Animal Biotelemetry

CASE REPORT

Open Access

The performance of alternative GPS tracking devices: a case report on wild boars (*Sus scrofa*)

Mervi Kunnasranta[1,2*], Elmo Miettinen[3,4*], Markus Melin[1], Anna Meller[5], Veli-Matti Väänänen[6], Otso Huitu[7] and Katja Holmala[3]

Abstract

Background Telemetry studies on terrestrial mammals have been carried out almost exclusively using neck collar-mounted devices. However, collars are not suitable for all species and all age classes and may therefore compromise animal welfare and data quality requirements. Here, we evaluate the use of non-collar tracking devices on wild boars (*Sus scrofa*), a species for which collars may be problematic due to neck shape and seasonal body mass variation. We tested pelt-glued tags and three types of GPS ear tags. In addition, animals were marked with plain cattle ear tags.

Results The tested GPS tags exhibited various technical challenges related mostly to satellite coverage of the study area and tag loss. However, GPS devices enabled moderate movement monitoring of weeks to months, whereas plain cattle ear tags offered information on displacement over longer time intervals. The longest direct dispersal distance (163 km) by a wild boar sounder was discovered by cattle tags.

Conclusions Data volume and quality obtained from small tags are inferior to data provided by GPS collars, but low-fix rate tags may enable monitoring of individuals with reduced invasiveness. Moreover, these tags enable tracking in cases where the collar is not an option. The low price and small size of the devices together with technical developments may offer cost-effective tools for future studies on dispersal and survival.

Keywords Animal welfare, Ear tag, Glued-on tag, Telemetry, Dispersal, 3Rs

Background

Telemetry devices using neck collars are popular for studying a variety of mammalian species. However, collars occasionally cause abnormal behaviour [1, 2], and tightening collars due to body mass variations have the potential to cause adverse effects ranging from hair loss or mild irritation to severe skin lesions or tissue damage [3–6]. Equally, a collar fitted too loosely may drop off on its own or become entangled [4, 5, 7]. In addition, not all species, age classes, or sexes are optimal for collaring due to their anatomy, or seasonal or age-related changes in their body weight or neck shape. Therefore, less harmful alternative approaches for wildlife tracking may be more suitable for such species and individuals. Alternative ways to attach external telemetry devices include harnesses [8], ear tags [9, 10], tail mounts [11], horn implants [12], and pelt glue [11, 13–15].

*Correspondence:
Mervi Kunnasranta
mervi.kunnasranta@luke.fi
Elmo Miettinen
elmo.miettinen@helsinki.fi
[1] Natural Resources, Natural Resources Institute Finland (Luke), Joensuu, Finland
[2] Department of Environmental and Biological Sciences, University of Eastern Finland, Joensuu, Finland
[3] Doctoral Programme in Wildlife Biology, University of Helsinki, Helsinki, Finland
[4] Natural Resources, Natural Resources Institute Finland (Luke), Helsinki, Finland
[5] Laboratory Animal Center, University of Helsinki, HiLIFE, Helsinki, Finland
[6] Department of Forest Sciences, University of Helsinki, Helsinki, Finland
[7] Natural Resources, Natural Resources Institute Finland (Luke), Tampere, Finland

The wild boar (*Sus scrofa*) has one of the largest geographic distributions among terrestrial mammals and has been widely studied by telemetry. During recent decades, wild boar tracking studies have been carried out almost exclusively using GPS collars. Although reports on collar-related tissue damage, drop-off mechanism failures, or inadvertent dropping of collars in wild boar studies are relatively scarce [6, 16], seasonal changes in body mass [17] and pig morphology ("the absence of neck") may indicate that more challenges occur in collar fittings than has been reported. Especially in the case of juveniles, pubertal body growth does not enable the long-term use of a fixed collar girth, and most telemetry studies therefore focus on adult wild boars. However, in addition to animal welfare issues, gaining reliable data on juvenile dispersal and survival requires a multitude of studied individuals, which in turn would benefit from low-cost tracking devices.

In this pilot study, we tested alternative approaches to neck collars for telemetry tracking of wild boar. The main objectives of this study were (1) to identify reliable and efficient methods for deploying low-cost and light GPS transmitters, and (2) to study the general performance, position deliverance, and durability of the selected devices and formulate best practices for their use.

