Current Forestry Reports (2026) 12:22
https://doi.org/10.1007/s40725-026-00282-y

REVIEW

Small Machines and Their Role in Forest Management - From Their Introduction to the Present Day with Automation

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Received: 9 July 2026 / Accepted: 13 July 2026
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Abstract

Purpose of review This review traces the development of mini forestry crawlers (MFCs) from earlier small-scale skidding machines to modern remote-controlled tool carriers, and evaluates their current applications, technological characteristics, operational performance, safety, soil impact, ergonomics, and automation potential.

Recent findings Recent studies show that MFCs have evolved from simple extraction-oriented machines into multifunctional platforms whose suitability depends on machine class, task–machine matching, site conditions, and work organisation. Field and bench studies report productivity, soil impacts, operator workload, remote-controlled felling performance, non-harvesting applications, and early automation functions.

Summary Mini forestry crawlers are most effective in constrained-access settings and in tasks that align with their limited payload while benefitting from high manoeuvrability, remote operation, and multifunctionality. Their advantages are therefore conditional on careful deployment, particularly with respect to soil moisture, turning intensity, traffic frequency, and operator workload. Future evaluations should adopt integrated performance metrics that jointly assess productivity, soil response, and human workload under realistic operating conditions.

Keywords Bunching · Environment · Ergonomics · Non-industrial private forestry (NIPF) · Skidding · Remote-controlled · Small-scale forestry · Soil impacts

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Published online: 31 July 2026

Introduction

Approximately 48 million hectares of forests in Europe are owned by more than 16 million non-industrial private forest owners [1, 2]. This highly fragmented ownership structure poses significant challenges for forest management and creates a strong demand for tools, services, and support systems tailored to small-scale operations under non-industrial private forestry (NIPF) conditions [3]. The diversity, fragmentation, and limited size of these holdings constrain management efficiency and increase the need for affordable technologies, targeted advisory services, and flexible operational solutions.

These challenges are particularly pronounced in forest operations, which represent the most resource-intensive component of forest management [4]. Consequently, both research and policy frameworks emphasise the importance of forest machinery that is economical, versatile, and adaptable to small-scale contexts. For example, Magagnotti et al. [5] describe a low-investment system for salvaging small-scale windthrow that relies on equipment capable of rapid reconfiguration for multiple tasks, illustrating the practical value of flexibility in small-scale forestry.

Mini-skidders and mini-crawlers generally meet these requirements, as they are comparatively economical, easy to operate, and flexible in use. In this review, mini-skidders and mini-crawlers are defined as compact tractors capable of negotiating sub-standard tracks and manoeuvring within dense residual stands. They typically feature low ground pressure, narrow width (≤2 m), and neutral-steering capability. Empty mass ranges from approximately 400 kg to 2500 kg, while engine power generally falls within the 15–30 kW range, although more recent models may reach 50–70 kW. Mini-skidders are most often tracked, which is why they are commonly referred to as mini forestry crawlers (MFCs). However, this terminology is not universally applicable, as wheeled variants with articulated or differential steering also exist, although they are less common.

Based on their origin, MFCs can be grouped into two main categories (Fig. 1). (a) Purpose-built machines are specifically designed and custom-built for particular forestry tasks. Their characteristics and attachments are tailored for efficient task performance. While specialisation is their main strength, it also constitutes a limitation, as it leads to small production volumes and relatively high purchase costs. (b) Adapted machines originate from compact vehicles that have been modified for forestry use, particularly for load pulling. This category includes all-terrain vehicles (ATVs), quad bikes, and snowmobiles (e.g., Ski-Doo Skandic), which are often fitted with simple roll-over protective structures (ROPS) and skidding attachments such as drawbars, winches, or small logging arches. Although their performance and versatility are limited, these machines benefit from wide availability, low purchase prices, and the ability to relocate independently and efficiently between work sites, with many being road-legal.

Based on general layout and mode of operation, three main machine types can be distinguished (Fig. 2). (a) Walk-along mini-skidders are operated by a driver walking behind or alongside the machine, controlling it via levers or an extended handle, similar to a motorised wheelbarrow. (b) Mini-tractors with a driver seat are operated from an onboard seat, typically protected by a ROPS or a basic cab, resembling conventional tractor operation. (c) Remotely controlled tool carriers are operated via wireless remote control, typically with an operating range of 50–150 m. This configuration offers maximum operator safety, particularly with respect to roll-over hazards, as the operator remains at a safe distance from the machine. Most modern mini forestry crawlers (MFCs) fall into this category.

Although mini-tractors, light harvesters, feller-bunchers, and forwarders may also be considered small and versatile machines, this review focuses specifically on equipment without enclosed cabins. Such designs represent compact and lightweight technical solutions that enable operation from a safe distance and provide a more cost-effective alternative to cabin-equipped machines. As a result, small multi-purpose tool carriers are becoming increasingly relevant for a broad range of forestry operations, from stand establishment and tending to final harvesting and extraction.

Furthermore, MFCs represent a modern alternative to traditional small-scale logging systems such as draft animal logging. The latter is increasingly constrained by high labour demands, continuous animal care requirements, an

Fig. 1 Mini tractor or skidder machines classified by origin: (left) purpose-built for extracting logs (credit: Schweier); (right) adapted for log skidding (credit: Spinelli)

Fig. 2 Classification of mini tractor or skidder machines by layout and mode of operation: (left) walk-along mini-skidder from 1985 (credit: Swiss Federal Research Institute WSL, Bildarchiv / FTE_01894_D_pos); (middle) mini-crawler with onboard driver seat (credit: Spinelli); (right) remotely controlled tool carrier (credit: Schweier)

Table 1 Temporal distribution of thematic forestry/MFC references cited in the Results section. Counts are descriptive and are intended to illustrate the temporal coverage of the literature discussed in the Results section

Publication period	Main literature focus	Reference numbers	*n*
1970–1989	Early development of mini-skidders, adapted small vehicles, mini-tractors, and first thinning/extraction concepts	[14], [15], [17], [18], [19], [21], [23], [24], [25], [26], [28]	11
1990–2009	Continued technical evaluations, ATV and mini-skidder studies, ghost-trail studies, cost comparisons, and early dedicated felling-head concepts	[16], [20], [22], [27], [29], [30], [31], [34], [35], [37]	10
2010–2019	Renewed interest in small-scale mechanisation, remote-controlled MFCs, productivity and environmental impacts, and forest-machine innovation	[32], [36*], [52], [55]	4
2020–2026	Recent studies and sources on remote-controlled MFCs, productivity and costs, soil impact, workload, safety, non-harvesting applications, market development, and automation/robotics	[33], [38*], [39], [40*], [41*], [42], [43*], [44], [45], [46*], [47], [48], [49], [50], [51], [53], [54], [56], [57], [58], [59], [60], [61]	23
Total			48

ageing practitioner base with limited succession, a declining number of commercial operators, and growing economic incompatibility with large-scale mechanised forestry infrastructure [6, 7]. These factors have contributed to rising interest in MFCs across many regions, particularly in Central and Southern Europe.

