas for each main type and category in the two regions. In *Annex 25*, altitude data (minimum, average, maximum) are presented for each type and category both in Aosta Valley and Piedmont.
The area investigated in Piedmont is only slightly larger than in Valle d'Aosta: 2478.25 ha (54%) and 2117.68 ha (46%), respectively.
Most of the productive swards, represented by the categories 'Productive' and 'Subalpine intermediate', were found in Piedmont (401 ha). This is linked to the altitude of the surveys carried out, as can be seen in *Annex 25*: in Piedmont, territories at quite low altitudes (1000-1100 m a.s.l.) are managed as summer pastures whereas in Aosta Valley the “alpeggi” summer pastures are normally at higher altitudes (> 1500 m a.s.l.), in conditions that are less favourable for very productive types. *Brachypodium pinnatum* swards and bare thermophile grasslands are also more common in Piedmont, where we found 89% and 69% of these two categories, respectively. In contrast, intermediate alpine types are much more widespread in Aosta Valley (81% of the category).
The other types are rather evenly represented in the two regions. *Festuca paniculata* swards are very unfrequent in the Park, covering less than 1 ha in Aosta Valley and being completely absent in Piedmont.

3) REMOTE SENSING AND DEVELOPMENT OF MODELLING APPROACHES

To understand and detect future land cover changes, it is essential to develop innovative modelling approaches to map mountain pastoral vegetation along complex environmental gradients. The newly available high-resolution remote sensing products offers promising avenues if we are able to better characterize the spectral signature of each main vegetation type. In this chapter, we provide two complementary approaches to model the distribution of mountain pastures using a combination of field data, remote sensing and classification algorithms.

The first part introduces the usefulness of Sentinel-2 images combined with bioclimatic and topographic indicators to map the mountain pastoral types. Using a simple decision tree, we produced predictive distribution maps of the vegetation types for the PNE. The classification accounts for the complex gradients of snow cover duration and of primary productivity, which are captured at an ecologically relevant scale by several sprectral indices.

The second part goes a step beyond by implementing a more sophisticated random forest classifier. The model was calibrated for the PNGP because it is only there that we had sufficient ground data to do it. A first attempt is made to assess the performance of the model for PNE.

All the produced maps have proved useful for experts in pastoral management as they provide a rapid assessment of favorable and unfavorable areas of grazing at multiple scales and a guide for field surveys. The work illustrates the usefulness of including high-resolution remote sensing data and field surveys to improve the performance of predictive distribution models of grasslands in complex mountain terrains.

3.1 Modelling the distribution of pasture types using random forest models

The pasture cartography was fundamental to the development of an automated method for detecting and mapping the main pasture types by the integration of satellite data.
In summary, a supervised classification method was developed, based on random forests, which deploied the field surveys as ground truth and several satellite-derived products as predictors, in order to model pasture distribution at the scale of the Gran Paradiso National Park.
To this end, the work was articulated in the following steps:
i) define a common methodology for classification and harmonisation of the macro-type classification of pastures across the two parks;
ii) choose representative pasture types used to train the random forest classifier;
iii) implement the random forest models;
iv) evaluate model performance, refine the classification algorithms and choose the best classification tools;
v) establish test sites where automated classification and ground truth were compared in detail.

Starting from the common legend between the two Parks, the 13 pasture categories have been aggregated into 3 classes according to their productivity (i.e. low, medium and high productive pastures). To this end, several on-line technical meetings were organized between pasture experts (PNE, CNRS, IAR) and modellers (UNIFI, INRAE and ARPA VDA) establishing a common approach to provide information on main characteristics of each pasture type.
For each type belonging to the two pasture typologies used in Aosta Valley (Bornard et al., 2007) and French Southern Alps (Jouglet, 1999) a productivity band was assigned. On the basis of biomass production

and harmonising the different typologies of the two Parks, the pasture types were grouped into three macro-categories.

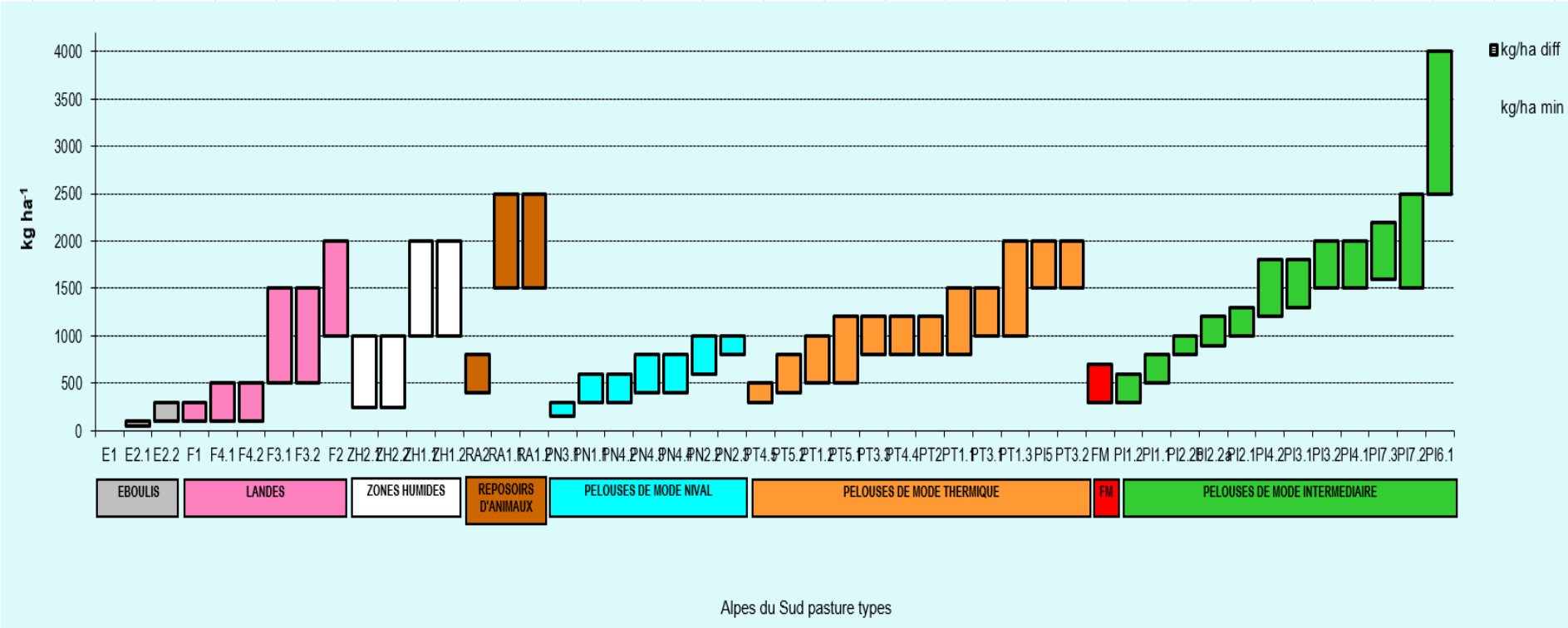


Figure 5. Biomass production of French southern Alps pasture types, according to Jouglet, 1999.

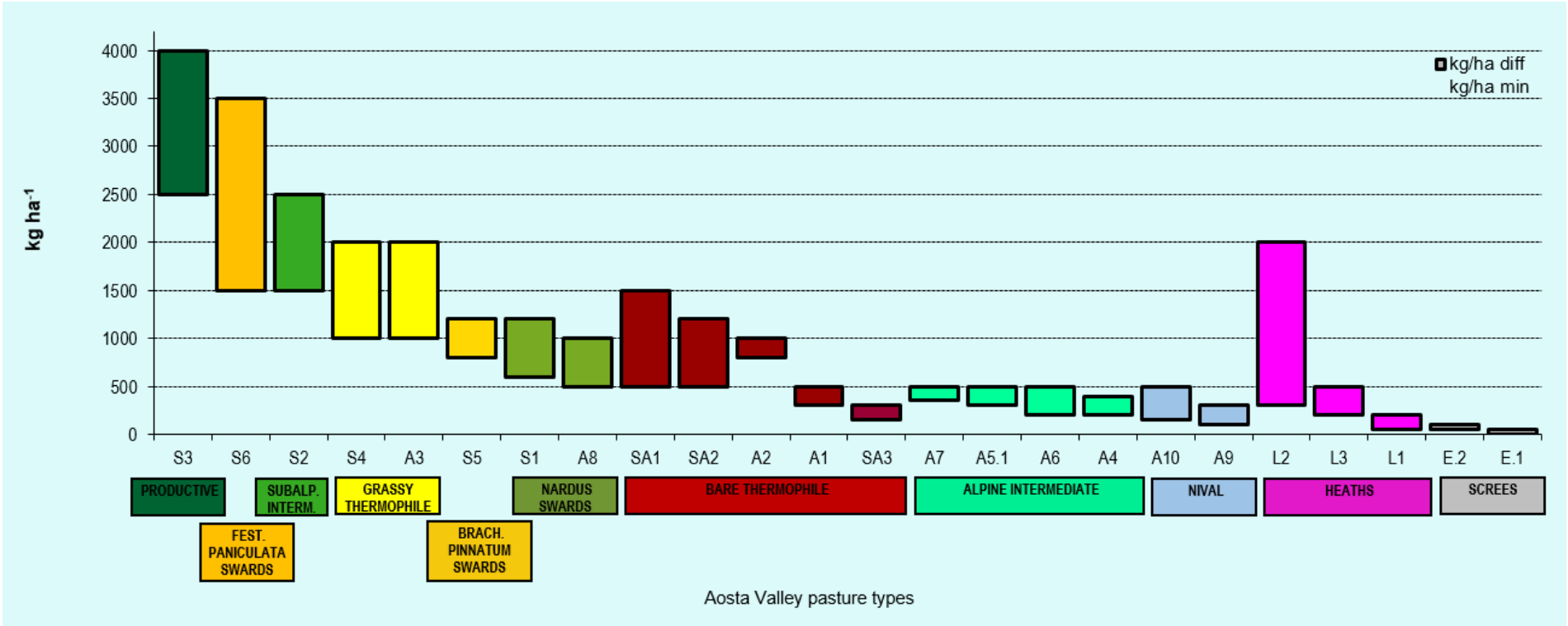


Figure 6. Biomass production of Aosta Valley pasture types, according to Bornard et al., 2007.

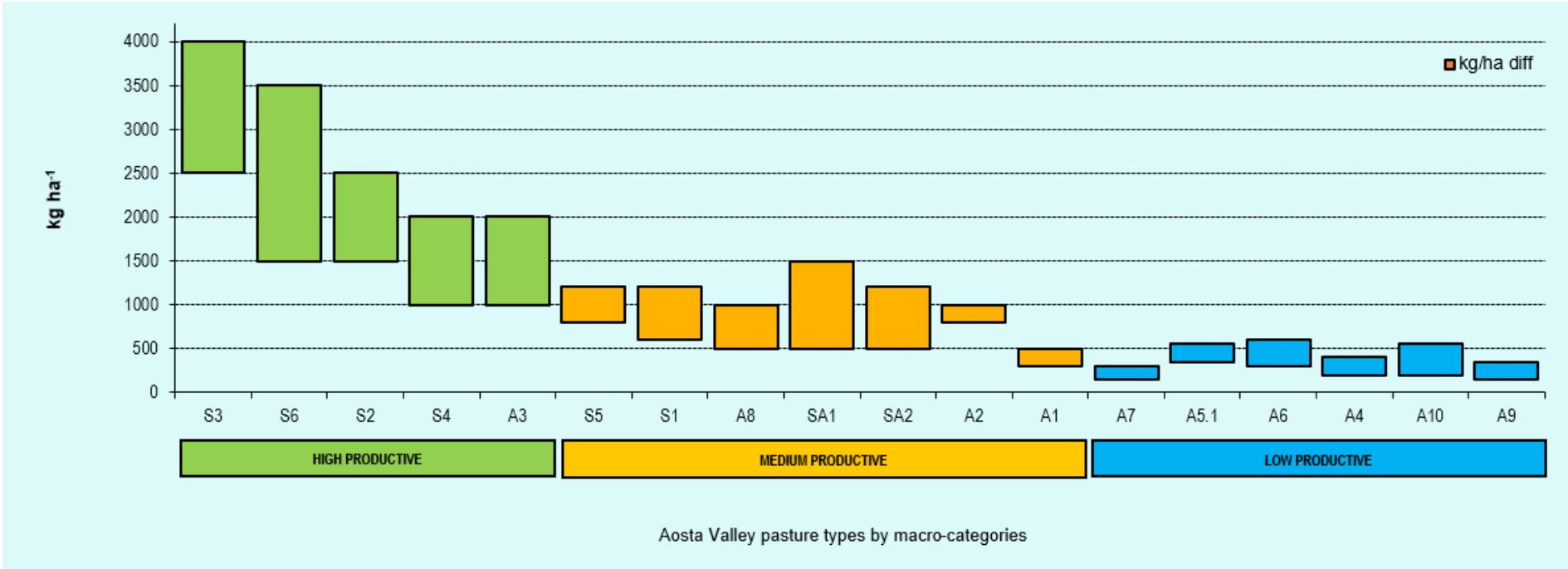


Figure 7. Aggregation of the Aosta Valley types in 3 macro-categories.

