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COFE-FETEC 2023

"Forest Operations: A Tool for Forest Management"

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May 23 – 25, 2023
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INTRODUCTION

International Conference of COFE-FETEC 2023 along with the **45th Council on Forest Engineering (COFE)** meeting was hosted by **Northern Arizona University**, **USDA Forest Service** and **FETEC (Forest Engineering and Technologies)** on 23-25 May 2023 in Flagstaff, Arizona. The conference aimed to offer opportunities for sharing new initiatives, innovations, and technology development in forest operations and networking with researchers, practitioners, and shareholders from industry.

During the three-day conference, we had the opportunity to discuss the most recent scientific research and professional works about the following topics:

- Workforce Training and Safety
- Ecological Restoration and Forest Sustainability
- Steep Slope Operations
- Biomass Utilization & Disposal
- Harvesting Operations Logistics
- Precision Forestry
- Forest Operations in Sensitive Zones

On behalf of the entire organizing committee, we would like to thank all the participants of the conference and express my best wishes to those who contributed during the preparation and organization stages of the conference.

Han Sup Han
Conference Chairman

Jeff Halbrook
Co-Chairman

Abdullah E. Akay
Co-Chairman

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Newly Developed Loading Grapple and Radio Controlled Hydraulic Stationary Yarder for a Conventional Cable System in Japan: Comparative Analysis with a Normal Type Cable System and Evaluation of Application for Retention Forestry

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Abstract
Although the use of tower yarders in logging operations has gradually increased in moderately steeply sloped forested areas, conventional cable systems with stationary yarders continue to play an important role in extremely steeply sloped forested areas in Japan. This is because the complicated topographical nature of the Japanese islands limits the construction of suitable forest roads in steep areas. However, in the past decade, inspired by requests from enthusiastic forest owners, dedicated cable system engineers have developed an operationally safe and efficient system using a radio-controlled loading grapple and a hydraulic yarder with the Endless-Tyler system, which is the most popular rigging method for conventional cable systems in Japan. A comparative study was conducted to test the new system against conventional cable systems. Significantly higher productivity was achieved for the new system due to the reduction of hooker evacuation time and unhooking time. Rigging labor was also reduced because the yarder could be remotely controlled during rigging and unrigging. The potential application of the system was evaluated for retention forestry, which requires the partial retention of trees in clear-cut operations to improve the ecosystem of plantation forests. For the greatest productivity gains in retention forestry there will be an optimum combination of hauling and lateral yarding distances.

Keywords: Hydraulic yarder, grapple equipped loading block, logging cable system, remote control, retention forestry

1. Introduction

As in the rest of the world, Japan's logging industry is moving toward the increased use of mechanized operations, especially vehicle-based systems such as the cut-to-length system. However, the Japanese islands have many areas of steep terrain that are not suitable for vehicle-based systems. Gotou (2011) analyzed terrain data across Japan and concluded that 36.3% of the total forest area was on slopes steeper than 30 degrees, and 22.8% of the total forest area on slopes steeper than 35 degrees. In such steep terrain areas, tower yarders are one of the few possible options for logging operations. European tower yarders have been introduced to steep forested areas in Japan in recent decades (Suzuki et al., 2015; Nakazawa et al., 2022). The undercarriages of these tower yarders have larger dimensions than normal Japanese forestry machines. Suzuki et al. (2023a, b) pointed out that even public roads in steep terrain areas in Japan are not wide enough for standard 10-ton logging trucks and large forest machines. On the other hand, yarders for conventional logging cable systems can be transported by smaller trucks, such as 4-ton trucks. Therefore, conventional logging cable systems are (Matsuoka et al., 2021; Yamasaki et al., 2021) and will continue to be needed in the mountainous, steeply forested areas of Japan.

Figure 1 illustrates the currently most popular rigging method for conventional cable systems in Japanese forestry, the Endless-Tyler system (Konuma and Shibata, 1976). The system requires a three-drum yarder and a crew of three or four persons for logging operations; i.e., a yarder operator at the landing, an unhooking worker at the landing, a processor operator at the landing and a hooker/choker at the logging site. In many cases, a yarder operator or a processor operator also works

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as an unhooker, reducing the crew size to three. The system also requires manpower for rigging and unrigging; typically, a week for rigging a few hundred meters of span and half a week for unrigging. From both safety and productivity standpoints, manual hooking and unhooking are the main challenges for conventional logging cable systems.

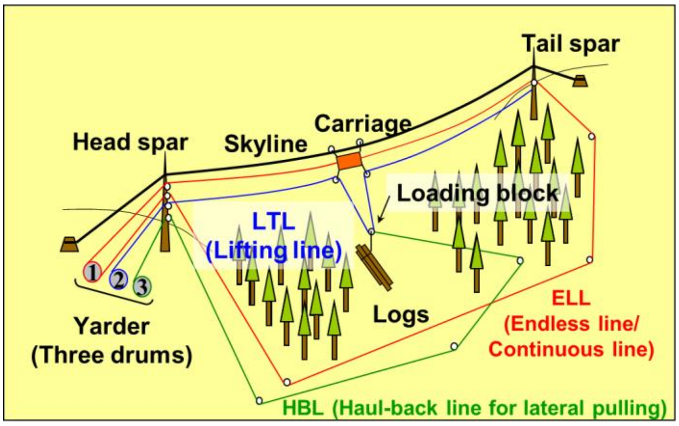

Figure 1. Conventional cable logging system (Endless-Tyler)

To address the safety and productivity issues of conventional logging cable systems, a hydraulically driven yarder combined with a remote control system has been developed. Development has continued since the 2010s at the request of the Yamacho Forestry Company in the Kii Peninsula area, an area in the middle of Japan with some of the country's steepest mountain areas (Enomoto, 2014, 2023a, b). The system is manufactured by MAEDA SEISAKUSHO CO., LTD. (MAEDA SEISAKUSHO CO., LTD., 2023) and is currently in use at many logging sites in the area. Although the power for the yarder is provided by a diesel engine, a fully hydraulic power transmission system from the engine to the drum transmission enables an electric remote control system. However, the system still requires a minimum of a three-person crew, including a hooker/choker on site.

Based on the development of the above-mentioned system with a remote-controlled hydraulically driven yarder, a renovated cable logging system was developed by adding a remote-controlled grapple to a loading block of the Endless-Tyler system (Figures 2 and 3; Iwafuji Industrial Co., Ltd., 2022, 2023). The yarder (model YR-302E) weighs 2.880 tons and is equipped with three interlocking drums that have a maximum pulling force of 28 kN on the lifting drum and an endless line speed of 417 m/min. The diameter of the working lines should be between 10 and 14 mm. The grapple (model BLG-16R) is combined with the loading block (total mass: 500 kg), powered by a lithium-ion battery and controlled by two sets of remote controls. These also control the yarder. The crew can be reduced to two people, a controller operator at the site (Figure 6) and a processor operator at the landing who also operates the other set of controllers. Rotation of a pulley built into the loading block charges the battery, i.e. the movement of the carriage during logging generates electrical power for the grapple. At least 200 meters of span is required for the arrangement of the cable system to charge the battery. A government-sponsored project supported the development of this system. A series of verification studies are currently being carried out in several steep forested areas in Japan. The first objective of the present paper was to confirm the claimed advantages of the newly developed system by analyzing the test operation conducted in the Kochi Prefecture, comparing productivity with case studies of conventional logging cable systems.

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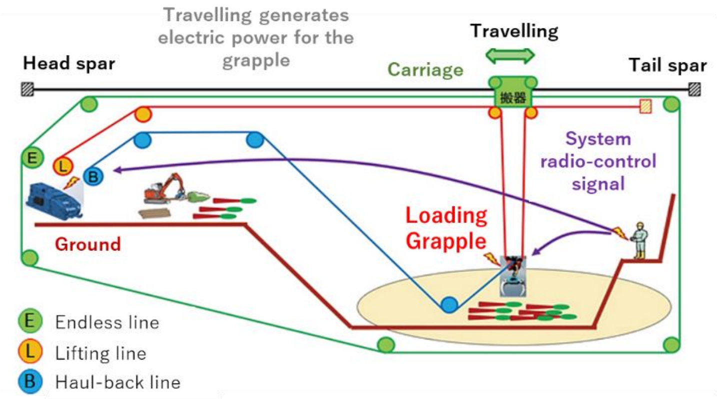

Figure 2. Newly developed cable logging system combined with hydraulic yarder and loading grapple. The figure has been modified from the original (Iwafuji Industrial Co., Ltd., 2022, 2023).

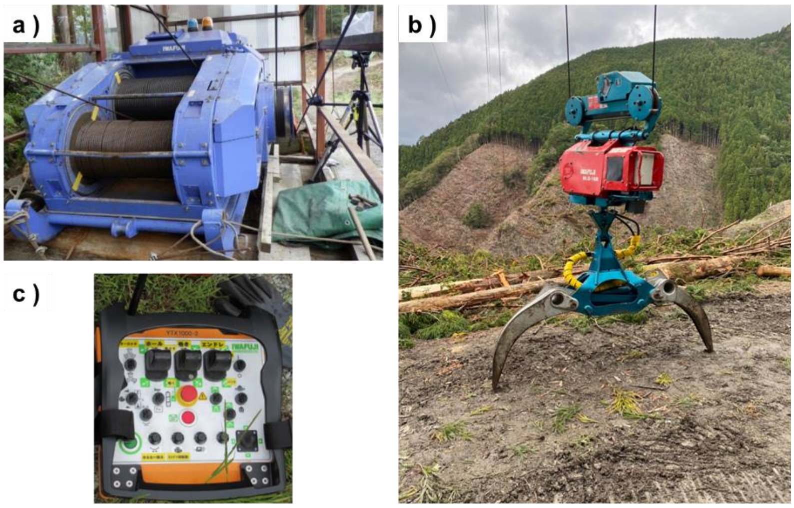

Figure 3. Main components of the newly developed cable system. a) Hydraulically operated remotely controlled yarder (model YR-302E), b) Loading block equipped with an electrically operated grapple (model BLG-16R), c) Remote control unit.

The second objective was to assess the applicability of cable logging operations in the context of a newly developed system for retention forestry. Retention forestry aims to enhance biodiversity in plantation forests by retaining a portion of trees or stands in otherwise clear-cut operations (Lindenmayer et al., 2012). Although the approach has been widely implemented in temperate and boreal forests in North America and European countries, only a few trials have been carried out in Japan, such as those in Hokkaido Island (Ozaki et al., 2018). Additional trials have recently started in the national forests of the Shizuoka and Kochi prefectures in central and southeastern Japan, respectively.

2. Materials and Methods

2.1 Comparative Study of Productivity

The test site was prepared over a private plantation forest of Japanese cedar (*Criptomeria japonica*) with trees over 60 years old, which was located in Nanato, Motoyama-town, Kochi prefecture, Japan (Figure 4). The geographic coordinates of the center of the site are 33°48'20.2"N, 133°34'24.6"E.

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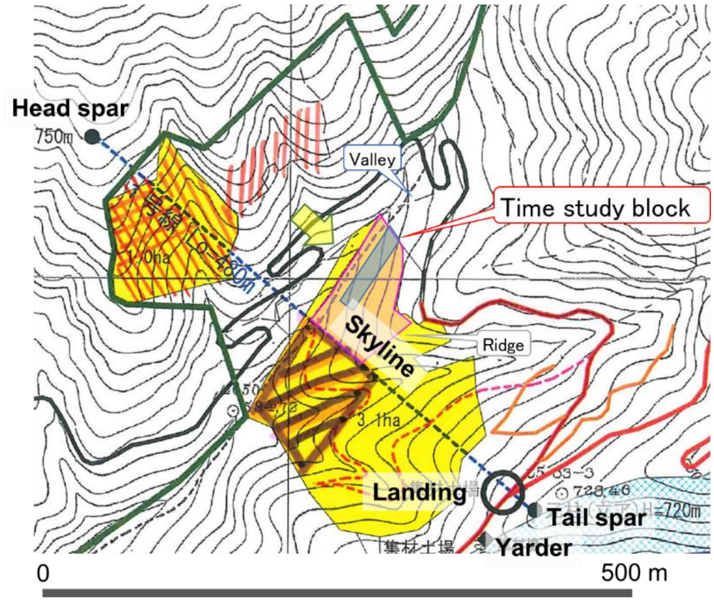

Figure 4. Study site. Nanato, Motoyama-town, Kochi, Japan: 33°48'20.2"N, 133°34'24.6"E.

The total clear-cut area of the site was approximately four hectares. The entire operation was carried out by an experienced three-person logging company crew with specific experience in cable logging (TOSA REIHOKU, 2023). Trees on the site were cut motor-manually in September 2022 prior to the logging operation. A stand investigation for the time study block was conducted before the felling operation to measure tree size and volume. The span of the cable system was 481 m with an almost flat slope, the diameter of the skyline was 24 mm, and the maximum load capacity was 1,400 kg, with the yarder placed close to the landing. A harvester (IWAFUJI model GPH-45A; base machine: KOBELCO model SK135SR) processed the felled full trees and bunched the processed logs at the landing. Initially, the crew carried out part of the logging operation using a normal Endless-Tyler system with a hydraulically driven yarder for several days. Then the loading block was converted from a normal one to the grapple-equipped one of the new system. A test run for the time study was conducted on October 4, 2022. The operation was videotaped and analyzed in terms of operation sequence (Figures 5 and 6). The movement of the carriage was measured by both a total station and a rotary encoder mounted on the endless drum of the yarder.

The working time elements of the cable logging operation have been defined as follows:

1. Loading grapple raising at the landing,
2. Empty travel of the carriage,
3. Lateral pulling of the empty loading grapple to the site,
4. Stopping the loading grapple,
5. Grappling,
6. Lateral pulling of the loaded loading grapple towards under the skyline,
7. Loading grapple raising at the site,
8. Loaded travel of the carriage,
9. Lowering of the loading grapple at the landing,
10. Unloading/Releasing of the loading grapple.

Break time was defined as “11. Break in operation”. Among the work time elements, “4. Stopping the loading grapple”, “5. Grappling”, and “10. Unloading/Releasing of the loading grapple” are not related to the carriage travel and lateral logging distances. Therefore, by comparing these time elements as well as “choker escaping”, which does not exist for the new system, with conventional

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cable logging system cases, the effect of cycle time reduction for the new system can be assessed against conventional systems. Note that an equivalent time element under the conventional system for "5. Grappling" should be "hooking/choker setting". Four cases of conventional cable logging system operations were selected for the comparison: the operations in Motoyama-town of Kochi Prefecture, Tokushima Prefecture, Kami-city of Kochi Prefecture, and Ino-town of Kochi Prefecture. All of the cases had a similar scale of the skyline span and volume of individual trees harvested. Since the number of trees for grappling in the new system was one or two, the work element times of "hooking/choker setting" and "unloading/releasing" in the conventional systems were adjusted to those per tree by dividing the times by the number of trees.

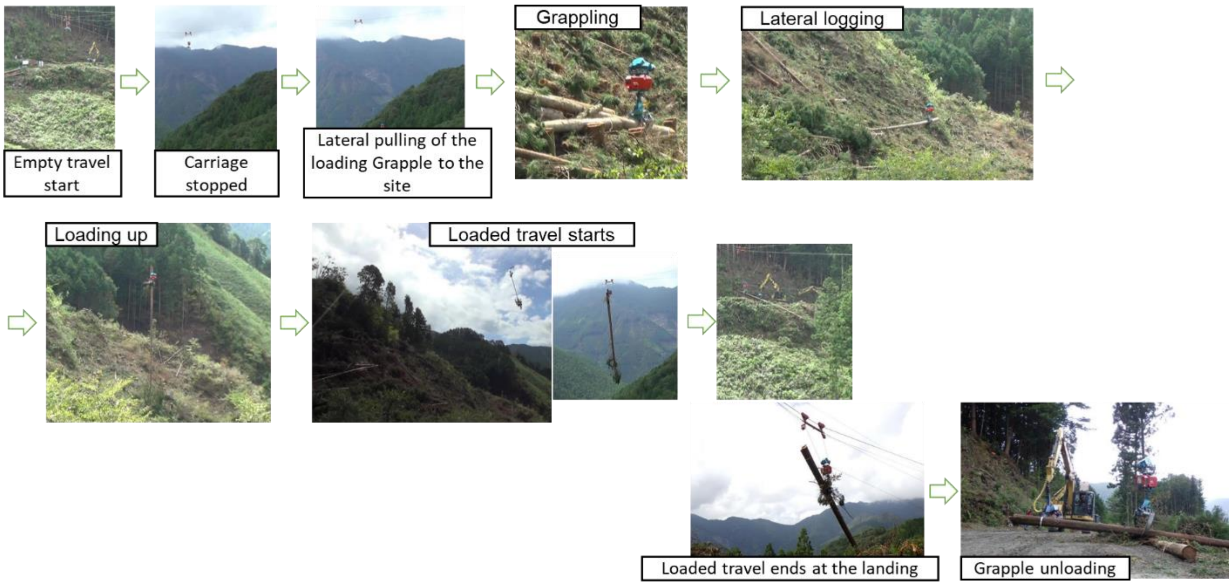

Figure 5. Sequence of the logging cycle

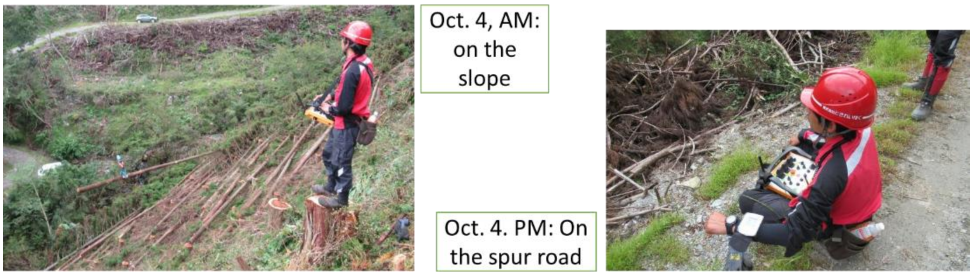

Figure 6. Controlling the loading grapple on the site

The results of the time study were used to obtain estimation formulas for work element times related to carriage travel and lateral logging distances. By combining the formulas the productivity of the new system was estimated in terms of both logging distance and logging volume per cycle.

2.2 Assessing the applicability of the New System to Retention Forestry

In the final cut for retention forestry, a specified portion of the trees/stands should be retained, i.e. left unharvested. While variable retention patterns could be applied in the case of vehicle-based logging, there are more limited options for cable logging, e.g. strip cutting or block retention. A modified Endless-Tyler system called the Collector-system (Konuma and Shibata, 1976; Suzuki and Omachi, 2005; Suzuki et al., 2011) is one of the possible solutions for cable-based retention forestry. Through

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the use of side hauling control blocks, the system enables strip patterns of clear-cut logging without damaging the remaining stands, as the blocks maintain the trajectory of the haul-back line (Figure 7). As the system is a variation of the Endless-Tyler system, it can be operated with the newly developed cable logging system with a hydraulic yarder and loading grapple.

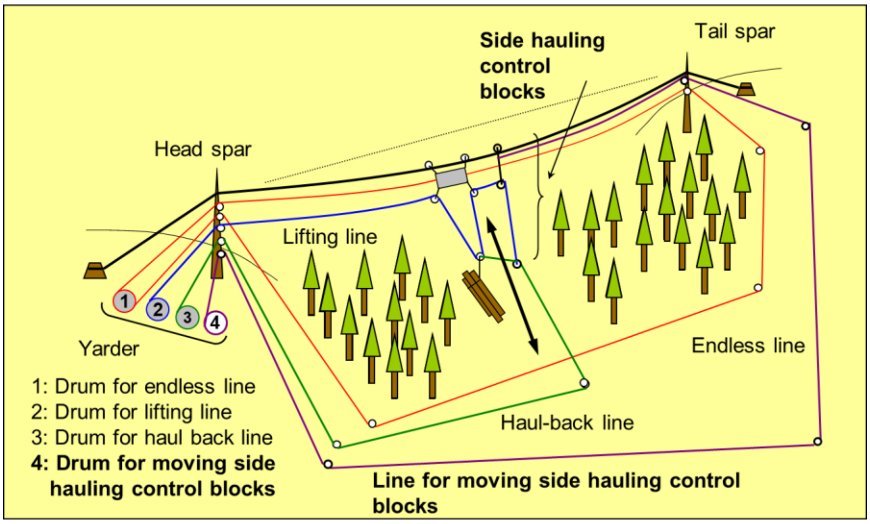

Figure 7. Modified Endless-Tyler system suitable for partial cutting: the Collector-system (Konuma and Shibata, 1976; Suzuki and Omachi, 2005; Suzuki et al., 2011)

The applicability of the new system to retention forestry was estimated by assuming that three patterns of retention methods were applied to the test site (Figure 8): A) 0.5 ha of harvest area near the landing, B) 1.0 ha of harvest area away from the landing, and C) 3.0 ha of harvest area in the center of the span. The retention rate was set at 20%. Productivity was estimated using the results from the comparative study (**2.1**).

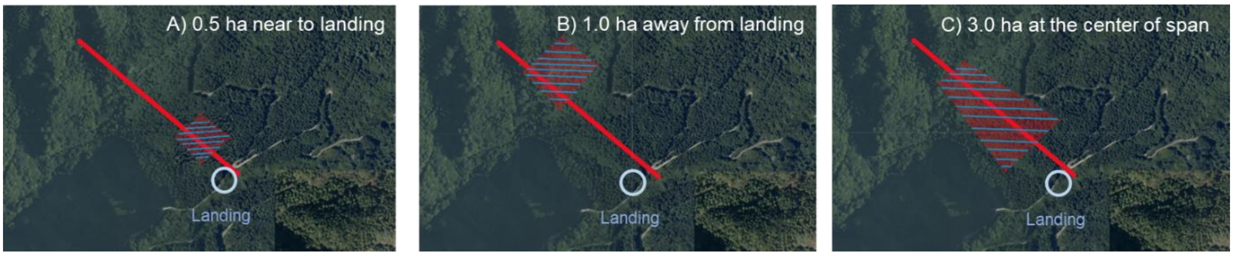

Figure 8. A simulated application of the new system combined with the Collector-method for retention forestry. Background aerial photographs were obtained from the Geospatial Information Authority of Japan (2023), the tile URL: https://cyberjapandata.gsi.go.jp/xyz/seamlessphoto/{z}/{x}/{y}.jpg, displayed through the QGIS software (QGIS development team, 2023).

3. Results and Discussion

3.1 Comparative Productivity Study

Felling productivity was 78.0 m^3/person-day (6 hours/day). Rigging up required 19 person-days. Assuming that rigging down requires half the labor of rigging up, and re-arranging the haul-back line requires 7.5 person-days (1.5 person-days/arrangement, 5 arrangements for the site), the total rigging labor would be 36.5 person-days. Total volume per site (4 ha) would be 2,240 m^3 (700 stem m^3/ha, utilization rate 0.8, 4 ha). Then the total rigging productivity would be 61 m^3/person-day.

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In the test operation, 41 trees (DBH 38 cm, height 28.4 m, volume 1.315 m^3) with 55.388 m^3 stem volume were logged by the new system in 38 cycles (Figure 9), with 1 tree per cycle except for 3 cycles (2 trees per cycle). The average travel distance of the carriage was 210 m. The comparison of the elemental operation times without relation to the yarding distance between the new system (Figure 10, 1.) and the conventional cases (Figure10, 2. – 5.) confirmed the significant reduction in operational time of the new system.

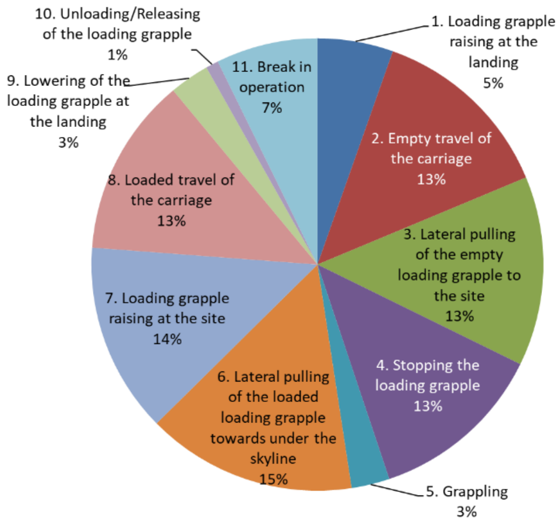

Figure 9. Work time elements of the logging operation.
n: 38 cycles, average cycle time: 354.7 seconds.

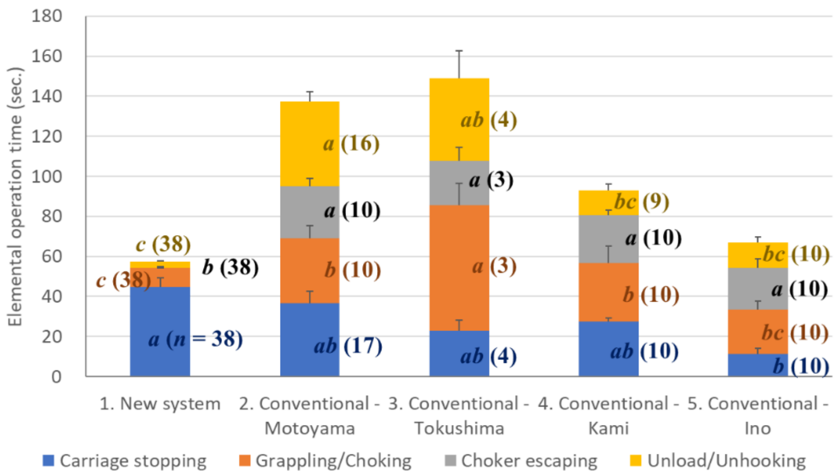

Figure 10. Comparison of the elemental operation times without relation to the yarding distance between the new system (1.) and the conventional cases (2. – 5.). Different letters indicate significant difference between cases for each time element (Tukey test, alpha = 0.05).

Figure 11 shows the estimated productivity of the new cable system classified by logging distance and load volume. The observed average load volume was rather high, indicating good condition. Assuming a processed log volume per log volume of 0.8, the logging and processing productivity was 11.8 m^3/hour (70 m^3/day). The system requires a 2-person crew, so the logging and processing productivity would be 35 m^3/person-day. Therefore, the total harvest productivity was calculated as 1/{(1/61) + (1/78) + (1/35)} = 17.3 m^3/person-day (Figure 12) using the system productivity method

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(Suzuki et al., 2019; Yoshimura and Suzuki, 2022). Compared with the national average total harvest productivity (4 and 7 m^3/person-day for thinning and clearcutting, respectively; Forestry Agency, 2022), the average conventional cable logging productivity (8 to 12 m^3/person-day; personal communication, Tosa-Reihoku Co. Ltd., 2022), and the European tower yarder (13.2 m^3/person-day; Nakazawa et al., 2022), the achieved result was encouragingly high. Even under the least productive conditions (3-person crew, smaller tree volume, and combination of these two), at just 10 m^3/person-day, would be the same as that of the normal system.

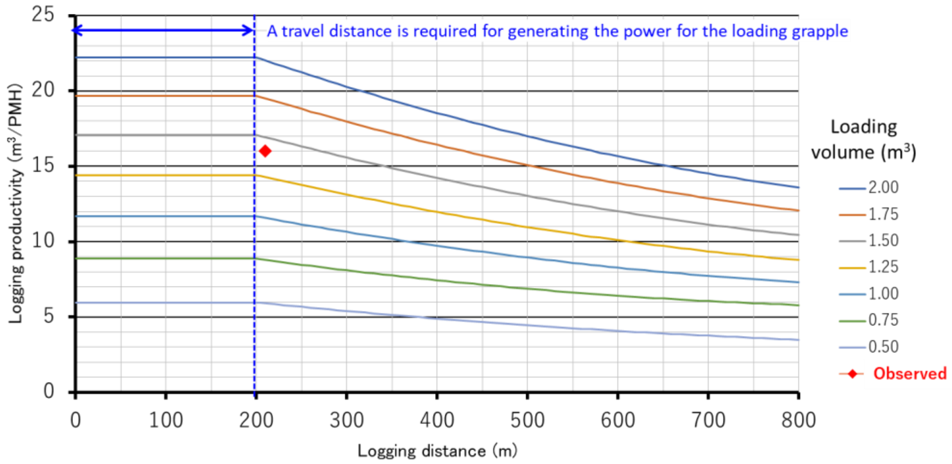

Figure 11. Estimated productivity of the new cable system classified by logging distance and load volume. The skyline slope was almost flat. The lateral logging distance was set to 70 m, loading-up height to 70 m, loading-down height to 10 m. Carriage traveling speed was set to 350 and 400 m/min for empty and loaded, respectively, when logging distance exceeds 200 m.

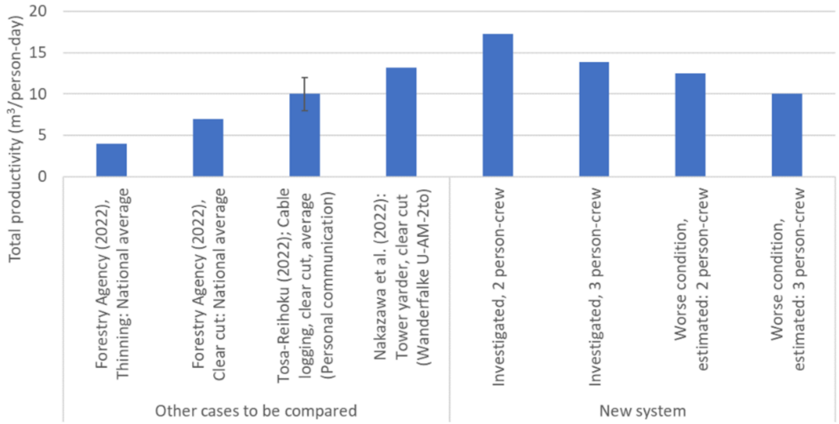

Figure 12. Comparison of total productivity

3.2 Assessing the Applicability of the New System to Retention Forestry

Figure 13 shows the estimated productivity of the new system applied to simulated retention forestry results. While Option C), 3.0 ha, had almost the same productivity as the best performance investigated (Figure 12), Option A), 0.5 ha, had slightly better productivity than that of Option B), 1.0 ha, which was almost equal to the national average for clear-cut (Figure 12). The reason for this is that the distance travelled by the carriage is more influential than the effect of the scale. Therefore, it can be surmised that the new system can be applied to retention logging in steep terrain with affordable productivity.

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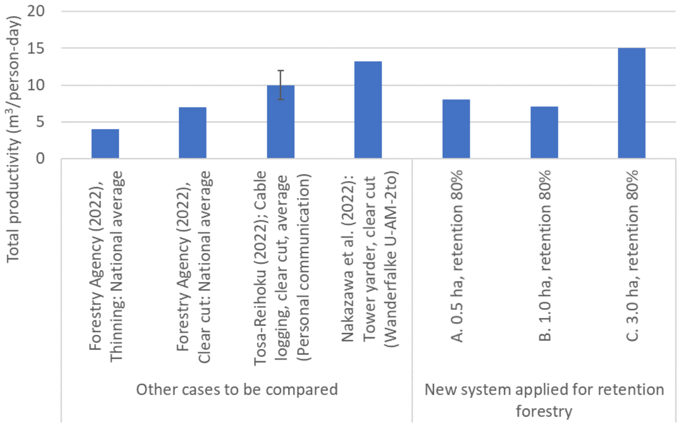

Figure 13. Estimated productivity of the new system applied to simulated retention forestry.

4. Conclusion

The findings of this study confirmed the productivity advantage of the new logging system. Safety is also improved by the reduction of one hooker/choker on site. The reduction in rigging should also be noted, because the system does not require a yarder operator during the rigging operation.

Acknowledgement

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Analysis of Open data on seasonal roads in a forestry transport GIS-project (Case study: Siberian federal district, Russia)

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Abstract
Paper covers the use and features of roads seasonality parameter in the presently publicly available Open datasets. Roads seasonality was considered as a factor of transport accessibility for the forest transport modeling at the regional level of large Siberian federal district, Russia. As analysis of papers shows, roads seasonality is mainly related to the winter conditions and low temperatures, researchers are focused on the winter roads. North big countries like Russia and Canada are the most interested data users in the domain of GIS transport projects. We state a lack of seasonality data, declared in the world databases, but not actually included. Forestry and forest industry need a combination of infrastructural data, and roads seasonality has a role of parameter to be included in the transport accessibility scenarios to reach forest fires and forest resources by ground means. Data on the roads seasonality for the regions of Russian could be found in the form of map view and text description. We have analyzed roads seasonality attributes of four Open datasets available online (Open Street Map, gRoads1, Natural Earth of 1:10 000 000, and Global roads inventory project or GRIP); for Siberian federal district only two of them have an indicator of seasonality (OSM and GRIP). Seasonal use of roads in the forest management depends on the features like relief and rivers, swamps and soils, they would be investigated in the future research. Roads conditions depending on season could be included in the transport scenarios for the regions. Artificial Intelligence and remote sensing materials in combination could lead to the continuation of such research.

Keywords: Open data, road network, seasonality, forestry, GIS

1. Introduction

Forest (timber) industry and forestry largely depend on the development of transport infrastructure. Among the more acute problems of the forest industry in Russia is the underdevelopment of transport infrastructure, which hinders the effective management of logging and forestry work. Forestry transport GIS-project like any other requires up-to-date data with roads attributes. Open data are in quite high demand in a variety of geographical research areas. Forestry in its activities involves a combination of infrastructure objects such as roads, logistic centers like fires stations, and settlements (Podolskaia, 2021a; Podolskaia, 2021b; Podolskaia, 2022).

Season of the year plays a key role in the ground transport modeling then there is a need to make a route to the forest fires (fire season) or forest resources (around the whole year). Seasonality of road use is directly related to the accessibility assessments at regional and country scales. In this regard, forestry transport modeling of ground access for roads of public and special use is becoming a crucial part of regional forestry data management aimed at reducing forest destruction, preventing deterioration of forest lands as well as reducing carbon dioxide emissions.

Specialists in topographic mapping from the Russian geographical scientific school (Alekseenko, Svatkova, 2005; Alekseenko and Svatkova, 2008) noted the significant and still insufficiently studied possibilities of special winter topographic maps like climate and terrain features in a certain period of the year. The paper of 2008 contains a list of conventional signs of seasonal changes in the content of winter topographic maps, namely: variability of areal and linear hydrographic features, flood pastures and hayfields, as well as relief features such as ice and passes.

Some papers cover roads seasonality at more than regional (administrative unit of Russia) scale. For instance, a study of seasonal traffic routes on roads aims to create a database to estimate transport accessibility within the territories of Russian Far North. In fact, it is one of the very few works at the extent of federal districts, namely Far Eastern federal district (Kopylov, 2022). Study discusses seasonal highways to form a database for the subsequent improvement of transport accessibility in the Far North in order to establish a stable, uninterrupted transport connection in the transport hub of the Arctic zone of the Far Eastern federal district.

There are some experiences on the roads seasonality from the researchers of Canada, Russia and Japan. Length and opening dates are two main parameters to evaluate operationality of winter roads in the western James Bay region, Ontario, Canada (Hori et al., 2016). Paper (Fu et al., 2009) is dedicated to the winter road maintenance operations and proposes a real-time optimization model which takes into account road network topology, road class, weather forecasts, and contractual service levels for producing a schedule to dispatch vehicles in Canada. For Russia logging roads operations time period and functioning of winter roads were considered in the papers (Shchegelman et al., 2007; Khoroshilov et al., 2019; Mokhirev and Petrova, 2020).

Different spatial extent and problematic has been discussed in the paper (Tanaka et al., 2014) for the city of Sapporo, Japan. It provides a set of practical GIS-tools for visualization and analysis or roads (streets) in winter then there is a need to deal with snow in a settlement environment. So, seasonality of roads and transport accessibility are very closely linked in the transportation and logistics at various scales and topics associated with management activities and operations.

Research purpose is to study seasonality as a factor of transport accessibility for the forest transport modeling at the regional level. Study includes following tasks:

- to collect papers on the seasonality of road use;
- to search for the Open datasets on roads with seasonality parameter;
- to evaluate presence of seasonality for the territory of Siberian federal district, Russia;
- and to propose some variants to implement roads seasonality into ongoing research activity on the transport modeling.

Research on the roads seasonality is a part of spatial transport modeling project we conduct in collaboration between Center for Forest Ecology and Productivity of the Russian Academy of Sciences (CEPF RAS) and Bursa Technical University (Akay et al., 2021; Akay et al., 2022). Transport modeling of forest fires and resources accessibility has been started as a research direction at CEPF in 2019 with a series of papers (Podolskaia et al., 2019; Podolskaia et al., 2020a; Podolskaia et al., 2020b; Podolskaia et al., 2020c) covering several regions of Russia like Irkutsk and Novosibirsk regions and then has been moved to the size of Russian federal districts.

2. Material and Methods

2.1. Seasonality of Roads

Seasonality of roads includes definition of winter roads. According to the Russian legislation document on the public automobile roads (State standard, 2020), winter road is a seasonal highway consisting of structural elements intended to be used for vehicles move. Its roadway is covered by ice, compacted snow and ice. These roads are being constructed on the frozen rivers of lakes. In Russia there is also an official classification of winter roads (https://base.garant.ru/26727807/b3975f01

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ce8b0eb0c9b11526d9b4c7bf/) built on the land or on the water bodies, varying by operational time (months, season of the year). In the Federal law of Russia "On highways and road activities" (https://rg.ru/documents/2023/03/02/document-dorogi.html) winter roads are described as artificial road structures with no further details. Lack of regulation has a negative impact on the development of Russian North, where these roads are mainly constructed and used.

Planning of the service life of winter public roads (and for forestry and forestry industry tasks) is carried out on the basis of analysis of climate data statistics (Mokhirev and Petrova, 2020). Weather and climatic factors have a significant impact on the reliability and safety of the functioning of roads of all types, with and without pavement. The maximum value of these factors is manifested in winter, when snow drifts, slippery surfaces and negative air temperature are added to meteorological conditions unfavorable for movement in other seasons of the year.

Forest transport modeling of ground access to the forest fires and forest resources is a research field and a forestry practice, which requires up-to-date data sources with the maximum possible set of road attributes to make an access route. Seasonality of road use is among the most crucial ones in the regional transport accessibility for the Russian Federation, especially in winter and summer. Russian geographers pointed out the significance and insufficiently studied special winter topographic maps with the data on climate and terrain.

Figure 1 was generated by the Word Cloud Maker, a free web-tool used to analyze text and make it visual (https://makewordcloud.com/ru/word-cloud-maker) for the papers names from the Reference section. Word cloud is an image made up of text, size of the word image is determined by the frequency of word appearance. All the prepositions in the papers names were removed before running the tool. As we can see on the Figure 1, word 'winter' is dominated, then 'roads', 'logging' as well as 'climate', 'transport' and 'accessibility' are the most frequent in the titles of reviewed papers. So, winter roads are the most common topic in the domain of roads seasonality, there are still very few researches on the off-season (not winter) roads conditions, at least for Russia we can mention the paper (Khoroshilov et al., 2019).

Figure1. Word cloud with the papers names mentioned seasonality (Russian and international examples)

2.2. Research on the Roads Seasonality in Russia

Winter roads and transportation accessibility in the Arctic were covered in the paper (Kuklina, Osipova, 2018). Winter trucks (winter roads) play an extremely important communication role in the Arctic region of Russia. The increase in the level of motorization has led to an increase in the winter mobility of residents of hard-to-reach settlements. Map of density of all-season motorable roads covering mainly the norrth parts of Russia from the paper (Nokelaynen, 2021) is shown on the Figure 2.

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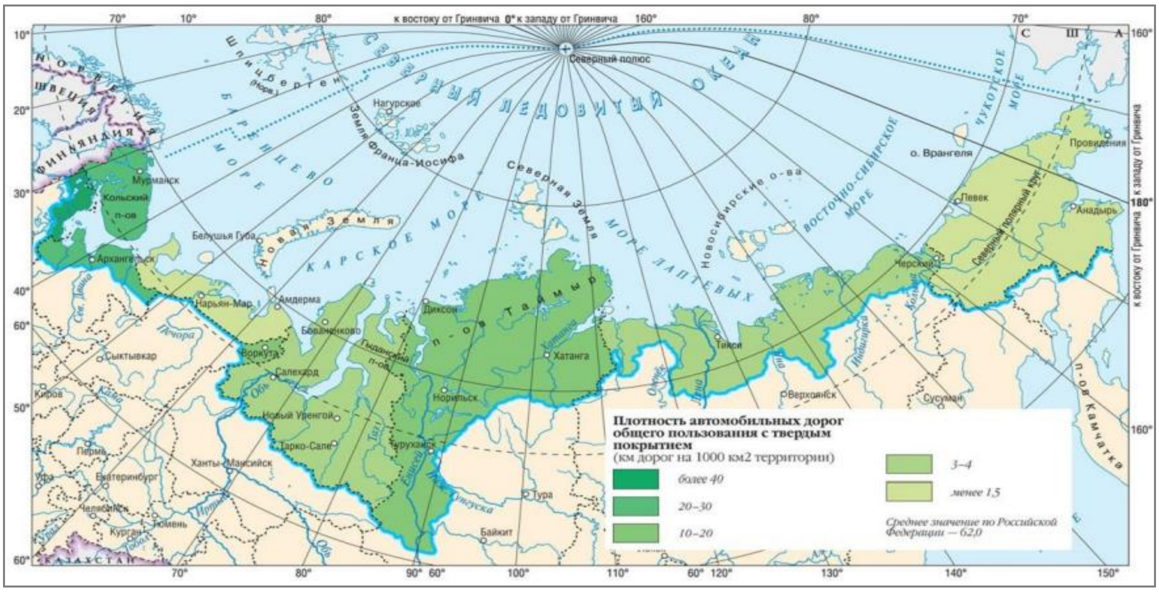

Figure 2. Density of all-season motorable roads, scale 1:30 000 000 (Nokelaynen, 2021)

2.3. Data on the Roads Seasonality for the Regions of Russian

There are few example of roads seasonality projects publicly available for the Russian regions, mainly located on the north of the country. As examples we can describe a geoportal of Yamalo-Nenets Autonomous region (okrug) which is available depending on the season (https://map.yanao.ru/eks/zimnik). It has a section of seasonal geoservices indicating name, status of the winter road, and a forecast of its opening. Another example is a web-page showing driving conditions on winter roads of Krasnoyarsk region (https://krudor.ru/actual/winter/) with their length and operational time frame. In that case there is only textual description of winter road with no map view. Their screenshots are shown on the Figure 3 and 4 successively, both views are as of 9th of May, 2023. Both examples show the data within the administrative unit's extent. So, we can note that for the present time data on the roads seasonality in Russia are being maintained and cartographically represented by administrative unite.

Figure 3. Interactive map of winter autoroads. Geoportal of Yamalo-Nenets Autonomous region (okrug)

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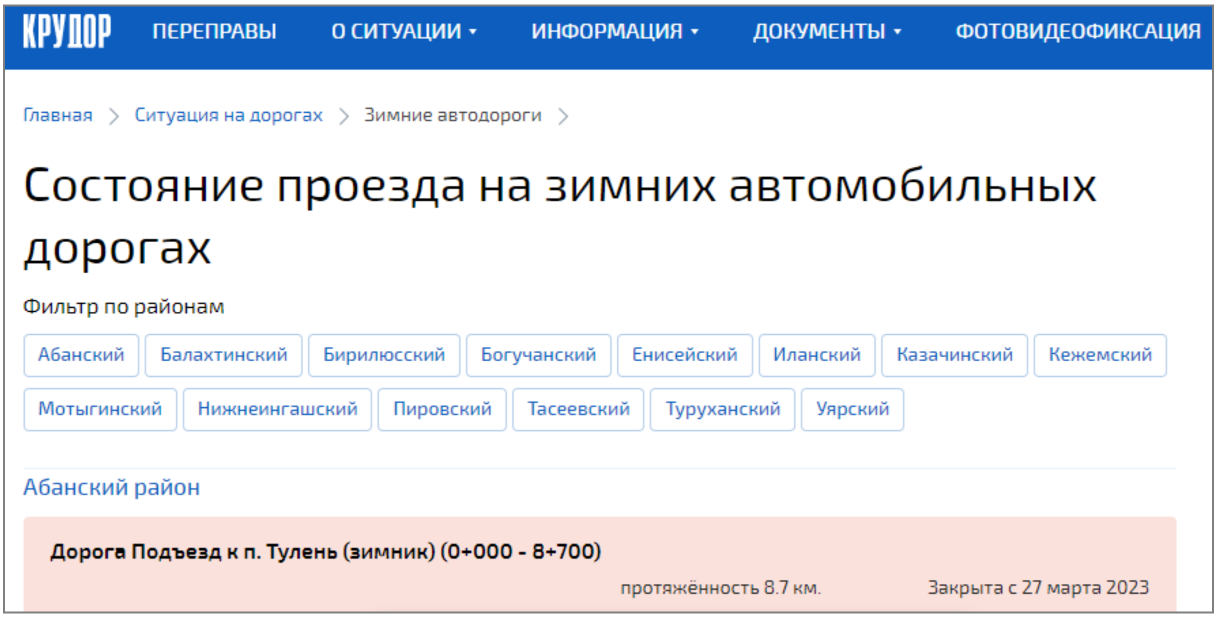

Figure 4. Driving conditions on winter roads of Krasnoyarsk region (road geoportal)

2.4. Forest Roads, Seasonality and Climate Change
It is well known that climate significantly affects condition and transport qualities of roads. Forestry and forest industry have specific features related to the definition of forest roads. Forest roads are roads located on the lands of forest fund (according to the Russian terminology). They are designed to serve the needs of forestry, to ensure access of forest users to the forest management units. Forest roads are adjacent to the public roads, railway stations and to the lower warehouses of logging enterprises (Buldakov, 2016).

Roads seasonality is being studied for the practical cases of roads construction. For the case of Sverdlovsk region (Russia) paper (Kruchinin et al., 2018) highlights the influence of seasonality on the physical mechanical characteristics of road. It has been established that an increase in the bearing capacity of the false-concrete coatings and an increase in the strength characteristics of subgrade soils is possible only during the winter. Based on the data obtained, researchers recommended to improve the transport and performance indicators of logging roads.

North of Russia is the most vulnerable zone in terms of climate change as it was noted in the work from Karelian Research Centre of Russian Academy of Sciences (Prokopyev et al., 2018). Climate warming will definitively reduce the operation life of winter roads. For the stable operation in the forestry it is important to invest in the development of year-round road infrastructure. The issue of quality and length of logging roads is very relevant for the heavily forested regions of the Krasnoyarsk region. Planning the timing of certain logging operations and timing of winter road construction is directly linked to the weather conditions. The main goal of the work (Mokhirev et al., 2018) is to determine the operational period of a winter logging road based on a probabilistic assessment of winter duration on the example of the Yenisei district of the Krasnoyarsk region. Roads seasonality factor, as the analysis of papers shows, has not still been considered widely enough due to the luck of data, and leaves the room to develop transport movement seasonal scenarios in the forest transport modeling projects.

2.5. Key Area, Open Datasets with Roads Seasonality
Siberian federal district has the following characteristics: low density of transport infrastructure with large extent from north to south of Russia, uneven settlement with low population density, economic

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dependency on the natural and climatic conditions, which determines the seasonality of transport functioning. These factors limit development of region's natural and economic capacity. It is a key area for the forestry research, including regional forestry transport modeling. Region is known by its constant long-term fire activity in the forests and by its seasonal winter roads.

Open Data are widely used in the research projects because of their global and regional coverage and availability; they are of value in the forestry as well. We have analyzed seasonality attributes of several Open datasets available online, namely:

- Open Street Map (OSM, as of October 2022),
- gRoads1 (The Global Roads Open Access Data Set, version 1),
- Natural Earth of 1:10 000 000,
- and Global roads inventory project (GRIP).

Global-scaled Open Street Map (OSM, https://www.openstreetmap.org) is mostly and commonly used source of data within the domain of Volunteered Geographic Information (VGI) for any GIS-projects including roads and transport. Researchers know that the certain number of OSM characteristics like completeness, quality of geometry and attributes, etc. is a subject to check and to combine with other spatial and non-spatial data (Barrington-Leigh and Millard-Ball, 2017). The OSM project is a real example of collective efforts from the interested developers and today it is the only map that can be downloaded for free to almost any device (Anop et al., 2016). It has the attributes for roads seasonality for the Siberian federal district.

Database gRoads1 (The Global Roads Open Access Data Set, version 1, https://data.nasa.gov/dataset/Global-Roads-Open-Access-Data-Set-Version-1-gROADS/bey2-56a2), divided by world regions, has an "IsSeasonal" parameter (affected by season – "depends on the season") of Long Integer type and takes the values "1", "2" or "0" if there is no information about seasonality. As mentioned in its description it contains the best available roads data by country. It has no attributes for seasonality of roads within Siberian federal district.

Project of global scale Natural Earth (https://www.naturalearthdata.com/) has a number of infrastructural features. We have checked the dataset of 1:10 000 000, the most detailed one among others, again no attributes for roads seasonality for key area. Quantitatively (by the number of road segments) and qualitatively (by the set of attributes to them), OSM project data from the studied variants is the most complete and informative one. Three datasets are shown on the Figure 5.

Additionally to OSM, we have to described the Global Roads Inventory Project (GRIP, https://www.globio.info/download-grip-dataset) includes vector data on roads and aimed for the global research environmental projects and biodiversity. Country-based GRIP delivers presently about 21 million km of road. It includes the data from OSM and can be named the best publicly available country-based global roads dataset. These dataset has been already used for the project of combining road infrastructural data (Meijer et al., 2018).

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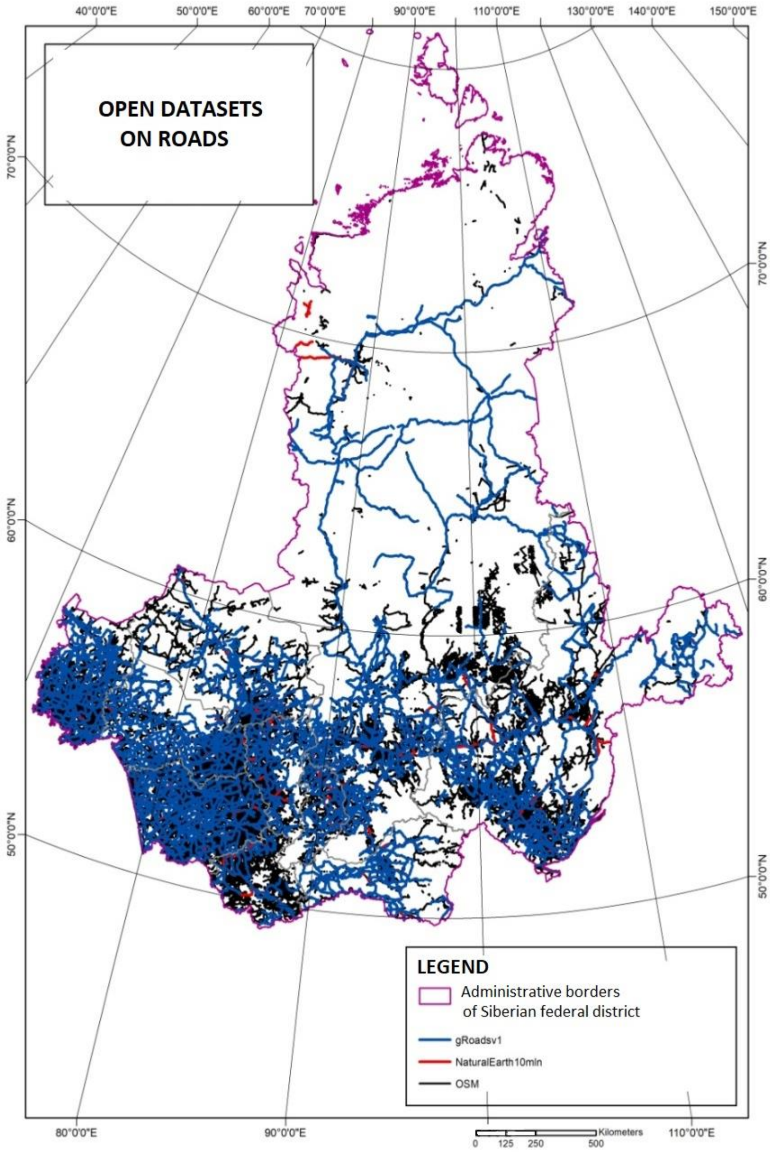

Figure 5. Open roads datasets for the territory of the Siberian federal district

3. Results and Discussion

As we can see from the Figure 5, OSM dataset, even taking into account its specificity and uncertainty, could be a source for a roads seasonality assessment. Data on roads indicating their operational period for a number of years can be systematized and then used as the most likely interval of roads operation. Type of road could be a parameter to investigate as well. In this regard, a certain comparison of roads classification between OSM-dataset and country official classification should be done before starting a forestry GIS-project.

As we can state from the papers and Open data analysis, roads conditions in summer, autumn and spring are the less studied ones, but they have a big influence on the all-the-year regional transport accessibility in the forestry for the forest fires and resources. Thus, roads seasonality could be a part of transport seasonal scenarios for the regions. Practically seasonality could be an input parameter for the technology of access routes creation developed at the Laboratory of forest ecosystems monitoring, Center for Forest Ecology and Productivity of the Russian Academy of Sciences (CEPF RAS). Relief and hydrographic features, swamps and soils are the key features that influence seasonal use of roads in the forest management. Factors of their influence could be investigated in further research.

4. Conclusion

Open Data have a value for the transport projects requested seasonality parameter. Open datasets of large scale covering the world, even declaring roads seasonality, have in fact very few and simply attributed roads. Two Open datasets have chosen (OSM and GRIP) for the Siberian federal region as they have a parameter of roads seasonality. They both may be used as a data source to create seasonal ground access routes to access forest resources and fires. Regional Open data (for instance: Federal Road Agency of Russia, Rosavtodor, https://rosavtodor.gov.ru/) should be monitored and studied in addition. Their non-spatial files could be converted to the GIS-layers. Quality and relevance of Open data should be investigated further in depth. Seasonality of roads as qualitative characteristic should be given more importance and it has the certain value for the forestry. Infrastructure, economics, sustainable development could certainly benefit from available data on the seasonal road use. Seasonality of roads could be studied on the space images of different nature; other the past several decades there is dynamically developing research area of Artificial Intelligence that could be used to detect roads seasonality.

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Assessment of Using UAV Photogrammetry Based DEM and Ground-Measurement Based DEM in Computer-Assisted Forest Road Design

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Abstract
Computer-assisted forest road design mainly relies on a high-resolution digital elevation model (DEM) to provide terrain data for supporting the analysis of road design features. The resolution and accuracy of the DEM in representing the terrain structures varies depending on the preferred dataset which then reflects some of the essential road features such as alignment, road slope, and earthwork. In this study, three forest road sections were designed by using high-resolution DEMs generated based on UAV photogrammetry data, GNSS-GPS data and Total Station data. Netcad 7.6 software, which is a domestic software used in road design applications in Turkiye, was used to perform the road design while calculating horizontal profile, vertical profile, curves, cross sections, and earthwork. The DEM generation capabilities for three datasets were compared based on spatial resolution, data collection and data processing stage. Then, the differences between three road sections were evaluated by considering specified road features such as alignment properties, road slope, and earthwork. The results indicated that the UAV (Unmanned Aerial Vehicles) based DEM generation method provided the highest resolution (10 cm), followed by the Total Station (56 cm) and GNSS-GPS (61 cm) based methods. It was found that time spent on data collection was 14 minutes, 70 minutes, and 110 minutes for DEM generation works using UAV data, GNSS-GPS data, and Total Station data, respectively. On the other hand, UAV based method falls into a disadvantageous situation in data processing stage, due to high data processing time (3 hours). However, GNSS-GPS and Total Station based methods work only with spatial point data, so they require less processing time of 15 minutes and 25 minutes, respectively. The results indicated that road lengths were 294.8, 272.4 and 282.1 meters and the average road slopes were 3.41%, 3.39%, and 3.31% for the road sections designed by using UAV, GNSS-GPS, and Total Station based DEMs, respectively. The excavation and landfill volumes were 369.16 m^3 and 166.98 m^3, 285.86 m^3 and 201.83 m^3, and 433.17 m^3 and 183.95 m^3, respectively. The results indicated that UAV photogrammetry data can be effectively used to design forest roads based on high-resolution DEMs.