When skid trail spacing exceeds the effective boom reach of harvesters, fully mechanised harvesting with state-of-the-art machines becomes infeasible [8]. This situation is common, for example, in German state forests, where skid trail spacing of approximately 40 m is applied to meet soil protection and certification requirements [9]. Given that the effective boom reach of modern harvesters typically ranges from about 8 to 10 m [10], trees located in the midfield between skid trails must be felled motor-manually [11]. Under such conditions, MFCs can be integrated as complementary elements within semi-mechanised harvesting systems. In this role, they perform stem bunching and short-distance extraction of chainsaw-felled trees beyond the harvester's reach, thereby facilitating subsequent processing and forwarding [8].

Despite their increasing relevance for efficient forest operations, this machine category has received limited scientific attention to date. Accordingly, this review synthesises existing knowledge on the technical evolution of small multipurpose tool carriers for forestry. Specifically, we (i) systematically examine reported use cases and recent technological developments, (ii) provide a comparative overview of machine characteristics and established work systems across European regions, and (iii) identify emerging trends shaping future applications.

Methods

To describe the historical evolution of mini forestry crawlers, we combined expert knowledge with information obtained from the scientific literature. In November 2025, a systematic literature review was conducted using the Scopus and Web of Science (WoS) databases to analyse and synthesise recent technological developments and reported practical use cases.

The review focused on studies from different European countries and regions to reflect contrasting forest management priorities, such as wildfire risk reduction in Southern Europe and improved occupational safety in Central Europe. Search terms covered small, compact, and mini forestry machines, as well as remote-controlled, robotic, and

autonomous ground-based systems used in forestry. Core search strings combined the term *forestry* with *crawler*, *tractor*, or *skidder*, together with the qualifiers *mini*, *compact*, or *small*. This approach yielded 185 records in Scopus and 84 in WoS.

To capture emerging technologies, additional searches targeted *remote-controlled* crawlers and skidders, *robotic* and *autonomous* forestry tractors and skidders, and *unmanned ground vehicles (UGVs)* used in forestry contexts. These searches returned up to 150 records in Scopus and 49 in WoS for remote-controlled crawlers, and between 12 and 54 records in Scopus for robotic, autonomous, and UGV-related terms. More specific machine designations were also included, such as *mini forwarder*, *mini skidder*, *mini tractor*, *small tractor*, *small skidder*, *small forwarder*, and *compact tractor*. These targeted searches generally produced fewer results, typically fewer than 40 records per term, and in some cases none (e.g., *compact forwarder* and *compact skidder*). Finally, a snowballing approach was applied to reference lists of relevant publications, yielding one additional record.

No restriction was applied to publication year, because the review aimed to capture both the historical development and the current state of small-scale forestry machines. To illustrate the temporal development of the literature base discussed in the Results, thematic forestry/MFC references cited in the Results section were grouped by publication period (Table 1). In addition to the literature review, a market survey was conducted to provide an overview of currently available machine models. Relevant manufacturers were identified through expert consultation, reviews of industry publications, and exhibitor catalogues from recent forestry fairs. Machine specifications were then extracted from manufacturers' websites. The consolidated information on brands, models, and technical specifications was analysed to further define the concept of a typical modern MFC and to highlight distinctive technical features.

These data were also used for the statistical characterisation of existing models and for unsupervised market segmentation. Two core technical features – machine mass and engine power – were selected to characterise their distributions and to identify natural clusters. The statistical workflow included data standardisation to remove scale effects, clustering using the DBSCAN algorithm [12], and iterative refinement of the clustering solution based on the epsilon parameter (eps = 0.1 to 1.0). An elbow point was identified in a k-distance plot at an eps value of 0.4, which was subsequently used for clustering. Clustering quality was evaluated using the silhouette score and the Davies-Bouldin index.

All analyses were implemented in Python 3.12 [13] using a PyCharm educational licence and were complemented by a cluster centroid map.

Results

Early Development Since the 1970s

Like the farm tractor, the mini-skidder was originally designed primarily as a pulling machine intended to replace draft horses for log extraction. Its main task was short-distance pre-skidding on terrain inaccessible to conventional forest machines, which would then take over once the load had been deposited along a proper skid trail. Over time, the mini-skidder evolved from a simple traction device into a multifunctional, self-propelled power unit integrating increasingly advanced technology and capable of performing a wide range of tasks, with skidding becoming just one of several possible applications.

Mini-skidders first appeared in the scientific literature in the mid-1970s, promoted by Nordic research institutions such as the Swedish University of Agricultural Sciences (SLU) in Garpenberg, Sweden, and the Norwegian Institute of Bioeconomy Research (then NISK, now NIBIO) in Ås, Norway. At the time, they represented a Nordic alternative to heavy mechanisation, when cut-to-length (CTL) harvesting had become dominant in industrial forestry but remained too costly for self-employed small-scale forest owners.

Already during this early phase, Nordic developers explored all three basic machine concepts: walk-along machines, mini-tractors with onboard operators, and adapted multipurpose units. Among walk-along machines, the Iron Horse and Skogsmyran were particularly popular, followed by derivatives such as the Goliat and Skogis [14–16]. However, the absence of a proper driver's seat proved to be a major limitation in terms of productivity and ergonomics, and subsequent development increasingly focused on machines with an onboard operator station.

Snowmobiles and ATVs were readily available and therefore examined early as potential platforms [17–20]. However, these vehicles exhibited significant constraints, most notably insufficient mass and tractive capacity. ATVs were primarily limited by the lack of a low-speed gear range, while snowmobiles lacked adequate obstacle-clearing capability [20].

As a result, the development of dedicated mini-skidders began almost immediately. Early designs were often inspired by snowmobiles (e.g., Terri [21]) or ATVs (e.g., Vimek Minimaster; [22]). The most distinctive evolutionary pathway, however, was that of the mini-tractor. This line emerged early with machines such as the Krabat 232 [23] and the Makeri [24–26], the latter already conceived as a multifunctional tool carrier capable of felling, processing, and skidding.

