From the restoration of French mountainous areas to their global management: historical overview of the Water and Forestry Administration actions in public forests

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ABSTRACT

To protect against natural hazards in mountainous areas, the French government has implemented a number of forestry and civil engineering works such as check dams in public forests since the 19th century. Specifying each dam's objective and protective functions is the first requirement for their continued maintenance. The potential technical functions of check dams have been clarified in a recent publication (Piton et al. 2016). In the first part of a series of papers on the analysis of the context and objectives, this paper focuses on how they were implemented in public areas by the Water and Forestry Administration from the end of the 19th century to the 1960s. We detail the objectives over time and the geographical locations. This national overview will help managers consider their present local protection structure management problems within an historical perspective.

KEYWORDS

Rehabilitation of mountainous areas; mitigation objectives; historical policy analysis; decision context

INTRODUCTION

In mountainous areas, natural phenomena put people and buildings at risk. Protection systems aim at mitigating this risk. In the French mountainous areas, a large number of protective structures and forestry works have been implemented since the 19th century.
As a consequence, more than 21,000 civil protection structures are presently registered in approximatively 3,800 km² of protective public forests.
The Water and Forestry Administration (WFA) carried out afforestation works and built these structures in public-owned areas from 1860 to 1964, focusing on torrential phenomena.
The National Forestry Office (ONF) has managed existing public forests, whereas the national government has been responsible for maintaining civil structures since 1964. These decision-makers must decide on actions to implement on protective systems. With its expertise, the present Rehabilitation of Mountainous Lands department (RTM) of the ONF assists them.

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Such decisions depend on the decision context, which includes regulatory obligations, technical limitations and the budget available that impose limitations and changes over time in relation to the sociopolitical context and technical knowledge. Making these decisions requires choosing the appropriate actions to implement. Protective actions on mountainous systems are compared based on several criteria such as the objective of the system, its effectiveness in achieving the objective, and its cost, all of which change over space and time. The objective of existing protection systems should be specified to decide on maintenance actions, but this also depends on the context in which it has been implemented. It can be difficult to understand it without overall knowledge of the changes in the decision context over time and space. To assist practitioners, we have undertaken an historical and geographical analysis to describe these changes examining several aspects at the French scale.

– Historical and sociopolitical contexts have already been thoroughly analyzed (Fesquet 1997).
– Scientific and technical knowledge on protection works has been reviewed in recent scientific papers and technical guidelines. For torrents, this knowledge has been operationally developed in France since the 19th century, but there was no summary of how it had evolved over time. Therefore, we analyzed the archives in detail to summarize the potential functions of check dams in torrential streams (Piton et al. 2016).
– Actual implementations of RTM laws provide a factual background for the decisions that have already been made. Analyzing these examples can help to describe decision contexts over time and space using several criteria: public-owned and afforestation areas as well as number and cost of civil protection structures. Up to the 1970s, three reports had summarized these aspects (Direction générale des eaux et forêts 1911; Messines du Sourbier 1964; Mougin 1931). There was, so far, no chronological comparison.

The present paper focuses on implementations of RTM actions by the WFA from the 19th century to the 1960s. In the Methods section, we detail the organization of the database. In the Results section, we briefly review the main elements concerning scientific, technical, and regulatory changes. We then provide an analysis of the implementations in public-owned areas. Overall, this analysis reminds the historical evolution of the RTM actions in France and helps to better understand some regional specificities or similarities.

METHODS

National archives reports were examined following three axes: i) local decision contexts within general, regulatory, and management contexts, ii) technical functions of protection structures such as check dams, and iii) the main implementations and resource distribution over time including the building of a database registered in a Geographic Information System (GIS). The data can be listed as follow:

works implemented by the WFA in public-owned areas

– technical aspects:
  – area (ha): public-owned, to be acquired, artificially afforested, naturally forested, impossible to afforest, to be afforested;