Keywords: Digital elevation model, forest roads, GNSS-GPS, Netcad, total station, UAV

1. Introduction

A digital elevation model (DEM) data structure, typically in raster and grid formats, stores cells in square matrices on a two-dimensional plane and hold the value of average cell height. A cell on a geographic plane is defined by its row and column position within the matrix. DEMs have a broad range of applications because they are easy to use and calculations are more efficient (Martz and Garbrecht, 1992). They provide fundamental representations of the three-dimensional shape of the ground surface (Guth et al., 2021). DEMs are widely used in applications of remote sensing and geographic information systems (GIS) in various disciplines as they enable various calculations through their included height information.

DEMs can be produced in different qualities using various devices. Today, it is possible to generate DEMs from photographs containing altitude information, especially with UAVs, and this has become quite widespread (Özemir and Uzar, 2016). Similarly, DEMs can be produced through ground-based measuring devices such as GNSS-GPS, Total Station, and terrestrial LiDAR sensors (Keim et al., 1999; Çelik et al., 2013). In recent years, UAVs have started to replace traditional surveying methods in DEM production as they are less time consuming and less labor intensive method (Polat and Uysal, 2015). UAVs are also relatively more sensitive, cost effective, and quick systems compared to traditional airborne technologies (Fritz et al., 2013). Thus, there can be numerical differences between the quality of DEMs produced with different devices depending on various factors such as the accuracy of the measurement, labor, and time.

Primitive methods for calculating the volume of three-dimensional objects can be difficult and time-consuming. Thanks to the development of GIS techniques and computer support, these types of studies can now be done with simple methods and in short periods of time. By combining computer graphics, database management, and multiple environments, topology, geology, hydrography, and other applications can be supported through the 3D modeling and analysis features of GIS. These features allow for surface analysis such as slope, aspect, and relief maps, as well as profile extraction and determining the field of view. Generally, GIS and 3D modeling projects have proven themselves worldwide and have become an inevitable reality in terms of mapping technology (Rüstemov, 2014).
Forest roads are constructed for various purposes of uses in forestry, as they provide access to forest areas to conduct forestry activities such as timber production, forest protection, afforestation, forest management, etc. Forest road design, taking into account of economic and environmental constraints, is quite complex task. The planning of the road network also involves social demands such as access to forest villages and recreation areas in Turkiye (Öztürk, 2009). The current studies on forest road design focus on challenging issues such as accurate measurement of earthwork volumes and determining the optimal routes. Road design software packages provide road engineers with advanced features such as locating horizontal alignment and earthwork calculations based on high resolution DEMs. Some of the software used in designing forest roads are RoadEng, Lumberjack, and Platea. There is a similar road design software, Netcad 7.6, widely used in road design studies in Turkiye. Forest road design is performed base on a contour map in Netcad 7.6 software. Netcad 7.6 produces solutions for the needs of professionals from different professional disciplines in spatial data production, analysis and management. It offers the users the advantages of the CAD environment and the recognized structure of the GIS environment at the same time. These two spatial data formats, which complement each other in geographic data production processes, are supported by dynamic CAD & GIS integration. Netcad 7.6 is constantly being developed in the focus of user needs and expectations with agile software development philosophy. It meets the digital data needs of user groups from different industries such as mapping, civil engineering, geology, roads, infrastructure and service.

In this study, an example forest road design was made by using Netcad 7.6 software based on UAV, GNSS-GPS, and Total Station generated DEMs. First, three different DEMs were produced using UAV and ground surveying devices. Then, road designs were made using Netcad 7.6 program with these DEMs. Forest roads were produced following similar routes as much as possible in the same study area. Finally, comparisons were made between the three different forest roads produced, and the differences obtained were examined.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Tuzaklı Forests located in the Osmangazi province of Bursa in Turkiye (Figure 1). The fieldwork was carried out in a relatively open stand with gentle slope. The dominant tree species is Black pine (*Pinus nigra*) and the average elevation and slope is about 750 m and 20%, respectively in the study area.

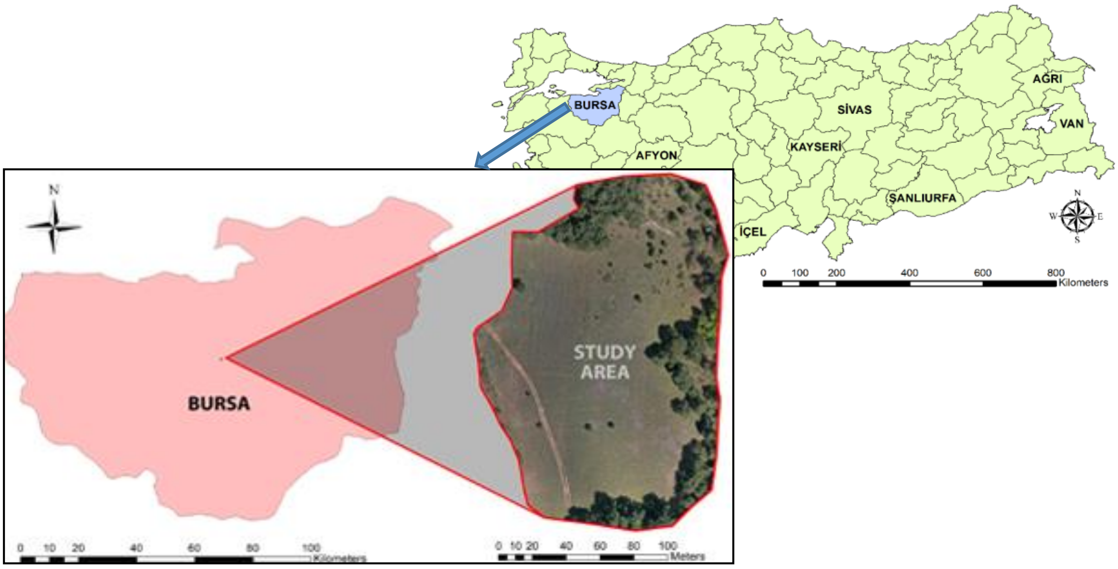

Figure 1. Study area

2.2. DEM Generation Methods
2.2.1. Generating DEM with UAV
DEM was produced using 3D data obtained by using a DJI Mavic 2 Pro (Figure 2) (Table 1). A total of 67 aerial photographs were obtained by flying over the study area with a UAV. The flight was conducted using the Grid Mission option in the Pix4D application, with a flight altitude of 100 m, a flight area of 160x176m, and an overlap ratio of 80% (Figure 3).

Figure 2. DJI Mavic 2 Pro

Table 1. DJI Mavic 2 Pro technical specifications (URL -1)

Specifications	
Weight	650 gr-750 gr
Battery	3830 mAH LiPo
Size	31 cm-35 cm
GPS Mode	GPS Yes
Camera	4K
Max Speed	45 kmp-65 kmp
Flight Distance	8000 m
Flight Time	30-31 Minutes

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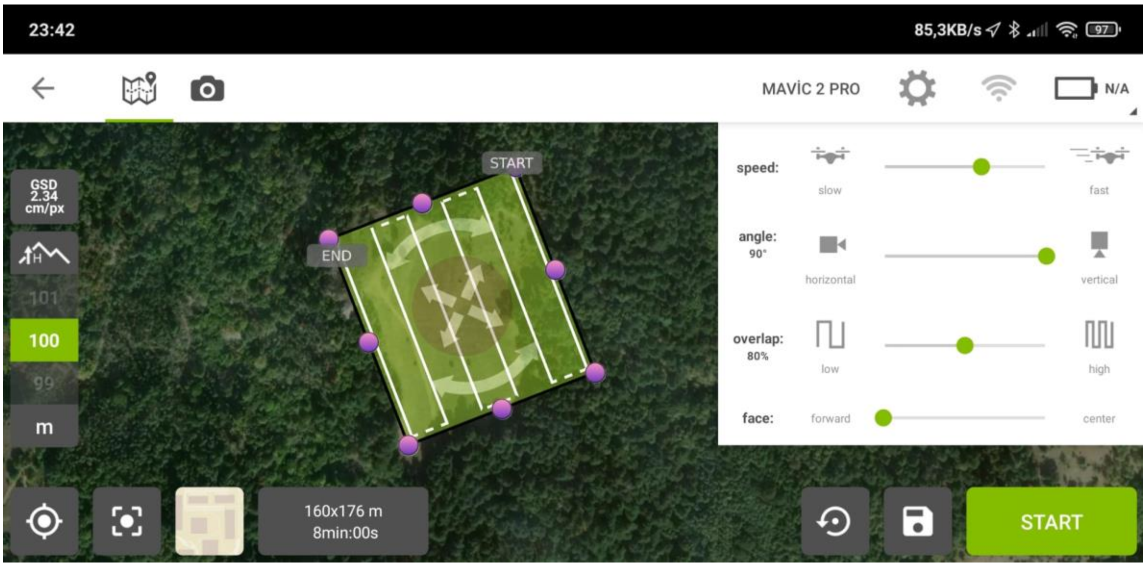

Figure 3. Pix4d flight settings

Seven control points were located in the study area and UTM coordinates were recorded by using GNSS-GPS. Then, office works were carried out using Agisoft Metashape 1.8.3 software based on collected 67 photographs and 7 control points. By aligning the photographs, 36220 tie points were obtained (Figure 4) and then aerial photographs were positioned according to the control points.

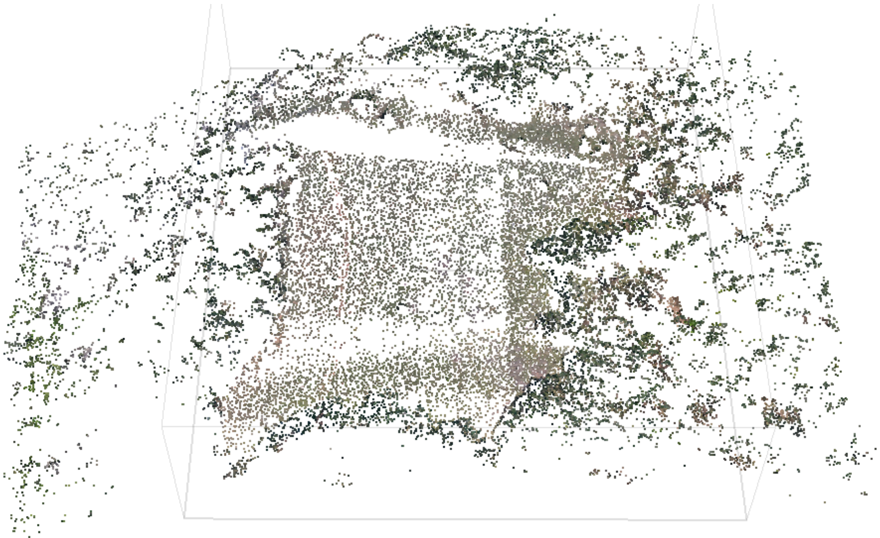

Figure 4. Tie points collected during UAV flight

After the spatial corrections were implemented on the images, a dense point cloud was generated using the "build dense cloud" process. These processes were carried out at a high quality level, resulting in a total of 23,187,020 points. As the aim was to generate a digital terrain model (DTM) from the point cloud data, all objects above ground level had to be removed. Therefore, in this stage, the point cloud was classified and the points belonging to the ground were used for the production of the DEM. An example of the classified point cloud is shown in Figure 5. Finally, the "build DEM" process was used to generate the DEM with a 10 cm pixel resolution.

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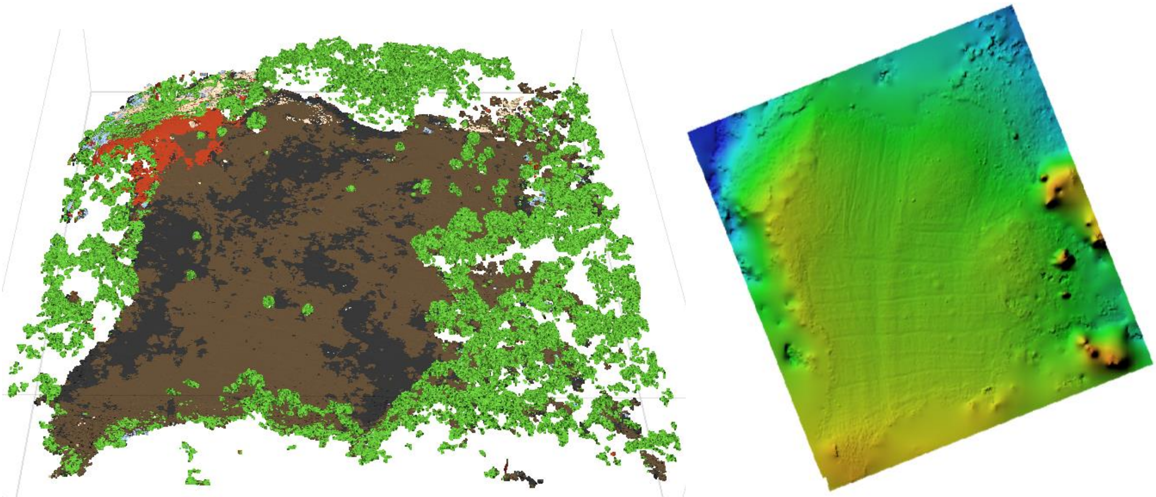

Figure 5. Classified point cloud (left) and digital elevation model (right)

2.2.2. Generating DEM with GNSS-GPS

A total of 1667 points were collected from the study area using Pentax G3100-R1 GNSS-GPS (Figure 6) in mobile mode (Figure 7, Table 2). The point acquisition interval was set as 2 m in the mobile mode. The collected points were then processed in ArcMAP 10.8 software. DEM production was provided by using "Topo to Raster" tool under ArcMAP 10.8. During the data production, the recommended pixel size of 61 cm was used in the study.

Figure 6. Pentax G3100-R1

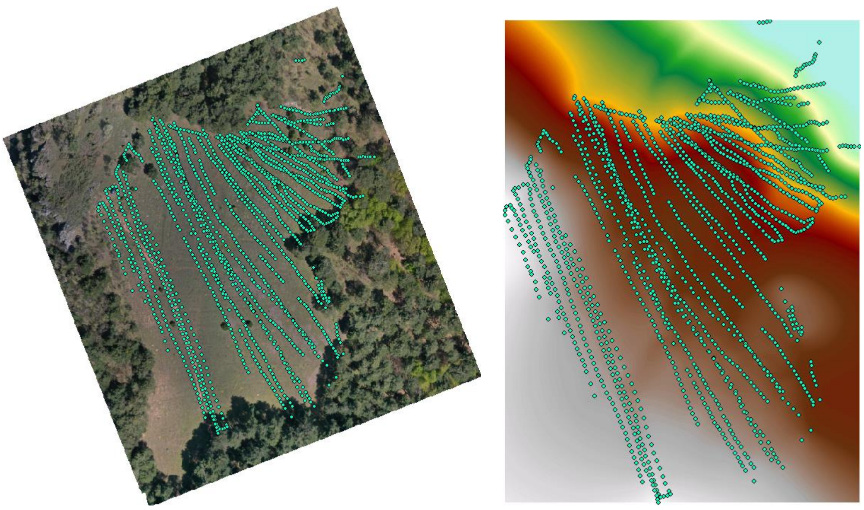

Figure 7. GNSS-GPS points (left) and GNSS-GPS based DEM (right)

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Table 2. Pentax G3100-R1 technical specifications (URL -2)

Model		G3100-R1	
Channel Configuration		136 channels (dual frequency) for GPS, GLONASS and SBAS	
Single Tracked	GPS	L1-C/A, L1-P(Y), L2-P(Y) and L2C	
	GLONASS	L1-C/A, L2-C/A	
Position accuracy		HORIZONTAL	VERTICAL
	Standalone	1.3 m	1.9 m
	SBAS	0.6 m	0.8 m
	DGPS	0.5 m	0.9 m
	SBAS	0.6 m	0.8 m
	DGPS	0.5 m	0.9 m
RTK Performance	Horizontal Accuracy	1 cm + 1 ppm	
	Vertical Accuracy	2 cm + 1 ppm	
	Average Time to Work	7 sec.	
	Availability	99.99%*1 (Baseline < 20km)	
Static Performance	Horizontal Accuracy	2 mm + 0.5 ppm	
	Vertical Accuracy	5 mm + 0.5 ppm	

2.2.3. Generating DEM with Total Station

DEMs were produced using Topcon Cygnus 2LS model Total Station (Figure 8) (Table 3). Total Station. The Total Station was placed at a point close to the center of the study area. The location information of the point where the device was installed was measured with GNSS-GPS and entered into the device. Then, one person stood at certain points with a reflector at intervals of approximately 5 meters. The other person measured the coordinates by pointing the laser at the reflector. In this way, a total of 579 points were collected (Figure 9). The obtained data was transferred to the ArcMap 10.8 interface. Then, DEM production was provided with the "Topo to Raster" process. A recommended pixel size of 56 cm was used during the data production.

Figure 8. Topcon Cygnus 2LS

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Table 3. Topcon Cygnus 2LS technical specifications (URL -3)

Specifications	
Magnification	30x
Image	Erect
Field of View	1°30'
Resolving power	3.0"
Minimum focus distance	1.3 m
Measuring range - Reflectorless	200 m
Measuring range - Prism	2,000m (Single Prism)
Accuracy - Reflectorless	(3+2 ppm x D)mm
Accuracy - Prism	(2+2 ppm x D)mm
Measuring time (Fine) - Reflectorless	1.1 s
Measuring time (Fine) - Prism	1.1 s

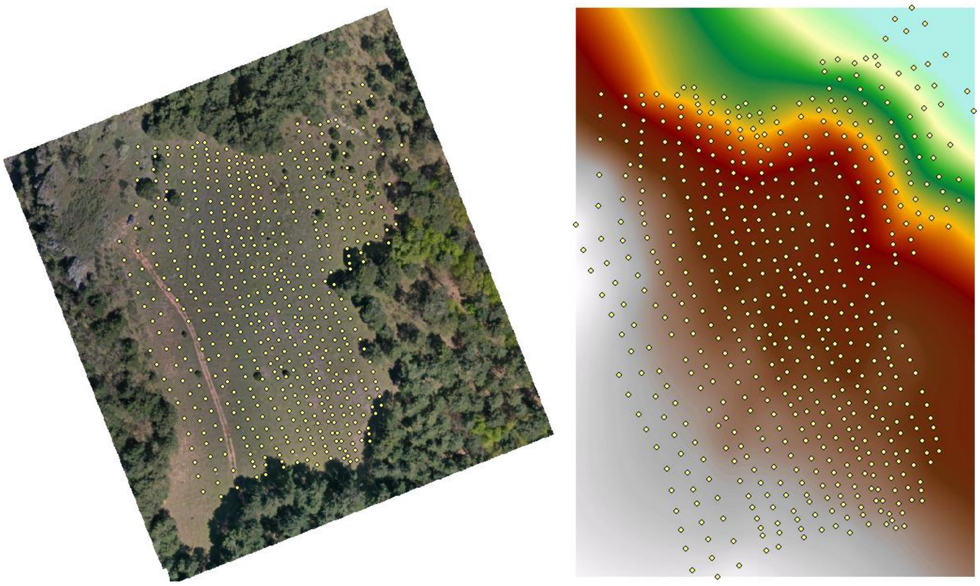

Figure 9. Total Station points (left) and Total Station based DEM (right)

2.4. Forest Road Planning

The digital elevation models (DEMs) produced by three different methods in the study were used to design a road using the Netcad 7.6 program. Netcad 7.6 requires triangulated models for volume calculations, so triangulated models were obtained from the produced DEMs. Then, contour lines were obtained to determine the route of the road. The contour lines were generated with a 0.5 m height interval. Figure 10 shows the triangulated models and contour lines generated from the digital elevation models produced by the UAV, GNSS-GPS, and Total Station methods, respectively.

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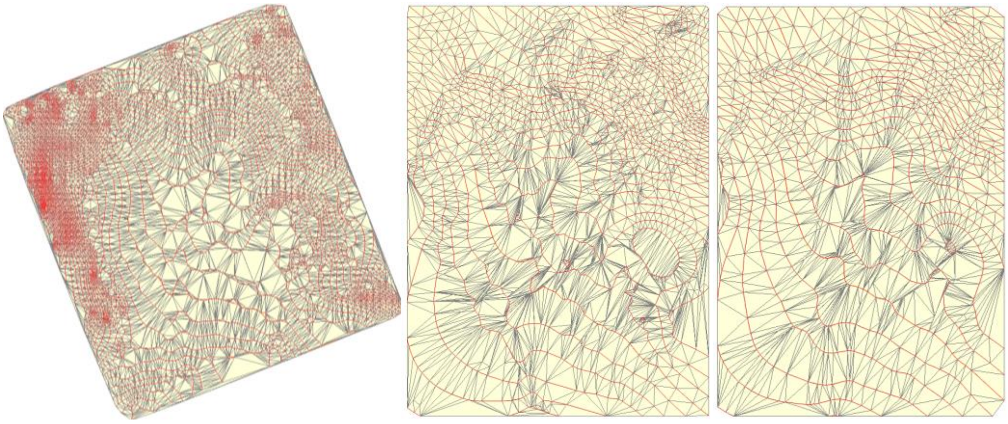

Figure 10. Triangular model and contour lines produced by UAV (left), GNSS-GPS (middle), and Total Station method (right)

After the contour lines were generated, the preliminary road alignment was located on the terrain by using 25-meter and 15-meter circles determined based on stepping out (divider) method for given average grade. In the next step, the route was determined and the horizontal and vertical curves were placed. These operations were performed by using the route editor. Figure 11 shows the preliminary alignment (black), road alignment (blue), and curve location (red) stages produced by using the 3D data of the UAV, GNSS-GPS, and Total Station methods. The same route was attempted to be used for each method in the operations. Curves of equivalent sizes were attempted to be used at similar points in all methods. In some points, these values have varied due to terrain structure and angles.

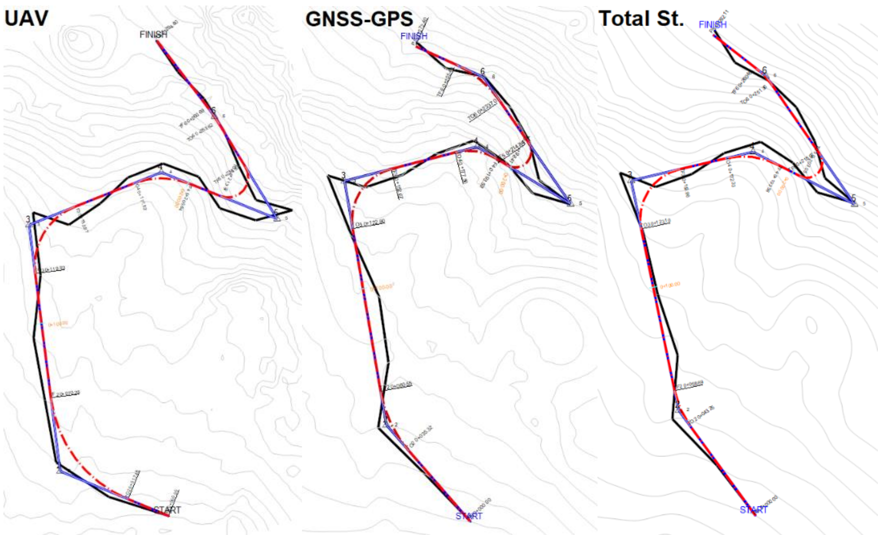

Figure 11. Preliminary alignment, road alignment and curve location determined by UAV (left), GNSS-GPS (middle), and Total Station (right) methods

In the next stage, the cross-section editor was used to determine the cross-sections. The cross-section editor enables the identification of excavation and filling areas by taking cross-sections of the terrain and road platform. An example cross-section is shown in Figure 12. Cross-sections were distributed at certain intervals along the roadway. The volumes were measured using cross-section areas and the distances between cross-sections and then volumes were transferred to the volume table.

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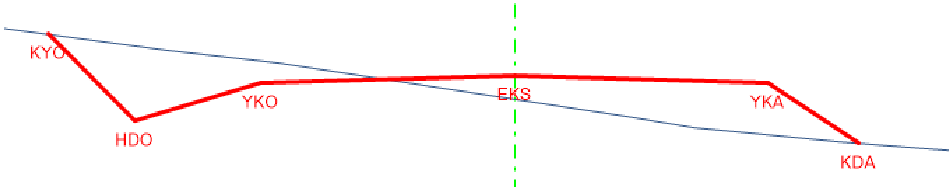

Figure 12. Cross section example.

After generating cross-sections, the road's horizontal profile and vertical curves can be defined using the profile drawing tool. In the next stage of the study, volumes were obtained and material distribution was determined. In this stage, volume information was obtained by filling in the volume table with the information obtained from the cross-sections. An example volume table is shown in Figure 13.

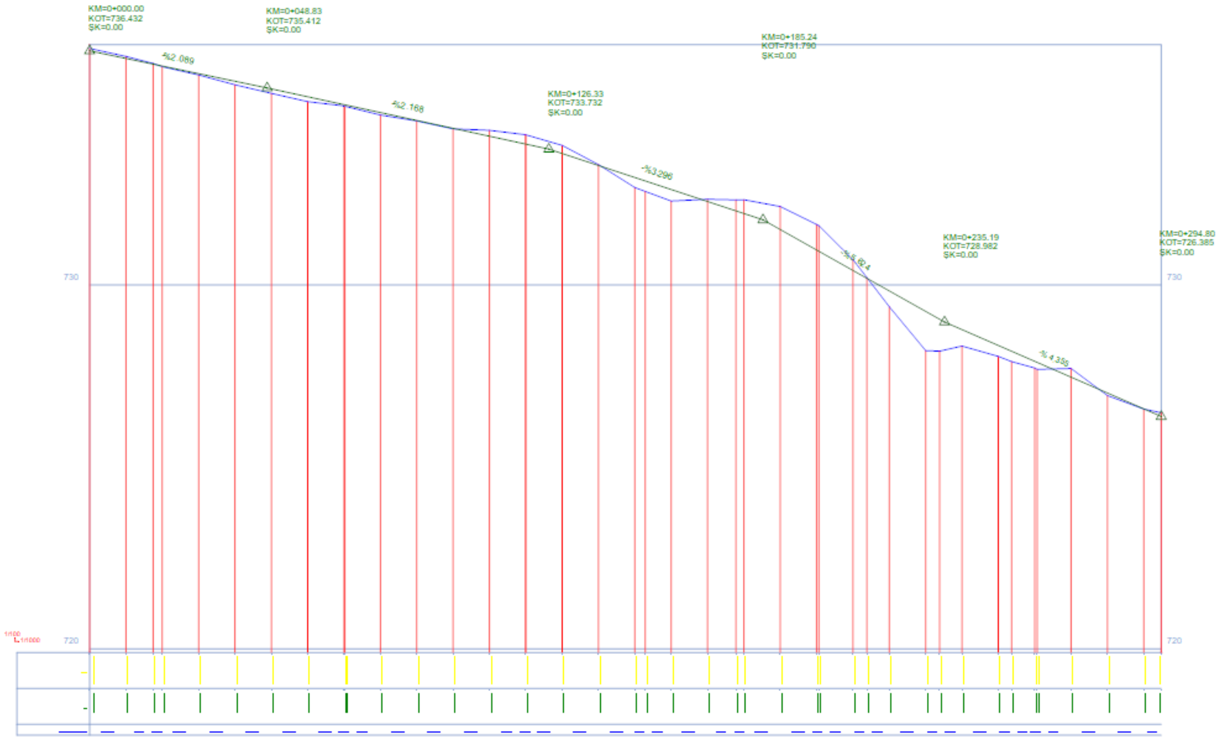
Figure 13. Horizontal profile and vertical curve definitions

Finally, a material profile was generated by using Bruckner tool based on the volume values. The relationships between the storage and borrow points determined for the material to be transported or stored can be seen. An example material profile is shown in Figure 14.

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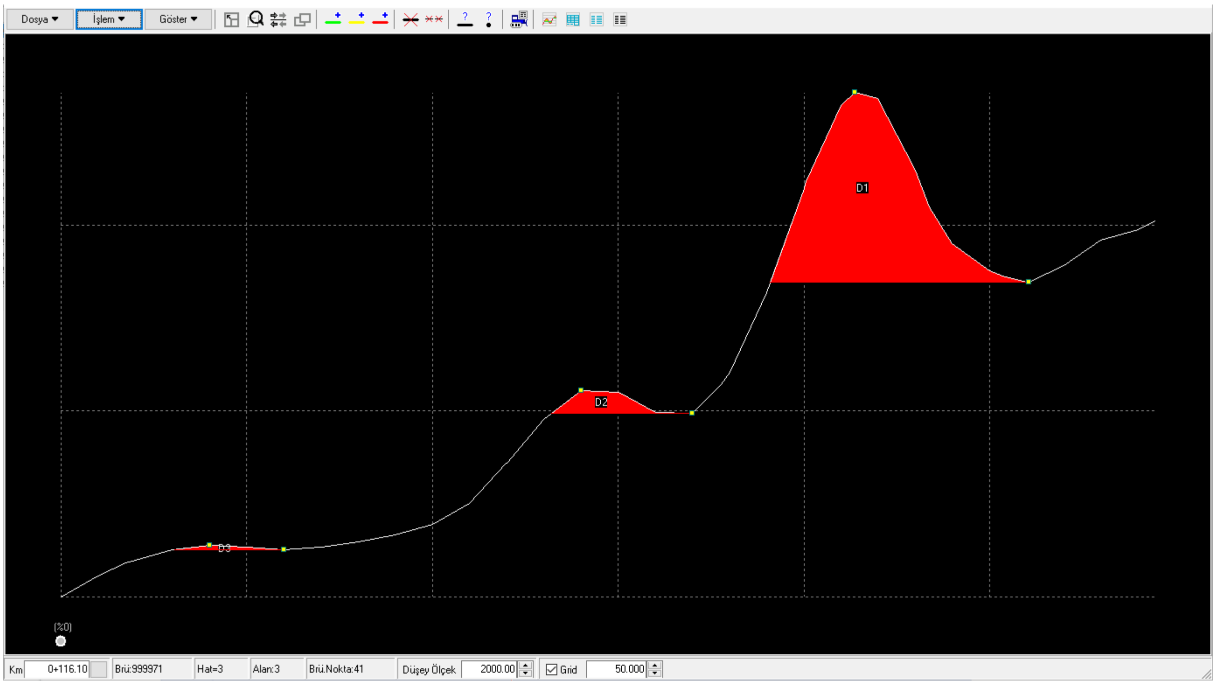

Figure 14. Material profile

3. Results and Discussion

The results indicated that DEMs obtained by UAV has a pixel resolution of 10 cm, while it was 61 cm and 56 cm for the DEMs obtained by GNSS-GPS and Total Station method, respectively. Therefore, UAV data provides the highest resolution. In terms of processing time, UAV requires the least amount of time and labor in field applications, taking only 14 minutes. GNSS-GPS, which can be used by a single person, comes in second place with 70 minutes. The device that requires the longest time and labor is Total Station, which took 110 minutes. However, in office stages, this situation is somewhat reversed. Processing and transferring images obtained by UAV takes more time compared to other methods. Data preparation and processing takes approximately 3 hours, depending on the performance of the computer used. In other methods, however, since point data is used, it does not require high processing capacity, which makes this situation a little more advantageous. Both GNSS-GPS and Total Station use only point data, so their data production processes are completed in 15 and 25 minutes, respectively.

When considering road planning with Netcad 7.6, triangle models were obtained using DEMs based on UAV, GNSS-GPS, and Total Station. The quality and accuracy of the obtained triangle models depend on the DEM data. Therefore, the triangle model obtained from the UAV DEM data, which has the highest resolution, represents the terrain better. The other models also show similar characteristics. The road lengths designed using DEMs based on UAV, GNSS-GPS, and Total Station were found to be 294.8, 272.4, and 282.1 meters, respectively. The average road slopes were 3.41%, 3.39%, and 3.31%, respectively. According to the earthwork volume information, excavation and filling volumes using DEMs based on UAV, GNSS-GPS, and Total Station were found to be 369.16 m^3 and 166.98 m^3, 285.86 m^3 and 201.83 m^3, and 433.17 m^3 and 183.95 m^3, respectively. The differences in road alignment for each method have affected both the distance and slope as well as the excavation and embankment volumes.

4. Conclusion

Due to the accuracy of UAV data, which reflects the terrain more realistically and has high data quality, it provides more accurate results in the study. Considering the labor and time consumption in

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the data production stages, UAV is still leading. On the other hand, there is a disadvantage of data processing stage which requires strong and fast computer processors due to high data production time of UAV data. However, if there are PCs with sufficient power, this situation becomes no longer a disadvantage. Thus, it can be concluded that UAVs can become indispensable when data processing is provided in a shorter time.

Compared to using UAVs, GNSS-GPS and Total Station require more manpower and time in generating DEMs. Especially when using Total Station, two people are needed to operate the equipment and certain conditions such as ensuring reflection from the reflector and aiming at the reflector significantly affect the work time. In addition, if the device is not on a water level, measurements cannot be taken, resulting in significant time losses. Therefore, compared to the other two methods, using Total Station for measurements becomes more disadvantageous. GNSS-GPS, on the other hand, can be considered advantageous compared to Total Station as it only requires walking around the area during data collection. However, network issues and terrain irregularities can make working with GNSS-GPS more difficult. Having points in the wrong places due to weak GPS and network signals in certain areas is another significant issue. Therefore, in studies using GNSS-GPS, measurements taken in areas where GPS and network signals are strong will be more efficient.

Road planning processes with Netcad 7.6 provide many advantages compared to traditional methods. In addition to obtaining all the information about the planned road, it is significantly faster than traditional methods. Furthermore, even if mistakes are made, correction processes can be completed in shorter periods of time, which provides an advantage. Planning that would take days with traditional road design methods can be completed in significantly shorter time using Netcad 7.6. Moreover, the high accuracy, measurement and calculation precision using computer-assisted method provides more realistic results, compared to traditional methods.

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Investigating the Effects of Salting Roads on the Forest Trees along the Roadway by Using UAV Imagery

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Abstract
Liquid water becomes frozen ice at 0°C which is freezing point for water. When rock salt is distributed on the road surface, it makes it harder for water molecules to form ice crystals. On the other hand, large quantity of salt increase chloride levels in the water resources which leads to detrimental impacts on plants along the roadway. In this study, UAV-based RGB images was used to investigate the potential effects of salting road network on forest trees in Uludag National Park located in the city of Bursa. This park is one of the favorite winter sports centers in Turkiye and the roads are subject to heavy salting to prevent ice on the pavement. Aerial photos were taken by using DJI Mavic 2 Pro model UAV and Agisoft PhotoScan Pro program was used to produce RGB image covering the Black pine (*Pinus nigra*) stands along the sample road section. Then, RGB image was classified in ArcGIS 10.8 by using the random trees classifier method which is a supervised machine-learning classifier based on constructing a multitude of decision trees. During the classification, image was divided into four main classes including live trees, dry trees, ground (ground surface, roads), and shadow. Training samples were collected from the image by using Training Sample Manger under Image Classification toolbar. Then, image was classified based on the classifier definition file generated by using Train Random Trees Classifier. Finally, accuracy assessment was implemented based on 500 accuracy assessment points generated by using stratified random sampling strategy. A total of 115 training samples were collected and train accuracy of the random tree classifier was 74.27%. It was found that large proportion of the trees (69.22%) along the roadway was dried due to salting road. The accuracy assessment indicated that overall accuracy of the classification was 71%. The user accuracy for dry tree class was 79% while it was 74% for the producer accuracy. The results suggested that salting roads negatively impact trees along the roadway; therefore, alternative solutions should be used for icy roads such as sands or even some organic material such as molasses or beet juice.

Keywords: Salting roads, UAV imagery, classification, detection of dried trees.

1.1. Introduction
Liquid water becomes frozen ice at the freezing point of 0°C. In winter season, salting roads lowers the freezing point of water to about -9°C, which makes it harder for water molecules to form ice crystals (URL-1). It is an effective and cheap way to improve roads safety during winter. On the other hand, it may cause negative effect on the forest ecosystems as rock salt carried by the surface water reaches the water resources and the ground water. Large quantity of salt increase chloride levels in the water resources which damages the plants along the roadway (Fosted and Pedersen, 2000; Matucha et al., 2010).

The salt mainly includes NaCl, CaCl2, MgCl2, and KCl (Forczek et al., 2011). When salt dissolves in water, sodium and chloride ions separate, which results lack of nutrients in the soil as sodium ions replace these nutrients such as potassium, calcium and magnesium. Besides, rock salt absorbs water that is necessary for plant roots, therefore, plants face serious water stress. Not only plant roots but also plant's leaves, buds, and small twigs are seriously affected by the salting roads (Beckerman and Lerner, 2008).

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Previous studies indicated that salt applied over the road surface can reach up to 40 meters away from the roadway (Blomqvist and Johansson, 1999). It is reported that salt causes damages on the needle tip first and then brownish red necrosis spreading towards the base of needles of different age classes in coniferous trees (Forczek et al., 2011). In deciduous trees, salt effect appears as a brown scorching along the leaf edges. Particularly, salting road results in detrimental impact on relatively small trees (Kayama et al., 2003). The degree of salt stress on the tree along the roadway may vary depending on the amount of salt and the salt resistance of the species. However, when amount of salt exceeds the tolerance level, it adversely affects the vitality of the trees and discoloration is observed on the needles or leaves of the damaged trees. In order to detect the stands that are potentially affected by the salting, remote sensing data can be used effectively. In recent years, Unmanned Aerial Vehicles (UAVs) have been effectively used to collect remote sensing data as they are relatively sensitive, cost effective, and quick.

In this study, aerial images collected by a UAV was used to detect the effects of salting roads on forest trees along a road section located in Uludag National Park in Bursa province of Turkiye. RGB image was classified into four classes including live trees, dry trees, others (ground surface, roads), and shadows.

Material and Methods
Study Area
The study was implemented on the sample road section located in which is a well-known winter sports centers and receives high number of people during winter. The road network in the park is heavily salted to prevent ice on the pavement and to keep the roads open during winter. Dominant trees in the area are fir, pine, and beech. Around the sample road section, stand consist of mainly Black pine.

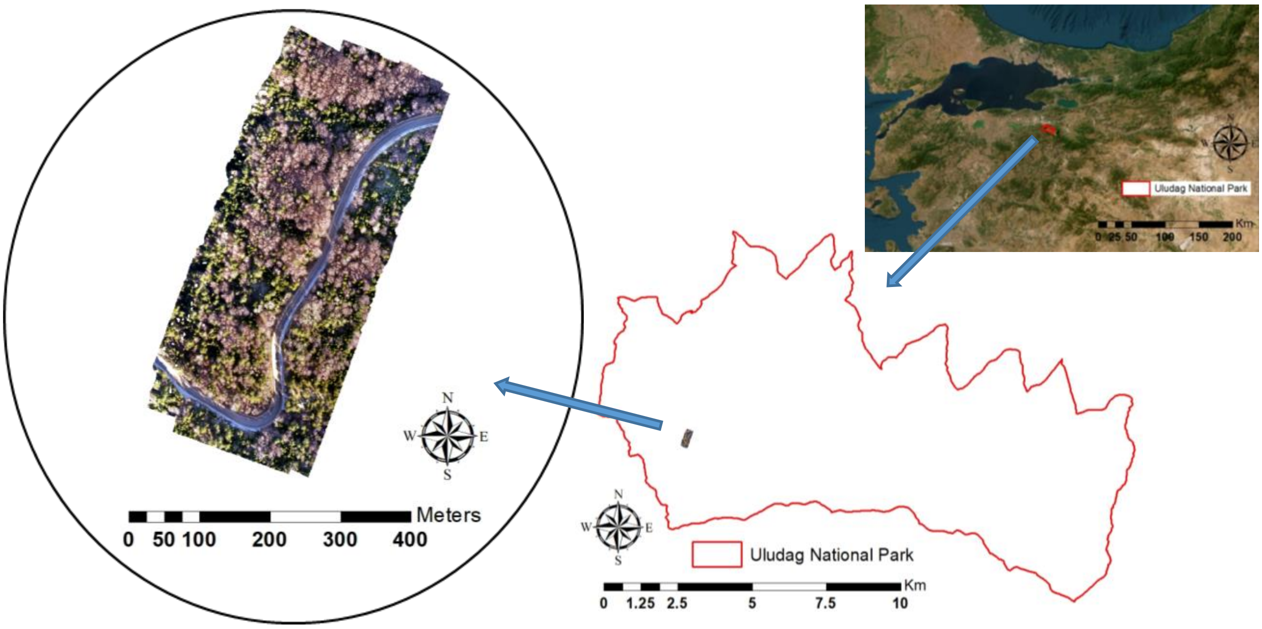

Figure 1. The location of Uludag National Park and sample road section

UAV Flight and Image Generation
Aerial photos were taken by using DJI Mavic 2 Pro model UAV and Agisoft PhotoScan Pro program was used to produce RGB image covering the Black pine (*Pinus nigra*) stands along the sample road

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section. DEM was produced using 3D data obtained by using a DJI Mavic 2 Pro (Figure 2). A total of 153 aerial photographs were obtained by flying over the study area using an overlap ratio of 80% and a flight altitude of 100 m. The flight time was 16 minutes covering the area of 223 m x 565 m. During the data collection in the field, six control points were located in the study area and UTM coordinates were recorded by using GNSS-GPS. Flight setting is indicated in Figure 3. Then, RGB image was generated by processing aerial photographs using Agisoft Metashape 1.8.3 software. In the image generation, 83014 tie points were obtained and aerial photographs were positioned according to the control points. After spatial corrections were applied on the images, a dense point cloud was generated using the "build dense cloud" process. These processes were carried out at an ultra-high quality level.

Specifications	
Weight	650 gr-750 gr
Battery	3830 mAH LiPo
Size	31 cm-35 cm
GPS Mode	GPS Yes
Camera	4K
Max Speed	45 kmp-65 kmp
Flight Distance	8000 m
Flight Time	30-31 Minutes

Figure 2. UAV data collection using DJI Mavic 2 Pro and its technical specifications

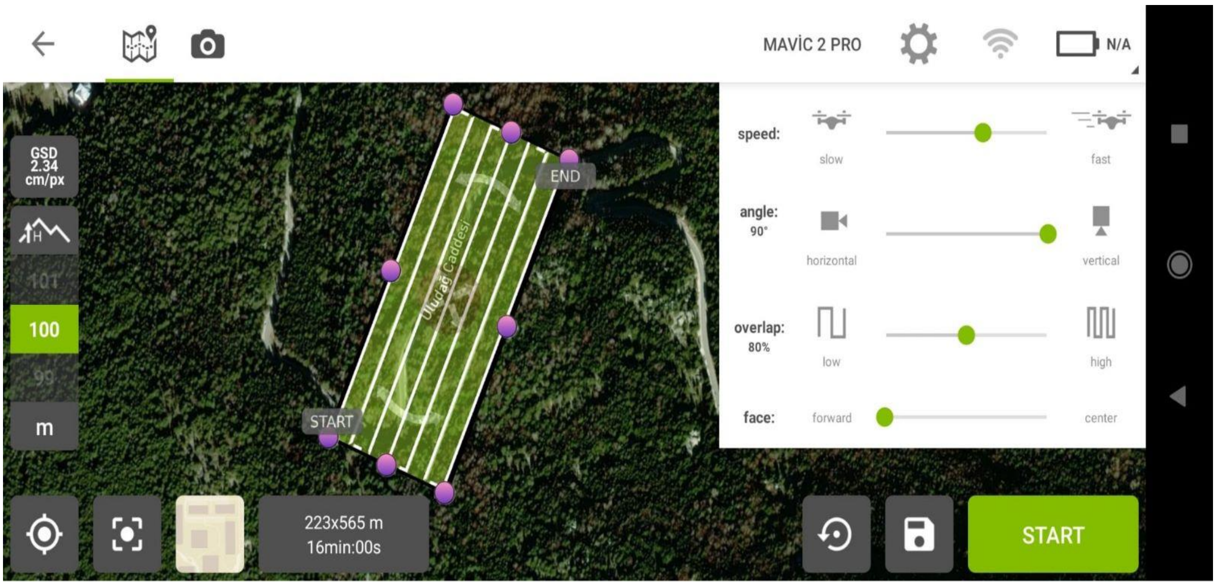

Figure 3. Flight area and settings on Pix4d interface

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Image Processing
The random trees classifier method in ArcGIS 10.8 was used to classify the UAV derived RGB image. The Random Trees classification method is a collection of individual decision trees in which each tree is generated from different samples and subsets of the training data. The objective is to made a number of decisions in rank order of importance for every pixel that is classified (URL-2). In this study, image was divided into four main classes including live trees, dry trees, ground (ground surface, roads), and shadows.

In the classification process, firstly, training samples were collected from the RGB image by using Training Sample Manger under Image Classification toolbar in ArcGIS 10.8 (Figure 4). The total number of training sample was 115 in which 50 points were from dry trees and 65 was collected from other classes (live trees, ground, and shadow). The train accuracy of the random tree classifier was computed. Then, image was classified based on the classifier definition file generated by using Train Random Trees Classifier under Segmentation and Classification methods.

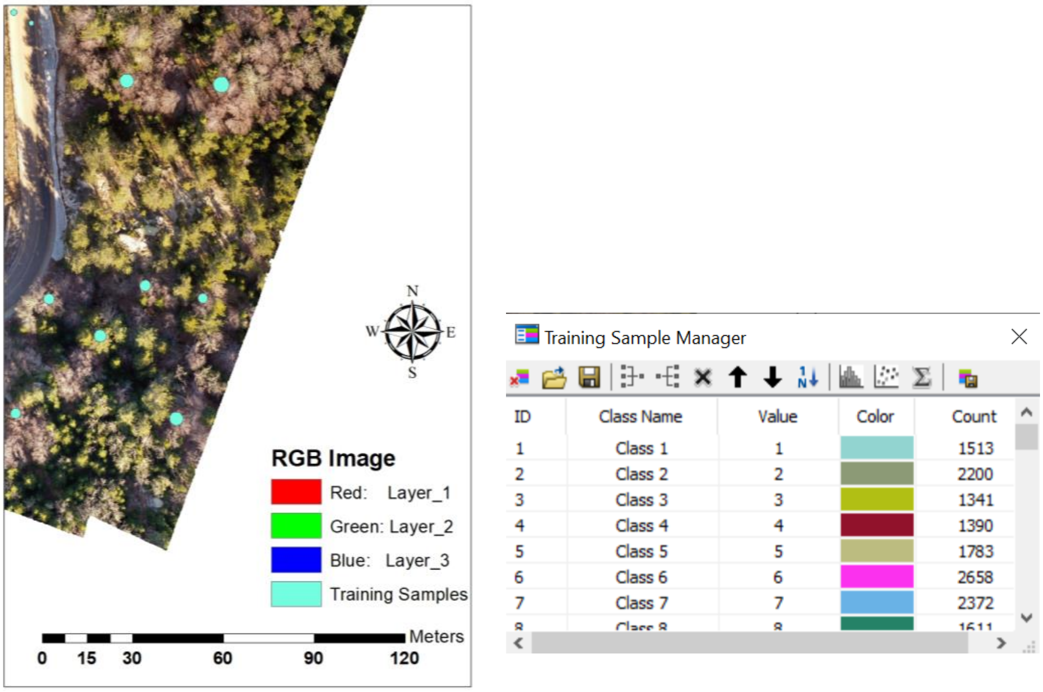

Figure 4. Training sample points (left) collected using Training Sample Manger (right)

Accuracy Assessment
In the next step, Create Accuracy Assessment Points tool was used to generate a set of random points and assigns a class to them based on reference data. In this study, accuracy assessment of the classification was implemented based on 500 accuracy assessment points generated by using stratified random sampling strategy. In this strategy, each class has a number of points proportional to its relative area. The classification types of the accuracy assessment points were labeled by referencing high resolution RGB image. Then, the reference points were compared with the classification results at the same locations.

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Results and Discussion
It was found that 83014 tie points were obtained during the flight and a total of 181,238,934 points was generated in building dense cloud at an ultra-high quality level. Finally, orthomosaic image with 2.18 cm resolution was generated for the study are (15 hectares) (Figure 5).

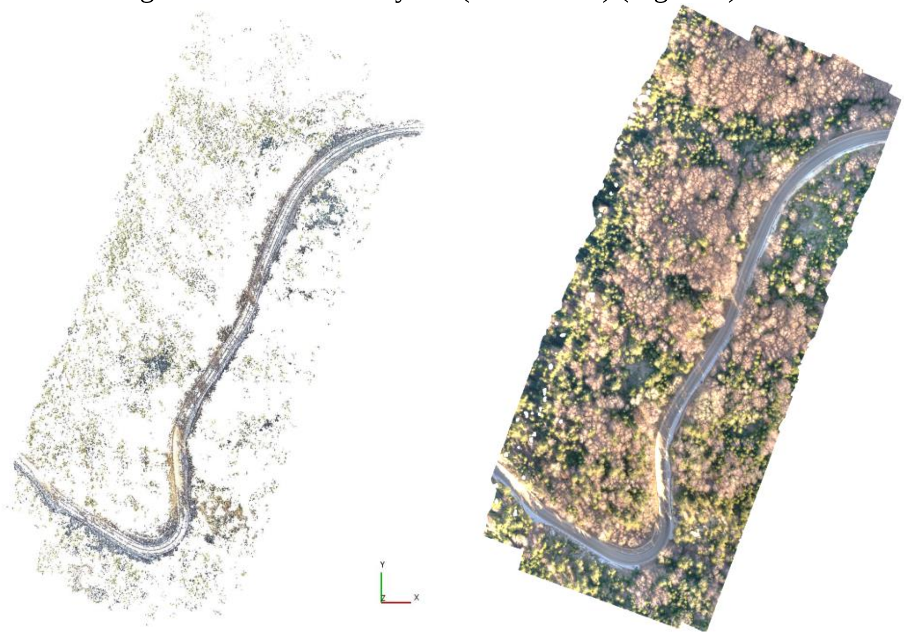

Figure 5. Tie points (left) collected during UAV flight and orthomosaic RGB image (right)

On the RGB image, a total of 115 training samples were collected and it was found that train accuracy of the random tree classifier was 74.27%. Then, Train Random Trees Classifier was used to classify the image using training samples. Figure 6 shows the classified image and recoded classified image indicating four main classes in the study area. The results indicated that 40.54% of the study area was covered with dry trees, while live trees and other classes covered 18.03% and 41.43%, respectively. It was also found that 69.22% of the trees was dry due to road salting along the roadway.

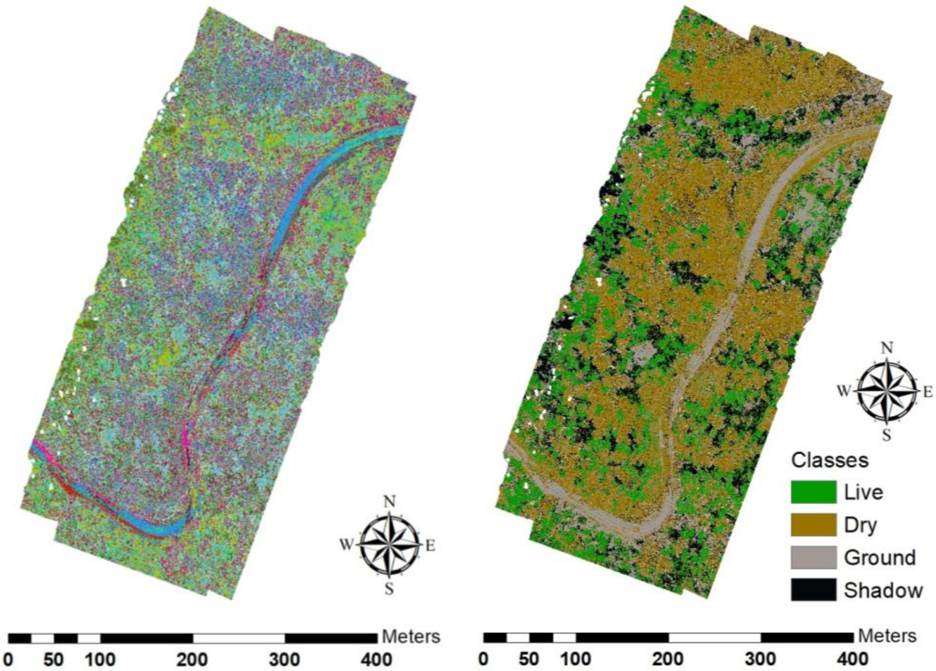

Figure 6. The classified image (left) and recoded classified image (right)

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Finally, accuracy assessment was run to evaluate the success of the classification based on 500 accuracy assessment points. In these points, 203 points and 90 points were labeled as dry and live trees, respectively, while 207 points were labeled as other classes. The overall accuracy of the classification was found to be 71% (Table 1). The user accuracy for live tree class and dry tree class was 90% and 79%, respectively. This results suggested that classification of live trees was very successful and it was also successful for the dry trees. On the other hand, user accuracy was 53% and 59% for ground and shadow classes, respectively.

Table 1. Accuracy summary table

Classes	Live	Dry	Ground	Shadow	Total	User Accuracy
Live	81.00	7.00	2.00	0.00	90.00	0.90
Dry	12.00	161.00	27.00	3.00	203.00	0.79
Ground	21.00	39.00	67.00	0.00	127.00	0.53
Shadow	16.00	10.00	7.00	47.00	80.00	0.59
Total	130.00	217.00	103.00	50.00	500.00	0.00
Producer Accuracy	0.62	0.74	0.65	0.94	0.00	0.71

Conclusions

In this study, UAV-based RGB images was used to investigate the potential effects of salting road network on forest trees in Uludag National Park located in the city of Bursa. It was realized that UAV technologies can be effectively used to detect salting effect on the trees along the roadway. The results indicated that high proportion of the trees (about 70%) was affected by the road salting along the sample road section evaluated in the study. Thus, decision makers should take necessary measures to prevent the impact of salting roads on the adjacent plants in the national park. First, UAV-based methods described here should be implemented all road network located in the national park. Then, alternative solutions should be considered and implemented in the area on icy roads. Previous studies indicated that there are some management techniques to prevent impact of salting roads on the trees. Sands and some organic material such as molasses or beet juice can be used in icy roads. Besides, applications of water can effectively leach salts out of the root zones. Finally, trees that are more resistant to salt should be planted in the risky locations along the roadway. In the future studies, soil samples should be collected from the risky areas and analyzed to estimate the salt content. Other factors such as slope, elevation, and aspect on salting effect should be studied.

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Determining the Relationship between Climate and Forest Zones in Future Depending on the Global Climate Change Scenarios

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Abstract
Climate exerts a profound influence on various aspects of human life, including physiological development, housing structures, food and clothing choices, and land distribution. Projections indicate that global climate change will lead to significant changes in climate parameters in the near future, directly or indirectly affecting all organisms on Earth. These changes are expected to result in substantial alterations in forest area zones, thereby impacting the climate. Therefore, it is crucial to determine biocomfort zones based on climate change scenarios and utilize them in urban and forest planning studies. This study aimed to assess the changes in bioclimatic comfort zones in Kutahya based on projected climate change scenarios. The analysis considered the SSPs 245 and SSPs 585 scenarios from the Coupled Model Intercomparison Project Phase 6, specifically the 6th assessment report of the IPCC. The objective was to determine the current status and potential changes in biocomfort zones in Kutahya for the years 2040, 2060, 2080, and 2100. The results revealed a general shift in comfort zones from cold to hot climates in Kutahya towards the year 2100, signifying a significant level of change. Notably, the southern regions, characterized by high forest density and intense forest activities, exhibited the highest level of temperature increase. These findings provide valuable insights into the potential impacts of climate change on bioclimatic comfort zones in Kutahya. The observed shift in climate patterns emphasizes the importance of incorporating proactive measures into urban and forest planning to ensure the well-being and sustainability of ecosystems and human settlements. By integrating these findings into future planning initiatives, decision-makers can take informed steps to mitigate the adverse effects of climate change and promote resilient and adaptive practices within both urban and forest environments.