Although mini-skidders remained a niche relative to CTL systems, sales figures reported by Nordfjell [20] for Sweden between 1983 and 1989 were substantial, increasing from 50

units manufactured in 1983 to approximately 1,400 units in 1989, with more than 6,000 machines produced over seven years. The concept of affordable forestry mechanisation also attracted interest in regions dominated by non-industrial private forestry, where limited annual utilization made large-scale mechanisation economically unviable. Some Central and Southern European countries expressed growing interest in mini-skidders [27], which was also reflected in the work of international organisations such as the FAO/ECE/ILO Committee [28] and the Forestry Commission in the United Kingdom. The Forestry Commission's Technical Development Branch conducted extensive evaluations of mini-skidder models with the aim of promoting their adoption among small-scale forest owners [29–31]. Despite these efforts, mini-skidder technology remained niche and was never expected to become mainstream.

ATV-based skidding continued to attract intermittent interest due to its apparent convenience [32, 33], yet purpose-built mini-skidders received relatively little scientific attention for several decades. Interest has only recently revived, driven by stricter regulations on in-stand traffic that impose ever-wider spacing between designated skid trails. Enforced by many German forestry administrations and by sustainable forestry management certification schemes, these rules prevent conventional forest machines from reaching all trees with their booms, regardless of boom length or carrier size. After the concept of ghost trails was also rejected [34, 35], the remaining solution involved motor-manually felling followed by extraction to a designated trail using light tractors or mini-skidders [36*].

Compared with their predecessors of the 1980s, modern mini-skidders are predominantly hydrostatic, remotely controlled, and highly versatile. No longer inexpensive or rudimentary, today's machines are sophisticated, state-of-the-art tool carriers compliant with stringent safety standards and equipped with powertrains capable of supporting a wide array of attachments, including dedicated felling heads [37, 38*]. Their evolution reflects not only technological advances but also changing silvicultural contexts. Whereas early mini-skidders were developed for early thinning in even-aged stands characterised by small tree sizes and high residual density, contemporary European forestry increasingly favours uneven-aged management. This shift has driven the development of heavier and more powerful mini-crawlers capable of handling larger stems and more demanding operating conditions.

Operational Performance, Soil Impact, Workload, and Safety of Remote-Controlled Small-scale Machines

Over the past decade, research on MFCs has increasingly moved from general descriptions of small-scale mechanisation and mini-skidders towards field- and bench-based evaluations of their operational performance, soil interaction, ergonomic demands, and safety potential. This transition is particularly evident in challenging terrain, where MFCs are described as compact yet versatile platforms suitable for a wide range of silvicultural treatments and site conditions [36, 39].

Several studies highlight the role of MFCs in combination with cable harvesting, including the pre-winching of stems towards a cable corridor to support tower-yarder operations in soil-sensitive terrain [38*, 3940*]. In a case study, Schweier and Ludowicy [40*] reported high pre-winching productivity (>21 m³ PMH_{15}^{-1}) and overall yarding productivity of approximately 20 m³ PMH_{15}^{-1}, suggesting that MFC-supported cable extraction is a viable low-impact option under limited terrain trafficability.

Given their intended operation on steep, sensitive, or low-bearing-capacity soils, recent studies have examined soil impacts associated with MFC use. Siebert et al. [41*] showed that repeated unprotected passes intensified soil structural damage and deep compaction, with turning manoeuvres producing the most severe effects. Although a portable matting system substantially reduced negative effects, it did not eliminate them. One unprotected pass caused soil effects comparable to five passes with matting; therefore, MFC traffic on moist soils near field capacity was not recommended without protective measures.

Complementary bench testing by Breinig et al. [42] assessed dynamic ground pressure distributions beneath different MFCs under representative load conditions. Under unloaded or low-load conditions, mean ground pressure closely matched theoretical contact pressure, whereas higher loads increased traction demand and ground pressure, approaching values observed for larger machines. Crawler tracks also exhibited pronounced pressure inhomogeneities, highlighting the influence of machine state and loading on soil interaction.

Operator workload has likewise received attention, particularly during manual winching. Using mobile spiroergometry and heart-rate monitoring, Berendt et al. [43*] demonstrated that manual cable pull-out over 50 m imposes a heavy physiological burden, with heart rate approaching 70% of heart-rate reserve. Consequently, they recommended limiting winching distances to ≤30 m and implementing task rotation and active breaks to reduce fatigue.

Worker safety has also been addressed through the development of compact, remote-controlled felling heads mounted on light MFCs [38*]. Designed to reduce exposure to high-risk motor-manual felling where full mechanisation is infeasible, the system mechanises critical felling steps using partially automated sequences with operator confirmation. During field trials in Germany, the prototype felled more than 100 conifer trees with high directional accuracy,

positioning remote-controlled felling as a promising alternative to chainsaw-based operation in inaccessible sites.

Productivity and cost efficiency remain decisive factors for adoption. Several trials report that MFCs can achieve competitive harvesting rates in small parcels and/or steep terrain while reducing labour and fuel costs, albeit with lower payload capacities compared with conventional machines [36, 39].

Use of MFCs Beyond Harvesting Operations

Mini forestry crawlers are increasingly applied in non-harvesting contexts, particularly wildfire prevention (Fig. 3) and vegetation management, including invasive species control. Their growing adoption is largely driven by versatility, as most MFCs can be equipped with attachments such as forestry mulchers (Fig. 4) to reduce vertical fuel continuity or grind stumps of undesirable species. Remote and potentially autonomous operation further enhances safety, comfort, and operational efficiency [44].

Fig. 3 Mini forestry crawler used for fire prevention (credit: Schweier)

Fig. 4 Mini forestry crawler used for mulching (credit: Spinelli)

These advantages are especially relevant for wildfire prevention, where maintaining fuel breaks and vegetation corridors near critical infrastructure is both essential and costly [44]. Similar constraints apply to invasive woody species control in steep or poorly accessible landscapes, where conservation of ecologically valuable grasslands and prairies can otherwise be labour-intensive and expensive [45].

Despite increasing interest, operational performance data for these applications remain scarce. Chetan et al. [45] evaluated a prototype MFC equipped with a chainsaw bar for felling invasive eastern redcedar (*Juniperus virginiana* L.) in the United States, demonstrating feasibility for stems up to approximately 20 cm DBH while identifying the need for further design improvements. Spinelli et al. [46*] assessed a commercial 36 kW remote-controlled carrier equipped with an Energreen 130 T mulcher for stump grinding in a restored chestnut orchard in southern Italy, reporting productivity below 3.5 SMH ha^{-1} and treatment costs exceeding € 200 ha^{-1}.

Although several research initiatives are ongoing, including the SAFEFOREST project in Portugal (https://safeforest.ingeniarius.pt), most studies remain conceptual and focus on defining key design requirements and performance characteristics for an "ideal" MFC for wildfire prevention and related tasks [44, 47].