Pasture macro-category	PNGP		PNE	
	Pasture category	kg/ha min-max	Pasture category	kg/ha min-max
High productive	*F. paniculata* swards	1000-4000	Pelouses de mode intermédiaire	300-4000
	Grassy thermophile			
	Productive			
	Subalpine intermediate			
Medium productive	Bare thermophile	300-1500	Pelouses de mode thermique	300-2000
	B. pinnatum swards			
	Nardus swards			
Low productive	Alpine intermediate	100-500	Pelouses de mode nival	150-1000
	Nival			

Table 12. Aggregation of the pasture categories used in PNGP and PNE into 3 productive macro-categories.

The researchers of the two parks jointly selected for each macro-category and each Park, two pasture types, which could be representative of the territories and adequately widespread.

Representative pasture types	PNGP		PNE	
Macro-category	Aosta Valley type	Corresponding PASTORALP common classification	PNE type	Corresponding PASTORALP common classification
High productive	S3	Productive	5	*F. paniculata* swards
	S2	Subalpine intermediate	9	Grassy thermophile
Medium productive	A8	*Nardus* swards	2	Subalpine intermediate
	A2	Bare thermophile	8	Bare thermophile
Low productive	A5	Alpine intermediate	1	Nival
	A6	Alpine intermediate	4	*Nardus* swards

Table 13. Representative pasture types for each macro-category.

These representative pasture types were used to train the multivariate classifier.

Modelling pasture distribution in PNGP

After a preliminary exploratory analysis, Random Forest was chosen as the best model and it was used to classify the surface of PNGP according to three different and subsequent levels of complexity:

1) define the presence or absence of grasslands;
2) classify pastures according to productivity classes (3 levels);
3) classify pastures categories (13 levels).

The three approaches had in input the same number and type of predictors. All predictors consist of gridded data at 20x20 m spatial resolution. They can be roughly ascribed to three categories:

1) predictors describing the thermal regime;
2) physiographic predictors;
3) productivity/phenology predictors.

- Thermal Regime

Accurate description of thermal properties of a given landscape is pivotal to understand the type of vegetation that can potentially characterize a given surface. A spatially explicit layer was computed, that integrates the snow cover regime and the thermal regime. The average day of snowmelt was computed based on a Sentinel2-derived snow presence/absence dataset (Theia Snow Collection, available at https://labo.obs-mip.fr/multitemp/sentinel-2/snow/#en) based on the following definition: "the first snow-free day corresponds to the day when the longest snow-covered period of the year ends". Hence, ephemeral snow falls are excluded from this computation. The first snow free day (FSFD) is used as a predictor *per se* and in conjunction with air temperature for the (pixel-wise) computation of a thermal sum. The concept of thermal sum as a trigger of vegetation development is well established in the scientific literature. In alpine pastures, however, the role of temperature is strongly mediated by the seasonal dynamics of the snow pack. The presence of a snow pack in fact, determines the decoupling between thermal forcing (represented by air temperature) and the thermal conditions experienced by plant tissues. For this reason, in snow covered systems, thermal sums must be computed taking into account the presence/absence of the snow pack. Thermal sum (growing-degree-days, GDD) were therefore computed starting from the snow melt day. Temperature layers used in this task are an operational daily product with 100 m spatial resolution.
The Diurnal anisotropic heating index (DAH[1]) was used as an enhanced topographical index that, by combining slope and aspect, describes the propension to warming of a pixel.

- Physiography

Two Sentinel2-derived vegetation indexes were used. The first one, the normalized difference vegetation index (NDVI) is widely used in multi-temporal analysis to depict the seasonal dynamics of vegetation but also as a static physiographic layer, for example, by computing a yearly maximum composite. In this work, a seasonal maximum composite was computed for three years (2017-2019) and then averaged. The second index used was the normalized anthocyanin reflectance index[2] (NARI), which is specifically designed for the detection of anthocyanins–rich plant tissues and thereby discriminate between shrubs (in autumn) and grasslands. An autumn cloud-free image (sampled between 1st and 15th of October) was chosen for each year and then averaged.
To discriminate between forested and non-forested areas, a further physiographic predictor was used, the tree cover density (TCD, year 2015). This is a freely available product from the EEA Copernicus Land Monitoring Service (CLMS, https://land.copernicus.eu) featuring a 10 m resolution map of tree cover density (0-100%). For this study, TCD was used as a binary presence/absence mask (>1% TCD = forest).

[1] Bohner, J., and O. Antonic, 2009. Land-surface parameters specific to topo-climatology. Dev. Soil Sci.,33, 195–226.
[2] Bayle, A.; Carlson, B.Z.; Thierion, V.; Isenmann, M.; Choler, P., 2019. Improved Mapping of Mountain Shrublands Using the Sentinel-2 Red-Edge Band. Remote Sens. 11, 2807. https://doi.org/10.3390/rs11232807

- Productivity/phenology

Productivity/phenology was accounted for by means of a NDVI-derived metrics, the area under the curve (AUC). For each pixel, the integral of the seasonal NDVI curve was computed for the three examined years, and then averaged. Compared to the simple NDVI max, this metrics also accounts for the timing of biomass production (the phenology of productivity) and is less affected by the well known issue of NDVI saturation at high biomass.

An additional set of layers was used based on the time-weighted dynamic time warping method[3]. This method is conceived for the analysis of irregularly sampled time series and/or out of phase time series, and recently implemented for the analysis of satellite–derived image archives, with classification objectives. This method requires the identification of a typical yearly time series of vegetation index (or band reflectances, or both) which serves as a template. Against this template, a multidimensional dissimilarity is computed for each pixel in the spatial domain, resulting in a dissimilarity map. Templates were identified for five key physiographic features in the PNGP: full canopy forests, sparse forests, highly productive pastures, medium productive pastures, low productive pastures. Each template resulted therefore in a dissimilarity map that was in turn used as a predictor.

Step 1: Pasture presence/absence map

A first important step for the construction of pasture productivity maps is a detailed delimitation of pasture area. From a remote sensing perspective, this exercise does not necessarily imply the discrimination between actually grazed surfaces and grasslands/prairies subjected to low or null stocking rate.

The ground truth used for training the random forest models was derived from Carta Della Natura (CDN), a national-wide initiative of habitat mapping that took place in 2006. Accordingly, vegetation types were mapped by photo-interpretation of aerial photographs collected in the years 2005 and 2006. Vegetation mapping was performed according to the habitats defined in Annex I of the Habitats Directive and described in detail in two dedicated publications[4]. The final product, digitized in the form of polygons at a scale ranging between 1:5000 and 1:10000, was then rasterized at 20 m to match the spatial resolution of the satellite products. CDN featured 56 habitats that were further simplified into 6 classes reported in the following table.

Class name	Class acronym	Description
Areas of recent colonization	ARC	Recently deglacized/colonized areas covered by sparse vegetation but not bare soil (max NDVI >0.25)
Deciduous forest	DF	Deciduous broadleave forest and deciduous evergreen forest (Larch)
Evergreen Forest	EF	Needleleave forests (mainly *Picea abies*, *Pinus sylvestris*, *Pinus uncinata*)
Grassland	GRA	Pastures and meadows
Shrublands	SHB	Short vegetation such as *Rhododendron*, *Vaccinium*, *Juniperus*
No vegetation	NOVEG	Cities, villages, roads and bare ground/rocks (max NDVI <0.25)

Table 14. Carta della Natura 6 main classes.

[3] Maus V, Câmara G, Appel M, Pebesma E, 2019. dtwSat: Time-Weighted Dynamic Time Warping for Satellite Image Time Series Analysis in R. Journal of Statistical Software, 88(5), 1–31. doi: 10.18637/jss.v088.i05

[4] See "Evans, D., 2006. The Habitats of the European Union Habitats Directive. Biol. Environ. Proc. R. Irish Acad., 106, 167–173" and "Commission DG Environment, 2007. The Interpretation Manual of European Union Habitats—EUR27. Eur. Comm. DG Environ. Nat. Biodivers, 27, 368".

Half of the pixels were randomly selected, which were assigned both a ground truth belonging to one of the 6 above described classes and a value for each of the predictors. This data set was used to train the random forests. The remaining 50% pixels were used for validation.

Random forest models were fitted in R with the caret package[5] and parameters were tuned. The final model parameter *mtry* was set at 4 and out-of-the bag (OOB-CV) cross-validation was repeated 10 times.

Because the objective of this part of the work was a pasture/no pasture mask, the 6-class-outcome of the random forest model was *a posteriori* simplified into a binary outcome where 1 is assigned to grasslands and ARC (being interpreted as herbaceous surfaces), whereas 0 is assigned to the rest.

Classification scores evaluated on this simplified outcome against the remaining 50% pixels, used for validation, were remarkably high, with 88% accuracy and a kappa of 0.76. Random forest results were then used in prediction over the entire Park to produce a pasture/no pasture mask. This mask was then post-processed by applying a threshold of NDVI <0.25. To remove single and sparse groups of misclassified pixels, an area of 5000 m^2 was considered as the smallest detectable surface and pixel clumps smaller than that threshold were masked out. Results are shown in *Figure 8*. The map was used to mask the results of the subsequent steps of the analysis.

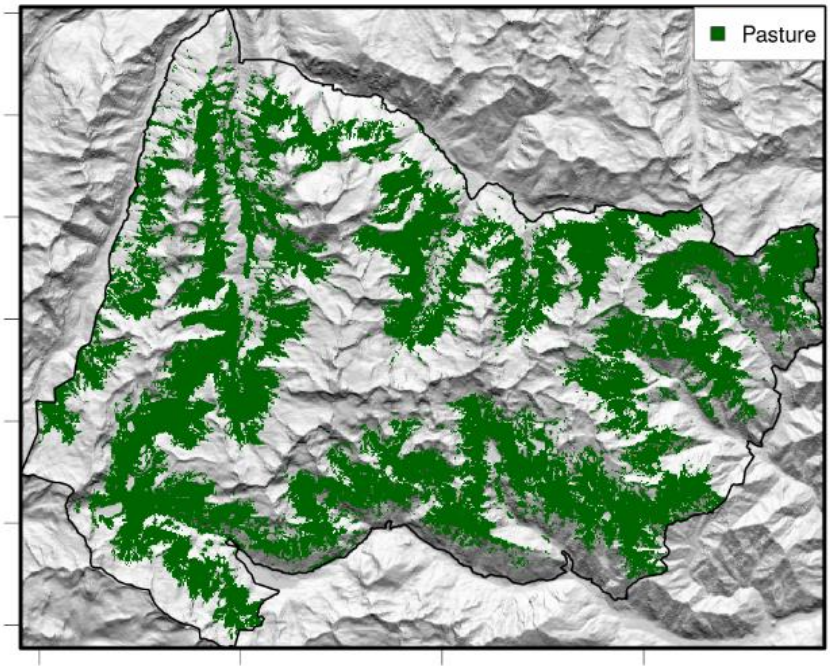


Figure 8. Modelled distribution of the herbaceous surfaces of PNGP at 20 m spatial resolution, as obtained by random forests.

Step 2: Classification of pastures according to 3 productivity macro-categories

The objective of this step was to model pasture resources of the PNGP according to three levels of productivity, or macro-classes (see *Table 12*). RF models were trained by exploiting field survey results. In particular, shapefiles of the pasture units were first simplified into the macro-categories and then rasterized to match the spatial resolution of the satellite products (*Figure 9*).

The accuracy, extent and degree of detail of the field surveys were highly beneficial for model training and allowed the performance of multiple calibration exercises (*Table 15*). First, thanks to the extension of the surfaces surveyed, it was possible to consider, for calibration, only the polygons featuring a single pasture

[5] Max Kuhn, 2020. caret: Classification and Regression Training. R package version 6.0-86. https://CRAN.R-project.org/package=caret

type (called “pure pastures”). Within this group, it was possible to further distinguish between surfaces fully covered by grass or with some extent of tare (surfaces other than grasses, most often bare ground, rocks or shrubs). Clearly, training with tare-free surfaces implies a reduced number of points available for the training. An analysis was run to determine the trade-off between purity and extension of the surfaces in terms of classification accuracy. The results are summarized in *Table 15*.