Keywords: Kutahya, biocomfort, global climate change

1. Introduction

Understanding the relationship between climate and forest zones in the future is crucial for assessing the potential impact of global climate change. Climate change scenarios provide valuable insights into the possible future states of our climate system. These scenarios consider various factors such as greenhouse gas emissions, atmospheric concentrations, and their effects on temperature, precipitation, and other climatic variables. By analyzing these scenarios, scientists can predict how different forest zones may be affected by changing climate patterns. Climate change scenarios suggest that rising global temperatures will lead to significant shifts in forest zones. As temperatures increase, certain forest zones may expand or contract, while others may disappear altogether. Warmer conditions could result in the migration of forest zones towards higher latitudes and altitudes, as plants and trees seek suitable habitats with more favorable temperature and moisture conditions. Changes in precipitation patterns are another crucial factor in determining the future relationship between climate and forest zones. Some regions may experience increased rainfall, leading to the expansion of forested areas. However, other areas might face drought conditions, which could cause the contraction or even disappearance of forest zones. Changes in water availability and soil moisture levels can profoundly impact the health and distribution of forests, influencing their composition and diversity. Furthermore, climate change scenarios also consider the occurrence of extreme weather events such as hurricanes, droughts, and wildfires. These events can have severe consequences for forest ecosystems, potentially leading to increased tree mortality, loss of biodiversity, and altered successional dynamics. They can

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also trigger forest disturbances, such as insect outbreaks and disease outbreaks, further influencing forest zone boundaries. It is essential to recognize that the relationship between climate and forest zones is complex and multifaceted. Factors such as soil characteristics, topography, and human activities also interact with climate change to shape the future distribution and composition of forest zones. Therefore, comprehensive and integrated assessments that incorporate various drivers and feedback mechanisms are crucial for understanding the potential impacts of climate change on forest ecosystems. In conclusion, climate change scenarios provide valuable insights into the future relationship between climate and forest zones. Rising temperatures, changes in precipitation patterns, and the occurrence of extreme weather events can significantly influence the distribution, composition, and health of forests worldwide. It is essential to consider a range of factors and conduct comprehensive assessments to understand and mitigate the potential impacts of global climate change on forest ecosystems.

Over the past three to four decades, the world has witnessed rapid economic growth, urbanization, and industrialization. These developments have led to an increased demand for energy and raw materials, resulting in extensive extraction of underground mineral resources and their utilization in various industries (Sevik et al., 2019; Cesur et al., 2021). As a consequence, the composition and structure of the atmosphere have undergone significant changes, characterized by a substantial increase in CO2 concentration (Cetin et al., 2019). These transformations have had both direct and indirect implications, ultimately leading to global climate change. Presently, the impacts of global climate change are evident worldwide, and it is anticipated that climatic anomalies will continue to escalate (Varol et al., 2021). The climate plays a crucial role in shaping various aspects of human life, including physiological development, housing structures, food and clothing choices, and population distribution (Cetin, 2020a, b; Kilicoglu et al., 2020). As warm-blooded organisms, humans are highly sensitive to external environmental conditions, and their well-being relies on specific ranges of climatic parameters (Cetin, 2020a, b; Adiguzel et al., 2021). The concept of "bioclimatic comfort," or simply "biocomfort," refers to the conditions that humans find comfortable in terms of temperature, humidity, and wind. Deviations from these optimal conditions can lead to various issues, such as irritability, fatigue, respiratory and circulatory problems, dry eyes, and throat discomfort (Cali, 2018; Canturk, 2018; Canturk, 2020; Saat, 2020; Elahsadi, 2020; Elhadar, 2020; Koleoglu, 2021). Therefore, it is recommended that humans reside in areas that meet the criteria of biocomfort for the sake of their health, well-being, and performance. In cases where the existing conditions do not provide biocomfort, individuals often resort to heating and cooling systems to adjust the microclimate within acceptable ranges. However, these systems not only contribute to significant environmental damages but also consume high amounts of energy. Thus, it is of utmost importance, both for human health and energy efficiency, to identify biocomfort zones and incorporate them into residential area planning (Elhadar, 2020; Kilicoglu et al., 2021; Bozdogan Sert et al., 2021). By considering the concept of biocomfort, it becomes possible to enhance the overall quality of life, comfort, and happiness of individuals while minimizing the negative environmental impact. Therefore, understanding and effectively applying the principles of biocomfort in urban planning and residential design can lead to healthier, more sustainable, and energy-efficient living environments (Elhadar, 2020; Kilicoglu et al., 2021; Bozdogan Sert et al., 2021). Biocomfort conditions are directly influenced by climate parameters, and it is evident that global climate change has the potential to significantly impact these biocomfort zones. Among the countries most vulnerable to climate change, Turkiye stands out as a nation highly sensitive to its effects, categorized as a "country at risk." Projections indicate that annual temperatures across the country will continue to rise until the year 2100, with certain regions experiencing temperature increases of up to 6 ºC (Varol et al., 2021). In light of these projections, extensive efforts are being made to assess the potential implications on key sectors such as forestry, agriculture, and tourism, and to devise strategies to mitigate and adapt to future changes (MEU, 2012).

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Considering the significant impact of climate change on biocomfort zones and the specific vulnerabilities faced by Turkiye, it becomes imperative to prioritize research and planning efforts that address the potential consequences of climate change. By understanding and predicting how biocomfort zones may shift in response to changing climate parameters, policymakers, stakeholders, and communities can proactively develop strategies to safeguard the well-being, sustainability, and economic stability of various sectors. These efforts will not only help minimize the adverse effects of climate change but also foster resilience and adaptive capacity to ensure a better future for Turkiye and its inhabitants.

The impact of climate change on climate parameters is undeniable, and it is expected to result in substantial modifications to biocomfort zones in the near future. However, limited research has been conducted thus far on how these biocomfort zones, which play a crucial role in urban planning studies, may be altered due to global climate change. Consequently, this study aims to address this gap by examining the potential changes in biocomfort zones within the Kutahya province. Given its significance in terms of residential and touristic aspects, understanding how the projected climate change scenarios might impact biocomfort zones in Kutahya will provide valuable insights for future planning and decision-making processes. By elucidating these changes, policymakers, urban planners, and stakeholders can better prepare and implement adaptive strategies to ensure the well-being and sustainable development of the region.

2. Material and Methods

The study was conducted in the province of Kutahya, situated in the eastern part of the Aegean region in Turkiye. Kutahya holds great appeal as a residential area due to its favorable geographical location and climatic and soil conditions. Additionally, it is renowned as a significant hotspot for forested areas, earning it the title of the "capital city of forests." As a result, the forested areas in Kutahya have been steadily expanding, necessitating the establishment of new forested regions (TMAF, 2023). The geographical location of the study area is depicted in Figure 1, providing a visual representation of the region under investigation.

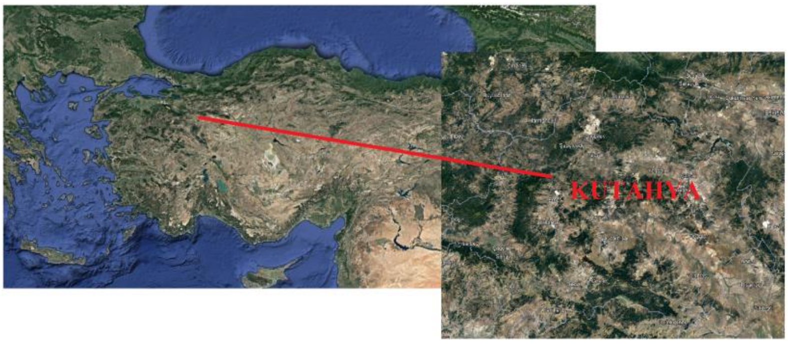

Figure 1. Location of Kutahya

The World Climate Research Programme (WCRP) has developed global models as part of the Coupled Model Intercomparison Project (CMIP6). These models have been continuously updated by the Intergovernmental Panel on Climate Change (IPCC) to reflect the latest developments and events. For this study, the CMIP6 models from the 6th assessment report of the IPCC were employed to determine the climate scenarios utilized. These scenarios are instrumental in understanding and projecting the potential impacts of climate change on the study area and form a crucial component of the research methodology. By incorporating these up-to-date climate models and scenarios, the study aims to provide valuable insights into the future changes in biocomfort zones in Kutahya.

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To gather climate data for this study, measurements collected by six meteorological stations under the General Directorate of Meteorology between 1970 and 2020 were utilized. These data sets served as the basis for creating climate maps using the "Inverse Distance Weighted (IDW)" method. This method allowed for the interpolation of climate variables across the study area, providing a comprehensive representation of the spatial distribution of climatic conditions. Subsequently, biocomfort maps were generated by applying biocomfort indices formulas to the interpolated climate maps. This approach facilitated the assessment of current and future biocomfort conditions in Kutahya, enabling a better understanding of the potential changes in comfort levels under different climate change scenarios.

The Department of Energy of Lawrence Livermore National Laboratory's data system provided the foundational data for local and regional climate change and impact assessment studies. These data sets enabled the generation of high-resolution climate projections at a 50 km resolution. Specifically, climate data from the CNRM-CM6-1 climate change model's SSPs 245 (representing intermediate radiative forcing of 4.5 W/m*2*) and SSPs 585 (representing the most extreme radiative forcing of 8.5 W/m^2) scenarios were downloaded in Netcdf file format. Subsequently, these data were imported into ArcMap 10.8 software, where conversion procedures were performed to facilitate their analysis. The mapping of the obtained data was conducted using the "Inverse Distance Weighted (IDW)" method. This approach utilized the simple equation of IDW to interpolate and visualize the climate data, allowing for a more comprehensive understanding of the spatial distribution of climate variables in the study area.

$$Z(X_0) = \frac{\sum_{i=1}^{n} = 1^{Z(X_i) d_{io}^{-r}}}{\sum_{i=1}^{n} = 1^{d_{io}^{-r}}} \quad (1)$$

The location X0, where the estimations were conducted, was determined based on adjacent measurements represented by z(X0i) for i=1,2,...,n. The exponent r was utilized to define the range assigned to each observation, while d denoted the distance between the observation location Xi and the estimation location X0. The weights assigned to observations that were further away from the estimation location decreased as the exponent increased. A higher exponent indicated that estimations closely resembled the nearest observations. These mathematical formulas were employed in the calculations conducted using ArcGIS software to generate climate maps (Cetin et al., 2018). Subsequently, two different biocomfort formulas were applied to the climate maps of each scenario, resulting in the creation of biocomfort maps. These maps were produced for various time intervals throughout the projection period, including the present year (2020) and 20-year increments until 2100 (2040, 2060, 2080, and 2100). First of these indices was DI (Temperature-humidity index (discomfort indices) and applied as reported by Cetin et al. (2019) in Table 1.

Table 1. Classification of indices and thermal comfort for people (Cetin et al., 2019)

Thermal comfort category for people	Index values (DI)
Extremely ice	< − 40.0
Freezing cold	− 39.9 to − 20
Extremely cold	− 19.9 to − 10
Very cold	− 9.9 to − 1.8
Cold	− 1.7 to + 12.9
Cool	13.0 to + 14.9
Comfortable	15.0 to + 19.9
Hot	20.0 to + 26.4
Very hot	26.5 to + 29.9
Extremely hot	> + 30.0

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DI = T−(0.55–0.0055 x RH) x(T−14.5) (2)

The discomfort index (DI) used in this study is calculated based on temperature-humidity indices. It takes into account the monthly mean temperature (T) measured in degrees Celsius (°C) and the relative humidity (RH) expressed as a percentage (%). These parameters are essential in assessing the level of discomfort experienced due to the combined effect of temperature and humidity. By considering the variations in T and RH, the DI provides a comprehensive measure of biocomfort conditions.

The second index used in this study is Effective Temperature taking wind velocity (ETv) and its implementation was explained by Lucena et al. (2016)

ETv = 37–(37-T)/[0.68–0.0014RH+1/(1.76+1.4v0.75)]-0.29T(1-RH/100) (3)

Where; T is dry bulb temperature (°C); RH is relative humidity (%); and v is wind speed (m/s).

In this study, the biocomfort maps of Kutahya province were created by initially utilizing data from existing meteorology stations. Subsequently, projected changes in climate parameters based on the SSPs 245 and SSPs 585 scenarios of the CNRM-CM6-1 model were incorporated into the current data. By applying the ID (discomfort index) and ETv (vapor pressure deficit) indices, the study aimed to determine how the biocomfort zones in Kutahya province would be influenced if these scenarios were to unfold. This analysis provides valuable insights into the potential future state of biocomfort conditions in the region.

3. Results

Figure 2 presents a map depicting the projected biocomfort zones in Kutahya province for the years 2020, 2040, 2060, 2080, and 2100 using the DI (discomfort index) method based on the SSPs 245 and SSPs 585 scenarios.

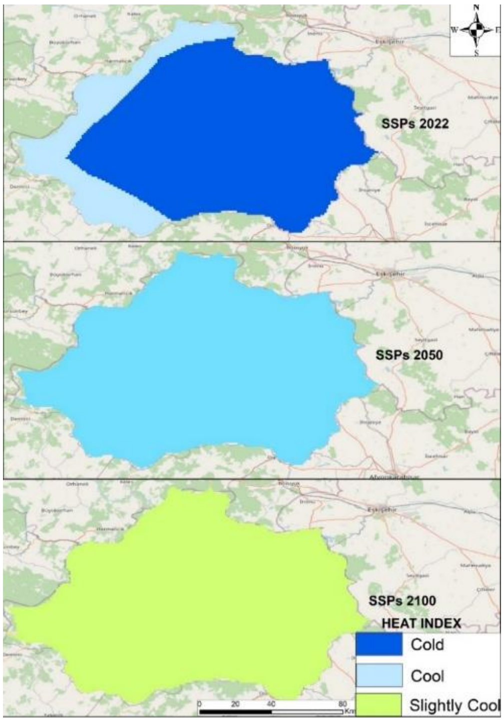

Figure 2. Models created

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The analysis conducted using the DI method reveals that the overall biocomfort zones in Kutahya province are projected to increase under both the SSPs 245 and SSPs 585 scenarios. Currently, the province comprises 34.61% cold zones, 19.07% cool zones, 18.12% comfortable zones, and 28.20% hot zones. According to the calculations based on the SSPs 245 scenario, by the year 2040, the distribution is expected to shift to 24.27% cold zones, 28.61% cool zones, 27.48% comfortable zones, and 19.64% hot zones. In 2060, the province is projected to consist of 9.76% cold zones, 34.86% cool zones, 35.67% comfortable zones, and 19.71% hot zones. By 2080, the composition is anticipated to be 13.12% cold zones, 32.12% cool zones, 33.42% comfortable zones, and 21.34% hot zones. The projections for the year 2100 suggest that the province will consist of 11.38% cold zones, 33.37% cool zones, 33.67% comfortable zones, and 21.58% hot zones. Considering the calculations made based on the SSPs 245 scenario, it is determined that the comfortable zones will constitute approximately 53% of the province.

Under the SSPs 585 scenario, the calculations indicate that in the year 2040, Kutahya province will consist of 32.91% cold zones, 26.06% cool zones, 21.02% comfortable zones, and 20.01% hot zones. By 2060, the distribution is projected to shift to 14.90% cold zones, 27.73% cool zones, 32.52% comfortable zones, and 24.85% hot zones. In 2080, the province is anticipated to comprise 8.96% cold zones, 23.56% cool zones, 43.69% comfortable zones, and 23.79% hot zones. For the year 2100, the projections indicate that there will be no cold zones in the province, with 5.15% cold zones, 24.56% cool zones, 45.71% comfortable zones, and 24.58% hot zones. The calculations suggest that, according to the SSPs 585 scenario, the province will have no cold zones in the year 2100, with comfortable zones constituting approximately three-fourths of the province and hot zones comprising one-fifth of the province.

The map presented in Figure 3 illustrates the projected future biocomfort zones of Kutahya province in years 2020, 2040, 2060, 2080, and 2100 using the ETv method, considering the SSPs 245 and SSPs 585 scenarios.

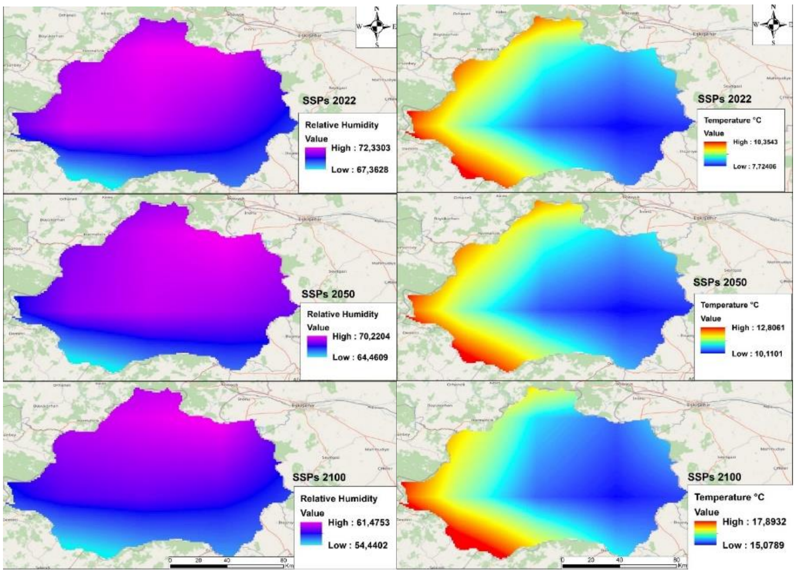

Figure 3. Models created using ETv method

Using the ETv method, similar to the DI method, the calculations indicate that under the SSPs 245 scenario, the comfortable zones in Kutahya province will increase until 2060 and then experience a slight decrease in 2080 before further increasing by 2100. However, under the SSPs 585 scenario, the comfortable zones will increase until 2060 and then decrease. Currently, the province consists of 25.43% cold, 22.07% cool, 19.23% comfortable zones, and 33.27% hot zones. According to the projections based on the SSPs 245 scenario, in 2040, the province will consist of 26.38% cold, 25.15% cool, 30.03% comfortable zones, and 18.44% hot zones. By 2060, the composition is estimated to be 19.23% cold, 28.17% cool, 31.26% comfortable zones, and 21.34% hot zones, with the majority of the province falling within the suitable zones. For 2080, the projected composition is 19.98% cold, 28.88% cool, 31.27% comfortable zones, and 19.87% hot zones. In the year 2100, it is projected that the province will have 19.02% cold, 29.01% cool, 31.96% comfortable zones, and 20.01% hot zones.

Based on the calculations using the SSPs 585 scenario, it is projected that in 2040, the province of Kutahya will consist of 29.23% cold, 22.83% cool, 23.29% comfortable zones, and 24.65% hot zones. By 2060, the composition is estimated to be 21.21% cold, 24.23% cool, 24.61% comfortable zones, and 29.85% hot zones. Furthermore, the projections indicate that in 2080, the province will consist of 30.11% cold, 18.81% cool, 19.96% comfortable zones, and 31.12% hot zones, and by 2100, the composition will be 32.17% cold, 17.01% cool, 18.57% comfortable zones, and 32.25% hot zones, which have not previously existed. According to the SSPs 585 scenario, cool zones will not be present until 2080, and the comfortable zones will cease to exist by 2100.

4. Discussion

The findings of the study indicate that substantial changes are expected in the biocomfort zones of Kutahya province as a result of global climate change, regardless of the method or scenario used. The projected temperature increase will lead to a transition from cold zones to hot zones, with a significant expansion of hot zones by 2100. The temperature rise will be particularly pronounced in the southern parts of the province, gradually spreading from north to south. These changes highlight the significant impact of climate change on the local climate conditions and underscore the need for adaptive measures to mitigate the potential adverse effects on human comfort and well-being in the region.

The findings of this study indicate that global climate change will have a significant impact on biocomfort conditions. These results highlight the emergence of a significant risk. The generated maps clearly demonstrate that Kutahya, particularly its southern region, will experience notable temperature increases, leading to the formation of hot zones by the year 2100. An important observation is that the regions with the highest temperature rise coincide with areas characterized by dense forest cover, which holds particular significance for the forested areas. In addition, urban centers experience further temperature increases due to factors such as buildings, paved surfaces, cooling systems, vehicles, and human activities. This leads to the development of heat islands where mean temperatures reach significantly higher levels (Gungor et al., 2020; Bozdogan Sert et al., 2021). Consequently, it can be concluded that regions with higher urban density will experience even higher mean temperatures.

Another important consideration is that the values obtained in this study were calculated based on annual mean meteorological data. Taking into account the mean values for the entire Kutahya province during the period of 1970-2020, the annual mean temperature was recorded as 19.2 °C. However, it is crucial to highlight that during the summer months, which hold particular importance for the region, the mean temperatures were significantly higher, reaching 24.1 °C in June, 27.1 °C in July, and 27.5 °C in August (TSMS, 2023). Consequently, the projected temperature increase will have particularly significant implications during these summer months, which are vital for both urban and forest activities, exerting adverse effects on these areas. The results of this study indicate a significant shift in comfort zones from cold to hot regions by the year 2100, with particularly noticeable changes expected in areas characterized by high forest density and forest-related activities. Considering the already high temperatures experienced during the summer season, where air-conditioning systems are necessary for maintaining comfortable conditions, it is projected that the demand for and use of such systems will increase significantly in the future. Consequently, this will lead to a substantial rise in energy consumption. It is estimated that global energy consumption will

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increase by 60% by 2030, and this doubling of energy consumption is anticipated for our country as well, despite a mere 1% population growth during this period (Cetin et al., 2018; Adiguzel et al., 2020, 2021; Zeren Cetin and Sevik, 2020; Zeren Cetin et al., 2020). The reliance on air-conditioning systems to regulate microclimate conditions to levels suitable for human comfort poses significant challenges in terms of energy consumption and associated costs. Additionally, the increased production necessary to meet the growing energy demand may contribute to higher carbon emissions, thereby accelerating global climate change (Elhadar, 2020).

The temperature increase resulting from global climate change has far-reaching implications, affecting not only human biocomfort zones but also all organisms. Climate represents a crucial factor that shapes the living conditions and phenotypic characteristics of organisms through the intricate interplay between genetic structure and environmental variables (Cetin et al., 2018, 2019). In particular, climatic factors exert a profound influence on plant development and distribution across the Earth, and climate change directly and indirectly impacts all organisms. Consequently, the projected effects of global climate change are expected to have destructive and potentially irreversible consequences for organisms and ecosystems. These effects encompass climate-dependent natural events such as forest fires, droughts, floods, desertification, and erosion, as well as an increase in ecological degradation rates, with temperature increase and water resource depletion being among the most significant factors (Dai et al., 2018; Mukherjee et al., 2018; Lee et al., 2019; Cetin, 2020a,b). Climate change plays a decisive role in shaping the distribution and functioning of ecosystems, thereby influencing their responses to habitat changes (Lenihan et al., 2008; Varol et al., 2021). Alterations in temperature and precipitation patterns are projected to intensify the frequency of biotic damages caused by insects and fungi, as well as abiotic damages such as forest fires and floods (Seidl et al., 2014; Birrell et al., 2020; Ertugrul et al., 2021). These changes in the ecological dynamics resulting from climate change have the potential to significantly impact ecosystems. One of the most vulnerable groups to the destructive effects of global climate change is plants, which lack effective migration mechanisms. The ongoing climate changes, which pose a threat to ecosystem continuity, trigger various responses among trees, including adaptation to changing climate conditions, local adaptation, migration, and even loss of life (Benito Garzon et al., 2019; Gárate-Escamilla et al., 2019). In addition to invasive species encroachment, climate change has been reported to hinder the growth of numerous plant species, potentially leading to significant impacts on the carbon balance of tropical forests (Rahman et al., 2018). Consequently, it is emphasized that many plant species may struggle to adapt to the anticipated effects of climate change, thereby giving rise to a range of issues such as species extinction (particularly for rare and endemic species), ecosystem loss, and biodiversity decline (Varol et al., 2021). The inability of certain plant species to cope with the forthcoming climate-related changes poses significant challenges to ecosystem resilience and functioning. The detrimental impacts of climate change on ecosystems will extend to human lives, as humans are an integral part of the ecosystem. The adverse effects of climate change on essential resources such as food and water will lead to challenges in accessing these resources, profoundly and irreversibly affecting human lives. Consequently, considering the findings of this study from multiple perspectives, it can be inferred that the results obtained for Kutahya province are likely to manifest in similar patterns worldwide. The changes that will significantly influence the lives of all organisms on Earth may occur within a relatively short timeframe, emphasizing the urgent need for global action to mitigate and adapt to the effects of climate change.

5. Conclusion

The findings of the present study indicate significant forthcoming changes in the biocomfort zones of Kutahya province, characterized by a general warming trend. These changes will result in a shift from cold zones to hot zones by the year 2100, with the regions of highest forest density and intense forest activities experiencing the most substantial temperature increases. This observation highlights the likelihood of increased usage and costs associated with cooling systems, which are employed to maintain comfortable conditions. However, it is important to note that cooling systems contribute to global climate change through their energy consumption and the use of certain gases. As temperatures continue to rise, the demand for cooling systems will intensify, creating a feedback loop where their increased use contributes to further temperature increases. This cycle underscores the need for sustainable and energy-efficient cooling solutions to mitigate the adverse effects of climate change. Numerous studies have highlighted the direct and indirect global effects of climate change. Slowing down and ultimately halting climate change is the most effective approach to mitigate its impacts. However, achieving this goal may seem challenging. In such circumstances, proactive measures become crucial in defending against the effects of climate change. Local and regional actions play a significant role in combating the negative consequences of global climate change. This study projects a shift of comfort zones from south to north throughout Kutahya province. As a result, it is essential to plan for new forest management and develop appropriate strategies for settlement areas in the northern regions of the province. By undertaking these measures, it is possible to anticipate and prepare for the projected changes effectively. The findings of this study highlight the increasing discomfort zones in areas characterized by improper planning and high forest density. To address this issue, immediate regulations should be implemented in accordance with key factors such as tree cutting, building construction, impermeable surfaces, vehicles, and human activities, all of which contribute to higher mean temperatures in these regions. Recommendations include increasing green spaces within cities, replacing light-reflecting hard surfaces with grass or more suitable alternatives, establishing rooftop gardens, utilizing appropriate materials to insulate building exteriors, and prioritizing sustainable building practices. To minimize the long-term effects of global climate change, it is crucial to reduce fossil fuel consumption and implement measures that decrease vehicle usage, such as developing efficient public transportation systems, planning cycling infrastructure, and promoting the use of electric vehicles. Additionally, increasing reliance on renewable energy sources is essential. Given that water is a vital resource profoundly impacted by climate change, it is necessary to conserve water, reduce factors that pollute water sources, and implement wastewater recycling for agricultural purposes. By implementing these measures, it is possible to mitigate the effects of global climate change, create more sustainable environments, and safeguard essential resources for future generations.

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Oral Presentations

Possible Effects of Forest Harvesting Activities on Soil Respiration

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Abstract
Soil plays an important role in the concentration of CO2 in the atmosphere, as it is one of the main sources of carbon. 10% of the CO2 in the atmosphere passes through the soil every year. This is 10 times more than the amount of CO2 released into the atmosphere with the use of fossil fuels. Soil respiration, defined as CO2 release; since it is an important indicator of several events in the ecosystem, such as metabolic activities in the soil, decomposition of plant residues, conversion of organic carbon in the soil to atmospheric CO2, it gives important information about the quality of the soil. Forest ecosystems have a significant impact on the storage of CO2, one of the greenhouse gases that cause global climate change, from the atmosphere. Forest harvesting activities, which form an important part of the forestry sector, which is the management of a biological entity open to natural conditions and dependent on the soil, and changes due to natural factors affect the physical quality of the forest soil, causing the chemical, biological quality and soil carbon pools to be affected. Therefore, it is critical to understand the carbon dynamic effects of forestry practices on forest ecosystems. Within the scope of the study, how harvestıng activities in forestry change soil properties and their possible effects on soil respiration were examined. In addition, this study focuses on the management of forest harvesting activities with a more sensitive approach within the scope of sustainable ecosystem.

Keywords: Forest Ecosystem, Production in Forestry, Soil Respiration

1. Introduction

Forestry is a multifunctional and sustainable activity that covers biological, technical, economic, social and cultural studies in order to meet the needs of the society for forest products and services continuously and optimally. Taking into account the demands of the society, its relations with other sectors, the region and the macro-economic structure, taking into account the country and sector opportunities, balancing monetary benefits with other benefits, producing alternatives with different economic, social and biophysical results, and choosing among them by using multi-criteria decision-making techniques are the requirements of modern forestry understanding. Forest ecosystems are at focus point of the sustainable development process. The basic element of this process, forests are renewable natural resources with functions for the production of goods and services and meeting the needs of society, and they are a biological entity open to natural conditions and dependent on the soil (Acar, 1998).

Soil quality is expressed as soil properties and soils as an effective component of a healthy ecosystem (Schoenholtz et al., 2000). The concept of soil quality may differ according to the services and products that the soil provides. However, when evaluated in terms of forest ecosystem in general, the concept of soil quality is defined by foresters as "the ability of the soil to produce biomass per unit area" (Ford, 1983).

The extent of the damage to forests is very important as it may adversely affect the sustainability of forests and the quality and quantity of products to be obtained from forests in the future. For forestry activities, this situation has revealed the necessity of planning by considering the environmental aspect, while in the past it was considered only for the production of wood raw materials for economic gain (Acar, 1998).

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Soil plays an important role in the flow of nutrients, water and energy to sustain forest productivity and biodiversity in forest ecosystems (Dominati et al., 2010). Soil is highly susceptible to largely inappropriate forestry activities (Akay and Sessions, 2001). Soil in forest ecosystems has a vital importance for all organisms living in that environment and for wood raw material production and environmental quality. However, forest soils form the basis of the whole forest ecosystem. There are long-term complex relationships and interactions between trees, soil animals and the microbial community (Fisher and Binkley, 2000).

During the forest harvesting activities, the log skidded and the harvest vehicles, which are known to be very productive in terms of forestry activities, cause various damages on the forest soil (Vossbrink and Horn, 2004). In general, the damage caused by skidding techniques in the uphill land shows itself in the form of fragmentation and erosion of the top layer, and soil compaction in the flat land (Ballard, 2000; Akay et al., 2007). In addition, heavy soil damage significantly reduces the carbon storage capacity of soils and seriously affects the ecosystem cycle (Özer Genç and Arıcak, 2022).

2. Effect of Extraction Activities on Soil Respiration and Soil Quality

Heavy vehicles such as Tractor, Harvester (cutter-destroyer-sorter), Forwarder (loader-carrier), Combined Harvester (Cutting-Stying-Loading-Carrier) used during logging operations in forest ecosystems can adversely affect the physical, chemical and biological properties of the soil and change the forest site productivity (Kezik and Altun, 2015). These vehicles used work in approximately 66% of the area. This causes the transport of the mineral topsoil together with the organic matter and the soil compaction (Hu et. al., 2014). Soil compaction damages the soil ecosystem and quality by changing the soil physical, chemical and biological properties (Tavankari et. al., 2013).

Harvesting activities can seriously damage soils and cause short and long-term changes in some soil properties. Significant reductions in organic carbon and microbial biomass can be observed, especially at skid trail. As a result of the harvesting activities, it was observed that the microbial properties of the soils decreased in parallel with the increasing soil temperature and decreasing soil moisture as a result of the removal of the litter from the soil surface. As a result, it is important for forest and soil health to monitor the changes in the microbiological properties of soils after logging operations in forests in the long term and to produce in a way that causes the least damage to the soil. Again, soil compaction, which is usually the most obvious result of skidding, increases soil endurance and limits gas diffusion, which inhibits root growth and microbial activity, delaying the physiological and growth characteristics of seedlings-trees (Babur, 2021).

Soil respiration is one of the important indicators of soil quality, especially soil biological activity. Soil respiration is controlled by soil organic matter, texture, pH, soil moisture, soil temperature, vegetation type and similar properties (Raich and Tüfekçioglu, 2000).

Respiration is one of the largest global carbon flows, emitting 10 times the amount of carbon released by the combustion of fossil fuels (IPCC, 2006). Soil respiration is soil CO2 flux that represents 30% to 80% of the total forest ecosystem (Davidson and Janssens, 2006). It consists of subterranean autotrophic (roots and related mycorrhiza) and heterotrophic (mainly microbes, microfauna and mesofauna) respiration. Soil respiration consists of three sources. These are soil organic matter, litter and soil-dwelling organisms. These sources change throughout the year as soil moisture and temperature affect microbial activity (Sakin and Elik, 2021). In addition, soil respiration of soils varies depending on vegetation type, harvesting activities, skidding activities, environmental conditions and land use types (Angert et al., 2015).

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Harvesting activities affect forest soil respiration by changing soil carbon input, soil organic matter, forest structure and microclimate, microbial biomass and microorganism community structure, root dispersal and biomass (Johnson, 1992; Cheng et al., 2023).

While many articles investigating the effect of silviculture studies on soil respiration can be found as a result of literature studies, there are not many articles dealing with the effect of harvesting and skidding techniques on soil respiration (Smenderovac et al., 2023; Korkiakoski et al., 2023; Zhang et al., 2023; Coletta et al., 2017; Tang et al., 2005). The effects of different skidding techniques on soil respiration and the comparison of these techniques are important for optimizing both soil quality and forest carbon sequestration strategies.

5. Conclusion and Recommendations

When considering the relationship between wood production and consumption in our country, it is known that the amount of production is less than the demand, and that damages and losses occur in the environment as a result of unplanned and irregular harvesting activities and the use of wrong methods. Within the scope of sensitive forestry, it is very important to determine soil losses and quality in terms of sustainability in forestry and to make plans to reduce these environmental damages.

In this study, it is emphasized that soil respiration may change as a result of the destruction caused by the skidding operations, which is the most difficult part of forestry. In addition, the study underlines the possibility of identifying and developing an appropriate skidding techniques that increases the soil carbon sequestration capacity, aiming to reduce atmospheric CO2 concentrations by considering the CO2 output from the soil surface. In this context, it is very important that the selection of secondary transportation modes, harvesting vehicles, log sizes and skidding techniques are suitable for the site. Only in this way will it be possible to implement a safe, environmentally friendly and rational forest management. Thus, with the most suitable harvesting and skidding plan, a healthy ecosystem will be achieved and less damage to the environment will be possible.

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Oral Presentations

Detection of Windthrow Areas from Sentinel-2A Satellite Image on GEE Platform and Modeling with MAXENT Method. Bolu-NW Turkiye Case Study

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Abstract
Climate change may lead to increased or decreased future forest productivity. However, more frequent storms expected for Europe and are considered to be increasingly important abiotic disturbance factor for forests. Forest disturbance results in losses on both economic and ecological. Remote sensing techniques can be used for rapid assessment to identify ecological and financial losses. By using satellite imagery, which is one of the most critical resources for remote sensing windthrow detection, affected forest stands even with unnoticeable damage can be identified. Many bands ratio-based indices produced from satellite images are used to determine windthrow areas. Presented study, carried out in Bolu Regional Forest Directorate, the windthrow areas between 2017-2019 were detected by using the Normalized Difference Fraction Index (NDFI) from the Sentinel-2A satellite image of Google Earth Engine Platform (GEE). The MAXENT method was utilized to identify the define environmental variables affecting windthrown event. Wind speed, stand type (pure/mixed), precipitation, texture, distance to road, elevation, root types, slope (degree), and site index were used as environmental variables in the modeling. As a result, 101 of the 155 windthrow areas that occurred between 2017 and 2019 were determined by NDFI. The Area Under Curve (AUC) value of the model was found 0.836. Site index and wind speed were determined as the environmental variables that most affected the model performance. It has been found that areas with a site index of '1' and wind speeds between 35 and 42 km/h and 53 and 65 km/h have increased windthrow. The environmental variables that contribute the least percentage to the model are distance to road and root type. In mixed stands where the root structure is pile root dominating and heart-root less, windthrow is more widespread in regions where the distance to the road is between 0 and 900 m. Finally, a suitability map for the the Bolu Regional Forest Directorate was generated using the Maximum Entropy approach. The suitability map (LSM) showed that the forest districts most susceptible to the windthrow is Aladağ, Kıbrıscık, Sarpuncuk, Aksu, Balıklı, and Almacık respectively.

Keywords: MaxEnt, modeling, remote sensing, windthrow

1. Introduction
In this study, the areas that were affected by 155 instances of windthrow between 2017 and 2019 in Bolu Forest Regional Directorate (FRD) were identified using the Normalized Difference Fraction Index (NDFI). After identifying the windthrow areas, the percentage contributions of environmental variables affecting the damaged areas were determined using MaxEnt, one of the Empirical Models. Finally, areas that could be sensitive to windthrow in the Bolu FRD's windthrow areas were mapped using the MaxEnt method.

Windthrow is a common phenomenon in forests worldwide, with the potential to cause significant impacts on both ecological and socio-economic systems (Romagnoli et al., 2022). Windthrow is the result of strong winds, often associated with storms, uprooting trees by breaking the roots' anchorage to the soil. In forests, windthrow can occur due to various factors, such as shallow soils, shallow root systems, high wind exposure, or forest fragmentation (Van den Meersschaut, 1997; Bouget and Duelli, 2004; Petucco et al., 2020). The impacts of windthrow on forests can be severe. Windthrown trees can create gaps in the canopy, altering the forest structure and composition, and changing the habitat for wildlife. Gaps created by windthrow can also impact the regeneration of the forest, creating an environment more favorable to invasive species (Ulanova, 2000; Meyer et al., 2008; Chirici et al., 2018). In addition, windthrown trees can damage remaining trees, causing death, and resulting in economic losses in commercial forests. Therefore, timely detection of windthrow is important l for effective forest management (Mitchell, 1995; Couture et al., 2016; Havašová et al., 2017).

Rapid detection of windthrow areas is essential for timely assessment of the damages and implementation of appropriate management strategies. The most suitable method for promptly detecting windthrow areas is remote sensing (Schwarz et al., 2003; Rüetschi et al., 2019; Deigele et al., 2020). Remote sensing enables the capture of images of forested areas through the use of sensors on satellites, airplanes, or drones in order to obtain images. Remote sensing can detect changes in forest canopy structure and vegetation cover, which are key indicators of windthrow (Jackson et al., 2000; Kislov and Korznikov, 2020; Vaglio Laurin et al., 2021). In remote sensing images, it is sometimes difficult to detect information regarding vegetation status. Vegetation indices can be utilized to obtain such information. The vegetation indices used are based on the spectral characteristics of vegetation and provide information about changes in vegetation cover, density, and health (Myneni et al., 1995; Huete, 2012; Xue and Su, 2017; Huang et al., 2021). The use of vegetation indices for windthrow detection has been applied in various forest ecosystems related studies (Furtuna et al., 2015; Matiu et al., 2017; Einzmann et al., 2017).

Intervening in areas that are quickly detected through remote sensing techniques is highly important. By taking early action, damage can be reduced and forest managers can take preventive measures. The measures that can be taken can help reduce economic losses (Don et al., 2012; Haidu et al., 2019). In order to estimate and manage the potential effects of windthrow areas detected, modeling tools can be used. Windthrow modeling involves the use of computer simulations to estimate the likelihood and severity of windthrow based on a range of factors such as topography,roads, tree species (characteristics) and wind speed. These models can help forest managers identify areas at high risk of windthrow, plan harvesting operations, and design silvicultural treatments to promote stand stability and resilience (Mitchell, 1995; Mitchell et al., 2001; Lanquaye-Opoku and Mitchell, 2005).

2. Materials and Methods

2.1. Study Area

According to the classical regional classification, Bolu FRD is located in the Western Black Sea region, while according to the Statistical Regions Classification (IBBS), it is located in the Eastern Marmara Region. Approximately 60% of the land cover consists of forests, forestry-related activities have an important share in the region. While the dominant climate in Bolu FRD is generally the Black Sea climate, transitions to continental climates are also observed in some areas (Lök and Yıldız, 2015). Due to the transitional climates in the region, in the climate assessment, 2016 was evaluated as having warm winters and summers, and rainy in all seasons, while in 2018 it was classified as a continental climate (General Directorate of Meteorology 2016-2018). Due to the climatic differences in Bolu FRD, many tree species are found in the region. The dominant tree species in the region are *Fagus orientalis*, *Abies nordmanniana* (Steven) spach subsp. Equi-trojani (Asch. & Sint. ex Boiss.) Coode & Cullen, *Carpinus betulus*, *Pinus sylvestris* L., and *Pinus nigra*. The location map of the study area is given in Figure1.

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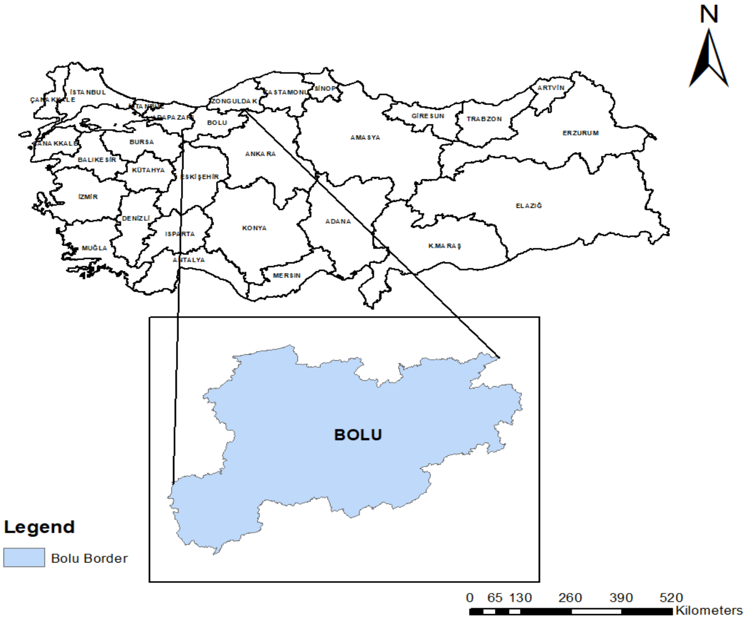

Figure 1. Location of the study area

2.2. Method

In this study, NDFI was calculated using Sentinel-2A satellite imagery to detect windthrowd areas recorded in extraordinary yield reports obtained from Bolu FRD. The windthrow areas have been identified with the help of an index. The index used in the study was coded in the Google Earth Engine Platform (GEE), which enabled rapid detection. Normalized Difference Fraction Index (NDFI) is a vegetation index that measures the fraction of absorbed photosynthetically active radiation (fAPAR) of a vegetation cover. It is calculated using the reflectance values of near-infrared (NIR) and red edge (Redge) bands (Souza et al., 2005). Formula (1) shows how NDFI is calculated, and the other variables used in the calculation are given in formulas (2) and (3).

$$NDFI = (GVsahde - (NPV + Soil)/(\text{GVshade} + (NPV + Soil)) \quad (1)$$

$$NPV = (\rho NIR - \rho \text{RedEdge})/(\rho NIR + \rho \text{RedEdge}) \quad (2)$$

$$GVshade = (GV)/(100 - shade) \quad (3)$$

The NDFI is calculated using green vegetation (GV), non-photosynthetic vegetation (NPV), bare soil, and shadow to determine the degree of forest degradation. The NDFI values range from -1 to 1, where higher values indicate higher fAPAR and therefore healthier vegetation. Negative values indicate the presence of non-vegetation features, such as bare soil or water. The NDFI is a useful index for monitoring vegetation growth, health, and productivity, and used in remote sensing applications, such as crop monitoring, forest management, and land-use planning (Bullock et al., 2020; Chen et al., 2021).

After identifying areas affected by windthrow, their relationship with environmental variables was to produced. Data on site index (I:1, II:2, III:3, IV:4, V:5), root type (1: Tap-Root,2: Heart Root,3: Tap-Root+Heart Root,4: Heart Root+ Tap-Root) and pure mixed (1: Coniferous Pure, 2: Latifolius Pure, 3: Coniferous + Coniferous Mix, 4: Coniferous + Latifolius Mix, 5: Latifolius + Latifolius Mix) were obtained from the FRD database. The slope(degrees), which is a different environmental variable, was derived from a digital elevation model (DEM). Wind speed and precipitation data were acquired from the National Oceanic and Atmospheric Administration (NOAA) database on the Google Earth Engine platform, and time-series analysis was performed on the maximum wind speed and average precipitation 5 days prior to the windthrow event. The data was then interpolated to the entire study

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area using Inverse Distance Weighted (IDW) method. Soil texture information (including clay, clay loam, sandy clay loam, loam, and sandy loam) was obtained from the United States Department of Agriculture (USDA) Texture-Class (1: Clay, 2: Clay Loam 3: Sandy Clay Loam, 4: Loam, 5: Sandy Loam) in the Google Earth Engine platform. Finally, distance to road data was generated using OpenStreetMap (OSM) road data.

After environmental variables was to produced, the modeling phase using MaxEnt method was initiated for the identification of sensitive locations within the windthrow areas. The Maximum Entropy method is a statistical approach used to estimate the probability distribution of a system given incomplete information or constraints. It is based on the principle of maximum entropy, which states that the probability distribution that best represents a system is the one that maximizes the entropy, subject to the constraints imposed by the available information (Banavar, 2010; Wu, 2012). The formula for Maximum Entropy is given in equation (4).

$$P(x) = 1/Z \exp(\sum \lambda i \; fi(x)) \quad (4)$$

where P(x) is the probability distribution function, Z is the partition function (a normalization constant), λi is a Lagrange multiplier that enforces the constraints, and fi(x) are the features or functions that represent the available information or constraints. The Maximum Entropy method has many applications in various fields processing. It is particularly useful in situations where there is incomplete or uncertain information, and where traditional statistical methods may not be applicable (Banavar, 2010; Wu, 2012; Xiao et al., 2015).

3. Results and Discussion

In the study conducted, NDFI was utilized for the detection of windthrowareas. Pre-windthrow ($q1$)and post-windthrow ($q2$) images were obtained using NDFI to detect windthrowareas, and formula (5) was utilized.

$$a = q1 - q2 \quad (5)$$

The formula used represents the windthrowareas with a, while q1 and q2 represent the NDFI index images before and after the storm, respectively. The pre- and post-storm Sentinel-2A satellite images where the windthrow was detected are given in Figure 2.

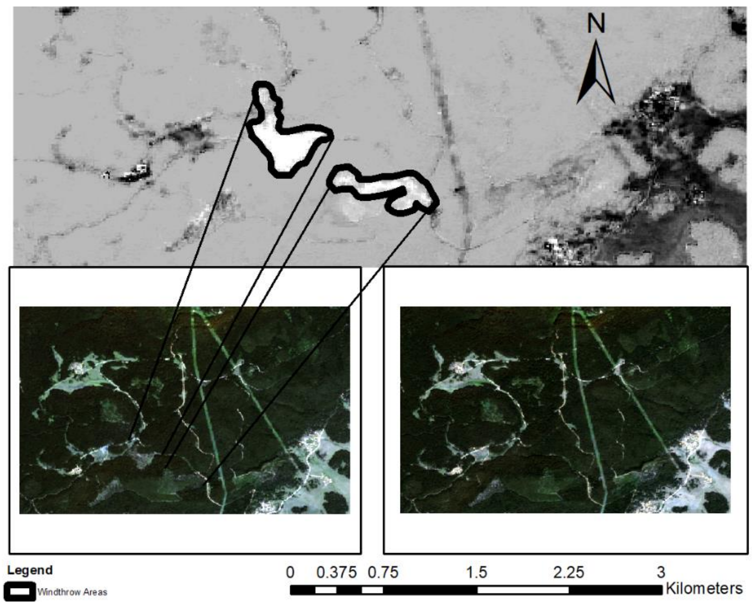

Figure 2. Detection of windthrowareas using NDFI

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Before proceeding with the modeling of the identified environmental variables, a Pearson correlation analysis was applied. According to the results of the analysis, no data was found to have high correlation among the environmental variables.

The red line in Figure 3 represents the performance of the training data set, while the blue line represents the performance of the test data set for the model. The success of this model is AUC=0.836. Figure 6 provides the representative variables that serve as input for the model and the impact of these variables on the model.

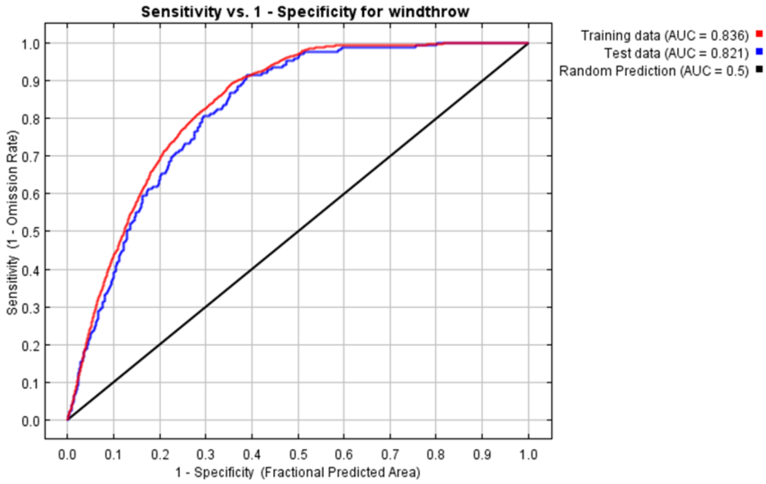

Figure 3. MaxEnt method training and test values.

The contribution rates of each environmental variable to the model are given in Table 1. According to this table, the variable with the highest contribution is wind speed and site index, while the variable with the lowest contribution is root types.

Table 1. Contribution percentages of environmental factors affecting windtrow in MaxEnt modeling

	Percent contribution	Permutation importance
windspeed	22.9	32.7
site index	21.3	9.5
precipation	19.4	19
elevation	16.7	30
slope (degree)	8.7	2.2
texture	4	1.4
pure mixed	3.8	1.4
distance to road	2.2	1.9
root types	0.9	1.9

According to the model graphs in Figure 4, wind speed is among the variable that cause most windthrow and loss of natural areas. An increase in windthrow is observed when wind speed is between 35-42 km/h and 53-65 km/h. However, a decrease in windthrow is observed in locations where the wind speed is between 42-47 km/h. When windthrow areas are examined according to tree root structure, it is determined that windthrow is more likely in areas with a dominant tap-root and fewer heart roots.

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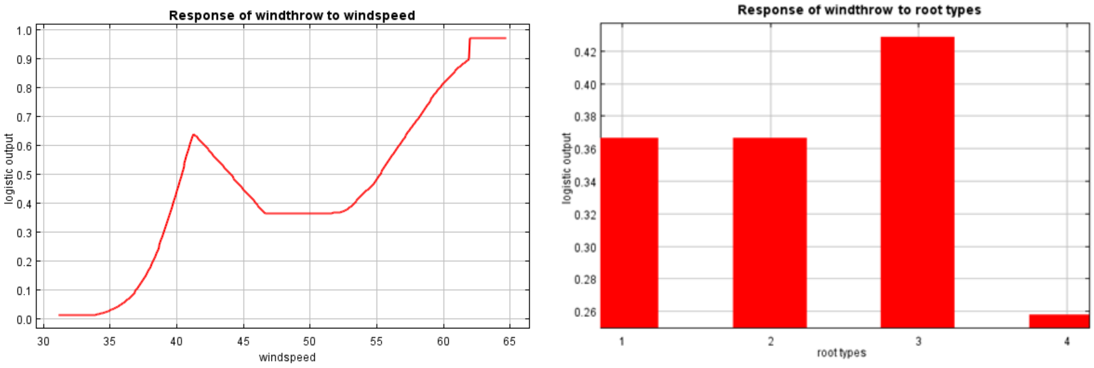

Figure 4. Variables that contribute to the model of windthrow areas from 2017 to 2019

It can be stated that the risk of windthrow is higher in the areas marked in red in the map seen in Figure 5. It is possible to say that there is a high risk of storm-induced windthrow in the regions of Aladağ, Kıbrıscık, Sarpuncuk, Aksu, Balıklı, and Almacık in the Bolu region.

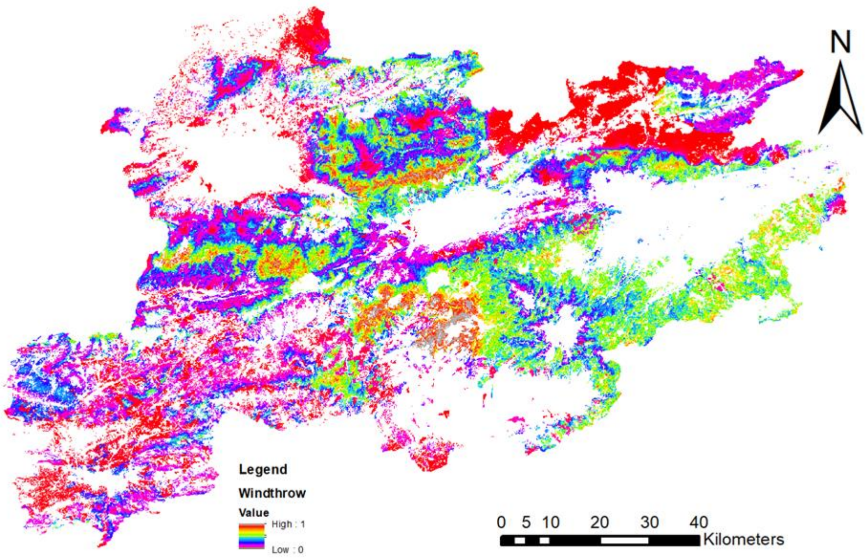

Figure 5. Map indicating the sensitive points to windthrow areas

Biotic and abiotic factors that cause damage in our country can significantly harm the sustainability of forests. Storm and snow damage are among the abiotic factors that harm forests the most, and the most effective of these factors is windthrows. There are limited studies that identify areas where windthrow has occurred and determine their relationship with environmental parameters.

There are limited studies identifying areas where windthrow has occurred. In the studies conducted, plant coverage indices such as NDVI, NDRE, and PSRI have been used. However, for the first time in this study, NDFI was used to detect areas where windthrows have occurred. The index used in this study was developed by Souza et al. (2005) and has been used to investigate locations in the deforestation process. This index was also used by Bullock et al. (2020) and Chen et al. (2021) and was found to be successful in identifying deforested areas. In this study, NDFI was preferred due to its ability to provide information on the history and location of damage in areas affected by the storm, using the verification data obtained from the Bolu Regional Directorate of Forestry. Due to the existence of verification data, areas affected by windthrows could be distinguished from other deforested areas.

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The most important envoromental factor in this modeling study is wind speed, as an increase in wind speed is observed to result in a higher incidence of windthrow in affected areas. However, in some locations where wind speed is between 42-47 km/h, a decrease in windthrow has been observed. These locations are found at elevations of 600-1000 m and 1400-2100 m. Upon examining locations with elevations of 600-1000 m, it was determined that deciduous species dominate. The presence of deciduous forest tree species reduces the risk of windthrow because deciduous tree species are more resistant to storm uprooting. The greater resilience of deciduous species' trunk structures compared to coniferous species is the reason for the reduced windthrow in deciduous species (Foster and Boose, 1995). In areas with elevations of 1400-2100 m, no windthrow was detected. This is because tree species at higher elevations gain more resistance as they are exposed to more storms (Schmoeckel and Kottmeler, 2008).

This study also utilized information from tree root structures, but it had low contribution to the modeling process. The results revealed that windthrow areas were more widespread in locations where pile roots were dominant in the Bolu Regional Directorate of Forestry. Mickovski et al., (2005) which evaluated the environmental factors of windthrow suggested that higher levels of precipitation could reduce the soil holding capacity of roots and increase the risk of windthrow during storms. Another study by Quine and Gardiner (2007) found that deciduous trees were less susceptible to windthrow risk compared to coniferous trees due to their deeper root systems.

4. Conclusion

In this study, windthrow areas were detected at the Bolu Forestry Directorate by calculating the NDFI from Sentinel-2A satellite imagery. After identifying the windthrow areas, environmental parameters were prepared at the border of the Bolu Forestry Directorate and modeled according to the MaxEnt method. According to the modeling results, the most important parameter affecting windthrowin the Bolu Forestry Directorate were found to be windspeed. The parameter with the least contribution to windthrowaccording to the model was root type. According to the LSM map created by the MaxEnt method, it was determined that there is a high risk of windthrowin the regions of Aladağ, Kıbrıscık, Sarpuncuk, Aksu, Balıklı, and Almacık. The areas sensitive to windthrowwere more clearly defined using the MaxEnt method used in this study. Also the results will help forest managers in making decision for planning afforestation studies in areaswith highly susceptible to windthrow occurrence.