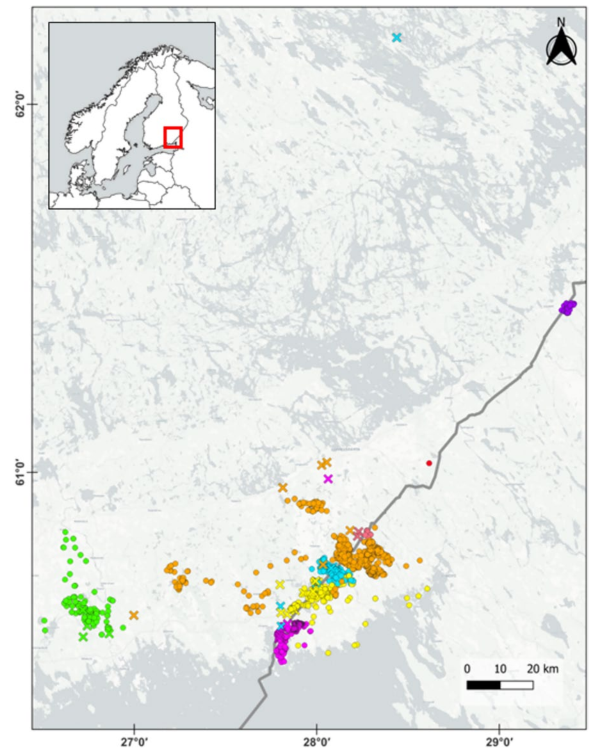

Fig. 1 Study area and location fixes of tracked wild boars ($N = 108$). Colours of the location markers represent the capture region of the individuals. GPS locations are presented as dots, and crosses represent locations provided by cattle ear tags (as reported by hunters)

Methods

This study was conducted as part of a wild boar collaring project in southeastern Finland (Fig. 1), where individuals with a weight of more than 60 kg were GPS collared (see Miettinen et al. [6] for details). Capturing was predominantly conducted in the Finnish–Russian border area. Of the captured animals, 103 individuals received uniquely numbered ear tags, and 65 individuals received pelt-glued or ear-attached GPS tags (Fig. 2). All glue tagging was conducted under sedation, while only the first ear-tagged individuals were sedated.

The Yabby GPS cellular tracker (2G; c. 100 €/item) was developed for tracking vehicles. It uses GSM networks to send GPS locations. The tag was attached to the pelage in the caudal back of the animal with glue (Super Epoxy, 5 min). With three AAA lithium batteries, the tag weighed 160 g and enabled around 750 locations. The Yabby tags allow changing the location interval setting during tracking, and the tags predominantly provided GPS locations two to eight times per day. We modified Yabby devices into ear tags by gluing the transmitter component and batteries onto a plastic cattle ear tag (total weight circa 60 g).

The other ear devices were originally developed for monitoring reindeer (Anicare) and livestock (Ceres Tag). Anicare tags (20 g; one-point attachment; c. 300 €/item) provided one location per day and, according to the manufacturer, the expected battery life with this setting is four years. It uses GSM networks to send location data. The Ceres tags (35 g; two-point attachment; c. 200 €/item) are solar-powered tags and, according to the manufacturer, their expected battery life is 10 years. Ceres tags provide locations ca. four times per day via Low Earth Orbit (LEO) satellites and can self-regulate the fix interval based on battery charge.

Monitoring tag data may involve recurrent (monthly/annual) costs depending on the map software provider chosen. In this study, the Mapipedia software [20] (monthly costs of c. 20 €) was used for monitoring and exporting the Ceres data. For Yabby tags, the device supplier provided Poroseuranta software [18] (included in the item price) for tag settings, monitoring, and data export. Anicare tags were monitored using the manufacturer's software application [19] (included in item price). Complete datasets were provided by Anicare via email.

