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Autonomous Mowers Working in Narrow Spaces: A Possible Future Application in Agriculture?

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Abstract: Autonomous mowers are becoming increasingly common in public and private greenspaces. Autonomous mowers can provide several advantages since these machines help to save time and energy and prevent operators from possible injuries. Current autonomous mowers operate by following random trajectories within areas defined by a shallow-buried boundary wire that has the purpose to generate an electro-magnetic field. Once the electro-magnetic field is perceived by the autonomous mower, the machine will stop and change direction. Mowing along random trajectories is considered an efficient solution to manage areas with a variable number of obstacles. In agriculture, autonomous technologies are becoming increasingly popular since they can help to increase both the quantity and quality of agricultural products by reducing productive cost and improving the production process. Thus, even autonomous mowers may be useful to carry out some of the agricultural operations that are highly time consuming. In fact, some autonomous mowers designed and realized to work in vineyards and home vegetable gardens are already available on the market. The aim of this study was to compare the work capacity of six autonomous mowers that move along random trajectories in areas with a high number of obstacles to assess if these machines may be employed in some agricultural contexts. The six autonomous mowers were split in three groups based on their size (large, medium, and small) and were left to work in two areas with equal number of obstacles but different layouts. The first area (Site A) had a square shape and an extension of 23.04 m^2, in order to keep the autonomous mowers enclosed inside it. The second area (Site B) had a square shape and an extension of 84.64 m^2, in order to have a part of the area with no obstacles. The layout and the size of the two areas affected the autonomous mowers performances in different ways. The six autonomous mowers working on Site A obtained similar results and higher performances compared to the same mowers working on Site B. All the autonomous mowers proved to be able to mow more than 89% of Site A after 2 h and more than 98% of Site A after 5 h. On Site B small size autonomous mowers obtained the best results mowing more than 83% of the area with obstacles after 2 h and more than 98% of the area with obstacles after 5 h. However, specific work settings allowed larger autonomous mowers to improve their efficiency, obtaining similar results compared to smaller autonomous mowers.

Keywords: robot; RTK-GPS; robots for agriculture; data processing

1. Introduction

Autonomous mowers are becoming increasingly common in public and private greenspaces. It has been estimated that by 2023 the global autonomous mower market will reach a value of approximately 3 billion dollars [1]. Autonomous mowers can provide several advantages since these machines help to save time and energy [2]. Moreover, autonomous mowers prevent operators from coming into contact with allergens, exhaust gasses, possible injuries, and noise emissions [3–5]. Current autonomous mowers operate by following random trajectories within areas defined by a shallow-buried boundary wire that has the purpose to generate an electromagnetic field. Once the electromagnetic field is perceived by the autonomous mower, the machine will stop and change direction. Although mowing along random trajectories is considered an efficient solution to manage areas with a variable number of obstacles, this operating scheme generates frequent overlapping, decreasing overall efficiency [5]. A lower efficiency leads to a higher energy consumption and to a faster wear of the equipment. Furthermore, a random motion may cause a non-homogenous cut throughout the area [6]. Preventing excessive mowing overlap can be achieved by providing the autonomous mower with a guidance system. The main guidance-sensing technologies commercially available for autonomous machines are machine vision and global positioning systems [7]. However, they are not commonly used on autonomous mowers. Chandler [8] used a texture-based vision system to help the autonomous mower to detect if the grass had already been cut. Real-time Kinematic Global Positioning Systems (RTK-GPS) guidance systems are currently installed only on very large autonomous mowers [9]. Some autonomous mowers are equipped with a GNSS positioning system to obtain a "random assisted" pattern [10]. No matter what guidance system is installed, the adoption of autonomous technologies in agriculture helps to increase both the quantity and quality of agricultural products [11,12] and may also help to support a more sustainable economic development [13]. These improvements are mainly exploited for agricultural productive process innovation and for the reduction of productive costs [14]. Horticultural crops mechanical harvesting has become possible using recent autonomous technologies, saving a great amount of time considering that these operations were carried out manually [15]. Moreover, recent autonomous technologies have also allowed to perform highly accurate real-time weed–crop detection [16]. Autonomous mowers may be useful to carry out agricultural operations that are highly time consuming and that require a great amount of human labor. For example, autonomous mowers can properly control the height of both grass and weeds with their constant mowing action. The effects of autonomous mowers constant mowing decreased the weed incidence on tall fescue [17] and manila grass [18] lawns compared to conventional rotary mowing. A constant mowing height showed to favor low creeping weeds [2]; however, the low height of these weeds resulted in an overall lower competition with the crops [19]. According to Slaughter et al. [7], autonomous weed control technologies contribute to reduce human labor and herbicides applications. In the last years, the use of herbicides in Europe has undergone major restrictions, leading farmers to look for alternative solutions. Due to the restrictions on herbicides applications, autonomous mowers that operate using random trajectories are becoming popular in vineyards [20] and in small vegetable gardens [21]. Small autonomous mowers have the potential to move between the crops and under the canopies providing advantages for operating where larger machines cannot. Moreover, these mowers can easily provide extra functionality such as high-resolution mapping and constant crop monitoring [22] in vineyards. Four-wheel drive autonomous mowers seem to better operate in tough conditions and steep slopes if compared to rear wheel drive mowers [22,23]. The constant mowing action of autonomous mowers may also help to manage living mulch, a type of cover crop that has shown to improve crop yield, crop quality, and physical and chemical soil properties [24]. Living mulch is also effective in controlling weeds [25] and pests [26]. The development of innovative technologies for cover crop management can encourage a larger use of conservative agriculture techniques, making them more sustainable for farmers [27]. However, no trial has been carried out to assess the working capacity of autonomous mowers when these mowers operate in areas with many obstacles. The aim of this study was to compare the performances of six autonomous mowers that move along random trajectories in areas that simulate a horticultural context (the most challenging scenario for these mowers) to evaluate possible future applications of these machines in agriculture (horticulture, orchards, and vineyards).