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ForSim: Forest Visualization and Management Simulation

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Abstract
Forests serve a wide range of critical ecological functions and provide significant resources, including the production of ecofriendly goods, carbon cycling, habitat. Regrettably, the capacity of forests to perform these functions, as well as their productivity and health, are jeopardized owing to insects and disease, drought, forest fires, trade, climate change, and forest area loss. To manage forests well, simulation software (ForSim) for forest visualization, analysis, and operation planning tasks has been created in this research, which can operate with images from drones and satellites and has diverse spatial analysis tools. "ForSim", which includes various tools from calculating area and volume to inspecting yield details or taking cross-sections, was written in the Python programming language. Although the C++ was revealed to be faster at processing and visualizing forest data in the experiments, the Python was discovered to be more advantageous for this research subject owing to artificial intelligence - data science infrastructure and its library diversity. For instance, the opengl library was proven to be very beneficial for the graphical programming of objects, terrain and forest models due to its usability, open access, and high-quality visualization. ForSim, which has superior graphics quality than the widely recognized other simulation software, can automatically calculate the trees that need to be removed from the forest due to tending operations and the quantity of yield to be obtained. The felling directions of the trees to be removed, the escape path for foresters, and the unsafe zones where no humans should be present during the felling may also all be calculated in ForSim. In this way, by establishing operational plans with computer power, it is possible to make more precise judgments without human mistake, and by making forest observations in 3D visual environment, high success is granted in both forest analysis and education applications.

Keywords: Forest management, visualization, 3D programming, decision support system

1. Introduction

Forests serve a wide range of critical ecological functions (Ramsfield et al., 2016) and provide significant resources, including the production of ecofriendly goods, carbon cycling, habitat, and carbon dioxide absorption (Isabel et al., 2020). Regrettably, the capacity of forests to perform these functions, as well as their productivity and health, are jeopardized owing to insects and disease, drought, forest fires, trade, land use and climate change, and forest area loss (Pautasso et al., 2015; Millar and Stephenson, 2015; Isabel et al., 2020). Since forests, an indispensable resource, are constantly under threat and human pressure, the forestry sector must transition to the precision forestry era. Precision forestry has attracted a lot of attention in the historical process and has been the subject of various studies (Taylor et al., 2002; Taylor et al., 2006; Kovácsová and Antalová, 2010; Holopainen et al., 2014; Dash et al., 2016; Fardusi et al., 2017; Corona et al., 2017; Choudhry and O'Kelly, 2018; Aza et al., 2022; Putzenlechner et al., 2023) with the development of technology in order to make more accurate calculations in analysis, to make observations and examinations more unbiased and elaborate, to carry out measurements and planning as far away from human errors as possible. To actualize elaborate and accurate forestry, i.e. precision forestry, with far away from biases and human errors, computers, visualization techniques, and decision support softwares should be utilized. Because decision support techniques that function with multiple parameters are quite beneficial in forestry (Leskinen et al., 2006).

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Visualization and its techniques have long been examined for forestry by specialists (McGaughey, 1998; Karjalainen and Tyrväinen, 2002; Stoltman et al., 2004). As a result of which, a number of researchers such as Oppenheimer (1986), De Reffye et al. (1988), Prusinkiewicz et al. (1988), De Reffye et al. (1991), Deussen et al. (2002), Hu et al. (2018), Crimaldi et al. (2021), have developed algorithms for modeling-visualization of plants or have presented studies to the literature that will add to development of algorithms, techniques, softwares, etc., in the previous 40 years. The softwares for forestry visualization can be described as follows (Buckley et al., 1998):

- Stand Visualization System: It is free software, suited for regions smaller than 2 hectares (ha) and the PC-DOS operating system (OS). The geometric modeling technique was utilized. Geometric modeling is the process of creating mathematical models of individual elements such as the trees, other plants, structures, ground, and then assembling them to produce a model of a forest stand/landscape (McGaughey, 1998).
- Utools and Uview: This free program, which employs geometric modeling technique, is intended for areas equal or bigger than 2 ha and the PC-DOS OS.
- SmartForest: This freeware program, which utilizes geometric modeling technique, is intended for areas equal or bigger than 2 ha and the UNIX system.
- VistaPro3: It is paid software, suited for regions bigger than 200 ha and the PC-DOS, PC-Windows, Macintosh system. The geometric modeling and image draping techniques was utilized. Image draping includes draping an image (classified satellite images, digital orthophoto) over a 3D perspective view.
- TruFlite: It is paid software but has demo version, suited for regions bigger than 200 ha and the PC-Windows OS. The image draping technique was employed.

Despite the fact that various software that visualizes forest or plant structure was developed, these software are unsatisfactory in terms of today's graphic quality and technological opportunities. The term "technological opportunities" refers to visualizing the forest in a 3D interactive virtual environment with high graphic quality & spatial accuracy and in the same structure as the real forest, and to move around in this visualized forest to perform operations such as observation, thinning and maintenance with the computer assistance. In this work, the software named "ForSim" was created to generate a coordinated, 3D, real-like terrain model, to situating trees with their actual locations – features on model, and to visualizing them with high graphic quality, while adhering exactly to DEM (digital elevation model) & Table (tree position, species, height, age, diameter, crown width) data's. In this manner, perfectly actual, coordinated and interactive 3D virtual forest environment will be able to created, in which silviculture operations can be carried out. "ForSim" was created as a user-friendly simulation suited for touring and investigating the forest, allowing for animate and perform of operations such as thicket treatment, tending, and thinning.

2. Material and Methods

"ForSim" was created on a computer with an Intel i5-7400 3.0 GHz (4 cores) processor, 8GB of RAM, and an integrated Intel HD graphics 630 128 MB (VRAM) graphics card. "ForSim" was introduced using a sample application. In the application, "ForSim" was run with a table data set consisting of artificially placed trees with real world coordinates. The application's DEM and orthomosaic data's were produced using drone and photogrammetry techniques. Studied field photographs with 70% horizontal and 80% vertical overlapping ratios taken via drone flight were merged with photogrammetric techniques in Agisoft software to produce an actual field (terrain) dataset.

2.1. Introducing The "ForSim" Software

"ForSim" was created for the goal of accurately and precisely planning forestry operations, simulating the operations to be carried out with computer graphics, developing precautions by identifying dangers (over deforestation, choosing the wrong tree to cut, etc.), and training forestry students and employees. "ForSim" was designed specifically for interactively touring and observing the forest, obtaining extensive information about the selected trees, and carrying out operations such as tending, thicket treatment, lighting, thinning. After determining which trees would get silvicultural treatments, "ForSim" gives residual and extracted yield volume information. The software also includes tools that may undertake cutting and felling procedures in an animated way.

"ForSim" was created in Python language utilizing fundamental open source libraries such as "pandas, numpy", without employing any licensed/paid APIs, software, tools or libraries. It is a standalone program designed for the Windows OS, comprising a large number of interconnected script files, data structures and functions (such as triangulated irregular network data, color settings and stored data for trees). To make its complicated structure easier to use and comprehend, the external involvement should be simplified as much as feasible. Because of that, umpteen transactions/calculations in the software (background procedures will be explained in the following chapters.) were automated for the end-user. A basic work-flow was offered to the user with an easy graphical user interface (GUI) (Figure 1). After installation, "ForSim" is ready to use. With "ForSim.exe," the program is launched, all prerequisite modules (such as file reading, analysis and import tools) are enabled, and the GUI appears. The GUI includes buttons to start data entering and analysis in the initial stage of the software, as well as an informative text area for cautions and reminders and a progress bar. The basic and user friendly interface was created with the intention of minimizing user mistake as much as feasible (for example, doing the processes consecutively) (Figure 2).

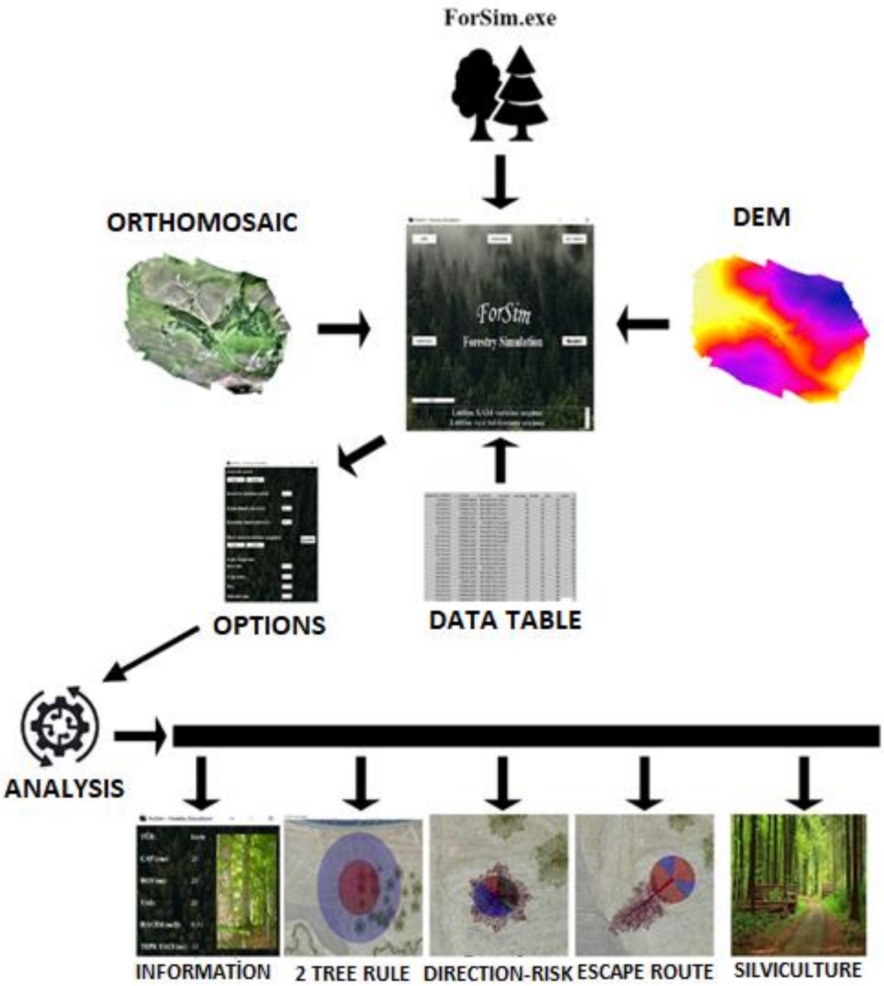

Figure 1. Work-flow diagram realized via GUI

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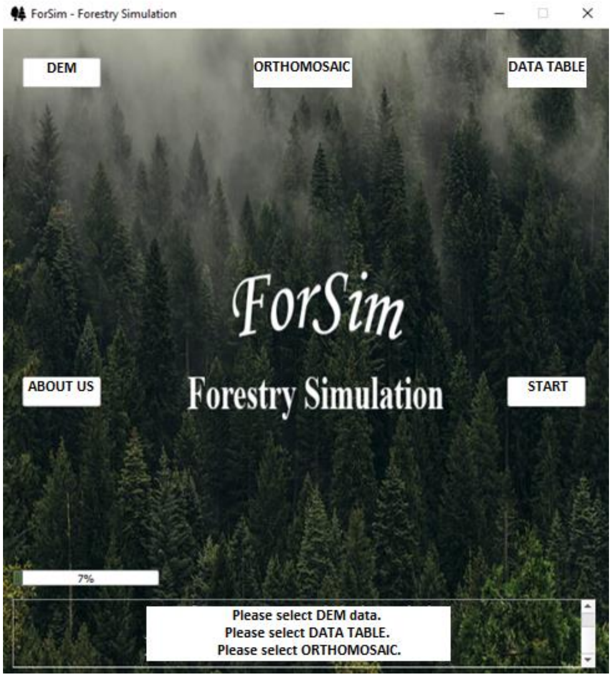

Figure 2. The main screen of the GUI

The data selection screen was designed using the typical file choosing mechanism. The data table containing the needed tree details, DEM, and orthomosaic (Figure 3) is chosen using the GUI's choosing mechanism. The chosen table data containing tree details must have ".csv" file suffix, and the orthomosaic and DEM must have ".tif" suffix, be digitized, and be in the same projection. "ForSim" also allows you to utilize image in any format (png, jpg, etc.) rather than orthomosaic. After the data has been chosen, the analysis phase begins. Throughout the analysis phase, which starts with the "Start" button, the user is provided with knowledge on the calculations and the data in the informative text area. The options window (Figure 4) appears once the analysis is completed. On this window, you can specify whether the field to be worked on is artificial or real, the drawing of negative felling points (NFP), the hazardous slope threshold, and the amount of spots the felling tree will touch the ground (for collision assess), the risky surface fracture threshold (degree), height-diameter-age-distance threshold values for treatment. The working logic of the threshold values for treatment is as follows: trees with the amount of height-diameter-age-distance above the specified value are marked as to be removed.

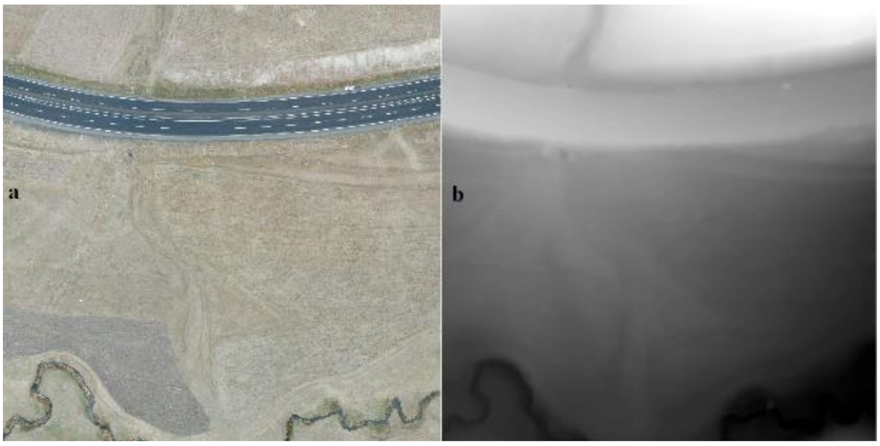

Figure 3. Orthomosaic (a) and DEM (b) data utilized in the sample implementation

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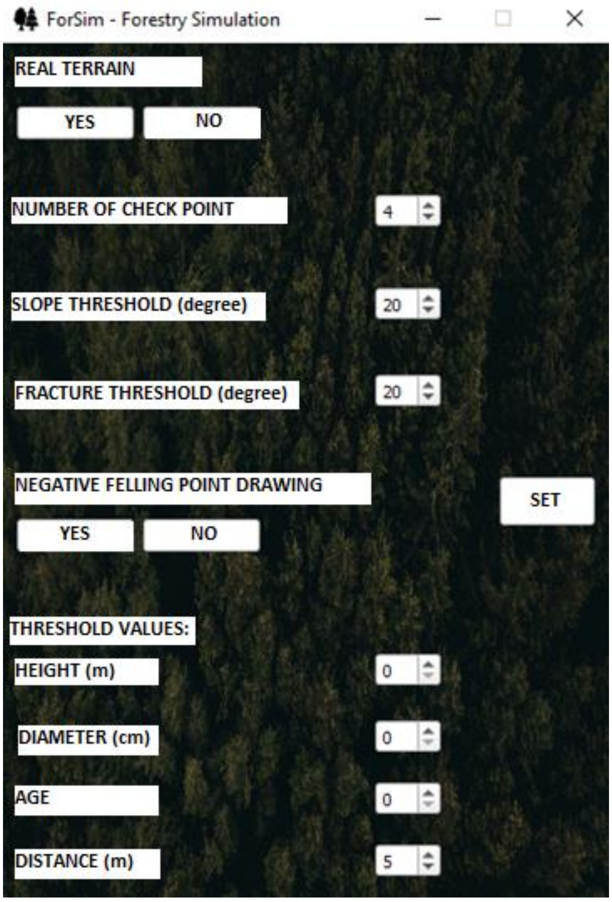

Figure 4. Options window

To exclude the desired parameter(s) (height, diameter, age, distance) from the treatment calculation, enter the value 0 to that parameter(s). After storing the settings in RAM (random access memory), the following phase is to generate the tree models and terrain, and to visualization the 3-D environment. At this point, two windows emerge, one for simulation and the other for information (Figure 5). Opening the simulation window allows you to perform analyses and treatment interventions, get details about the trees, touring the forest, and obtain the results of the escape route, direction-risk and two tree rule, which are shown in the work-flow chart and explained in Türkay and Aydın's (2021) article. Each action can be carried out with high graphic quality (Figure 6-7) on the simulation window, while the information window presents selected tree's (demonstrates as maroon on the window) general species image, species name, diameter, height, age, volume and crown details. On the simulation screen, there are possibilities for performing treatment operations that are computer-aided and/or that the user can manually select (or modify the computer's selections). "ForSim" can determine the appropriate trees to be handled in computer-assisted treatment, depending on the user-specified parameter combination and values. The user is continually offered with detailed information (volume, diameter, etc.) of the selected trees, as well as current removed and remain yield volumes with each selection. The trees selected by computer calculation are shown in dark blue, while the trees chosen by the user are shown in maroon (Figure 8). Detailed felling calculations and analyses of chosen trees, as well as animated tree felling, are all possible, although these procedures are explained in Türkay and Aydın's (2021) article.

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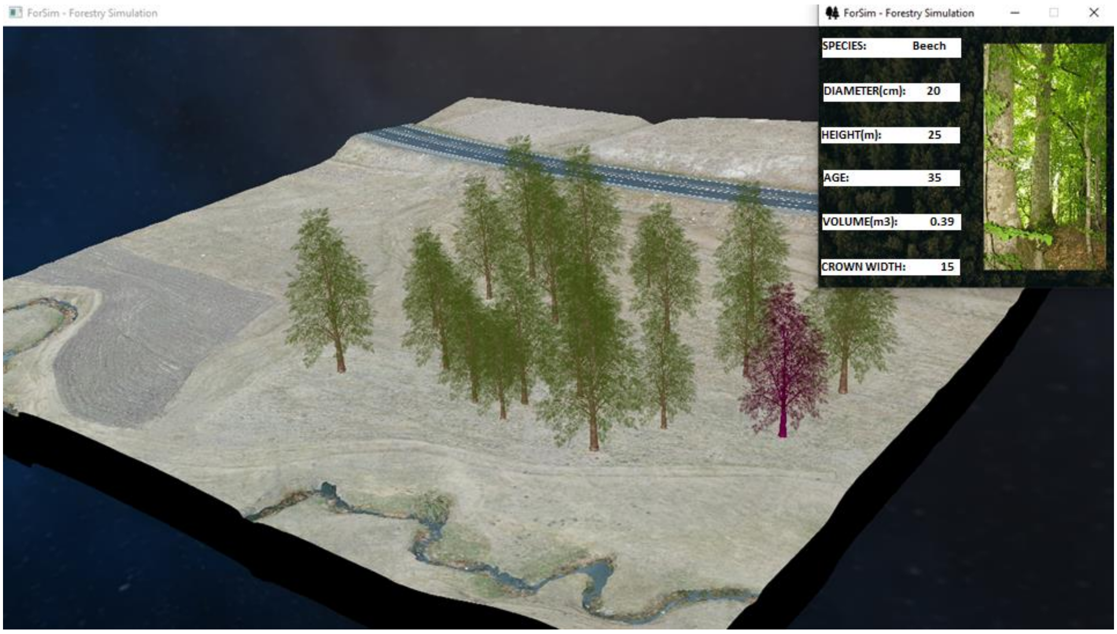

Figure 5. The main simulation window along with the information window (chosen tree is maroon)

Figure 6. Tree graphic quality (distant view)

Figure 7. Tree graphic quality (close view)

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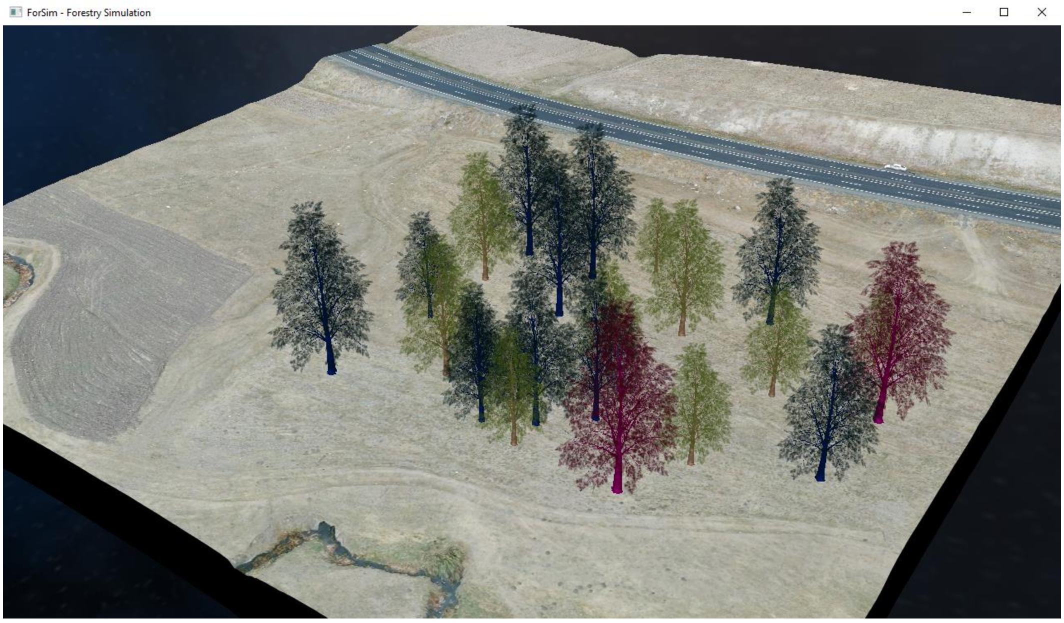

Figure 8. Tree selection for silvicultural operation with computer-aid (dark blue) and user choice (maroon) based on preset parameters

Since grasping the layered structure of the forest is important in planning forestry operations, a cross-section tool added to "ForSim". In this developed tool, the user determines the cross-sectional area via mouse, then the top view of this area is shown. Total volume (m^3) and number of trees in the cross-sectional area are given in this view, and the trees within the cross-sectional area are colored maroon. For the 2D cross-section, a line is generated based on the user-drawn border and landform. Then, trees that can be seen along the line are visualized considering their crown size and height (Figure 9). To maintain depth perception and discern the proximity of the trees, the trees were visualized by making them translucent based on their distance from the looking spot. Along with all of these, with the keyboard-mouse interactivity, "ForSim" permits to tour in the forest as you choose, to present the remaining forest view after the forestry operation, to take screen-shot, and to look from the desired location and angle.

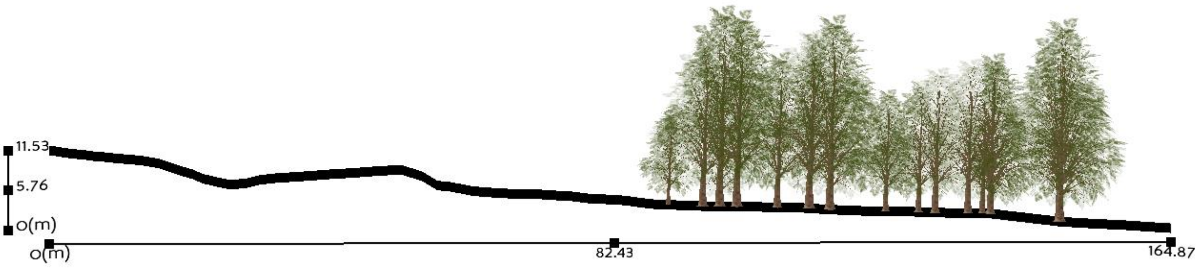

Figure 9. Cross-sectional forest

3. Results and Discussion

In this research, 3D simulation software was created to successfully manage, observe, and analyze forests, as well as educate forestry employees and students. During the development process, it was discovered that DEM and orthomosaic data had an impact on the visual quality of the 3D terrain model, computational precision and modeling time. The visual quality and computational precision improved substantially as the resolution of DEM and orthomosaic data increased but the computational speed decreased as well. Following the performance analysis, it came to light that although processing data with a resolution of 1m took 3.27 seconds, using data with a resolution of

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10cm increased this time to 3 minutes and 24 seconds, or 62 times (depending on the computer). The increase in resolution has an adverse effect on the speed of terrain modeling and analysis, as well as significantly increasing the hardware required. However, no significant changes in software performance or fluency were found while using the software. According to the study's findings, data quality can be enhanced as desired depending on computer force, although data with a resolution of less than 2m is not recommended to be used.

The 3-D method of visualization via orthomosaic has been thought to be most efficient technique due to; computers provide an another dimension to the realm of visualization (Strong and Smith, 2001), 3-D visualization began to spread quite quickly and the utilize of actual images in computer graphics has garnered a lot of interest since it gives more improved photo realistic image synthesis (Naemura et al., 2001). The terrain model generated with orthomosaic was quite realistic in the example application made in this research. Furthermore, the example study demonstrated that this realistic visual allows for more precise planning and aids comprehension. If an example comparison is given, average improvement in knowledge is forty percent lesser in the class with plain text, than in the visualized class (Lis, 2014). Although technological advancements, few research have investigated the possibilities of employing 3D visualization methods to represent actual data of forest structure (Kantartzis, 2018). Prior researches revealed that relatively few program, for example the "Stand visualization system (SVS)", might be utilized in forestry for visualization (McGaughey, 1997). Nevertheless, these programs provide generic designs that symbolize the field, not visualize each point the same as in the actual field with real data in navigable, interactive virtual environment, and the graphic quality is inadequate.

4. Conclusion

Activities including youth care, density care, lighting, thinning, and felling are at the very core of forestry operations. These activities, which are carried out for the purposes of production and maintenance, must be implemented, planned, and educated to the relevant personnel/students in a quality way in terms of efficiency, life and yield safety. The fundamental output of this project is a 3D visualization of the forest structure on a coordinated real terrain model, which can be used to evaluate the forest, plan, and monitor forestry activities. "ForSim," which was created for this purpose, generates a 3D virtual forest environment with the needed SAM, orthomosaic, and tree information. In the generated virtual forest environment; it is possible to get detailed information about trees, to inspect the stand structure, and to navigate interactively. "ForSim" is a Python-based program designed specifically for planning and monitoring maintenance-felling operations, as well as visualizing forests. The trees to be maintenance or felled can be chosen automatically according on the parameters given, or manually by the user. As a consequence, a decision-support system for the maintenance/cutting/production operations has been developed. The selection of the tree to be treated is followed by the felling procedures. Because felling direction is vital in felling operations, "ForSim" shows the best felling direction by examining the environmental variables indicated in the preceding sections. In this manner, the user may make judgments by forecasting the different outcomes following the felling. Using the "DEViR" tool, "ForSim" can assess the dangerous areas for humans and the environment (according to 2 tree rule), as well as create an escape route for personnel. When the study's findings are examined, it is discovered that work and personnel safety are improved, forest productivity is increased, damage to remaining/cut trees is avoided, and more successful forestry operations are carried out by making plans/implementing and trainings with this software. Moreover, the software is significant since it integrates theoretical knowledge in schooling with field research. It is advised to utilize "ForSim" during the training, theoretical, and practical stages.

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Effects of Forest Harvesting on Soil Properties of Karacabey Forested Wetlands, Bursa, Turkiye

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Abstract
Wetlands, including forested wetland, are the "filters" of our natural system, combating pollution, removing excess nutrients, and securing fresh drinking water for surrounding and downstream communities. They provide critical protection from dangerous flooding in vulnerable regions. Wetland forests rank among the most important in the nation for carbon sequestration and biodiversity. Forested wetland can also play a significant role in timber supply for forestry business. However, harvesting activities may alter wetland functions and cause tremendous changes to the ecosystem but the magnitude and direction of the effects depend upon the intensity of the harvest and associated activities. In this study, we aimed to investigate the effects of forest harvesting operation on soil properties of ash tree stands in Karacabey Forested Wetlands. Soil samples were collected from two sites: (1) naturally protected and (2) managed ash tree stands. The soil samples were taken from 5 different soil depths (0-10, 10-20, 20-30, 30-60 and >60 cm) and analyzed for soil pH, texture, EC, moisture, soil bulk density, organic matter, bulk density, soil organic carbon, total nitrogen concentrations and stocks. Forest floor litters were also sampled 50 x 50 cm^2 quadrates of 5 points in research plots of 20×20 m. The results showed that the harvesting activities can result in significant variation in soil properties. For example, soil organic carbon and total nitrogen concentrations were lower in the harvesting sites (2.80% and 0.284% respectively) than in the naturally protected ash tree stands (3.40% and 0.342% respectively). Similarly, soil organic carbon and total nitrogen stocks were also lower in the harvesting sites (206.8 Mg C ha^{-1} and 21.1 Mg N ha^{-1} respectively) than in the naturally protected ash tree stands (274.7 Mg C ha^{-1} and 27.2 Mg N ha^{-1} respectively).

Keywords: Forested wetlands, harvesting, wood production, soil properties

1. Introduction
Timber production is one of the most important forest ecosystem services, which provides stable wood and fiber supplies and contributes to the economy. However, logging with heavy machinery can vary the physical and chemical properties of soil even when it is carefully planned (Nambiar, 1996; Miwa et al., 2004; Cambi et al., 2015). On the other hand, soil disturbances can become more severe during wet site harvest conditions and may lead to decreased site productivity (Powers et al., 1990; Aust et al., 1998a, Aust et al., 1998b, Dominati et al., 2010). The soil disturbance with heavy machineries can increase soil bulk density (Williamson and Neilsen, 2000), alters pore size distribution (Steinbrenner and Gessel, 1955), lowers organic matter content (Rab, 2004), reduces aeration and water movement (Xu et al., 2002), and reduces nutrient availability (Gent et al., 1983).

Potentially highly productive sites such as forested wetlands are exceptionally prone to adverse effects of harvesting equipment traffic due to frequent high soil moisture conditions (Miwa et al., 2004; Richardson, 1994). In Turkiye, a hundred years ago, the total number of natural wetlands was 1299 with a total surface area of 1,376,505 hectares. In 2014, the total number of natural wetlands had decreased to 900, with a total surface area of 1,085,936 hectares, so that 21.2% of the original wetlands were lost (291,339 hectares) (Ataol and Onmuş, 2021). Unfortunately, only 11,400 ha forested wetlands have remained in Turkiye. With 3800 ha areas, Bursa, Karacabey Forested wetland is one of the biggest coastal forested wetlands in Turkiye. The most dominant tree species in Karacabey Forested wetland are ash (*Fraxinus angustifolia* Vahl.), alder (*Alnus glutinosa* (L.) Gaertn., oak (*Quercus robur, Quercus cerris, Quercus pubescens*). Ash tree and alder stands efficiently used to provide timber and ecosystem services in the region.

Several riverine and floodplain forests in Turkiye have already been studied in terms of ecology, biology (Çiçek 2002) and soil and root carbon and total nitrogen stocks (Sariyildiz et al., 2022, 2023). However, there has been no study available in Turkiye investigating the effects of forest harvesting on soil disturbance. Therefore, main objective of the study was to investigate the effects of management /harvesting activities on some soil properties, forest floor litter weight and soil organic carbon and total nitrogen stocks.

2. Material and Methods

The study site is located at the forested wetlands of Karacabey (40º23 38´´- 40º21 43´´N, 28º23 02´´-28º34 21´´E) which is the third-largest wetland in Turkiye (Figure 1). Total size of the Karacabey floodplain is approximately 3800 ha. (Akay et al., 2017). According to previous year's meteorological data (2007–2020), mean annual precipitation was 719 mm and mean temperature was 15.5 ^{0}C.

Figure 1. Location of the research area in Turkiye

Soil samples were collected using the core sampling method from the harvester tracks. A 98 cm^3 (5 cm inner diameter, 5 cm length) soil corer (Eijkelkamp Soil and Water, Giesbeek, Netherlands) was used to collect the soil samples from five depths: 0-10, 10-20, 20-30, 30-60 and >60 cm. The samples were collected on the harvester tracks at 2 m intervals along the 10 m harvester trails. A total of 90 samples (3 replicate plots) were randomly collected in the tracked harvester. A total of 60 samples (2 replicate plots) were also randomly collected from the natural sites. Two sites were within 2 km of each other and located in Karacabey forested wetland in Bursa Coastal Plain region. We also determined the stand characteristics and the forest floor litter weight at each replicate plots of the natural and managed sites (Table 1).

The oil samples were analyzed for soil pH (Allen 1989), electrical conductivity (EC) (Allen 1989), soil organic matter (Kalra and Maynard, 1991), soil texture (Bouyoucos 1962) and soil bulk density (Black 1965). The soil bulk density was used to calculate soil organic C and N stocks. A CNH-S elementary analyser (Eurovector EA3000-Single) was used to determine mean SOC and TN in the soil samples (Vesterdal and Raulund-Rasmussen 1998). Volume, bulk density, soil carbon and nitrogen content of the soil were used to calculate the SOC and TN pools as Mega gram C or N in per hectare (Mg / ha) (Lee et al. 2009). Dry mass of the soil was found as follows:

Dry soil mass (Mi) = bulk density (BDi) x thickness of the soil depth (Ti) x 10^4.
Soil organic carbon or nitrogen stock (kg C or N ha-1) in the soil depth was found as follows:
C or N mass to the soil depth (i) = Carbon or nitrogen concentration x Mi.

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Table 1. Stand characteristics of the natural and managed sites of ash tree stands. Very dense stands (tree canopy density >70%), Moderately dense stands (tree canopy density 41-70%).

Study Sites	Diameter (cm) Ort. ± S.S. (Min.-Mak.)	Height (m) Ort.±S.S. (Min.-Mak.)	Age (Yıl) Ort.±S.S. (Min.-Mak.)	Canopy closure
Natural	33.5 ± 2.24 (27.8-34.5)	15.5 ± 1.42 (9.1-17.3)	79.3 ± 2.12 (75-82)	Very dense stands
	48.4 ± 3.56 (47.8-50.7)	17,1±1,16 (12,2-20,2)	83.0 ± 3.25 (79-87)	Moderately dense stands
Managed	28.2 ± 1.34 (24.3-32.1)	17.3 ± 0.54 (13.1-21.4)	68.2 ± 4.22 (65-72)	Very dense stands
	37.9 ± 1.26 (36.1-49.2)	20.4±2,26 (16.2-23.1)	74.1 ± 4.15 (69-77)	Moderately dense stands

4. Results and Discussion

4.1. Forest Floor Litter

Forest floor litter weight was greater in the natural stands (3.58 Mg/ha) than the managed stands (1.85 Mg/ha) (Table 2). In the moderately managed stands, the reduction of forest floor litter weight was 52%, while it was 44% in the open stands. The forest floor serves as a bridge between the above ground living vegetation and the soil, and thus is a crucial component in nutrient transfer through the biogeochemical cycle. Leaf litter and other plant litter transmits nutrients from plants to the soil (Zhang et al., 2017). The plant litter of the forest floor (or L horizon) prevents erosion, conserves moisture, and provides nutrients to the entire ecosystem (Stohr, 2013). Increased decomposition following the management activities or clear-cutting, due largely to increased temperature and moisture, has been generally regarded as the dominant factor responsible for this forest floor decrease (Likens et al., 1970; Bormann et al., 1974). In addition, the reduced litter input in the cut area lowers the size of the L layer.

A study of northern hardwood forest floor dynamics following cutting indicated an approximate 20-year decline in forest floor weight, followed by a subsequent 20- to 40-year increase to precutting levels (Covington, 1976; Aber et al., 1978). However, this relatively long response time is by no means universal. Zavitkovski and Newton (1971) reported a steady-state forest floor mass in red alder stands in Oregon by 6 years following establishment. Matson and Vitousek (1981) found identical forest floor masses in a 7-year-old clear-cut and uncut control in a southern Indiana hardwood forest.

4.2. Soil Properties

Soil characteristics of the natural and managed sites of ash tree stands are shown in Table 3. Among the soil properties, soil bulk density and silt content were higher in the managed stands than the natural stands, whereas electrical conductivity, organic matter, sand and clay contents were lower in the managed stands. However, soil pH did not vary between the natural and managed stands.

Soil bulk density of the moderately and open stands in the managed stands was 1.33 and 1.62 g/cm^3 respectively, while they were 0.79 and 0.72 g/cm^3 in the natural site. Soil silt content was nearly 2-fold higher in the managed stands (mean 31%) than the natural stands (mean 16%). However, mean EC (0.27 dSm^{-1}), organic matter (9.75%), sand content (49%) and clay content (20%) were lower in the managed stands compared to the natural stands (1.11 dSm^{-1}, 18.5%, 58% and 26% respectively).

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Table 2. Amounts of forest floor litter of the natural and managed sites of ash tree stands.

Sites	Canopy closure	Forest floor litter (Mg / ha) mean ±S.S. (Min.-Max.)	Differences (%)
Natural stands	Very dense	4.38 ± 0.82 (3.40 - 5.23)	
	Moderately dense	2.78 ± 0.41 (2.15 - 3.24)	
	Mean	3.58 ± 0.62 (2.78 - 4.24)	
Managed stands	Very dense	2.12 ± 0.32 (1.75 - 2.50)	-52%
	Moderately dense	1.57 ± 0.30 (1.26 - 1.98)	-44%
	Mean	1.85 ± 0.31 (1.51 - 2.20)	-48%

Table 3. Soil characteristics of the natural and managed sites of ash tree stands.

Sites	Canopy closure	Soil depths (cm)	pH	EC dSm^{-1}	Bulk density (g/cm^3)	Organic matter (%)	Sand (%)	Silt (%)	Clay (%)	Soil type
Natural stands	Very dense stands	0-10	6.20	1.22	0.64	21.9	55	13	33	Loamy clay
		10-20	6.14	1.12	0.75	18.4	56	15	29	Loamy clay
		20-30	6.87	1.29	0.85	17.6	60	14	26	Sandy clay
		30-60	6.50	1.14	0.81	16.9	66	19	15	Sandy clay loam
		>60	6.74	1,08	0.92	18.4	67	20	13	Sandy clay
		Mean	6.49	1.17	0.79	18.6	61	16	23	Sandy clay
	Moderately dense stands	0-10	6.50	0.87	0.59	18.4	56	15	29	Sandy clay
		10-20	6.57	0.93	0.65	15.7	53	16	31	Loamy clay
		20-30	6.65	1.07	0.73	18.9	55	17	28	Loamy clay
		30-60	6.40	1.14	0.79	23.7	52	14	34	Loamy clay
		>60	6.61	1.18	0.84	14.7	58	17	25	Sandy clay loam
		Mean	6.55	1.04	0.72	18.3	55	16	29	Loamy clay
Managed stands	Very dense stands	0-10	6.40	0.25	1.24	8.5	41	41	18	Loamy clay
		10-20	6.45	0.21	1.34	12.7	39	29	32	Loamy clay
		20-30	6.34	0.28	1.31	10.7	48	28	24	Clay loam
		30-60	6.20	0.34	1.36	11.7	58	33	8	Sandy clay
		>60	6.71	0.38	1.42	12.6	65	17	18	Sandy clay loam
		Mean	6.42	0.29	1.33	11.2	50	30	20	Clay loam
	Moderately dense stands	0-10	6.60	0.28	1.59	8.10	34	55	11	Silty loam
		10-20	6.68	0.27	1.65	9.45	48	42	10	Loamy clay
		20-30	6.57	0.21	1.31	11.7	42	28	30	Loamy clay
		30-60	6.80	0.19	1.70	6.60	52	15	33	Loamy clay
		>60	6.94	0.32	1.84	5.47	58	24	18	Clay loam
		Mean	6.72	0.25	1.62	8.3	47	33	20	Clay loam

Our results are in accordance with the results of the other authors who are generally in agreement that harvesting activities can result in increasing soil compaction. The degree of disturbance caused by the forces (normal and shearing forces) varies with weight of the machine, number of machine passes, ground pressure exerted, ground cover, soil texture, soil organic matter content, soil surface slope, and soil moisture content at the time of disturbance (Greacen and Sands, 1980; Miwa et al., 2004; Cambi et al., 2015; Naghdi et al., 2016). In general, soil disturbances associated with the normal and shearing forces induced by forest operations are categorized as compaction or rutting/puddling (Aust et al., 1998).

Lang (2016) showed that harvesting resulted in compaction and rutting, which changed soil air–water content and balance. Reduced macroporosity can lower infiltration and results in saturated hydraulic conductivity rates. This could reduce root growth and water supply (Greacen and Sands, 1980, Powers et al., 1990; Gomez et al., 2002; Eisenbies et al., 2005). Soil texture and water content can be also strongly affected by soil disturbance. Sites with soil moisture near field capacity or greater are most susceptible to machinery compaction because of lower cohesive forces and load bearing capacities (Akram and Kemper, 1979, Greacen and Sands, 1980). More severe soil disturbances, such as deep rutting, puddling, or churning caused by logging machinery generally occur when soils are saturated (Burger et al., 1988).

The influence of different logging machines on soil compaction was investigated by Allman et al. (2015) who reported that all wheeled machines caused the same amount of soil compaction in the ruts, despite differences in tires, machine weight, etc. Cambi et al. (2016) reported a clear difference in the physical parameters of the soil before and after operations. Eroğlu et al. (2016) found that logging by skidder had a clear influence on soil permeability, bulk density and soil water balance, and reduced the content of organic matter and nutrient levels in the soil. The results by Lang et al. (2016) showed that macroporosity had not recovered to the pre-harvest levels for any site preparation treatments in harvested wet lands, except Mole-Plowed; bulk density and total porosity recovered to near pre-harvest levels for all treatment combinations, but saturated hydraulic conductivity rates remained lower than the pre-harvest values.

4.3. Soil Organic Carbon and Total Nitrogen Stocks

Soil organic carbon (SOC) and total nitrogen (TN) contents and stocks of the natural and managed sites of ash tree stands are shown in Table 4. The managed stands had lower SOC and TN contents and stocks than in the natural stands. In natural sites, SOC and TN were 2.90% and 0.279% for the very dense stands respectively, while it was 3.89% and 0.405% for the moderately dense stands respectively. SOC and TN were lower in the managed site, with 2.11% and 0.202% for the very dense stands respectively and 3.49% and 0.366% for the moderately dense stands respectively. Much clear differences between the natural and managed sites were seen for SOC and TN stocks. Mean SOC and TN stocks in the natural site ranged from 267 and 22.8 Mg/ha in the very dense stands to 283 and 31.7 Mg/ha in the moderately dense stands respectively, while it ranged from 200 and 17.7 Mg/ha in the very dense stands to 213 and 24.6 Mg/ha in the moderately dense stands respectively.

Our results are in agreement with the results of the other authors who found that harvesting activities can reduce soil organic carbon and nitrogen contents. Several meta-analyses have assessed the impacts of harvesting and residue removal on soil C (Achat et al., 2015; James and Harrison, 2016; James et al., 2021). In recent meta-analysis by James et al. (2021), it was reported that BO (partial or clearcut) + Removal (O horizon removal) (-19.2%), WTH (whole tree harvests) (-15.4%) and WTH + Removal (-24.9%) contained significantly less soil C than no-harvest controls across combined soil depths, while BO had no difference. Achat et al. (2015) showed that intensive harvests led to soil C losses in all layers of forest soils. Similarly, James and Harrison (2016) found that harvesting reduced soil C, on average, by 11.2% and there was substantial variation between responses in different soil depths, with greatest losses occurring in the O horizon. Nave et al. (2010) stated that one of the most important overall findings of this analysis was that C stored in forest floors is more vulnerable to harvest-induced loss (-30% on average) than mineral soil C (no significant change). They added that species composition (hardwood vs. coniferous/mixed) had a significant effect on forest floor C storage responses to harvest, with hardwoods generally losing more forest floor C than coniferous/mixed stands

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Table 4. Soil organic carbon and total nitrogen contents and stocks of natural and managed of ash tree sites

Sites	Canopy closure	Soil depths (cm)	C (%)	N (%)	SOC-stock (Mg C ha^{-1})	Total N-stock (Mg N ha^{-1})
Natural	Very dense stands	0-10	5.65	0.487	70.6	5.45
		10-20	5.32	0.458	73.5	5.24
		20-30	2.14	0.268	34.9	2.93
		30-60	0.94	0.125	55.8	5.44
		>60	0.46	0.058	31.7	3.69
		Mean	2.90	0.279	267	22.8
	Moderately dense stands	0-10	7.25	0.697	74.1	7.15
		10-20	6.98	0.678	76.8	6.67
		20-30	3.16	0.318	37.5	3.73
		30-60	1.37	0.247	58.7	8.64
		>60	0.70	0.087	35.7	5.48
		Mean	3.89	0.405	283	31.7
Managed	Very dense stands	0-10	4.66	0.359	61.5	5.14
		10-20	3.47	0.372	52.8	3.56
		20-30	1.14	0.158	21.4	1.99
		30-60	0.55	0.056	25.2	2.78
		>60	0.73	0.065	39.4	4.11
		Mean	2.11	0.202	200	17.6
	Moderately dense stands	0-10	7.11	0.789	62.4	5.87
		10-20	5.88	0.547	55.5	6.66
		20-30	2.47	0.247	24.6	2.87
		30-60	0.99	0.147	27.9	4.02
		>60	0.99	0.102	42.5	5.15
		Mean	3.49	0.366	213	24.6

Forest harvesting may shift the soil C balance by many mechanisms, including altering the quantity and quantity of detrital C inputs, changing soil microbial community composition, and affecting the climatic conditions that drive plant and microbial processes (Gray et al., 2002; Hassett and Zak, 2005). On the other hand, the intensive removal of forest residues can affect nutrient fluxes in the soil (Achat et al., 2015; Clarke et al., 2021). Nutrient concentrations in logging residues are high, which might increase the risk of a nutrient imbalance and reduce forest production over time (Egnell, 2017). Nitrogen is the most common limiting nutrient for plant productivity (LeBauer and Treseder, 2008), and the removal of nitrogen contained within forest residues may induce or deepen N limitation.

5. Conclusion

Our results from a forested wetland have shown that forestry practices can results in soil compaction and recusing forest floor litter and soil organic carbon and total nitrogen stocks. Therefore, before any forestry machine is allowed to operate in forest stands the soil moisture content also should be monitored throughout the whole forest harvesting process to ensure that the forest manager has enough information on the natural conditions and the susceptibility of soil to disturbance. The number of passages on the skid trails was not considered in this study and the measurements took place in stands of ash tree. This area of research requires a larger, more extensive research, which would consider more machine types and various volume of harvest as well as consideration of the effects of harvesting remains on the soil compaction levels. Despite this, the study provides valuable objective results of the compaction levels reached by the given machines and in given natural conditions. Forested wetlands provide many beneficial functions that need to be protected. Harvest planning and selection of the right harvest system are essential in achieving the management objectives of timber production, ensuring stand establishment, and avoiding adverse effects on water quality and wetland functions and values. Moreover, the responses of forested wetland ecosystem to forest harvesting need long term observation. Therefore, more long-term, regional studies considering specific site requirements of individual species and forest type is needed in order to understand the complex interactions between wetland ecosystem function and forestry practices.

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Determination of the Forest Road Alignment in Landslide-Prone Areas based on Landslide Susceptibility Map Generated by Machine Learning Approaches

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Abstract
The intention to conduct forestry activities throughout the year is one of the fundamental requirements of the sustainable forest management. Forest road networks are key structures that provide access to forest areas to carry out forestry activities such as afforestation, forest protection, forest transportation, and forest management. In order to benefit the important functions of the forest roads, road alignment should be carefully determined by considering site conditions especially in unfavorable forest areas that are subject to natural disasters such as forest fires, landslides, avalanches etc. Among these disasters, landslide is one of the dangerous phenomena that can severely damage forest ecosystem and threaten human life in the region. It has been stated that unplanned or improperly implemented forest roads may trigger landslide risks. The aim of this study was to utilize a decision support system based on geographic information systems (GIS) to locate the optimal alignment for forest roads in areas prone to landslides. This has been achieved by harnessing advanced technology to effectively address the requirements of forest road construction. In the solution process firstly, machine learning (ML) approaches including logistic regression (LR) and random forest (RF) were used to build a landslide susceptibility map (LSM). The risk factors considered in the study were curvature, elevation, distance to fault, distance to road, distance to stream, lithology, slope, stream power index, and topographic wetness index factors. Two models with the highest area under curve (AUC) values have been demonstrated in this study. According to the computational results, two ML approaches had the AUC-LR and AUC-RF values of 80.85% and 92.11%, respectively. The result also indicated that the approach with the highest LSM score was the RF. In this study, alternative forest road alignments were generated with CostPath analysis, using b traditional approach and the LSM based on RF approach. The workflow outlined in this study has a structure that can be used as an effective platform for suggesting alternative forest road alignments by planners and decision-makers during the forest road planning stage.

Keywords: Forest roads, landslide, road planning, multi-criteria, modeling

1. Introduction

Forest road networks are essential structures that provide access to forest areas for forestry activities such as afforestation (Buğday and Özel, 2019), forest protection (Talebi et al., 2022), forest transportation (Aricak et al., 2023), and forest management (Amrutha et al., 2022). To ensure that forest roads serve their important functions, road alignment should be determined by considering site conditions, especially in areas with natural disaster risk such as landslides and avalanches (Buğday and Akay, 2022).

Landslides are one of the most dangerous natural disasters that can severely damage forest ecosystems and threaten human life (Evans, 2018). Unplanned or improperly implemented forest roads can trigger landslide risks, so it is important to carefully plan and construct these roads in landslide-prone areas (König et al., 2019).

In this study, it was aimed to determine forest road alignment in landslide-prone areas based on Landslide Susceptibility Maps (LSMs). We aimed to develop nine different LSMs using two Machine

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Learning (ML) approaches. The two most successful models were used to generate alternative forest road alignments using Least Cost Path analysis in ArcGIS software.

2. Material and Methods

2.1. Study Area

The study area is located in Eldivan (Çankırı) in the north of Turkiye. The Eldivan forests is 4366 ha where Black pine is the dominant tree. The most of the roads within the designated area for analysis are specifically forest roads, characterized by a width of 6 meters. The total length of these roads are 477 kilometers, with the road density of 7.9 meters per hectare. The elevation within this region ranges from 679 to 1,861 meters, with an average elevation of 1,116 meters. The steepest slope recorded is 53.3 degrees, while the average slope measured as 11.1 degrees. Throughout the study area, a total of 96 instances of landslides were documented. Among all the recorded data points, 67 landslides, which accounts for 70% of the total, were utilized for the training stage. The remaining 29 landslides, equivalent to 30% of the data, were reserved for the testing stage.

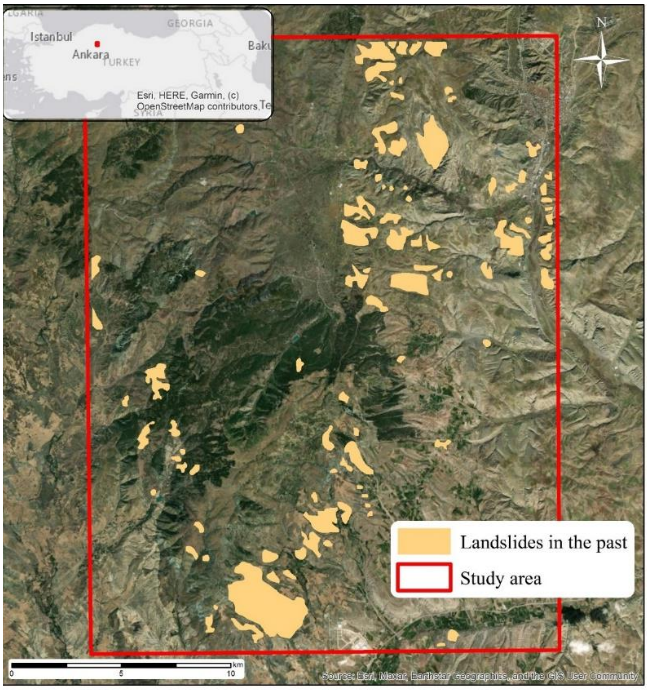

Figure 1. Distribution of landslides in the study area

2.2. Method

During the research, we acquired the Digital Elevation Model (DEM) via ASTER-GDEM from www.usgs.gov web site. Subsequently, we created various layers pertaining to elevation, curvature, slope (measured in degrees), SPI (stream power index), and TWI (topographic wetness index) factors utilizing the aforementioned DEM. The factor of road proximity was derived from the Forest Subdistrict databases, which cover the area of interest for the study. Information regarding lithology, proximity to faults, proximity to streams, and field data on previous landslides were procured from the digital data obtained from General Directorate of Mineral Research and Explorations (GDMRE) (Duman et al., 2011).

2.2.1. LSM modeling process

Curvature, depicted in Figure 2a, is a widely utilized factor in LSM modeling studies as it contributes to the prediction of landslides by offering insights into their direction and severity (Sun et al., 2020). Elevation, another commonly employed factor, influences the cost of constructing forest roads

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(Saleem et al., 2019). In this study, elevation was categorized into evenly spaced intervals of 200 meters, as illustrated in Figure 2b. Distance to faults is a fundamental triggering factor for landslides (Massey et al., 2020). In this study, distances were classified into zones of 0.5, 1, 3, 5, 10, and 20 km, as shown in Figure 2c. The distance to roads, an artificial factor impacting landslide occurrence, is frequently utilized in international literature to determine landslide susceptibility (Bugday, 2022) (Figure 2d). Distance to streams, which highlights the proximity relationships relevant to landslide susceptibility, is commonly employed in studies (Senouci et al., 2021). In this research, distances were expressed as zones 0.1, 1, 2, 5, and 10 km apart, as described in Figure 2e. Lithology, an effective factor in landslide susceptibility and the cost of constructing forest roads, provides information about bedrock characteristics (Yu and Chen, 2020). The study evaluated lithology in nine distinct groups (Figure 2f). Slope, a primary factor in landslide formation, also impacts costs similarly to lithology. The analysis introduced five classes based on IUFRO slope classes: 0-5.71º, 5.71º-13.80º, 13.80º-21.88º, 21.88º-31.99º, and >32º (Demir, 2019) (Figure 2g). The Stream Power Index (SPI) calculates the erosive potential of water flow within a basin based on the assumption that the flow (q) is proportionate to the specific catchment area (As) (Badola et al., 2023) (Figure 2h). The topographic wetness index (TWI) is employed to express the spatial distribution and dimensions of water-saturated areas (Chaikaew et al., 2023) (Figure 2i).