The reasons for why tracking ended were classified based on observations if the animals or devices were found on the Finnish side of the border and on GPS location patterns in cases where the last connections were on the Russian side and the animals were not observed

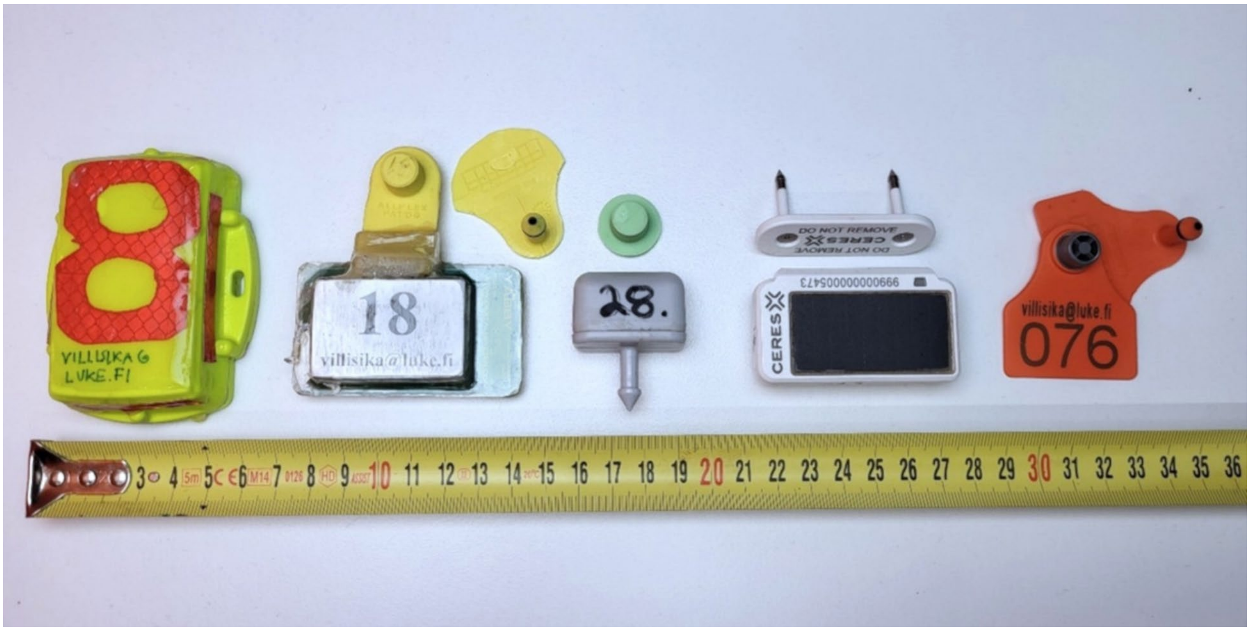

Fig. 2 Glued-on and ear tags of wild boars. From left: Yabby glued-on GPS tag, custom-made Yabby GPS ear tag, Anicare GPS ear tag, Ceres GPS ear tag, and plain cattle ear tag

anymore. If the last fixes prior to the end indicated clear movement with subsequent displacements of over 50 m, we assumed that the device malfunctioned (including the running out of battery) while on the animal, whereas over a week of locations from a single point (within 50 m) were considered a dropped tag. However, GPS locations from a stationary device may also have resulted from the death of the animal (even though no such cases were confirmed during this study).

Results

We received a total of 4928 (median = 23, range = 2–715; Table 1) GPS locations from the 65 devices. Yabby tags, with a shorter interval positioning, provided the most data. The largest number of fixes were provided by the unmodified large glued-on Yabby tags. The Anicare and Ceres tags provided less data, with Anicare's one daily fix and Ceres's adaptive positioning intervals that account for battery life. In addition to GPS devices, the cattle tags provided 51 locations, based on recaptures and hunting sites.

The realized tracking duration of the ear tag devices varied between 2 and 85 days. The duration of glued-on tags depended on seasonal hair types. GPS tracking most often ended in tag malfunction, especially in the ear-attached devices. Glued-on devices most frequently dropped off as per design. However, 20% of the working ear-attached Yabby tags dropped along with some Anicare (11%) and Ceres tags (17%). Half of the cattle tags were recovered by wild boar hunters.

Discussion

The 3R principles (replace, reduce, refine), originally developed for laboratory animal experiments, encourage minimizing harm to the animals also in wildlife studies [21]. Utilizing small GPS devices, where the attachment is not influenced by growth or weight changes, can be considered a refinement of collar-dominated wild mammal studies, especially for wild boar. One of the welfare challenges of wildlife tracking is to ensure that the devices do not harm the animals or otherwise interfere with normal behaviour. The quick attachment of ear tags is possible without prolonged stress even without sedation, providing an improvement to this challenge. The use of anaesthetics includes physiological risks and prolongs the procedure and recovery process [22]. While the pointed and strong ears of wild boar are considered suitable for tag attachment, excessive tag weight may lead to ripping of the ear lobe. Higher fix rates and longer study periods would require more or larger batteries, which increase tag weight.