2. Materials and Methods

2.1. The Experimental Trial

The study was carried out from January to June 2019 at the experimental farm of the Department of Agriculture, Food and Environment of the University of Pisa (San Piero a Grado, Pisa, Italy; 43°40′ N, 10°19′ E, 6 m.a.s.l.). The trial area was accomplished on a mature stand of manila grass (*Zoysia matrella* (L.) Merr., cv "Zeon"). The wear resistance of manila grass does not change when this species is dormant compared to when it is in full activity. On 21 January 2019, six different types of autonomous mowers (Table 1) were tested on two different areas containing the same number and pattern of obstacles. The obstacles consisted of 25 vertical wooden poles (ø 0.05 m, height 0.6 m) that were placed at a distance of 0.8 m from center to center, forming a square of 5 × 5 poles, considering that, in horticulture, 0.8 m × 0.8 m is a common plant spacing. Moreover, a spacing between the obstacles of 0.8 m is a very challenging scenario for autonomous mowers that move with random trajectories. Studying the performances of these mowers in a critical environment helps to achieve information about their performances in less challenging situations. The first area (Site A) measured 23.04 m^2 and was obtained by installing the boundary wire at a distance of 0.8 m around the square area with obstacles. The second area (Site B) measured 84.64 m^2 and was obtained by installing the boundary wire at a distance of 3 m around the square area with obstacles. One at a time, the six autonomous mowers were tested four times each on both Site A and Site B. Each testing had a duration of 5 h (actual mowing time, no recharging).

2.2. Description of the Machines

The autonomous mowers tested in this trial were two Husqvarna Automower 450X (Husqvarna, Stockholm, Sweden) [10], two Husqvarna Automower 310 (Husqvarna, Stockholm, Sweden), a Husqvarna Automower 105 (Husqvarna, Stockholm, Sweden), and an Ambrogio L15 Deluxe (Zucchetti Centro Sistemi Spa, Terranuova Bracciolini, Arezzo, Italy) [9]. All the machines studied in this trial were autonomous mowers designed for lawn applications. The operative characteristics of the autonomous mowers highlighted in Table 1 were taken from the manufacturer's manuals [9,10]. Of the two Husqvarna Automower 450X, one was tested with "open areas" setting and the other was tested with the "complex areas" setting. Of the two Husqvarna Automower 310, one was tested with "open areas" setting and the other was tested with the "complex areas" setting. The "open areas" setting is suggested when the autonomous mower is set to work in areas with no obstacles and the "complex areas" setting is suggested when the autonomous mower is set to work in areas with many obstacles. The two different settings thoroughly affect the movements of the autonomous mowers during their operation. Adding the Husqvarna Automower 105 and the Ambrogio L15 Deluxe to the previous four autonomous mowers makes a total of six different autonomous mowers that were tested in this trial. The choice of the autonomous mowers for this trial was carried out mainly depending on their dimensions. The overall dimension of the autonomous mowers selected for this trial had to allow them to move inside the area with the obstacles in all directions. Thus, autonomous mowers were split in three groups based on their size: small, medium, and large. For each group, two different autonomous mowers were tested. The two small size autonomous mowers were the Ambrogio L15 Deluxe and the Husqvarna Automower 105, hereafter referred to as Small 1 and Small 2, respectively. The two medium size autonomous mowers were the Husqvarna Automower 310 working with the "open areas" form of the installation setting (Medium 1) and the Husqvarna Automower 310 working with the "complex areas" form of the installation setting (Medium 2). The two large size autonomous mowers were the Husqvarna Automower 450X working with the "open areas" form of the installation setting (Large 1) and the Husqvarna Automower 450X working with the "complex areas" form of the installation setting (Large 2).

Table 1. Main features of the six autonomous mowers studied in the trial.

Parameter	Unit	Autonomous Mower					
		Automower 450X "Open Areas" Large 1	**Automower 450X "Complex Areas" Large 2**	**Automower 310 "Open Areas" Medium 1**	**Automower 310 "Complex Areas" Medium 2**	**Ambrogio L15 Small 1**	**Automower 105 Small 2**
Working Capacity	m^2	5000 ± 20%	5000 ± 20%	1000 ± 20%	1000 ± 20%	600 ± 20%	600 ± 20%
Average Mowing Time	min	260	260	70	70	150	70
Average Charging Time	min	75	75	60	60	60	50
Blade Motor Speed	rpm	2300	2300	2300	2300	4200	2900
Cutting Width	cm	24	24	22	22	15	17
Dimension (Length × Height × Width)	cm	72 × 31 × 56	72 × 31 × 56	63 × 25 × 51	63 × 25 × 51	42 × 25 × 22	55 × 25 × 39
GPS Assisted Navigation		yes	yes	no	no	no	no