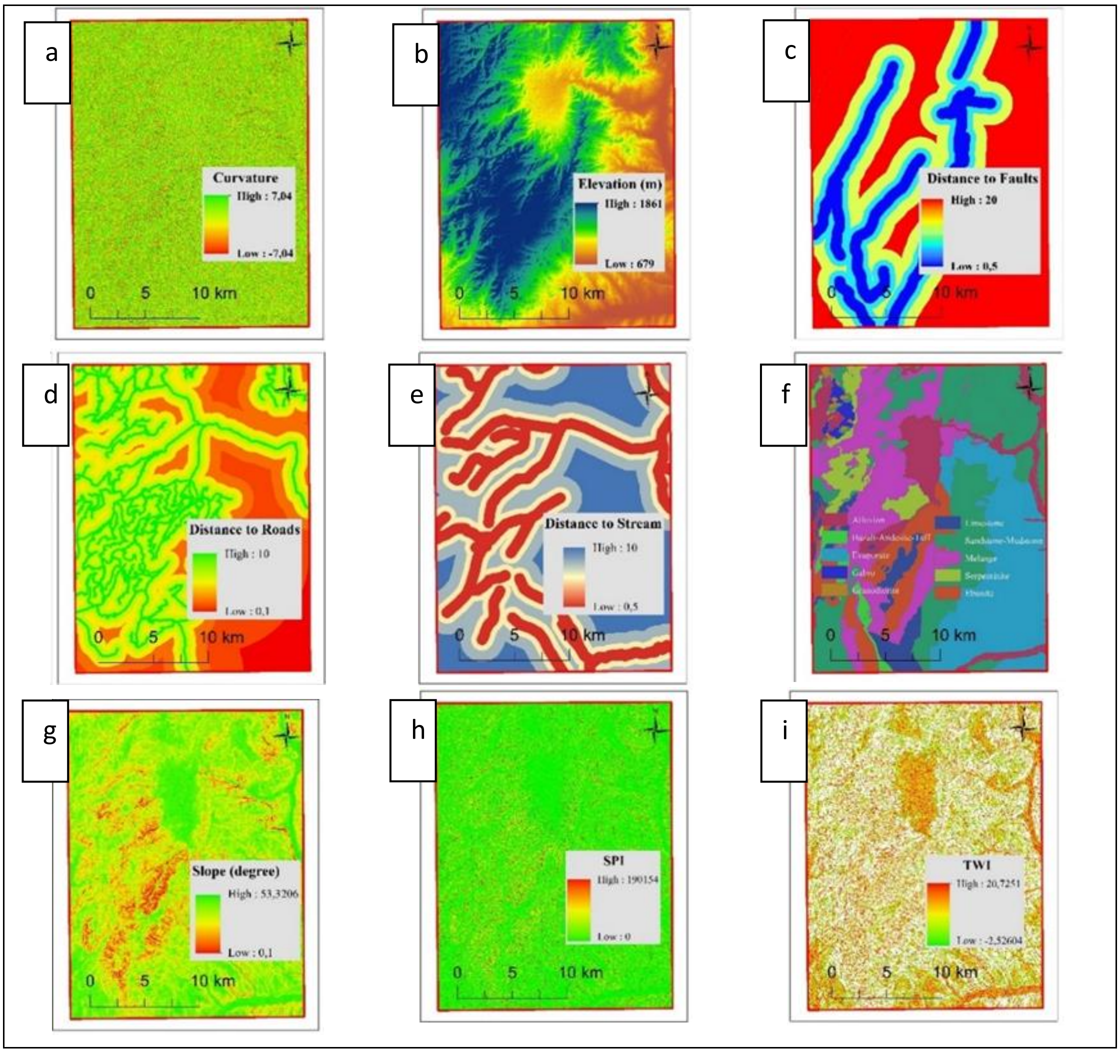

Figure 2. LSM factors in forested area; (a) curvature, (b)elevation, (c) distance to fault, (d) distance to road, (e) distance to stream, (f) Lithology, (g) Slope(degree), (h) Stream Power Index (SPI), (i) Topographic Wetness Index (TWI)

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2.2.2. LSM process

LSM tool pack suggested by Şahin et al. (2020) was used in this study. LSM tool pack facilitated the creation of LSM prediction models through the application of LR and RF modeling methods using the factors shown in Figure 2. Evaluation of these factors using LR and RF methods was performed using ArcGIS 10.3 software. In order to validate the models created by these approaches, both historical landslide occurrences and non-landslide areas were examined. The validation process included the use of Receiver Operating Characteristic (ROC) analysis and calculation of the Area Under the ROC Curve (AUC) value. In the literature, AUC scores between 0.9 and 1.0 are classified as excellent performance, 0.8 to 0.9 as very good performance, 0.7 to 0.8 as good performance, 0.6 to 0.7 as moderate performance, and 0.5 to 0.6 shows poor performance (Bradley, 1997).

2.2.3. Detection of alternative forest road routes

The final stage of the research includes the search for alternative road routes. Computer-assisted ArcGIS-CostPath analysis was used to achieve this. The analysis involved using bases with single or multiple criteria, both weighted and unweighted, to identify optimal routes (ESRI 2016). As a methodology, three different scenarios were used to identify alternative road routes and a comparison was provided to evaluate the effectiveness and sensitivity of this approach. The first step in the route setting process involved identifying two points outside of existing roads that required connectivity, and then planning alternative routes. Start and destination points are strategically positioned to create route constraints. Following a traditional approach, the first phase involved road planning based on slope criteria. Then, considering the landslide susceptibility evaluated by LR and RF methods, the route was recalculated using CostPath analysis. The overall workflow of this study is briefly depicted in Figure 3.

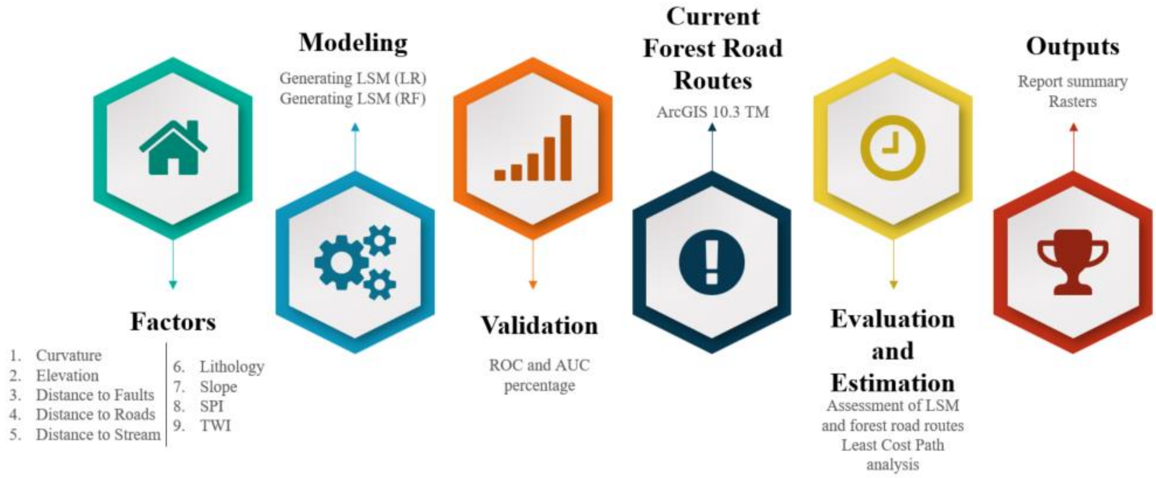

Figure 3. The flowchart illustrating the progression of the study

3. Results

We employed Chi-Square, Information Gain, and Random Forest Importance techniques, presenting the results in Table 1 with factors arranged in descending order of importance. The table is highlighted how each statistical method and factor yield distinct feature weights, resulting in varied rankings. Notably, disparities emerge between the top three factors in the Chi-square ranking and those identified through Information Gain and Random Forest Importance. These contrasting outcomes influenced the selection of models, with Chi-Square values serving as the basis for decision-making and subsequent modeling processes.

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Table 1. The rankings of feature importance generated by the feature ranking algorithms

No	Factors	Chi-Squared	Factors	Information Gain
1	Curvature	0,48363	Dis.to stream	0,27114
2	Dis.to faults	0,40660	Elevation	0,23300
3	Dis.to roads	0,35962	Slope (Degree)	0,11658
4	Dis.to stream	0,24392	Lithology	0,08317
5	Lithology	0,23980	Dis.to faults	0,05243
6	Slope (Degree)	0,22645	Dis.to roads	0,03330
7	SPI	0,22143	SPI	0,02611
8	Elevation	0,11068	Curvature	0,01192
9	TWI	0,08544	TWI	0,00740

In order to evaluate the effect of the factors used in this study on the performance of the predictive model (Şahin et al., 2020), the factors were ranked in ascending order according to their respective importance values. By detailed estimation, factors that provide superior performance predictions (through selection of the optimal subset) and models that exhibit the highest AUC values were identified. The LSM Toolkit used a variety of statistical tests, including the Wilcoxon signed-rank test, the F-Test, the Kolmogorov-Smirnov test, and the One Sample T-Test (Table 2). Among the various scenarios, Case-1 - Model 8 emerged as the preferred option in this study. Table 2 presents the optimal factor combinations corresponding to the most suitable scenarios.

Table 2. The optimal combinations of factors determined based on Chi-Square and Information Gain

Feature ranking method	Case no	Statistical test used for subset selection	Model No: The best subset size selected by performance of LR	Features in the best subset
Chi-Square	Case 1	F-test	Model 8	Dis.to Stream, TWI, Slope, Lithology, Dis.to Faults, Dis.to Road, and SPI
	Case 2	Kolmogorov Smirnov test	Model 8	Dis.to Stream, TWI, Slope, Lithology, Dis.to Fault, Dis.to Road, and SPI
	Case 3	One Sample T-Test	Model 7	Dis.to Stream, TWI, Slope, Lithology, and Dis.to Fault
	Case 4	Wilcoxon signed-rank test	Model 9	Dis.to Stream, TWI, Slope, Lithology, Dis.to Fault, Dis.to Road, SPI, and Curvature
Information Gain	Case 5	F-test	Model 8	Dis.to Stream, TWI, Slope, Lithology, Dis.to Fault, Dis.to Road, and SPI
	Case 6	Kolmogorov Smirnov test	Model 7	Dis.to Stream, TWI, Slope, Lithology, Dis.to Fault, and Dis.to Road
	Case 7	One Sample T-Test	Model 9	Dis.to Stream, TWI, Slope, Lithology, Dis.to Fault, Dis.to Road, SPI, and Curvature
	Case 8	Wilcoxon signed-rank test	Model 6	Dis.to Stream, TWI, Slope, Lithology, and Dis.to Faults

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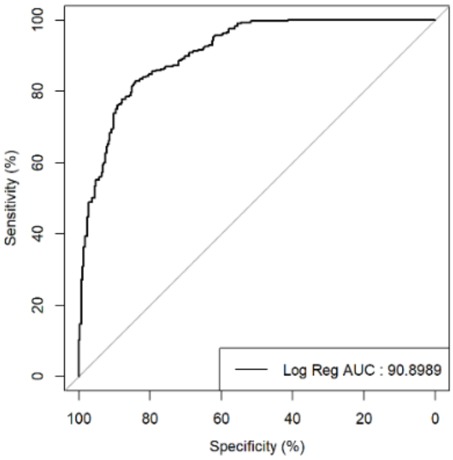
3.1. Logistic Regression

The LR approach is a modeling approach that has been used frequently and widely in landslide susceptibility studies in many researches. In this study, the most successful combinations among a total of nine factors are given in Table 2. The AUC value (90.8989) of the Case 1 model-8, which was selected as the most successful according to the LR approach. The factors estimated along with Std. Error, z-value and Pr values are given in Figure 4. In terms of the landslide formation, the analysis revealed a negative correlation between distance to roads, lithology, distance to faults, and elevation factors. Conversely, there was a positive correlation observed among curvature, distance to stream, slope (degree), SPI, and TWI. Additionally, the calculations indicated that slope, SPI, lithology, distance to fault-road-stream, and elevation factors held greater significance compared to other factors such as curvature and TWI.



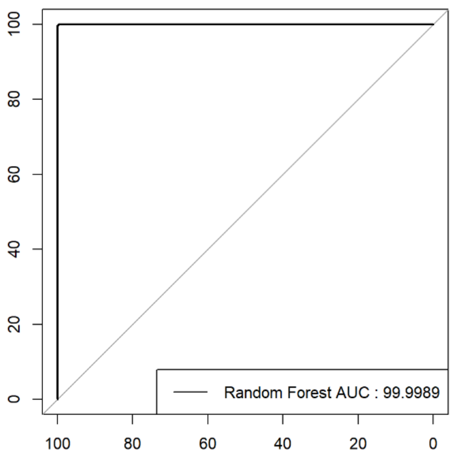
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.4039265	0.6358151	2.208	0.027239 *
Dis.to.Roads	-0.5620349	0.2491506	-2.256	0.024083 *
Slope (degree)	0.1327375	0.0138131	9.61	< 2e-16 ***
SPI	0.0001098	0.0000375	2.929	0.003403 **
TWI	0.0450793	0.0415823	1.084	0.278321
Dis.to.Stream	0.857646	0.0676901	12.67	< 2e-16 ***
Lithology	-0.1953561	0.0328738	-5.943	2.81e-09 ***
Dis.to.Faults	-0.8735061	0.0832887	-10.488	< 2e-16 ***
Curvature	0.1222141	0.1007926	1.213	0.22531
Elevation	-0.0013985	0.0004103	-3.409	0.000652 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 (Dispersion parameter for binomial family taken to be 1) Null deviance: 1921.4 on 1385 degrees of freedom Residual deviance: 1038.6 on 1376 degrees of freedom AIC: 1058.6 Number of Fisher Scoring iterations: 6

Figure 4. The statistical analysis pertaining to the AUC score and factors of the best LR model

3.2. Random Forest

For the purpose of comparison between alternative approaches, the study employed the RF approach to model using the same set of nine factors. The most effective model (Case 1 Model-8) yielded an AUC value of 99.9989. The calculated AUC value for this modeling approach and the ranking of factor importance are presented in Figure 5. Consequently, the priority ranking based on the RF approach revealed the following order: distance to stream, elevation, distance to faults, lithology, slope (degree), distance to roads, SPI, TWI, and curvature.



Factors	IncNodePurity
Dis.to.Stream	78.93176
Elevation	78.5044
Dis.to.Faults	57.71706
Lithology	44.50194
Slope (degree)	40.14615
Dis.to.Roads	16.7021
SPI	10.97754
TWI	9.7218
Curvature	4.317836

Figure 5. Best RF model AUC score and order of importance of factors

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3.3. Generating LSMs raster data

LSMs are produced by using alternative approaches. The models produced according to the LR and RF approaches are shown in Figure 6.

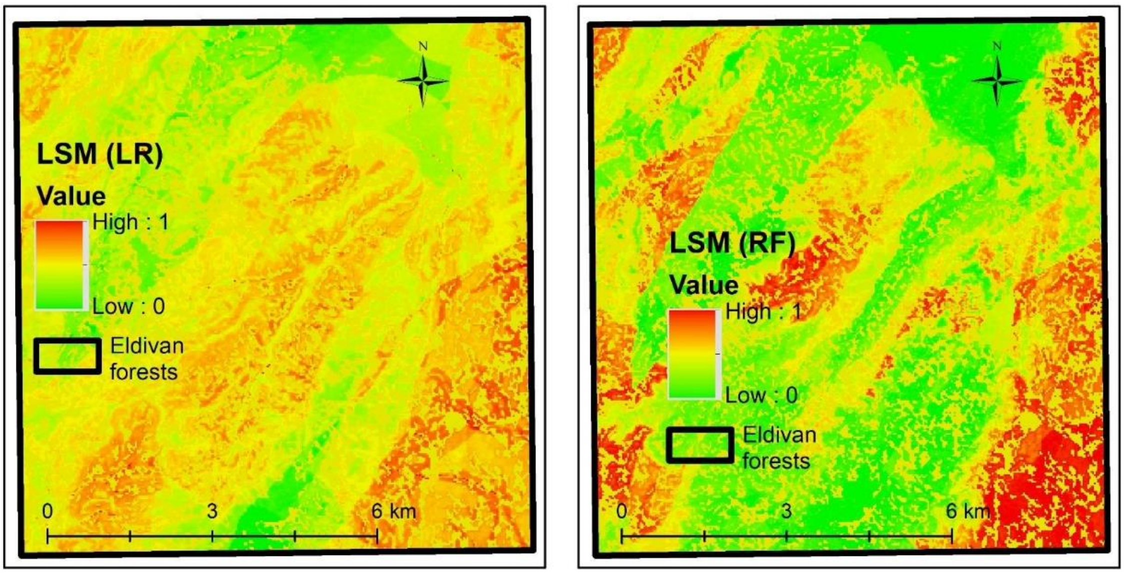
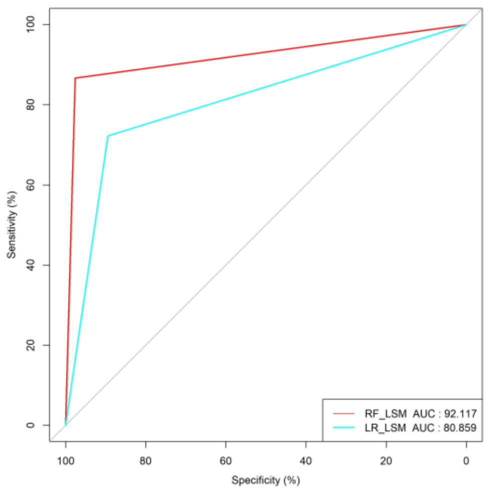


Figure 6. Generated LSMs (LR and RF) in the study

3.4. Comparing the performance of the best performing model

During this stage, a comparison was made regarding the performance of Model 8, which emerged as the top LSM model produced with LR and RF approaches. Based on the results of the performance tests (Figure 7), the Model 8 outperformed both approaches, with an LR-AUC score of 0.8085 and an RF-AUC score of 0.9211. The LR approach was considered very good, while the LR approach was classified as a very good level of model success.



	LR LSM	RF LSM
Accuracy	0.814102564	0.924679487
AUC.Classified	0.808590526	0.921170985
AUC.NonClassified	0.952405512	0.98011223
MAE	0.185897436	0.075320513
RMSE	0.431158249	0.274445829
Kappa	0.623094226	0.847763797
Precision	0.857723577	0.969348659
Recall	0.72260274	0.866438356
F1	0.784386617	0.915009042

Figure 7. Models' performance results of LR and RF

3.5. Detection of Alternative Forest Road Alignment

The study encompassed the specific regions identified by the forest district chief to enhance accessibility for conservation efforts and address road requirements. This designated area predominantly comprises Black Pine (*Pinus nigra*) forests. By employing the LR and RF methods, it was revealed that the northeast and southwest axes of the study area exhibited greater susceptibility to

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landslides compared to other regions (Figure 8). Both modeling approaches were utilized to generate LSMs, and subsequent CostPath analysis enabled the identification of alternative routes that could traverse areas with exceptionally low landslide susceptibility. After conducting the CostPath analysis using the LSM-LR model, the length of forest roads was determined to be 5184 meters. Similarly, employing the LSM-RF model for the CostPath analysis yielded a calculated forest road length of 5307 meters.

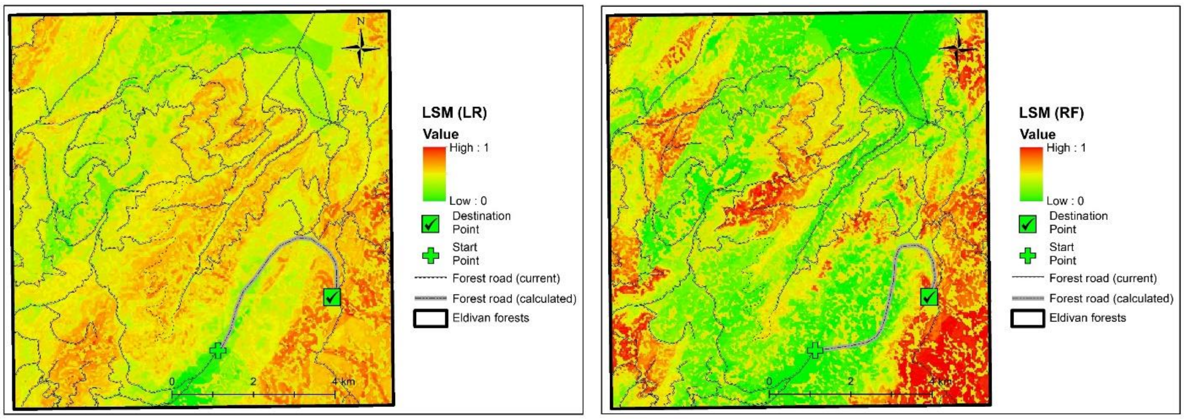

Figure 8. The road routes obtained through CostPath calculation using LSMs generated from the LR and RF methods.

4. Conclusions

The use of GIS software has revolutionized planning studies, expediting the process and offering decision-making opportunities for managers. One valuable application of GIS is landslide susceptibility mapping (LSM), which entails the identification and mapping of landslide-prone areas. In this study, LSM models were generated using two different approaches, LR and RF, and the success rate of these models was found to be good and very good. The effectiveness of the LSM models depended on factors such as the size of the study area, sensitivity of the landslide data, and the resolution of the digital elevation model (DEM). These findings further support the notion that LSM modeling with GIS software is a valuable decision-making tool across various domains. To explore alternative routes in a sample forest area, CostPath analysis was employed using LSM models obtained through LR and RF methods. While previous studies have also utilized CostPath analysis for alternative route determination, this study stands apart by specifically aiming to present route options that fulfill the road requirements within the forest area. Unlike other studies that primarily consider factors like road alignment, this study also incorporates the landslide criterion as a vital decision variable. The study underscores the significance of meticulous planning to ensure sustainable forestry practices that preserve the integrity of the ecosystem. Particularly in sensitive areas, the adoption of modern approaches to determine alternative routes becomes crucial. The study determined that the length of the routes calculated using the LR and RF methods was approximately 5184 meters and 5307 meters, respectively. This further emphasizes the importance of employing multifactor analyses, providing valuable insights to practitioners, planners, and decision-makers to minimize the adverse impact on the environment and uphold ecosystem health. By highlighting the significance of detailed planning and leveraging the power of GIS software, this study reinforces the importance of sustainable forestry practices while meeting the evolving needs of road infrastructure.

Acknowledgements

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Forest Operations Planning to Preserve Riparian Ecosystems

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Abstract
The riparian ecosystems, one of the most important zones of forest habitat in terms of protecting and strengthening the biodiversity, have been degraded in many parts of the forested areas in Turkiye. To ensure restoration of riparian ecosystems, specific strategies for forest operations in the riparian zones should be developed and properly integrated into the forest management plans. Establishing environmentally sustainable forest operations in areas adjacent to water bodies improves forest ecosystems, protects water quality, preserves aquatic life and terrestrial wildlife by reducing negative impact of forest operations. The forest operations should be planned and implemented in a way that protects core riparian zones and ensures sustainable use of management zones. Forest operations should be restricted in the core zones and only environmentally sustainable forest operations should be applied in the management zones. Road constructions in the riparian areas should be restricted, length and number of stream crossings must be limited. In this study, a general guideline for planning forest operations is described to preserve riparian ecosystems.

1. Introduction

The forest zones adjacent to surface water networks such as streams, lakes or reservoirs and wetlands, called riparian forests, maintain the functions of forest ecosystems that support nutrient cycling, plant communities, water quality, aquatic life and wildlife (Poulin et al., 2000). The riparian forests are vital for the protection of forest ecosystems and increasing biodiversity. Besides, riparian vegetation plays a critical role in reducing the amount of sediment delivered into streams (Newton et al., 1996). Moreover, riparian areas provide better habitat for adjacent aquatic species and wildlife (Lathrop and Haag, 2007).

The riparian areas have been degraded in many parts of the world mainly due to anthropogenic factors (Mayer et al., 2005). One of the major causes of the degradation is considered to be forest operations since riparian forests often have high-quality timber and forest roads can be easily located along the streamside. To prevent the long term impacts of degradation, ecologically feasible forestry operations should be practiced in riparian areas (Akay et al., 2007).

To maintain and preserve the riparian areas, they must first be subdivided into buffer zones. To determine the buffer zones of the riparian zones; firstly, water bodies (streams, wetlands, lakes) should be classified. The streams are categorized into small, medium and large size by Water Protection Rules (OAR 629-635-0200) based on the average annual flow (OAR, 2007). For the large streams category, an average annual flow is greater than of 0.283 m^3 $s{-}1$. Medium streams have an average flow range of 0.057 m^3 $s{-}1$ and 0.283 m^3 $s{-}1$, while the small streams have an average annual flow of 0.057 m^3 $s{-}1$ or less (Figure 1).

The streams are also classified into three beneficial use categories including types F, D and N. Type F streams are for both fish-use and domestic water use. Water having some characteristics such as streams having channel of 2 feet or greater, a gradient of 16- 20 percent, and greater than 50 acres in contributing basin size. Type D streams are for only domestic water use, while Type N stream means a stream with neither fish use nor domestic water use (OAR, 2007).

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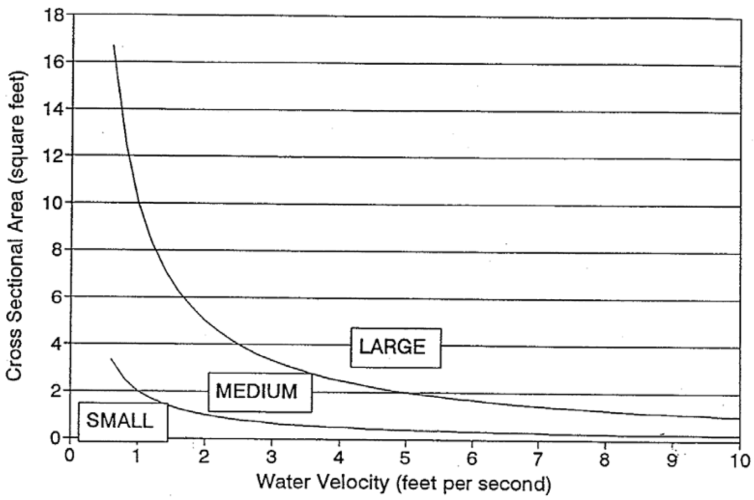

Figure 1. The relationship between stream size with wetted cross-sectional area and stream velocity (OAR, 2007)

Riparian Management Area Guidebook (RMA Guidebook, 1995) suggested six stream classes from S1 to S6, considering fish presence, watershed type, and channel width (Table 1). In this categorization, S1 to S4 streams are fish streams or streams in a community watershed, while S5 and S6 streams are not fish streams and are not in a community watershed. In the guide book, wetlands are divided into five classes from W1 to W5, based on type, size, and bioclimatic unit. W1 to W4 are representing simple wetlands while W5 is a wetland complex. Simple wetlands include all classified wetlands that are not wetland complexes (Table 2). A wetland complex consists of two or more individual wetlands with overlapping riparian areas and a combined wetland area of 5 ha or more. RMA Guidebook (1995) also suggested to divide lakes into four classes from L1 to L4, considering lake size and bioclimatic unit (Table 3).

Table 1. Properties of riparian stream classes (RMA Guidebook, 1995)

Riparian Classes	Width of the Average Stream Channel (m)
S1*	> 20
S2*	5-20
S3*	1.5-5
S4*	< 1.5
S5	> 3
S6	≤ 3

* Community watershed or fish stream

Table 2. Properties of riparian wetland classes (RMA Guidebook, 1995)

Riparian Classes	Area of the Wetland or Lake (ha)
W1	> 5
W2	1-5 (dry regions)
W3	1-5
W4	0.25-1
W5	> 5 (complex)

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Table 3. Properties of riparian lake classes (RMA Guidebook, 1995)

Riparian Classes	Area of the Wetland or Lake (ha)
L1	> 5
L2	1-5 (dry regions)
L3	1-5
L4	0.25-1

2. Riparian Areas

Riparian areas are generally divided into the zones including riparian reserve zone (RRZ) and riparian management zone (RMZ) (Figure 2). Forest practices are applied in the RMZ while it is restricted in the RRZ. The width of the zones is determined based on the classes of streams, wetlands or lakes, and adjacent terrestrial ecosystems. Riparian areas should be preserved to minimize impacts on stream channel dynamics, sustainability, aquatic life and wildlife, riparian vegetation, and water quality of water bodies. Table 4 shows the average slope distance of the reserve and management zone for streams, wetlands, and lakes class.

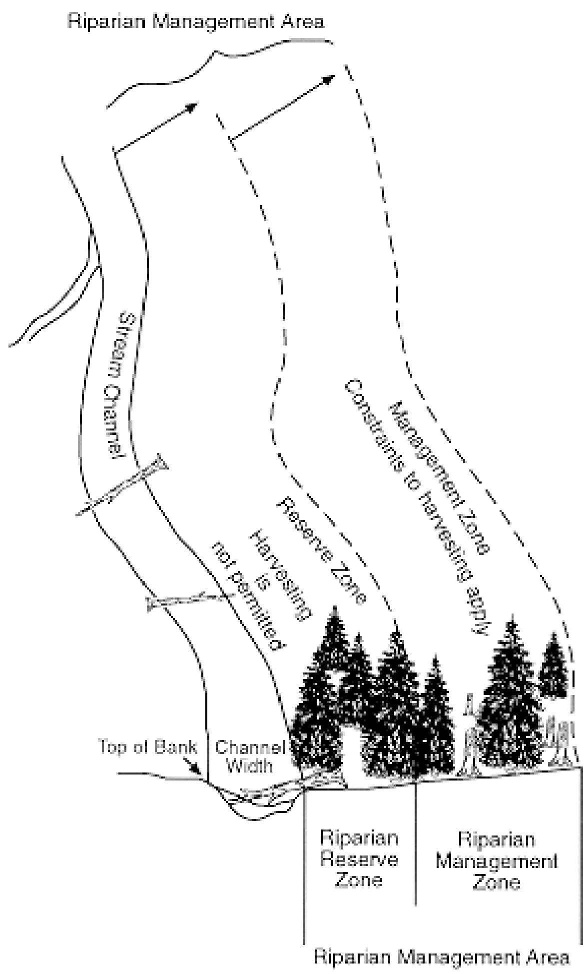

Figure 2. Forested riparian area with riparian reserve and management zone (RMA Guidebook, 1995)

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Table 4. Average slope distances of the reserve and management zone for water bodies (Riparian Management Area Guidebook, 1995).

Riparian Classes	Width of the Reserve Zone (m)	Width of the Management Zone (m)
S1*	50	20
S2*	30	20
S3*	20	20
S4*	0	30
S5	0	30
S6	0	20
W1	10	40
W2	10	20
W3	0	30
W4	0	30
W5	10	40
L1	10	0
L2	10	20
L3	0	30
L4	0	30

* Community watershed or fish stream

3. Forest Operations in Riparian Areas

3.1. Reserve Zones

In reserve zones, logging activities should not be undertaken on streams, wetlands, or lakes to ensure restoration of riparian areas. When the streambanks are stable in S5 and S6 streams, cross-stream yarding can be permitted to transport logs over a stream. The risk of windthrow to the reserve zone should be minimized. The important wildlife habitat attributes including wildlife trees, large trees, hiding and resting cover, nesting sites, structural diversity, coarse woody debris, and food sources characteristic of natural riparian ecosystems should be retained (RMA Guidebook, 1995). Inadequately planned and implemented logging activities have great potential to increase the magnitude of sediment yield and the frequency of landslides (Sauder et al., 1987) in the riparian management zones. Besides, logging activities increase stream temperature over fish tolerance limits (Brownlee et al., 1988) and alter the water chemistry and stream characteristic (Chatwin, 1989). It would take hundreds of years to recover the negative impact of logging activities on aquatic habitat.

Inadequately constructed and maintained forest roads can produce the significant amount of sediment yield to streams in riparian reserve zones due to removal of forest vegetation, forest floor, and soil layer (Grace, 2002). Road construction potentially increases the magnitude of surface runoff and landslides, while reducing peak groundwater levels. When crossing a stream or wetland, ecologically suitable and cost effective crossing with minimum impact must be implemented. The road sections at the stream crossings should cross the streams with nearly perpendicular angle to minimize the impact on streambanks in the reserve zones (Akay et al., 2007). Stream crossings structures (bridges and culverts) should be constructed to handle the maximum water flow and to avoid disrupting the migration or movement of fish and other aquatic life (Figure 3). To solve drainage problems in wetland crossings, wood mats, wood panels, wood pallets, expanded metal grating, plastic road, or geotextiles can be used (Akay and Sessions, 2005).

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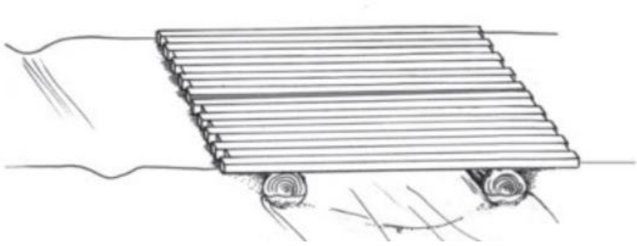

Figure 3. Portable bridge for stream crossing (URL 1)

3.2. Management Zones

In management zones, sufficient vegetation along streams to provide shade should be retained, bank microclimate changes should be reduced, natural channel and bank stability should be maintained, important attributes for wildlife should be protected where specified. To minimize the impact of logging activities in management zones, the following requirements should be considered (RMA Guidebook 1995; Bunnell et al. 1995):

- Logging machinery should not be used within the 20 m of the stream and it should be limited in the management zone.
- Falling operations should be performed in a way that the logs can be removed without damaging the streambanks and residual trees.
- Logging activities should be scheduled during the periods of low flow, especially in erosion sensitive areas.
- Only selective logging should be permitted in management zone and mature streamside trees, snags, and nonmerchantable trees should be left to provide future organic debris sources.
- Logging intensity should be well planned to maintain 75% of original shade over the aquatic area and 50% of the original tree canopy over the riparian area.
- Skidding activities should be performed with extra caution to prevent erosion damage.
- To minimize the impact of logging debris, stream channels should be cleaned out to prevent obstruction of streamflow and fish passages.
- Nonmerchantible conifer trees, understory deciduous trees, shrubs, and herbaceous vegetation within 5 m of the stream channel should be retained to protect and enhance aquatic habitat.
- Arial logging systems (skyline, helicopter, etc.) should be employed in fisheries and marine sensitive zones.
- Uneven-aged management practices with long rotation periods should be preferred instead of even-aged management in riparian areas.

In order to minimize the long term impact of forest roads in management zones, road width and right-of-way width should be minimized. To reduce the potential sediment yield from a road section, cut-slope and fill-slope areas must be immediately revegetated following road construction activities. Besides, fill-slope heights should be minimized especially within the active floodplain. Abandoned temporary roads should be permanently deactivated after harvesting operations (RMA Guidebook 1995).

In construction of forest roads, a minimum distance from road embankment to stream should be maintained to protect riparian ecosystem based on the ground slope between forest road and stream (Wiest, 1998) (Table 5). A forest road section with a long distance to the stream produces low percentage of sediment yield. A GIS-based sediment prediction model, SEDMODL, suggested that a road section within 30 meters and 60 meters of a stream results in a sediment yield of 35 % and 10 %, respectively (Boise Cascade Corporation, 1999). In the model, the road section at the stream crossing directly deliver the sediment with the yield of 100 %, while road segments further than 60 meters do not deliver sediment to streams since sediment traps in the forest land.

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Table 5. The distance range between road embankment and stream (Wiest, 1998).

Ground Slope (%)	Minimum distance from road to stream (m)
0-10	15
10-20	15-20
20-40	20-35
40-70	35-45

Conclusions

If forest operations in riparian areas adjacent to streams, wetlands, and lakes are not much different than that of in other forested areas, riparian ecosystem can be greatly degraded. To restore and maintain riparian ecosystem, first, the importance of ecological and hydrological values of the riparian ecosystems should be well understood by the key stakeholders, including Local Forestry Districts, relevant regional directorates, local governing units, and local communities. Then, specific strategies for logging operations and forest road construction should be developed and properly integrated into the forest management plans. Within these strategies, the streams, wetlands, and lakes should be classified and then the width of reserve zone and management zone should be determined. Environmentally sustainable logging activities should be established in riparian management zones. Forest roads should be constructed considering minimum ecological impact approach in the riparian areas. The ecologically sound forest practices should be established and aquatic life and terrestrial wildlife should be preserved within the riparian zones. It is highly anticipated that implementing this strategy by the local forestry districts can play a crucial role to restore, maintain, and improve riparian ecosystem.

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Positioning Accuracy of Smartphone in Forested Environment

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Abstract
Accurate and precise information in forest inventories is crucial. All technologies used for forest inventories, including ground measurements such as recreational-grade GPS for precise point positioning, and remote sensing technologies such as satellite imagery, LiDAR, and UAV, require the use of reference measurement on the ground. There are many devices in the markets for the foresters to use for surveying and mapping. Recently, rapid development in smartphone technologies and apps associated with them have replaced the use of other technological devices, including recreational grade-GPS receivers, computers, and tablets, in many diciplines. In this study, the positioning accuracy of smartphones in forested environment are evaluated comparing various levels of Global Navigation Satellite System (GNSS) devices. A smartphone with two different apps (CarryMap and Avenza Maps), one recreational-grade receiver, and survey-grade GNSS devise, considered as reference data, were used. It was aimed to examine whether the use of smartphone-based position information is acceptable positional accuracy compared to recreational-grade GPS receiver. For this aim, these devices are tested under different canopy openness (open sky, Forest with high canopy cover, forest gaps, where there is an openness but surrounded closely with trees, and forest edge) in forested environment. The results pointed out that the canopy cover affects the accuracy and precision of all types of GNSS receivers. Also, the result of this study helps explore the usefulness of smartphone based positional accuracy in forested environments. The findings of this study have been useful in continuous evaluation of recent GNSS technologies.

Keywords: Precision forestry, GNSS, smartphone, mobile maps, accuracy assessment

1. Introduction

Global Navigational Satellite Systems (GNSS) are frequently used in forestry and natural resources for navigating and recording position and mapping purposes. These systems are known as Global Positioning System (GPS) in many parts of the world. The system uses electromagnetic energy emitted by satellite and received by devices often placed in a car or plane, held or carried in the hand of a person, or attached to the animal (Bettinger and Merry, 2011; Ucar et al., 2014). In comparison to traditional geodetic techniques, GNSS can often be a highly accurate source of location information (Ucar et al, 2014; Bettinger et al, 2017; Tomaštík Jr., 2016).

Many tasks in forestry, such as mapping, inventory, and monitoring, require location information as spatial data, including satellite imagery, LiDAR (Light Detection and Ranging) and UAV (Unmanned Aerial Vehicle) technologies. These technologies require the use of ground reference measurements (Akbulut et al., 2017; Brach 2022), and the positional accuracy of ground measurements varies depending on the type of GNSS receiver. The use of expensive and sophisticated equipment, such as survey-grade GPS receivers, provides the highest accuracy, but may not be a practical tool for foresters and natural resource managers. While not as accurate as a survey-grade GPS receiver, a recreational-grade GPS receiver is often preferred for forest applications because of its affordability, ease of use, and adequate measurement accuracy (Wing 2011; Tomaštík Jr., 2016; Huang et al., 2022).

Recently, smartphone technologies have become the most popular and rapidly evolving computed devices, along with their applications. They have replaced other technological devices and have been widely used as portable handheld GNSS receivers in navigation and positioning, computers, or tablets in many areas, including forestry (Tomaštík Jr., 2016). In particular, as smartphone location services become more prevalent, more studies have begun to evaluate the positioning accuracy of smartphones for various purposes, such as using smartphone GPS location data to evaluate human movements and to track their health or transportation (Wang et al., 2015; Merry and Bettinger, 2019; Huang et al., 2022). Additionally, the positioning accuracy of smartphones has been evaluated within different environments. For example, studies by Wang et al. (2015) and Merry and Bettinger (2019) were conducted to evaluate positioning accuracy in urban environments. Huang et al. (2022) also evaluate the accuracy of smartphones under different canopy openness within an ecological park. Moreover, Tomaštík Jr. et al. (2016) tested the horizontal accuracy and applicability of smartphone GNSS positioning in a mixed deciduous-coniferous forest (during leaf-on and leaf-off season). All these studies conducted by using different smartphones and their associated applications, supporting different constellations, indicated mixed results on whether smartphones could be a reasonable alternative for traditional GPS receivers under different environmental.

In this study, we evaluated whether smartphone GPS applications provide comparable positional accuracy with the recreational-grade GPS receiver. Smartphones and their apps have been widely used in Turkish Forestry for inventory, positing and navigation, delineating boundaries, and mapping by local foresters and rangers. However, the accuracy of these two apps has yet been tested in forested environments. Hence, the positioning accuracy of one smartphone with two different mapping apps (CarryMap and Avenza Maps) in forested environments was evaluated by comparing with recreational-grade GPS receiver and reference data under different canopy openness in forested environments.

2. Material and Methods

2.1. Study area

The study was conducted in a forest area in Bornova Forest Enterprise (located in İzmir Regional Directorate of Forestry, the western part of western Turkiye (Figure 1). WGS 1984 World Mercator coordinate system, the left and upper coordinates in decimal degrees of the area are 27.116 Lon and 38.554 Lat, and the right and lower coordinates are 27.124 Lon and 38.547 Lat, respectively. The mean altitude of the study area is 553 m AMSL (above mean sea level) (Eker et al., 2021).

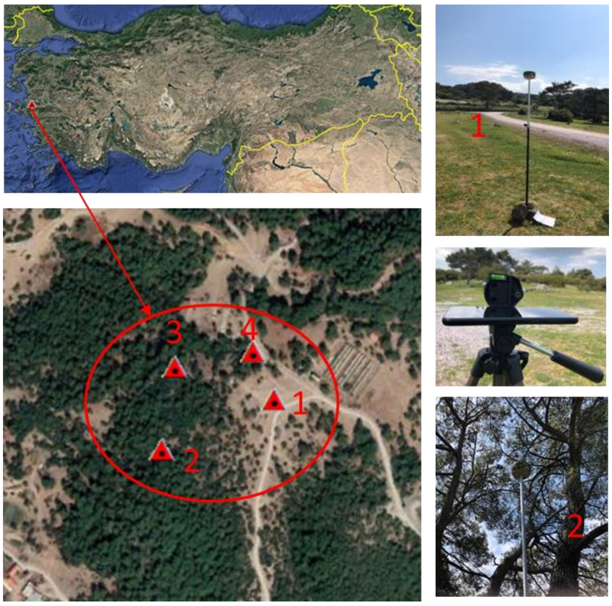

Figure 1. Locations of the survey points under different canopy openness – an example photo of open sky and Forest HCC study site

2.2. Method

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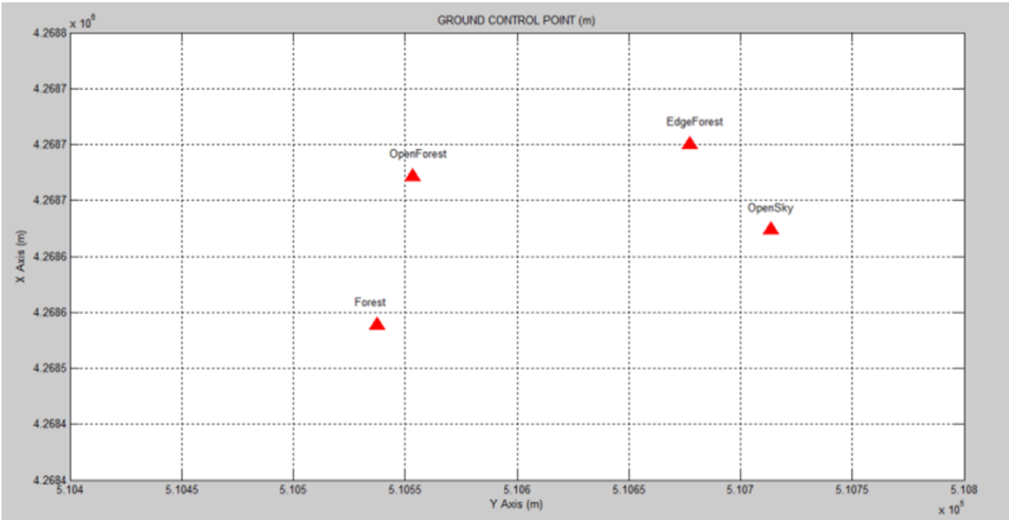
Data was collected on April 25th, 2023. To determine the control point, we used SATLAB SL600 GNSS receiver, which can track six different satellite constellations, including GPS, GLONASS, BeiDou, GALILEO, QZSS, and SBAS. It can also process all standardized correction formats from local sources to national CORS networks. For this study, we used local services in Turkiye known as the "TUSAGA-Aktif" project, which shares base corrections over the Internet via NTRIP (Networked Transport of RTCM via Internet Protocol) technology (Eker et al., 2021). The "TUSAGA-Aktif" project was established by Istanbul Kultur University in association with the General Directorate of Land Registration and Cadastre of Turkiye and the General Command of Mapping of Turkiye and was completed between 2006 and 2009. It was also sponsored by the Turkish Scientific and Technical Research Agency (TUBITAK) (Mekik et al., 2011). Fifty points were surveyed at each point using SATLAB SL600. Absolute coordinates of the control points were calculated with less than mm error by using line-of sight-observation for each location (Open sky, Forest HCC, Forest gap (FOA), and Forest edge). Figure 2 shows calculated horizontal location of Ground control for each survey point and their absolute coordinates with mean error.



AbsoluteCoordinate (UTM ITRF96-3°) and Mean Eror						
NN	X (m)	Y (m)	Z (m)	m_x (mm)	m_y (mm)	m_z (mm)
OpenForest	510553.159	4268671.679	628.174	0.00000000000259	0.00000000000316	0.00000000000409
EdgeForest	510677.202	4268700.052	631.658	0.00000000000227	0.00000000000285	0.00000000000369
Forest	510537.447	4268538.647	626.374	0.00000000000606	0.00000000000747	0.00000000000790
OpenSky	510713.482	4268623.732	633.565	0.00000000000255	0.00000000000311	0.00000000000450

Figure 2. Horizontal position of Ground control points for each survey point (above) and their absolute coordinates with less than mm mean error (below)

Then, recreational GPS recorded 50 points using the tripod over each point where the control point data was recorded. Garmin eTrex10 was used to record the horizontal position of the points. According to the manufacturer, accuracy was approximately within 10 m. The smartphone also was placed on the same tripod to record the positions of the points. For this study, Samsung Galaxy A2, which can use multi-satellite constellations, including GPS, GLONASS, and Beido, was employed. wo applications associated with the smartphone (CarryMap and Avenza Maps) are widely used in Turkish Forestry for inventory, positing and navigation, delineating boundaries, and mapping by foresters and rangers, been selected for this study. However, horizontal accuracy has yet to be tested to determine whether their accuracy is sufficient to replace the recreational GPS receiver. The same tripod over each point was employed to record 50 horizontal positions with both apps. Additionally, while recording horizontal positional accuracy with both apps, Wi-Fi was enabled as default based on the information obtained from interviews with foresters or rangers.

After 50 horizontal positions were recorded with each device (recreational-GPS, Smartphone-CarryMap, and Smartphone-Avenza Maps) at the four different points, Root Mean Square Horizontal Error (RMSExy), one of the most common accuracy measurement methods in geodesy, is used as the primary index to compare the positioning accuracy of devices for four points.

$$\text{Error} = (X,Y_{REF} - X,Y_{GNSS})^2 + (X,Y_{REF} - X,Y_{GNSS})^2 \quad (1)$$
$$\text{RMSE} = \sqrt{}\,(X,Y_{REF} - X,Y_{GNSS})^2 + (X,Y_{REF} - X,Y_{GNSS})^2 / n \quad (2)$$

Where n is the number of records (epochs), X,Y_{REF} coordinates from the Ground control Points, calculated by absolute coordinates, and X,Y_{GNSS} coordinates from field measurements with Rec-GPS receivers and two different smartphone apps (Android CarryMap and Android Avenza Maps).

Also, the Circular Error Probable 50 (CEP50) Coefficient of Variation (CV) was calculated. CEP 50 is the radius of the circle around the known checkpoint where 50% of the fixes occur. CV is the ratio of the standard deviation to the mean, and the higher the CV, the greater the variation from the mean. Conversely, the lower the CV, the closer the values are clustered to the mean. In addition, a statistical test was performed to determine whether errors from one device were different from others. In order to do that, first, the normality of the data was checked, and the results showed that the data was not normally distributed. Hence, a non-parametric Kruskal-Wallis test was used.

3. Results and Discussion

When examining all horizontal position errors derived from three different GNSS receivers at four points (Open Sky, Forest HCC, Forest OA, and Forest Edge) (Table 1), all devices produced lower errors in Open Sky. RMSE for all data collected with recreational-GPS receiver generally produced lower error at each point regardless of the obstruction from the canopy closure. However, the RMSE of the Android CarryMap (A_CarryMap) at the Open Sky point was the minimum. As expected, forests with high canopy closure had higher RMSE derived for all data recorded with three different devices than other points due to canopy closure.

Table 1. RMSE, CEP 50 and CV for horizontal positions collected with three different GNSSreceivers at four different points

Points	Devices	RMSE (m)	CEP50 (m)	CV
Open Sky	Rec GPS	3.081	3.130	0.207
	A_Carry Map	1.126	1.133	0.092
	A_Avenza Maps	2.066	2.138	0.210
Forest_HCC	Rec GPS	3.635	3.435	0.492
	A_Carry Map	4.869	4.365	0.754
	A_Avenza Maps	5.876	5.997	0.332
Forest-OA	Rec GPS	2.206	2.036	0.363
	A_Carry Map	3.755	1.461	1.229
	A_Avenza Maps	6.231	5.991	0.115
Forest-Edge	Rec GPS	2.873	2.721	0.307
	A_Carry Map	4.060	4.493	0.351
	A_Avenza Maps	4.289	4.417	0.157

Although the larger variation was observed for the CarryMap device at Forest OA (Figure 3. 3), the largest RMSE was observed with the Avenza Maps app at Forest OA point compared to all devices

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and all four points. Also, the data collected with the Avenza Maps app at each location showed the smallest variation, except at the Open Sky (Figure 3). Moreover, in comparison of RMSE and CEP 50 between devices and locations, the results were quite comparable, except CarryMap app at Forest OA point (Table 1).

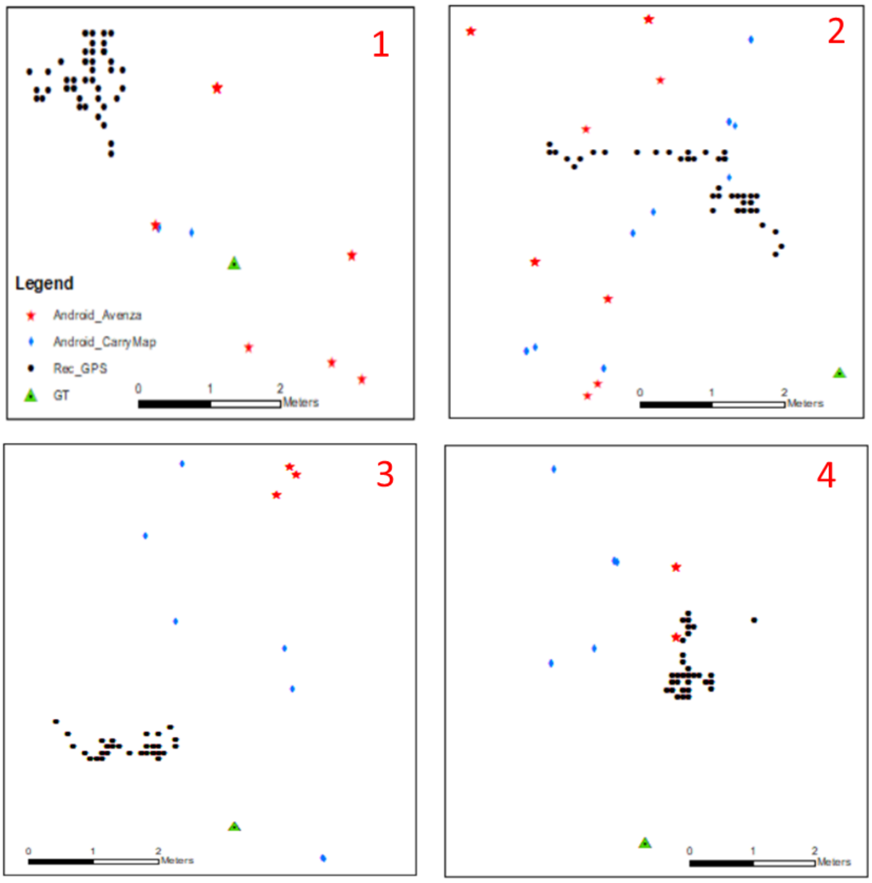

Figure 3. A map of horizontal positions collected with three different devices at four different points

The statistical tests showed a significant difference between all three devices, meaning that the error from all three devices was not the same. The same results were observed at each of the four points. Then, the pairwise comparison was employed within the Kruskal-Wallis test. It showed us that the errors from the three devices were different from each other. Based on the pairwise comparison, the error of all three devices in Open Sky and Forest w/HCC differed. However, in Forest OA point, the error distribution from Rec GPS and CarryMap was similar, but the Avenze Maps showed different error distribution from both Rec GPS and CarryMap. Also, mixed results were observed in Forest Edge. The pairwise comparison showed that CarryMap and Avenza Maps were not statistically different, meaning that the error distribution was the same, but Rec GPS was different from both.

The accuracy and precision of the horizontal position in forestry and natural resource management are crucial. With the development of new technology, the users in forestry want to use these technologies to quickly and effectively determine land areas associated with forest inventory, potential timber sales, natural or man-made disasters (fires, illegal harvesting, flooding, and wind throwing), and monitoring or determining critical habitat (Ucar et al., 2014). In this study, we examined smartphone-based GPS receiver apps, which have become more prevalent in forestry and many different disciplines, and whether they can be a reasonable substitute for recreational grade GPS receivers. An Android phone with two different mapping apps (CarryMap and Avenza Maps) was used in this study. Results showed that horizontal position error from smartphone apps was comparable to the recreational grade GPS receiver at each of the four points, even though the statistical test showed mixed results between devices within different points. Our finding indicated similarities with previous studies that the horizontal accuracy of smartphone apps is relatively consistent with recreational GPS receivers (Merry et al., 2019; Tomaštík Jr. et al., 2016). It was also observed that positional accuracy improves when canopy cover effects decrease using recreational GPS and smartphone apps (particularly CarryMap). However, the lowest accuracy was observed in the Forest OA point, where the canopy cover is not directly above the devices.

4. Conclusion

This study evaluated the horizontal accuracy of different smartphone apps in Turkish forestry to understand whether they can be a reasonable substitute for the recreational-grade GPS receiver. According to our results, the current generation of smartphones could successfully compete with some consumer-grade GPS receivers regarding accuracy. As expected, the horizontal positional accuracy from all devices at the point under Open Sky was better than points within different forested environments. Still, the positional accuracy of smartphone devices had a minor variation compared to the recreational grade GPS receiver in most points, except the CarryMap app in Forest OA. The results indicated that the smartphone and its associated apps could be an alternative to the traditional recreational GPS receiver in many forestry tasks with lower accuracy demands application. Although our study showed promising results, only one brand was used in this study, and different smartphone brands need to be added to future studies.

Besides, smartphone technology can be widely used for different purposes. For example, foresters could use it for inventory, delineating forestry roads or natural or artificial impacts, and monitoring or determining critical habitat. Smartphones can combine more than one future; thus, using smartphones in forested environments will be practical. It would reduce the number of devices to be carried to the field.

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Operations Planning for Salvage Logging After Forest Fires in Turkiye

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Abstract
After the devastating effects of wildfires, rapid removal of debris is necessary to quickly repair and restore the ecosystem. In this process, the logging of woody biomass having commercial value should be conducted quickly and without damaging the field. Thus, forest areas damaged by fire should be made suitable for reforestation by natural or artificial treatments. After forest fires, procuring wood raw materials and removing debris from the burnt stands can be time consuming and costly, which prolongs the renewal process of the ecosystem. Technically, this type of operation may require different planning and practices than the usual logging processes. Therefore, there is a need for operation planning that can support rapid decision-making in accordance with the current capacity and effective use of time and resources. Due to the resource allocation problem, especially after the fires, which are effective in very large areas, there were situations where the fire debris could not be removed before the vegetation period. Recent lessons learned from the great fires in Turkiye in recent years have pointed out to the necessity of operational planning for salvage logging. This study aims to explain what kind of planning procedure should be for the logging of the woody material with commercial added value remaining in the forest area after the forest fire and to introduce the conceptual framework of the planning. The operational planning approach, it is aimed to solve problems such as how sensitive data should be collected, how to obtain data on existing resources and capacity, how much and when these resources will be needed, and how to make multi-purpose, fast and consistent decisions in parallel with conflicting criteria. In this context, information was given on examples of operational planning models specific to the removal of fire debris. With the operation plan, it has been understood that solution sets can be produced for resource allocation such as the working time needed to remove the debris, the labor force and machine power that will be needed.

Keywords: Salvage logging, forest fires, operational planning, debris management

1. Introduction

When listing the natural disasters; it is seen that the most frequent or severe destructions are caused by forest fires. Following the chain reactions due to climate change, massive and catastrophic forest fires of various sizes have started to occur in forest ecosystems (Çelik, 2008). In Mediterranean countries such as Turkiye, natural or man-made forest fires; it negatively affects the forest ecosystem, forest inhabitants and forestry activities. Various questions are encountered during forest fires or immediately after the fire. These consist of questions such as what's going on in forest fires, what happens after fires, conditions, and compelling reasons, what can be done, how to create a planning model, and what can be provided. After forest fires damage the forest ecosystem, what should be done to produce forest products that can offer commercial value or added value from the remaining forest stands with the debris removal strategy is an important problem, as well. These problems are markers of a state of chaos that requires quick decision-making (Eker, 2022).