Pelt glue is a leading method for attaching tracking devices to pinnipeds [14], and it has also been implemented in other taxa such as insectivores [13], leporidae [15], and castoridae [11]. To our knowledge, this was the first pilot study to use glue for attaching telemetry devices to free-ranging wild boars. Gluing typically requires

Table 1 Summary of cattle tag and GPS tag details and performance in wild boars ($N = 108$)

	Yabby (ear)	Yabby (glue)	Anicare	Ceres	GPS devices (total)	Cattle ear tag
Device information						
Weight (g)	60	160	20	35		5
Attachment	One-point, ear	Glue, pelt	One-point, ear	Two-point, ear		One-point, ear
Data communication	GSM	GSM	GSM	satellite		None
Expected daily fixes	1–8	2–16	1	4		
Expected battery lifespan	c. 750 fixes	c. 750 fixes	4 years	10 years		
Price class per item (2024)	c. 100 €[a]	c. 100 €	c. 300 €	c. 200 €		< 1 €
Utilized devices						
N	20	12	27	6	65	103
Provided any data	95%	83%	78%	100%	86%	50%
Median statistics of working devices (min–max)						
Fixes	38 (7–224)	310 (82–715)	7 (1–61)	16 (2–24)	23	1 (1–2)
Duration (days)	13 (3–71)	60 (5–94)	15 (3–85)	17 (2–38)	16	237 (11–732)
Fix rate (% of expected fixes)	100 (79–100)	100 (97–100)	70 (1–100)	20 (13–42)	96	
Reasons for end of tracking						
Animal died			3		3	44
Device failure	15	1	16	5	37	
Device dropped	4	9	2	1	16	

[a] Costs of modifying items onto ear tags are dependent on used materials and expertise, and thus not included

sedation due to the hair cutting and glue hardening processes. However, the actual marking method is non-invasive when ensuring that the glue does not have direct skin contact, as the devices drop naturally during the following moult. Devices attached to winter hair yielded the longest tracking periods, which is in accordance with earlier tests with captive wild boars [23]. According to our observations, no marks were left by past tags on the new pelt after moulting. The potential animal welfare issues with this method are related to the high temperature of the epoxy glue during the hardening process, but this can be avoided by using thin glue layers that do not reach the skin. In addition, other glue types, such as non-heating super glues, should be tested.

Cattle ear tags represent low-cost passive tracking, but typically they only offer two-point displacement data which are also highly dependent on hunting. In this study, nearly half of the cattle tags were recovered and reported by hunters. The cattle ear tags are light and may provide recoveries even years after tagging. Therefore, it is not surprising that these tags provided the longest durations between capture and recovery in this study (up to 732 days). In addition, as the likelihood of detecting long movements may increase with time, the cattle ear tags provided the longest observed dispersal distances. One of these included a sow farrowing in a new region, which indicates breeding dispersal. Interestingly, another dispersing sounder, tagged 20 months earlier, exhibited the longest direct dispersal (163 km) observed in our study. This, to our knowledge, is the longest observed travel distance by a wild boar sounder, exceeding the maximum direct distance of 100 km observed by Jerina et al. [24]. The cattle tags may be most suitable for low-cost side studies (e.g. tagging the by-catch of whole piglet sounders, while trapping adults for collaring) providing data on population level displacement rates and distances over long time periods. However, the low recovery rates and lack of detailed spatiotemporal data decrease cattle ear tag usability for analysing many ecological aspects of dispersal.