2.3. Data Collection

The data collected in this trial were the percentages of area mown by each autonomous mower. Data were measured with a remote sensing system consisting of two Emlid Reach RTK devices [28] along with two software packages to extract and display the data. One of the two Emlid Reach RTK devices was used as a base station and was installed outside the two working areas. The other Emlid Reach RTK device was used as a rover and was attached on each autonomous mower while it performed mowing [29]. The two Emlid Reach RTK devices recorded GNSS signals and calculated the distance between the base station and the rover by running the RTK algorithm. One of the two software packages used for collecting the data was RTKLIB (version 2.4.3), an open-source RTK processing software (T. Takasu, Tokyo, Japan) written by Takasu [30]. This software allowed extracting and processing the data collected by both devices. The RTKLIB off-line processing generated a position file that showed the trajectories carried out by the autonomous mower during the entire work session. The custom-built software "Robot mower tracking data calculator" (Qprel srl, Pistoia, Italy) was used to help process the data concerning the autonomous mowers work. The software processed the position file data and displayed a two-dimensional map showing the recorded points (with an accuracy of 0.05 m). The custom-built software allowed selecting a specific area on the map (e.g., the area with obstacles), the cutting width of the different autonomous mowers, and calculating the percentage of area mown (Figures 1–3). The custom-built software calculated the percentage of area mowed by the machines based on the movements and the cutting width of the autonomous mowers. The percentage of area with obstacles mowed by the machines was recorded every 10 min.

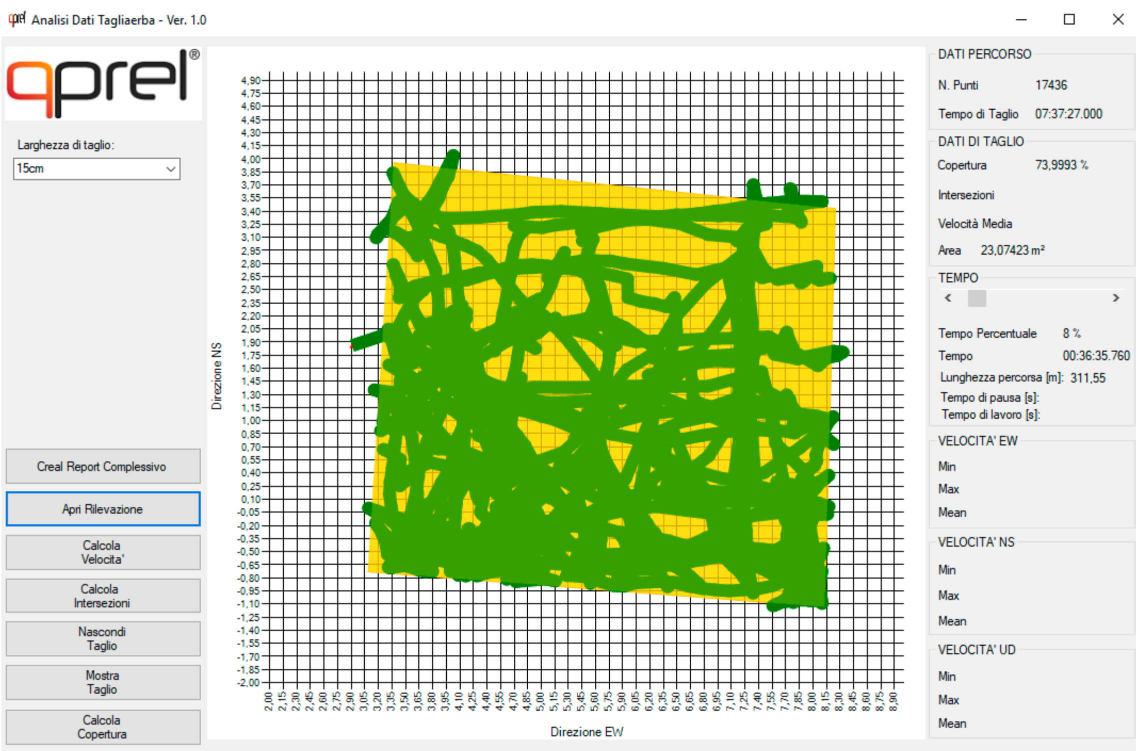

Figure 1. Custom-built software "Robot mower tracking data calculator" showing the percentages of turfgrass mown by the autonomous mowers Small 1 (green lines) at the 8% of the working time (on 18 June 2019) on Site A. The yellow area is the area with obstacles (extension: 23.04 m^2).