Interestingly, disasters/destructions are no longer unique to a particular geography. Because the destructive effects of forest fires concern not only the ecosystem but also the life of all living things, at least biologically. Regarding forest fires, it is necessary to accept some facts in Mediterranean

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countries such as Turkiye and other countries with fire-sensitive forests. For example, the first- and second-degree fire-sensitive areas in Turkiye are near to 13 million ha. More than half of the forests are fire-prone. Nearly 4 million m^3 of extraordinary allowable cut after the latest fires in one region were recorded. The number of forest fires, the destroyed areas, and the interventions in the burned areas are important source of information in terms of understanding the events. Forest fires are inevitable for some forest ecosystems. This is also the case in Turkiye's Mediterranean type forests (Figure 1 and 2) (GDF, 2023). Although many operational measures are taken, fires do break out, but their destruction and size vary depending on the professionalism of the interventions (Eker and Çoban, 2009). As can be seen in Table 1; Attempts to leave the burnt areas and re-establish forests are started. For example, according to the data of 2022 (GDF, 2022); more than 70% of the burned areas have been regenerated by natural or artificial means. This situation dictates that the burned areas should be rapidly rehabilitated and restored to their old structure.

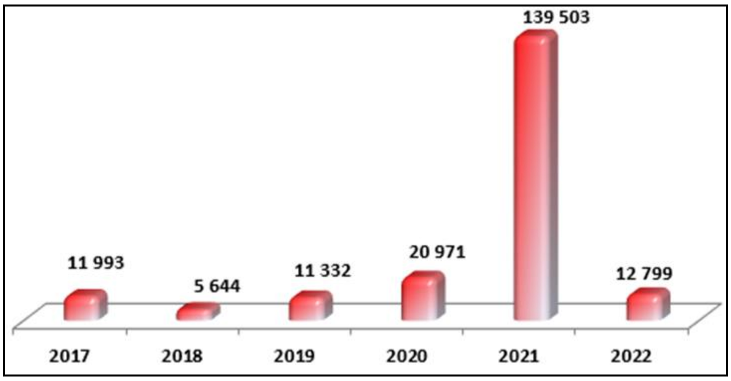

Figure1. Burning forest areas between 2017 and 2022 years in Turkiye (as hectare)

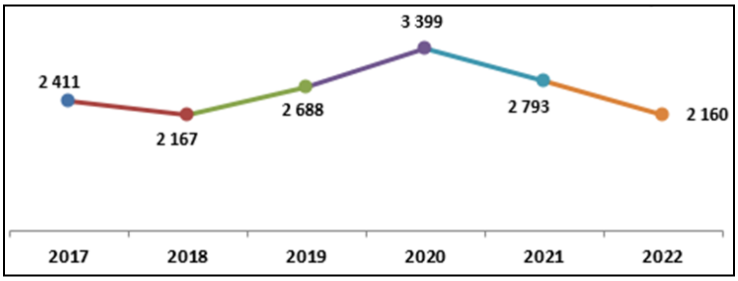

Figure 2. Number of forest fires between 2017 and 2022 in Turkiye

Table 1. Interventions after forest fires of 2021 in Turkiye (areas in ha)

Total area	Whether cover exposure to fire, undamaged areas	Preparing for natural regeneration areas made	Area gets the artificial regeneration program	Rehabilitation	Taken to forestation program areas	Things to technical process are not taken into protection areas
139.503,16	4.702,15	72.511,65	28.426,29	7.761,44	4.602,63	21.499,00

After major forest fires, severe debris remains on the forest floor and must be removed quickly. Moreover, there will be a great chaos in the decision-making and implementation phase for the cleaning of the site after the fire. As well, the big fires alter; the annual harvest programs/schedules (in the short term), the treatments of management and silviculture plans (in the medium term), and the strategic targets by interrupting the forest functions (in the long term).

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A rapid removal of debris to restore ecosystems after forest fires; it is necessary to prepare for the supply of commercially valuable material and to re-forest the damaged areas (STODAFOR, 2004). This process called salvage logging, practice involves the removal of dead, dying, or deteriorating trees from a forest before the value of the wood products become worthless. Cleaning up this debris can be time-consuming and costly, extending the recovery from the fires. Technically, these types of operations could be applied to every stand having even-aged or uneven-aged. The trees removed from the stands may be pre-commercial or elderly and therefore subject to damage imposed by fire or other natural events (Eker, 2022). In this operation, the timing of the harvest is not consistent with the timing of a thinning or a final harvest operation. Therefore, there is a need for an operation planning (Eker, 2004) in accordance with the current capacity for the effective use of time and resources.

The objective of this study was to provide targeted suggestions based on prior research. Our previous efforts have taken a somewhat systematic approach to addressing the aftermath of natural or man-made forest fires. While the biological, social, and economic impacts of such disasters are always a primary topic of discussion, this study focuses on improving the post-activity situation. Recent major forest fires have provided valuable insights into understanding the impact of forest fires. This study aims to explain what kind of planning procedure should be for the logging of the woody material with commercial added value remaining in the forest area after the forest fire and to introduce the conceptual framework of the operational planning.

2. Operational Planning

Planning is a decision-making process, which is arranged at three levels: strategic, tactical, and operational, according to this approach. Operational Planning (OP) is the final stage in the hierarchical planning method (Weintraub and Cholaky, 1991; Laroze and Greber, 1991; Lockwood, 1998). OP is responsible for short-term planning and can help create daily, weekly, monthly, 3-month, yearly, or 18-month implementation plans (Eker and Sessions, 2020). At this stage, production techniques are detailed, and truck transportation programs can also be determined. The aim is to ensure the usefulness of the implementation. The scope of the plan is narrow, and the planning is very detailed. The level of uncertainty and risk is low (Martel et al., 1998; McNaughton et al., 2003; Weintraub et al., 2000, Eker, 2004).

OP in timber harvesting involves planning the quantity and quality of wood raw material, resource allocation (fuel, labor, money, time), production timing, transportation logistics, and considering topographic/technical, economic, environmental, ergonomic, and socio-economic criteria within the scope of timber harvesting activities (Eker and Acar, 2006). Operational Harvest Planning Model (OHARP) was developed by Eker in 2004 to solve the harvest planning problem for Turkish forestry. OHARP considers which harvest unit/block to harvest, which harvesting system to use, how many harvesting crews to employ, which state forest storage area to use, and which forest roads to use. OHARP considers technical-topographical conditions, economic limitations, environmental restrictions, and social-institutional expectations within a 12-18 month harvesting period in a forest district.

Eker and Çoban (2009) presented a comprehensive framework for planning logging and transportation for post-fire forest operations. They described the model's system structures and capabilities. In a subsequent study, Çoban and Eker (2010) assessed the efficiency of new and existing roads during post-fire forest operations. According to Bilici et al. (2017), using an operational planning-based Post-fire Action Planning (PFAP) model can lead to economically and environmentally responsible forest operations after forest fires. The study found that estimated durations of salvage logging operations were 15 to 75 days less than actual operations in the field.

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With our knowledge from the past and what we have learned from recent experiences; when we evaluate the effects of climate change on ecosystems, we need to know well some of the facts we will face and their effects and their reflections on our forestry. The facts and figures:

- Disasters such as forest fires and their damages will be inevitable.
- More frequent and greater destruction will be encountered.
- There may be catastrophes on a scale that cannot be easily intervened with human means.
- Very large forested areas will suffer severe damage.
- Structured systems will not be able to work.
- The extraordinary harvesting will alter the supply-demand balance in terms of quantity and quality.
- Large damaged areas will require extensive forestry operations.
- The labor system based on forest-public relations will encounter a work volume that cannot be operated.
- It will be difficult for managing and administrating the spatial and temporal distribution of labor and machine power.
- Unplanned-irregular roads will be built based on sudden decisions and the effects will take a long time.
- The necessity of recovering the value-added or commercial product from the debris will complicate the work.
- It will be getting hard to leave the disaster areas before the start of the vegetation period due to extraordinary conditions.

Plans should be established in advance for debris removal and the supply of products in the damaged forest. Within the scope of the risk plan; Planning methodologies that will enable optimal decision-making in a chaos environment should be designed and kept ready. The philosophy of taking precautions and risk planning should be done beforehand (proactive behavior). In this context, it is necessary to prepare a planning framework/base where quick decisions can be made by allocating resources optimally with available opportunities. This planning procedure framework; should have the capacity and content to provide decision support to managers by being applied in any size area after any disaster. Although the removal of the debris left behind after such disasters and the evacuation of the forest area do not differ much from ordinary production operations in theory; technically requires a planning procedure that is sensitive to the variability of constraints. The problems and solution opportunities are examined in Figure 3 and the result leads us to OPaFire (Operational Planning after Forest Fire) model.

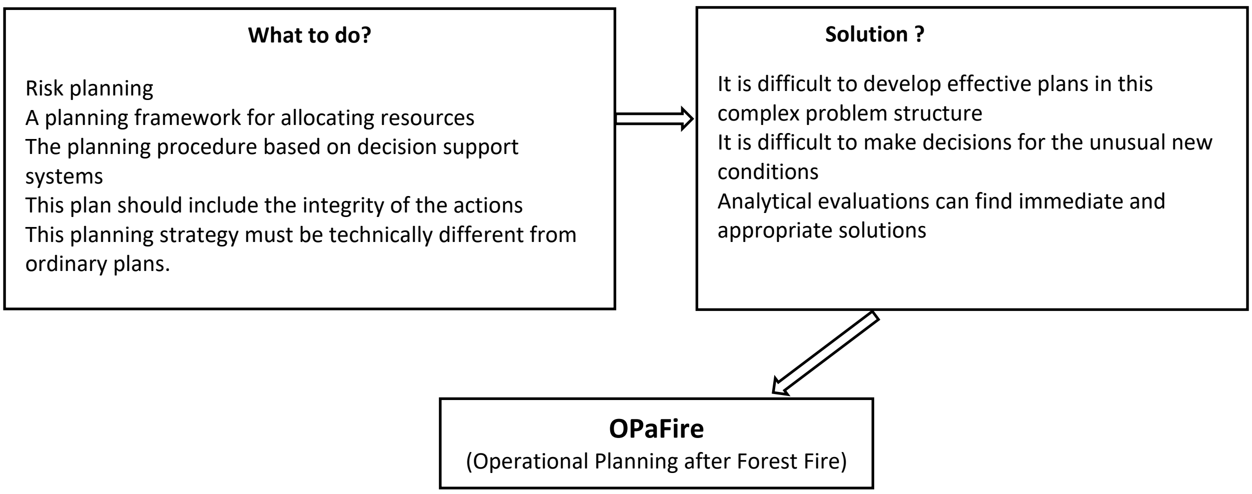

Figure 3. The development process of the OPaFire model

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3. Operational Planning after Forest Fire (OPaFire)

The planning procedure proposed for extraordinary forest harvest, called as OPaFire, is based on a well-known operations research methodology. This procedure is devised to help forest enterprises plan and manage the short-term production process for wood raw material, taking into account various factors such as fuel, human-animal-machine labor, money, time, topographic/technical, economic, environmental, ergonomic and socio-economic criteria.

However, the extraordinary harvest process can be challenging due to several reasons. Firstly, the time required to harvest and transport the product is usually short, as a way to prevent pests, fungi, invasive species, erosion, quality losses, and other potential issues. Secondly, the regular production process of forest enterprises is disrupted by the extraordinary harvest, which can lead to a range of consequences, including changes in the quantity and quality of wood products intended for sale.

Moreover, the extraordinary harvest is usually spread over a large integrated area, which makes it challenging to manage and plan. There is also the issue of low value-added products that may not find customers, which can further complicate the process. Sales methods may vary, and in a short period of time, there may be problems with storage areas and depots where the product will be accumulated or managed due to mass production.

Within the local possibilities, it may be difficult to provide sufficient labor and machinery power for harvesting in a short time. The road network infrastructure may not be suitable and sufficient in terms of speed and capacity for transport logistics. All of these factors need to be taken into account when planning for an extraordinary harvest, and the OPaFire planning procedure aims to provide decision support to managers during this process. OPaFire's planning procedure is a comprehensive framework that helps forest enterprises plan and manage the short-term production process for wood raw materials in extraordinary harvest situations. Despite the challenges, this procedure can help managers make optimal decisions by allocating resources efficiently and effectively, thereby ensuring the success of the operation (Eker and Çoban, 2009; Bilici, 2014).

OPaFire contains several base subjects including system analysis, crisis management, spatial data, database management, decision making, roading, supply chain management, harvest and transportation logistics, spatio-temporal design, resource allocation, and work safety and health. Details regarding the structure of the OPaFire are indicated in Figure 4.

After forest fires, many factors must be taken into consideration such as; the area damaged, utilizable biomass amount, severity of damage, date of disaster occurrence, required manpower and workdays for debris removal, necessary amount of machinery and equipment, establishment of work schedule, deployment of different companies or teams from nearby villages to work in the area, determination of forest road and skid road densities, organization and coordination of cutting, splitting, removal, and waiting on the ramp, volume and control of transportation on forest and highways, evacuation of the area before vegetation time, current condition of the area where operations have been completed, risks of work accidents, insufficiency of local technology, focus on advanced technology, preference for low environmental impact technology, and problems related to worker health and safety (Çoban and Eker, 2010; Bilici and Akay, 2015, Bilici et al., 2017)**.** The problem contents of debris removal depending on the factors in the context of salvage logging are summarized as is;

- Time is a critical constraint.
- Organization, coordination, and control of all activities
- Dirty, dangerous and difficult working conditions for all operations
- Sensitive forest floor (erosion, flood, soil compaction, etc.)
- Sales methods and customer searching for extraordinary products

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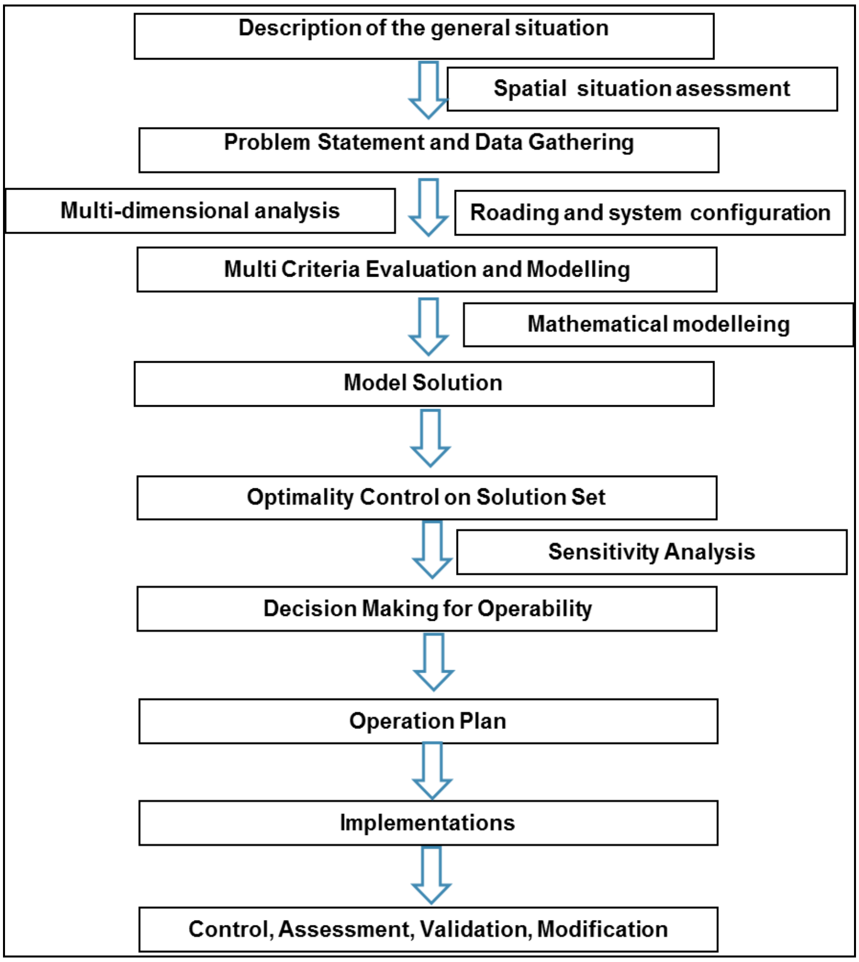

Figure 4. OPaFire's Concept

- Requiring fast, efficient, intensive and longtime work
- Amount of labour 'required to remove the debris and salvage harvest,
- Distribution of workforce to damaged area,
- The amount of roads needed and
- In what order and on which route they will be built

Burnt stands may also have a background structure that complicates logging and hauling and thus debris removal operations. This situation can be grasped by the following elements:

- Short operational time
- Disrupted ordinary business practices
- Changed quantity (+) and quality (-) of usual forest products
- Scattered (damaged) trees to a large integrated area
- Changing sales patterns
- Lots of low value-added products
- Logistics problems (handling, landing, storage, etc.)
- Insufficient workforce (labour and machine force)
- Insufficient infrastructure (forest roads, etc.)
- Insufficient transport capacity

In a chaotic structure, it becomes difficult to make appropriate and accurate decisions. This creates a complex and interrelated problem structure. Because the problem may show a multidimensional or even multi-purpose structure. Although the main aim is to remove the debris in a short time, evacuate the damaged area and bring the generation back again, it is necessary to take into account the economic, social and institutional constraints and objectives.

4. Opafire Database

The main object of OpaFire type of planning procedure is the database (Figure 5). Especially the data that will reflect the post-damage landscape; must be collected quickly and precisely. Other data is already in forest administrations in the ordinary process. Management plans, digital maps, forest road network plans, current warehouse locations, customer profile and market supply demand information are the usual data that can be found in forest administrations. Data can be collected in a short time in order to have information about the current technology used in local production works. It is also possible to use various data sources for damage determination. Especially drones can be used to shorten the time for data collection. Data sources for various purposes include reports, documents, maps, aerial photos, satellite images, UAV data, LIDAR, terrestrial data, quick surveys, open sources, and more.

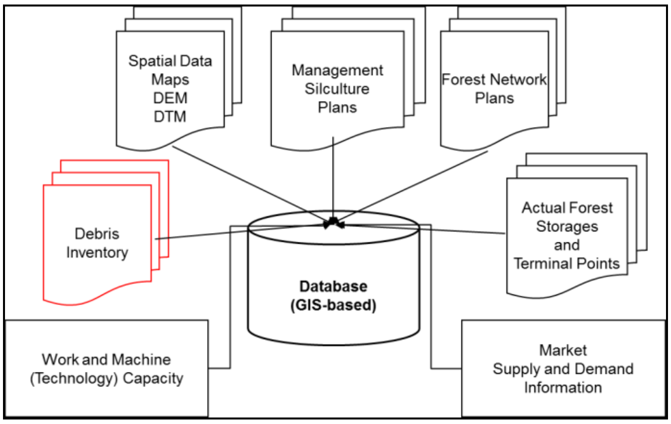

Figure 5. OPaFire Database sources

In forest enterprises, there are generally no operational-scale plans, at least in Turkiye. However, such plans may be needed for sudden and accurate decisions after major disasters. The necessary spatial data, management and silviculture plans, road network plans, and information on existing storage locations are routinely available in the enterprise inventory and can be used. Information on the local workforce and market supply-demand can also be collected. However, the inventory of debris/damage is the most important aspect of this planning. The choice of technology for salvage harvest and the amount of resources to be used depend on the debris inventory.

5. OPaFire Analyzes

Once a sufficient database has been developed for this planning procedure, it is possible to perform many analyses in a concise and effective manner. The OPaFire model includes Technical Analysis, Spatial Analysis, Ecological Analysis, Economic Analysis, Societal Analysis, and Institutional Analysis. The spatial analysis outlines various aspects related to forest management, including identifying boundaries of damaged areas, functional terrain classification, forest road analysis, skidding and tractor road networking, slope length and skidding distances, road planning, landing locations, and terminal and storage points. Recoverable material quantity and quality, alternative harvest and transportation technologies, and supply chain structure are being carried out through technical analysis. The details of the analysis for OPaFire are indicated in the workflow (Figure 6).

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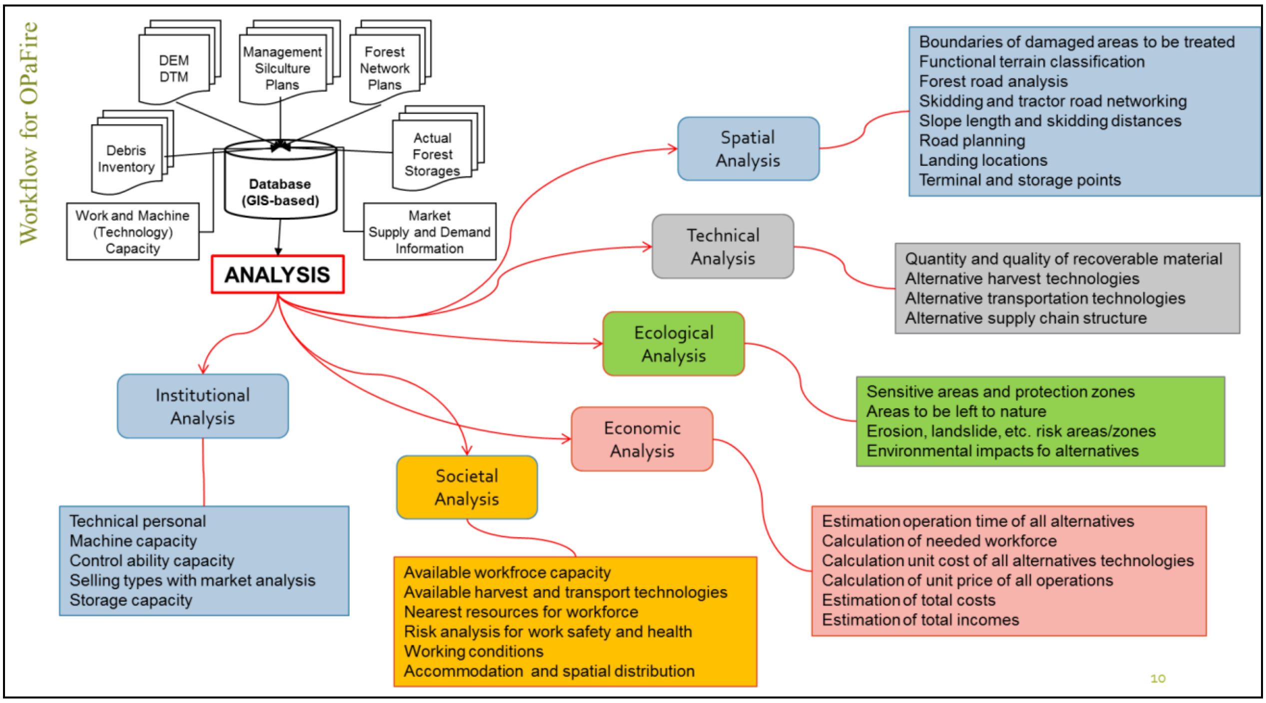

Figure 6. Workflow for OPaFire concept

In the damaged areas, after the existing and alternative technologies are listed by spatial and topographic analysis, a weight coefficient or score is determined according to the criteria and indicators of alternative technologies that cannot be quantified. This determination can also be per stand/compartment (Figure 7).

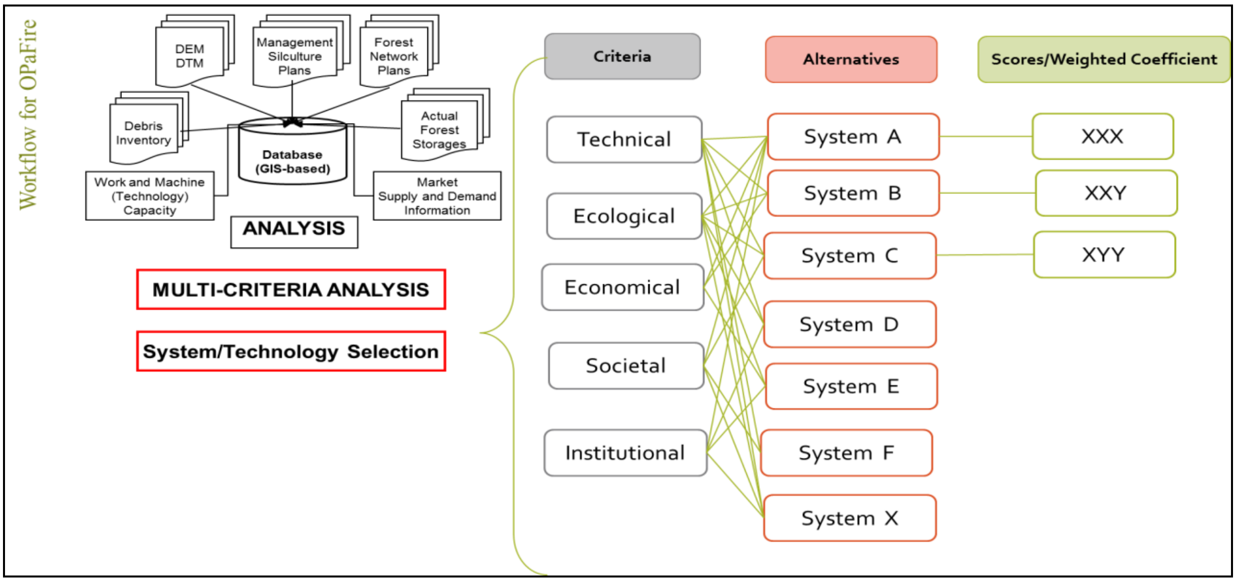

Figure 7. System selection procedure via multi-criteria analysis in OPaFire model

It may be necessary to decide where to start the debris removal work and what amount of labor should be allocated where and how first, by prioritizing damaged compartments (Figure 8). For this, Multi Criteria Decision Making techniques are used such as Analytic Hierarchical Process.

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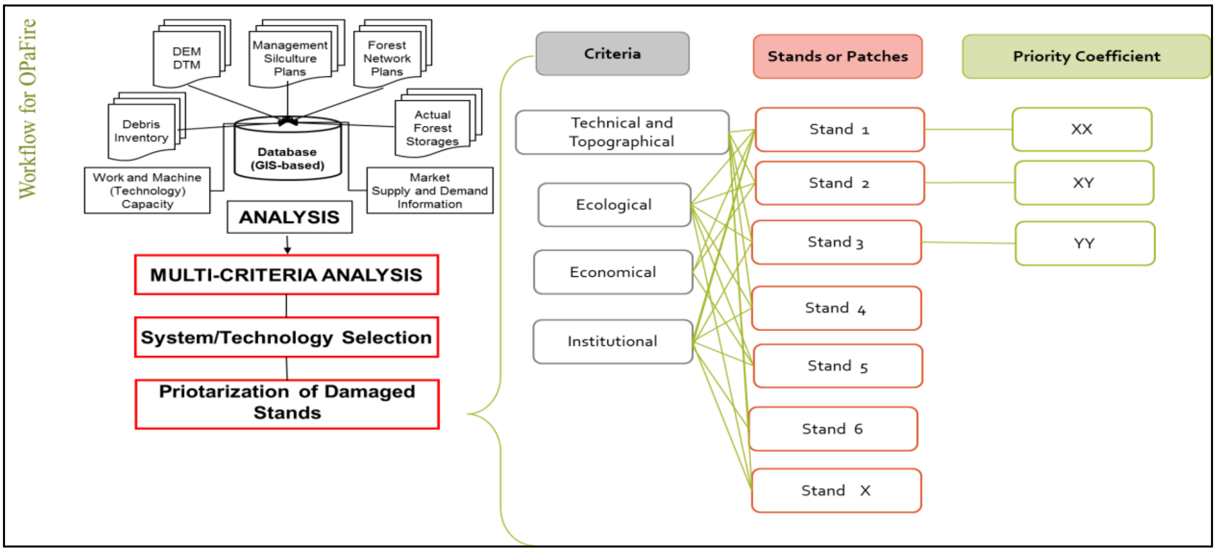

Figure 8. Priotarization process of the burnt stands for assessment procedure

It is useful to use operation research techniques to make a decision that optimizes the objective function on a temporal or economic scale in the face of many constraints. Mathematical modeling is a useful tool in finding the optimal solution to such quantifiable problems (Eker, 2004, Martell, 2007; Rönnqvist et al., 2015). In order to create such a model, it is necessary to determine the objectives, constraints, the amount of resources and decision variables (Figure 9).

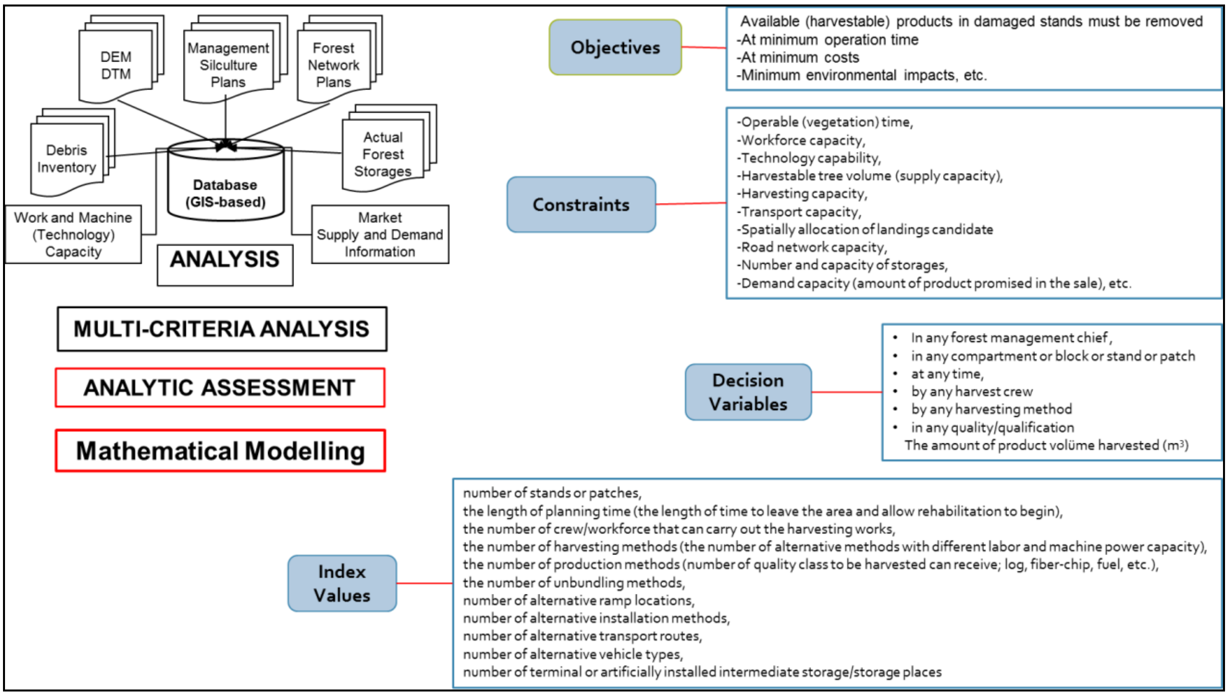

Figure 9. Objectives, constraints, amount of resources and decision variables for mathematical model

With the help of various mathematical programming techniques and solvers, it is possible to find solutions by modifying the problem structure (Björndal et al., 2012). In the example provided here, the model can work with continuous or discrete number-dependent variables that are appropriate for linear programming (Eker, 2004; Eker and Çoban, 2009).

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The structural components of the mathematical model developed for OPaFire are summarized below:
Objective function;

$$Z_{\min} = \sum_{i}^{\dot{I}}\sum_{b}^{B}\sum_{t}^{T}\sum_{e}^{E}\sum_{h}^{H}\sum_{v}^{V} X_{ibtehv} * HM_{ibtehv} + \sum_{i}^{\dot{I}}\sum_{b}^{B}\sum_{t}^{T}\sum_{v}^{V}\sum_{s}^{S}\sum_{r}^{R} Y_{ibtvsr} * SM_{ibtvsr} + \sum_{i}^{\dot{I}}\sum_{b}^{B}\sum_{t}^{T}\sum_{v}^{V}\sum_{r}^{R}\sum_{l}^{L}\sum_{y}^{Y}\sum_{k}^{K}\sum_{d}^{D} T_{ibtvrlykd} * TM_{iibtcrlykd}$$

Where,
HM_{ibtehv} = Cutting time (h/m^3);
SM_{ibtvsr} = Extraction (logging) time (h/m^3)
$TM_{ibtvrlykd}$ = Loading and hauling time (h/m^3)

Subject to;

- Harvest and transport works must be completed within the specified time,
- Each stand or patch must be harvested,
- The amount of products is limited to the amount detected in the debris,
- The number of teams and workforce capacity to be employed is limited,
- The capacity of the harvesting method to be used by harvesting team is limited,
- The harvestable product are limited to the capacities given in the inventory,
- Logging methods are limited to local and available technology,
- Landing locations are limited,
- Loading type and capacity are limited,
- Each road network section should be open to traffic,
- The specified axle load should not be exceeded,
- The number of usable trucks and their carrying capacity are limited,
- Number of terminals, storage capacity and capacity of intermediate storage locations limited, etc.

Solution procedure;

- Solving the mathematical model by commercial software
- Sensitivity analysis of the solution set
- Completion main decision making process
- Planning stage for the appropriate solutions and applications

When it is concluded that the optimal decision-making process is provided for OPaFire by evaluating the solution set obtained, a plan text and mapping is carried out to transfer the work and operations to the implementer. After a feasibility assessment of the plan's feasibility with stakeholders (manager, decision maker, contractors, operators, local people, etc.) implementation begins.

3. Results and Discussion

The OPaFire planning procedure is a powerful tool for forest management that can help answer critical questions related to operation time, costs, sequence of operations, resource allocation, and transportation networks. This model was initially developed to optimize ordinary harvest operations while minimizing costs, as reported by Eker in 2004. Since then, the model has been expanded to include salvage harvest operations and was successfully operated using hypothetical data, according to Eker and Çoban in 2009. In 2014, Bilici developed another model with some similarities to the previous ones, which claims to save up to 60% of operation time. However, despite the success of these models, similar planning and decision-making procedures have not yet been applied in practice in Turkiye.

In order to achieve the best results, OPaFire focuses on minimizing total operation time, determining the operation times based on stand or patch, identifying the most suitable harvest and transport technology, determining the required work and machine power for the fastest operation technology, determining the amount of forest product that can be handled, identifying the landing locations to be used, determining the road lines to be used, and determining the storage places required, among other factors. By considering all of these factors, OPaFire is able to provide suitable answers to a variety of WH-questions, including what, when, where, who, whom, which, whose, why, and how for effective decisions to achieve the desired results. As such, it is important to ensure that the planning and decision-making procedures are optimized for different types of operations, including both ordinary and salvage harvests. By doing so, forest management teams can leverage the full power of the OPaFire planning procedure and achieve optimal results in terms of efficiency, cost, and sustainability.

The OPaFire procedure provides various benefits that can significantly improve decision-making processes. For instance, this procedure enables the elimination of deficiencies associated with the rule-of-thumb approach. Additionally, it facilitates the adoption of precise decisions by allowing for comparative analyses. Moreover, sensitivity analysis can be conducted to evaluate all alternatives by examining their applications. Another advantage of the OPaFire procedure is that it enables the production of holistic plans based on optimal decisions for large damaged areas. This is particularly useful in areas where the damage is extensive and requires careful planning. Furthermore, the procedure allows for the creation of a coherent road network that is both technically and economically viable. This is crucial for ensuring that the transportation of goods and materials is efficient and cost-effective. In addition, the OPaFire procedure enables the selection of the most suitable harvesting and transport technologies at the site-specific level, which can significantly improve operational efficiency. Moreover, accurate estimates of the amount of labor and machine power needed can be made, which can help to prevent unnecessary expenses. Additionally, the procedure facilitates the optimal determination of landing storage locations, which can help to streamline the logistics process. Lastly, the distribution of labor and machine power to the area can be optimally planned and spatially balanced, and harvest schedules for damaged stands or patches can be developed, which can help to improve the overall productivity and efficiency of the operation.

4. Conclusion

The planning approaches required for tasks such as those related to forest areas or other environmental conservation projects require intensive and precise data. The success of these projects depends heavily on the accuracy of the data gathered, analyzed, and used for decision-making. It is important to note that this type of planning is not a one-time activity but rather a continuous process that requires regular updating of data and information. This requires the collection of relevant data and information about the area, including its topography, soil type, vegetation, and other environmental factors. To ensure that the dataset is comprehensive and up-to-date, it is necessary to strengthen the ordinary dataset in these types of fields, as proactively. In this model, the unusual data of the dataset is based on damage detection. Remote sensing tools can be used to collect data on the extent of damage caused by natural disasters, including the type and severity of damage, and the areas that have been affected. This information can be used to guide the planning process and ensure that the right resources are allocated to the right areas. It is important that we continue to learn about forest areas that are vulnerable to disasters. By doing so, we can avoid repeating past mistakes and improve our ability to respond to future events. In order to be better prepared for salvage logging in high-risk forests, it is necessary to develop operation plans in advance. To further improve our disaster planning capabilities, a pre-constructed planning model should be developed. This model should be regularly updated to reflect changing objectives and constraints, as well as any new data that becomes available.

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Evaluation of the New Generatıon Tajfun Moz 500 Gr Yarders in Turkiye; Operational Costs and Their Contribution to the Sector

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Abstract
Primary transport, which is the initial stage of timber production, is heavily intertwined with technical and economical sensitivities by causing the most environmental concern during timber production. The depth of the environmental concerns, has direct effects over the sustainability of the resources, thus especially in and around the steep and treacherous topography, which majority of Turkish forests reside, utilizing new technological advancements, such as yarders, are becoming more widespread with each passing day. The soil and remaining-stand saving nature of the yarders help save the foresters greatly in work-force and time constraints. However, outdated, but still operational 80s and 90s imported yarders, such as KOLLER-K300 and URUS-MIII, are nevertheless forced to be operated despite being non-economical and plagued with metal fatigue problems, forcing their stationary and variable operational costs high. The purpose of this particular study is to calculate the stationary and variable costs of the recently imported TAJFUN-MOZ 500 GR yarders with 500 m main line and 2500 kg payload capacity and to compare them to those of the older yarders in operation, as well as to show the earnings gained using these state of the art new machinery. Accordingly, stationary costs; depreciation, interest, insurance, operator and helper, and variable costs; fuel, maintenance and lubrication are respectably calculated as 18.94 $/ha and 16.23 $/ha.

Keywords: Primary transport, yarders, improvement, cost

1. Introduction

Turkey resides among 36-42˚ Norther latitudes and 26-45˚ Eastern longitudes. It's real geographical extend reaches 814.578 km^2, however its planar extend is 783.562 km^2. The discrepancy between these two figures comes from the fact that the country is rather mountainous. More than half of the country's land acreage correspond to elevations which are more than 1000 m. above sea level, thus making the average elevation around 1141 m. About one third corresponds to mid-level lowlands, plateaus and mountains and 10 % as low-level lowlands and coastal areas. High peaks are in the East, the Mount Agri (Ararat) being the highest at 5137 m. Nothern Anatolian mountains run parallel to the Black sea coast while Taurus mountains exist in Southern, Eastern and Southeastern part of the country (Figure 1).

Figure 1. Continental placement and geodesic map of Turkiye (URL-2)

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Turkiye with its 78 mil. ha land mass, is an ecologically gifted country. Among this wealth, forests fill a respectable percentage, 29.4% (Figure 2), and generally exist in treacherous topographies. Forests which have been revered for economic, ecologic and socio-cultural amenities, are globally viewed as precious, and every attempt is made to conserve them for sustainable management (OGM, 2021).

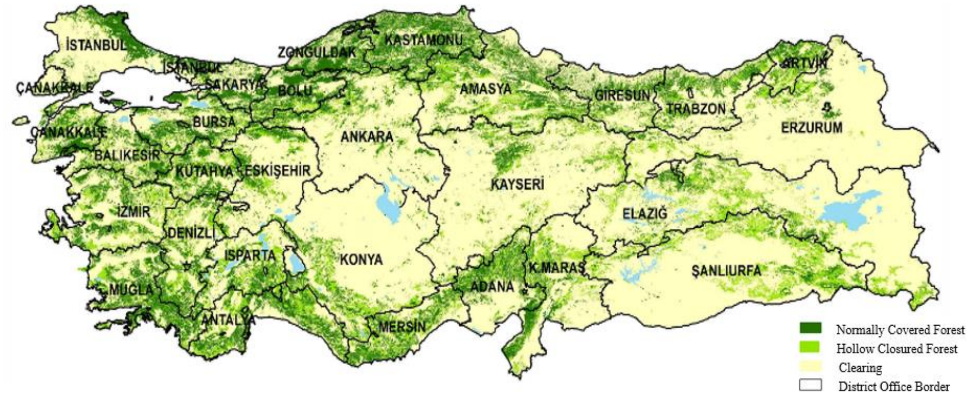

Figure 2. Turkish forests (URL-3)

In this context, the fact that mechanization in forestry is rather important, is better understood so finding suitable means where needed for timer production, become a strategic undertaking for foresters to master (Gul et al. 1999). Yarders for the same reason, are crucial tools in forest management. Whenever the slope of the terrain exceeds 40%, operating yarders become undeniable (Spinelli et al., 2015). They are practically the only solution when it comes to moving the harvested timber upslope or downslope (Erber et al., 2017). Thanks to yarder usage, the negative aspects of other primary transport methods, such as losses in timber quality, soil compaction and unavoidable remaining stand injuries, are minimal, if not non-existing. In the scope of this particular study, new generation TAJFUN MOZ 500 GR yarders imported from Slovenia are evaluated in terms of the technological advancements and high mobility they provide along with the stationary and variable costs to operate them.

2. Material and Methodology

The countries leading the forestry sector, tend to invest in manufacturing modern and complicated machinery, e. g. processor, harvester, forwarder etc. to put into timber production (Ozturk, 2006). On the other hand, in Turkiye, 2x4 and 4x4 farm tractors, tractor tail mounted cable drums and chainsaw modified hand winches, are utilized. Additionally, chutes made from halved corrugated plastic tubes are widely used to extract small-diameter secondary products left over from the timber production (Figure 3). For short distances and less than 40 % gradient, these machinery and means are frequently used, however when the gradient exceeds 40 %, the use of yarders becomes the only solution. Although the tractors and winches are both economic and efficient, they, though unintentional, cause soil compaction and remaining stand injuries (Cambi et al., 2015). Utilization of yarders in steep topography, on the other hand, allows efficiency while preserving the above mentioned adversities.

Figure 3. Tractor variants used in Turkiye and a chute example

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For this study, to be able to show the suitability of the yarders in Turkish topography, a nationwide percent slope map was crafted using Shuttle Radar Topography (SRTM) version 4.1 with 90 m ground sampling. Then, the distribution of this new yarders as reported by the Turkish Forest Service, was showed over the same geography drafted by the administrative boundaries of the regional directories of forestry. Finally, the advancements they will provide as compared to the still operational older yarders were elaborated. Based on the purchase prices, TAJFUN MOZ 500 GR model yarder depreciation values were calculated, so the cost of operating the new machines per work cycle in unit time was determined.

3. Results and Discussion

Figure 4 shows the percent slope distribution and corresponding acreage in km^2 across Turkiye. The amount of forest as reported in a forest service notification (OGM, 2021) was also given within the provinces administrative boundaries in Figure 5.

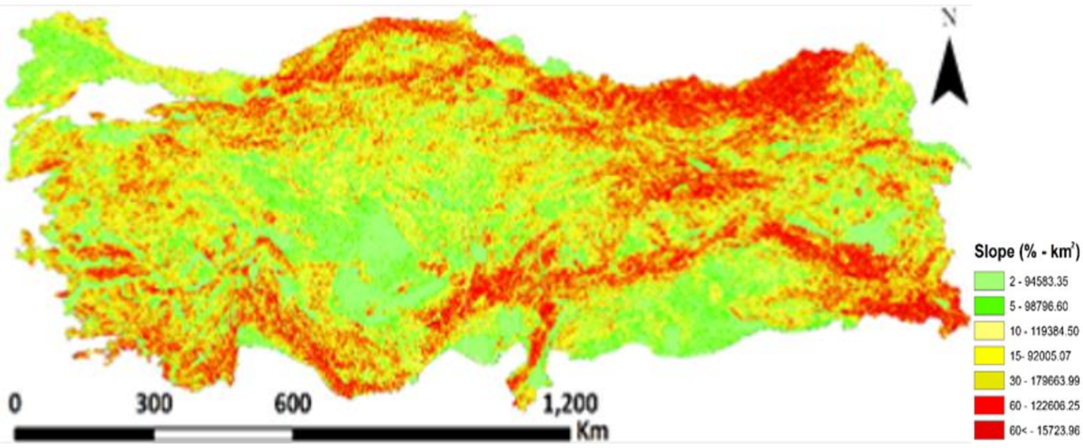

Figure 4. Slope map of Turkiye

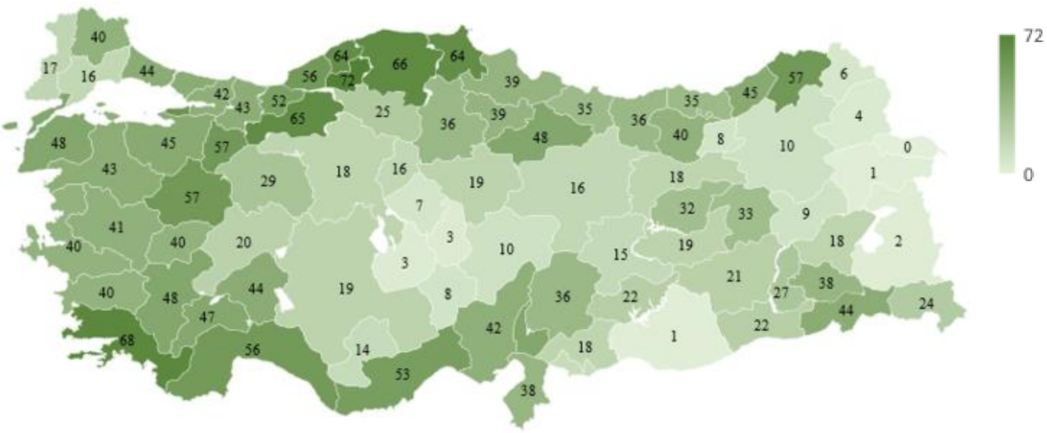

Figure 5. Percent forest distribution per province

Although the above mentioned tractors are widely used in primary transport all across the country, yarders are the number one such means especially in the Northeast (Ozturk, 2004; Ozturk and Senturk, 2010). If one wanted to see the distribution of the currently operational yarders in Turkish forest service possesion, the tally by the brand name and model, is as followed in Figure 6. These yarders in our inventory are the Urus M III medium-haul winch yarder, Gartner long-haul skid-winch yarder, Koller K 300 short-haul mobile winch yarder and the new generation Tajfun Moz 500 GR medium-haul winch yarder (Figure 7).

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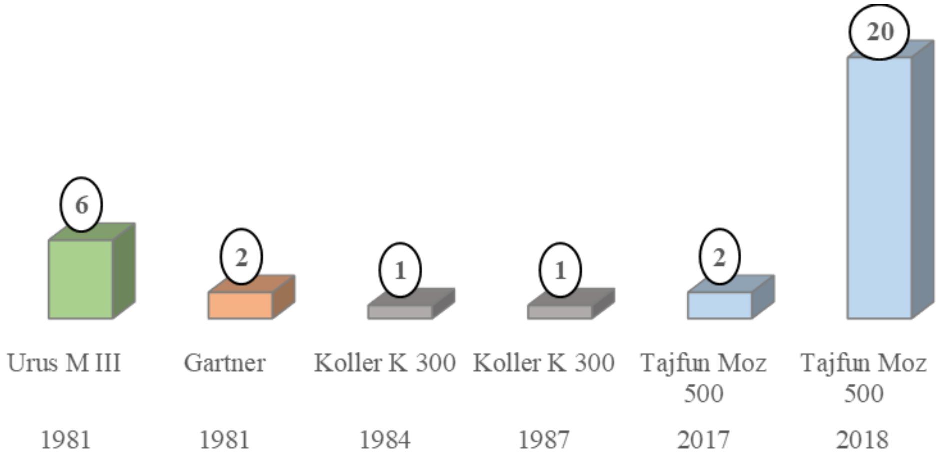

Figure 6. Operational Yarders in Turkish Inventory and Acquisition Dates

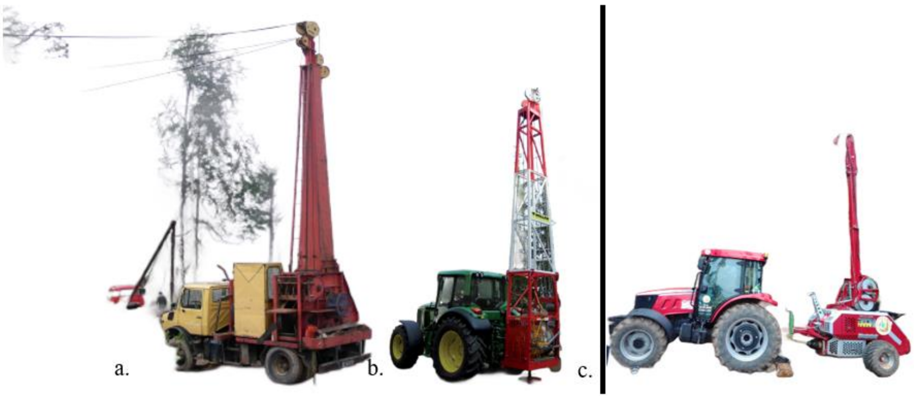

Figure 7. URUS MIII medium distance yarder (a), KOLLER K300 short distance yarder (b) and the new generation TAJFUN MOZ 500 GR yarder

When the operational extents of the current yarders are evaluated, it is obvious that there are 33 yarders which are currently in operation in 14 different provinces, forests of which exist on or over 60 % slope. Especially, in Artvin province where the majority of the province's land mass reside on extreme topography, 15 of such yarders are used to efficiently to log the forests (Figure 8).

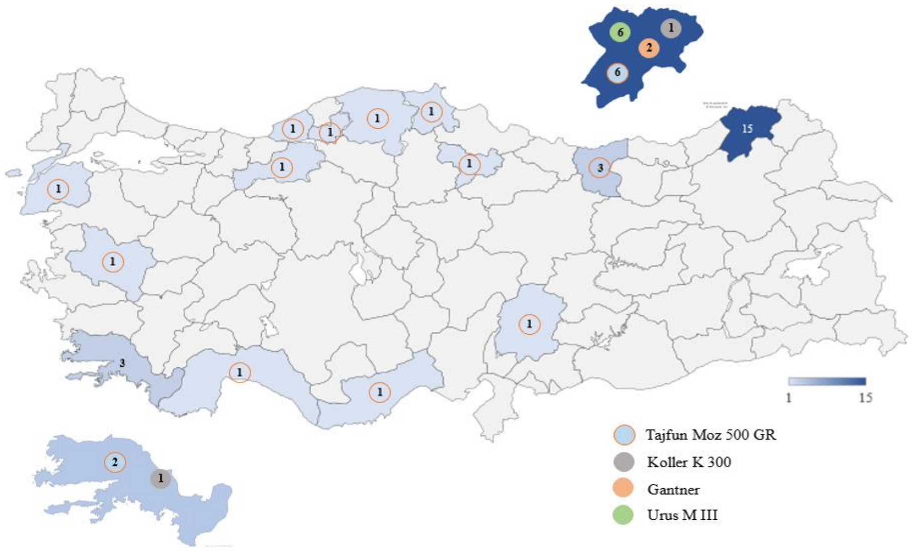

Figure 8. Density and distribution of the currently operational yarders in Turkiye

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Based on the total number of yarders, it is apparent that 69.7 % of them are comprised of the new generation TAJFUN yarders (Figure 9). It is obvious that utilizing environment-conscious new technology will surely help the foresters to perform their logging tasks more efficiently while safeguarding the sustainable forest management principles.

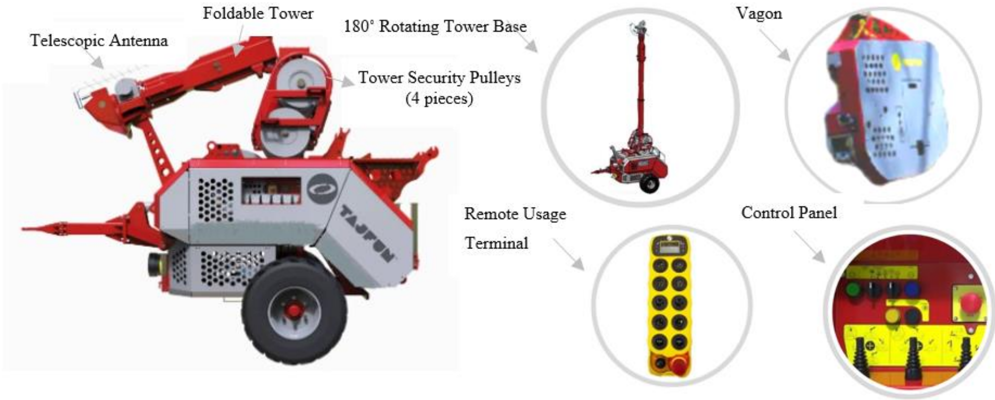

Figure 9. TAJFUN MOZ 500 GR mobile yarder

TAJFUN MOZ 500 GR mobile tower yarders are significantly different from other similarly fashioned machines on grounds of closed circuit hydraulic system supported by a hydraulic motor with full cable pull-back capability directed by a pulley, and another hydraulic motor controlling the main line again directed and positioned with a separate pulley. Foldable tower is very practical for easy transport and positioning in any new site, besides either-way 180˚ degree rotating base helps position the main line in close quarters for easy handling. Two-way radio communication, which is in constant contact up to two remote devices, is very handy for the field crew to guide the fully electric wagon with ease and continue operating safe and comfortable without necessarily seeing the tower. Another innovation is the presence of a disc-brake which dissipates the heat happening during operation better for unimpeded operation. These are the leading features of these yarders making them productive primary transport means in various terrain conditions.

The depreciation value calculated basing on the initial purchase price of each unit, and the cost of per work in a particular cycle time based on the calculated costs are given in Table 1. Stationary costs are viewed and calculated as depreciation, interest, insurance, operator and helper and variable costs are viewed and calculated as fuel, maintenance and lubrication. Accordingly, the stationary and variable costs calculated for operating TAJFUN MOZ 500 GR yarder are 18.94 $/ha and 16.23 $/ha. Besides, when the depreciation period is considered, if leased based on the calculated depreciation value, the lease amount should be 2721 $/month.

Table 1. The Stationary and variable costs of TAJFUN MOZ 500 GR yarders

Purchase price (I)	$ 111,790	
Salvage value (R)	$ 7,987	
Depreciation value (I-R)	$ 103,803	
Depreciation period (N)	10 years or 20000 hours	
Average investment A=2[(I-R).(N+1)/2N]+R	$ 122,171	
Interest	10 %	
Stationary costs	**$/h**	**$/min**
Depreciation (I-R)/20000	$ 5.19	1.62
Interest (A).0,10/2000 hours	$ 6.10	1.91
Insurance and other costs (I).0,03/2000 hours	$ 1.67	0.52
Operator wage (Wage x 12 months)/2000 hours	$ 3.32	1.04

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Helper wage (Wage x 12 months)/2000 hours	$ 2.66	0.83
TOTAL (1)	**$ 18.94**	5.94
Variable costs		
Fuel	$ 6.43	2.01
Maintenance (I-R).%100/20000	$ 5.19	1.62
Lubrication	$ 4.61	1.45
TOTAL (2)	**$ 16.23**	6.55
OVERALL TOTAL (1+2)	**$ 35.17**	

Besides, Acar et al. (2022) when evaluated the performance of this yarder, found out that hourly productivity was 8.39 m^3/h. When compared to Table 2, by Hatay (2014), the evaluation regarding the older yarders' performances showed that TAJFUN MOZ 500 GR could easily outperform the best recorded value of older yarders in Turkish inventory.

