Human Impact on the Environment in the Annecy Petit Lac Catchment, Haute-Savoie: A Documentary Approach

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ABSTRACT

It is axiomatic that mountain environments are particularly vulnerable to changes in patterns of human use, over both long and medium terms, but also over quite short periods of critical activity. This paper uses archaeological and documentary records to look at the human impact on one such montane environment, the pre-alps of Savoy, over the long-term, from pre-history up to the pre-modern period. The use and modification of landscape is estimated at the level of the Annecy Petit Lac hydrological catchment taking into account spatial differences in land use in the uplands, mid-slope and plain. Land use patterns and nutrient balance are reconstructed for specific periods in time between 1561 and 1892. Results from this study demonstrate that seven main phases of human activity have left their traces in the environmental record during the historical period through to the pre-modern period. Of these the 1730–1770s and 1840–1860s stand out as two discernible periods of heightened environmental pressures at higher altitudes, which manifest themselves as discernable lowland environmental problems, such as flooding, increased erosion and declining soil fertility.

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KEYWORDS

Savoy, land-use change, soil fertility, erosion

INTRODUCTION

Human impacts, such as settlement, land-use change, population increase, industrialisation, and urbanisation have had a measurable impact on the environment through time. These point and diffuse responses can be primarily physical, such as increased sediment deposition and soil erosion, or biological in character, such as epidemics, epizootics, loss of biodiversity and natural resource depletion.[2] In order to compensate, people develop new techniques, access new resources, increase knowledge, skills, funds and contribute additional labour to maintain, restore or abandon landscapes. The speed and scale of change differs markedly for different areas. Sometimes changes are slow and laboured, at other times fast and accelerating with effects ranging from minute to ubiquitous and ephemeral to permanent. The patterns of change can occur over millennial, centennial, decadal, annual, daily and hourly timescales. This paper focuses only on the historical period covered by both archaeological and documentary evidence. There is no assumption of an initial steady state, which characterised the relationship between people and the environment, before this historical period.

Both climate and human-driven changes are particularly acute, relevant and observable in sensitive environments, such as mountain zones.[3] With many poor and socially marginalised ethnically diverse peoples living in these areas, social inequities are common and people are vulnerable to change. Thus, it is crucial to understand more clearly the processes of change affecting such areas and to assess peoples' vulnerability to future climate change. This paper concentrates on the human-driven changes of this relationship. A multi- and inter-disciplinary project lies at the heart of our research programme, which centres on a small micro-region in the French pre-Alps, the Annecy Petit Lac catchment in Haute-Savoie.[4] The project uses palaeo-environmental (e.g. pollen, hydrological and sedimentary records), archaeological and documentary records to provide a continuous time series of environmental change.[5] Thus, it contributes towards promoting global action aimed at equitable and ecologically sustainable mountain development. This paper is presented as a historically oriented contribution to this programme and draws only on the archaeological and documentary evidence. It aims to produce a time series of specific land uses, crop yields and large livestock stocking regimes, and provides a partial reconstruction of nutrient balance based on manure production and upland grazing.

Our approach allows us to pose the question: To what extent have proximal and distal, endogenous and exogenous, anthropogenic forces driven land-use change within different biomes, micro-regions and locations within the Annecy Petit

Lac catchment? It becomes possible to weight which factors are most important in driving land-use change and to identify both negative and positive feedback mechanisms that are driven by the crossing of important environmental thresholds. It is our argument that understanding such forces is crucial to identifying zones of vulnerability to future predicted global and regional scale pressures. Such a study also contributes to the debate on what constitutes a sustainable system. Can current farming systems be defined as indefinitely sustainable?

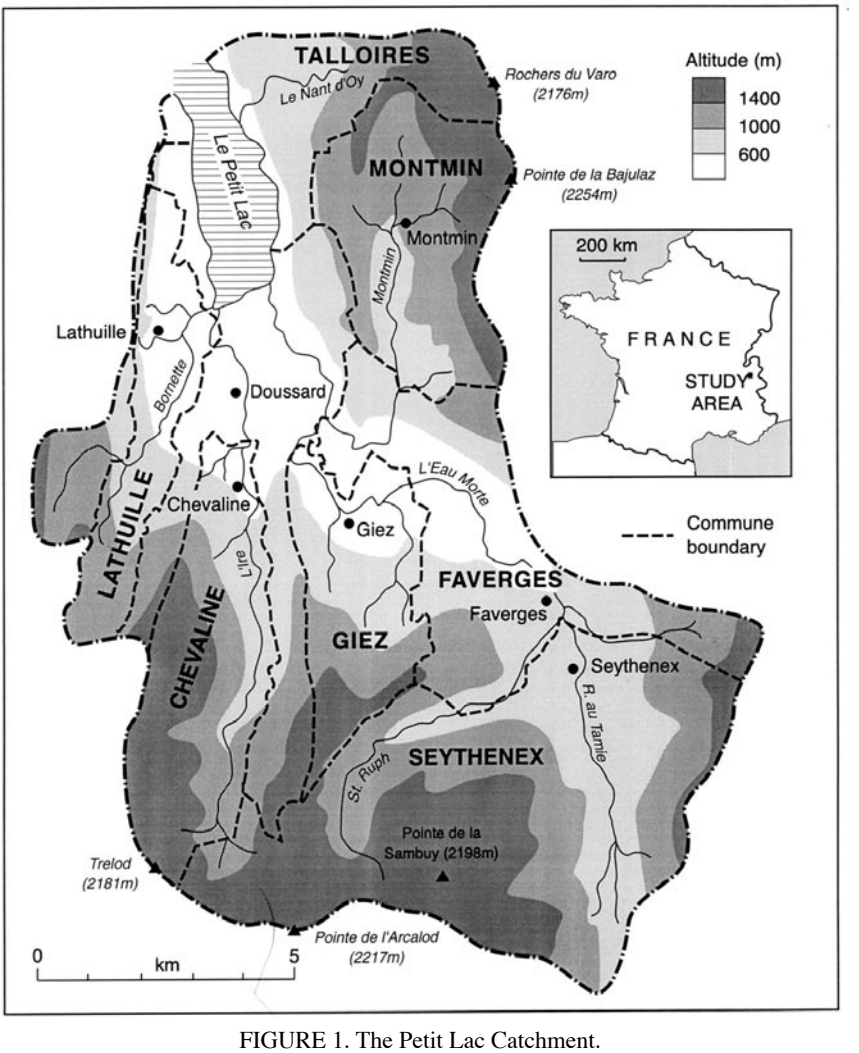


FIGURE 1. The Petit Lac Catchment.

REGIONAL CONTEXT

The main valley floor (*cluse*) separates the Bornes (east) and Bauges (west) mountain massifs. The limestone massif (2351 metres) of La Tournette dominates the east of the catchment whilst the Montagne de Charbon and Peak de Sambuy dominate the west of the catchment. Constrained within the boundaries of the Annecy Petit Lac are seven principal administrative communes, which together have a surface area of 131.27 square kilometres in a total surface area of 170.4 square kilometres (Figure 1). The main sub-catchments are contained within these units, with those units not included having only minor hydrological importance. The seven communes mostly have a land surface that both straddles the flood plain of the main Eau Morte tributary and also contain upland pasture and woodlands. Soils on the *cluse* floor are mainly well drained[6] and alluvial in origin, although in parts areas of marshy land remain. Only two communes, Montmin and Seythenex, can be considered totally mountainous. In these communes the topography is generally steep with the main settlements being scattered around the gentler relief of upland valley floors that lie at an average altitude of 1100 metres.[7] In general, south facing '*adret*' slopes are used for arable farming, garden agriculture and pasture, whilst the north facing '*ubac*' slopes are home to forest and woodlands. The climate of the *cluse* for the period 1876–1999 was cool temperate with a mean annual temperature of around 10.5 °C at Annecy and a temperature gradient of around 0.6 °C per 100 metres.[8] Annual rainfall is around 1250 mm on the plain, but precipitation increases *c*. 70 mm for every 100 metres gain in altitude.[9] The Annecy *cluse* is susceptible to severe convective summer thunderstorms that have intensities typically of around 20–50 mm per hour.[10] The spring snowmelt and autumn runoff are important components to discharge in river hydrographs.[11]

METHODOLOGY

Our purpose in this paper is to identify phases of human occupation using archaeological and historical evidence. The reconstruction that follows is based on fragmented sources (Figure 2). It is not our intention to create a fully comprehensive account for the whole period. Only those eco-system reactions large enough and important enough to have left traces in the historical record can be analysed for their distinctive patterns and probable causes. It is not until the sixteenth century when various enumerations, vital event registers and censuses have allowed us to reconstruct human and livestock populations in the catchment that a higher degree of confidence can be placed on our results.[12] Part of our purpose is to set a template on which to compare independently derived palaeo-environmental records at a later date. Pre-nineteenth century population

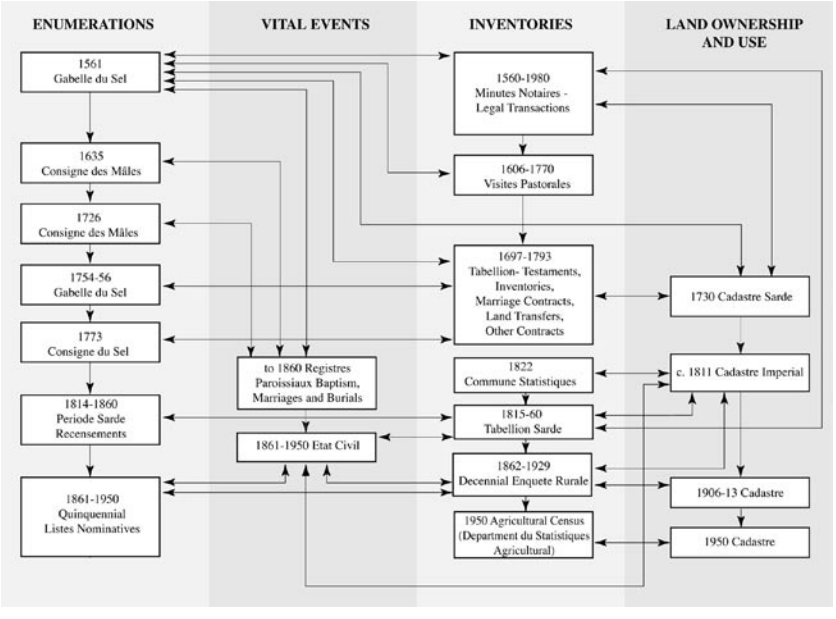


FIGURE 2. Documentary sources and their linkages 1561 – 1950.

reconstruction is based on informed estimates of household (*feux*) sizes and known numbers of *feux*.