  - structures (against torrential floods): types, number of civil engineering and rustic check dams, channels (km), wattlings and fascines (km), drainage networks (km);
  - structures (against avalanches): types, supporting walls (m), benches (m), diversion dams (m);
- cost in current monetary value:
  - cost of public acquisition;
  - cost of works (against torrential floods): forestry, correction (civil engineering and rustic check dams), auxiliary (surveillance paths, fences, etc.) and others (studies);
  - cost of works (against avalanches): new, maintenance;
- contextual aspects:
  - exposed elements: type and number;
  - specified objectives of works;
  - natural phenomena involved;

forestry works implemented by local municipalities or by private owners, funded by the WFA

- Technical aspects:
  - area (ha): artificially afforested;
- Cost in current monetary value:
  - local municipality subsidies;
  - department subsidies;
  - WFA subsidies;
  - WFA subsidies to improve pastures and develop dairy cooperatives.

These aspects have been registered at the RTM perimeter scale (independent geographical entity where afforestation and civil engineering works have been carried out according to the laws), and they have been clustered within the administrative departments and the mountainous massifs. The data come from three sources (Direction générale des eaux et forêts 1911, Mougin 1931, Messines du Sourbier 1964) which summarized the WFA actions from 1860 to their publication (Fig. 1, 2a & 3a), at the national scale for the first and the third sources, and at the French Alps scale for the second. A chronological view can be extracted (Fig. 2b) that is completed by a new analysis of the existing RTM database. Overall, it describes the present protection systems that are now managed in the French RTM public-owned areas (Fig. 3b) and how we inherited these thousands of structures with their regionally specific types, locations and objectives.

RESULTS

Scientific and technical changes and debates

During the first part of the 19th century, the civil engineers Fabre (1748–1834) in 1797 and Surell (1813–1887) in 1841 advocated mountain afforestation as a national concern to control soil erosion in the mountains and limit solid transport in rivers and torrents. To reforest the headwater areas, Surell proposed using check dams, if needed, to stabilize the

stream bed before planting trees and bushes on their banks. Even if he also considered afforestation as an effective long-term solution, the mining engineer Gras (1806–1873), followed by Breton (1811–1892), first theorized specific check dam functions in 1850 and 1857: to curtail sediment recruitment from the bed and banks within a short-term objective, to consolidate cliffs and highly unstable areas, to definitively trap sediments upstream of dams, and to regulate sediment transport in torrent beds (Piton et al. 2016).

Everywhere the government owned the areas to reforest after 1860, works were tested. First check dams were built to support afforestation, stabilizing the stream-bed at its current level, applying Surell's theory. They were mainly local construction initiatives, rustic, lower than 2 m in height, and made of diverse materials: dry stones, wattlings and fascines, brush mattresses, sods with or without stones, and wood. Larger check dams in masonry or cut stones were also built in fewer numbers, e.g., since 1868 in the Saint-Marthe torrent (Hautes-Alpes) under the management of Demontzey (1831–1898), a renowned forestry engineer (Direction générale des eaux et forêts 1911).

Based on the aforementioned preliminary theoretical books and empirical implementations, in 1882 and 1897 the forestry engineers Demontzey and Thiéry (1841–1918) published technical guidelines. They distinguished forestry works, correction works (civil engineering and rustic check dams), auxiliary works, and others (studies) (Fig. 1). For torrents, higher check dams (more than 2 m high) were needed in addition to rustic dams. They generally were less than 4 m high and made of dry stones when sufficiently large stones were available. Masonry was used when stones were too small and for higher check dams. Other restoration works were also newly implemented, e.g., temporary retention dams, groynes, and embankments to center flow, diversion channels to bypass unstable banks, or dry stone drainage systems in landslide areas. For avalanches, techniques were limited to cut-stone walls and benches.

After the period of intense WFA actions (1886–1914), their utility, notably afforestation, was debated during the 1920s. This issue was explained in the scientific discourse between the geographer Lenoble and forestry engineers (Mougin 1931). Since the 1950s, technical developments have broadened actions. Steel and reinforced concrete have helped to develop sediment traps and higher check dams as well as new avalanche and rock-fall protection structures (snow bridges, netting fences).