Table 2. Productivity Results of the Older Yarders in Operation (Hatay, 2014)

Yarder Type	**References**	**Yarder Model**	**Skidding Distance (m)**	**Slope (%)**	**Capacity (m^3/h)**
Short Distance	Degirmenci (2007)	Koller K300	200	70	5.333
	Caglar and Acar (2005)	Koller K300	250	75	4.825
	Caglar (2002)	Koller K300	280	78	4.967
	Aykut et al. (1997)	Koller K300	170	68	2.19
	Eroglu (1997)	Koller K300	200	50	4.614
	Eroglu (1997)	Koller K300	175	50	5.529
	Eroglu (1997)	Koller K300	190	56	4.852
	Ozturk (2003)	Koller K300	300	45	5.151
	Ozturk (2003)	Koller K300	220	64	6.27
	Ozturk (2003)	Koller K300	290	40	6.256
	Erdas and Acar (1995)	Koller K300	300	50	7.834
	Erdas and Acar (1995)	Koller K300	150	70	3.499
	Erdas and Acar (1995)	Koller K300	250	-	3.75
	Pollini et al. (1989)	Koller K300	-	90	6.625
AVERAGE			**212.5**	**57.6**	**5.12**
Medium Distance	Degirmenci (2007)	URUS MIII	400	60	4.713
	Caglar (2002)	URUS MIII	600	49	4.268
	Aykut et al. (1997)	URUS MIII	242	45	8.63
	Ozturk (2003)	URUS MIII	500	55	7.872
AVERAGE			**435.5**	**52.3**	**6.37**
Long Distance	Degirmenci (2007)	Gantner	1300	65	6.098
	Caglar (2005)	Gantner	1200	78	4.161
	Aykut et al.(1997)	Gantner	673	65	4.56
	Aykut et al. (1997)	Gantner	900	64	5.81
	Ozturk (2003)	Gantner	1400	55	3,4
AVERAGE			**1094.6**	**65.4**	**4.81**
OVERALL AVERAGE			581	58	5.43

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4. Results and Recommendations

Utilization of yarders is important if the operation is carried out in treacherous topography in vast geographies, if the soil, the next generation seedlings and the remaining stands are responsibly cared for and if worker comfort and safety are prioritized, when the topographic conditions, forests' presence and the timber harvesting work-load are considered in Turkiye. Gantner, URUS and KOLLER yarders have been in operation for quite some in Turkiye (Ozturk, 2006). When skidding distance is considered, the ideal distance where the yarders are put into the operation, was reported as medium (Erdas, 2008). This determination paved the way for the acquisition of TAJFUN MOZ 500 GR yarders while saving labor and time, considerably and improving the production capacity.

Hatay (2014) showed while studying in Northeastern Turkiye that the engine power of the yarder should at least have been 50 hp. or more, whereas the wagon's carrying capacity should have been no less than 2900 kg. Additionally, as the skidding or transporting distance grown, the need for more engine power significantly increased the operating costs of the yarders. TAJFUN MOZ 500 GR mobile yarders with 500 m main line distance, 2500 kg payload and minimum 105 hp. capable tractor coupling capability could very well be the ideal solution in Turkiye conditions. Besides, the additional amenities already mentioned as coming with them still allows the integration of newer technologies.

5. Conclusion

Especially in countries where the forests reside around steep and treacherous topographies, mobile yarders have considerable advantages in primary transport of harvested logs. A new addition to the long list of name brands, TAJFUN MOZ 500 GR is a competitive and compact new yarder, worth investing.

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Oral Presentations

A faith-based Approach to Drug Abuse in the Forest Products Industry

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Abstract
The forest products industry has struggled to maintain adequate workforce levels in recent years. An important and largely unspoken contributor to this trend is the impact of drug abuse in rural communities. Not only does drug addiction affect the health of a worker, but it can also influence the risk of serious injury or death on the job. This presentation will cover the impact of drug abuse in the logging and wood processing industries in West Virginia and its surrounding states. Findings will emphasize practical approaches to target this serious public health and workforce safety issue, including the role of a faith-based approach. Through a qualitative lens, this presentation will highlight the lived experience of a logging and mill safety professional who also serves as a drug addiction recovery coach for those working in the industry. Several case studies will be presented. We will discuss the extent to which the issue permeates the forest products industry, the role of faith in rural Appalachia, the signs of drug abuse, the impact of drug abuse on workplace safety, the role of Narcan in the workplace first aid kit, options for treatment, and how to support employees with addiction issues.

Keywords: Forest products, drug abuse, addiction

Oral Presentations

Determining Facial Validity of a Forest Harvest Simulation

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Abstract

Simulated environment in this context is a 3-dimensional representation of the forest harvest unit complete with trees, roads, streams, slopes, and selected harvest machines. People viewing simulated environment experience it as resembling reality (facial validity), however, this does not mean the underline algorithms generating the simulation are faithfully reproducing real world physics. What is important in the simulation for an educational application in teaching forestry harvesting is that the closeness to reality of the simulation output captures the essential features of the real environment that elicit practical actions from the people viewing it. Harvest unit design and logging are closely related; however, that the harvester simulators have been found to be facially valid for logging does not necessarily mean they are facially valid for harvest unit design. This study contrasted the performance limits for the cut-to-length machines in the John Deere simulator system with expert opinion to ensure the performance limits given for developing a harvest plan for commercial thinning are consistent with the simulated environment that subjects review and are sufficiently challenging to require tradeoffs to be considered. The facial validity of the simulated environment was examined based on slope limits provided by the expert from logging industry in Oregon, and reach limits determined from videos of an experienced operator working in the simulated environment. Though the simulator has stability limits that are potentially greater than the real machine, when the simulator is operated by an expert operator, we conclude that it is sufficiently similar to the real machine that the slope limits of 30% adverse, 40% favorable, and 15% side slope provided by the expert operator are suitable for developing harvest plan for commercial thinning using forwarder and harvester combination. While considering 11.7m maximum design reach limits for the harvester provided by John Deere equipment manufacturer and the results from expert videos, we conclude that the 11m reach and 22m are reasonable trail spacing in the design of a trail system and are sufficiently similar to those of a harvester working in the real world.

Keywords: Facial validity, forest harvest, simulation

Oral Presentations

Multi-Faceted Approach to Addressing Idaho's Logging Sector Workforce Challenges

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Abstract
For over 100 years the University of Idaho has equipped forestry professionals to address the complex challenges facing the sustainable management of our forestlands through our 4-year forestry programs. Although the B.S. degree has been highly successful preparing professional operations foresters in the western US, current and future workforce deficiencies have become a persistent topic of concern for the forest products industry. Training of the logging workforce has historically occurred primarily through on-the-job training. Unfortunately, increased challenges associated with recruitment and retention have yielded an insufficient number of employees. Extensive communication with industry and agency stakeholders has led the University of Idaho to pursue new workforce development opportunities at various levels. These efforts target recruitment and outreach, K-12 career and technical education, equipment operator training, and continuing education programming. Taking this wholistic approach creates a roadmap with multiple on-ramps and training pathways. Increased public education and outreach related to the logging industry and professions have yielded positive results and continue to build momentum. The launch of a new Forest Operations and Technology A.S. degree offered through the University of Idaho is gaining traction. Acquisition of modern, cutting-edge mechanized logging equipment on the University's 10,000+ acre working Experimental Forest synthesizes teaching, training, and outreach that is coupled with emerging smart and precision forestry research. Further, significant collaboration and cooperation with industry stakeholders continues to drive additional efforts related to K-12 CTE as well as stand-alone operator training pathways independent of the A.S. degree. By embracing our social contract with Idaho citizens and communities, our multi-faceted approach is helping address logging sector and greater forest products industry needs.

Keywords: Logging sector, multi-faceted approach, workforce challenges

Oral Presentations

Developing a Strategic-and-Sustainable Business Plan for the Forest Operations Training Program in Northern Arizona

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Abstract
Wildfires are a problem and have been getting progressively worse, especially in the American West. Wildfires have been getting worse in part due to climate change, to misjudgments in forest management policies, and to increasing human pressure on the forests. In order to deal with this problem, the Forest Service has developed both a strategy and an implementation plan. The plan calls over the next ten years to increase forest treatments on National Forest System lands by up to 20 million additional acres and by up to 30 million acres on other Federal, State, Tribal, and private lands. In addition, the Forest Service intends to develop a plan for long-term maintenance beyond the initial 10 years. But in order to implement this plan, a trained workforce is needed. The Ecological Restoration Institute at Northern Arizona University is taking the lead to create a forest operations training program with three career paths for its students: forestry equipment operators, truck drivers, and heavy equipment maintenance and repair professionals. The program is being set up in conjunction with Coconino Community College and Yavapai Community College along with other partners and stakeholders. To establish this program a sustainable business plan is being created based on a set of linked Excel-based workbooks that will allow analysis of the individual career path streams as well as an analysis of the overall program over a 20-year time horizon. The workbooks show sensitivities of program cash flows to key costs and revenues. They may be used to help develop pro forma budgets and for strategic long-term planning. The workbook structure is flexible, so that the set may be used to analyze and help to establish additional forest operations training programs elsewhere. The Excel-based workbook model will be discussed, along with preliminary results, key costs and revenues, and considerations when developing such a training program.

Keywords: Business plan, forest operations, training program

Oral Presentations

The Need for A Chainsaw Safety Training Program for Female Forest Landowners

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Abstract
Chainsaw safety training programs are often geared towards the professional logger and chainsaw users with a fair amount of experience. A population of private forest owners that is emerging and increasing in numbers are female forest landowners (FFLO). FFLO have been marginalized in technical training programs in the past and current chainsaw training programs, if available, often do not suit the needs of this population. We conducted chainsaw safety training programs geared towards FFLO and compared program evaluation results with results from male-dominated chainsaw training workshops. FFLO are limited in their technical knowledge at the beginning of a workshop, are more likely to own different types of chainsaws than male participants, and generally liked having a women-only workshop. However, few chainsaw safety training programs are available to private forest owners, and even fewer are geared towards female forest owners. There is an opportunity for forest operations specialists and logging businesses to establish training programs for private forest owners, as demand for this workshops is often surpassing workshop capacity.

Keywords: Chainsaw, safety, training program

Oral Presentations

Assessing the Potential for Exoskeletons (wearable assistive technology) in the Forestry Sector

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Abstract
Forestry workers suffer from a high prevalence of both fatal and non-fatal (i.e. musculoskeletal disorders) injuries. Timber felling, in particular, is a leading injury cause among other logging and in-woods forestry work. Although timber harvesting is becoming more mechanized, manual timber felling may not be completely avoidable, especially in steep rugged terrain inaccessible to harvesting machines. Manual timber felling with a chainsaw is an extremely physically demanding job that poses various physical risk factors, including forceful exertions, awkward postures, and repetitive motions. Despite such physically demanding nature, there is a lack of research that objectively quantify physical risks of injuries during regular timber harvesting activities. Therefore, using wearable sensors, this study objectively quantified biomechanical stress while 10 professional timber fellers performed their regular work in the field. Our results showed that manual timber felling posed substantial shoulder and low back strain due to various awkward postures. These physical stress measures can be alleviated by passive exoskeletons that have been recognized as an effective ergonomic control to reduce the physical risk factors in various industries, but these exoskeletons have not been examined for use in forestry. Another objective of this study was to examine forestry workers' awareness and acceptance of exoskeletons using an online questionnaire, and identify potential barriers/risks to implementation of exoskeletons in the forestry industry. The results showed that while the forestry workers were not familiar with exoskeletons, they expressed considerable interest and acceptance level in exoskeleton use in the forestry industry. The important factors of the exoskeletons included weight, comfort, and simplicity/portability. The results identified timber felling, cutting/sawing, and mechanic work as potential forestry tasks that may benefit most from the exoskeleton use. This study provides important evidence for the feasibility and readiness of exoskeletons in the forestry industry.

Keywords: Exoskeletons, forestry sector, wearable assistive technology

Oral Presentations

Challenges and Needs of Minority, Beginning, and Young Logging Business Owners in North and South Carolina

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Abstract
Across the United States, the forest industry and landowners rely on thousands of individual logging businesses to harvest and supply timber. Logging business surveys are prevalent across several states in USA, with the motive of understanding the logging industry and its present state. Within the logging industry, multiple groups of loggingbusiness owners exist (e.g., minority, young, and beginning owners), each with unique challenges and needs. We are conducting in-person and telephone interviews with MBY (Minority, Beginning, and Young) logging business owners in North and South Carolina to better understand where they stand in this industry today and the challenges, they have experienced. We are aware that established businesses will phase out over time and that MBY logging business owners are important for the future of the logging industry. Our survey collected information on the general business characteristics, owner's background, perception of challenges and future outcomes, access to capital, and future plans of MBY logging business owners. So, far we have interviewed six logging business owners. Our preliminary results show 66% of MBY loggers don't have any family history in the logging industry before starting their businesses. Some major challenges were difficulty in receiving financial aid for the business and racial discrimination within the logging industries. However, the strong will of loggers wanting to stay in their businesses despite the challenges shows their determination towards their logging jobs. We are hopeful of receiving meaningful information as we move along with more surveys that can give us more insights into the current MBY loggers and their businesses and these important findings will be discussed in the presentation.

Keywords: Forest harvesting, logging business owners, MBY

Oral Presentations

Workload Evaluation of Forest Logging Equipment Operators in the Southern U.S.

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Abstract
The southern United States account for approximately 40% of the productive timberland in the United States and produce around 16% of the global industrial wood. Although the timber production is high in South Carolina and surrounding states due to increased mechanization of forest logging over time, there are only few crew members in each logging crew, which can cause a higher workload for individual operators. The use of heavy and complex machineries for logging increases the efficiency of timber harvesting, however, the extensive use of these machineries for long durations increases the cognitive demand of the machine operators. The variation in factors such as site and weather conditions at each logging site can also affect the mental workload. Working under demanding conditions can decrease the health of forest equipment operators over time, reducing the productivity of individual operator. This study aims to provide an initial assessment of the workload of logging equipment operators during timber harvesting operations using conventional wheeled feller-buncher, grapple skidder, and knuckle-boom loader harvesting systems by assessing the subjective workload of the logging equipment operators and to observe heartrate variations to evaluate mental workload associated with the observed activities. The subjective workload was studied using the NASA Task Load Index survey for the six dimensions of mental, physical, and temporal demands, performance, effort, and frustration for multiple logging crews in North and South Carolina. Heartrate was measured using Polar Verity Sense Model 4J optical heartrate sensor worn on the lower arm. Videographic information was collected on operator activities in parallel with the heart rate sensor. Results show that the subjective workload for each machine operator under different site conditions varies, with some of the highest changes observed for the feller-buncher operators. Further, skidder operators showed a high level of frustration due to equipment limitations. Sudden heartrate increases, indicating increases of mental stress, were observed when operators were conducting specific activities such as working with hardwood and softwood trees as well as doing physical activities.

Keywords: Equipment operators, logging operations, workload

Oral Presentations

Factors Associated with Injury Among Maine Logging Workers

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Abstract
Despite dramatic improvements in safety, logging remains one of the most dangerous industries in the United States. The purpose of this study was to explore longitudinal injury trends among Maine logging workers. Loggers participated in seven quarterly surveys, over the course of eighteen months. Categorical and free text data related to traumatic and acute injury, musculoskeletal disorders (MSD), and chronic pain were exported from REDCap into SAS 9.4, Excel, and NVivo, for quantitative and qualitative analysis, respectively. Time to injury was modeled using two different approaches: 1) time to the occurrence of first injury modeled by proportional hazard regression and 2) an intensity model for injury frequency. Two research team members also analyzed qualitative data using a content analysis approach. During the study, 204 injuries were reported. Of the 154 participants, 93 (60.4%) reported musculoskeletal pain on at least one survey. The majority of injuries were traumatic, including fractures, sprains, and strains. Lack of health insurance was found to be related to increased risk of first injury [HR=1.41, 95% CI=0.97-2.04, p=.069]. Variables found to be related to injury intensity at the univariate level were: 1) a lack of health insurance [HR= 1.51, 95% CI=1.04-2.20, p=.030], 2) age [HR for 10-year age increase=1.12, 95% CI=0.99-1.27, p=.082], and 3) years employed in logging industry [HR for 10-year increase =1.12, 95% CI=0.99-1.26, p=.052]. Seeking medical attention for injury was not a priority for this cohort, and narratives revealed a trend for self-assessment. We found that loggers still experience serious, and sometimes disabling, injuries associated with their work. It was unsurprising that many injuries were due to slips, trips, and falls along with contact with logging equipment and trees/logs.Entrenched values that prioritized independence, traditional masculinity, and financial considerations were consistently cited as a barrier to adequate care. There is a continued need to emphasize occupational health and safety in the logging industry. Implementation of relevant safety programs is key, but it is likely that the benefits of these will not be fully realized until a cultural shift takes place within this industry.

Keywords: Dangerous industries, injury, logging workers

Oral Presentations

Chainsaw Operator Use of Personal Protective Equipment in Indonesian Natural Forest Concessions

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Abstract
Tree felling with chainsaws is a dangerous occupation rendered even more so when workers do not utilize the recommended personal protective equipment (PPE). Despite regulations in Indonesia that require fellers to use PPEs, workers often do not comply, even in Forest Stewardship Council-certified operations. This study analyses the impediments to using PPEs (i.e., safety boots, felling chaps, reflective vests, gloves, helmets, and eye and ear protection). In 2020-2022 we visited 10 concessions in Kalimantan and 1 in Papua to observe and interview tree fellers (N = 48). We also interviewed supervisors and forest managers to discuss issues related to PPE use. Fellers often wore boots (N = 48), helmets (N = 44), and gloves (N = 42) but less often wore reflective vests (N = 10), ear protection (N = 7), felling chaps (N = 3), and eye protection (N = 2). Although all 11 concessions required fellers to use all these PPEs, workers were not provided felling chaps in 6, reflective vests in 3, eye and ear protection in 3, and boots and gloves in 2 of the concessions. Only four concessions provided workers with all the required PPEs. FSC-certified concessions (N = 7) were more likely to provide all required PPEs, except felling chaps, but we observed workers not wearing all of them when felling. While workers in concessions logged by subcontractors (N = 3) only received gloves and no more likely to use PPEs. There was no relationship between worker age and PPE use, but more experienced workers were more likely to wear gloves. Many excuses were offered for not employing PPEs of which the most common were that hearing protection increases the risk of being hit by fallen branches or trees (N = 17). We recommend frequent safety training, regular monitoring by logging supervisors, and trying out different brands/styles of PPEs. Worker safety in the Indonesian forestry sector clearly remains a challenge that could met with better enforcement of labor laws by the government and more rigid adherence of forest auditors to the principles and criteria of certification schemes.

Keywords: Chainsaw operator, forest operatons, personal protective equipment

Oral Presentations

The Trend of Occupational Injuries and Fatalities in Forestry South Korea from 2010 to 2020

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Abstract
The forestry activities, principally in timber harvesting, have been considered one of the most dangerous occupation accidents and fatalities in all industry sector because of harvesting activities on steep terrain and extreme weather conditions in remote areas. In South Korea (hereafter Korea) occupational accidents and fatal injuries have been a crucial challenge for Korean forestry sector over the past decades. Although fatal injuries have declined about 63% during 2010–2020 period (11-year), the number of occupational accidents is increasing compared to other sectors. In addition, Serious Accidents Punishment Act emerged in January 2021, that the target for fatal injuries reduction. Therefore, the objective of the study is to investigate the latest trends and risk factors related to incidence of work-induced injuries in forestry sector. To evaluate the current trend occupational injuries and fatalities for the period from 2010 to 2020, we used databases of the Korea Occupational Safety and Health Agency's internet homepage, where the raw data are easily accessible for downloading. During the analyzed period, the highest number of workplace accidents occurred in timber harvesting and silviculture operations. The number of occupational accidents in "amputation and laceration", and "slip and trip" groups were increasing than other. The results can be an important knowledge to reduce occupational. Further, our results may provide forest workers (also called logger) with information to make mitigation strategies for occupational safety and health issue.

Keywords: Forestry, occupational injuries, fatalities, injuries

Oral Presentations

Full-Cost Accounting Remeasurement of the 2010 Schultz Fire: Understanding the Long-Term Socio-Economic Implications of High-Severity Wildfire and Post-Wildfire Flooding

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Abstract
The Schultz Fire was ignited by an abandoned campfire on June 20, 2010, and burned 15,075 acres northeast of Flagstaff, Arizona. Following the fire, intense monsoon rains over the burned area produced heavy flooding that resulted in extensive damage to properties in neighborhoods downstream from the fire, as well as one death. A full-cost accounting of the 2010 Schultz Fire and post-fire flooding was conducted in 2013 to capture initial damage over a three-year period. This analysis builds on and revises the 2013 study to derive a ten-year full-cost accounting. This multi-year analysis is a unique contribution to the understanding of the long-term economic, ecological, and social effects of a major fire and post-fire flooding. Events like the 2010 Schultz Fire and post-fire flooding can have long-lasting effects that often go undocumented. These include long-term financial costs, but also effects that are more difficult to quantify, such as those to local ecosystem services and societal costs like community well-being. Long-term studies, such as this one, that provide a unique look at the ongoing costs of a major wildfire are important to understand the true scope and scale of the effects of uncharacteristic wildfire and post-fire flooding. Studies such as this can provide further justification for the importance of proactive forest restoration and fuel reduction treatments to reduce the risk of uncharacteristic wildfire to ecosystems and communities.

Keywords: Flooding, post-wildfire, socio-economic implications

Oral Presentations

An Arizona Flood Control District's involvement in Forest Restoration

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Abstract
The Coconino County Flood Control District (FCD) is charged with reducing the risk of flood loss, minimizing the impact of floods on human safety, health and welfare, and restoring and preserving the natural and beneficial values served by floodplains. Much of the watersheds that feed into these floodplains originate on National Forest lands in Coconino County. Past management and grazing activities coupled with the practice of suppressing all wildfire on National Forest lands has produced uncharacteristically dense forest conditions on much of the landscape. Dense, suppressed tress in the understory form a fuel ladder, through which flames can climb to the forest canopy, creating catastrophic wildfires that burn hotter than normal. These "hot" fires cause the soils to become hydrophobic, where the soils repel water, reducing the amount of water infiltrating the soil, which can result in increased erosion and quicker stream flow delivery increasing the potential for flooding. The FCD has experienced first-hand the impacts of wildfire and post-wildfire flooding following the Schultz Fire on the east side of the San Francisco Peaks in 2010, where the post-wildfire flooding resulted in one death and millions of dollars to repair the watersheds and communities. In, 2017, the Coconino County Board of Supervisors identified catastrophic wildfires and post-wildfire flooding as the number one public safety risk for our citizens, communities, and County. In response, the Board of Supervisors approved the creation of the Forest Restoration Initiative within the FCD to serve as an important facilitator and liaison – linking county interests and assets with broader regional restoration efforts and opportunities. One aspect of the Initiative is to use scientific data to analyze potential post-wildfire flood threats within Coconino County and to develop partnerships with other government agencies, non-governmental organizations (NGO's) and private industry to determine priorities of forest restoration projects while finding funding mechanisms to implement those projects. This science has been instrumental in assisting the FCD in identifying critical areas to treat, as well as in responding to multiple post-wildfire flood events since the Schultz Fire in 2010.

Keywords: Flood, flood control, forest restoration

Oral Presentations

Reverse Logging in Northern Arizona

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Abstract
Restoration Forest Products, LLC (RFOR) is a vertically integrated logging, trucking, and sawmill operation working to restore the forests of northern Arizona by consuming the small diameter timber that is prevalent in the area. With forest restoration, as opposed to traditional "logging", RFOR hasadapted to the smaller diameter profile of the forest inseveral ways and designed the system to account for "negative value timber" as well as more merchantable specifications of larger diameter stands. With a "sticks per load" count of 100 to 130, it is imperative that the operations are as efficient as possible given the additional harvest, processing, skidding, and loading times that come from this diameter class. Where innovations in operations and technology are approved for use by the USFS, such as Designation by Prescription (DxP), RFOR has embraced the new technology with open arms to try and innovate and find the efficiencies that exist in the newer systems. Pairing our adaptability to new systems such as DxP with the execution of existing designation and whole tree harvest systems (e.g., with Leave Tree Marking), RFOR has found efficient operations are possible within both, and have a similar operational pace and scale. One of the largest challenges faced in restoring the smaller diameter timber is adding enough value to the "negative value" in order to bring it to a point of break even, or positive value. This is primarily accomplished thru the Engineered Wood Products (EWP) line at RFOR's Bellemont, AZ facility. This EWP system can take defect out of the small diameter wood and rejoin it into clear boards, or other qualities as the marketallows, to create sustainable forest restoration strategies that benefit both local ecological and economic systems.

Keywords: Forest products, reverse logging, Arizona

Oral Presentations

Carbon Footprint of New Zealand's Logging Operations

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Abstract
The forest industry is experiencing the early stages of pressure to measure and report their carbon footprint. Currently, there is little research on the emissions produced by harvesting operations or options for crews to reduce emissions. This report provides carbon footprint estimates for harvesting crews in New Zealand. It demonstrates a simplified methodology for emissions reporting, outlines the potential advantages and disadvantages for forest managers and harvest crews to measure emissions. For reporting carbon footprint, an important step is to set the 'scope'. The Scope defines the extent that carbon is included or excluded in the analyses. 'Scope 1' has been used and specifically focuses on 'direct GHG emissions and removals'. For logging operations, fuel use is expected to contribute to well over 90% of the total carbon footprint under Scope 1. Hence the focus was on the collection of fuel use data primarily through a survey of forest managers and crews. The data collected included 30 ground based, 13 swing yarder and 12 tower yarder crews with an average number of machines of 4.8, 8.1 and 7.4. Fuel use ranged from 1.2 - 11.2 L/m3 (average of 3.67) for ground based, 2.8 - 9.1 L/m3 (4.3) for swing yarder, and 2.0 - 11.3 L/m3 (5.0) for tower yarder crews. Carbon footprint is reported in tonnes of CO2 equivalent (tCO2e), and a published fuel to CO2e conversion factors are used. The highest carbon footprint both per annum and per m3 logged were the tower yarder (hauler) crews, with an average of 920 tCO2/annum and 14.5 kgCO2e/m3 respectively. Swing yarder crews averaged the next highest (770 tCO2/annum and 12.4 kgCO2e/m3) with ground based resulting in the least (685 tCO2/annum and 10.5 kgCO2e/m3). The key benefits of GHG reporting were to prepare for potential disclosure requirements, potentially reduce costs long term, have better investment/financing opportunities and help reach the nation's net-zero targets. The negatives were costs, time, and reporting not necessarily making reduction action occur.

Keywords: Carbon footprint, forest industry, logging operations

Oral Presentations

An Analysis of Forest Harvesting Duration

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Abstract
Timber harvesting operations in West Virginia are characterized by a diverse number of hardwood species, product types, and even silvicultural systems. The average unit size is about 73 acres and almost all harvesting is completed using ground-based harvesting methods. All timber harvest activities are reported to the State Division of Forestry, who then provides assistance with and enforcement of the State's Best Management Practices. A study was completed to analyze the duration of timber harvest activities on over 51,000 timber operations using the State's notification data, dating back to the year 2000. With all durations normalize based on the number of acres harvested, we report annual differences as harvesting technologies related to the trend towards more mechanized harvesting activities. Additionally, differences based on the harvesting prescription used, such as uneven aged, even aged, fixed diameter, or landowner choice are analysed and significant differences are reported. Results from this study provide all parties involved in a timber harvest transaction a better understanding of the number of days that are involved in different sized operations within the state and discusses many of the constraints, challenges, and opportunities that harvesting operators face timely completing harvesting units.

Keywords: Forest harvesting, duration analysis, best management practices

Oral Presentations

An Evaluation of the Erosion Potential and the Implementation of Best Forestry Management Practices in the Southeastern US

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Abstract
Biomass for energy may result in a greater use of forest residues. Increasing the use of logging residues will reduce the amount of biomass retained in the soil and could result in soil erosion. This study evaluated 29 operational harvests in the Coastal plains of Alabama, Florida, and Georgia, comparing erosion rates and BMP implementation status. The clear-cut areas were divided into 6 operational categories (harvest area, roads, skid-trails, SMZs, decks, and stream-crossings) and the Universal Soil Loss Equation Forest method (USLE-Forest) was used to estimate the potential erosion within each operational category. BMP audits were conducted following the BMP implementation guidelines of each state. Results showed a slightly higher mean erosion rate from biomass harvests, however, the two-sample t-test resulted in no significant differences (P-value = 0.111). In both Biomass and Conventional harvest sites, there was a significantly higher erosion rate from roads compared to other categories (p-value < 0.05). However, the erosion rates were not significantly different between Biomass and Conventional harvest sites according to the operational categories. The overall BMP implementation rate in both Biomass and Conventional harvest sites was more than 90%. The correlation between BMPs and weighted average erosion was -0.376. This is based on the preliminary results of the study, and the results of the complete study will be presented at the meeting.

Keywords: Erosion, forest management, best forestry management practices

Oral Presentations

Use of Drones to Assess Forestry Best Management Practices at Biomass Harvest Sites

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Abstract
The use of drones to monitor environmental mitigation efforts is an area where research seems to be lacking. There was a limited number of studies that investigated the applications of drones for surveying and monitoring forestry best management practices (BMPs). Sites where biomass was collected or harvested and other clearcut sites are well suited to be analyzed by drone due to the lack of canopy blocking the capture of ground features within the harvest area. In this study, a drone is used to collect imagery in addition to on the ground BMP sampling to determine the suitability of using a drone for the assessments of BMPs. The results from the ground sampling are compared to the drone imagery. After the collection of the data in the field with the drone, data can be transferred to a computer for further manipulation. Pix4Dmapper is then used to create Orthomosaics and Digital Surface Models (DEMs) that can be used for analysis within ArcGis Pro. With hydrology tools such as Flow Accumulation the effectiveness of BMPs within the harvest area can be assessed. These processes may be improved with the addition of machine learning which could help with the delineation of surface features such as skid trails, brush piles and landing areas. Preliminary data seems to indicate that drones are well suited for the task.

Keywords: Biomass, drone, best management practices

Oral Presentations

Thinning as a Tool to Increase Resistance to Stressors in the Interior of British Columbia

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Abstract
Commercial thinning (CT) is a versatile and widely implemented mid-rotation silvicultural treatment. Despite the multiple benefits associated, foresters find challenges in implementing CT for multiple reasons, mostly related to the profitability of the operations. In the interior of British Columbia, Canada, fibre supply shortages are a current reality and the interest in CT is high, but at the same time, there is a lack of sufficient scientific knowledge of CT operations. In this research, we study the productivity and cost of common approaches to CT operations in mixed conifer stands and residual stand damage. Following, we will study cutting-edge CT technologies and harvesting layout by transferring know-how from other jurisdictions and compare the results and evaluate the implications again on productivity and residual stand dam age. A combination of direct observations with machine on-board-computer data, LiDAR and forest inventories to precisely measure the productivity of the operations and identify the main factors that influence productivity. The final result will be a cost-benefit analysis of CT operations to quantify and help inform how CT can be used as a tool to increase resistance to fires, drought, eruptive insects and windthrow while providing multiple values in British Columbia.

Keywords: Thinning, stressors, British Columbia

Oral Presentations

Restoring a Globally Threatened Forest Ecosystem- a Logging Solution

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Abstract
Atlantic white cedar forests have declined by 90 % across its natural range along the eastern United States since colonial settlement. That decline continues from weather, storms, wildfire and beaver flooding! Without restoration intervention this unique and valuable wetland forest resources will be lost! Restoration of white cedar requires specialized logging techniques did to its location on wetland muck soils! The science for cedar restoration is well understood at this juncture! This presentation will show how integration of active forest management is the only answer to saving the ecosystem! Specialized harvesting tied directly to local markets that would support local economies and the cultural heritage of the Pinelands National Reserve is the key to success to prevent the loss of this forest ecosystem! The largest single successful restoration in north America of this species will be used as the demonstration for the pathway to success both ecologically and economically!

Keywords: Forest ecosystem, logging, restoring ecosystem

Oral Presentations

Developments, Challenges and Opportunities Unique to Steep Slope Harvesting in the Southern and Central Appalachians

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Abstract
The southern and central Appalachians host conditions that must be understood to see advanced or alternative harvesting systems successfully deployed. Terrain specific nuances include access, slope length, brokenness, and road cost. Stand variability is typical across tracts with tree height, stem density, volume/acre and value/acre fluctuation. Stem diameters on a tract can range from 8 to 38 inches, the harvest prescription can vary just as widely. Ownership includes private industrial and non-industrial, federal, and state owned. Typically, average tract size and harvested volume per tract is low with negative effects on mobilization costs. Slopes often exceed 50%, slopes greater than 80% are common. Adverse weather is found throughout the year with periodic rainfall throughout all seasons and no dependable frozen ground. Regional steep slope mechanization in recent decades has decreased on-the-ground labor improving safety and efficiencies in harvesting. Mechanization has in some cases brought increased disturbance and new safety risks. Increased skid trail density has allowed more mechanized access to steeper ground. Rather than purpose-built forestry equipment, modified equipment is sometimes deployed at potential risk to the operator. An aversion to road construction only serves to increase exposure to weather, decreasing utilization and the effects thereof. Cable yarding has proven difficult to deploy successfully due to terrain and stand conditions and a lack of knowledge in planning and deploying cable. Modernized systems have been deployed, highly specialized equipment can be effective in narrow niches of conditions but may leave timber outside those ideal operating conditions prohibitively expensive or inaccessible. Some tethering has been deployed and in cases provides great potential. Helicopter logging has been deployed successfully as an expensive turnkey solution, but this remains a minor component of harvesting volume. Advancement in steep terrain harvesting in the Appalachians is necessary and must progress with an understanding of the uniqueness of the region. Solutions must be tailored for the circumstances. Planning, system balance, scale, supervision, training, logistical analysis, cultural adaptability, and risk management can forge reasonable solutions to help move the industry forward. Solutions to regional challenges may come from unsuspected sources, and our solutions may serve otherâ€™s challenges.

Keywords: Steep slope harvesting, mechanization, Appalachians

Oral Presentations

Advanced Applications of Winch-Assist in New Zealand

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Abstract
Winch assist machinery is well established in New Zealand steep slope operations with over 220 logging crews using them in them in their larger scale clearfell operations. They application primarily supported mechanised felling and pre-bunching on steep terrain. This presentation will summarise recently completed case studies that include: (a) winch assist skidding to increase the operating range of ground-based equipment (b) winch assist shovelling as an alternative to cable yarder extraction (c) winch assist live-skyline to facilitate the operation of motorised grapple carriages with older tower yarders. The studies include common aspects such as productivity under various operating scenarios, levels of soil disturbance, as well as operator insight as to advantages and disadvantages. Indicative cost, as well as cost saving, will also be presented.

Keywords: Forestry, logging operation, winch system

Oral Presentations

Production Analyses of Winch-Assist Harvesting Operations

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Abstract
Winch-assist harvesting technologies have spread around the world over the last decade as effective solutions for steep slope harvesting. The key drivers that are leading to the successful implementation of these technologies included the potential benefits in terms of safety and cost-effectiveness. While a significant research effort has been made to develop best practices and validate the safety benefits of these newly introduced harvest systems, there is still a significant gap of knowledge regarding their production performances in the multitude of possible configurations and applications. Production analyses of winch assist harvesting operations, in both academic and industry environments, are particularly challenging when the logging operations are based on whole-tree harvest methods, which lack the capacity to measure tree volume at the stump, as well as when the tethering solution is based on anchor machine winch systems (i.e., dynamic systems), which require simultaneous and integrated monitoring of coupled machines. To provide insights into the production capacities of these operations (whole-tree winch-assisted harvesting operations) and support supply chain visibility of logging operations, this study is presenting a digitalized solution for full-automatic production performance analyses. The proposed approach is based on the instrumentation of winch-assist harvesting systems (including both the forest and the anchor machines) with dedicated on-board computer systems (FPDat II) able to provide machine movement and location information. These machine data are then post-processed based on defined criteria for time analysis and area allocation in order to calculate various production metrics, including productive and tethering time, productivity, and utilization. The work will describe the overall approach and report the preliminary findings of field observations carried out for the validation of the criteria and algorithms used for the analysis. The results will also provide evidence of the capabilities and limitations of full-automatic production monitoring of winch-assist harvesting operations based on the integration of remotely collected machine data and forest inventories.

Keywords: Forest hrvesting, production analysis, winch assist harvesting

Oral Presentations

Automated Work Data Collection in Yarding Equipment

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Abstract
For a long time, cut-to-length equipment were the only forest machines capable of recording work data. However, things have changed over recent times: the need for machine optimization has led to the installation of sophisticated sensors and electronic processors on most machines, so that the potential for capturing working data is now present for almost all equipment. The connectivity demands of the Industry 4.0 European regulations have provided manufacturers with the motivation for equipping their products with data transmission and storage facilities. As a result, users can now access their machine work data and download it, or even obtain summary reports. European yarder manufacturers make no exception to this general picture. Some of them have built their own systems, more are relying on general purpose commercial packages that are easily available on the market and can be configured according to machine type and user needs. The Authors present the example of the Proemion software (https://www.proemion.com/en/products.html), as configured and installed on tower yarders of the Valentini range (https://www.valentini-teleferiche.it/). With IoT capability on board, yarders can transport a live data feed anywhere around the world. The system connects to many of the onboard sensors and can transmit and store data on such work functions as drum activity and pressure, fuel use, engine rpm and temperature, carriage position, joystick activation etc. The proof of live feed information on a hauler being analysed and providing real time beneficial feedback is a huge step in Forestry 4.0. In this presentation we report about how those data was used to determine: 1) Machine utilization; 2) Home range; 3) Minimum, maximum and average cycle time and extraction distances (and their correlation); 4) fuel use as a general average and as a function of other operating variables. This research confirms the possibility to use automatically collected data to conduct yarder performance assessment from anywhere around the world with internet access. The study allowed estimating classic time consumption-extraction distance functions, as well as reliable fuel use figures. Remotely recorded data also allow conducting long-term follow-up studies for a reliable assessment ofhome range, utilization and use intensity.

Keywords: Cut-to-length, data collection, yarding equipment

Oral Presentations

Estimating Soil Bearing Capacity Using GIS-based Maps

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Abstract
Logging operations may cause soil disturbances, e.g., rutting and compaction, to forest soils. Planning logging operations using GIS-based soil bearing capacity estimates can reduce soil disturbances. Soil moisture and soil type are important for these estimates. Our aim was to evaluate the use of soil moisture and soil type, estimated by depth-to-water (DTW) maps and an updated soil type map, to estimate soil bearing capacity in the field. Field measurements were carried out in 120 sample points, on combinations of three soil classes (clay-silt, sand, and till) and two soil moisture classes (wet: DTW , 1m, dry > 1m). Soil moisture and soil bearing capacity, Californian bearing ratio (CBR), were measured in top 20 cm of the soil. Time domain reflectometry (TDR) measurements together with vegetation inspections determined the soil moisture classes in the field. CBR values were measured using a dynamic cone penetrometer (DCP). Soil samples were collected at each point for validation of the cartographic soil type estimations. Our preliminary results show a high conformance between soil moisture content predicted by DTW maps and the field measurements. Significant differences between wet and dry soil moisture classes were only observed on clay-silt sediments. Conformance of the soil classes in the maps to the field estimates varied for different classes. Soil bearing capacity, was higher on soils classified as dry by DTW-maps than on wet soils. For sediment soils the difference in soil bearing capacity between dry and wet condition was consequent. Bearing capacity of till soils were more complicated and the CBR distribution are binary depending on soil stoniness. Till soils, where it was possible to penetrate the top 20 cm with the DCP, got CBR values close to those for sediment soil. Stony till soils, not possible to penetrate with DCP, can be assumed to have high CBR values. In conclusion, the studied soil moisture and soil type maps had potentials for estimating soil bearing capacity measured by CBR. Improving the accuracy of soil type maps can improve the planning of logging operations.

Keywords: Soil disturbance, soil moisture, soil type, logging operations, planning

Oral Presentations

Impacts on Soils from Mechanized Steep Slope Operations - Learnings from Widespread Implementation of Winch-Assist CTL Equipment

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Abstract
Mechanized steep slope operations have become increasingly common in the forest industry in recent years, as advancements in technology have enabled efficient and safe harvesting of timber on steep terrain. Winch-assist cut-to-length (CTL) equipment has been widely implemented, but concerns remain about the impacts of these operations on soil quality and long-term productivity. This presentation examines the impacts of mechanized steep slope operations on soils, with a focus on the learnings from widespread implementation of winch-assist CTL equipment. The presentation draws on case studies from different regions, highlighting the challenges and opportunities associated with implementing this technology in various forest types and soil conditions.Key topics covered in the presentation include: the effects of winch-assist CTL on soil disturbance, compaction, erosion, and nutrient cycling; best practices for minimizing the impacts of mechanized steep slope operations on soil quality; and the importance of ongoing monitoring and adaptive management to ensure the long-term productivity and sustainability of forest ecosystems.The presentation provides practical insights for forest industry professionals, scientists, and researchers working on sustainable forest management. By sharing the latest research and insights, the presentation aims to facilitate a deeper understanding of the impacts of mechanized steep slope operations on soil quality, and to provide practical guidance for minimizing these impacts and ensuring the long-term productivity of forest ecosystems.

Keywords: Soil disturbance, steep slope operations, winch-assist CTL

Oral Presentations

Production and Seasonal Utilization of Tracked and Rubber-Tired Articulated Grapple Skidders in the Inland Northwest

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Abstract
Tracked, articulating grapple skidders have the potential to reduce soil impacts of ground-based skidding in the inland northwest. The ground pressure associated with machines refitted with track attachments is approximately 50% of that of the same machine on rubber tires. Tracked machines have greater stump clearance but a lower center of gravity. Tradeoffs associated with fitting existing rubber-tired skidders with track attachments include balancing loss of upper end speed with 1) increased utilization rate during wetter weather conditions, and increased traction that facilitates skidding of larger loads. To understand some of the factors affecting whether investment in track attachments is justified, high-accuracy GNSS and smartphone IMU sensors were used to quantify production rates and movements of rubber-tired and tracked machines operating in consistent conditions in a clearcut operation on the University of Idaho Experimental Forest. A Deere 648H on rubber tires and 648L fitted with the G and R track system were monitored for 3 turns each as they worked in productive operations at each of three skid distances. Maximum speed, production rate, and inertial movements were quantified using GNSS and mobile device IMU sensors. Results and modeled seasonal utilization are presented and discussed.

Keywords: Production of skidding, tracked and rubber-tired grapple skidders, GNSS and smartphone IMU

Oral Presentations

An Integrated Modeling and Analytical Framework of Machine Learning, Optimization, and Spatial Analysis in Forest Biomass Supply Chain Management

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Abstract
An integrated machine learning (ML), optimization, and spatial analysis framework was developed for strategic management and tactical decision support of the forest biomass supply chain. The supply and demand of forest biomass were estimated through ML algorithms and GIS-based suitability analysis was employed to identify candidate sites for potential biomass conversion facilities, while a mixed integer linear programming model (MILP) was developed to aid in biomass procurement and optimize the flow of biomass from suppliers to conversion facilities. This modeling and analytical framework was applied in the Mid-Atlantic region, where abundant forest biomass resources show great potential for biomass industrial development. Our results indicated that the MILP model, coupled with results derived from ML models and spatial analysis, can help minimize procurement and logistics costs. The application of this integrated modeling framework can further improve the sustainability and economics of the industrial development of forest biomass for bioenergy and bioproducts.

Keywords: Forest biomass, supply chain management, machine learning, mixed integer linear programming, GIS

Oral Presentations

Biochar Demonstration Kiln

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Abstract
Biochar are charcoal particles mixed with soil. Participants will learn about building a portable flame cap kiln for demonstrating how to make biochar with clientele. Details such as burn permits, fire safety, a water source, and lighting and quenching the fire are discussed. Emerging markets for biochar include:1) An agricultural and horticultural soil amendment that improves water and nutrient availability; 2) Contaminant adsorption for dairies, landfills or mining; 3) Hazardous fuels reduction in forests and wildland urban interface communities, as well as reduction of yard waste; 4) Production of bioenergy fuels including syngas and bio-oil; and 5) direct carbon sequestration: the half-life of a biochar molecule is 1,000 years. Benefits and challenges of using biochar are discussed, including raising awareness about biochar; creating markets; feedstock properties and variability; and matching biochar qualities to specific applications. Biochar is popular with early adopters.

Keywords: Biochar, kiln, soil amendment, fuels reduction

Oral Presentations

Supply-side Financial and Operations Research Models for Biomass and Small Log Logistics: Overcoming Barriers to Utilization of Fuel Treatment Removals as an Alternative to Pile Burning

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Abstract
Under its 10-year Wildfire Crisis Strategy (WCS), the U.S. Forest Service intends to conduct fuel treatments on an additional 20 million acres (8 million hectares) of U.S. National Forest land and facilitate treatment on an additional 30 million acres (12 million hectares) of Federal, State, Tribal, and private lands to reduce wildfire risk. The WCS specifically identifies the need to generate revenues from the removal of biomass and small-diameter logs harvested during mechanical thinning to supplement existing public investment. In many places these materials are currently burned for disposal, but technically they could be used for a wide variety of products including heat and power, biochar, green hydrogen, liquid fuels, advanced bioproducts, and lumber and other solid wood products. Yet, opportunities for commercial removal and use of biomass and small diameter logs is far below projected production of these resources under the WCS. This gap is driven in part by a supply-side bias, the inappropriate use of traditional green timber supply chain models applied to the restoration economy, outdated appraisal methods and federal contracting policies, and spotty markets for biomass due to high supply chain risk. In this session, the authors present new financial and operations research models for fuel treatment and forest restoration to address this gap, with the goal of facilitating the effective and efficient use of restoration materials. Drawing on the latest forest operations research and inventory estimates, we contrast traditional approaches to financial analysis with new models that decouple service activities along the supply chain from delivered product value. Using a marginal product costing approach, results quantify how applying green timber appraisal and supply chain models to fuel treatments results in market failure by overvaluing stumpage and undervaluing non-market benefits associated with these removals. We illustrate how such market failure theoretically results in less treatment, lower efficiency and a net loss of economic value under current and potential future market conditions. The authors also provide an overview of a new 3-year project designed to develop and apply updated conceptual, statistical and mathematical supply chain models of the restoration system to facilitate the WCS.

Keywords: Biomass, small log, pile burning, fuel treatment removals

Oral Presentations

Forest Biomass Markets and Utilization in Arizona

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Abstract
Our method is inspired by a successful benchmarking carried out since 2009 in New Zealand. The factors affecting productivity were adapted to fit the Quebec operational context. Participation can be self-reporting contractors or supervisors from wood supply organizations. The participants must provide data on the characteristics of the forest stand, the harvesting system used, and the productivity of the team. Initially deployed using Excel work sheet, the benchmarking tool is now available on-line. Participants can fill-out the form anywhere with network connectivity and obtain immediate feedback regarding their relative performance. Preliminary results confirm the interest of contractors and company representatives in this type of benchmark. Confidentiality is paramount and several measures ensure that data cannot be presented in ways that would allow us to identify a participant from the group.

Keywords: Forest biomass, biomass markets, biomass utilization

Oral Presentations

Post-harvest Energy Chipping: A Viable Option in the US South?

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Abstract
There are three approaches to harvesting non-merchantable stems for energy use: pre-harvest integrated, and post-harvest. Past research has demonstrated that integrated harvesting systems, in which energy chips and roundwood are harvested simultaneously, produce energy chips at the lowest cost. However, integrated systems are cost-effective across a narrow range of energy chip volumes per hectare. Furthermore, wood-energy facilities have elected to source raw material from a small number of high-production loggers rather than accepting chips from a large number of loggers using integrated systems. In Georgia, approximately 70% of Georgia logging businesses report having a market for energy chips but fewer than 20% own a chipper. Post-harvest energy chipping in which roundwood is harvested by one logging crew and energy chipping conducted independently by a second crew would allow energy chips to be recovered from more harvest sites. We evaluated the productivity and cost of post-harvest energy chipping on three clearcut harvest sites in the Coastal Plain of South Carolina. Harvest sites ranged from 11.7–13.9 ha and contained an estimated 19.7–24.4 tonnes per ha of non-merchantable stems. A conventional logging crew harvested the merchantable roundwood and the feller-buncher felled and bunched the non-merchantable stems. A second crew chipped the non-merchantable stems after the conventional crew had completed its work. An elemental time study was conducted to estimate hourly productivity of each harvesting function. Hourly costs of owning and operating the harvesting equipment were estimated using the machine rate method. Hourly productivity and hourly costs were combined to estimate costs per tonne using the Auburn Harvesting Analyzer. Requiring the feller-buncher to fell and bunch non-merchantable stems for later chipping reduced feller-buncher productivity by an average of 42% but did not reduce roundwood productivity overall because felling productivity exceeded skidding and loading productivity. Felling non-merchantable stems increased roundwood harvesting costs by $0.70 per tonne. Energy chips were produced at an average estimated cost of $22.04 per green tonne (USD, onboard truck) and $31.96 per tonne delivered. This study suggests that post-harvest energy chipping can be a cost-effective alternative for logging businesses and land managers.

Keywords: Energy chipping, post-harvest, feller-buncher productivity

Oral Presentations

Modeling Inventory Management Policies for a Willow Pellet Facility to Adapt to Seasonal Biomass Supply and Demand Fluctuation

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Abstract
The seasonality of willow harvest can have substantial influence on the profitability of a wood-pellet facility that uses willow biomass as the main feedstock. Strategies can be designed to mitigate the impact of seasonal willow biomass supply fluctuation and therefore reduce supply risk. Those strategies may include implementing a seasonally adjusted inventory management policy, such as increasing the raw material inventory before the end of a harvesting season. Inventory management should also be coordinated with regional willow harvesting and transportation plans and market demand for wood pellets, which is also seasonal. Allowing the coordination of willow production and transportation from multiple feedstock suppliers may also improve the overall efficiency and resilience of this supply chain. In this study, we developed a mix integer linear programming model (MILP) to optimize the combinations of different willow harvesting, inventory management, and feedstock supply diversification strategies. Our study is based on a hypothetical wood pellet facility located in West Virginia. We identify the regions that could provide willow raw materials to the facility, calculate the annual willow production potential from different locations within that region, and build a model to find the optimal inventory management policies to adapt to biomass harvesting seasonality. We compared a baseline scenario with shorter harvesting season (from November to March) to a scenario of extended harvesting season (from August to March). Longer harvesting season allows more flexible inventory management with a tradeoff of lower willow biomass productivity when harvesting is scheduled during the leaf-on season. We also compared the inventory management requirements of an assumed deterministic wood pellet demand to that of a stochastic demand. We believe this research can help wood pellet facilities to better design their procurement, storage and production plans to achieve higher efficiency under uncertain raw material supply and market demand.

Keywords: Biomass, inventory management, willow pellet

Oral Presentations

The Current Status of Logging Residue and Disposal Machinery in Turkiye

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Abstract
The term slash is not commonly used in Turkish forestry. The slash expression is more suitable for Turkish agriculture. Instead of the term slash, forest residues, which are the pieces of wood left (logging residues) in the forest after logging operation with the exception of logs, are commonly used in Turkish forestry. As Turkiye conducts intensive forestry activities based on industrial timber production, forestry activities are mainly focused on harvesting and transportation activities. Although the stands are damaged by natural disasters (such as forest fires, windthrow, landfalls, etc.), the main focus is on industrial timber production in Turkiye. Wood-based materials from stands that do not have the enough quantity and quality in stands (trunks, tops, branches, roots and other unsuitable for industrial production) are mostly considered as fuel wood. Due to the high transportation costs and ecological forest management approaches, forest residues (residues of logging or damaged forests) are left in the stands. Slashes or other logging waste are often either left in stands or utilized to generate electricity. Due to the high demand for wood materials from plantation forests in recent years, some domestic enterprises have also processed thick branches into industrial products such as chipboard and paper. Inaddition, some small-scale studies have done to reduce transportation costs in order to bring forest residues to the economy. The recent studies involve the storage and disposal of logging residues on the ramp to prevent erosion on top soil or silvicultural purposes in forestlands. Small-scale chopping or chipping machines are produced by the domestic industry. Thus, the slash disposal and mechanization have a very limited place in Turkish forestry. Decision-makers should prepare action plans on this and support by working on projects with academic units.

Keywords: Forestry, disposal machinery, logging residue

Oral Presentations

Differentiations in Wood Chip Quality from Various Harvest Types

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Abstract
For decades, humans have been using an abundance of non-renewable resources such as oil and gas to fuel the ever-growing demand for energy production. However, the rise of fossil fuel prices and environmental concerns have left the energy sector to seek other means of fuel production. Biofuels have become a growing means of fuel in the energy production world, with one of them specifically being wood chips from the forestry industry. The market for wood chip production is gaining speed throughout Europe and the United States as a global push for the implementation of this byproduct is increasing. However, wood chips in the United States and abroad come from a variety of harvest sites each with their own unique characteristics. The goal of this study is to analyze any possible differences in wood chip energy production between harvest types. Samples were collected via a large net of mills in the southeastern United States through coordination with the U.S. Forest Service-Southern Research Station. Harvest types analyzed fall in the categories of restoration harvest, first thinning, as well as final harvest, including differentiation between softwood and hardwood harvests. Samples collected from these harvest types were tested for quality factors consisting of energy output, ash production, and ash particulate makeup. Results will be presented to show differences in wood quality factors important for the energy sector between the different harvest types and sources of raw material.

Keywords: Wood chip, harvest types, wood

Oral Presentations

Bioenergy in a Time of Crisis

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Abstract
In the summer 2022, the post-pandemic rebound and an escalation in the Ukrainian conflict determined a severe energy crisis. Within few months, gas and fuel prices climbed to unprecedented heights, endangering many businesses and applying new pressure onto the economy of Europe. Energy-demanding industries took the hardest hit and many had to suspend operation. European governments had to pause or reverse their enlightened green policies and look again at coal or nuclear energy… That was the time when the financial and strategic benefits of local bioenergy chains could eventually show their worth. At the end 2022, CNR, LUKE and the University of Warmia conducted a quick survey among bioenergy businesses in Italy, Finland and Poland, respectively. Those three countries were taken as representative of Northern, Eastern and Southern Europe. The survey indicated that bioenergy users suffered a much lighter energy cost increase compared with conventional energy users. They also had to cope with fewer or no interruptions in their power supplies, compared to other users in the region. Bioenergy suppliers dramatically increased the financial sustainability of their operations due to a dramatic growth of market prices, which was much higher than the increase in fuel cost incurred by their equipment. Bioenergy plants had to expand the share of locally sourced material, due to the sudden drying out of all wood import channels, to the benefit of localrural economy that had been choked by global prices until recently. The sudden and significant increase of wood fuel prices provided sufficient motivation to forest owners and wood suppliers to get organized and overcome many of the obstacles that had previously constrained correct exploitation and blocked access to an abundant local resource.

Keywords: Bioenergy, energy crisis, green policies

Oral Presentations

Estimation of Biomass Loss Resulting from Powerline Clear-Cutting Using Airborne LiDAR Data

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Abstract
Airborne LiDAR, a pulse laser system has been widely used to collect data related to both individual tree and stand parameters. With accurate assessment of these parameters due to characteristic of lidar technology, estimation of above ground forest biomass and volume have been improved rapidly. Forest biomass is an indicator of carbon sequestration in trees and consider as a potential source for renewable energy. In general, field measurement method is used to assess biomass; however, it is not cost and time effective. Also, this method includes destructive sampling within a limited area. LiDAR systems are active remote sensing technology that provides a precise three-dimensional information of ground surface, including vegetation, building and other ground objects. Integrating LiDAR data with in situ field measurement produces accurate estimation biomass and carbon in a forest at a wide range scale. This study aims to develop a methodological framework for assessing aboveground biomass loss due to powerline clear-cutting. Besides that, the study also reports results for biophysical parameters for forest inventory such as tree height, crown diameter and dbh, which is most reliable parameter for biomass estimation. The results of the study have offered practical and accurate estimation for biomass and biophysical parameters before destructing forest at large scale.

Keywords: Biomass, clear-cutting, LiDAR

Oral Presentations

Industry Based Log Grading in the Appalachian Region

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Abstract
This paper discusses an innovative log grading system for the Appalachian Hardwood industry. Hardwood log grading practices have evolved into an ad hoc system that is typically based on scaling diameter, clear faces, and species. Individual companies also add their own additional nuances, which has led to a profusion of grading approaches. Log grading is a critical component in maximizing value throughout the supply chain from landowner and loggers to overall mill profitability. We have developed a new standardized hardwood log grading system that uses these three basic criteria, species, diameter, and clear faces, and aims to maximize the proportion of higher-grade lumber. The grading system groups logs into grades based on the number of clear faces and nine diameter classes. These grades can then be used to develop log pricing with additional data we have collected regarding lumber grade yields, overrun/underrun, sawing cost, and product pricing. Examples are presented on how the system can be used in the context of these data and how this system can be used by log buyers and even adapted to develop stumpage prices.