One focus of this paper is to identify different phases of resource use and depletion and how these changes affect different parts of the landscape, broadly divided between the plain, mid slopes and uplands. The great land registrations of the Kingdom of Savoy, known as the 1730 Cadastre Sarde, provide a baseline figure for land cover in the catchment.[13] These taxation documents provide a benchmark for any subsequent relative changes in land use in the catchment, and in the case of Montmin it was possible to back project grassland and cultivated land figures to 1561 based on reconstructed population and livestock figures (Figure 9).[14] The Cadastre Sarde also provided information on crop yields, soil fertility and land value. Alongside these documents there are a suite of land and animal taxation documents, agricultural inquiries, census and inventories which provide further evidence on land cover and use, agricultural practice and crop yields. Data from 1561 up to 1892 are standardised at either whole catchment or local commune scales using conversion tables and general land use categories to enable comparisons between census dates.[15]

A rough estimate of annual manure production in the catchment (Figure 8) was based on livestock weights and lifecycle information in the 1882 and 1892

agricultural census complemented by estimates of manure production in 1561, 1754, 1773 and 1822.[16] These were calculated using the average weights[17] of cattle and a linear regression analysis ($y = 11.49x - 52.515$; $R^2 = 0.9569$) of livestock weight vs manure production based upon nineteenth-century figures for Lathuille.[18] Results are presented at a communal level, as there is little evidence to suggest outside sources of manure or exchange between communities. Using data from one such self-contained community, Montmin, it was then possible to model manure dispersal between 1561 and 1892. Estimates of the amount of time livestock spend on the cultivated area and pasturelands were based on two *estivage*[19] periods, one short (88 days) the other long (189 days), which leaves in the former scenario a 180-day stabling period and 97 days grazing at lower altitudes and in the latter scenario a 120-day stabling period and 56 days grazing at lower altitudes. It is assumed that manure from the stabling period will be placed onto nearby fields[20] and thereafter livestock will be turned onto the cultivable area in the proximity of the village. Thus, in total, manure will be directed onto around 50 per cent[21] of the cultivable area for a period of between 176–277 days. The rough pasture will receive the remaining manure for the period of the *estivage* (88–189 days). From the results generated it was possible to calculate the potential average annual amount of manure applied to a single hectare of land.

To provide a measure of the grazing pressure placed on upland pastures stocking ratios in Montmin were calculated for the periods 1561, 1754, 1773, 1822 and 1892. With one adult bovine animal designated as the equivalent of one livestock unit (LU) all livestock were then converted into equivalent fractions of bovine livestock units to simplify the ratio.[22] The same bovine ratio has been used for equine species, and the same ovine ratio for caprine and porcine animals, with all grazing ratios doubled for young and immature animals. Then both the upper and lower stocking ratios were matched to the amount of upland pasture calculated from cadastral records. It is known that rapid degrading of pasture occurs at stocking ratios of more than 1–2 bovines/hectare or more than 4–6 ovines/hectare.[23] The results generated mark the difference between the ideal stocking ratio on good quality pasture and the reality, which represents either a surplus or shortfall in pasture.

Finally, evidence from regional studies of climate changes acts as a backdrop to this work.[24] The good match (P 95 per cent) between local and longer regional temperature records, made it possible to hindcast with confidence the number of growing degree-days in Montmin at an altitude of 1500 metres above sea level.[25] Assuming that plant growth commences at a temperature of 5°C, then a day with a mean temperature of 7°C would contribute two growing degree-days to the total and a temperature of 8°C three growing degree-days.

RESULTS

The seven main phases of occupation of the environment

Archaeological and documentary records point to seven main phases of human occupation and exploitation:

i) a long phase of pre-history which embraces all the archaeological periods, including the Roman occupation and beyond;

ii) a phase of mediaeval rapid population growth and colonisation, which ended with the great plague of the mid fourteenth century. This heralded

iii) a period of decline in population which lasted until the last decades of the fifteenth century

iv) a late mediaeval expansion of population and reoccupation in the sixteenth century, which was followed by

v) a period of Malthusian checks in the seventeenth to late eighteenth century (poor harvests, famines, plagues, wars) and

vi) an early modern phase of concurrent economic and demographic expansion, followed by

vii) a period of economic malaise and population decline starting in the late nineteenth century and capped by the two World Wars

What follows amounts to an examination of the extent to which competition between people and resources built quickly enough to cause severe environmental pressure in the Petit Lac catchment. To keep the paper at an acceptable length it stops short of the modern period of rapidly changing social and economic circumstances associated with population expansion, urbanisation and tourism.

i) The Long Phase of Prehistory

Both the archaeological and historical records indicate that until the mediaeval period, the human impact on this environment was very restricted, with earliest developments on the lighter drained and less heavily forested soils in the *cluse*, which formed a natural route way from the Isere valley to the lowlands to the west (Figure 3). There is little doubt that the floor of the *cluse* and more particularly the littoral zones near to the lake were opened up first during the mid-Neolithic, Bronze and Iron Ages, as at first the benches and cirques of the mountains formed a hostile and uninhabitable upland area of forests and streams, although some palaeo-ecologists believe that upland clearances to create alps began some time during these periods.[26] Celtic peoples and then later the

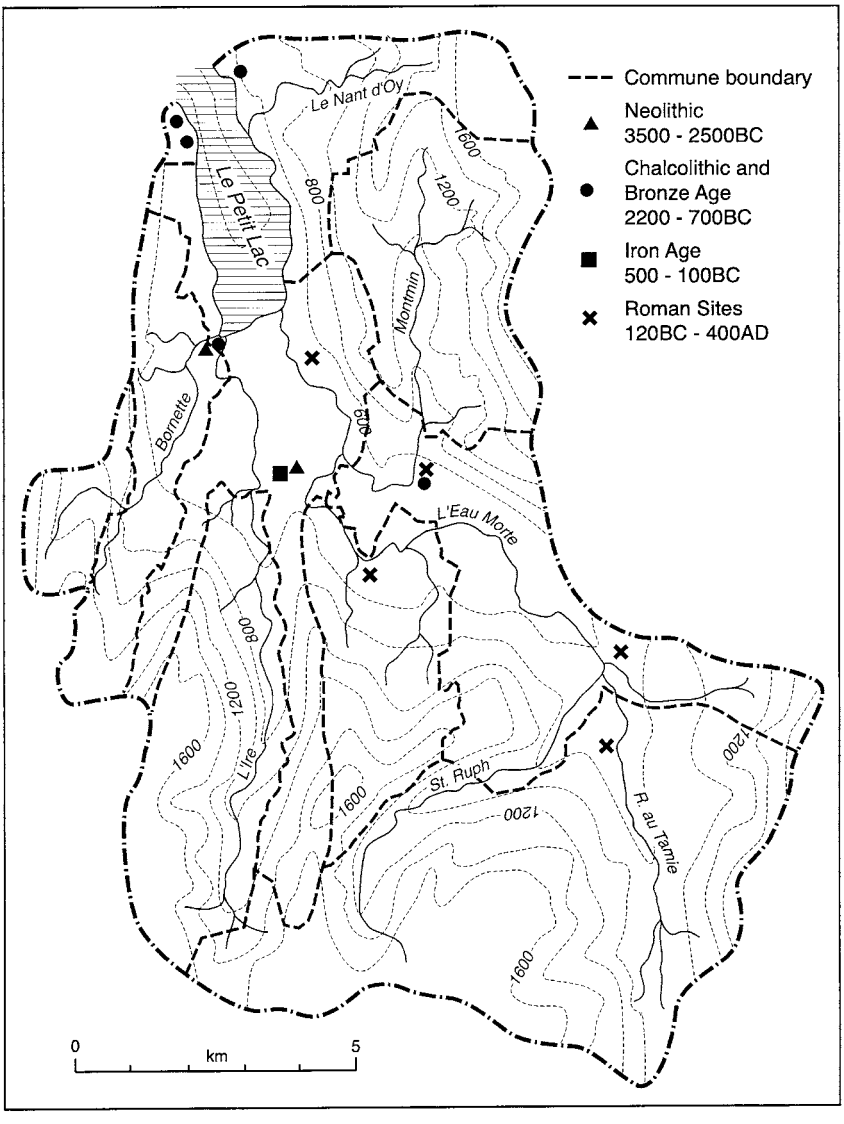


FIGURE 3. Sites of early settlement in the Petit Lac Catchment: Neolithic to Roman Period.

Source: Privat 1973.

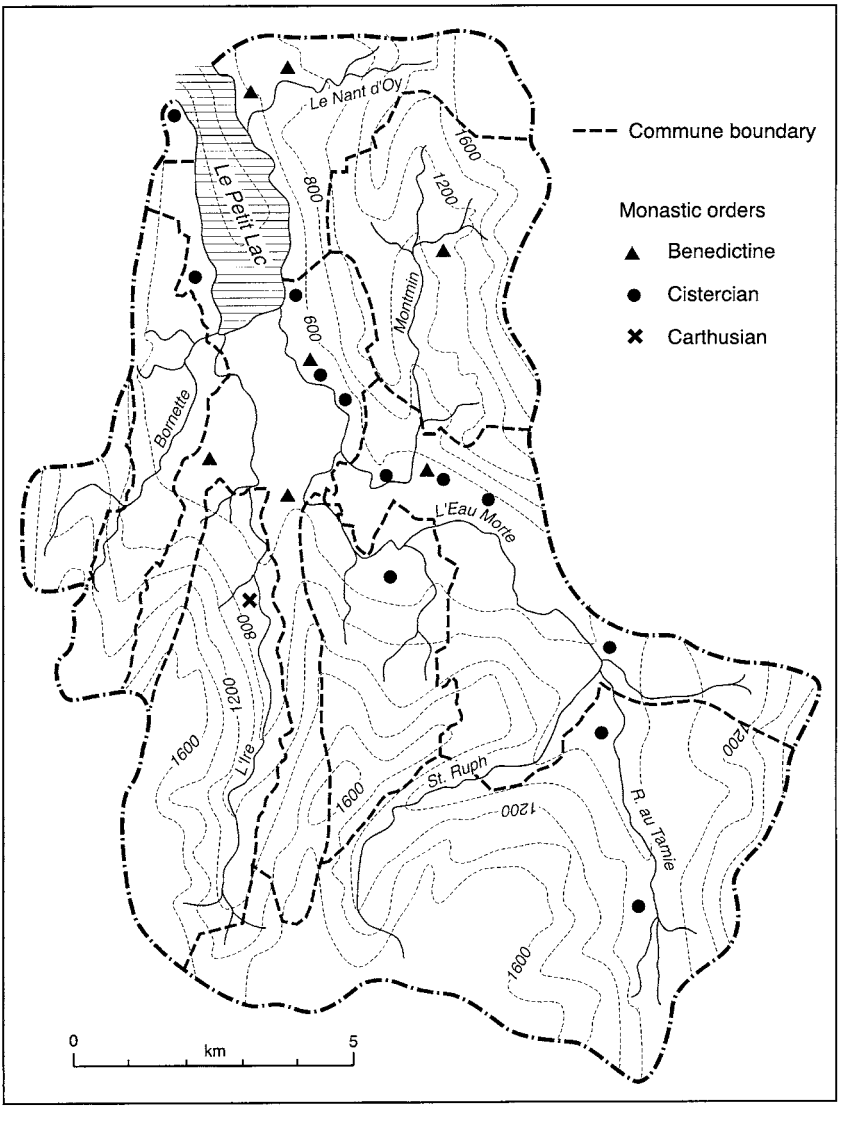


FIGURE 4. Monastic demesnes and granges found in the Petit Lac Catchment at the end of the period of Monastic expansion and population growth 879-*c.*1348.