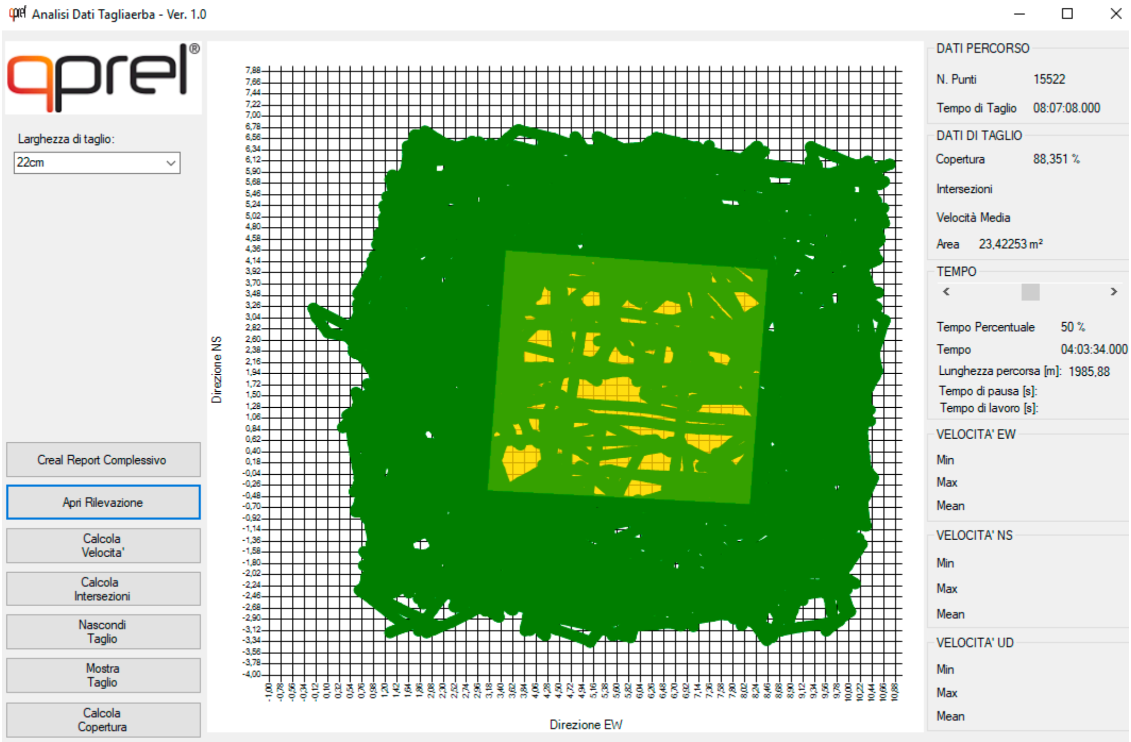

Figure 2. Custom-built software "Robot mower tracking data calculator" showing the percentages of turfgrass mown by the autonomous mowers Medium 1 (green lines) at 50% of the working time on Site B (on 12 February 2019). The yellow area is the area with obstacles (extension: 23.04 m^2).

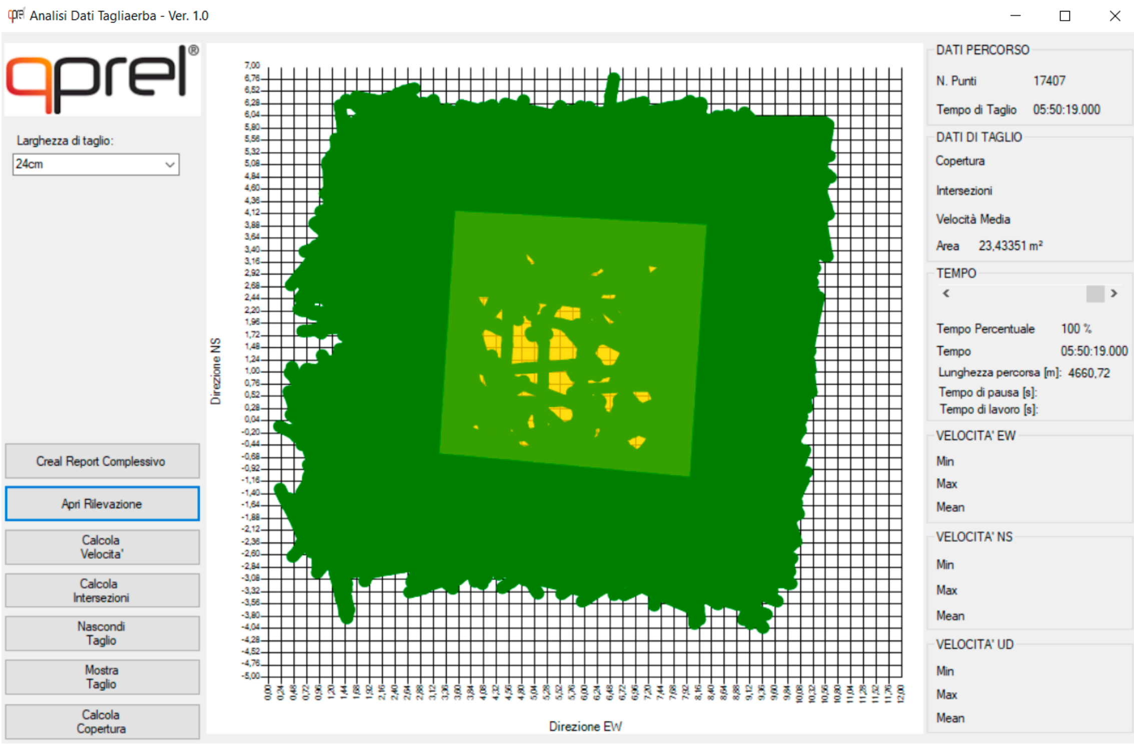

Figure 3. Custom-built software "Robot mower tracking data calculator" showing the percentages of Table 1. (green lines) at 100% of the working time on Site B (on 15 February 2019). The yellow area is the area with obstacles (extension: 23.04 m^2).