This, as far as we know, is the first study to test GPS ear tags on wild boars. Evidently, the data volume and quality from small tags are notably lower than those of collar-mounted large devices. The tested GPS tags provided a median of 23 locations during an average 16-day study period. For example, in the same study area, collars provided a median of 1628 locations per tracked wild boar, with a daily average of 20 fixes [6]. Thus, the small tags with low fix rates are not yet sufficient in replacing collars, but nonetheless provide tracking possibilities when collars are not an option. Device failure was the predominant reason for a GPS ear tag monitoring to end, and the causes for failure varied depending on the device. The larger size of the Yabby ear tag may predispose it to structural damage or to dropping off due to rough behaviour by the animals. The Ceres solar panels may not be sufficient for studying a forest-dwelling and mud-bathing nocturnal species. The Anicare tags most often lost their GSM connection when entering Russian GSM coverage, indicating general challenges in network roaming. However, in this study as well as in our preliminary observations from a study on white-tailed deer (*Odocoileus virginianus*), the Anicare tags remaining within the Finnish mobile network coverage yielded significantly longer tracking times.

Despite technical challenges, developing and testing alternative tracking options is beneficial not only for improving animal welfare and study possibilities with wild boar but also for research of many other mammal species. The improvements in sensor technology [25] and reductions in battery sizes may make tag alternatives more competitive compared to collars in the future. We emphasize the importance of documenting and mitigating the possible adverse effects of tracking devices on wildlife, with the aim of improving both practices in science and animal welfare.

Acknowledgements
The authors thank the field workers and local hunters that participated in the data collection for this study. We thank Stella Thompson and Mairi Young for the language revision. This study was funded by the Ministry of Agriculture and Forestry and by Karjalan Kulttuurirahasto sr (the Carelian Culture Foundation).

Author contributions
All authors contributed to the study conception, design, and data collection. Analysis and the first draft of the manuscript were prepared by MK, EM, and MM. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding
Open Access funding provided by University of Helsinki (including Helsinki University Central Hospital). This study was funded by the Ministry of Agriculture and Forestry and by Karjalan Kulttuurirahasto (the Carelian Culture Foundation) [Grant number: 20210050].

Availability of data and materials
The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The capture and handling were permitted and performed following a protocol approved by the Project Authorisation Board (ESAVI/4904/2020) and the Finnish Wildlife Agency (2020-7-000-25421-0). Animal welfare was supervised by a designated veterinarian and by the Animal Welfare Body of the Natural Resources Institute Finland.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 27 June 2024 Accepted: 15 September 2024
Published online: 28 September 2024