Source: Brondy et al. 1984.

Romans left their mark on the landscape, most noticeably on the floodplain of the Eau Morte. Roman villas at Frontenex and Vesonne formed along the main Republican/Agrippan road linking the provincial capital of Genava with Axima and Lugdunum: and a small town known as Casuaria (Faverges) was established.[27] The Romans drained and improved parts of the Eau Morte floodplain and may have seasonally ventured onto the mid-slopes and mountains, a view supported by the establishment of Sextinacus Villa in the Tamie valley, which was later to become Seythenex. The introduction of feudalism in the ninth century along with the earlier fifth century flood of Christianity led to the nucleation and distinction of settlements as parishes with churches and burial grounds.[28]

ii) First Mediaeval Period of Rapid Population Growth, 900–1348

When Benedictine Monks established an abbey at Talloires on the north-eastern shores of the lake in 879 they became probably the first people to use the uplands for summer grazing after substantial initial assarts and clearance by fire.[29] Pioneering activity prior to this had remained locally dispersed and discontinuous. Much of these new lands, ceded or donated by private landlords, became the parish of Montmin at sometime towards the end of the eleventh century.[30] Later the Cistercian Order established an abbey at Tamie in 1132, which opened up the uplands on the west side of the catchment to agro-pastoral farming and permanent habitation. Some of the granges associated with this abbey were to become the focus for the nascent nucleated settlements in the *cluse* (Figure 4). Other large landlords in the catchment were the Lord of Duingt and the Abbey at Chartreuse, both of which lay just outside the Petit Lac catchment.[31] Both Benedictine and Cistercian Orders followed codes of living which endorsed the exploitation of the land for agriculture.[32]

Monastic organisation favoured sheep rearing for wool, which required large areas of mountain pasture. It seems that these pastures were developed fully during the monastic expansion and demographic increases of the twelfth and thirteenth centuries.[33] Thus, in the first phase at least upland pastures were created and managed in an environmentally benign process, in particular because as animal numbers increased farmers were able to add precious manure not only to arable plots and gardens close to houses, but also to some pastures in a practice known as *'fenage'*.[34] Moreover the Cistercians demonstrated a level of environmental awareness by restricting cutting of wood on steep slopes and by leaving a crown of forest on mountain tops to prevent soil erosion.[35] During this period woodland was not only cleared to make pastures, but also cut for charcoal to support a burgeoning metal industry.[36] As yet we have found little evidence in documents to suggest a dramatic phase of deforestation, but it seems likely that this relates more to poor documentary survival rates than the likelihood that woodland was significantly reduced during this period.

It seems probable that population continued to grow dramatically as it did in Europe in the two centuries before the Black Death in 1348.[37] Whilst we have no evidence for the catchment this population increase was noted in two contiguous regions. Firstly, a doubling of the number of households in the Isere valley (South) occurred in the period 1296–1347. Secondly local taxation records suggest that the population in Faucigny (East) had reached a density of 35 people per square kilometre in 1335 with an average of over seven people in each household.[38] This population underwent a further 31 per cent rise (an average of 2 per cent per annum) between 1333 and 1347.[39] When one considers that in an age before significant urbanisation all but a small fraction of this population depended directly on the product of the soil, these are truly remarkable figures. It is easy to imagine that even greater pressure was applied to limited lowland resources where population was even higher. Constrained by low yields this population expansion in the lowlands led rapidly to '*un pays surpeuplé*', which was ever more susceptible to food shortages, poor diet and eventually to epidemics.[40] So the colonisation of the upper surfaces, formerly the *estivages* and alps of communities on the plain, was almost certainly the product of a combination of monastic enterprise and demographic pressure. In addition, the nobility who maintained a nominal ownership of the areas of *gaste* or 'wasteland' enthusiastically encouraged this colonisation and its promise of wealth both economic and spiritual.[41] As population and economic pressures mounted, however, lands started to be conceded to less responsible private and parish hands. By the fourteenth century agriculture in general was deemed to be in a crisis attributed to the inexperience and lack of technical knowledge of early settlers who cultivated marginal lands, which resulted in declining soil fertility.[42] It is possible that the consumption of famine crops, such as chestnut, increased at this time.

iii) The Phase of Decline in Population 1348–1470

The brake provided by the demographic crisis produced by the bubonic plague of 1348–50 came at a time when pressures on resources were severe. The whole of this period coincided with very wet decades, in the early fourteenth and fifteenth centuries in northern Europe, which marked the onset of the 'Little Ice Age'.[43] At the same time taxes placed economic constraints on peasants who were forced to provide tithes, taxes, monopolistic rights, labour obligations and other mainmortables often to absent or distant landlords. Only in Montmin did allodial freedom come relatively early. Thus, agro-pastoral farming provided only an economically marginal livelihood in this period of climatic constraint. It may also represent the beginning of a phase when out-migration of one sort or another became an increasingly important safety valve for the population of the region as a whole.[44] There is certainly clear evidence that mining and metal manufacturing activity fell into decline and was not revived for at least a

century.[45] Ironically, this may have represented a period of soil fertility recovery in some of the more marginal fields, because as of yet no critical threshold had been crossed to trigger complete soil exhaustion, so this period acted as a fallow period.

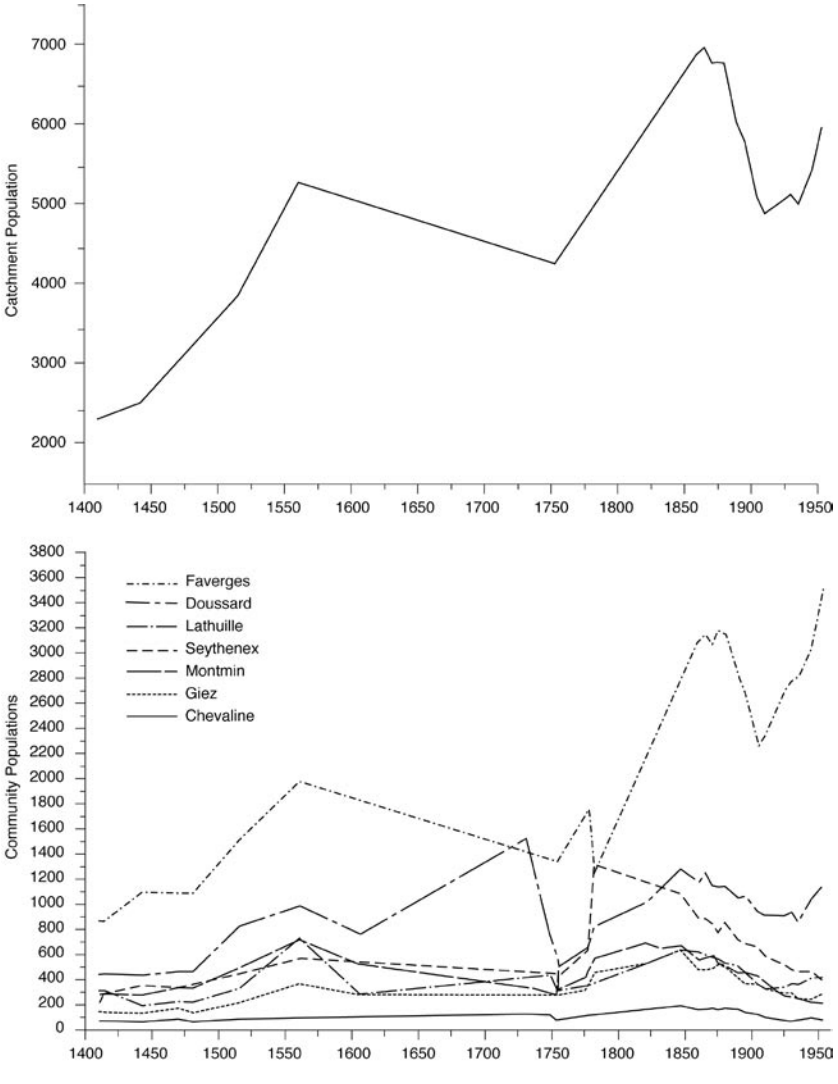


FIGURE 5. Catchment and community population figures 1413-2000.

iv) The Recovery of Population 1470–1600

A series of pastoral visits in the fifteenth century mark the progress of demographic and economic recovery throughout the catchment, albeit in some communities rather than others (Figure 5).[46] This increase was most notable in the upland community of Montmin, with an annual increase of 0.47 per cent between 1413 and 1561.[47] It is noteworthy that significant increases in the population of Faverges were accompanied by the revival of a number of small industrial processing units, which took advantage of improved drainage and increased hydraulic power of local streams and nearby mineral deposits, particularly iron ore extracted from the peak de Sambuy.[48]

Throughout the course of the fifteenth century, Monastic rights to utilise upland pastures began to be ceded to village communities and co-operatives. This allowed the growing population to expand their activities more into these areas.[49] The relatively high number of growing degree-days in Montmin probably provided the conditions necessary for an upward shift in cultivation, although there are no documents to support this view (Figure 6).

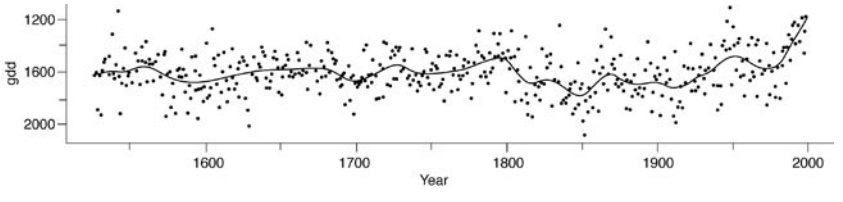


FIGURE 6. The number of growing degree-days at Montmin (1500 m.a.s.l) 1525–2000.