Decisions concerning the management of protection systems in public areas have been progressively integrated into a new global natural hazard prevention policy since the 1970s, notably including land-use plans (Brugnot & Cassayre 2002). At the global watershed scale, current management must also take into account sediment continuity problems and sediment starving of valley fluvial systems, even though the initial objective was to curtail sediment production.

Regulatory context and management organization

The first law on afforestation (1860) aimed at extensively reforesting land to curtail sediment production in headwater areas and to limit flood peaks. Overly ambitious, it raised pastoralists' ire, leading to local armed revolts in some regions, such as in the Southern Alps. The law

on afforestation and grass seeding (1864) attempted to reconcile pastoral activities and soil protection using grass's stabilizing effect. They introduced public management in mountainous areas (Fesquet 1997). Afforestation and grass-seeding works were decreed to be in the public interest within designated perimeters. Within these areas, private owners and local municipalities had to build the structures on their land or the government would impose their construction. Moreover, private and local municipalities could carry out voluntary afforestation works with state subsidies out of the nationally defined afforestation perimeters. In 11 mountainous forestry districts, a specific afforestation department was associated with the local WFA administration.

The law on mountain area conservation and restoration (1882), also called the RTM law, reduced the afforestation ambition: the torrent control measures were concentrated in active areas (torrents, erosion, and avalanche release zones). The objective was to stop destructive events through restoration works. In these areas, the law attempted to reconcile mountain agriculture and sustainable behavior. Restoration works were declared of public utility within a given perimeter through a specific law. Previously treated areas could be integrated if restoration was needed: 703 km² in 1886 (Fig. 2B). Restoration actions could be implemented by: (i) the WFA in perimeters acquired by the French national government, (ii) local municipalities, or (iii) private owners through subsidized works, which were implemented mainly in the Cevennes and in the Northern Alps. Simultaneously, grants were awarded to support and improve land, pastures, and cheese cooperatives, mainly in the Pyrenees and the Northern Alps.

The law on the regulation of the water regime (1913) made it possible to declare new perimeters of public utility to protect areas from erosion processes even if they were not active. This had been partially anticipated in some regions (Cevennes, Southern Alps).

Since 1966, the WFA has been divided into local agricultural services and the ONF, which implemented actions according to the RTM laws in 25 departments (Fig. 2A). Ten specialized RTM departments within the ONF were created in 1971 (Fig. 3B).

Afforestation and civil engineering as technical tools to implement RTM laws

The 1860 and 1864 laws were applied to limited reforested and grass-seeded areas. The 1882 law aimed at controlling active areas subjected to erosion, landslides, avalanches, etc. Its implementation had different objectives depending on the areas' geography (Direction générale des eaux et forêts 1911).

– On slopes, stopping the loss of pastoral lands aimed at limiting rural exodus. Curtailing sediment production in the headwaters also aimed at limiting distant sedimentation damage such as in the Bordeaux harbor receiving sediments from the Mont-Aigoual massif (Lozère - 48). Notably in the Southern Alps and the Cevennes, forestry works were favored (Fig. 1) in extensive areas that had already been acquired (Fig. 2A), mainly using rustic correction works to stabilize torrents and gullies (Fig. 3A).
– Curtailing sediment production in the headwaters aimed at limiting increases in riverbed deposits and bed-shifting of torrential rivers, which aggravated floods and damaged fertile

agricultural lands, roads, and housing such as on the Var River's banks (Alpes-Maritimes - 06).

– In local torrent valleys, stabilizing materials or snow in the headwater areas aimed at limiting direct damage on productive agricultural lands, housing, industrial areas, roads, and railroads such as on the Arc River's watershed (Savoie - 73). In the Northern Alps, the dairy industry purchased limited afforestation areas (Fig. 2A) and favored civil structures such as check dams (Fig. 3A).