Experiment	% of tare (surfaces other than grass)	Surface available for model training (ha)	Classification accuracy (%)
Exp 1	0	1006	90%
Exp 2	<50%	2147	88%
Exp 3	Any tare allowed	3933	87%

Table 15. Characteristics and performance of the three experimental set up for random forest calibration.

Exp 1 shows slightly better performance compared to the others, even though for this experiment only 1000 ha surfaces were available for training (a quarter of the number of samples available for Experiment 3). This demonstrates that the reduction of samples was not detrimental for model accuracy. It was therefore decided that the setup of Experiment 1 was the best choice.
The best model (accuracy 90%, kappa 0.84) was used to predict pasture productivity at the scale of the whole park (*Figure 9*).

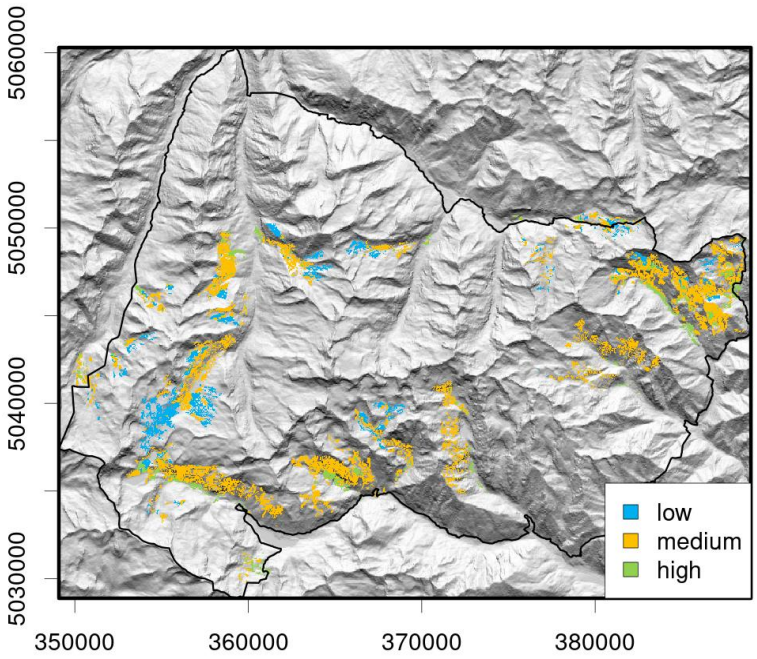


Figure 9. Observed distribution of pasture types, classified in productivity classes according to the criterion reported in *Table 12*. These polygons served as ground truth for the random forest calibration.

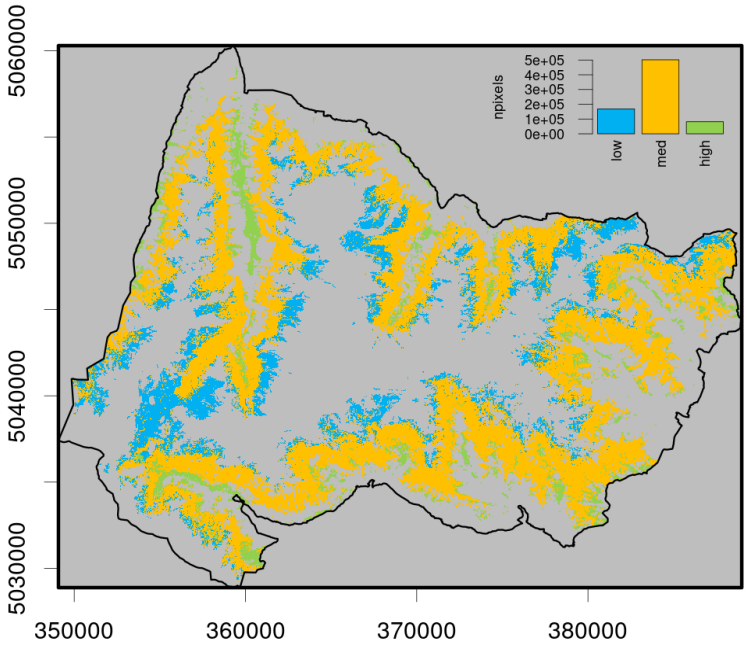


Figure 10. Modelled distribution of pastures classified according to three productivity classes, as obtained by random forest models. Predicted productivity map was masked with the pasture distribution map shown in *Figure 8*.

Step 3: Classification of pastures according to 13 categories

The same procedure was applied to the thirteen categories shown in *Table 1.*

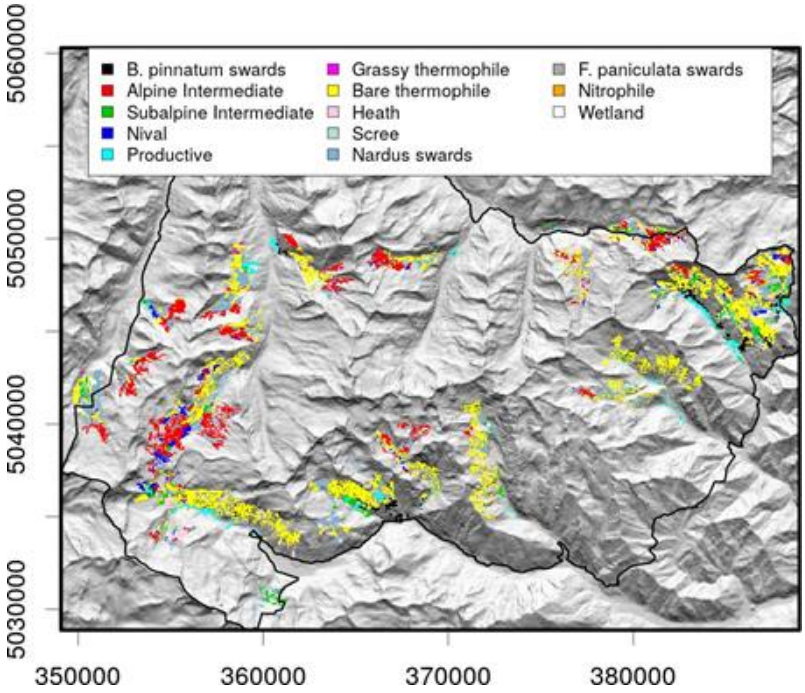


Figure 11. Observed distribution of pasture types, classified in 13 categories reported in *Table 1*. These polygons served as ground truth for the random forest calibration.

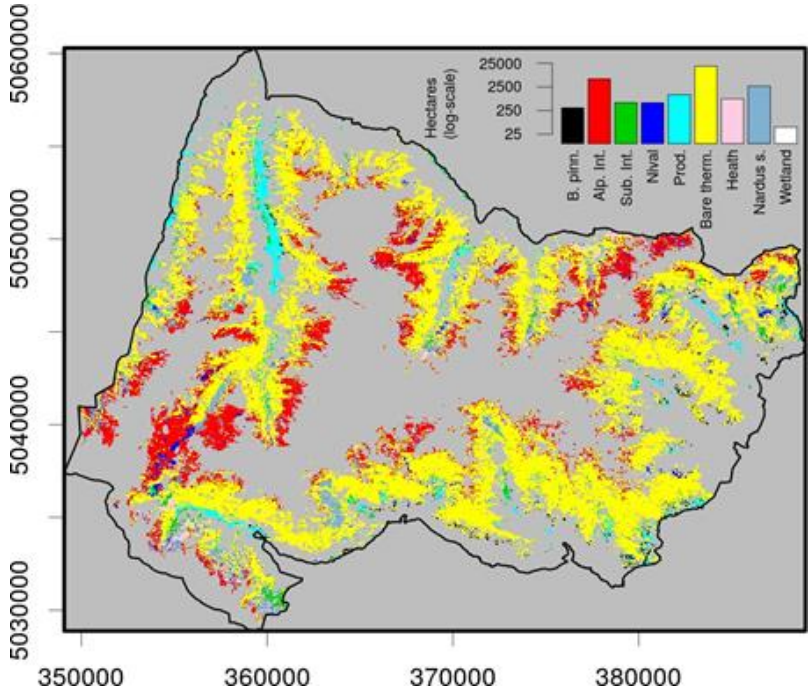


Figure 12. Modelled distribution of pastures classified according to the 13 categories, as obtained by random forest models. Predicted pasture map was masked with the pasture distribution map shown in *Figure 8*.

Compared to step 2, classification accuracy was, as expected, slightly lower, but yet very high, with accuracy = 0.83, kappa = 0.78. The classification performance can be here observed in more detail in terms of type I and II error, or better their complementary values, sensitivity and specificity, respectively. *Table 16* provides a synthesis. These scores can be used to evaluate the reliability in the modelization of single pasture categories.

	Sensitivity	Specificity
B. pinnatum swards	0.75	0.99
Alpine intermediate	0.87	0.96
Subalpine intermediate	0.67	0.98
Nival	0.65	0.98
Productive	0.93	0.98
Bare thermophile	0.89	0.94
Heath	0.65	1.00
Nardus swards	0.82	0.94
Wetlands	0.27	1.00

Table 16. Sensitivity and specificity of classification for main pasture categories.

The use of remotely sensed data coupled with detailed field observations has shown very good performance in the classification of pasture productivity. The same approach looks very promising to modelling the distribution of pasture categories, even though it is clear that the results must be interpeted with caution. Traditionally, satellite observations have proven succesful in the discrimination between markedly different land uses such as different crops, or grasslands *vs* forests, etc. To our knowledge, no remote-sensing based classification has been pushed toward the discrimination of subtle differences such as those occuring between different pasture types. However, here, the tight coupling between remote sensing, phisiographic information, ecological and climatic layers and a field work tailored to the objectives likely helped in reaching high classification performances.

In order to get an indication of the sensitivity of NDVI to different pasture categories over the whole Park, we extracted average trajectories of S2-derived NDVI across markedly distinct pasture categories (*Figure 9*). This plot illustrates the wide range of productivity (max NDVI between 0.4 and 0.7) and the large differences in seasonal amplitude of NDVI curves. For example, low-altitude productive pastures display maximum NDVI at peak similar to subalpine intermediate, which shows that max NDVI may not be the ideal parameter for their discrimination. In contrast, the much larger trajectory, as a consequence of earlier spring development, clearly distinguishes between the two rather similar pasture types. In the following figures, more small-scale examples illustrate the good agreement between automated classification and field surveys.

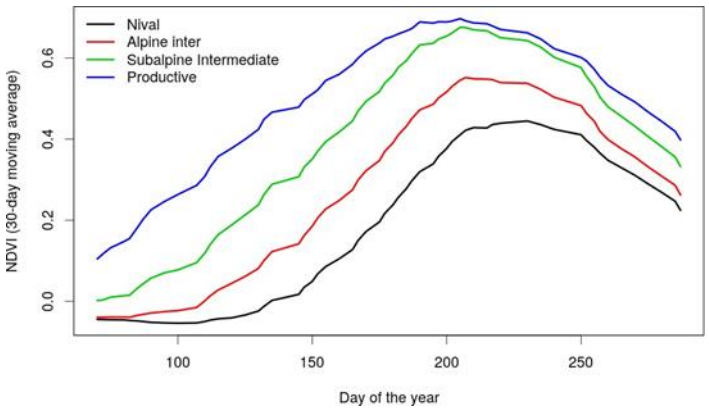


Figure 13. Average seasonal NDVI trajectories for selected pasture categories.

Example of classification in the mountain pasture of Djouan-Orvieilles (Valsavarenche, AO)

In order to show the outcome of the unsupervised classification on an area surveyed by pasture experts, the Pasture district of Djouan-Orvielles was taken as the study area.

1) Defining the presence or absence of grasslands

The identification of the pastures in the prediction map gave very good results: comparing it with the verification on the ground, it is observed that they match very well. The lower area of Djouan-Orvielles is heavily forested, which the model distinguishes very well. At higher altitudes, the classification went further up, where the pasture experts stopped because of the dangerous nature of the sites (rock jumps, steep slopes that do not allow grazing by domestic herbivores).