N.B. Refer to the methodology for an explanation of meaning.

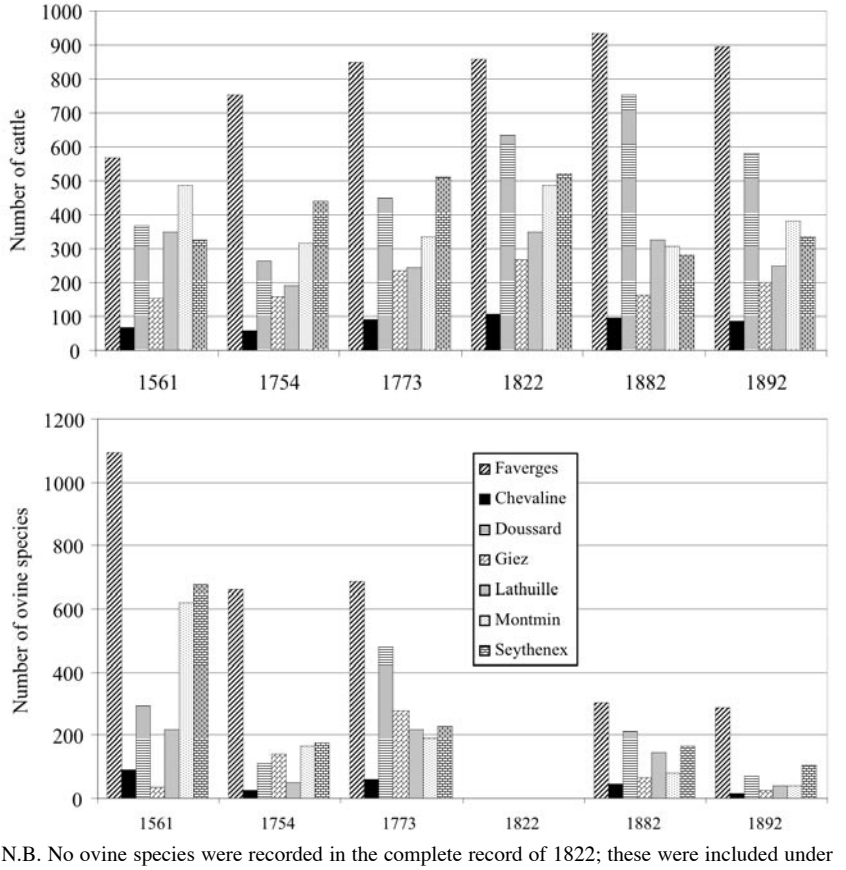
Assuming that farming systems did not change by the time of the first census of people and animals in 1561, we find an agricultural system which was again under stress by the end of the sixteenth century, if not before. A subtle relationship had developed between agricultural and pastoral practices in which a balance was struck between animal rearing and manure production on the one hand and lands set-aside for subsistence crops (a melange of cereals and beans) and feed for over-wintering animals, mainly hay. It was a farming system that relied heavily on co-operation between closely related kinsmen. The number of animals kept by each farming clan and the area of land farmed was a function of the labour units generated by the clan.[50] Hard-pressed communities became ever more dependent on co-operative livelihood strategies and common lands, most noticeably upland pastures and woodlands. Rights to these pastures were

passed on through inheritance. The inheritance system, which deferred partition for as long as possible, assured continuity of ownership and use of land.[51]

Population increases suggests that pressure on resources may have built up towards a crisis by the middle of the sixteenth century, if not earlier. There is significant evidence for the re-emergence of pressures on land resources, with disputes over cutting wood and pasture rights along the margins of communities as people tried to exact greater returns from land. The temptation to overstock inevitably resulted in the depletion of the natural resource base. Field and community boundaries were susceptible to dispute as private and inter-communal interests infringed upon intra- and inter-community rights of common for firewood, construction wood and pasture.[52] These disputes had a tendency to smoulder over the course of centuries.[53] The desire to solidify legal claims for land provided a political incentive to overstock pastures.

It is not until the first salt tax (*Gabelle du Sel*) on people and livestock in 1561 that we gain our first detailed view of farming in the catchment, which following subsequent census allows us to monitor changes in livestock numbers and large livestock composition in communities through to the late nineteenth century (Figure 7). Livestock provided meat, hides, dairy products, manure and draught power. The major livestock, cattle, sheep, goats and pigs, were raised in a seasonal pattern of transhumance similar to that described for an alpine community in Switzerland, which took advantage of different biomes to develop responding land tenure arrangements.[54] The total number of large livestock belonging to inhabitants living within the catchment in 1561 was 7617. Faverges, as the largest community, had the greatest numbers of animals. Sheep dominated in all communities, although goats are strikingly prevalent in greater numbers than cattle. Clearly there was no distinction between the stocking policies and livestock species composition found in mountain and lowland village communities. The amount of manure available to village communities was relatively low given the typically small size and low productivity of livestock at this time (Figure 8).

In this largely subsistence society the number of animals was closely related to the land available for forage crops to sustain flocks through a period of winter stabling.[55] High population and high stocking rates made for a close correlation between animals and the total land area available for each family, with this land best managed in large family groupings known as *gens*.[56] With no cadastre available in 1561, we can only assume from what we know of subsequent inheritance and land use practices that the large human and animal populations would have resulted in a very fragmented landscape of small strip fields, even with co-operative land use strategies in operation. The large number of plots registered in all communities in the 1730 Cadastre supports this view. Nowhere was this more evident than in the mountain communes of Montmin and Seythenex, which points to pressures in these steep and potentially unstable upland environments. This is further emphasised by reviewing the amount



N.B. No ovine species were recorded in the complete record of 1822; these were included under caprine species.

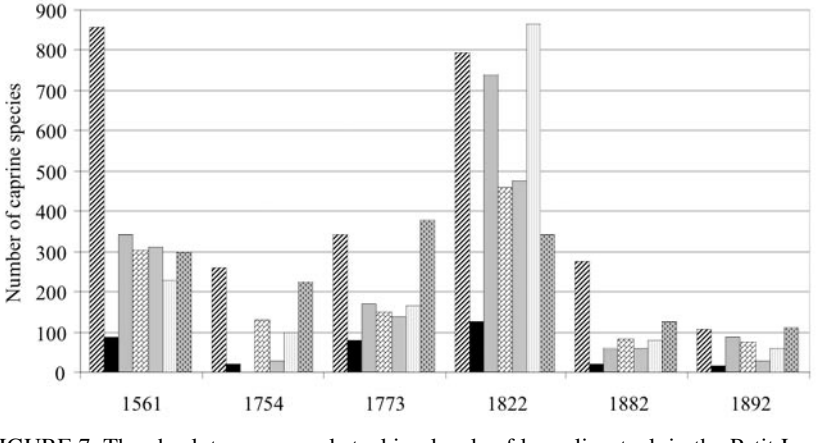


FIGURE 7. The absolute communal stocking levels of large livestock in the Petit Lac Catchment 1561–1892.

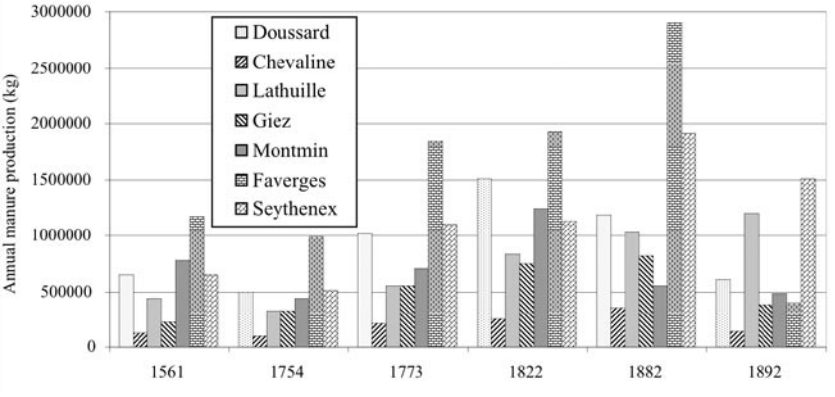


FIGURE 8. Annual manure production (kg) in the Petit Lac Catchment 1561–1892.

of pasture available to cattle in Montmin during this period. In doing this we discover that there was a potential shortfall (-89.4 hectares) in pasture given the known number of livestock units, which would have forced livestock into woodland pasture or led to overgrazing (Table 1).

TABLE 1. Excess and shortfall in the upland pastures in Montmin 1561–1892.

Year	1561	1754	1773	1822	1882	1892
Area of upland pasture (ha)	280	280	280	279.91	388	388
Total Livestock units	369.4	188.95	216.9	408.9	202.4	236.5
Shortfall/Excess (ha)	**-89.4**	91.05	63.1	**-128.99**	185.6	151.5

The benefit of having so many animals in Montmin is that manure availability was good despite the small size and stature of livestock (Table 2). Thus, soil fertility was unlikely to be compromised during this period.

It is interesting to note that around this time a major flood record begins at Annecy.[57] It seems likely that this problem was triggered to some degree by renewed grazing pressures on upland resources, which had not yet progressed into a problem of declining soil fertility.

v) Malthusian Checks in Population 1600–1750

During the late sixteenth and seventeenth centuries plagues[58] and the ravages of the Little Ice Age (1670–1690s), when it became noticeably colder and wet-

ter in northern Europe, rocked the population.[59] Furthermore peasants suffered from the relatively suppressed wheat and rye prices in the Annecy markets during the period 1633 to *c.*1684.[60] These factors running alongside the impacts of foreign occupations and a rising tide of worker migrants gave this area its lowest resident population.[61] These conditions persisted into the eighteenth century (Figure 5).