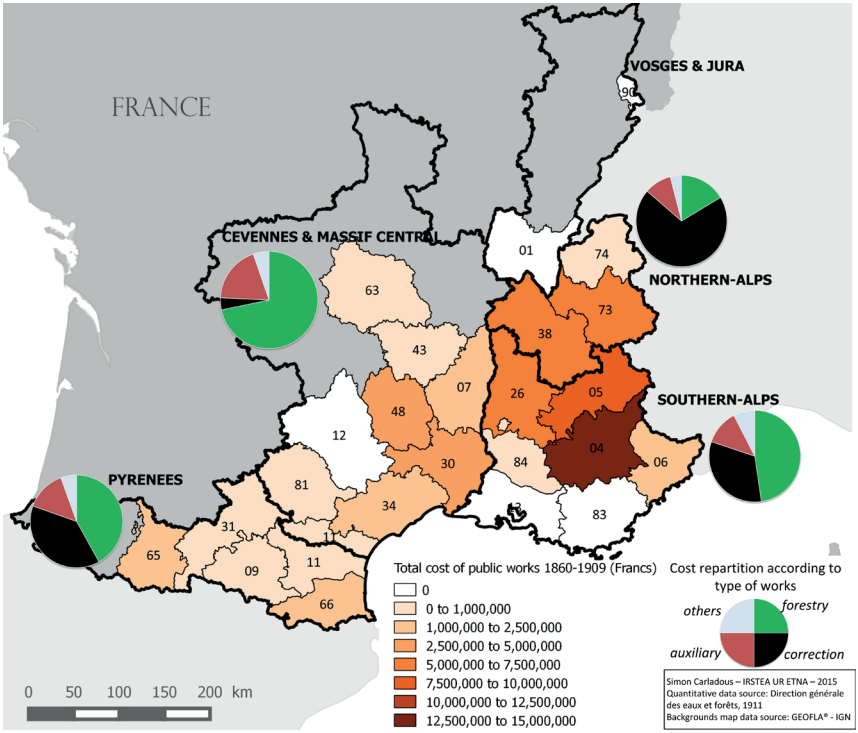

Figure 1: Cost distribution of works implemented in public forests in application of RTM laws between 1860 and 1909 depending on the administrative department. Correction structures were the priority in the Northern Alps. Forestry works were mainly used in the Cevennes. Correction and forestry works were more evenly distributed in the Southern Alps and the Pyrenees.

Since World War I, the number of new projects has decreased even if land acquisitions were not discontinued (Fig. 2B). Following World War II, the decrease in funding to maintain structures continued. Messines du Sourbier (1900–1989) provided a detailed national survey of implementations in 1964 (Fig. 2, Fig. 3A). Acquired areas at the national scale reached approximately 3,700 km², mainly in the Southern Alps and the Cevennes (Fig. 2) (Messines du Sourbier 1964).