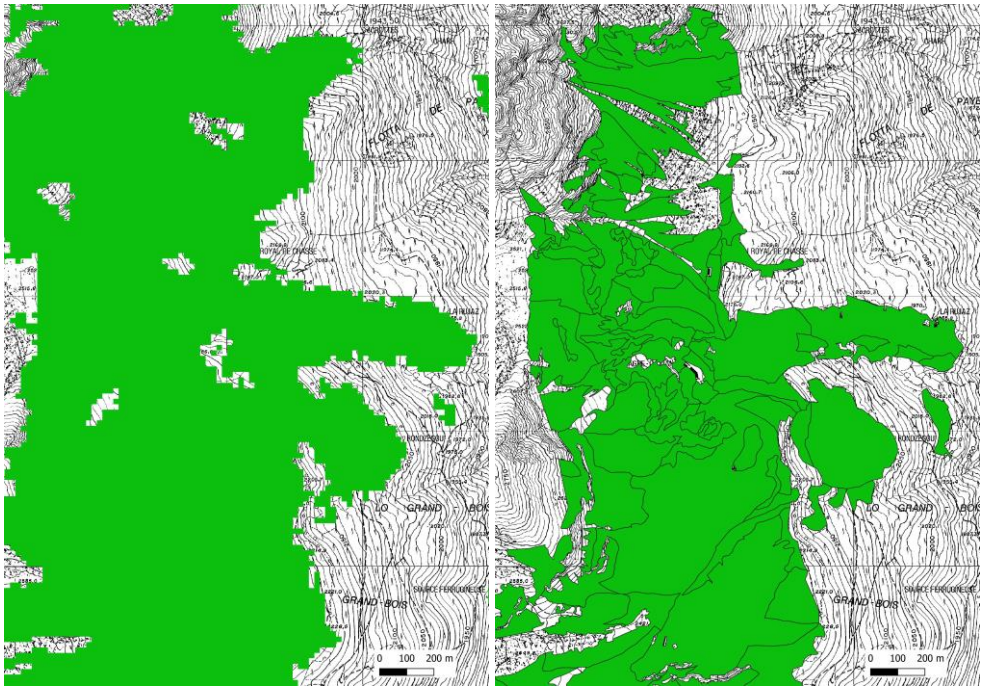


Figure 14. Comparison between the prediction map on the left and the ground truth on the right.

2) Classification of pastures according to 3 productivity macro-categories

When comparing the two maps, one can immediately see that the restitution of the classification is much more detailed. In fact, the pasture experts only reported on maps areas that were larger than 500 m^2. This is why the remote sensing classification is even more precise. This is particularly noticeable in the small "low productive" areas.

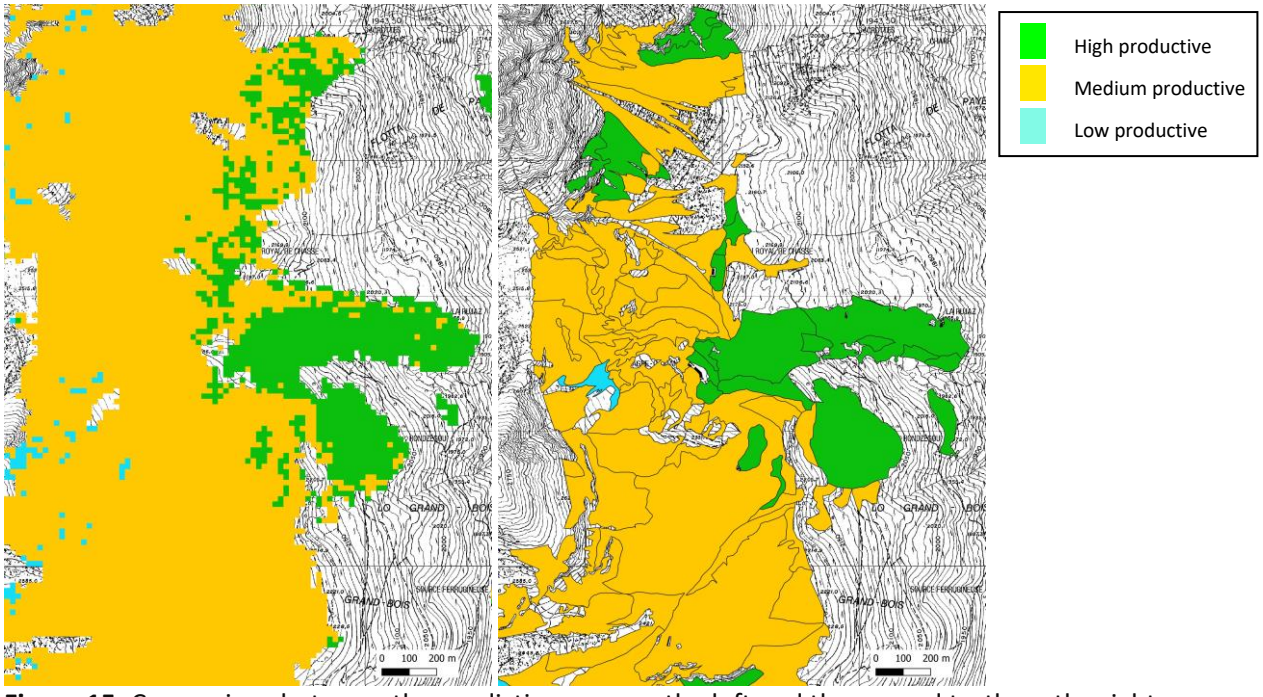


Figure 15. Comparison between the prediction map on the left and the ground truth on the right.

3) Classification of pastures according to 13 categories

The more complex test, with the recognition of the 13 pasture categories gave very good results, as well. In an area such as Djouan, where the grasslands are very heterogeneous, it can be observed that remote sensing is able to perceive and recognise each category even more accurately than field surveying.

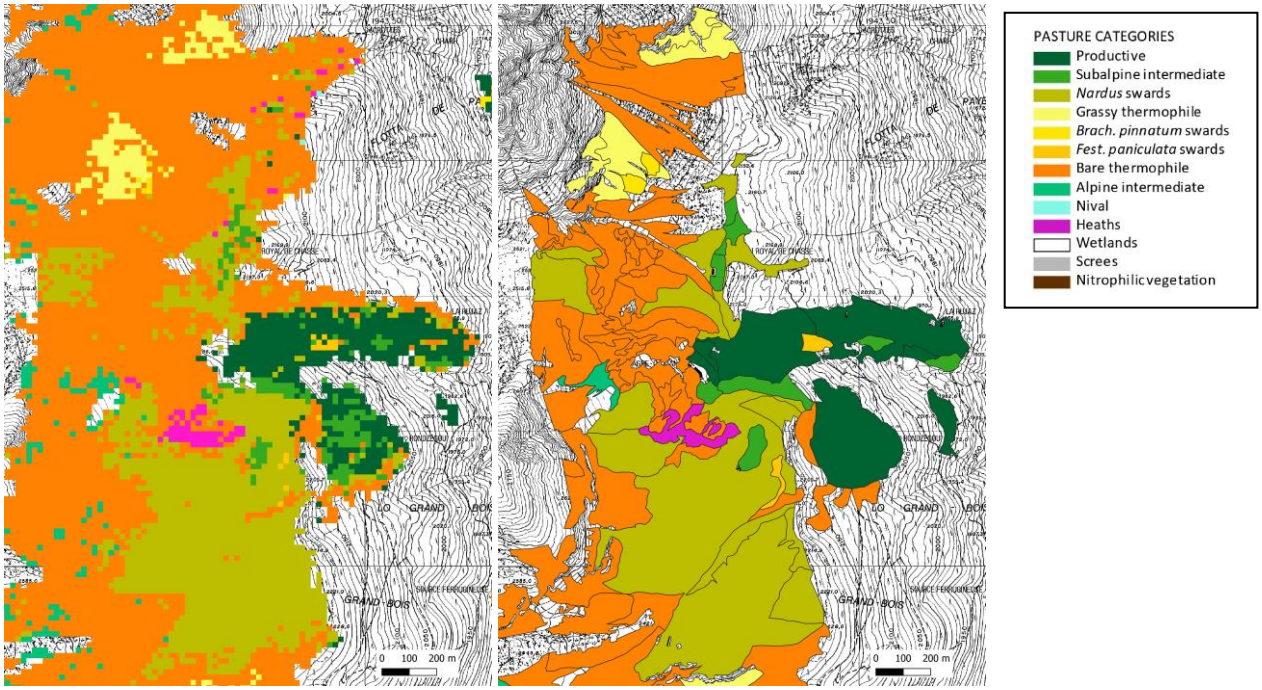


Figure 16. Comparison between the prediction map on the left and the ground truth on the right.

Application of Random Forest models in pure prediction: the example of PNE

Random forest models trained at the PNGP were used to model pasture presence/absence and distribution in selected areas in PNE. The objective of this application was to apply fitted random forest models on a truly independent dataset.

PNE inventory of pasture resources is focused on specific well know and monitored areas, the so called *Alpages Sentinelles*. In these areas, we will therefore focus our examination of RF models. We chose 4 of such sites, each covering an area between 500 and 1000 ha, where pasture units were delimited and classified according to the three-level productivity classes illustrated in *Table 12*. These ground truth polygons were compared to the automated classification with the same procedure adopted in PNGP. A visual synthesis is provided in *Figure 17*, where the ground truth mapping is shown (top row) together with prediction maps (bottom row) for each of the four districts.

A first accuracy assessment can be performed on the ability of the RF classificator to discriminate beween herbaceous and non herbaceous surfaces (pasture/no pasture in *Figure 8*). This comparison reveals fairly good results, with accuracies ranging between 71 and 75%. This is promising because it suggests that the random forest models trained in a very different area are applicable in a pure prediction exercise with acceptable results. The training of the RF models with site-specific ground truth would likely lead in even better results.

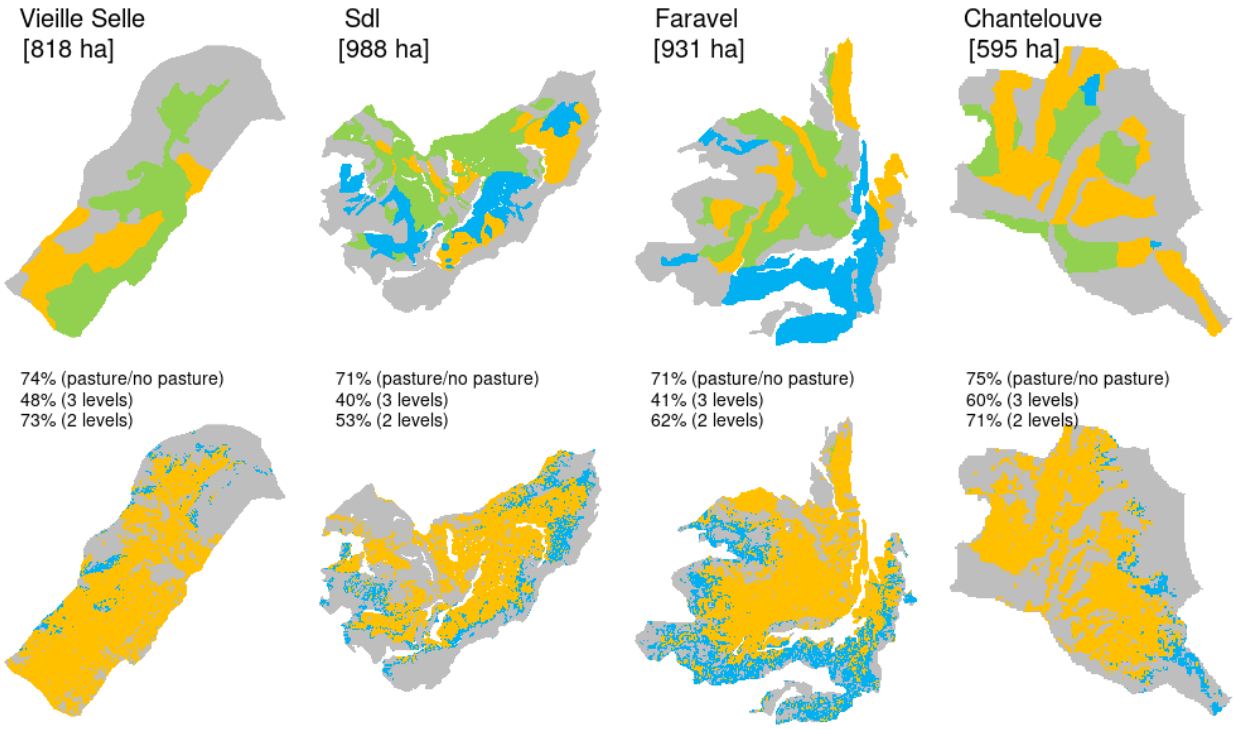


Figure 17. Comparison between observed (top row) and modelled (bottom row) productivity across 4 selected areas (Alpages Sentinelles) in Ecrins National Park. Locations and total surface of the districts are annotated in the first row, whereas in the bottom row are annotated classification accuracies. See the text for details.