The documents of the Cadastre Sarde gives a clear indication of the poor conditions at this time, with leading families consolidated in their core settlements in both the mountain and plain communities whilst extending into the gaps left in neighbouring communities.[62] Social mobility increased and the economic bases of communities widened as younger sons served in foreign regiments, travelled as peddlers and street traders and eventually as merchants and shop keepers in the growing cities of Lyon and Paris.[63] Even though the rural way of life changed very little over this period, niches were opened in the human ecology of peasant Savoy.[64]

All communities employed a mixed agro-pastoral system, but each community had different opinions on how best to manage their agrarian, pasture and woodland. For Montmin at least it has been possible to reconstruct changes in land use from 1730 through to 1950, whilst other communities have less completely reconstructed land use data, which show how land use has changed throughout the nineteenth and early twentieth centuries (Figure 9). In the 1730s arable crops were grown both individually and in melanges on different grades of fertile and productive lands found at different altitudes. Typically mountain agriculture followed a bi- or triennial rotation with short periods of fallow.[65] Rotations possibly differed over a small geographical area as they did later in the nineteenth-century agricultural census, although owing to the reduced fallow in the three-year rotation and the high numbers of livestock in these communes a two-course rotation was probably favoured throughout most of the catchment. The Cadastre Sarde reveals that during this period of reduced population pressures and clement climate, it was possible to cultivate arable land and convert rough grazing to meadows as high as *c.* 1500 metres in Montmin. The clear dominance of births over deaths in Montmin for this period suggests that population should have been growing; that it is not provides clear evidence of the importance of out-migration strategies to people from this community.[66] Unfavourable taxation conditions and poor returns from agriculture provided the antecedent conditions for the remaining opportunist farmers of Montmin to push cultivation to the altitudinal limit of viable agriculture in areas where soil fertility was naturally low and manure availability limited (Table 2).[67]

The general condition of the 1735 harvest in the canton of Faverges was poor, with the harvests significantly down on the previous years, but with landlords preference for payments of tithes in grain peasants were forced into adopting such crops as part of their livelihood strategies.[68] Despite these large and onerous tithes[69] the relatively large amount of uncultivatable lands and difficulty

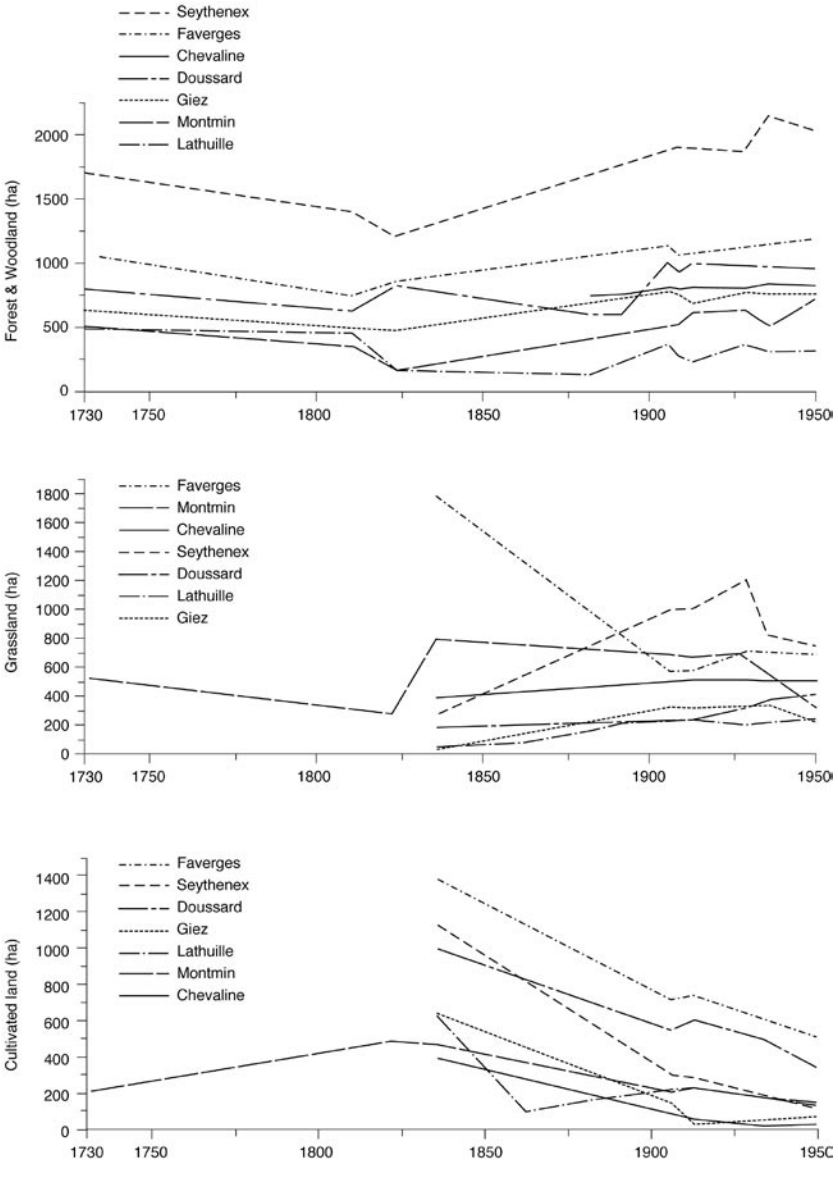


FIGURE 9. Land use change 1730–1950.

Data sources: Crook et al. 2002.

TABLE 2. Manure production and its potential application per hectare in Montmin 1561–1892

Year	**1561**	**1754**	**1773**	**1822**	**1882**	**1892**
Annual manure (kg/yr)	351600	247100	232580 –243280	463500	247100	560800
Daily manure (kg/day)	963.3	676.9	637.2 –666.5	1269.8	676.9	1536.4
Stabling period & Remue (days)	**120+56**	**120+56**	**120+56**	**120+56**	**120+56**	**120+56**
*Cultivated area**						
50% area (ha)	240	229.2	229.2	240.3	239.5	239.5
Total kg/yr	169539	119150	112148 –117308	223496	119150	270413
Per ha kg/yr	706.4	519.8	489.2 –511.7	930.0	497.5	1129.1
BUE†/ha	0.71	0.52	0.49 –0.51	0.93	0.50	1.13
Pasturelands						
Area (ha)	280	280	280	279.9	280	280
Total kg/yr	182061	127950	120432 –125972	240004	127950	290387
Per ha kg/yr	650.2	457.0	430.1 –449.9	857.4	330.0	748.4
BUE†/ha	0.65	0.46	0.43 –0.45	0.86	0.33	0.75
Stabling period & Remue (days)	**180+97**	**180+97**	**180+97**	**180+97**	**180+97**	**180+97**
*Cultivated area**						
50% area (ha)	240	229.2	229.2	240.3	239.5	239.5
Total kg/yr	266831	187525	176506 –184626	351752	187525	425593
Per ha kg/yr	1111.8	818	770.0 –805.4	1463.7	783	1777
BUE†/ha	1.11	0.82	0.77 –0.81	1.46	0.78	1.78
Pasturelands						
Area (ha)	280	280	280	279.9	280	280
Total kg/yr	84769	59575	56074 –58654	111748	59575	135207
Per ha kg/yr	302.7	212.8	200.3 –209.5	399.2	153.5	348.5
BUE†/ha	0.3	0.21	0.20 –0.21	0.4	0.15	0.35

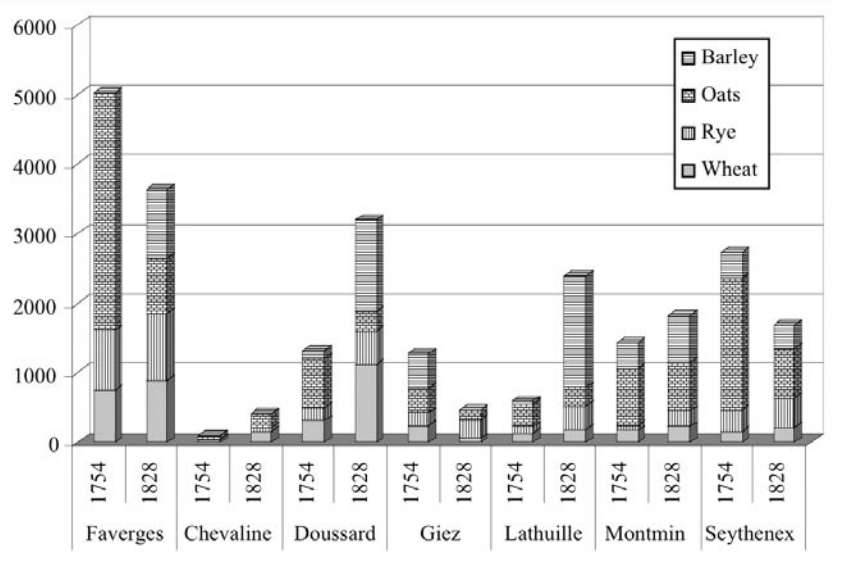
* Cultivated Land = *champs*, *prés*, *terres*, *prairie* and *jardins*

† Bovine Unit Equivalence 1 unit = 1000 kg/yr

in exploiting inaccessible forests explains the modest revenues attributed to noble and ecclesiastical lords per unit area compared with those *biens roturiers* in the other regions.[70] In Montmin over-taxation of inaccessible infertile and arid fields in the location of Sarroisse, which were prone to annually occurring natural hazards and dynamic slope processes, such as early snows, avalanche, landslide, and rockfall was an issue. At least 48 named people consisting of family members and consorts, who had rights to 2.1 per cent of the surface area, complained that the tallage, tithe, tax and high costs of maintaining buildings and land on the mountain exceeded between one third to a half of net revenue.[71] The petitioners issued a threat that these lands would be abandoned because they were no longer economically sustainable. A further concern was expressed that abandonment of these lands, including wasteland, meadow and pasture, would reduce the quality of cultivable fields, because the number of livestock would have to be reduced and the amount of manure decline. Clearly the absence of surpluses was making the infliction of heavy tithes difficult throughout the catchment. This was borne out by the 341 erratum noted in the Montmin Cadastre Sarde, with 340 plots of land receiving a reduction in tallage as a result of a reclassification of fertility to a lower level. This is, perhaps, further evidence of declining fertility, brought about by a shortfall in manure. Somewhat surprisingly, forest cover remained high at this time despite incursions of arable land into higher areas and the fact that woodlands and scrub had commercial value, acting as it did as a reservoir for building materials, fuel, resins and forage including hunting. Three types of wood in particular had commercial value in 1730: chestnut, fir and brushwood. [72]

By the mid-eighteenth century population had reached a nadir and fewer animals needed to be maintained whilst a protracted period of climate change exacerbated by anthrax epizootic,[73] low livestock and meat values in local markets and the Spanish occupation resulted in a reduced number (4406) of livestock in the catchment.[74] Faverges, with more access to pasture and forage from lower lying land, continued to have around double the livestock of the nearest rival Seythenex, although all communities excluding Giez experienced a significant decline in livestock, particularly in goats and sheep. This decline was felt most in Faverges, Montmin and Doussard respectively, leaving pastures in Montmin under-exploited. In some communities this also represented a shortfall in livestock and concomitantly manure was scarce.[75] A hay shortage meant that less financially liquid farmers were forced into selling their cattle after the sowing of seeds at Pâques, and restricted labour and seed sowing during autumn. In Doussard, Chevaline and Lathuille the community emphasis switched from sheep and goats more towards cattle breeding for sale to lowland farms.