Current Market Overview

The market survey identified 28 manufacturers offering 71 MFC models (Table 2; Table 4 in the Appendix). The market is dominated by German (11) and Italian (10) companies, followed by Swiss manufacturers (3) and individual manufacturers from Sweden, the Netherlands, Denmark, and the Czech Republic. Although the survey was based on recent industry surveys [48], major forestry fair catalogues [49], and expert knowledge, the list may not be exhaustive, particularly outside Europe.

Table 2 Core technical parameters and cluster assignment of screened mini forestry crawler models

Cluster	*n* (models)	Mean mass (kg)	Mass range (kg)	Mean power (kW)	Power range (kW)
Cluster 0	28	1330.7	750–1750	36.6	27–45
Cluster 1	3	1400.0	1350–1450	55.0	55–55
Cluster 2	8	2565.0	2470–2750	44.2	36–55
Cluster 3	16	759.1	435–1230	18.1	13–20
Cluster 4	5	2070.8	1910–2200	55.2	55–55
Outliers (Cluster − 1)	11	2425.5	300–4200	52.6	2–105

Clusters were derived using DBSCAN (eps = 0.40) based on machine mass and engine power. Values represent mean and observed range within each cluster

Not all identified machines were originally developed specifically for forestry. Several manufacturers originate from the agricultural or landscape management sectors, however, their machines are relevant for forestry applications because of their high terrain trafficability and suitable power ratings. Forestry-focused MFCs are typically equipped with integrated winches, while many multifunctional models feature PTOs, hydraulic couplings, standardised three-point hitches, and optional traction winches, enabling broad functional flexibility.

Terrain adaptability is a defining feature, with alternative undercarriage options, adjustable track widths, and, in some cases, adjustable ground clearance or automated levelling systems. High-speed travel gears further support rapid relocation between work sites, reinforcing the suitability of MFCs for small-scale, fragmented ownership structures.

Market segmentation based on engine power and machine mass reveals five distinct technical clusters, ranging from light-duty to heavy-duty MFCs (Fig. 5). However, despite several common features shared by most models, it is also apparent that some machines focus on specific niches. For example, the Schwarz Black Tiger is not the only machine exceeding the 3,000 kg mass threshold and therefore falling outside of the strict specification for an MFC. With its 90 kW diesel engine, 120 l/min hydraulic flow rate and 60 kN winch, it clearly aims at replacing traditional skidders. In contrast, the Muffel, produced by Stahltechnik Feher, with its 300 kg mass, electric drive motor, and small cargo platform, is intended for general support tasks such as plant transportation during manual operations. The cargo concept is further developed by the Suffel SmartSkidder, with a 2 m^2 cargo area and a full-scale 40 kN winch, enabling multiple additional tasks, including firefighting with an extinguishing module. Conversely, other large-capacity crawlers such as the MDB LV1400 not only exceed the typical MFC range with a mass of 4,200 kg, but also allow operator transport despite the availability of remote-control. This diversity highlights how many manufacturers are extending the original MFC concept, to address specialised niches and develop entirely new work systems for challenging operational conditions.

Those niches are also reflected in the key technical specifications of the machines: engine power and mass. Among the screened machines, the average engine power rating (38 kW) and mean machine mass (1,565 kg) align well with the traditional specifications of MFCs, and the distributions indicate a strong mid-range concentration (Fig. 5a). Overall, the market segmentation identifies five clusters defined by machine mass and power rating (Fig. 5b and c). These clusters can be interpreted as machine classes ranging from light to heavy-duty MFCs, with distinct inter-cluster separation (Fig. 5d). Nevertheless, the specialisation of individual models across a wide range of segments makes it difficult to place some machines within any cluster. They emerge as outliers, reflecting the diversity of niches addressed by manufacturers and the evolving scope of MFC applications.

Although mass and engine power provide a useful first-order basis for classifying the current MFC market, they do not determine operational suitability by themselves. For users and contractors, adoption decisions ultimately depend on whether a given machine class can deliver acceptable productivity, cost efficiency, soil protection, and workload under the intended operating conditions. The technical clusters presented here should therefore be interpreted as a framework for comparing machine capability, while future evaluations need to link these classes more directly with task-specific productivity, cost, and impact data.

Trends Since 2020

Since 2020, growing attention has been directed towards integrating automation into MFC technology, particularly in the areas of autonomous navigation, GPS-guided operation, and sensor-driven control [44, 4738*]. Automation has the potential to increase operational efficiency, reduce operator workload, and enhance worker safety, especially in steep or hazardous environments. When coupled with data acquisition systems, automated MFCs could also support precision forestry by improving extraction planning and enabling real-time monitoring of site and environmental conditions.

Despite widespread interest, automation in MFCs has not yet advanced beyond the prototype stage. A survey of electric-powered machines available in 2022 – covering platform size, automation level, traction, energy source, locomotion, and sensor/actuator integration – found no market-ready electric, remotely controlled machine suitable for forest clearing. Consequently, subsequent research has focused on improving navigation and control systems. Although early results have been promising, these technologies generally remain below the Technology Readiness Level (TRL) required for routine operational deployment.

Progress towards automation is slowed by the inherently challenging forest work environment, characterised by harsh, variable, and constantly changing conditions, including strong seasonal variability. Automation is further constrained by limited communication infrastructure and reduced positioning accuracy under forest canopies. Nevertheless, recent years have seen substantial technological advances driven by the availability of lower-cost and more robust sensors (e.g., LiDAR, RGB cameras, improved GNSS), increased onboard computing capacity, and improved algorithms. Autonomous functions have been demonstrated on retrofitted full- and mid-sized forest