References

1. Stabach JA, Cunningham SA, Connette G, Mota JL, Reed D, Byron M, Songer M, Wacher T, Mertes K, Brown JL, Comizzoli P, Newby J, Monfort S, Leimgruber P. Short-term effects of GPS collars on the activity, behavior, and adrenal response of scimitar-horned oryx (*Oryx dammah*). PLoS ONE. 2020;15: e0221843. https://doi.org/10.1371/journal.pone.0221843.
2. Brooks C, Bonyongo C, Harris S. Effects of global positioning system collar weight on zebra behavior and location error. J Wildl Manag. 2008;72:527–34. https://doi.org/10.2193/2007-061.
3. Krausman PR, Bleich VC, Cain JW III, Stephenson TR, DeYoung DW, McGrath PW, Swift PK, Pierce BM, Jansen BD. From the field: neck lesions in ungulates from collars incorporating satellite technology. Wildl Soc Bull. 2004;32:987–91. https://doi.org/10.2193/0091-7648(2004)032[0987:FTFNLI]2.0.CO;2.
4. Coetsee A, Harley D, Lynch M, Coulson G, de Milliano J, Cooper M, Groenewegen R. Radio-transmitter attachment methods for monitoring the endangered eastern barred bandicoot (*Perameles gunnii*). Aust Mamm. 2016;38:221–31. https://doi.org/10.1071/AM15029.
5. Bergvall A, Jäderberg L, Kjellander P. The use of box-traps for wild roe deer: behaviour, injuries and recaptures. Eur J Wildl Res. 2017;63:67. https://doi.org/10.1007/s10344-017-1120-7.
6. Miettinen E, Melin M, Holmala K, Meller A, Väänänen VM, Huitu O, Kunnasranta M. Home ranges and movement patterns of wild boars (*Sus scrofa*) at the northern edge of the species' distribution range. Mamm Res. 2023;68:611–23. https://doi.org/10.1007/s13364-023-00710-5.
7. Jones M, Hamede R, McCallum H. The Devil is in the detail: conservation biology, animal philosophies and the role of animal ethics committees. In: Banks P, Lunney D, Dickman C, editors. Science under siege: zoology under threat. Mosman: Royal Zoological Society of New South Wales; 2012. p. 79–88.
8. Theuerkauf J, Barrière P, Cadin K, Gula R. A trial of satellite GPS telemetry on feral pigs in tropical mountain rainforest. Aust Mamm. 2022;45:121–4. https://doi.org/10.1071/AM22015.
9. Keuling O, Stier N, Roth M. Annual and seasonal space use of different age classes of female wild boar *Sus scrofa* L. Eur J Wildl Res. 2008;54:403–12. https://doi.org/10.1007/s10344-007-0157-4.
10. Keiter DA, Kilgo JC, Vukovich MA, Cunningham FL, Beasley JC. Development of known fate survival monitoring techniques for juvenile wild pigs (*Sus scrofa*). Wildl Res. 2017;44:165–73. https://doi.org/10.1071/WR16204.
11. Pitman JB, Bastille-Rousseau G. Retention time and fix acquisition rate of glued-on GPS transmitters in a semi-aquatic species. Anim Biotelem. 2023;11:24. https://doi.org/10.1186/s40317-023-00335-0.
12. Seidel DP, Linklater WL, Kilian W, Preez PD, Getz WM. Mesoscale movement and recursion behaviors of Namibian black rhinos. Mov Ecol. 2019;7:34. https://doi.org/10.1186/s40462-019-0176-2.
13. Rautio A, Valtonen A, Kunnasranta M. The effects of sex and season on home range in European hedgehogs at the northern edge of the species range. Ann Zool Fenn. 2013;50:107–23. https://doi.org/10.5735/086.050.0110.
14. Horning M, Andrews RD, Bishop AM, Boveng PL, Costa DP, Crocker DE, et al. Best practice recommendations for the use of external telemetry devices on pinnipeds. Anim Biotelem. 2019;7:20. https://doi.org/10.1186/s40317-019-0182-6.
15. Voigt U, Siebert U. Living on the edge circadian habitat usage in preweaning European hares (*Lepus europaeus*) in an intensively used agricultural area. PLoS ONE. 2019;14: e0222205. https://doi.org/10.1371/journal.pone.0222205.
16. Wyckoff C, Henke S, Kleberg C. GPS telemetry collars: considerations before you open your wallet. In: Nolte DL, Arjo WM, Stalman DH, editors. In: Proceedings of the 12th wildlife damage management conference, University of Nebraska, Lincoln; 2007. p. 571–6.
17. Gethöffer F, Keuling O, Maistrelli C, Ludwig T, Siebert U. Heavy youngsters—habitat and climate factors lead to a significant increase in body weight of wild boar females. Animals. 2023;13:898. https://doi.org/10.3390/ani13050898.

18. Poroseuranta. https://www.poroseuranta.fi (2024). Accessed 10 Jan 2024.
19. Anicare. https://application.anicare.fi (2024). Accessed 10 Jan 2024.
20. Mapipedia. https://mapipedia.com (2024). Accessed 10 Jan 2024.
21. Zemanova MA. Towards more compassionate wildlife research through the 3Rs principles: moving from invasive to non-invasive methods. Wildl Biol. 2020;1:1–17. https://doi.org/10.2981/wlb.00607.
22. Morelli J, Rossi S, Fuchs B, Richard E, Barros DS, Küker S, Arnemo JM, Evans AL. Evaluation of three Medetomidine-Based anesthetic protocols in free-ranging wild boars (*Sus scrofa*). Front Vet Sci. 2021;8: 655345. https://doi.org/10.3389/fvets.2021.655345.
23. Beckmann J, Klamm A, Wurm J. Seasonal hair growth and loss in wild boar (*Sus scrofa*) and its implications for research. Suiform Sound. 2023;22:19–21.
24. Jerina K, Pokorny B, Stergar M. First evidence of long-distance dispersal of adult female wild boar (*Sus scrofa*) with piglets. Eur J Wildl Res. 2014;60:367–70. https://doi.org/10.1007/s10344-014-0796-1.
25. Arablouei R, Wang Z, Bishop-Hurley GJ, Liu J. Multimodal sensor data fusion for in-situ classification of animal behavior using accelerometry and GNSS data. Smart Agric Tech. 2023;4: 100163. https://doi.org/10.1016/j.atech.2022.100163.

Publisher's Note