2.4. Statistical Analysis

Data were analyzed after being processed by using an angular transformation. Data were analyzed using statistical software R [31]. The Shapiro–Wilk test was used to settle data normality and the Levene's test for homoscedasticity (package "car"). ANOVA was performed to test the significance ($p < 0.05$) of different autonomous mowers and sites on percentage of area mowed every hour. The ANOVA analysis was followed by post hock LSD test at the 0.05 probability level provided by the package ("agricolae").

The percentage of area with obstacles mown in function of the time for the six autonomous mowers was studied separately for Site A and Site B. The extension package "drc" (Dose–Response Curve) of R [32] was used to fit the nonlinear regression model, plot the graphs, and estimate the parameters and the effective time values [29]. The non-linear function corresponded to a two-parameter asymptotic regression (Equation (1)):

$$f(x) = d\left(1 - \exp\left(-\frac{x}{e}\right)\right) \quad (1)$$

The model estimated the parameters d and e. d corresponds to the upper limit of the function for x going to infinity. e expresses the steepness of the increase of the function [33].

The estimated values were compared in pairs by estimating the 95% confidence interval of the difference between the values (Equation (2)):

$$CI\ (\text{difference}) = (x_1 - x_2) \pm 1.96\sqrt{\left(SE_{X_1}\right)^2 + \left(SE_{X_2}\right)^2} \quad (2)$$

where x_1 is the mean of the first value and x_2 is the mean of the second value. SEx_1 is the standard error of x_1 and SEx_2 is the standard error of x_2 [34]. The resulting confidence interval (CI) of the difference between values should not cross the value 0 in order to accept the null hypothesis that the compared values were not different.

3. Results

The back-transformed mean values of the percentage of area with obstacles within Site A mown after 1–5 h by the six different autonomous mowers are shown in Table 2. On Site A, the six autonomous mowers mowed more than 98% of the area with obstacles after 5 h, showing no significant differences (Table 2). Furthermore, the six autonomous mowers mowed more than 89% of the area with obstacles after the first 2 h (Table 2).

Table 2. Back-transformed mean values of the percentage of area with obstacles within Site A mowed after 1–5 h by the six different autonomous mowers.

Mowing Time (h)	Percentage of Area with Obstacles Mowed (%)						LSD	*p* Value
	Autonomous Mower Type							
	Small 1	Small 2	Medium 1	Medium 2	Large 1	Large 2		
1	85.06 a	83.05 a	65.94 c	73.84 bc	79.64 ab	76.85 ab	1159	**
2	94.13	94.36	89.12	94.83	89.75	93.03	1635	ns
3	98.93 a	98.52 a	94.21 b	98.27 a	94.52 b	97.65 ab	1084	*
4	99.82 a	99.63 a	97.98 bc	99.20 ab	96.85 c	98.63 abc	0626	*
5	99.95	99.95	99.85	99.71	98.71	99.7	0431	ns

** $p < 0.01$; * $p < 0.05$; ns, not significant. Different letters on the same line indicate significant difference at $p < 0.05$ (LSD test).

On Site B, the autonomous mowers Small 1 and Small 2 mowed more than 98% of area with obstacles after 5 h and their values were similar after every hour. Autonomous mowers Medium 2 and Large 2 mowed more than 95% of the area with obstacles after 5 h and their values were similar after every hour. Moreover, after 5 h, autonomous mowers Large 1 and Medium 1 mowed an area significantly smaller compared to the other autonomous mowers (Table 3).

Table 3. Back-transformed mean values of the percentage of area with obstacles within Site B mowed after 1–5 h by the six different autonomous mowers.

Mowing Time (h)	Percentage of Area with Obstacles Mowed (%)						LSD	*p* Value
	Autonomous Mower Type							
	Small 1	Small 2	Medium 1	Medium 2	Large 1	Large 2		
1	64.04 a	57.00 ab	43.21 cd	48.16 bc	34.26 d	51.15 bc	1163	***
2	86.51 a	83.43 a	66.39 bc	76.14 ab	56.04 c	80.85 a	1982	***
3	95.01 a	93.33 ab	80.40 d	85.08 cd	66.30 e	89.19 bc	1198	***
4	97.32 a	97.03 a	88.43 b	91.15 b	78.23 c	92.81 b	0943	***
5	98.52 a	98.42 a	93.59 b	95.06 ab	83.01 c	95.97 ab	1078	***

*** $p < 0.001$. Different letters on the same line indicate significant difference at $p < 0.05$ (LSD test).

The asymptotic regression model well describes the recorded data (lack-of-fit test: p value = 0.8997 for the Site A and p value = 1 for the Site B). Data trends are shown in Figure 4 for Site A and in Figure 5 for Site B.