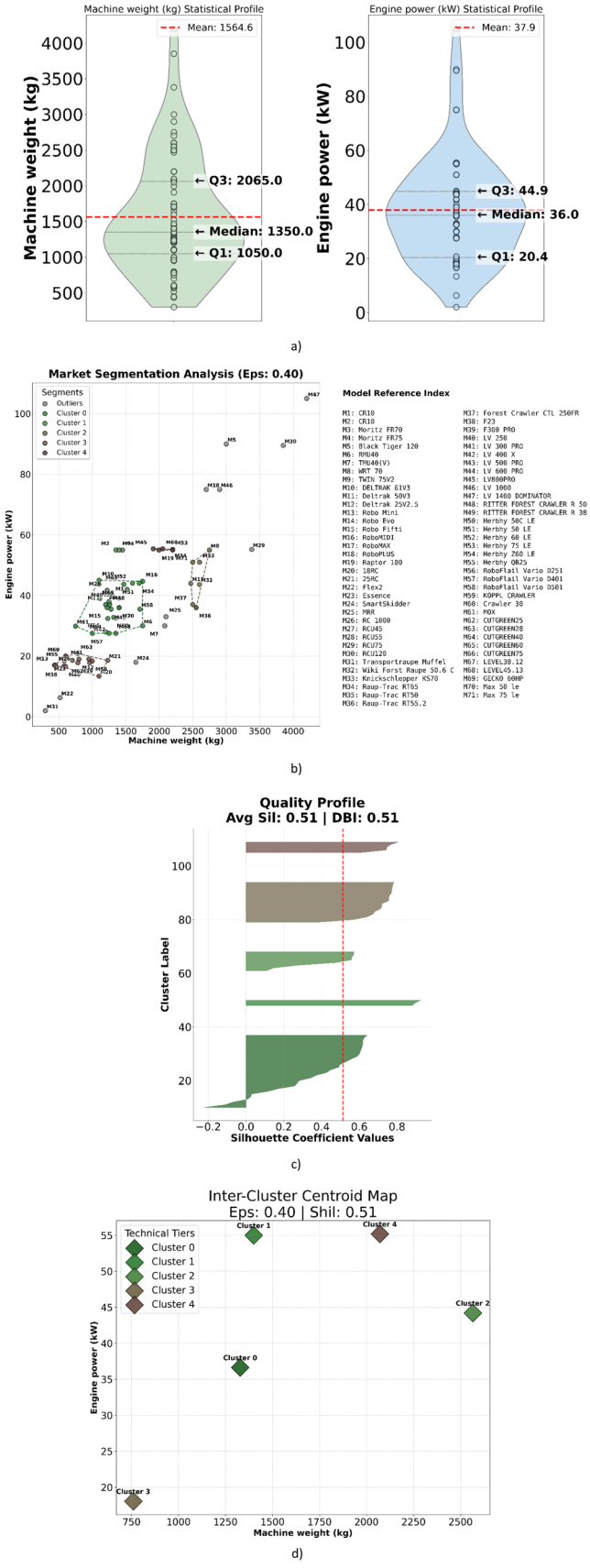

Fig. 5 Statistical characterisation and market segmentation of mini forestry crawler models. (**a**) Violin plots illustrating the distributions of machine mass and engine power. (**b**) DBSCAN-based market segmentation of crawler models using machine mass and engine power at eps = 0.4. (**c**) Silhouette profile used to assess the structural validity of the clustering solution. (**d**) Inter-cluster centroid map showing distances among the resulting clusters. The analysis identifies five distinct technical clusters, with a strong concentration in the mid-range segment (1,350-1,500 kg; 36–38 kW) and several high-power or high-mass outliers, including the LV 1400 DOMINATOR and RCU120. An average silhouette score of 0.51 indicates moderate to good cluster separation, although some overlap remains

machines [47, 50], and dedicated autonomous forestry platforms are also emerging [51].

These developments align with broader technological, market, and regulatory drivers identified as key forces shaping mechanised timber harvesting [52]. In this context, automation spans a wide spectrum, from computer-assisted motion control to early concepts of fully unmanned machines. Navigation, localisation, and sensing remain central challenges for forest autonomy, as machines must reliably perceive their surroundings [53], assess terrain traversability [54], operate under limited communication coverage [55], and process large data volumes efficiently [56, 57].

Advances in these domains have enabled several platforms to demonstrate autonomous or semi-autonomous forestry tasks (Table 3; Fig. 6), suggesting that precision forestry systems may become operationally feasible in the near term. For example, Hansson et al. [58] report the development and field-oriented testing of the autonomous MFC prototype “Autoplant”, which integrates planning, navigation, site preparation, and mechanised planting into a single workflow. In parallel, commercially available remote-controlled machines, together with recent reviews [44, 53, 59], indicate that such platforms provide a practical basis for incremental transition towards autonomy when equipped with appropriate sensor systems.

Felling heads and timber harvesting solutions for small machines such as MFCs are also transitioning from conceptual designs towards implementation. The adaptation of harvesting implements for automated or semi-automated operation is underway. Badgujar et al. [60] and Knobloch et al. [38*] demonstrated the feasibility of tree felling with MFCs, with the respective prototypes representing different technology readiness levels (TRLs).

Beyond stand-alone applications, felling crawlers could be integrated into multiple harvesting configurations, including (1) as complementary units within fully mechanised cut-to-length systems, (2) as components of fully mechanised full-tree extraction combined with cable yarders, and (3) within semi-mechanised cut-to-length systems, particularly in hardwood stands where full mechanisation is constrained.

Table 3 Overview of demonstrated autonomous forestry systems, summarising the task(s), deployment platform or setting, and the main contribution of each reference

Demonstrated task(s)	Platform or setting	Key contribution and reference
Precision harvesting	Full-size hydraulic machine validated under realistic forest and under-canopy conditions	Field-demonstrated add-on system integrating sensing, planning, control, and navigation; potentially adaptable to mini crawlers. Platform: Menzi Muck M545; Jelavic et al. [50].
Mulching with autonomy stack	Mulching machine	"Universal" perception, control, and navigation system demonstrated on an MFC. Platform: MDB-LV600; Gameiro et al. [47].
Log handling, forwarding, and planting	Autonomous forestry platform	Multi-task autonomous platform covering operations from log handling to regeneration. Platform: AORO autonomous off-road vehicle platform; Hansson et al. [58][1].
Selective thinning	Supervised autonomous harvester	Demonstration of supervised autonomy for thinning operations. Platform: SAHA platform[2]; Nan et al. [61].
Automated planting and scarification	Planting and scarification platform	Automation targeted at site preparation and planting workflows. Platform: Södra BraSatt[3].

[1] https://nordictestbednetwork.se/885-2/

[2] see also Fig. 6

[3] https://www.sodra.com/en/global/about-us/innovation/sodras-innovation-projects/brasatt/

Discussion

A useful general distinction can be made between mini-skidders and mini-forestry crawlers (MFCs). Mini-skidders emerged in the 1970 s and were designed specifically for short-distance timber extraction, whereas MFCs appeared much later and were conceived as multifunctional platforms capable of performing a wide range of site-management tasks. In both cases, machine development was driven by the need for agile equipment able to operate on narrow trails, steep slopes, and soft terrain that are inaccessible to heavier conventional machinery.

Fig. 6 Recently developed SAHA platform performing autonomous tree felling operations in Switzerland (credit: Schweier, DIGIFOREST project)

Although these machines have existed for almost 50 years, their growing popularity can be explained by a convergence of drivers. First, increasing emphasis on forest soil protection has restricted the use of heavy machinery to designated trails, creating operational gaps between trails that can only be addressed by manual labour or by light mass platforms capable of traversing soils with minimal impact. Second, the expanding multifunctionality of modern MFCs improves utilisation rates and asset depreciation, which is particularly important for small-scale owners and contractors.