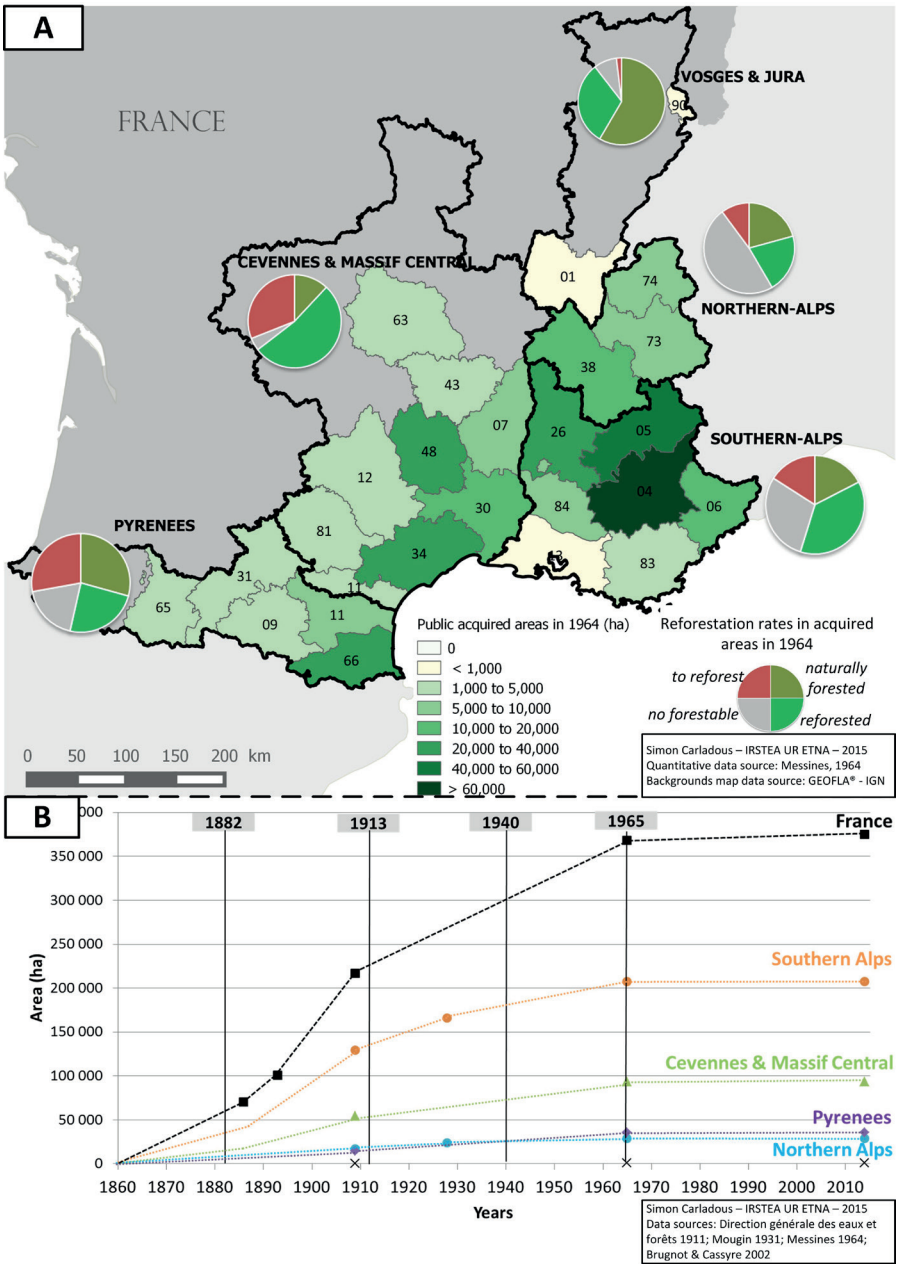

Figure 2: Distribution of RTM-acquired lands in 1965, their afforestation rate (A) and their evolution in the 25 RTM departments and the mountain massifs (B).

In application of the RTM laws in publically owned areas, more than 100,000 check dams, mainly rustic dams made of dry stones (Fig. 3A), 28 km of channels and tunnels (exclusively in the Northern Alps), 663 km of drains, and 68 km of avalanche protection structures (mainly in the Alps) were registered (Messines du Sourbier 1964).