In grain production Faverges dominated, whilst Chevaline barely produced any grain. Oats was the principal grain crop in the catchment at this time, which reflects the relatively harsh agrarian conditions (Figure 10). The large tithe deductions for all grain and leguminous crops but rye probably made the



N.B. Whilst potatoes were included in the incomplete 1822 census they were for some reason not included in the 1828 census.

FIGURE 10. Grain production in the catchment 1754 and 1828.

latter a more important staple crop in peasant diets, it being used in particular for bread making.[76] Legumes and barley had most importance in the mountain communities of Montmin and Seythenex, whilst the hardy crop barley also predominated in Giez, a north-facing parish with poor aspect. Arable farming went into decline throughout Savoy in the period between 1735 and 1775, with wheat and rye prices rising in the Annecy market over the period 1717 to 1792,[77] although these increases were said to also reflect wider economic trends found throughout Savoie, France and Catalogne.[78] Excesses and shortfalls, beyond a community annual subsistence need in grain production, were found in a number of communities, with shortfalls mainly occurring in important staple crops[79]. During these hard times it seems likely that chestnuts once again assumed great importance as a famine crop.

Some of this scarcity can be attributed to the low average seed yield ratios for all grain crops and legumes in the mid-eighteenth century. This suggests that soil fertility was low and agricultural practices ineffective. There is evidence that most communes on the plain were suffering from declining soil fertility and poor drainage, flood damage to land, particularly from the Ire, and abandonment of marshy meadows and other forms of rough pasture.[80] This was placing economic pressures on communal funds, a problem exacerbated by onerous taxes and dues and the increasing drain on family savings caused by the failure of young men

to send back remittances whilst in military service. These economic pressures were obviously a forcing factor in the individual abuse of upland pasture rights on the Charbon Mountain in the mid-eighteenth century[81] whilst late winters and heavy precipitation also delayed the period of summer pasturing.[82] Consorts from Doussard with rights to pastures on the Charbon Mountain complained that the produce of the mountain did not match the tallage over the past two years, forcing consorts to pay through other means, such as selling wood. This was an agricultural system crying out for improvements. It was a deteriorating agricultural system vulnerable to climate change and prone to erosion if overworked without additional organic or mineral inputs or overstocked.

vi) The Early Modern Period and Climatic Amelioration, 1750s –1850s

Climatic amelioration (Figure 6) began to be reflected in population and salt tax registrations in the later years of the eighteenth century. The 1773 registration of livestock is again a revealing proxy for changing conditions.[83] By now population had begun to recover from the slumbers and checks of the previous 150 years. This recovery in population was set to last just over 100 years, and was marked by distinctive changes and modifications to the agricultural landscape and the re-emergence of major mining activities in the region, which offered alternative employment and new markets.[84] These changes began slowly, but then accelerated exacerbating environmental deterioration along the way.

By 1773 the total number of livestock in the catchment had risen from its mid-century nadir to 6437, with goat numbers in particular rising with disconcerting rapidity.[85] Five of the seven communities now recorded upland pastures,[86] but with the cycle of out-migration and use of remittances abruptly broken by the invasion of Napoleon in 1792 peasants were forced to look inwards and upwards to expand arable farming. Driven on by an increased number of growing degree-days at altitude they were able to push arable farming to its local upper extremes (Figure 6).[87] With crops being grown at higher altitudes cereal production rose considerably from the mid-eighteenth century.[88] Seed yield ratios remained low in most communities, which suggests that the increase was due to expansion in the arable area as opposed to major improvement in inputs, although manure levels had began to increase.[89] The biggest relative increases in community production came in Doussard, Lathuille and Montmin, suggesting a partial switch to upland expansion, although total grain production had dropped in Seythenex. The composition of the cereal crop changed quickly between 1822 and 1828; as a result of these changes, barley became the most important grain crop in the catchment, but a far more even spread of crops was evident in each community.[90] There is no definite date for the introduction of the potato into the catchment, but the earliest record appears in 1822.[91] The large amounts of potato grown in the catchment suggest that this crop was well established and probably introduced sometime earlier, perhaps nearer to the

more general dates given for Faucigny.[92] The liberating dietary properties of this sturdy and robust starch crop are well known. It solved a serious famine problem whilst its surplus was sold in markets. Maize also appears for the first time in the incomplete inventories of 1848, whilst barley is not recorded at all. Chestnut remained an important crop in all communities, except for Montmin, where it was not recorded.

In 1822 we see that large livestock numbers (7544) had risen considerably from the late eighteenth century and as a result there was substantially more manure available now than in previous times. In all communities except Faverges, where the ratio was 50:50, and Seythenex, where cattle were dominant, there were more goats than cattle.[93] The numbers of livestock were greatest in three communities, Faverges, Doussard and Montmin. At the turn of the nineteenth century the general condition of alpages in the region of Annecy was said to be poor – '*a peine les habitants peuvent hiverner la moitié des bestiaux qui leur sont nécessaires pour l'agriculture*' – and for the second time a potential shortfall in upland pasture arose in Montmin (-128.99 hectares), which indicates that grazing pressures were likely during this period.

Endogenous and exogenous forces also placed both greater existing and new demands on woodland resources. These were driven by the need for more fuel wood, timber and charcoal. With a large mine partially in the catchment, wood had a high value, particularly relative to agricultural produce. Woodlands were ravaged, often illegally, although poor management and a lack of regulation were equally to blame.[94] That pressure on resources especially forestry and cropland occurred simultaneous to this population peak suggest a strong anthropogenic driver towards environmental degradation.

vii) A Period of Economic Malaise and Population Decline, 1860–1950

The Treaty of Turin in 1860 led to the incorporation of Savoy into the French State. People's freedom to move was reinstated and peasants once again chose strategies of out-migration and sent back remittances to the catchment and as a result population duly fell. At the end of Sardinian rule cereal production in Lathuile was low and seed yields pitiful, which reflected a drop in production from 1822.[95] Tubers and root crops were not widely grown, but a very small plot of maize had been introduced. The amount of pasture available for grazing was also relatively low and reliant on temporary meadows and pasture. If we look more closely at the pattern of growing degree-days it is clear that the peak at the end of the eighteenth century was actually followed by a dramatic decline into the middle of the nineteenth century. Thus, the earlier late-eighteenth-century expansion of the cultivated area into higher altitudes was short-lived, peaking in the 1820s. It seems likely that yields from these upper fields quickly became uneconomical and led to their abandonment and the retraction of the cultivated area at some point between 1830 and 1860.

By the late nineteenth century the number and variety of different crops grown in the catchment had expanded greatly from the early nineteenth century (Figure 11). Seed yield ratios for cereal crops, however, remained very low given the widely disseminated knowledge on land improvement.[96] The seed yields per hectare were generally greater for oats than any other cereal crop, which suggest that this crop above all others was suited to the environmental conditions found throughout the catchment at this time. The main cultivated area, including cereal crops and potatoes, was found in the community of Doussard, which marks a shift from the dominance of Faverges. Seythenex expanded its arable area principally through increasing the area of oats, wheat and a mixture of rye and wheat. Vines and chestnuts remained important crops on the catchment floor, whilst arboreal oil crops (e.g. walnut) had expanded from the mid nineteenth century.

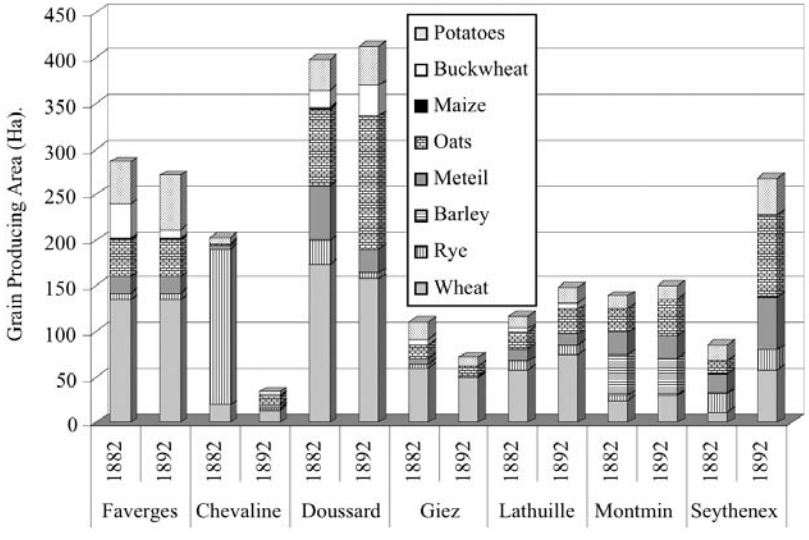


FIGURE 11. Grain producing area in the catchment 1882 and 1892.

For those communities where information exists there was a mixture of triennial and quinquennial rotations,[97] which indicates some improvement upon the late-eighteenth-century bi- and triennial rotations. Those communities operating a triennial rotation were also reliant on the application of manure, as no nitrogen-fixing species (a recent introduction) were used in these rotations, unlike the quinquennial rotation. The relative contribution of inorganic fertilisers was minute in comparison to natural fertilisers, and only appeared in the later decades of the nineteenth century and then only in Doussard, which was also a

community with a wider variety of nitrogen-fixing fodder crops than any other.[98] Clearly communities were adaptive and responsive to ephemeral sources of agricultural inputs when and where they became available. Major increases in manure occurred in the mountain commune of Seythenex, which suggests that radical improvements to soil fertility may have occurred in this community at this time. Fertiliser was the most important single input to agriculture and its use peaked in 1882 as a result not only of livestock numbers, but also improvements in livestock breeding.[99]

Permanent natural non-irrigated meadows predominated, except in Chevaline and Doussard where temporary meadows were more dominant. Chevaline, Montmin and Lathuille all extended their pasturelands during the later part of the nineteenth century, in line with a reducing human population. Later in the century livestock censuses indicate a shift towards a pastoral-dominated rural economy, with cattle numbers dominating large livestock composition in all communities. This points to a greater emphasis on the *fruitière* system[100] with a clear transitional shift in agriculture towards adopting more intensive milk produce-orientated '*vente du lait*' pastoralism.[101] With this came a significant decrease in total large livestock in the catchment between 1882 (9552) and 1892 (7482), but unlike in earlier periods manure availability did not decline.