Low mass and compact dimensions also facilitate transport between sites, reducing relocation time and costs, an important advantage in landscapes characterised by small, fragmented holdings. Most importantly, the versatility of modern MFCs has driven their adoption among landscape-maintenance contractors responsible for clearing invasive vegetation along roadsides, ditches, and riverbanks. This sector represents a large market with specific operational demands and strong purchasing power, which has justified investment in technical development and enabled large-scale production. As a result, affordable and capable machines equipped with modern hydraulics and remote-control technology are now widely available. Teleoperation and specialised attachments further reduce worker exposure to high-risk tasks and to agents associated with work-related illness, such as noise, vibration, and exhaust emissions.

However, the assumption that MFCs are inherently soil-friendly under all operating conditions is not supported by the literature. Recent studies indicate that repeated traffic, turning manoeuvres, high traction demand, and moist soils can substantially increase soil disturbance, demonstrating that machine mass alone is an insufficient proxy for impact risk.

Soil-protection performance therefore depends as much on deployment strategy as on machine design. From a practical perspective, this underscores the need for site-specific traffic planning, operational restrictions under wet conditions, and protective measures such as brush matting on sensitive soils. From a research perspective, it highlights the limitations of relying solely on theoretical or mean contact-pressure values, given the pronounced spatial heterogeneity of ground-pressure distribution in crawler systems.

A similar role-specific logic applies to productivity and costs, and this is where the technical mass–power classes require operational interpretation. Because MFCs have lower payload capacities than conventional machines, their competitiveness depends on task–machine matching rather than on absolute output alone. Available trials suggest that MFCs can achieve competitive harvesting rates in small parcels and steep terrain, particularly where reduced relocation effort and lower labour and fuel requirements offset lower per-cycle extraction volumes. Cost-effectiveness therefore hinges on careful deployment within the intended operational niche, and productivity assessments should reflect utilisation strategy rather than isolated performance metrics.

Despite the use of remote control, MFC systems remain labour-intensive, as several tasks still impose high physiological loads than can become system-level bottlenecks. Performance and sustainability thus depend as much on work organisation as on machine capability, favouring shorter winching distances, task rotation, and terrain-adapted pacing. Intuitive controls, good worksite visibility, and effective cable-handling aids can reduce unnecessary exertion, while maintenance-friendly layouts that minimise awkward postures are critical, as small inefficiencies quickly translate into fatigue, productivity losses, or long-term health risks.

Remote-controlled felling and handling remove workers from high-hazard zones and may substantially reduce risks associated with motor-manual felling and steep-slope traffic. This is especially relevant in high-risk felling scenarios, such as large hardwoods or trees with dry crowns, where increased distance from the stem is crucial for reducing exposure but can compromise operational feasibility. Similar considerations apply to salvage operations after climatic extremes, including windthrow, snow or ice breakage, and drought-related tree damage, where unstable stems, root plates, broken crowns, and interlocked trees substantially increase risks for motor-manual work. If such disturbance events become more frequent or severe, small remote-controlled machines may offer a useful alternative for reducing worker exposure during salvage logging, particularly in terrain or stand conditions where conventional mechanisation is constrained. However, this approach introduces new hazards related to machine instability on uneven terrain, limited operator depth perception, unexpected movements, and the need to manage exclusion zones for bystanders during felling or winching. Safe deployment therefore requires standardised operating procedures, dedicated training, and robust fail-safe and emergency-stop concepts.

Advances in sensor technology could play a significant role in mitigating these risks. Comparable systems are already deployed in semi-autonomous agricultural machinery and in recent developments of fully autonomous mini-crawlers for vineyard spraying, which integrate Multisensor Integrated Navigation & Drive (M.I.N.D.) systems (https://www.agricobots.com/en/). These developments suggest a plausible technological pathway for future forestry applications.

Multifunctionality also reshapes how MFCs should be evaluated, as acceptable impacts, constraints, and performance metrics vary by use case. Harvesting-oriented applications emphasise volume-based indicators (e.g., m^3 per productive machine hour), whereas vegetation management and wildfire-prevention activities often rely on area-based metrics (e.g., € per ha) and attachment duty cycles. In this broader context, the business case increasingly depends on year-round utilisation across diverse tasks (such as fuel management, corridor maintenance, invasive-species control, and selective interventions) rather than on timber extraction alone. Technically, this versatility is enabled by hydrostatic transmissions and standardised mechanical and hydraulic interfaces that support rapid attachment changes and a growing implement ecosystem. Consequently, diffusion is increasingly driven by non-skidding applications, with more units likely sold outside traditional timber extraction than within it.

This shift is reflected in demonstrations and trade fairs, where MFCs are often showcased with mulching or cutting attachments rather than winches. At the same time, adoption appears to be advancing faster than independent evaluation, as published assessments of operational performance and environmental impact for non-harvesting applications remain scarce.

Near-term automation for MFCs is therefore most plausibly incremental, emphasising assistive functions such as improved sensing, operator support, and semi-automated routines for repetitive manoeuvres rather than full autonomy. Progress towards higher levels of autonomy is constrained by forest-specific challenges, including under-canopy localisation, perception uncertainty in cluttered environments, intermittent connectivity, and the difficulty of certifying safety for machines operating near people and standing timber. Irregular terrain, unstable soils, dense vegetation, and dynamic obstacles further complicate traversability assessment and real-time perception, making robust navigation under canopy a primary bottleneck. Nonetheless, MFCs remain a promising testbed for automation because their low mass reduces kinetic risk, and their teleoperation heritage naturally supports supervised autonomy. Even so, harsh terrain, variable soils, and strong seasonal dynamics will continue to limit reliable unattended operation.

Outlook

Despite a literature base dominated by small-sample case studies, MFCs appear best suited to environments where access is constrained and tasks can be organised around short working distances and moderate payloads, ideally combined with sufficient task diversity to ensure high utilisation. The ability to mechanise such tasks and operate machines remotely – and potentially autonomously in the longer term – offers clear benefits for operational efficiency as well as operator safety and comfort. To minimise soil disturbance and worker fatigue, deployment should prioritise planned routing that limits turning, avoidance of wet soils near field capacity, protective measures on sensitive ground, and winching strategies that minimise manual pull-out distances while supporting task rotation and paced work.

Future operational research should extend beyond mean ground-pressure metrics to account for pressure distribution, turning effects, soil moisture, pass frequency, and traffic intensity, alongside productivity and physiological workload indicators. Standardised protocols linking dynamic ground-pressure distributions to observed soil responses under realistic manoeuvres and moisture conditions would substantially improve comparability across studies. In particular, coupled assessments that simultaneously evaluate productivity, soil impact, and human workload on the same sites and machines are needed to identify optimal operating envelopes rather than single-metric optima. Such evaluations should also be stratified by machine class, so that differences in mass and engine power can be interpreted in terms of productivity, cost, soil response, and ergonomic performance rather than as stand-alone technical descriptors.