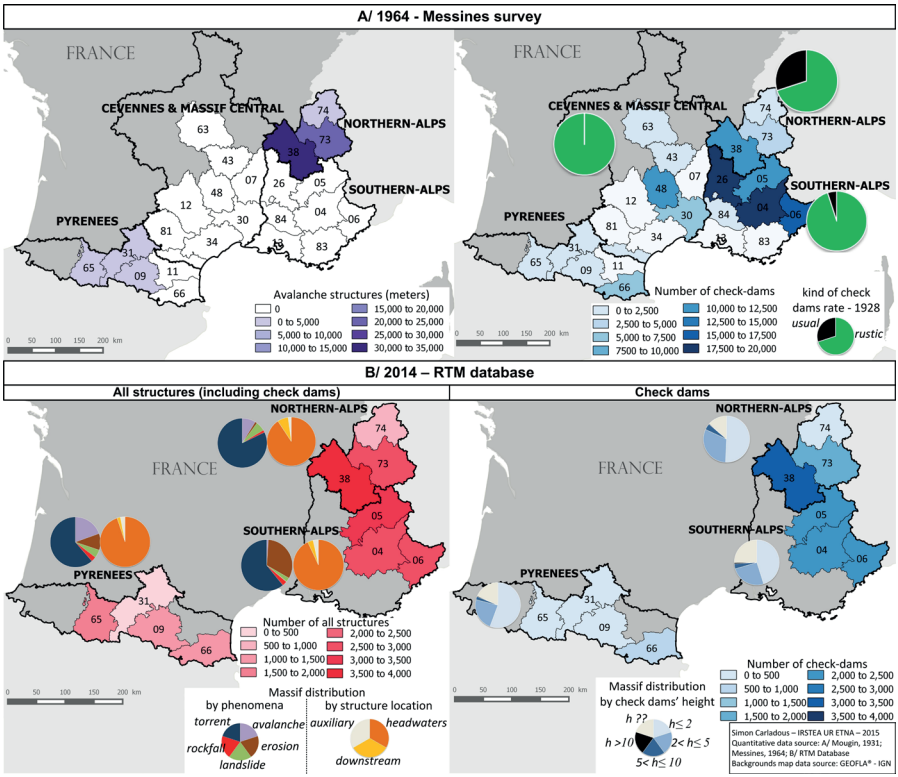

Figure 3: Geographical distribution of (A) works in 1964 and (B) managed works in 2014. The present distribution of managed avalanche structures (B) is explained by the historical preferential implementation of these works in the Northern Alps and the Pyrenees (A). The RTM civil engineering actions have been mainly implemented in headwater areas and in the Alps (B). In 1965, more than 100,000 check dams were registered, but they were mainly rustic dams. The proportion of usual dams was higher in the Northern Alps (A). In April 2014, more than 14,000 check dams were registered in the RTM database, covering 10 departments. Around 50% of them are lower than 2 m in height (B).

Many rustic check dams built before 1914 have not been maintained as planned in initial guidelines (Demontzey 1882), due to the lack of grants but also for multiple reasons such as technical evolutions (e.g. open check dams advent), decrease in expectations concerning the hydrological role of forests, artificial and spontaneous afforestation, rural depopulation and changes in the decision makers' priorities. Even if they were registered in 1964, the new organization of the RTM reduced the number of managed structures, focusing on the most relevant ones in the current decision context and technical comprehension of natural hazards

(Fig. 3). Today, as a result of all the past implementations, 85% of managed structures in the public forests maintained by the 10 RTM departments are located in headwaters and seek to limit the impact of torrents, including erosion processes. Eighty-five percent of torrential protection structures are check dams (Fig. 3B).

CONCLUSIONS

This paper overviews the changes in WFA actions according to the RTM laws from the 19th century to the 1960s. Several objectives have been assigned to protection systems within their geographical contexts: from extended afforestation in headwater areas to local protection. Protection structures have specific functions designed to meet their objectives. Forestry works and check dams have been the most widely implemented.

Presently, RTM experts are expected to manage protection structures, mainly check dams, both technically and strategically. For the former, the local functions of the existing check dams must be specified with their objective in mind. For the latter, the objectives should be reviewed. Maintenance decisions are taken according to the present context and protection objectives but must optimally be aware of the past historical decisions.

In the second part of this historical analysis (in preparation), we will describe the development of the overall management of mountainous areas since the 1970s, highlighting several key points such as the role played by avalanches, the public finance policy in favor of municipally-managed structures and of land-use plans, as well as the need for forest renewal.

REFERENCES

- Brugnot G., Cassayre, Y. (2002). De la politique française de restauration des terrains en montagne à la prévention des risques naturels. In FAO, ed. XII World Forestry Congress Conference proceedings.
- Demontzey P. (1882). Traité pratique du reboisement et du gazonnement des montagnes.
- Direction générale des eaux et forêts (1911). Restauration et conservation des terrains en montagne. Trois parties.
- Fesquet F. (1997). Un corps quasi-militaire dans l'aménagement du territoire : le corps forestier et le reboisement des montagnes méditerranéennes en France et en Italie aux XIX et XXèmes siècles. PhD Thesis, Université Paul Valéry, Montpellier III.
- Messines du Sourbier J., (1964). Enquête sur la conservation et la restauration des terrains en montagne.
- Mougin M.P. (1931). La restauration des Alpes.
- Piton, G. et al. (2016). Why do we build check dams? An historical perspective from the French experience. Earth Surface Processes and Landforms.