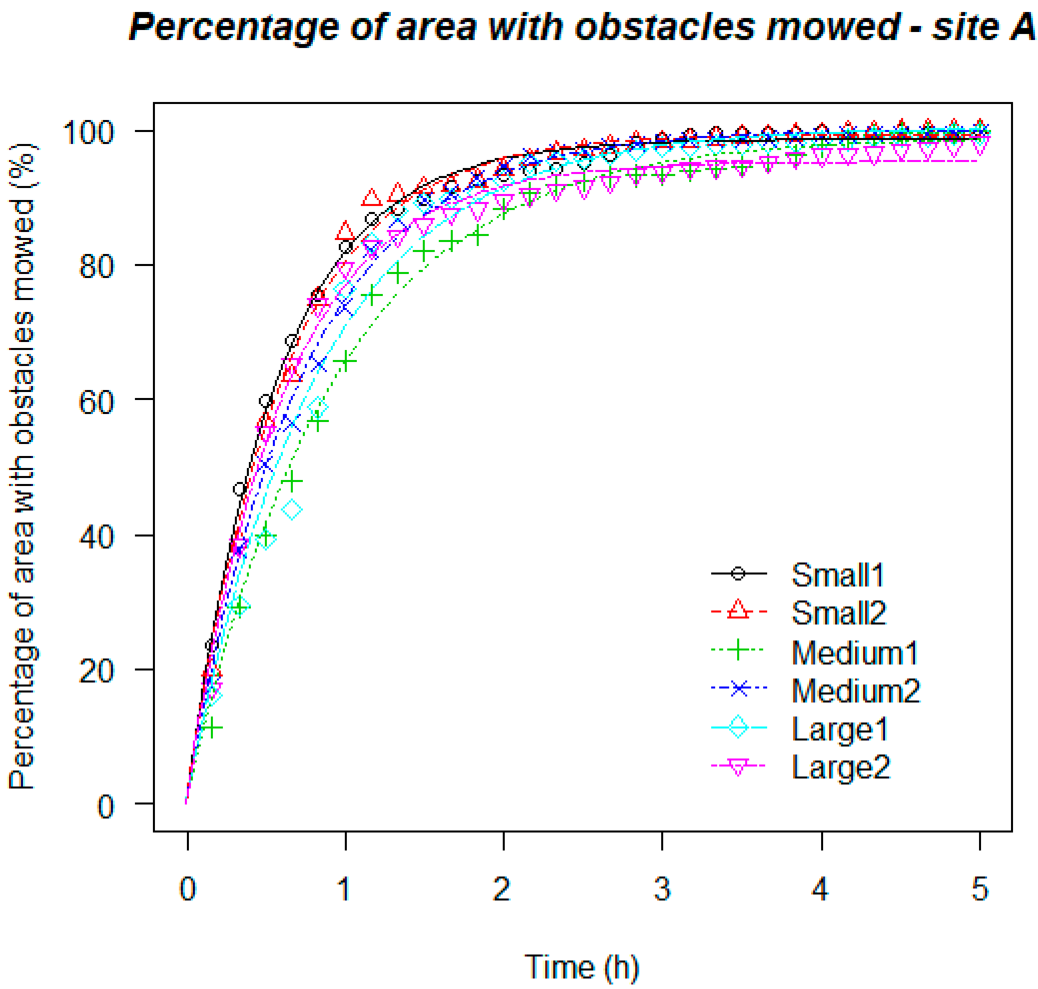

Figure 4. Fitted asymptotic regression curves with average points of the percentage of area with obstacles mown as a function of time (h) and autonomous mower type on Site A.