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  ◦ This publication is a strong reference for the often-overlooked point that remote control does not eliminate physical strain. Using spiroergometry and heart-rate monitoring, the authors showed that manual cable pull-out during winching can impose substantial metabolic strain on operators. They therefore recommended limiting winching distances to ≤30 m, together with task rotation and active breaks, to reduce fatigue and support recovery.

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  ◦Key reference for commercial MFC use outside harvesting. The authors used a MFC with a forestry mulcher to manage invasive *Alnus* stumps in a chestnut orchard. This study showcases a possible application of MFCs outside strict forest operations.

Appendix

Table 4 Technical specifications, cluster assignment, and selected forestry-relevant features of screened mini forestry crawler models Note: Data were compiled from manufacturer information, industry sources, and expert knowledge available at the time of the market survey. Cluster assignment is based on the DBSCAN classification using machine mass and engine power; "Outlier" denotes cluster − 1

Cluster	Manufacturer	Model	Country	Mass (kg)	Power (kW)	Control	Interfaces/equipment	Main use/selected features
Outlier	C4 Meccanica	TMU40(V)	Italy	2080	30	remote and on board	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; hydraulically adjustable track width; high speed travel gear (9 km/h); on-board operator drive option
Outlier	Energreen	RoboPLUS	Italy	2700–2900	75	remote	hydraulic couplings; integrated winch	Multi-purpose carrier for forestry implements; multiple track options
Outlier	FAE	RCU120	Italy	3850	89.5	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; integrated traction winch with 20kN line-pull (optional)
Outlier	FAE	RCU75	Italy	3380	55.2	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; integrated traction winch with 20kN line-pull (optional)
Outlier	Lennartsfors	Flex2	Sweden	520	6.3	handle	hydraulic couplings; integrated winch	Timber extraction; material transport; cargo plate
Outlier	MDB (Vogt)	LV 1000	Italy/Germany	2900	75	remote		Multi-purpose carrier for forestry implements
Outlier	MDB (Vogt)	LV 1400 DOMINATOR	Italy/Germany	4200	105	remote and in cabin		vegetation control
Outlier	Mueller	MRR	Germany	2100	33	remote	integrated winch	Timber extraction; integrated winch with 50 kN line-pull
Outlier	Schwarz	Black Tiger 120	Germany	3000	90	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; 24.5 kN power lift at front and rear, high speed travel gear (12 km/h)
Outlier	Stahltechnik Feher (Grube)	Transportraupe Muffel	Germany	300	2	remote	integrated winch	material transport; cargo bay (EU pallet size), integrated 20 kN traction winch

Table 4 (continued)

Cluster	Manufacturer	Model	Country	Mass (kg)	Power (kW)	Control	Interfaces/equipment	Main use/selected features
Outlier	Suffel	SmartSkidder	Germany	1650	18	remote	integrated winch	Timber extraction; material transport; integrated winch with 40 kN line-pull; 2 m2 cargo platform (adjustable in length); available fire fighting add-on
0	Alpirobot	LEVEL38.12	Italy	1350	27.5	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; rear power lift (4 kN); automatic machine leveling (chassis and undercarriage independently of each other)
0	Alpirobot	LEVEL45.13	Italy	1350	32.5	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; rear power lift (5 kN); automatic machine leveling (chassis and undercarriage independently of each other)
0	Antolini	CUTGREEN40	Italy	1230	32.4	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; adjustable track width
0	Antolini	CUTGREEN60	Italy	1470	43.7	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; adjustable track width
0	C4 Meccanica	RMU40	Italy	1750	30	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; hydraulically adjustable track width; high speed travel gear (9 km/h)
0	Energreen	Robo Evo	Italy	1200	28	remote	hydraulic couplings	vegetation control
0	Energreen	Robo Fifti	Italy	1220	36	remote	hydraulic couplings	vegetation control
0	Energreen	RoboMIDI	Italy	1750	44.7	remote	hydraulic couplings	vegetation control; multiple track options
0	FAE	RCU45	Italy	1320	32.8	remote	hydraulic couplings	vegetation control; electric recovery winch at the back (optional)
0	FAE	RCU55	Italy	1220	41.7	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; integrated traction winch with 20kN line-pull (optional)
0	Frontoni	GECKO 60HP	Italy	1100	43.7	remote	hydraulic couplings	Multi-purpose carrier for forestry implements

Table 4 (continued)

Cluster	Manufacturer	Model	Country	Mass (kg)	Power (kW)	Control	Interfaces/equipment	Main use/selected features
0	Geraetetechnik-Sauerland/ Haake & Holthoefer GbR	MOX	Germany	750	29.9	manual	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; passenger plate for operator to travel on the machine
0	Herder (Alamo Group)	CR10	Netherlands	1300	40	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; adjustable track width; hydraulic pendulum undercarriage (both track sides adjust independent of each other to the ground); high speed travel gear (14.5 km/h)
0	Hymach	Herbhy 50 LE	Italy	1400	39	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
0	Hymach	Herbhy 50 C LE	Italy	1110	39	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; adjustable track width
0	Hymach	Herbhy 60 LE	Italy	1600	44.1	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
0	Hymach	Herbhy Z60 LE	Italy	1700	44.1	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; vertically alignable tracks, independent of side for movements at terraces
0	IRUS	DELTRAK 61V3	Germany	1100–1200	45	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; hydraulically adjustable track width and ground clearance; high speed travel gear (10 km/h)
0	IRUS	Deltrak 50V3	Germany	1200–1300	37	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
0	MDB (Vogt)	LV 400 X	Italy/Germany	1000	27.5	remote		vegetation control
0	MDB (Vogt)	LV 500 PRO	Italy/Germany	1280	35.5	remote		Multi-purpose carrier for forestry implements
0	MDB (Vogt)	LV 600 PRO	Italy/Germany	1520	42	remote	hydraulic couplings	Multi-purpose carrier for forestry implements

Table 4 (continued)