The 3-levels accuracies inform about the ability of the classification in the discrimination of the three productivity classes. Scores range between 40 and 60%, revealing a poor performance. This is due to the fact that the automated classification identifies very few areas of high productivity whereas many areas are classified as highly productive in the field. If we consider a two-level classification (low and medium/high productivities) the accuracies become sensibly higher, ranging between 53 and 73%.
We conclude that the RF models trained in PNGP can be applied blindly in certain PNE districts with good results for the identification of herbaceous and non-herbaceous surfaces. Fairly good results are also obtained in the discrimination of low and medium productivity surfaces. The discrimination of high productive surfaces requires likely detailed *in situ* calibration of the RF models.

3.2 Predicting the distribution of pasture types in PNE using a simple decision tree

The LIFE project Pastoralp has put emphasis on the need to develop vegetation survey methodologies that would allow the comparative assessments of pastoral vegetation across mountain regions. The elaboration of a simplified typology for pastoral vegetation and the design of methods to map pastoral vegetation types are the key objectives of action C2. A particular challenge was to reduce the disconnect between detailed ecological studies using complex vegetation typologies and the requirements of experts in pastoralism that need rapid assessment of land suitability for grazing based on broad functional classifications of vegetation. Of paramount importance for pastoral diagnostic are the primary productivity of mountain vegetation and the seasonal phenology of the ecosystem. The first has a direct relation to the amount of forage resource and the second determines the favorable period for grazing.
Over the last years, there has been an increasing number of studies attempting to monitor high mountain vegetation using high resolution satellite imagery (Carlson et al. 2017, Anderson et al. 2020, Xie et al. 2020). This work is notoriously difficult in high elevation complex terrains where fine-scale variations in land cover

types predominate (Dedieu et al. 2016). However, the newly available high-resolution Sentinel-2 imagery has opened new perspectives for the automatic mapping of mountain vegetation. Specifically, the five day revisit time of Sentinel-2, its high spatial resolution (10–20m) and its thirteen spectral bands ranging from visible to short-wave red provide novel opportunities for modelling the distribution of mountain vegetation types.

The Parc National des Ecrins has a long tradition and a solid expertise in the monitoring of pastoral vegetation (Bonet et al. 2016). The land cover of several pastoral units is well documented as part of the so-called "pasture diagnostics" whereby several characteristics are analyzed including vegetation physiognomy, management practices, and external constraints (Dobremez et al. 2014). We built on this knowledge to examine the usefulness of high-resolution remote sensing to inform on the distribution of vegetation types that are relevant for pasture diagnostic. Based on previous studies (Choler 2005, 2015, 2018), we put emphasis on three key indicators for mountain vegetation; (i) the snow cover duration that determines the length of the favorable period for growth, (ii) the maximum value of a vegetation indice used as a proxy of plant primary productivity and (iii) the Growing Degree Day, a thermal indicator that captures the effect of topography. Our aim was to provide high-resolution mapping of these indicators and to test their usefulness in classifying pasture types.

Methods

We assembled data from Sentinel-2 imagery, the SAFRAN-CROCUS (S2M) regional climate re-analyses and the topography. The test cases were the three PNE pastoral units (re)-surveyed in 2018 (Chantelouve, Faravel and Saut-Du-Laire) and the three units (re)-surveyed in 2019 (Lanchatra, Tramouillon and La Veille Selle) in the framework of the Pastoralp project (action C6) (*Figure 18*).

Predictive maps were also produced for the other pastoral units of the PNE (see *Annex n.26*).

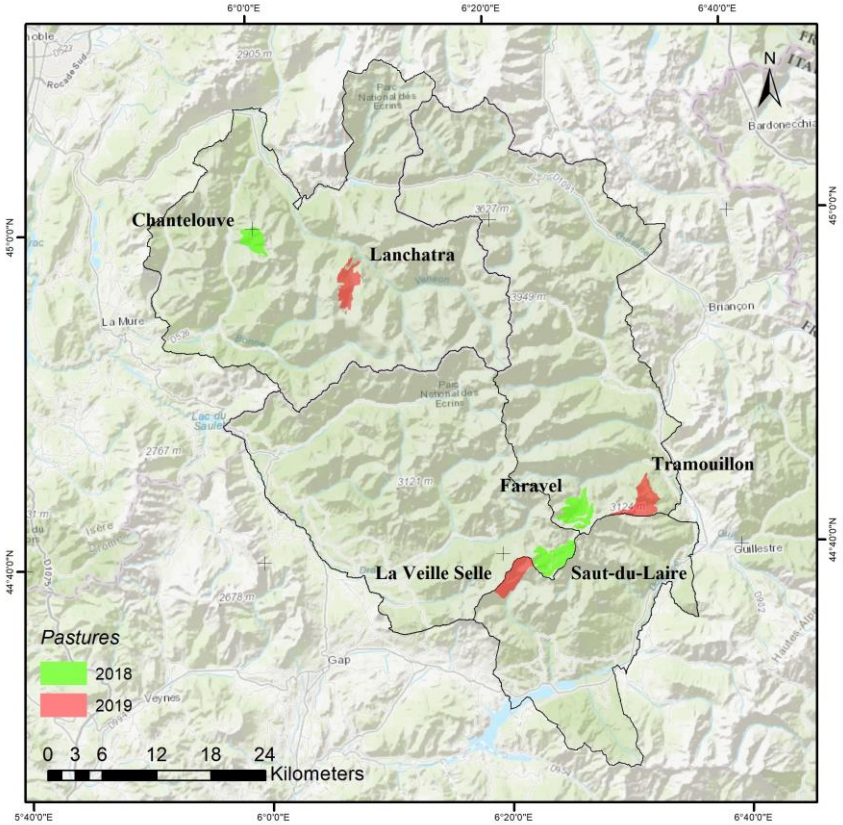


Figure 18. Location of the pastoral units surveyed in 2018 (green) and in 2019 (red).

A common typology of mountain pastures has been agreed upon in the framework of Pastoralp. Examples of maps resulting from fieldwork in three pastoral units of the PNE are shown in *Figure 19*. The maps

exhibit broadly defined polygons as a result of the rapid assessment of the vegetation physiognomy and the dominant species. Noticeably, we had no available field data at the pixel scale.

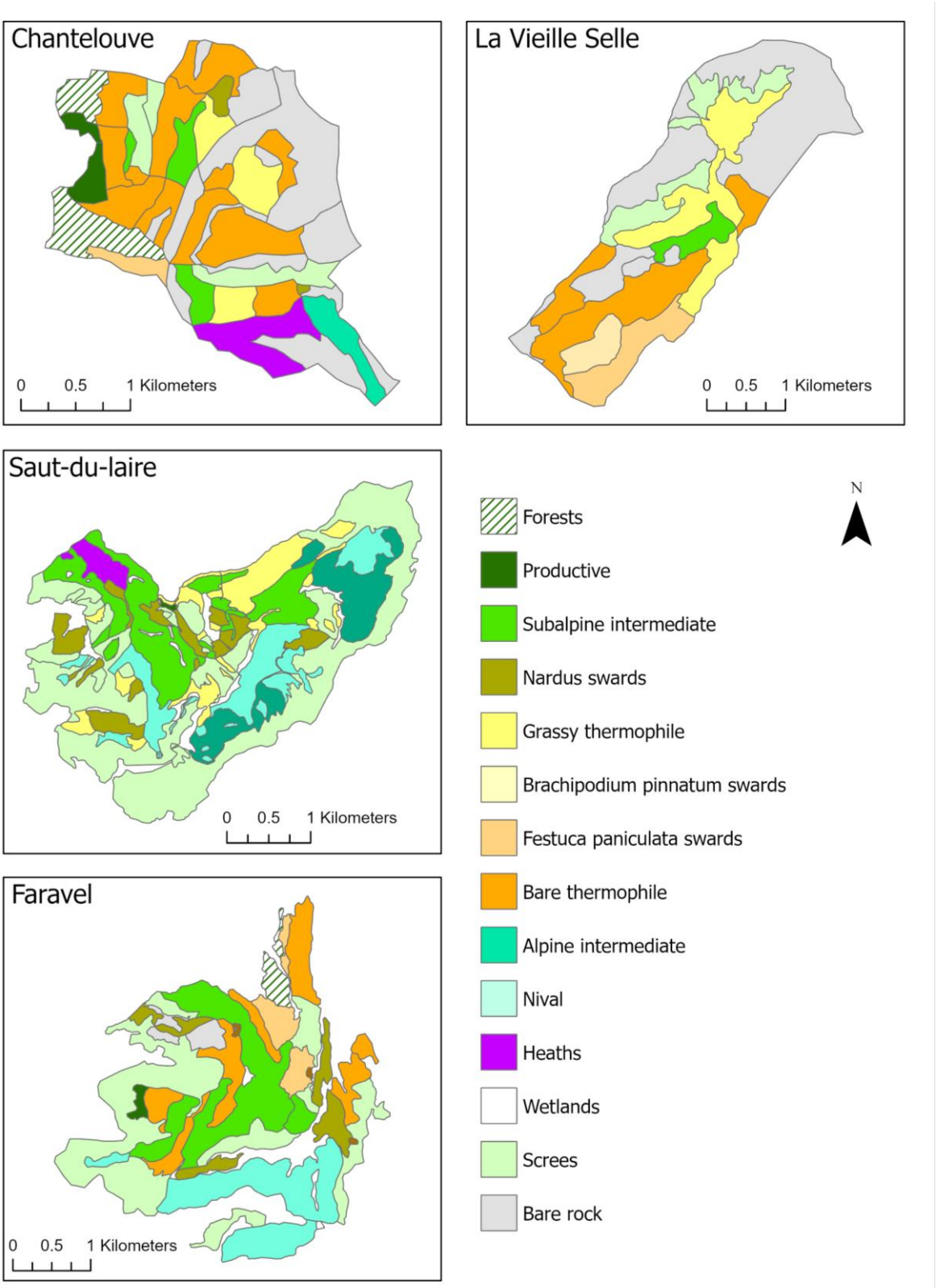


Figure 19. Land cover of four pastoral units surveyed in 2018 and 2019 in the framework of action C6: Chantelouve, Faravel, Saut-du-Laire and La Vieille Selle. The mapping uses the Pastoralp categories of vegetation as described in the legend. The maps were completed in 2018-2019 by experts in pasture managements working at CERPAM and FAI.

Using remote sensing data, we tested several methods to map the land cover of pastoral units including machine learning (Random Forest algorithm), kinetic-based classification or decision tree with different use of the field data. Finally, the retained method uses a simple step-by-step decision tree that relies on indices derived from a combination of remote sensing indices, climate and topographical variables. Field data were used to estimate the most appropriate threshold values for classification. In a more sophisticated approach, we also used these field data as training datasets of random forest models (see below).
The following text presents the variables that were used to map land cover types and the maps resulting from the application of a decision tree.

Remote sensing data and climate variables

Sentinel-2 data

The recently launched Sentinel-2 constellation (Sentinel-2A and Sentinel-2B) allow repeated surveys of the same area every 5 days with a spatial resolution of 20-m. Because of such spatial and temporal resolution, it is expected to offers unprecedented accuracy in vegetation discrimination. Sentinel-2 satellites have multispectral sensors composed of 13 bands from visible to short-wave infrared allowing computation of pertinent indices for our purpose. Sentinel-2 data were downloaded from the French national THEIA platform (http://www.theialand.fr/en/products/sentinel-2) at level 2A (i.e. orthorectified product in surface reflectance) with clouds and cloud shadows masks provided at 10-meter spatial resolution. The time series for 2018 over the PNE (tile T31TGK) represented 55 images (21.9 Go).

Primary Productivity

To capture ecosystem phenology, the commonly used Normalized Difference Vegetation Index (NDVI) was used (Myneni and Williams 1994). It is a vegetation indice that uses the reflectance in the red (visible) and near-infrared (NIR) spectrum to estimate the greenness of a given surface using the following formula:

$$NDVI = \frac{(R_{NIR} - R_{red})}{(R_{NIR} - R_{red})}$$

where R_{NIR} and R_{red} stand for the spectral reflectance in the near-infrared and red respectively. The admitted range goes from 0 to 1 with mineral surfaces or urban area between 0 and 0.1 and dense forest from 0.8 to 1. Using Sentinel-2, it is possible to acquire NDVI estimates every 5 days and to derive yearly metrics from time series. Here, we simply chose to extract the yearly maximum NDVI value as a proxy of peak standing biomass (*Figure 20*). Complementary analyses using a time-integrated value of NDVI over the year gave similar results (data not shown).