At the end of the nineteenth century all communities were characterised by highly fragmented field systems with the average size of field plot below one hectare in all but two communities, Seythenex and Chevaline.[102] Having said this, for all communities this constituted a process of consolidation from the conditions of the early eighteenth century. There were a large number of small parcels and a small number of large parcels, the latter of which constituted a large part of the overall surface area. As a general rule of thumb larger parcels related to pasturelands or forestry, medium parcels to natural and artificial meadows, whilst the smaller parcels were associated with arable, legumes, tubers, hemp, flax and garden cultivation.

Woodlands had gradually and somewhat intermittently recovered from the dramatic deforestation of the 1840s and for a large part the landscape assumed stability, particularly as the cultivated area in the catchment also declined (Figure 9).[103] Not even the effects of two World Wars could derail this process of environmental improvement, although the upsurge in pastoralism lasted only roughly to the end of the Second World War and the start of the modern period, not discussed here.

DISCUSSION

The documentary evidence points to seven main phases of human occupation and exploitation of the environment in the Petit Lac catchment from pre-history up to the pre-modern period. It is in a long-term context of the threat of overex-

ploitation that we should read this archaeological and documentary archive of land use change. All periods have distinguishing demographic characteristics, varying agrarian conditions and different land use strategies, thus demonstrating the non-stationary characteristics of this system. The question asked is how these factors combined or indeed decoupled to create periods of environmental stress. It is necessary to identify what triggered these events, such as earlier demographic phases or human mismanagement, and to ask at what scale and spatial pattern these events took place on. Further to this we must look for evidence of environmental thresholds being crossed and look for patterns of linear and non-linear response. Only then can we answer questions on the sustainability of farming systems in this area.

The evidence shows that the ebb and flow of population was driven by family group strategies that responded to both endogenously and exogenously driven changes in technology, the economy and political circumstances, whilst also running alongside natural population checks like epidemics and climate change. During times of peak population the pressures on land resources increased, particularly during times of reliance on pre-improvement agriculture. Paradoxically, both success and failure in the agricultural system could lead to circumstances whereby population was checked or reduced. The use of out-migration strategies and remittances provided an important safety valve for families that lived at a community subsistence level. When this was not an option population increased and the pressure on resources was felt most acutely at the margins of communities where an expansion of the cultivated zone was a strategy favoured to increase crop yields in a system where yields per unit area were typically low and taxes high. Thus, the cultivated area expanded rapidly in the twelfth century as a result of Cistercian assarts; it then peaked again at some time around 1561 as a result of demographic recovery and latterly in the early nineteenth century as a response to trade restrictions. The intervening periods were characterised by a general trend for the cultivated area to decline. Our more detailed understanding of agriculture from the mid sixteenth century through to the 1950s tells us that it lay in a precarious position. Just a small market dip in crop prices could create an agricultural crisis, as experienced in 1869 and 1877.

Low seed to yield ratios reflected the almost sole dependency on manure inputs until the twentieth century in all communities, which meant that until improvements in livestock breeding, changes in livestock numbers created changes to soil fertility. A close symbiosis developed between the demands for livestock and those for crops. At all times there was the need to provide enough winter fodder for livestock. Livestock figures were found to have a high degree of intra- and inter-community variability affected by demographic flux, extreme meteorological events, murrains and epizootics. Thus, the amount of manure available was seasonally and annually variable both in and between communities. The amount of manure required to maintain a hectare of arable land, without fertility declining and the risk of erosion increasing, varies according to local

conditions. A useful general figure for pre-improvement agriculture is that each improved arable land hectare needed the added input of around 1.75 Livestock Units to maintain fertility.[104] Estimates closer to Montmin, point to the manure of four oxen, or four Livestock Units, filling two to three good carts being sufficient to fertilise one journal (0.295 hectares) of arable land in Savoy, which is somewhat less efficient.[105] Based on the general figure, there was only one period, 1892, when there was sufficient manure to maintain soil fertility in the cultivated area. This was only possible under a longer 180-day stabling period, when it was easier to collect and distribute manure onto the cultivable area. It is likely that night soil was also used on fields, although there is no documentary reference to this practice, and that manure from the upland pastures was brought down to some degree to the arable fields. All of which means that the main pressures on soil fertility fell on the upland pastures, which normally received less manure and where it was difficult to distribute this manure evenly. Thus the full impact that natural fertilisers had on soil regeneration was dependent very much on how this manure was distributed, which unfortunately is a question that remains outside the scope of this paper. Clearly though, manure scarcity in the eighteenth century led to soil fertility being compromised both in the uplands and on the plain.

Woodland and scrubland clearance and regular maintenance were all quintessential properties of maintaining high quality upland pasture. Each phase when sheep and goats dominated livestock figures points to increasing pressures at the margins of these pastures. It is feasible that the high numbers of goats and sheep found in both 1561 and 1822 would have placed a grazing pressure on upland pastures that could have altered the vegetation cover, deflecting succession processes and degrading the quality of pasture.[106] This would lead to a reduction in the number of livestock that could be maintained with profit on such pastures, as experienced in the eighteenth century. Goats in particular applied a grazing pressure when allowed, or indeed forced, to graze on young saplings, turning woodland-pasture into poor pasture. Importantly, the grazing requirements of a goat doubles on lower quality fodder, thus accentuating this problem.[107] The grazing regimes of goats and sheep also meant that less manure was available for the high quality pasture required for lactating cattle. Thus, periods of pasture deficit, such as 1561 and 1822, could have led to overgrazing and, when combined with deficits in manure, could have led to periods of declining soil fertility and enhanced vulnerability to soil instability, high rates of runoff and erosion. It is argued that these patterns of change may have been accentuated by coinciding reductions in forest cover.

Forests and woodlands have been quite robust to change in this part of Western Europe.[108] A felled tree rarely dies unless uprooted and can, depending on the species, quickly re-establish as coppice, which can provide even greater economic return as wood rather than timber. The largest impact on forestry probably came during the monastic period as assarts and clearances were

established. Any earlier uprooting and clearance was most likely small-scale, although large enough for agricultural fields, fragmentary and temporary. Post Monastic deforestation was found to be driven by periods when revenue from wood and timber sales remained relatively high in relation to crop sales, as the woodlands were likely to be over-exploited by individuals, communities and timber merchants at these times.[109] This, however, was not enough to drive major catchment-scale changes in forest cover, that is, not until these periods coincided with major mine workings in the catchment and military invasion as happened in the early nineteenth century. So it seems that the latest phase of pressure on woodlands coincided with pressure on upland pastures, and the flood record to some degree concurs with this, particularly in the Ire valley.[110] That there is no discernable record of major flooding in the catchment until 1570,[111] unlike in contiguous regions, suggests that the increased pressure on upland resources noted at this time may have triggered a delayed slope destabilisation effect that probably had its root cause in the assarts and clearances of the Monastic expansion. The short-lived environmental recovery, which occurred during the demographic collapse of the fourteenth century, merely served to slow down a longer term pattern of environmental deterioration.

Agriculture during the period studied in detail was unable to sustain intensification in forms other than self-limiting bursts, which created a myriad of problems for populations born into one system but having to adapt to the other.[112] This was an oscillating system unaccustomed to stasis and steady state over generations. It appears that whilst the catchment remained locked in a largely closed socio-economic subsistence system, agricultural objectives sufficed to sustain livelihoods at the level of the family. It seems that only modest objectives in returns from this agricultural system allowed it to remain ecologically sustainable. Periods of slacking off in the arable system allowed a level of recovery in the hinterlands, whilst bursts of increased productivity in the arable led to a rapid depletion of nutrient supplies from the arable hinterlands. These later periods were possible precursors to increased upland erosion driven by financial burden, making them vulnerable to periods of heavy precipitation and/or rapid snowmelt.

The question remains, did people recognise these problems? The issue of agricultural and forest sustainability was realised as early as the Monastic period and perhaps earlier, whilst the concept of livestock carrying capacities on pasturelands was introduced early into contractual rents.[113] These concepts were carried through into eighteenth-century *Gabelles* and nineteenth-century agricultural censuses. Throughout this time families adjusted their dependent numbers through migration, with only selected individuals allowed to stay and marry until further land had been acquired or deaths occurred and new niches arose. Caveats, promulgations and laws periodically regulated or outlawed what were perceived as economically damaging activities, like goats grazing in new plantations, which in turn were also perceived as environmentally damaging.

This partly drove the fluctuations in animal numbers. Forest regulations also prohibited such activities as clear felling and regulated grazing in young plantations, as it was said to cause erosion and destabilise slopes and be connected with flooding.[114] Thus, environmental problems were recognised throughout the study period and their effects generally understood, but the causes were often less than transparent and accountability for prevention and rectification hard to establish and prove. This process has become more scientific and empirical in conjunction with greater centralisation of environmental guardianship and stewardship, but environmental laws remain hard to enforce. Recent agricultural trends have provided far greater stability to the surface foliage, reducing susceptibility to topsoil erosion. Abandonment of cultivated fields has provided greater stability to the landscape with woodlands in particular returning to early-eighteenth-century levels.

CONCLUSION

- There were two main demographic crisis periods where both human and livestock numbers were high, around 1560 and 1780–1840.
- Environmental deterioration in the form of a combination of physical and biological responses, such as depleted soil fertility, overstocking of pastures, epizootics, deforestation and flooding, which sometimes coincided, occurred most in the 1730–1770s and 1840–1860s.
- Lowland demographic change to some degree drove upland land use into unsustainable practices. The effects of these upper land use changes were felt most on the plain.
- Changes in land use were driven by demographic fluctuations, fiscal constraints and economic incentives. Peasants were responsive to both proximal and distal push and pull factors, such as the development of commerce and peddling trade and new and alternative employment and trading opportunities arising from periods of industrial and technological innovations, eventually associated with a process of urbanisation both in the Prealpine lowlands and further afield.
- Military invasions periodically heightened the problem of over-exploitation of landscape, increasing local people's vulnerability to environmental change.
- The documentary record points to only occasional periods when the agrosystem was sustainable, which were characterised by a release in demographic pressure in the upland regions of communities.

NOTES

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[2] Elvin et al. 2002,1.

[3] Becker and Bugmann 2001.

[4] More details of the project can be found on http://www.liv.ac.uk/geography/levan.

[5] See Foster et al. 2003 in press.

[6] A process probably started in the later Roman period (Boissonnade 1937, 4).

[7] Mariotte et al. 1978, 322.

[8] Foster 2001, 24.

[9] Ibid.; Hu 1997,15–16.

[10] Van Steijn 1996.

[11] See Benedetti-Crouzet 1972.

[12] Siddle and Jones 1983.

[13] Bruchet 1977; Guichonnet 1975; Vayssiere 1981; Barbero 2000.