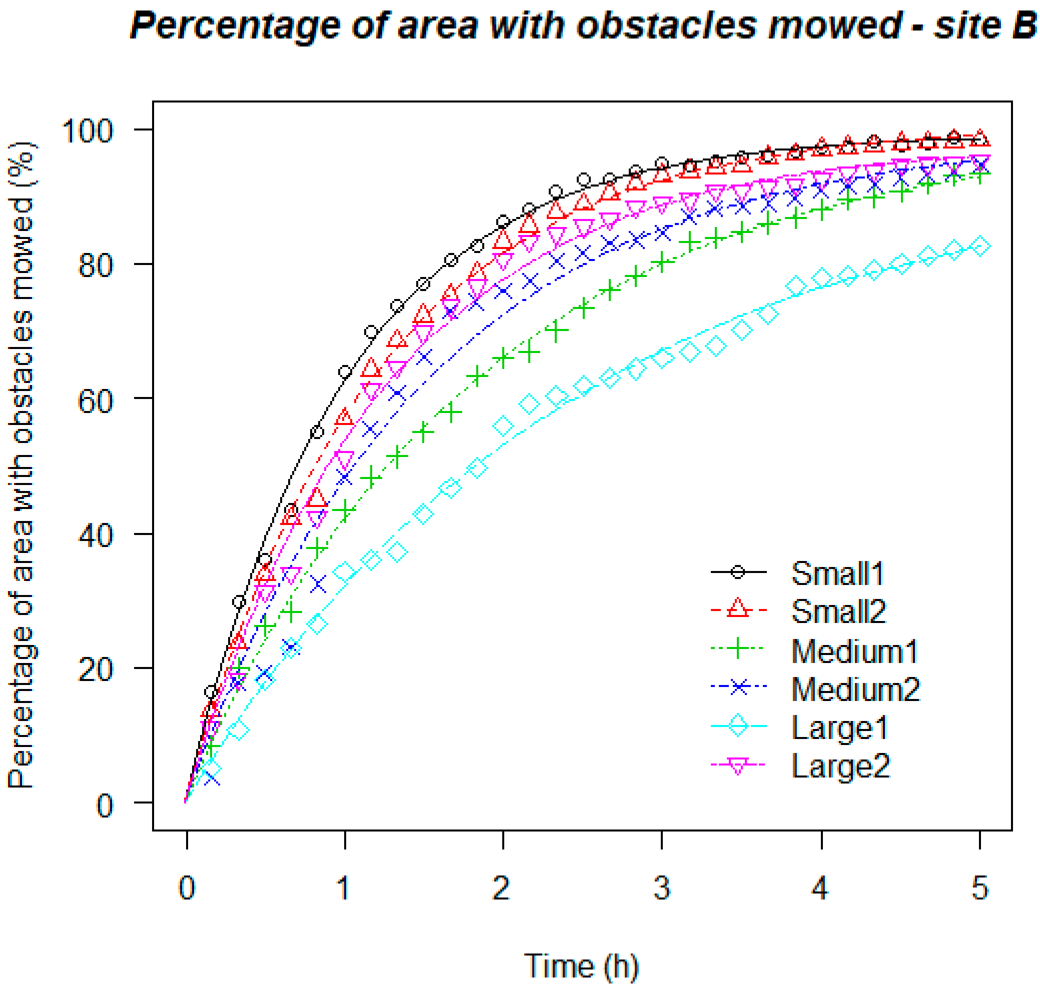

Figure 5. Fitted asymptotic regression curves with average points of the percentage of area with obstacles mown as a function of time (h) and autonomous mower type on Site B.

The parameters of the non-linear asymptotic regressions (Equation (1)) and the effective times estimated from the two-stage meta-analysis dose–response model are reported in Table 4 for Site A and Table 5 for Site B.

Table 4. Parameters of the non-linear asymptotic regressions (Equation (1)) and effective time of the autonomous mowers estimated from the two-stage meta-analysis dose–response model on Site A.

Autonomous Mower	*d*	*e*	Effective Time (h)		
			ET10	ET50	ET90
Small 1	98.71 (0.587)	34.07 (1.132)	0.06 (0.002)	0.40 (0.013)	1.31 (0.044)
Small 2	99.48 (0.593)	36.40 (1.129)	0.06 (0.002)	0.42 (0.013)	1.40 (0.043)
Medium 1	99.06 (0.749)	55.52 (1.673)	0.10 (0.003)	0.64 (0.019)	2.13 (0.064)
Medium 2	100.09 (0.642)	43.69 (1.297)	0.08 (0.002)	0.51 (0.015)	1.68 (0.050)
Large 1	100.40 (0.678)	49.43 (1.405)	0.09 (0.003)	0.57 (0.016)	1.90 (0.054)
Large 2	95.40 (0.600)	36.69 (1.219)	0.06 (0.002)	0.42 80.014)	1.41 (0.047)

d is the upper limit of the curve; *e* determines the steepness of the increase as time; ET10 is the time required to mow 10% of the area with obstacles; ET50 is the time required to mow 50% of the area with obstacles; and ET90 is the time required to mow 90% of the area with obstacles.

Table 5. Parameters of the non-linear asymptotic regressions (Equation (1)) and effective time of the autonomous mowers estimated from the two-stage meta-analysis dose–response model on Site B.

Autonomous Mower	*d*	*e*	Effective Time (h)		
			ET10	**ET50**	**ET90**
Small 1	99.25 (0.968)	60.41 (2.218)	0.11 (0.004)	0.70 (0.026)	2.32 (0.085)
Small 2	100.62 (1.134)	71.84 (2.699)	0.13 (0.005)	0.83 (0.031)	2.76 (0.104)
Medium 1	99.21 (1.942)	109.20 (5.315)	0.19 (0.009)	1.26 (0.061)	4.19 (0.204)
Medium 2	98.87 (1.450)	90.68 (3.729)	0.16 (0.007)	1.05 (0.043)	3.48 (0.143)
Large 1	94.75 (3.017)	145.92 (9.544)	0.26 (0.017)	1.69 (0.110)	5.60 (0.366)
Large 2	97.87 (1.190)	75.91 (2.943)	0.13 (0.005)	0.88 (0.034)	2.91 (0.113)

d is the upper limit of the curve; *e* determines the steepness of the increase as time; ET10 is the time required to mow 10% of the area with obstacles; ET50 is the time required to mow 50% of the area with obstacles; and ET90 is the time required to mow 90% of the area with obstacles.

All the autonomous mowers required a significantly lower amount of time to mow 10%, 50%, and 90% of the area with obstacles on Site A compared to Site B. Autonomous mower Small 1 required less time, compared to the other mowers, to mow 10%, 50%, and 90% of the area with obstacles on both Site A and Site B. On Site A, the time required for the autonomous mowers Large 2, Small 2, and Small 1 to mow 10%, 50%, and 90% of the area with obstacles was similar. On Site B, autonomous mowers Large 2 and Small 2 required similar times to mow 10%, 50%, and 90% of the area with obstacles. On both Site A and Site B, autonomous mowers Medium 1, Medium 2 and Large 1 required more time to mow 10%, 50%, and 90% of the area with obstacles.

4. Discussion

The aim of this study was to evaluate the ability of autonomous mowers working with random trajectories to operate in areas that are similar to agricultural contexts. The values of the percentage of area with obstacles mown by the different autonomous mowers showed that their performances are affected by the layout of the working area and by the typology of autonomous mower. On Site A, the autonomous mowers were enclosed inside the area with obstacles. This layout allowed studying the performances of autonomous mowers moving with random trajectories when they are forced to operate in an area full of obstacles. Conversely, the layout of Site B allowed studying the potential of autonomous mowers working with random trajectories to reach the inside of an area with many obstacles when coming from an obstacles-free area.