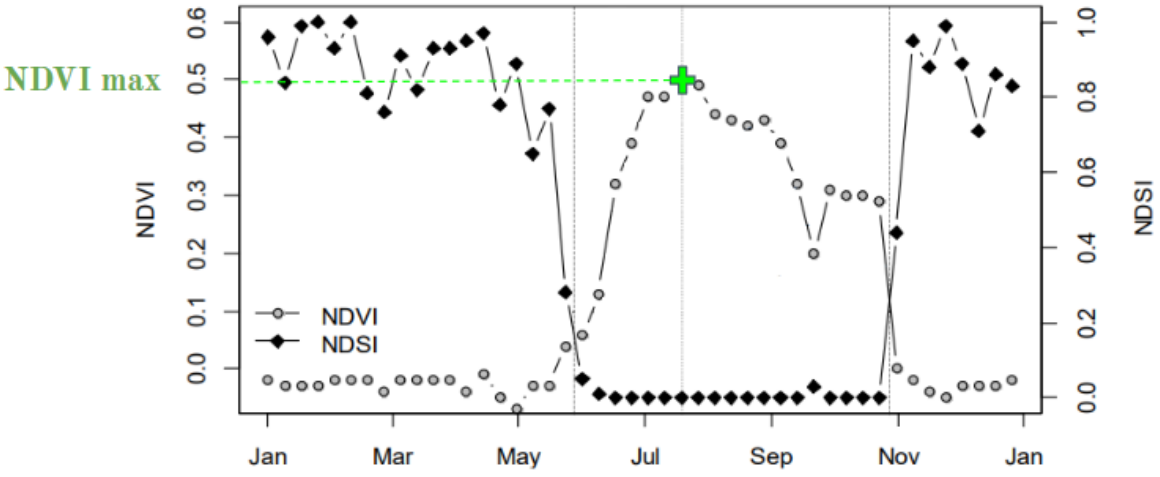


Figure 20. Example of a typical yearly course of NDVI and NDSI for a mountain pasture with vegetation onset occurring at the end of May and peak standing biomass in the second half of July.

First Snow Free Day

Snow cover dynamics is a key variable in mountainous habitat distribution because it controls the length of the favorable period for growth. Our previous studies highlight the importance of taking into account snow cover duration to predict pasture productivity (Choler 2015) and plant functional diversity (Carlson et al. 2015). Here, we used the First Snow Free Day (FSFD) as a proxy of snow cover duration. To estimate FSFD, time series of cloud free images are needed (Dedieu et al. 2016). The presence of snow can be estimated using the Normalized Difference Snow Index (NDSI) that uses the reflectance in green and shortwave infra-red (SWIR) as follows:

$$NDSI = \frac{(R_{green} - R_{SWIR})}{(R_{green} - R_{SWIR})}$$

The admitted range go from 0 to 1 representing the intra-pixel snow cover as the index increases. Binary maps of snow (presence/absence) were produced using a threshold value of 0.4 wa following (Dozier 1989). We used sigmoid curves to derive FSFD from time series (*Figure 21*).

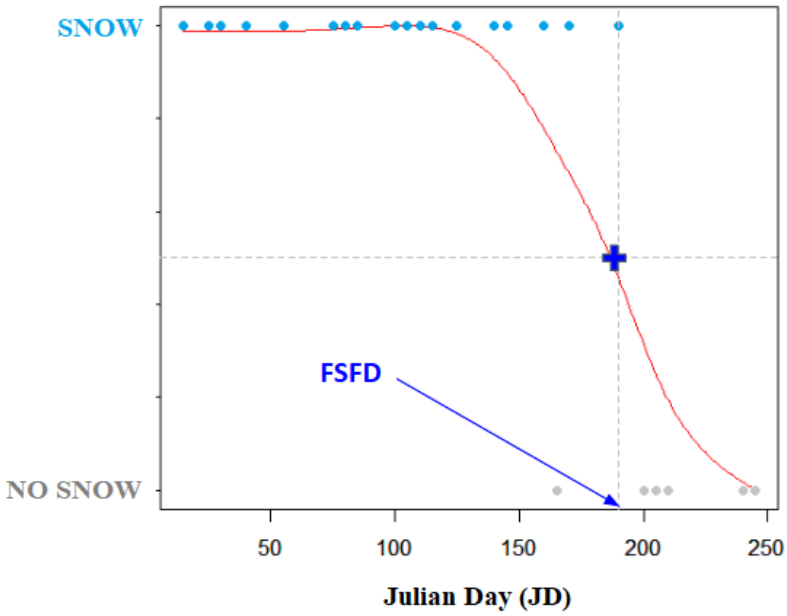


Figure 21. An example of estimation of FSFD using a full time series of binary snow map.

In case of repeated cloud cover over the same point, the estimation of the FSFD may be inaccurate. Orographic clouds are frequent and is the main issue to derived snow cover time series from optical sensors (Parajka et al. 2010). Several methods have been proposed to fill the cloud gap with binary information about the presence or absence of snow (Hall et al. 2010). We developed our own cloud gap-filling algorithm based on topographic indices that represent the mechanism of accumulation and ablation of snow.

First, to recover the snow information of a masked pixel at $t1$, the algorithm finds the snow condition at $t0$ and $t2$. If the pixel is covered by snow at $t0$ and $t2$, then we consider that there is snow at $t1$, else, we don't. Secondly, to represent the accumulation and ablation conditions at a pixel scale, three topographic index are derived for the area of interest using a Digital Elevation Model (DEM) (Böhner and Antonić 2009) :

- The **Diurnal Anisotropic Heat** (DAH) index is a terrain-derived index combining slope and aspect representing the potential amount of heat received per pixel.
- The **Wind Exposure** (WE) index is a terrain-derived index that compute the average exposition to wind of an area (ablation) by simulating the exposition from all angles.
- The **Topographic Position Index** (TPI) represents an indicator of a given pixel's position relative to the mean elevation of a defined surrounding area. It thus allows to discriminate area where snow will accumulate.

For a masked pixel, pixels with similar values of DAH, TPI and WE were searched for in a 10 km² area around the point. If more than half of the pixels identified as similar are covered by snow, we considered that the masked pixel is covered by snow. This method allowed us to derive consistent FSFD maps (*Figure 22*).

Growing Degree Day

Temperature is the main driver of mountain plant distribution (Körner 1999). It is thus pivotal to produce consistent maps of ecologically-relevant thermal indicators for pasture mapping. Thermal conditions during the favorable period for growth can be summarized using the Growing Degree Days (GDD). GDD is a measure of heat accumulation that is highly correlated to plant growth. It is calculated as follows:

$$GDD = \sum_{i}^{FSFD \rightarrow DAY} \left(\frac{T_{i,max} + T_{i,min}}{2}\right)$$

where DAY is an arbitrary day to stop the calculation (250 JD in this study), $T_{i,max}$ and $T_{i,min}$ are respectively the maximal and minimal temperature of the day i. Thus, GDD is the sum of the daily mean temperature from the first snow-free day to a constant day. Because thermal conditions are related to topographical gradients, spatial interpolation of temperature need to be done taking into account topographic heterogeneity.

Time series of air temperature were provided by the SAFRAN-CROCUS (S2M) model chain developed by Météo France for the French Alps (Durand et al. 2009a, Durand et al. 2009b, Vionnet et al. 2012). S2M is a meteorological reanalysis that simulates surface conditions as a function of elevation in 300m increments and for 23 massifs of French Alps. These massifs were defined for their climatological homogeneity. The S2M reanalysis was evaluated against in-situ observations and has been used for many real-time and climatological applications in the French mountain areas (Verfaillie et al. 2018, Corona-Lozada et al. 2019). For the period 2000 - 2012 we extracted data for all combinations of elevation bands, aspect and slope, and for the three massifs included in the PNE (Oisans, Pelvoux et Champsaur). The daily mean temperature was averaged across the 13 years to obtain a "baseline" of air temperature. Temperature data were interpolated using a common lapse rate of 0.65°C / 100m. GDD was calculated as the sum of daily mean air temperature above the threshold value of 0°C. The computation of GDD was done from the First Snow Free Day to the end of July (*Figure 22*).

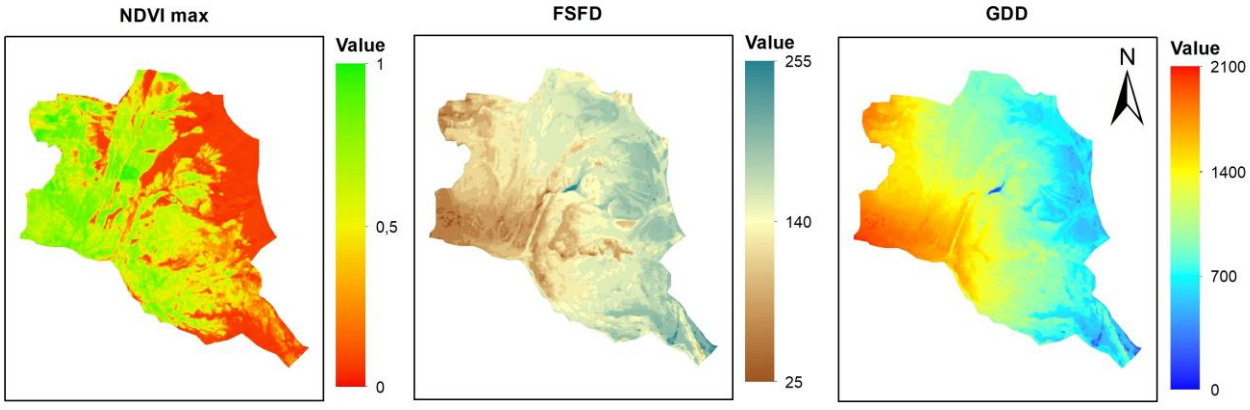


Figure 22. High-resolution maps of the three indicators that were used to map pasture types of the Chantelouve pastoral unit: NDVImax, First Snow Free Day (FSFD) and Growing Degree Days from snowmelt to end of July (GDD).

Shrub cover

Current land cover products tend to underestimate the extent of mountain shrublands dominated by *Ericaceae* because heathlands are often confounded with grasslands. We have designed a novel method to

improve the mapping of this vegetation type in the Alps (see Bayle et al. 2019 for details). Briefly, the method is based on an anthocyanin-responsive vegetation indices as most of the dominant shrubs accumulate anthocyanin, a red pigment, in late-fall. A new index called the Normalized Anthocyanin Difference Index (NARI) was proposed (Bayle et al. 2019) and is calculated as follows:

$$NARI = \left(\frac{R_{green}^{-1} - R_{red-edge}^{-1}}{R_{green}^{-1} + R_{red-edge}^{-1}} \right)$$

where R_{green}^{-1} and $R_{red-edge}^{-1}$ is the reciprocal reflectance in the green and red-edge. A simple threshold of 0.195 derived from previous study allows us to discriminate shrub lands from other grasslands.

Forest cover

The mapping of forest was estimated using two existing land cover products: the French OSO Land Cover product (Inglada et al. 2017) and the European Tree Cover Density of year 2018 from Copernicus (https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density/).

Figure 23 provides an overview of the data we assembled in this study.

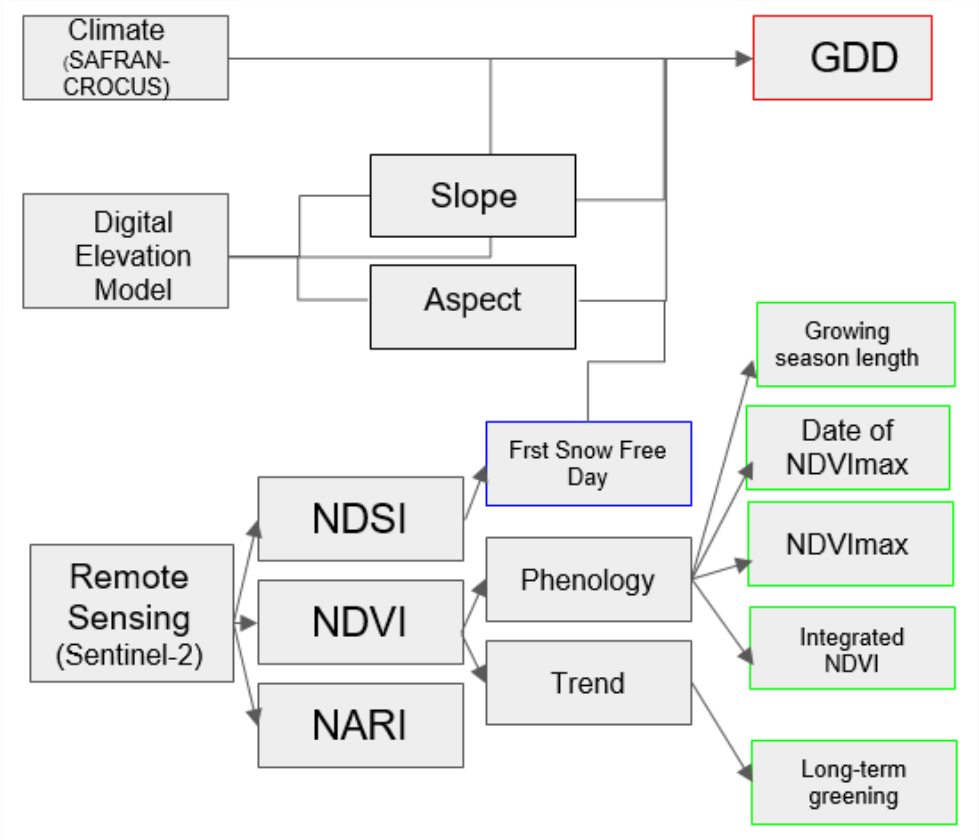


Figure 23. Overview of the data layers used in this work. See text for details.