[14] The assumption was made that a prerequisite area of land is required for a known number of animals, given that the area of cultivated land has remained relatively constant through time.

[15] D'Helens 1996, 25–32.

[16] The widespread availability of inorganic fertilisers in the catchment did not occur until after 1892.

[17] Nicolas 1978, 699–707.

[18] Lathuille was chosen because it had detailed individual records in 1882 and 1892 and was also the only commune with a surviving record for 1862, thus crossing a wider time span than the other communes.

[19] The period of time for which livestock are moved onto the upper pastures and alps in summer.

[20] There is a clear spatial relationship between distance from settlements and declining soil fertility that also manifests itself in yield values found throughout the 1730 cadastre.

[21] Based on a biennial rotation with one-year fallow.

[22] see Slicher Van Bath 1963, 294.

[23] Viallet 1998, 127.

[24] Pfister 1993.

[25] Roughly speaking the highest altitude at which crops can be grown in the catchment.

[26] The pre-Celtic origins of the word Alp point to a possible earlier period of clearance (see Chavoutier 1977, 5; Jeanneret 2001, 314–19).

[27] Privat 1973, 78.

[28] Grande and Delatouche 1950, 42.

[29] The monastic *essart* involved *fourgons* cutting down trees, tearing out undergrowth and then setting fire to this kindling to burn out root systems usually over the period of a day (Chavoutier 1977, 10).

[30] Mariotte et al. 1978, 322; Coutin 1933.

[31] Detraz 1992, 75–99.

[32] Salaried labourers and tenants under *corvée* obligations carried out most of the work on the directly exploited cultivable land, using newly improved agricultural techniques (Grande and Delatouche 1950, 147), whilst sheep rearing for wool required large areas of mountain pasture.

[33] Guichonnet 1975, 138–96; Chavoutier 1977, 18; Viallet 1998, 125–6.

[34] Grand and Delatouche 1950, 147 & 150; Duby 1991, 387 & 390.

[35] See Burnier 1865, 34; Grande and Delatouche 1950.

[36] Mougin 1914, 86.

[37] Braudel 1966 Vol 1, 138; Duby 1968, 119; Koenigsberger 1987, 137.

[38] Brondy et al. 1984, 183.

[39] It may be that these population figures represent under-estimates in the catchment, given that many people were needed to create assarts by grubbing out trees. Thus, the number of people per *feux* may have been larger.

[40] See Braudel 1966; Duby 1968, 27; Slicher Van Bath 1963,18–19; Brondy et al. 1984,183; Binz 1963, 182–3.

[41] Brondy et al. 1984, 183.

[42] Bautier 1971.

[43] Depending on whom you believe, either c. 1350 or c. 1450. (Ladurie 1972; Pfister 1993).

[44] Siddle 1997, 1; Viazzo 1989 chp. 1–6.

[45] Forbes 1956, 69.

[46] Binz 1963, 182–3; Coutin 1933.

[47] Binz 1963, 182–3.

[48] Tissot-Dupont 1975, 1–19.

[49] Chavoutier 1977, 14; Viallet 1998, 50.

[50] Siddle 1986b.

[51] Siddle and Jones 1983; Jones 1987; Siddle 1986a & 1986c.

[52] Bautier 1971, 155.

[53] Ibid.

[54] Netting 1972, 143.

[55] Siddle 1986b, 132.

[56] Ibid., 136.

[57] Higgitt 1985, 36.

[58] Unidentified plague, not recorded elsewhere in the catchment, was recorded in Montmin in the early part of the seventeenth century, with 43 deaths recorded in 1629 and 48 deaths in 1630 (Mariotte et al. 1978, 322).

[59] Devos and Grosperrin 1985, 123–148; Poitrineau 1983; Guichonnet 1975; Ladurie 1972.

[60] Nicolas 1978, 589–90.

[61] Siddle 1986c, 137.

[62] Ibid.

[63] Siddle 1997, 1–20.

[64] Jones 1987.

[65] Beauregard 1812.

[66] Jones 1983 Figure 9 between pp. 16 and 17.

[67] For example, 37 per cent absent owners on the Pre Verel. See Siddle 1997, 1–20.

[68] By $^{1}/_{3}$ winter wheat; ½ legumes; ¾ barley and oats; ½ wine; and ¼ fruits.

[69] In Montmin each Savoy journal of land belonging to the Abbey at Talloires was charged an annual tithe (Annecy measures) of ½ quart (11.1 litres) of ears of wheat, 14 coupes (1244 litres) of wheat and 20½ coupes (1821.6 litres) of oats. Other land was subject to an annual payment to the Reverand Cuvés of ½ quart of ears of wheat, 3 coupes (266.6 litres) of wheat and 4½ coupes (399.9 litres) of oats. All other crops were exempt from these tithes.

[70] Nicolas 1978, 143.

[71] E.g. the annual return from an undisclosed area of communal land on the mountain, which was charged a *taille* of 19 livres, was only one livre.

[72] Crook et al. 2002.

[73] The pays-bas suffered from fodder shortages and poor quality fodder because of rain and cold weather. These deficiencies in diet led to annual outbreaks of epizootic that ravaged cattle in the environs of Annecy and the *bailliages* of Bauges. In 1746 a period of excessive heat led to a new anthrax epidemic that forced the conseil de santé to ban cattle commerce until March 1747.

[74] Nicolas 1978, 707.

[75] There was an almost catchment-wide shortfall in pigs, whilst Faverges and Giez lacked adequate cattle and Montmin adequate goats. Strangely Doussard had a shortfall of cheese, but no shortfall in cattle.

[76] Montmin, 1754.

	Yield (hl)	Seed (hl)	Seed: yield	Tithe ratio	Tithe (hl)
Wheat	171.91	37.4	1 : 4.6	1 : 7.5	22.9
Rye	60.17	20.06	1 : 3	0	0
Barley	371.22	106.06	1 : 3.5	1 : 20	18.11
Oats	552.57	188.52	1 : 2.93	1 : 23	24.02
Legumes	60.17	20.06	1 : 3	1 : 7.5	8.02

Thus, wheat and legumes in particular were susceptible to large tithe deductions.

[77] Between 1717 and 1792 the value of wheat increased by 66.3 per cent, rye 80.5 per cent and oats 74.8 per cent in Annecy markets (Nicolas 1978, 705).

[78] Slicher Van Bath 1963, 213; Nicolas 1978, 587.

[79] In all communities but Montmin, there was a shortfall in essential grain crops such as rye, oats and barley, although there was excess wheat in Giez and Lathuille.

[80] In Doussard the general demise in harvests was not down to specific crop failure, but poor soil fertility.

[81] Communal land was exploited for personal gain, perhaps putting additional grazing pressure onto extensive upland pastures. Consorts from Lathuille and Doussard failed to pay tallage over 25 years leaving 42 livres outstanding. Thus, families faced with increasing financial hardship were possibly forced to exploit and abuse this system to offset debts.

[82] Nicolas 1978, 580–1.

[83] This document was not as broad in scope as the earlier 1754 salt tax and only included livestock numbers, tithe deductions and a few additional items.

[84] A later paper will address the build-up of industry in the catchment.

[85] An increase felt in all communities, but for Montmin, which stayed at a similar level to 1754. More sheep and goats were stocked than cattle.

[86] Seythenex had three upland pastures, Giez two, and Chevaline and Faverges one each. Montmin also had upland pastures, but was excluded from the list.

[87] It was possible to cultivate arable land as high as *c*. 1400 m in the cirque and on the slopes above the Montmin hamlets and to convert rough grazing to meadows.

[88] Catchment cereal production in 1828 (13638 hl) was considerably higher than in 1754 (11737 hl). Faverges, Giez and Lathuille dominated grain production in the catchment in 1822 (Seythenex is missing), whilst in Montmin production almost halved despite cereals being grown at the highest recorded altitudes in this community. Oats remained the dominant crop in the catchment.

[89] Seed/yield ratios in 1822 for all grain crops in Doussard 3:1, Montmin 4:1, Chevaline 2:1, Lathuille 3.5:1, Giez 3.5:1 and in Faverges rye/barley 3.5:1 and oats 4:1.

[90] In 1828 oat production fell by over half (-57 per cent), whilst wheat, rye and barley all increased production (+126 to 159 per cent) from the 1754 baseline figure.

[91] Statistique des Animaux: Province de Genevois: 1822 Observations from Faverges 25 July 1822 taken from 1821 harvest.

[92] The potato was introduced into mountain agriculture between 1740 and 1760 (Nicolas 1978; Blanchard 1956; Viallet 1998, 154).

[93] With no sheep category and extremely high levels of goats this suggests that sheep were counted in this category, a view supported by the fact that another incomplete record for 1822 does include sheep.

[94] See Crook et al. 2002.

[95] Seed yield/ha ratio in 1822 for all grain was 3.5:1. Seed yield/ha ratios for the years 1862, 1882 and 1892 are found in the brackets for wheat (2.4:1, 3:1, 3:1), rye (2.1:1, 3:1, 3:1), a mixture of wheat and rye (2.4:1,3:1, 3:1), oats (3:1, 3:1, 3:1) and maize (0.3:1, 1.2:1, 1.2:1).

[96] Beauregard 1812; Tochon 1871.

[97] Late nineteenth-century agrarian rotations: Faverges triennial – 42m^3 manure for each ha; Chevaline quinquennial – wheat; metail; clover; oats; potatoes; Doussard triennial – 120 gm/ha manure; Lathuille triennial – 180 gm/ha manure; and Seythenex quinquennial – potato; wheat; clover; wheat; oats.

[98] The main mineral input was chalk, which was used in most communities and there was a small amount of residue from urban and industrial processes, such as ash, also used.

[99] These improvements were slow to filter through (Cholley 1925, 451).

[100] Intensive cheese production on the alp.

[101] Steel 1981, 61; Montmayeur 1865, 43.

[102] Land units for 1882:

	Number of parcels	Ha	Average size
Faverges	9746	2520	0.3
Chevaline	1145	1504	1.3
Doussard	3778	1898	0.5
Giez	2815	642	0.2
Lathuille	1273	512	0.4
Montmin	2345	1214	0.5
Seythenex	3578	3430	1.0

[103] Crook et al. 2002.

[104] Slicher van Bath 1963, 294.

[105] Beauregard 1812, 167.

[106] Cooter 1978, 469.

[107] Mackenzie 1980, 22.

[108] See Rackham 1976.

[109] Crook et al. 2002.

[110] Ibid.

[111] Higgitt 1985, 36.

[112] See Cooter 1978, 471.

[113] Burnier 1865, 34; Chavoutier 1977, 17; Viallet 1998, 50.

[114] Crook et al. 2002.

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