While Site A corresponded to the area with obstacles of 23.04 m^2 (Figure 1), Site B measured 84.64 m^2 and was characterized by having an obstacle-free frame of 61.60 m^2 around the area with obstacles of 23.04 m^2 (Figures 2 and 3). On Site B, all autonomous mowers struggled to get inside the area with obstacles since their trend was to remain in the obstacle-free area and change direction after hitting the obstacles. In general, when working on Site A, the time estimated for all autonomous mowers to mow 10%, 50%, and 90% of the area with obstacles was lower compared to the same time estimated for Site B (Tables 4 and 5). When the autonomous mowers worked on Site B, they mowed 90% of the area with obstacles in a significantly higher estimated time (1.7–2 times higher) compared to when the same machines worked on Site A (Tables 4 and 5). Furthermore, on Site B, after 5 h of actual work, Large 1 and Medium 1 autonomous mowers mowed an area significantly smaller compared to the other autonomous mowers (Table 3). Autonomous mowers Large 1 and Medium 1 were working with the “open areas” settings. The results reported in Tables 4 and 5 show that the estimated time required by autonomous mowers Large 1 and Medium 1 to mow 10%, 50%, and 90% of the area with obstacles was higher compared to the time required by autonomous mowers Large 2 and Medium 2 on both sites. On Site B, autonomous mower Large 1 required 5.60 h to mow 90% of the area with obstacles (Table 5), requiring the highest time estimated in this trial. Moreover, autonomous mower Large 1 operating on Site B was the only case in which an autonomous mower mowed less than 90% of the area with obstacles mown after 5 h of actual cutting time (Table 3). On Site

A, it was estimated that the six different autonomous mowers mowed 90% of the area with obstacles in approximately 2 h (Tables 2 and 5). After 5 h of actual mowing, on Site A, there were no significant differences between the percentages of area with obstacles mown by the six autonomous mowers (Table 2). These data imply interesting information concerning the behavior of autonomous mowers operating on areas with different layouts. In particular, this trial highlighted that, as the working time increases, the differences in efficiency between different autonomous mowers forced to operate in an enclosed area with many obstacles become not significant (i.e., working efficiency of the different mowers becomes the same). Concerning the differences between the types of autonomous mowers studied in this trial, it has been possible to see that the smaller autonomous mowers (Small 1 and Small 2) were able to mow 90% of the area with obstacles in a shorter time compared to the four larger machines. In fact, as shown in Table 4, on Site A, autonomous mowers Small 1 and Small 2 mowed 90% of the area with obstacles, respectively, in an estimated time of 1.31 h for autonomous mower Small 1 and 1.40 h for autonomous mower Small 2. On Site B, the time estimated to mow 90% of the area with obstacles was 2.32 and 2.76 h, respectively (Table 5). The significantly shorter time required by the same mowers (Small 1 and Small 2) on both Site A and Site B is due to their significantly smaller dimensions compared to the other autonomous mowers (Table 1). The smaller size of the autonomous mowers Small 1 and Small 2 allowed them to move between the obstacles with less direction changes. These results indicate that small size autonomous mowers well suite these applications. Bechar and Vigneault [35] suggested utilizing small autonomous vehicles in agriculture as a consequence of their lower energy consumption, reduced ground pressure, lower functioning overlap, and lower cost. The two largest autonomous mowers used in this trial had the widest cutting width (Table 1). Even though the dimensions of autonomous mower Large 2 were a hindrance to move inside the area with obstacles, its large cutting width and “complex areas” settings allowed it to operate as efficiently as a smaller sized autonomous mower in terms of mowing percentage of the area with obstacles. In fact, autonomous mower Large 2 mowed 90% of the area with obstacles in 1.41 h on Site A (Table 4) and in 2.91 h on Site B (Table 5). These results are similar to those obtained by smaller autonomous mowers and suggest that a higher level of technology and a specific work setting may overcome the problems associated to larger dimensions in such a restricted working area layout.

5. Conclusions

Autonomous mowers working with random trajectories have shown an interesting potentiality to work in areas with many obstacles such as agricultural fields. In general, the six autonomous mowers were able to mow more than 89% of the area with obstacles in approximately 2 h and more than 98% of Site A after 5 h when they were forced to work enclosed inside an area with many obstacles (Site A). Moreover, the autonomous mowers working on Site A showed an efficiency up to two times higher compared to the autonomous mowers working on Site B and the efficiency differences between the six mowers became not significant as the working time increased. On Site B, it was possible to appreciate differences between autonomous mowers. On Site B, small autonomous mowers obtained the best results, being able to mow more than 83% of the area with obstacles after 2 h and more than 98% after 5 h. The performances of small size autonomous mowers can be attributable to their ability to move between the obstacles with less direction changes compared to larger mowers. However, specific settings developed to improve the work of larger mowers in areas with many obstacles have shown the potential to increase autonomous mowers working efficiency. Larger mowers operating with specific settings obtained similar results compared to smaller sized autonomous mowers. In recent times, in many countries there is the innovative trend to turn ornamental landscaping into edible landscaping [36,37] and autonomous mowers operating with random trajectories may be the optimal management solution in such areas without requiring specific upgrades. Despite the autonomous mowers studied in this trial have shown a great ability to move inside a simulated agricultural field, the improvement of their mechanical drive system is mandatory in order to operate in real field conditions.

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