Decision tree and predictive mapping of pasture types

In a first approach, a simple decision tree was elaborated to classify pixel according to the values of the indicators (*Figure 24*). The threshold values were set to obtain a plausible match with field surveys and our previous studies.

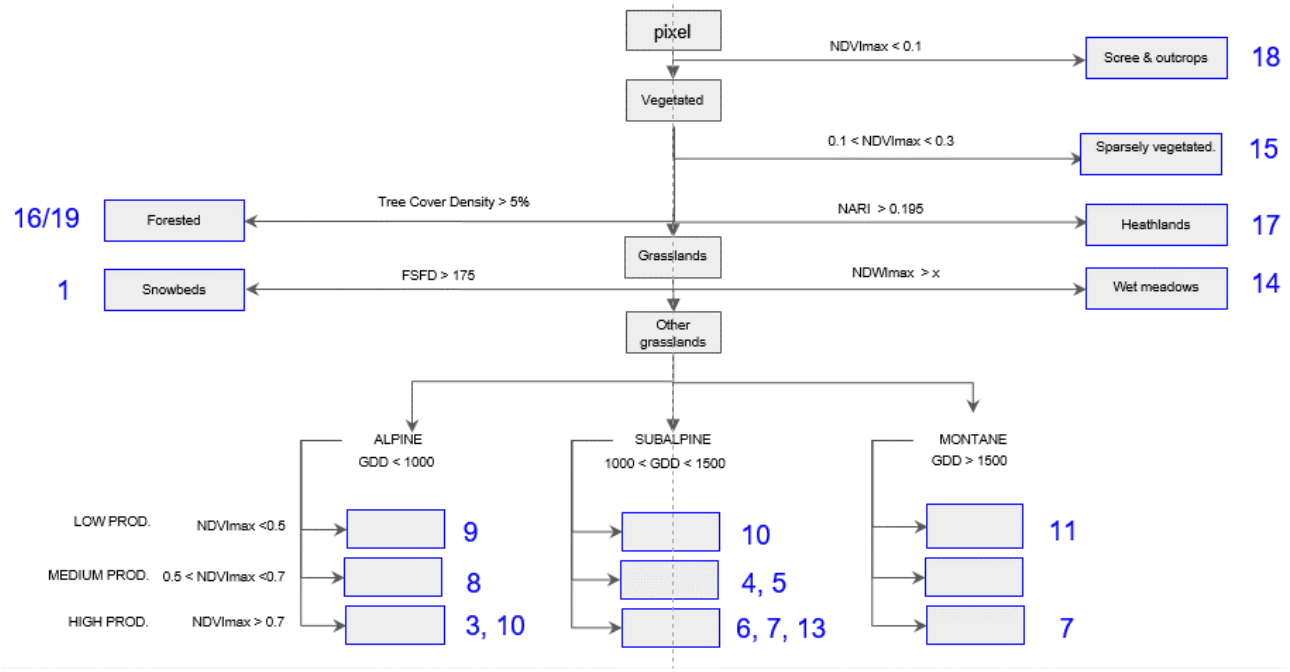


Figure 24. The decision tree used to map land cover in pastoral units of PNE. A correspondence between the remote sensing based classes and the pasture typologies is suggested. See figure 2 for the description of pasture types.

The merit of this approach lies in its simplicity and its workable correspondence with pasture types. The first steps allow to separate unvegetated (class 18), sparsely vegetated areas (class 15), heathlands (class 17), snowbed communites (class 1). The remaining pixels correspond to dense grasslands. They are classified into nine classes using three levels of NDVImax and three levels of GDD (*Figure 24*). The thresholds were adjusted to capture the montane, subalpine and alpine thermal regimes and three levels of productivity. The area covered by these pastures is shown in *Figure 25*. By far, the most represented class was low productive alpine grasslands with a cover of more than 1500 hectares. High productive grasslands dominate in the subalpine and montane thermal belts.

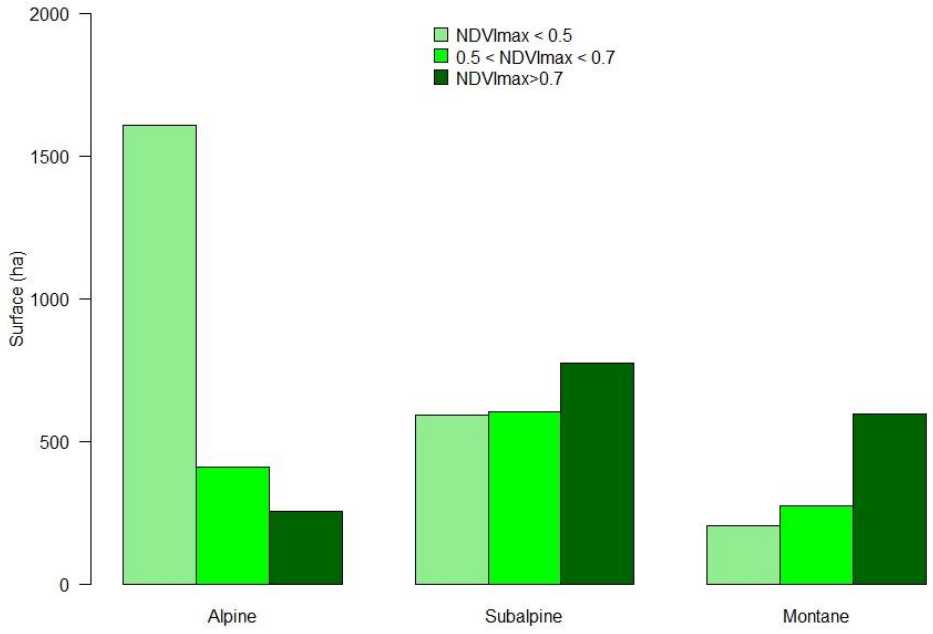


Figure 25. Areas (in hectares) covered by the nine categories of grasslands in the PNE.

The correspondence between these nine remotely-sensed grassland classes and the grassland types of the pasture typology has not been fully evaluated yet and we only show preliminary results (*Figure 26*). There is a clear signature for class 11 (montane dry grassland). High productive grasslands include the class 6, 7 and 13, with *Patzkea paniculata* dominated grasslands being the most abundant. Low productive grasslands (class 8 and 10) of high elevation are well separated from other types. For pasture types of medium productivity (classes 3, 4, 5), the GDD gradient is pivotal to discriminate the different types. Overall, these first results suggest that the combination of the three indicators is a promising way to discriminate the main types selected for pasture diagnostic.

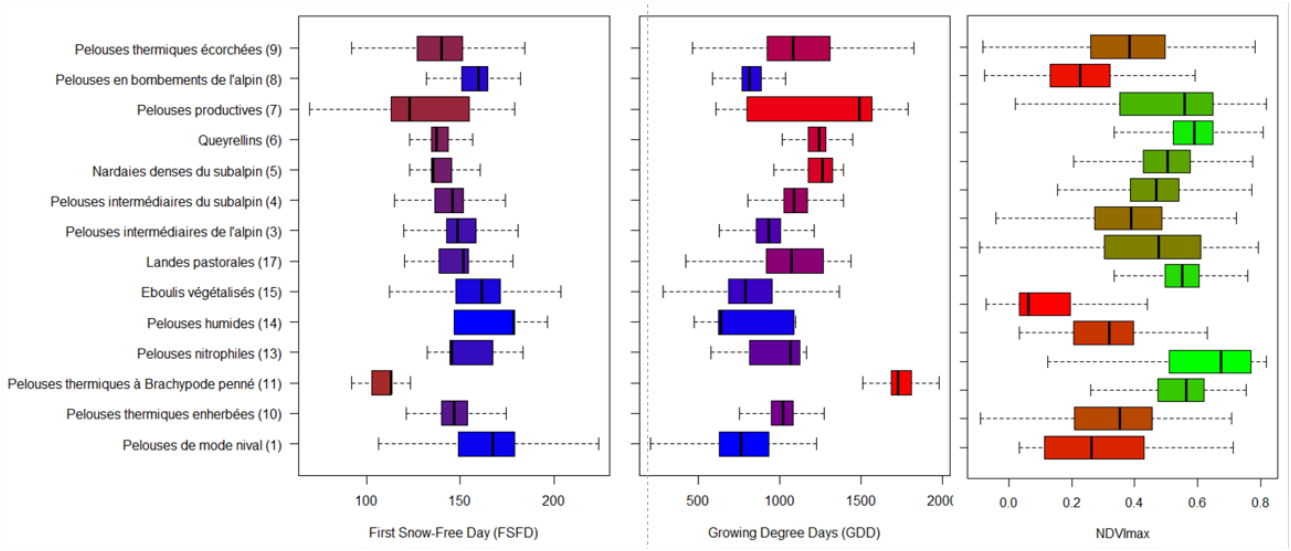


Figure 26. Distribution of the three indicators for each mapped pasture types. Example for the Chantelouve pastoral unit. Wet grasslands (class 14) and grasslands under Mediterranean climate (class 12) were not included because no field data were available.

The predictive land cover maps of the pastoral units are displayed in *Figure 27*. The main areas are consistent with those identified by field surveys, although they are spatially more resolved (compare with *Figure 19*). A clear discrepancy is the cover of heathlands which is either overestimated in the field and/or underestimated using the NARI indice.

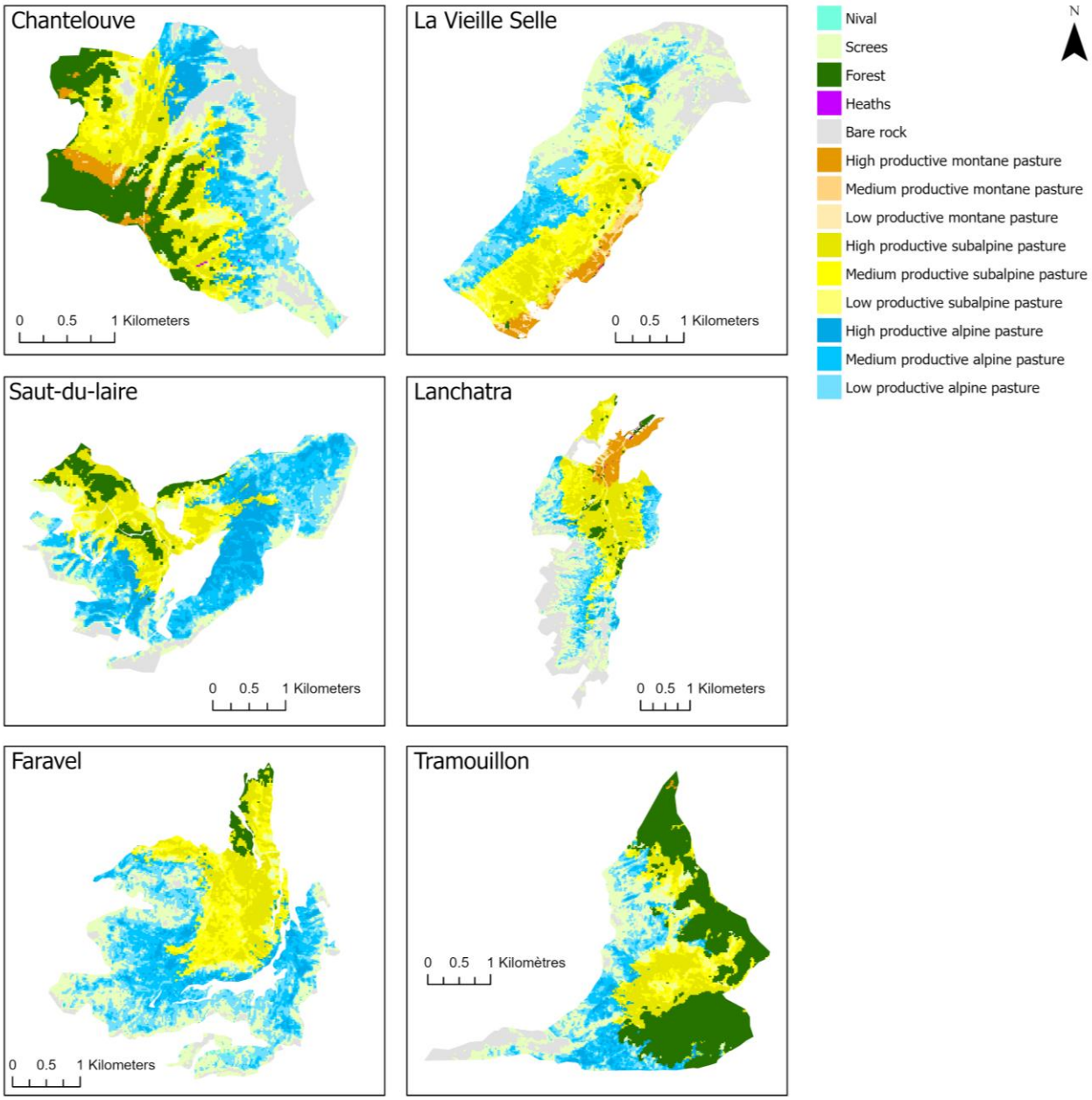


Figure 27. Predictive land cover maps of the six pastoral units surveyed in 2018 and 2019 using the decision tree.