Cluster	Manufacturer	Model	Country	Mass (kg)	Power (kW)	Control	Interfaces/equipment	Main use/selected features
0	Pfanzelt	Moritz FR70	Germany	1400	36	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; additional 7kN front power lift; hydraulically adjustable track width
0	Rapid (Niko)	RoboFlail Vario D401	Switzerland/ Germany	1250	27.5	remote	hydraulic couplings	vegetation control and trail maintenance; adjustable track width
0	Rapid (Niko)	RoboFlail Vario D501	Switzerland/ Germany	1710	35.5	remote	hydraulic couplings	vegetation control and trail maintenance; adjustable track width and height
0	Ritter	RITTER FOREST CRAWLER R 38	Germany	1250	38	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; Delta-shaped chassis with roller chains
0	Ritter	RITTER FOREST CRAWLER R 50	Germany		37	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; Delta-shaped chassis with roller chains
0	Seppi M.	Max 50 le	Italy	1400	36	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; adjustable track width
1	Herder (Alamo Group)	CR10	Netherlands	1350	55	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; adjustable track width; hydraulic pendulum undercarriage (both track sides adjust independent of each other to the ground); high speed travel gear (14.5 km/h)
1	IRUS	TWIN 75V2	Germany	1400–1500	55	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; hydraulically adjustable track width and ground clearance; high speed travel gear (10 km/h), patented DUAL-FLOW hydraulics for front and rear implement
1	Pfanzelt	Moritz FR75	Germany	1450	55	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; additional 7kN front power lift; hydraulically adjustable track width

Table 4 (continued)

Cluster	Manufacturer	Model	Country	Mass (kg)	Power (kW)	Control	Interfaces/equipment	Main use/selected features
2	Alther	Knickschlepper KS70	Switzerland	2600	51	remote		Multi-purpose carrier for forestry implements; integrated winch with 60 kN line-pull, optional traction winch (18 kN), rear blade and infeed roller hydraulically adjustable, 60% of the mass distributed on the front axle.
2	Alther	Raup-Trac RT50	Switzerland	2550	36	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; integrated winch with either 55 or 60 kN line pull, optional traction winch (18 kN), hydraulically tensioned track system, rear shield and feed roller hydraulically adjustable
2	Alther	Raup-Trac RT55.2	Switzerland	2550	36	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; integrated winch with either 55 or 60 kN line pull, optional traction winch (18 kN), hydraulically tensioned track system, rear shield and feed roller hydraulically adjustable
2	Alther	Raup-Trac RT65	Switzerland	2500	51	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; integrated winch with 55 kN line pull, rear shield, hydraulically double-acting, feed roller adjustable in height by 250 mm
2	Energreen	RoboMAX	Italy	2470–2640	44	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; multiple track options
2	HSM	Forest Crawler CTL 250FR	Germany	2500	37	remote	hydraulic couplings; integrated winch	Timber extraction; integrated winch (line pull options from 55–70 kN), optional front traction winch (23 kN)

Table 4 (continued)

Cluster	Manufacturer	Model	Country	Mass (kg)	Power (kW)	Control	Interfaces/equipment	Main use/selected features
2	Weiss	WRT 70	Germany	2750	55	remote	hydraulic couplings	Timber extraction; Integrated winch with 60 kN line-pull
2	Wicki	Wiki Forst Raupe 50.6 C	Switzerland	2600	43.7	remote		Timber extraction; integrated winch with 80 kN line-pull, optional additional traction winch (19 kN)
3	Antolini	CUTGREEN25	Italy	960	17.8	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
3	Antolini	CUTGREEN28	Italy	780	20.8	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
3	Energreen	Robo Mini	Italy	435	17	remote	hydraulic couplings	vegetation control
3	Hymach	Herbhy QB25	Italy	580	18.4	remote	hydraulic couplings	vegetation control
3	IRUS	Deltrak 25V2.5	Germany	800–900	19	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
3	Kapsen	18RC	Czech Republic	1100	13.4	remote	integrated winch	Timber extraction; integrated logging winch (16kN line-pull), logging arch and skidding shield
3	Kapsen	25RC	Czech Republic	1230	18.6	remote	integrated winch	Timber extraction; integrated logging winch (24kN line-pull), logging arch and skidding shield
3	Köppl	Crawler 30	Germany	603	20	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements
3	Köppl	KÖPPL CRAWLER	Germany	603	20	remote	mechanical	Multi-purpose carrier for forestry implements
3	Lennartsfors	Essence	Sweden	700	18.6	remote	hydraulic couplings; integrated winch	Multi-purpose carrier for forestry implements; cargo plate & accessory lift
3	MDB (Vogt)	F23	Italy/Germany	570	16.6	remote		vegetation control
3	MDB (Vogt)	F300 PRO	Italy/Germany	785	17.8	remote		vegetation control
3	MDB (Vogt)	LV 250	Italy/Germany	600	16.6	remote		vegetation control
3	MDB (Vogt)	LV 300 PRO	Italy/Germany	950	19	remote		vegetation control
3	Rapid (Niko)	RoboFlail Vario D251	Switzerland/ Germany	1000	18.4	remote	hydraulic couplings	vegetation control and trail maintenance; adjustable track width
3	Timan	RC 1000	Denmark	450	17	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
4	Antolini	CUTGREEN75	Italy	2050	55.4	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; optional integrated winch

Table 4 (continued)

Cluster	Manufacturer	Model	Country	Mass (kg)	Power (kW)	Control	Interfaces/equipment	Main use/selected features
4	Hymach	Herbhy 75 LE	Italy	2200	55.2	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
4	MDB (Vogt)	LV800PRO	Italy/Germany	1910	55.4	remote	hydraulic couplings	Multi-purpose carrier for forestry implements
4	Prinoth	Raptor 100	Italy	1994	55	remote	mechanical/hydraulic couplings	Multi-purpose carrier for forestry implements; additional 7kN front power lift; hydraulically adjustable track width
4	Seppi M.	Max 75 le	Italy	2200	55	remote	hydraulic couplings	Multi-purpose carrier for forestry implements; adjustable track width

Author contributions J.S. wrote the main manuscript text with support from R.S., F.L., N.M., and S.H.; F.L., R.P., and J.S. performed the literature screening; N.M. and R.S. drafted the historical evolution of MFC; C.M.H. drafted the trends since 2020 section; S.H. and S.A.B drafted the current market overview and prepared figure 5; J.S., S.H. and S.A.B. prepared the machine overview table in the annex; and S.H. and J.S. drafted conceptual plan; L.G.B. supported writing the draft manuscript; all authors reviewed the manuscript.

Funding Open Access funding provided by Lib4RI – Library for the Research Institutes within the ETH Domain: Eawag, Empa, PSI & WSL. Some authors are members of the Small4Good consortium, which received funding from the European Research Council (ERC) under the European Union's Horizon Europe research and innovation programme (grant agreement No. 101135517) and from the Swiss State Secretariat for Education, Research, and Innovation (SERI).

Data Availability No datasets were generated or analysed during the current study.

Declarations

Human and Animal Rights and Informed Consent This article does not report any studies involving human or animal subjects conducted by any of the authors.

Competing interests The authors declare no competing interests.

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