Keywords: Forest industry, log grading, Appalachian Region

Oral Presentations

Sustainability of Wood Pellet Harvesting in the U.S. South: A Literature Review

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Abstract

Current increases in global demand for biomass products are being driven by the creation of legislation promoting the use of renewable fuel sources for energy production, rising fossil fuel costs, concern over greenhouse gas emissions, and increased energy utilization. In response, the U.S. South has expanded biomass production to meet rising global sustainable energy policy requirements by producing approximately around 70% of the global pellet feedstock demand, with 98% of the pellets exported to the EU. Importing nations specify sourcing from the U.S. South must be harvested and managed under international sustainability standards. For example, mills exporting biomass are required to be in good standing with the Sustainable Forestry Initiative's (SFIs) certified Fiber Sourcing Standard. The majority of mills sourcing wood pellet feedstock follow the Sustainable Biomass Program (SBP), a monitoring program meant to evaluate sourcing and management practices. However, through this program management practices for pellet feedstock harvesting are diverse with variable methods. Additionally, due to a lack of empirical data available for review and the new development of the wood pellet market, limited literature has been published evaluating the interaction of pellet feedstock management practices and resulting site sustainability. This is exacerbated by the fact that approximately 87% of land in the southeast is privately owned, the majority of which have their own management goals and maintain on average less than 13 hectares of operatable land. Current public concerns regarding long-term site sustainability include increased removal of woody debris, nutrient loss, debris distribution, increased erosion rates, and potential negative water quality impacts. This review will evaluate the status of knowledge related to biomass harvesting sustainability to develop a baseline for future policy, practice, and implementation. Key objectives include (i) defining the differences between conventional harvesting, biomass harvesting, and pellet feedstock harvesting, (ii) characterizing the broad scope of harvesting effects from feedstock procurement, (iii) addressing harvesting guidelines, both conventional and biomass, and attributes in conventional harvesting, biomass harvesting, and pellet feedstock harvesting that may require separate monitoring practices, and (iv) detailing potential barriers to harvesting sustainability in correlated environmental, social, and economic elements.

Keywords: Harvesting, wood pellet, sustainability

Oral Presentations

Log Truck Transportation Challenges and Innovative Solutions: Evaluating the Perspectives of Truck Drivers, Logging Business Owners, and Forest Industry Representatives

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Abstract
Currently the wood supply chain is experiencing significant logistical and operational challenges in truck transportation. Obstacles related to driver shortages and retainment, increases in insurance premiums and diesel fuel costs, insufficient training, and truck/part shortages are especially pronounced. These obstacles have led to many business closures, consolidations, and increased hardships for many business owners. The goal of this project was to evaluate the inefficiency in the transportation link of the Georgia, U.S.A. wood supply chain and to determine the primary obstacles leading to a disconnect between logging business owners and truck drivers. To allow business owners to create a more sustainable business structure. Online surveys were used to target logging business owners, foresters, and wood dealers. These surveys were distributed by forestry and logging professional organization's email address list servs. A second survey targeted log truck drivers, contract haulers, and log truck owners/operators with paper questionnaires distributed at five mill scale houses in Georgia. Both surveys used similar questions to evaluate opinions regarding challenges and obstacles in forest transportation. Preliminary analysis indicates that log truck drivers believe increased benefits will have a large positive impact on transportation obstacles whereas logging business owners believe it will only have a small positive impact. However, both logging business owners and log truck drivers agree that a fair log truck driver annual salary is $60,000-$80,000. Both groups also agree that increased haul rates and wages for truck drivers would have a large positive impact on forest transportation.

Keywords: Forest industry, log truck, truck drivers

Oral Presentations

Forest Biomass Supply Chain Management for Regional Self-Sufficient Thermal Energy Utilization

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Abstract
It is increasingly interested in using forest biomass as renewable energy resources by the RPS (Renewable Portfolio Standard) and revising the weight of REC (Renewable Energy Certificate) in South Korea. So, it is time to make sustainable and economical supply chain management. This study showed the selection of efficient supply chain systems from the forest biomass center for self-sufficient thermal energy utilization. It was conducted to develop a cost prediction model and sustainable forest biomass supply chain. For efficient management of the forest biomass center, it was necessary to reduce fuel costs or increase the number of households to increase the energy utilization rate (%). The whole-tree system was more economical than the conventional cut-to-length system for producing forest biomass as a low-cost fuel. It was also most effective to transport the collected forest biomass to the plant after chipping in the field. The forest biomass center was selected as the final customer and constructed a supply chain map. It can be used to plan cost-effective and sustainable forest biomass production.

Keywords: Forest biomass, supply chain, self-sufficient thermal energy

Oral Presentations

A Multi-Criteria Evaluation Process for Cost Efficient Operations in Fragmented Forest Landscape

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Abstract
Nordic forests, such as those found in Canada, used to offer opportunities for large and relatively homogeneous harvest blocks. Fragmentation of forests makes planning difficult and increases costs of road building and machinery relocation. While operational solutions have been developed in regions characterized by small forest tracts, their transferability in a different setting is unknown. Finding the most suitable combination of equipment for a given context is challenging considering the multitude of possibilities that are available. The objective of this study is therefore to identify, from all possible options, a subset of harvest systems expected to perform well in the context of fragmented forests. The results from this research are two-fold. First a comprehensive review of existing forest machines and harvest systems is provided. Second, a multi criteria decision analysis (MCDA) methodology to evaluate the selected alternatives. In a boreal forest context, the conventional harvester-forwarder system (CTL) with mild adaptations of the usual configuration was ranked among the best solutions. Several whole tree (WT) system configurations also presented a potential for efficient operations. While the results are specific to the case studied, the review and selection methodology can serve in different operational contexts. While this study was conducted for a boreal forest landscape, the results may be applied in other regions. It provides guidelines for improved logistics for forest operations in sensitiveareas.

Keywords: Cost efficient, fragmented forest, multi-criteria evaluation process

Oral Presentations

An On-Line Tool for Productivity Benchmark of Harvesting Contractors

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Abstract
The lack of knowledge of the factors that affect the productivity of harvest contractors leads to a gap in the identification of actions that can improve the efficiency of harvesting operations. The purpose of this research is to implement a method to measure and track the relative performance of harvesting contractors. To achieve this, we have created a benchmarking tool that can be used by and for forestry contractors throughout a large geographic area. Once sufficient data is available, it will be possible to establish relationships between the different variables that affect ground-based operations, in a context that promotes data sharing and continuous improvement. Our method is inspired by a successful benchmarking carried out since 2009 in New Zealand. The factors affecting productivity were adapted to fit the Quebec operational context. Participation can be self-reporting contractors or supervisors from wood supply organizations. The participants must provide data on the characteristics of the forest stand, the harvesting system used, and the productivity of the team. Initially deployed using Excel work sheet, the benchmarking tool is now available on-line. Participants can fill-out the form anywhere with network connectivity and obtain immediate feedback regarding their relative performance. Preliminary results confirm the interest of contractors and company representatives in this type of benchmark. Confidentiality is paramount and several measures ensure that data cannot be presented in ways that would allow us to identify a participant from the group. The next step for the project requires increasing the number of participants and obtaining a fair representation of all harvesting systems working in the province of Quebec in all its main ecoregions. This is essential to conduct statistical analyses of the factors affecting productivity. The results expected through this tool are the establishment of a practical benchmark applied to current forest harvesting operations with the aim of improving the productivity and profitability of the entire supply chain. Next the development of a mobile application is envisioned to provide more rapid feedback to the participants Finally, the research team will seek international collaborations to allow for harvesting system comparison among several world regions.

Keywords: Harvesting contractors, on-line tool, productivity

Oral Presentations

Fuel Consumption for Cut to Length Harvesting Operations

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Abstract
When calculating logging costs and when estimating environmental impacts of logging operations, fuel consumption is an important factor affecting the results. Fuel consumption for harvesters and forwarders have been estimated through case studies of individual machines, long term follow-up studies where fuel has been measured and reported in company systems, or through questionnaires where machine owners has reported fuel consumption and production levels for a specific period. In recent years a fourth method has become available, the use of automatically collected data from the machine computers in form of standardised harvester and forwarder production files and machine operational monitoring files. This can, in combination with other data sources, be used for both case studies and large scale follow up studies. Our aim was to estimate fuel consumption for cut to length harvesting operations based on data available in the machine data, and to evaluate if it needs to be complemented with data from other sources. Automatic data collection was made from 2932 harvested sites and 1571 forwarded sites. The participating machines were mainly medium to large sized all-round machines and large final felling machines, i.e. they are not representative for the overall machine fleet used. Fuel consumption per m3 was 1.62 l for thinning harvesters, 0.80 l for all-round harvesters and and 0.68 l for final felling harvesters. For forwarders, fuel consumption per m3 were 1.0 l for small, 0.9 l for medium and 0.7 l for large forwarders. Both harvester and forwarder fuel consumption are dependent on machine class, harvested volume per ha and either number of trees or distance travelled per m3. These variables are correlated, which affects the modelling of fuel consumption. Further studies are needed to establish conversion factors between machine measured variables and variables used in the forest industry. Classical fuel consumption studies are needed to complement the analyses of machine data, with effects of variables currently missing in the machine data. This can be information on e.g. terrain, soil type, snow conditions, or on the use of auxiliary equipment such as wheel chains and bogie tracks.

Keywords: Fuel consumption, forest harvesting, CTL

Oral Presentations

Analysis of Road Alignment Improvement Effects by Construction of Landing Areas Related to Forest Roads

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Abstract
South Korea's forestry has been promoted through afforestation since the 1990s to develop the commercial forest, and as of 2021, the growing stock has increased to 168.7m3/ha, and it is expected that there will be a transition to the stage of final yield where high-quality timber production is possible. Therefore, the entry of large logging trucks (25ton) onto forest roads has been gradually increasing for efficiently transport large amounts of timber and reduce harvest costs. The quality of the forest road has a great impact on transportation efficiency, and the speed of the logging trucks, the slope, and curvature radius of the forest road can change depending on various factors. In order to ensure the smooth passage of logging trucks, linear improvement is necessary in the form of structures suitable for timber transportation. In addition, as the production of timber is increasing, the need for landing areas is accordingly increasing for efficient timber production through mechanized operation. In this study, the construction method of a landing areas related to forest roads was applied to the curved part using rock-fill for alignment improvement of forest road and secure work space. We analyzed the change of the forest road alignment and running speed of logging trucks. The results showed that the road linearity and traffic flow have improved, and it is possible to secure the space required for mechanized operation. It appears that in order to secure running speeds that conform to future facility standards, comprehensive reviews and studies of various factors such as structural linkage, pavement construction, and driver psychology must be conducted.

Keywords: Forest roads, landing areas, road alignment

Oral Presentations

Estimating the Economic Value of Timber Products Potentially Saved from Wildfires by Improving Forest Road Standards

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Abstract
Wildfires affect the forest resources particularly in forests with high fire risk. It is crucial for the ground-based firefighting team to reach a fire area in critical response time to reduce the ecological damages and the economic losses caused by wildfires. Forest roads are the key infrastructures that provide access to the forest areas during fire extinguishing activities. In fact, a considerable amount of wood-based timer products can be saved from the fire by improving the forest road standards which increases the travel speed of the wildfire trucks and allows firefighting team to reach larger areas within the critical response time. In this study, it was aimed to estimate the economic value of the timber products from the forest stands that are potentially saved from the wildfires after improving road standards. The study was implemented in Alanya Forest Enterprise Directorate (FED) in the Mediterranean city of Antalya in Turkiye, where forests are classified as first degree sensitive to wildfires. In the solution process, firstly, the possible increase in the accessible forest areas with improved forest road standards was investigated by using GIS-based network analysis methods. Secondly, the timber production in the forest areas potentially saved from the wildfire was calculated based on parameters such as site index, rotation period and stand structure. Then, the economic value of timber product types was calculated by using market prices. The results indicated that increasing the design speed on improved forest roads reduced the arrival time of firefighting teams to the forests which consequently increased the accessible forest areas in critical response time. It was found that the accessible forest areas in critical response time increased from 47,231 hectares to 59,354 hectares when standards of the forest roads were improved. Thus, about 12,123 hectares of additional forest area could be saved from the wildfire in the Alanya FED. It was calculated that the total timber products obtained from this potentially saved forest area was about 94,719 m^3, and worth $7,545,579 at market prices. The results from this study can be used by policy makers in determining the potential investments on improving forest roads standards to enhance the efficiency of firefighting activities.

Acknowledgement: This study was supported by The Scientific and Technological Research Council of Turkiye (TUBITAK), Project No: TOVAG-221O309.

Keywords: Wildfires, forest road standards, network analysis, timber products, economic analysis

Oral Presentations

Assessment of Culverts on Forest Road Under Maintenance Cessation

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Abstract
Culvert in forest roads appears to be one of the principle components in terms of conducting the water flow. This infrastructure is most likely to be damaged and destructed as time goes by due to the circumstances such as the inappropriate environmental conditions as well as the poor management. In the current research the road network's culverts in the Shenrood forest, Guilan Province, has been evaluated five years after the last repair conducting. In the first place, we had a go at trying to pinpoint the type and location of the culverts located at the areas of road networks. Afterwards, quite a large numbers of the culvert's elements which encompassed the wide range of the points like the pipe diameter and length, culvert grade, skew angle, pool depth, pipe depth from roadbed in cut fill slopes, sediment catch basin size, sediment catch basin situation, sediment catch basin situation, culvert intel situation, culvert outlet height form ground surface, culvert outlet material, culvert outlet height form ground surface, culvert outlet material, outlet scouring, erosion in cut and slope and bypass, were measured. The results indicated that over 87% of culvert's Intel are classified in the plugged or semi-plugged ones. Moreover, the outlet scouring comes up in 50% and the erosion has been the crucial issue in the culverts. Furthermore, the sediment catch basin has not been observed in the studied culverts. Surveying the end results, the eliminating of the road maintenance operation and the culvert repair are substantially contributing factors in the road destruction.

Key words: Road Network, Cut and fill slope, Maintenance operation

Oral Presentations

Benching in Forest Roads to Support Infrastructure Stability

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Abstract
The construction of forest infrastructure is essential to provide access for harvesting first-rotation forests. The primary principle of road and landing design is to support the expected traffic in terms of geometry, loading and duration. In steep terrain, the long-term stability of the road becomes critical, not only for continued access, but also for minimising possible environmental impacts. In New Zealand approximately 2000km of new forest roads are constructed each year, much now located in highly erodible and steep terrain. Recent intense storm events have resulted in road failures that have led to pollution of waterways and subsequent enforcement action. The concept of using a sub-terrain bench to support the top-most fill batter, in comparison to side-casting, is intended to help stabilise and reduce the overall footprint of the road at reasonable cost. Specifically, a bench is first cut into the slope a small distance below the intended road or landing, and the material cut to make the road (or landing) is cast onto the bench and progressively compacted. This methodology is now also established in New Zealand law, in that (at a minimum) benching is required on all new forest roads constructed on side slopes greater than 40%. However, the details and efficacy of both design and construction is not well established. This paper and presentation will step through the benching design concept, provide details on benefits and costs. It provides three case studies of roads constructed using benches, including the use of drone-based LiDAR for pre and post construction results. It will also show how benches can be designed in RoadEng10, and constructed using road equipment commonly used in forests.

Keywords: Forest roads, infrastructure stability, LiDAR

Oral Presentations

Investigating the Effects of Forest Roads on the Spread of Forest Fire in the Republic of Korea

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Abstract
Forest roads are essential to effective forest management, timber production and recreational activities. Under fire control and operation perspectives, well-developed forest roads can guarantee a rapid and efficient access for quick initial response in case of a fire. Forest roads also function as fuelbreaks and firebreaks particularly for low-medium intensity fires, thus getting the fire slower down and reducing the spread and size of surface fires. Despite the recent interest in forest fire management, the quantitative effect of forest road on fire spread is still unclear. Therefore, this study was to investigate the spatial extent of forest fires across forest roads, and examined the effects of forest roads on the spread of fires. Field observation was conducted on the Yeongdeok forest fire, south Korea, that occurred on February 15th, 2022. The 44 sites along forest road route were selected regarding the spread and size of fire across the roads. Among 44 sites, fire spread was blocked or slowed at 32 sites (72.7%), and got through the road at 12 sites, when the fireline reached the forest roads. The extent of fire spread varied, depending on road width, cut/fill slope steepness, and fuel (vegetation) type and amount beside forest road. The fuel distribution was also quantitatively measured on the 8 sites (4 blocked and 4 slowed), based on the LiDAR measurement. Further, the effects of road dimension and fuel treatment on forest fire behavior were evaluated with the fire spread simulation. (This study was carried out with the support of ´R&D Program for Forest Science Technology (Project No. 2023474B10-2325-BB01)´ provided by Korea Forest Service (Korea Forestry Promotion Institute)).

Keywords: Forest fire, forest roads, LiDAR

Oral Presentations

LiDAR Based SLAM Road Scanning: A BIM Based Assessment for Measuring road Surface Material

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Abstract
In terms of sustainability and continuity of forestry activities, forest roads should be open to transportation continuously. However, as with every infrastructure element affected by environmental factors, forest roads may also deteriorate. The majority of these deteriorations occur on the road surface. Accordingly, maintenance and repair work is required on the road surface, which is a costly process. At this stage, the most important issue is to estimate the pavement material, which can be subject to the volumetric calculation of the deteriorated areas on the road surface, as close to reality. State-of-the-art LiDAR-SLAM data acquisition technology and BIM approaches have great potential in the realization of these calculations. In this context, the aim of the study is to reveal the amount of material required for road rehabilitation in terms of volume from point cloud data of different densities obtained using aforementioned technologies on a sample forest road and to evaluate the differences. In the study, two different densities sub-datasets were generated from the LiDAR dataset on a 170 m long forest road. While the original point cloud dataset density was 4900 points/m², the sub-dataset with a point density of 10.5 points/m² was generated by defining the minimum spacing between the points as 25 cm. Recap, Infraworks and Civil 3D software will be used to create terrain and road models. In the Scan to BIM phase, linear elements were not produced from the automatic road line since the sample road is in the dirt road class and does not contain a road line. Instead, the axis and sides of the road with an average width of 4m will be created manually using slope analysis, cross-sections and 3D model. Consequently, the amounts of stabilized material to be laid under the pavement material in road rehabilitation projects will be calculated and the results will be compared.

Keywords: LiDAR-SLAM, forest road, road surface

Oral Presentations

Observing and Detecting Changes in Forest Lands Using Google Earth Engine

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Abstract
Remote sensing technology is commonly used in both military and scientific applications. This involves processing images or signals with different spectral ranges, which can be useful for observing and assessing things such as landscapes or forests. Satellite data has long been used in large ecosystems such as forests as a low-cost technique of monitoring and follow-up studies. In this study, in-forest structure and soil movements (such as excavation, fill, accumulation, and slide) were observed and tracked by using satellite imagey over a short period of time. Changes were observed between 2019 and 2021, including increases in the amount of soil movement (such as excavation, fill, accumulation, and slide). This information may help scientists better understand how ecosystems work by monitoring changes on a short-term basis. This study has took into account differences in pixel-based spectral values between old and new satellite images. Changes to the area due to activities such as building, road construction work or natural disasters were determined using this technique, which was conducted in Google Earth Engine (GEE) cloud computing environments. Within two years, it was detected that there had been a change in forest area and geographical differences within the study area. As a consequence, it has been shown that it has the potential to be employed in small and large scale analysis as a high-sensitivity automated spatial detection technique. It is an excellent approach for observing and monitoring of protected areas and forests. It may be used to conduct particular research on the change of forests that will be determined in the study. Based on the results of this study, a very fast and reliable change detection study was performed. In future studies, studies are planned to monitor the condition and impact of construction works on forest road edges and within forests.

Keywords: Forest lands, land use change, Google Earth Engine, remote sensing

Oral Presentations

Climate Vulnerability Forest Management (CVFM) Tool & Prioritizing Resource Road Climate Adaptations

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Abstract
The next step for the project requires increasing the number of participants and obtaining a fair representation of all harvesting systems working in the province of Quebec in all its main ecoregions. This is essential to conduct statistical analyses of the factors affecting productivity. The results expected through this tool are the establishment of a practical benchmark applied to current forest harvesting operations with the aim of improving the productivity and profitability of the entire supply chain. Next the development of a mobile application is envisioned to provide more rapid feedback to the participants Finally, the research team will seek international collaborations to allow for harvesting system comparison among several world regions.

Keywords: Climate, forest management, CVFM, road climate adaptations

Oral Presentations

Image Processing Techniques Based Feature Extraction for Insect Damage Areas

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Abstract
Feature extraction is an important step in Computer Aided Diagnosis of insect damage monitored by Unmanned Aerial Vehicle (UAV) imagery. By reducing the size of the UAV image data, it is possibleto distinguish between damaged and healthy areas from the extracted features. The accuracy of the classification algorithm depends on the segmentation method and the extracted features. The Grey-Level Co-occurrence Matrix (GLCM) characterizes areas texture based on the number of pixel pairs with specific intensity values arranged in specific spatial relationships. In this paper, texture characteristics of insect damage areas were extracted with (GLCM) using UAV images. The 3000*4000 resolution UAV images containing damaged and healthy larch trees were analyzed using Definiens Developer (e-Cognition software) for multiresolution segmentation to detect the damaged areas. In this analysis, scale parameters were applied as 500, shape 0.1, color 0.9 and compactness 0.5. As a result of segmentation, GLCM homogeneity, GLCM contrast and GLCM entropy texture parameters were calculated for each segment. In the calculations, were performed for all direction (three texture parameters) it was determined that the value range of the damaged segments on the basis of GLCM homogeneity varied in the range of 0.08 - 0.2, GLCM contrast between 82.86 - 303.58 and GLCM entropy between 7.81 - 8.51. On the other hand, GLCM homogeneity for healthy areas varies between 0.05 - 0.08, GLCM contrast between 441.70 - 888.80 and GLCM entropy between 8.93 - 9.40. The study demonstrated that GLCM technique can be a reliable method to detection of insect damage areas from UAV imagery.

Keywords: Image processing, insect damage, gray level co-occurrence matrix

Oral Presentations

Evaluating the Feasibility and Potential of Unmanned Aerial Vehicles to Monitor Implementation of Forestry Best Management Practices

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Abstract
Timber harvest activities such as the construction of roads, skid trails, and stream crossings have the greatest potential for erosion and sedimentation problems. Forestry best management practices (BMPs) monitoring serves as a tool to evaluate the status of implementation and determine the effectiveness of BMP guidelines. The use of BMP implementation rates as an indicator of water quality protection is logical since properly applied BMPs have been shown to reduce erosion and sedimentation. Conventional BMP monitoring has contributed substantially to assessing BMP implementation. However, conventional on-the-ground surveys can be time consuming. Unmanned aerial vehicles (UAVs) have been rapidly emerging as a new tool for local-scale monitoring. In this study, we evaluated the feasibility and potential of UAVs for monitoring forestry BMPs. By utilizing BMP guidelines and survey questions from Alabama, Georgia, and Florida, this study compared the performance of UAV live feed surveys and UAV-created map surveys with conventional surveys across major BMP categories on 30 study sites utilizing the BMP survey for that state. We found that using a UAV for monitoring BMPs was efficient for providing a general overview of an area from above. UAV live feed surveys were as effective as conventional surveys across all major BMP categories. The correlation coefficient (r) for all BMP categories combined (UAV live feed vs conventional) was 0.98 for detecting when BMPs were implemented and 0.94 for detecting when BMPs were not implemented and needed to be. However, UAV-created map survey results (UAV map vs conventional) were not as effective (r of 0.87 for detecting implemented BMPs and 0.49 for detecting not implemented BMPs). Stream crossing BMP questions were the main issue impacting map surveys which was not an issue with the live feed surveys due to being able to lower the UAV and evaluate the crossing at different angles. While UAV-created map surveys may be less effective, they provide a permanent observation record. This project also developed a standardized framework for using UAVs to monitor forestry BMPs. In conclusion, the usage of a UAV using live feed data in the field is a capable option to monitor forestry BMPs.

Keywords: Aerial vehicles, UAV, best management, BMP

Oral Presentations

Managing Forest Disasters Arising in Districts Prone to Landslides Using Geographic Information Systems (GIS): A Study in the Forests of the Uludag Mountains

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Abstract
landslides are considered one of the natural risk hazards phenomena which spread in mountain areas, especially if there are natural and human factors that help in the occurrence of these slides, such as fragile soil, heavy rain, and desertification resulting from climate change, industrialization, and urbanization. On the other hand, forests contribute to a large extent to these risks, the danger is remaining in many regions and often leads to loss of life and property as well as loss of vegetation cover, reduction of green areas, and changes to the landscape of the region. The suggested study area is in Bursa province. It suffers from these risks and the forests of the Uludag Mountains were chosen as the study area. Additionally, previous studies show parts of the study area, especially northwestern were at risk of landslides. The study assumed that Geographic information systems(GIS) could be used effectively as a tool that helps greatly in the spatial analysis of this phenomenon and in building a spatial database through which changes can be monitored over time by observing these landslides and their locations. The study shall use mapping and qualitative analysis such as point analysis and overlay analysis besides time detection analysis. The study expects that the spatial analysis of the attribute data and spatial data, in both its vector and raster forms, can identify the causes leading to these landslides and thus minimizing them and protecting the affected parts by proposing recommendations and policies that help increase the capability of forests in the study area to mitigate such hazardous risks and protect the forests in the study area.

Keywords: Forest disaster, landslides, GIS, forest mitigation

Oral Presentations

Spatial Modeling of Landslide Susceptibility: An Open-Source Web-Based Approach Using Interactive R Shiny

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Abstract
This study presents an interactive web-based prototype for modeling landslide susceptibility using GIS FOSS (Geographic Information System Free Open Source Software). The prototype integrates Shiny for the R programming language coupled with the shallow slope stability model (SHALSTAB) from SAGA GIS. The implementation uses a client-server architecture where up-to-date web browser (i.e., Chrome or Firefox) is used for the client side and Nginx with RStudio Server for the backend. The easy-to-use Shiny application includes a modeling and validation pages accessible from a sidebar navigation menu and embeds customized user-input controls (i.e., sliders, buttons) organized in sidebar layouts. By changing model inputs in the modeling page, users can run the simulation and visualize maps and other statistical outputs, while in the validation page modeled outputs are evaluated and assessed by different measures of accuracy (i.e., sensitivity, specificity, kappa, and ROC curve). The usefulness of this interactive approach for mapping landslide susceptibility are demonstrated in a case study in the Clearwater National Forest (CNF), in northcentral Idaho. The presented approach used an interactive model calibration that produced an AUC of 0.715 with overall accuracy of 0.894 and kappa of 0.789. However, the key benefit of the proposed R Shiny app is that extends current modeling efforts to non-expert R or GIS users who can easily interact with the model and formulate real-time questions based on personal and local knowledge. The proposed web-based prototype can also be used in an educational context for classroom teaching activity and enabling research-informed learning.

Keywords: Spatial modeling, landslide, R Shiny

Oral Presentations

The Role of Forestry Mechanization After Catastrophic Events: European Experiences in Salvage Logging

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Abstract

Forest disturbances have caused noticeable damage to European forests over the last few decades. Different abiotic and biotic disturbances are expected to become more common in the future due to a warming climate. In order to prevent biological diseases (fungi and insects) and to foster active forest restoration, forest managers apply salvage logging in affected stands with the intent of recovering maximum value prior to deterioration. These interventions differ from the common planned logging activities, for the higher harvesting intensity or for their higher difficulties founded during harvesting operations. For these reasons, post-disturbance salvage logging is becoming more predominant to recover economic value from timber in disturbed forests, and this purpose has motivated several studies in recent years to determine productivity models and cost assessments to support a correct decision in choosing between alternative wood harvesting systems. The salvage logging is increasing in Europe because of the growth of severe meteorological events and timber harvesting in these conditions is challenging in terms of both productivity performances and safety of the operations. In recent years, with the increase of natural calamities, several researchers have studied machinery productivity performances regarding salvage logging carried out by ground-based systems. In this paper, system productivity and harvesting costs during salvage logging are analyzed in different European forest stands collecting different wood harvesting experiences. This study has been implemented in order to evaluate the productivity and cost-effectiveness of wood extraction collecting data about operational performances during the use of forwarders, skidders, and cable cranes after catastrophic events occurred in Europe.

Keywords: Catastrophic events, forestry mechanization, salvage logging

Oral Presentations

Harvesting Hurricane Damaged Timber Using a Redesigned Felling Head for a Rubber-Tired Feller-Buncher

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Abstract
This research project is with the Downed Timber Initiative project which is a bold yet obtainable idea which benefits areas devastated by hurricanes and tornados in environmental, economic, and social aspects. The Downed Timber Initiative proposes a new method for harvesting downed timber by implementing redesigned technology on ground-based equipment that is commonly used by logging crews in the Southeastern United States. In this research project, a new kind of felling head will be designed, fabricated, tested, and analyzed. This felling head will attach to a standard rubber-tired feller-buncher and will feature a boom that can extend a felling head grapple saw around eighteen feet from the base of the machine. The felling head can then grab, cut, and accumulate downed or standing timber for a grapple skidder to skid to the logging deck. The feller-buncher equipped with the Downed Timber Initiative felling head will move through the stand in straight lines down the rows, harvesting timber on either side in its boom operating zone. The mechanical integrity of individual components, hydraulic system requirements, and dynamic (tipping) simulations of the machine system have been tested in engineering software, and the results of each show the machine is suitable for in-woods use. A prototype will be manufactured to confirm the tests. This prototype consists of a Barko 80 XLE boom mounted on a modified John Deere FD45 felling head that will be attached to a John Deere 843L feller-buncher. On the end of the boom will be a Waratah FL85 dangle head saw. It is expected that this machine will vastly improve the efficiency of a downed timber harvesting operation for a standard southeastern logging crew.

Keywords: Feller-Buncher, felling head, hurricane damage

Oral Presentations

Effects of Thinning on Litterfall Production and Leaf Litter Decomposition Rates of Karacabey Forested Wetlands, Bursa, Turkiye

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Abstract
The contribution of litterfall (dead leaves, twigs, etc., fallen to the ground) and forest floor (organic residues such as leaves, twigs, etc., in various stages of decomposition, on the top of the mineral soil) is fundamental in both forest ecosystem sustainability and soil greenhouse gases (GHG) exchange system with the atmosphere. A focus on forested wetlands is particularly important, as these systems account for a disproportionate amount of global carbon flux relative to their spatial coverage, and the decomposition of leaf litter is a major contributor. In this study, we aimed to investigate the effects of two different thinning treatments (low thinning-canopy closure 41-70% and intense thinning-canopy closure 10-40%) on litterfall, forest floor litter and leaf litter decomposition rates of alder (Alnus glutinosa) stands in Karacabey forested wetlands. The litterfall was monthly collected using open litterfall traps for 2 years from 2021 to 2022. The forest floor litter was also sampled 50 x 50 cm2 quadrates of 5 points in research plots of 20×20 m. The differences in leaf litter decomposition rates between the low and intense thinning stands were investigated using the litterbag method in the field for 18 months. The results indicated that the intense thinning significantly reduced the total litterfall production (7.24 ± 0.384 Mg ha-1) and the forest floor litter (2.78 ± 0.41 Mg ha-1) compared to the low thinning stand (10.8 ± 0.527 Mg ha-1 and (4.38 ± 0.82 Mg ha-1 respectively). Lower leaf litter decomposition rates were also seen in the intense thinning stands than in the lower thinning stands. At the end of the 18 months, the leaf litter mass loss was 83.6% in the intense thinning stands compared to the lower thinning stands (88.3%).

Keywords: Decomposition rates, leaf litter, thinning density, wetlands

Oral Presentations

Use of Single-tree LiDAR Data to Model Stream Protection Zone Harvesting

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Abstract
Riparian harvesting adjacent to fish-bearing streams must be planned carefully in order to comply with state-specific rules protecting water quality and fish habitat. Sustainability is of primary importance within the scope of sustainable forest management. these reasons, riparian harvesting must be planned correctly. Streams are important for spawning, breeding, or migration of fish. For this reason, Idaho's Class I stream protection rules regulate levels of adjacent harvesting permitted. Trees falling within each of three zones may be harvested according to size-specific weight factors defined in the Idaho Forest Practices Act. Lidar-based single tree inventory (STI) has been developed for the UIEF and has 963,937 georeferenced individual tree records that comprise the composition of 698 mixed-species stands of varying ages. It contains various attributes associated with each tree, including height, canopy closure, diameter at breast height (DBH), gross volume, and probability of defect. Using this data and current Class I stream locations, a 75-foot-wide tree retention buffer was created, corresponding to the Class I Stream Protection Zone (SPZ). A linear model is planned to depend on the rules specified. The objective function of determining the optimum protection zone for harvesting has been evaluated. Constraints in the model are zone width, diameter, tree weight, and tree species. Our methods demonstrate use of single tree inventory (STI) for precision, smart harvest planning. The methods can be used to implement riparian stand prescriptions in areas with different stream functions or management goals over time.

Keywords: LiDAR, single-tree inventory, stream protection zone

Poster Presentations

Instructions for Full Proceeding Paper for Submission Examining the Potential for Increasing the Forest Resource Availability by Introduction of Semi-trailers and European-type CTLs in Hokkaido, Japan

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Abstract
With the introduction of both semi-trailers and European-type CTLs in Hokkaido, the availability was estimated to be 6,638,618 m^3/year and 1,327,724 m^3/year for used and unused woody materials, respectively. As for used woody materials, the value was significantly higher than 3,741,000 m^3/year of coniferous material production in Hokkaido. The value of unused woody materials also showed a value that almost satisfied the wood chip of 1,431,753 m^3/year, which was a woody biomass fuel in Hokkaido. The increased availability was estimated to be 141,953 m^3/year and 28,391 m^3/year for used and unused woody materials, respectively. As for used woody materials, the value was converted to 1.19 billion yen/year in terms of monetary value and 3,596 houses/year in terms of single-family homes. For unused woody materials, the value for power generation was converted to 190 million yen/year in terms of monetary value and 3,634 households/year in terms of the number of households. The effects obtained by introducing both semi-trailers and European-type CTLs would not be small, and this implies that the introduction will lead to further use of forest resources.

Keywords: Feed-in tariff, harvesting, monetary value, power generation, transportation.

1. Introduction

Feed-in Tariff (FIT) started in July 2012, and many power generation facilities that use unused woody materials as fuel are operating in Japan. However, there are concerns about whether unused woody materials can be procured stably for a purchase period of 20 years, and the profitability of woody biomass power generation after the end of FIT. In this study, we estimated the cost reduction when introducing a semi-trailer with 20-ton payload from a conventional truck with 10-ton payload, and when introducing a European-type CTLs using a wheel-type harvester and forwarder from a conventional CTL (excavated harvester and forwarder) in Hokkaido where it is presumed that high effects will be obtained by the introduction because of relatively large operation areas and gentle slopes in Japan. Silvicultural prescriptions, harvest volumes, operation system, and transportation distances were set for each subcompartment. Then, revenues, costs such as harvesting, transportation, and regeneration as well as subsidy for each cutting period were estimated. Finally, supply potential from a profitable subcompartment was estimated as the availability, and the possibility of increasing the availability of forest resources was examined.

2. Material and Methods

In this study, we used the forest data and forest plan map of private and public forests, which were the open data of the Hokkaido, and the national forest data of the Geographical Survey Institute. Study sites were 407,672 subcompartments of private and public forests as well as 186,753 subcompartments of national forests for a total of 594,425 subcompartment, with Cedar (Sugi, *Cryptomeria japonica*), Cypress (Hinoki, *Chamaecyparis obtusa*), Pine (Ezomatsu, *Picea jezoensis*, Todomatsu, *Abies sachalinensis*, etc), and Larch (Karamatsu, *Larix kaempheri*) in Hokkaido. Silvicultural prescriptions were set based on the regional forest plan, which was the open data of the

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Hokkaido. The harvesting volumes were estimated by muptiplying the stocks at the time of thinning and final cutting using the Local Yield table Construction System (LYCS3.3) for each tree species by the cutting ratio and the area of each subcompartment. Revenues were estimated by multiplying the harvesting volumes of each subcompartment for a cutting period by prices of used and unused woody materials.

The harvesting costs were estimated by multiplying the harvesing volumes for each subcompartment by the harvesting costs for each operation system (Battuvshin et al., 2020) determined using topography such as the slope and the hight difference (Goto, 2016). For the transportation distance of used woody materials, the shortest routes from the subcompartments to all the destinations (124 sawmills) were obtained using the Dijkstra method. Then, the distances from those to the destinations with the most profits were used for estimation. Similarly, for the transportation distance of unused woody materials, the shortest routes from the subcompartments to the six power plants in Hokkaido, which were certified by FIT as of June 2020 and mainly used unused wood materials in operation, were obtained using the Dijkstra method. Then, the distances from those to the destinatiosn with the most profits were used for estimation. Based on the fare table of the Hokkaido District Transport Bureau of the Japan Trucking Association, the transportation costs for 10-ton trucks and 20-ton semi-trailers were set, respectively.

Regeneration costs were set by multiplying the unit cost of each work for each tree species and each forest planning region in Hokkaido by the number of each work planned with the regional forest plan for a cutting period. Subsidies were obtained for regeneration and thinning operations as well as forest strip road constructions. The regeneration subsidy were obtained for all subcompartments whereas the thinning and forest strip road construction subsidies were obtained for subcompartments with an area of 5 ha or more and a harvesting volumes of 10 m^3/ha or more (Matsuoka et al., 2021). Subsidies were estimated by multiplying the standard unit costs by the assessment coefficient, 1.7 and the subsidy rate, 4/10.

Increments from the availability estimated with the harvesting cost of the conventional operation system and the transportation cost of the truck with 10-ton payload to those with the introduction of the semi-trailers with 20-ton payload, the European-type CTL, and both were evaluated by converting to the amount of money and power generation quantity. The monetary conversion of used and unused woody materials was calculated by multiplying the average prices for each tree species set in this study by the available increase. In terms of power generation conversion of unused woody materials, the dry weight of the available increase was first calculated by multiplying the coniferous wood chip conversion coefficient, 0.5 from the National Wood Chip Industry Association. The power generation amount was calculated by multiplying the dry weight of the available increase by the power generation efficiency of the woody biomass power generation/heat supply small plant, Spanner. With reference to the electricity consumption per household in Hokkaido of 3,906kWh/year, we calculated how many households could cover the power consumption.

3. Results and Discussion

With the introduction of both semi-trailers and European-type CTLs in Hokkaido, the availability was estimated to be 6,638,618 m^3/year and 1,327,724 m^3/year for used and unused woody materials, respectively. As for used woody materials, the value was significantly higher than 3,741,000 m^3/year of coniferous material production in Hokkaido. The value of unused woody materials also showed a value that almost satisfied the wood chip of 1,431,753 m^3/year, which was a woody biomass fuel in Hokkaido. The increased availability was estimated to be 141,953 m^3/year and 28,391 m^3/year for used and unused woody materials, respectively (Table 1). As for used woody materials, the value was converted to 1.19 billion yen/year in terms of monetary value and 3,596 houses/year in terms of

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single-family homes (Table 2). For unused woody materials, the value for power generation was converted to 190 million yen/year in terms of monetary value and 3,634 households/year in terms of the number of households. The effects obtained by introducing both semi-trailers and European-type CTLs would not be small, and this implies that the introduction will lead to further use of forest resources.

Table 1. Increased availability (m^3/year)

	Used woody materials	Unused woody materials	Total
Semi-trailer	100,409	20,082	120,491
CTL	44,201	9,940	53,041
Both	144,035	28,807	172,842

Table 2. Increased availability converted

	Used woody materials	Unused woody materials	Power generation	Household
	Billion yen/year	Billion yen/year	TWh/year	Household/year
Semi-trailer	1.04	0.13	10.0	2,571
CTL	0.45	0.06	4.4	1,132
Both	1.49	0.19	14.4	3,688

Acknowledgements
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Technodiversity-An International E-Learning Course on Forest Technology and Operations

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Abstract
Technodiversity is a European project supported through the ERASMUS+ programme and geared to produce a permanent E-Learning platform devoted to forest technology and operation. At present, the platform hosts a complete Forest Technology course addressed to Master Students and practitioners. Users can navigate between the different course component and develop their own ad-hoc learning programme. ECS credits are released based on the modules attended, after verification tests. Up to 10 ECS credits can be released through course attendance, after successfully passing all tests. The project as develop along four main activities: PR1) Contents: that consists in designing lectures on forest operations in order to deliver the intellectual knowledge that is needed for the optimization, and building a comprehensive glossary of forest technology terms based on already existing European and American glossaries; PR2) Scientific audiovisuals: project partners produced video strings to illustrate machines as well as typical harvesting systems under regional forest situations; PR3) Knowledge platform: the course architecture was built based on MOODLE, so as to allow barrier-free access for everybody, who is interested and PR4) Test courses: the E-learning course is being offered to Master students in 4 specific events, one of them has already taken place in Rome, Italy. To date, the initiative has been joined by the Universities of Brasov (RO), Dresden (D), Poznan (PL), Umea (S), Vienna (A) and Zagreb (HR). The end of the project is set for March 2024. In order to reflect the diversity and also get to know other opinions, the project team is open to including other partners besides the official project participants. Although later arrival would exclude new partners from direct EU funding, they will be co-opted into the network so that they can actively contribute to the development process.

Keywords: Forest Technology, technodiversity, forest operations

Poster Presentations

Changes of Some Elements Harmful to Human Health in Gold Mining Forest Fields Depending on Soil Use and Soil Depth

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Abstract
In order to meet the increasing need for raw materials with the industrial revolution, mining activities have increased and continue to increase throughout the world. Soil character and content can vary considerably in areas where mining activities are carried out. This situation can cause serious problems in terms of human and environmental health. Therefore, it is critical to determine the changes in the concentrations of elements that may be harmful to human and environmental health in the places where mining activities are carried out to evaluate the environmental effects of mining activities and to take the necessary protection. Within the scope of this study, the changes in the concentrations of indium (In), tin (Sn), and antimony (Sb) in the soil, which are elements that can pose a great risk to human and environmental health, were tried to be determined in gold mining areas. Within the scope of the study, soil samples were taken from the existing pulp area within the mine site, from the larch forest area where the ongoing mining process, and from the larch forest and plane tree forest outside the mine site in the region. The variation of the element contents in these areas depending on the soil depth was evaluated. As a result, it was determined that the element contents were at very high concentrations in soils, especially in the larch forest in the mining area and in the pulp area. This situation poses a significant risk for the workers working at the mine site.

Keywords: Gold mining, human health, soil

Poster Presentations

Hybrid-Electric Self-Propelled Carriage - First Field Tests

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Abstract
Cable logging can benefit from electrification in many ways, and more than other forest technologies. A significant percentage of cable logging setups transport timber downhill, providing an excellent opportunity for energy recovery. It is widely known that electrification is ideally suited to handle this task. However, due to the highly dynamic duty cycles, harsh working conditions, and tight weight constraints of forestry equipment, technical implementation is difficult. Equipment manufacturers started to electrify cable logging equipment with the introduction of electric slack-pullers almost a decade ago. Electric slack pullers are now mainstream. More recently, the first models of a hybrid tower yarder and an electric dropline carriage have been presented. This poster presents the second prototype and the early test results of a hybrid-electric self-propelled carriage, developed by the Italian start-up Leitalpin Ltd., with the scientific support of the Free University of Bolzano and CNR IBE. The machine is named HULK and is accordingly powerful and green. Its patented concepts enable it to efficiently transport uphill, downhill, and on flat terrain. HULK's traction drive and dropline winch are powered via independent electric motors, powered from an on-board energy storage system. When moving downhill and when lowering the load, energy is recovered and stored in the storage system. On sufficiently long and steep lines, energy neutral operation is possible. In all other cases, an on-board combustion engine supplies electric energy to the storage system. A first field test of HULK was conducted on a single-span line in the Northern Italian Alps. Travelling speeds and winch forces beyond 10 m/s and 40 kN were verified, respectively. Moreover, it was verified that the transport of 20 kN of timber 350 m downhill on the skyline with an average slope of 21 degrees could be performed energy neutrally. After extensive field trials throughout 2023, this new product is expected to achieve its market launch in early 2024.

Keywords: Hybrid-Electric, logging, self-propelled carriage

Poster Presentations

Examining the Potential for Increasing the Forest Resource Availability by Introduction of Semi-Trailers and European-Type CTLs in Hokkaido, Japan

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Abstract
With the introduction of both semi-trailers and European-type CTLs in Hokkaido, the availability was estimated to be 6,638,618 m3/year and 1,327,724 m3/year for used and unused woody materials, respectively. As for used woody materials, the value was significantly higher than 3,741,000 m3/year of coniferous material production in Hokkaido. The value of unused woody materials also showed a value that almost satisfied the wood chip of 1,431,753 m3/year, which was a woody biomass fuel in Hokkaido. The increased availability was estimated to be 141,953 m3/year and 28,391 m3/year for used and unused woody materials, respectively. As for used woody materials, the value was converted to 1.19 billion yen/year in terms of monetary value and 3,596 houses/year in terms of single-family homes. For unused woody materials, the value for power generation was converted to 190 million yen/year in terms of monetary value and 3,634 households/year in terms of the number of households. The effects obtained by introducing both semi-trailers and European-type CTLs would not be small, and this implies that the introduction will lead to further use of forest resources.

Keywords: Forest resource, semi-trailers, CTL

Poster Presentations

Harvesting Options for Medium-Rotation Poplar Plantations Established on Ex-Farmland

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Abstract
Tree farms have been a common solution for the temporary medium-term exploitation of marginal farmland for many decades. Among the many different farm models proposed over the years, the one that is currently most popular is a medium rotation (5-8 years) tree plantation established with poplar, eucalypt or acacia, depending on the ecological regions. The plantation is often managed as a coppice and kept on site for 3 to 4 rotations (app. 20 years) before the eventual return to farming. These plantations have attracted the interest of conventional wood industries which are leading the resurgence of short rotation forestry on ex-arable land. In Europe, much new planting is occurring East, in countries such as Poland, Romania or Slovakia, which offer an ideal combination of good soil conditions, moderate land price and a rapidly developing economy. So far, low labour cost in Eastern Europe has allowed the widespread use of manual or semi-mechanized work techniques for establishment and harvesting: however, the rapid development of these regions generates a growing concern about the future availability of cheap labour, which determines a strong interest for mechanization. Furthermore, mechanized harvesting offers distinct advantages in terms of simplified logistics and enhanced work safety. The main challenge with harvesting these plantations is presented by the small individual tree size. Even the smallest tree harvesting machines are designed for trees with an optimum size around 0.2 m3, and productivity declines very quickly when stem size is smaller than that. In such instance, the most common solution lays with mass handling, whereby more trees are harvested in one cycle in order to compensate for their small size. This presentation reports about the results of full-size controlled field experiments conducted by CNR for IKEA over five harvesting seasons, from 2018 to 2023. These trials allowed testing a full range of techniques and technologies, including cut-to-length harvesting, whole-tree harvesting, all implemented with different machines and models for side-to-side performance comparison. The goal was to find the system that resulted in the highest productivity, lowest cost and maximum value recovery for any given conditions.

Keywords: Ex-Farmlands, harvesting, poplar plantations

Poster Presentations

Operational Performance of a Combi - Forwarder in Shelterwood System

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Abstract

In many parts of the world, small-scale harvesting machines have been used in forest operations on various terrain conditions. Forwarders are a mechanized alternative to agricultural and forestry tractors and animal logging and currently, these machines are among the most used ground-based machineries to extract the wood around the world. Forwarders are self-propelled vehicles intended for the transport of trees and their parts loaded in the vehicle bunk area. The development of the first forwarders started in Sweden in the 1950s. Forwarders are not conceptually different from those from a half a century ago, but they have made major progress in terms of environmental soundness and ergonomics and steering automation. Fortunately, in recent years the development of new technological progresses in forestry mechanization created an alternative operation on ground-based system with the use of a combi-forwarder for wood extraction. These innovative machines pull stems by the winch from the stump to the road, after they have been cross-cutted by chainsaws, it loads by the forwarder's crane the logs and transports them to the landing, where they are unloaded with the crane in piles. As reported in several studies, the forwarder efficiency is affected by numerous factors. The most important factor is travel distance. With the increase of the travel distance the impact of the load volume on the vehicle productivity is also increased. The aim of the present study was to estimate the productivity of the combi-forwarder in beech stands evaluating the forwarding and winching distances, log's volume transported per turn by the machine, as well as the extracting costs. The results from the study are useful to introduce and to integrate the combi-forwarders in shelterwood system and to achieve economic and environmental efficiency of timber harvesting in deciduous forests.

Keywords: Combi forwarder, mechanization, shelterwood system

Poster Presentations

Challenges Related to the Economic Sustainability of the Logging Industry in Virginia

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Abstract
The three pillars of sustainability are environmental, social, and economic. The forest supply chain experiences challenges in all three of these categories. This supply chain includes landowners involved in growing and harvesting timber, logging businesses harvesting and delivering wood to mills, and the mills producing primary wood products. Logging businesses are the common link connecting the landowners and raw materials to producers and consumers of finished products in the forest supply chain. Numerous studies have focused on the environmental sustainability of forest harvesting operations; however, few have focused on the broader economic sustainability. Economic sustainability of the logging industry involves maintaining economic viability without compromising the environmental and social aspects of forest management and utilization. The primary goal of this study is to evaluate the economic sustainability of the logging industry in Virginia by determining and ranking the economic viability challenges faced in each aspect of their harvesting operations. Additionally, we will evaluate opinions from professionals in other segments of the forestry supply chain related to the economic sustainability of the logging industry. Mail surveys will be used to collect data from our survey populations which will include logging business owners, consulting foresters (proxies for landowners), and mill owners or procurement representatives. Results will allow us to identify differences by region and type of operation and compare differences in perspectives across participants in the supply chain. Results will provide the industry a ranking of the most significant challenges related to economic sustainability of logging businesses across Virginia and highlight specific needs for future research.

Keywords: Economy, logging industry, sustainability

Poster Presentations

Exploring the Soil Layer Distribution of Forest Roads Using Ground Penetrating Radar Method

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Abstract
Forest road is a crucial element for sustainable forest management, but its impact on environmental issue can be significant. In the republic of Korea, the slope failure is often caused by the construction of forest roads. Since fill slope failures have been more frequent than cut slope failures on steep terrains, accurate understanding of geological and geotechnical properties of forest roads is emerging issue for stability assessment of forest roads. Direct geotechnical investigation provides precise information on sampling points, but it is not suitable for use in forest roads because the limited resources and high spatial variation. Therefore, indirect, non-destructive technique called ground penetrating radar (GPR) was used to detect the distribution and geotechnical properties of subsurface soils along forest roads. The GPR data acquisition along road centerline was carried out using an IDS Georadar Operaduo GPR. GPR system operated with 250 and 700 MHz central frequencies. 250 MHz frequency was used to detect mother rock on subsurface as it penetrates 3 to 4 meters perpendicular to the road, while 700 MHz was used to distinguish soil layers. The data was analyzed with time zero correction, background removal and migration technique. The mother rock and filled up soil layer appeared in the form of a line crossing laterally in the processed 2D profile. The results showed that the GPR survey can be applicable to distinguish between fill materials and mother rock in subsurface soil layers after forest road construction.

Acknowledgement: This study was carried out with the support of Program for Forest Science Technology (Project No. 2023474B10-2325-BB01) provided by Korea Forest Service (Korea Forestry Promotion Institute).

Keywords: Forest roads, soil layer distribution, radar

Poster Presentations

Assessment of Real-time Positioning Using GNSS-RTK for Precision Forest Operations

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Abstract
In the recent forestry field, the role of accurate positioning data has become more important as the desire for precise forest management grows. Various real-time positioning systems such as global navigation system (GNSS), integrated GNSS and inertial navigation system (INS), and LiDAR simultaneous localization and mapping (SLAM) are being adopted for precise forestry works. Among them, GNSS-RTK is known as the most convenient and cost-efficient and has sufficient positioning accuracy for the field manager and workers. However, since the GNSS-RTK decides ones, position based on the radio frequency (RF) signal received from the satellites, the accuracy of the position tends to be influenced by the forest environmental factors such as forest canopy and density, etc. Therefore, this study aimed to evaluate the applicability of the GNSS-RTK (Trimble R12i) in the forest by 1) comparing the horizontal RMS(HRMS) and time to first fix (TTFF) of GNSS-RTK by the basal area (BA, 30/ 40/ 50/ 55 m2) in each experimental plot and 2) comparing the HRMS and radio signal strength index (RSSI) by the distance between the base-station and the rover of the GNSS-RTK (50m intervals, Maximum 1km). As a result, the average RMS of GNSS-RTK showed the lowest at BA30 for 2.3 m, and gradually increased up to 2.6 m at BA55 ($p < 0.05$). Also, the average TTFF showed a dramatic increase at the larger BAs, minimum 10 sec at BA30 and maximum 43 sec at BA55 ($p < 0.05$). The average RSSI showed a significant decrease as the rover went further from the base-station, highest at -53.8 dBm at 50m and lowest at -107.7 dBm at 750m. However, there was no significant correlation between the HRMS and RSSI ($p>0.05$). The result of this study implicates the possibility of GNSS-RTK utilization for forestry works within the range of 1km from the base-station. However, since the accuracy of GNSS-RTK might get influenced by other forest environmental factors such as terrain and sky visibility, it will be broadly analyzed in further study.

Keywords: GNSS-RTK, precision forestry, real-time positioning

Poster Presentations

Informing Bucking Rules for Storm Damage Timber with Acoustics

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Abstract
Wind events, hurricanes and tornadoes are some of the most common weather events that damage individual trees and even entire stands. There is a need for guidance in determining where to buck damaged stems to maximize value. Traditional bucking rules might have a logger buck at a predetermined distance from the break, but there are no published guides that determine the bucking location to optimize log value in reference to snap or tree variables. We measured acoustic values (m s-1) to determine the extent of the fracture within stems that were pulled over in an experiment to measure the force needed to damage mature longleaf trees. We sampled radial acoustic values on 29 trees about six months after the trees were pulled over. We generated a significant model for acoustic values at each tree position (distance from snap) that included distance from snap, tree dbh, snap height and the maximum acoustic velocity in the tree. The model could be used to identify optimum bucking location as distance from snap.

Keywords: Storm damage, bucking rules, acoustics

Poster Presentations

Construction of Natural Water Pathways in South Korea's Mountainous Areas

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Abstract
The current construction method of water pathways in the mountainous areas in South Korea is to control soil erosion, instability, and destructive water flow by using construction materials like concrete and stone. Water flows in the mountainous areas are essential components of maintaining a healthy ecosystem of forest and are critically important to preserve the environment and landscape, including water quality, wildlife habitats, and native species, through the construction of water pathways that promote natural benefits. Mountain stream restoration technologies that consider ecosystem stability and landscape help stabilize stream floors and flow, offer fish and wildlife habitats, allow building forest road and can be applied to various protected areas, including cultural heritage protection areas, natural reserves, and national parks going beyond the forestry applications.

Keywords: Restoration, water pathway, grade stabilization

Poster Presentations

Development of Rapidly Constructible Prefabricated Debris Dam

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Abstract
Global warming and abnormal weather patterns have led to an increase in damages caused by debris flows, particularly in areas affected by recent wildfires, where heavy rainfall poses a high risk of soil-related disasters. As a result, there is an urgent need for technologies that can respond quickly to these situations. While we are building debris dams to mitigate soil-related disasters, many of these structures made of concrete materials are not suitable for emergency repairs because of their lengthy construction periods. Furthermore, constructing these dams may also have adverse effects on the ecosystems in both the upper and lower regions of the valleys. We have developed a prefabricated debris dam that can be constructed without the use of heavy machinery such as mixer trucks, by avoiding the use of concrete. To ensure its construction performance and safety, we conducted a thorough evaluation through structural analysis, experiments, and on-site construction. The prefabricated debris dam is constructed by assembling steel components that are manufactured in a factory and then transported to the construction site. The foundation of the dam is created by using a steel frame filled with stones to provide stable resistance against external loads.

Keywords: Prefabricated dam, debris flows, debris dam