In a second approach, we built a random forest model to assess the usefulness of the three predictors for classifying pixels into the different pasture types. We randomly selected 1000 pixels in each surveyed pastoral to assemble a calibration dataset. The remaining pixels were classified and the resulting maps are displayed on *Figure 28*. The complete evaluation of the performance of random forest models including out-of-bag classification accuracy and partial dependency tests is ongoing.

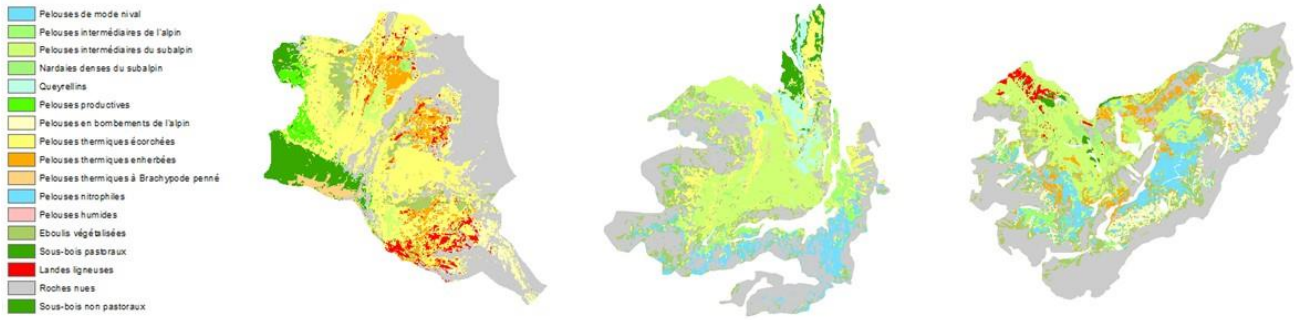


Figure 28. Predictive maps of pasture types resulting from a random forest model.

Discussion & perspectives

We implemented a remote-sensing based approach to map the land cover of pastoral units at a high spatial resolution (10m²). The resulting maps provide valuable information from a pastoral perspective as it combines indicators of primary productivity (amount of resource) and indicators of ecosystem phenology (period of forage availability). Preliminary results indicate a fair correspondence between these classes and those utilized in "pasture diagnostics". The interest of developing more complicated methods - such as random forests - is questionable as available ground (calibration) data suffer a number of limitation : large uncertainties in the delineation of polygons, lack of pixel-based observations. To overcome these issues, there would be a particular interest to adjust field data collection in forthcoming "pasture diagnostic". Specifically, a collection of geolocated point data whereby homogeneous land cover can be assigned to a pasture type would be extremely useful to implement more sophisticated analyses. This is the reason why there are ongoing discussions with the PNE and experts in pasture managements to further improve interactions between field surveys, remote sensing and data analysis.

Other methods would deserve more specific attention. For example, the spectral signature of pasture types could be refined by using all the available spectral bands of Sentinel-2 and the full seasonal time series of different spectral indices. These variables may be included in supervised classification following existing methodologies for land cover mapping at high resolution (Inglada et al. 2017). Once again, the usefulness of these approaches is completely dependent upon the availability of appropriate field calibration datasets.

Prospects and future

Remote sensing for modelling pasture productivy across the domain of the PASTORALP study areas proved to be effective and succesfull. The resulting maps may be used an operational tool for the management of the protected areas, and in particular can serve as:

- indication and guidance for future field surveys;
- intervention planning (quantitative inventory of the surfaces);
- layer for modelling activity (Actions C.6, C.1).

Many of the predictors used are dynamic in the short (e.g. NDVI, Area under the curve, NARI) and medium-to-long term (tree cover density). The models can be applied dynamically across years to:

- validate or update field surveys (short/medium term);
- quantify medium-to-long-term phenomena (shrub encroachment, pasture degradation, effectiveness of improvement strategies).

REFERENCES

Anderson, K., D. Fawcett, A. Cugulliere, S. Benford, D. Jones, and R. L. Leng. 2020. Vegetation expansion in the subnival Hindu Kush Himalaya. Global Change Biology **26**:1608-1625.

Bayle A., Carlson B.Z., Thierion V., Isenmann M., Choler P., 2019. Improved Mapping of Mountain Shrublands Using the Sentinel-2 Red-Edge Band. Remote Sens. 11, 2807.

Bohner J., and O. Antonic, 2009. Land-surface parameters specific to topo-climatology. Dev. Soil Sci.,33, 195–226.

Bonet, R., F. Arnaud, X. Bodin, M. Bouche, I. Boulangeat, P. Bourdeau, M. Bouvier, L. Cavalli, P. Choler, A. Delestrade, C. Dentant, D. Dumas, L. Fouinat, M. Gardent, S. Lavergne, E. Naffrechoux, Y. Nellier, M.-E. Perga, C. Sagot, O. Senn, and W. Thuiller. 2016. Indicators of climate: Ecrins National Park participates in long-term monitoring to help determine the effects of climate change. Eco Mont-Journal on Protected Mountain Areas Research **8**:44-52.

Bornard A., Bassignana M., Bernard-Brunet C., Labonne S., Cozic Ph., 2007. Les végétations d'alpage de la Vanoise. Description agro-écologique et gestion pastorale. Éd. Quae, Versailles (F).

Bornard A., Bassignana M., 2001. Tipologia agroecologica delle vegetazioni d'alpeggio in zona intra-alpina nelle Alpi nord-occidentali. Progetto Interreg Itlia-Francia n. 110. Cémagref Grenoble, IAR Aoste.

Carlson, B. Z., P. Choler, J. Renaud, J.-P. Dedieu, and W. Thuiller. 2015. Modelling snow cover duration improves predictions of functional and taxonomic diversity for alpine plant communities. Annals of Botany **116**:1023-1034.

Carlson, B. Z., M. C. Corona, C. Dentant, R. Bonet, W. Thuiller, and P. Choler. 2017. Observed long-term greening of alpine vegetation-a case study in the French Alps. Environmental Research Letters **12**.

Cavallero A., Aceto P., Gorlier A., Lombardi G., Lonati M., Martinasso B., Tagliatori C., 2007. I tipi pastorali delle Alpi piemontesi. A. Perdisa Editore, Bologna.

Choler, P. 2005. Consistent shifts in Alpine plant traits along a mesotopographical gradient. Arctic Antarctic and Alpine Research **37**:444-453.

Choler, P. 2015. Growth response of temperate mountain grasslands to inter-annual variations in snow cover duration. Biogeosciences **12**:3885-3897.

Choler, P. 2018. Winter soil temperature dependence of alpine plant distribution: Implications for anticipating vegetation changes under a warming climate. Perspectives in Plant Ecology Evolution and Systematics **30**:6-15.

Commission DG Environment, 2007. The Interpretation Manual of European Union Habitats—EUR27. Eur. Comm. DG Environ. Nat. Biodivers, 27, 368.

Corona-Lozada, M. C., S. Morin, and P. Choler. 2019. Drought offsets the positive effect of summer heat waves on the canopy greenness of mountain grasslands. Agricultural and Forest Meteorology **276**.

Dedieu, J.-P., B. Z. Carlson, S. Bigot, P. Sirguey, V. Vionnet, and P. Choler. 2016. On the Importance of High-Resolution Time Series of Optical Imagery for Quantifying the Effects of Snow Cover Duration on Alpine Plant Habitat. Remote Sensing **8**:481-481.

Dobremez, L., B. Nettier, J.-P. Legeard, B. Caraguel, L. Garde, S. Vieux, S. Lavorel, and M. Della-Vedova. 2014. Sentinel Alpine Pastures: An original programme for a new form of shared governance to face the climate challenge. Revue De Geographie Alpine-Journal of Alpine Research **102**.

Dozier, J. 1989. SPECTRAL SIGNATURE OF ALPINE SNOW COVER FROM THE LANDSAT THEMATIC MAPPER. Remote Sensing of Environment **28**:9-&.

Durand, Y., G. Giraud, M. Laternser, P. Etchevers, L. Mérindol, and B. Lesaffre. 2009a. Reanalysis of 47 Years of Climate in the French Alps (1958–2005): Climatology and Trends for Snow Cover. Journal of Applied Meteorology and Climatology **48**:2487-2512.

Durand, Y., M. Laternser, G. Giraud, P. Etchevers, B. Lesaffre, and L. Merindol. 2009b. Reanalysis of 44 Yr of Climate in the French Alps (1958-2002): Methodology, Model Validation, Climatology, and Trends for Air Temperature and Precipitation. Journal of Applied Meteorology and Climatology **48**:429-449.

Evans D., 2006. The Habitats of the European Union Habitats Directive. Biol. Environ. Proc. R. Irish Acad., 106, 167–173.

Hall, D. K., G. A. Riggs, J. L. Foster, and S. V. Kumar. 2010. Development and evaluation of a cloud-gap-filled MODIS daily snow-cover product. Remote Sensing of Environment **114**:496-503.

Inglada, J., A. Vincent, M. Arias, B. Tardy, D. Morin, and I. Rodes. 2017. Operational High Resolution Land Cover Map Production at the Country Scale Using Satellite Image Time Series. Remote Sensing **9**.

Jouglet J-P., 1999. Les végétations des alpages des Alpes françaises du Sud. Guide technique pour la reconnaissance et la gestion des milieux pâturés d'altitude. Cemagref Éditions and ATEN (Atelier Technique des Espaces Naturels).

Körner, C. 1999. Alpine Plant Life. Springer Verlag, Berlin.

Maus V., Câmara G., Appel M., Pebesma E., 2019. dtwSat: Time-Weighted Dynamic Time Warping for Satellite Image Time Series Analysis in R. Journal of Statistical Software, 88(5), 1–31.

Myneni, R. B., and D. L. Williams. 1994. ON THE RELATIONSHIP BETWEEN FAPAR AND NDVI. Remote Sensing of Environment **49**:200-211.

Parajka, J., M. Pepe, A. Rampini, S. Rossi, and G. Bloeschl. 2010. A regional snow-line method for estimating snow cover from MODIS during cloud cover. Journal of Hydrology **381**:203-212.

Verfaillie, D., M. Lafaysse, M. Deque, N. Eckert, Y. Lejeune, and S. Morin. 2018. Multi-component ensembles of future meteorological and natural snow conditions for 1500m altitude in the Chartreuse mountain range, Northern French Alps. Cryosphere **12**:1249-1271.

Vionnet, V., E. Brun, S. Morin, A. Boone, S. Faroux, P. Le Moigne, E. Martin, and J. M. Willemet. 2012. The detailed snowpack scheme Crocus and its implementation in SURFEX v7.2. Geoscientific Model Development **5**:773-791.

Xie, J., T. Jonas, C. Rixen, R. de Jong, I. Garonna, C. Notarnicola, S. Asam, M. E. Schaepman, and M. Kneubuehler. 2020. Land surface phenology and greenness in Alpine grasslands driven by seasonal snow and meteorological factors. Science of the Total Environment **725.**