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The reliability of Citizen-science data collection - analysis of *Natur i Endring* project

Michal Torma

Faculty of Technology, Natural Sciences and Maritime Sciences
Campus Bø

University of South-Eastern Norway

www.usn.no

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Student: *Michal Torma*
Supervisor: *Anders Bryn, Peter Horvath, Mona Sæbø*
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Summary:
In this study we evaluate *Natur i Endring* citizen science project after the first season of running (2018). *Natur i Endring* is a project focused on crowd-sourcing data collection of naturally occurring treeline and forest line in Norway. We use Kirkpatrick taxonomy model of evaluation to assess the project from these four perspectives: (1) Reaction evaluation of the ways public was engaged and how effective was the outreach strategy. (2) Learning evaluation of feedback analysis after certain time the project was running. Main goal is to identify if participants learned something new and what is the overall sentiment about the project. (3) Behavior evaluation of users engagement patterns and activity in the field. (4) Results evaluation of actual data provided by citizen scientists and assessment of data quality.

Preface

I would like to give huge thanks to all participants of this citizen science project. Gathering treeline and forest line data on such scale would not be possible without you.

I would also like to express my gratitude to the staff at Natural History Museum (UiO) and The Norwegian Trekking Association (DNT) involved in the project. A special thanks for financial support goes to The Saving Bank Foundation DNB (Sparebankstiftelsen DNB).

Last but not least I would like to thank to my supervisors Anders Bryn, Peter Horvath and Mona Sæbø for all the valuable input and Inger Kristine Volden for all the help with the survey. Bø i Telemark, 15th May 2019

Michal Torma

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Nomenclature

Symbol	**Explanation**
DBH	Diameter at Breast Height
ECSA	European citizen science association
GNSS	Global navigation satellite system
LiDAR	Light Detection and Ranging
CS	Citizen Science

1 Introduction

Citizen science is an innovative bottom-up approach for data collection that is rapidly gaining popularity in scientific community (Irwin 2018). By method, it involves voluntary, non-professional citizens in research. The public involvement varies among projects, and the family of methods has many names, for example participatory research, crowd-sourced science and community science[1] . The advantages of using citizen science, compared with traditional research, are many. If well organized, citizen science can generate tremendous amounts of data (*GBIF* 2019; *Artsobservasjoner* 2019). In addition, by involving the general public in research, participants can be educated and bring their knowledge into a broader part of society (Hecker et al. 2018; Bonney et al. 2014).

Historically, people started contributing to scientific activities through early astronomy projects (Mims 1999), which later expanded into counting and tracking exercises in entomology (Swaay et al. 2008) and ornithology (McCaffrey 2005). With the advent of the internet, citizen science projects became even more popular and easier to establish (Bonney et al. 2014).

With multitude of citizen science projects being active in the past, The European Citizen Science Association (ECSA) compiled a list of ten principles that describe such projects, and that preferably could be followed to increase success rate of any new citizen science project. These ten principles of citizen science are as follows:

1. Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding.
2. Citizen science projects have a genuine science outcome.
3. Booth the professional scientists and citizen scientists benefit from taking part.
4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process.
5. Citizen scientists receive feedback from the project.
6. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for.

[1]In Norwegian citizen science is most often called *f*olkeforskning or *g*rasrotforskning (Woldstad 2019; Anders L. Kolstad 2018)

7. Citizen science project data and meta-data are made publicly available and where passible, results are published in an open access format.
8. Citizen scientists are acknowledged in project results and publications.
9. Citizen science programmes are evaluated for their scientific output, data quality, participant experience, and wider societal or policy impact.
10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreement,confidentiality, attribution, and the environmental impact of any activities.

(Hecker et al. 2018)

1.1 Technologies for citizen science

New technology expands the possibilities for citizen science projects, as well as it lowers the threshold for participating in citizen science (hereafter abbreviated CS) projects. To simplify submission of data collected by citizen scientists, digital technologies are being used increasingly and with widespread use of smartphones, well designed mobile applications can increase the amount and quality of data collected (Sturm et al. 2018). With high precision positioning systems integrated in mobile phones, possibilities for geospatial data collection are becoming more reliable than before (Zandbergen and Barbeau 2011).

1.2 *Natur i Endring* project

Following the guidelines for citizen science projects described by The European Citizen Science Association above, a recent citizen science project implemented mobile phone technology for mapping of climatic tree- and forest lines. This project focused on collecting data about treelines and forest lines of Norway. The aim of this project was to collect geospatial points of these lines along the altitude gradient in as many parts of Norway as possible. Citizen scientists were encouraged to take a picture of the highest tree of treeline or forest line while hiking in mountainous regions. Alongside taking picture, users also filled in various metadata about the registered trees and forests consisting of following inputs:

- Treeline or forest line registration
- Tree height
- Diameter at breast height (DBH)
- Tree species

The project uses mobile phone technology to make input user friendly and fast. Thanks to localization properties of the device we could alleviate the burden of manual location input and automate submission process.

Figure 1.1: The mobile application used for the *Natur i Endring* CS project in Norway.

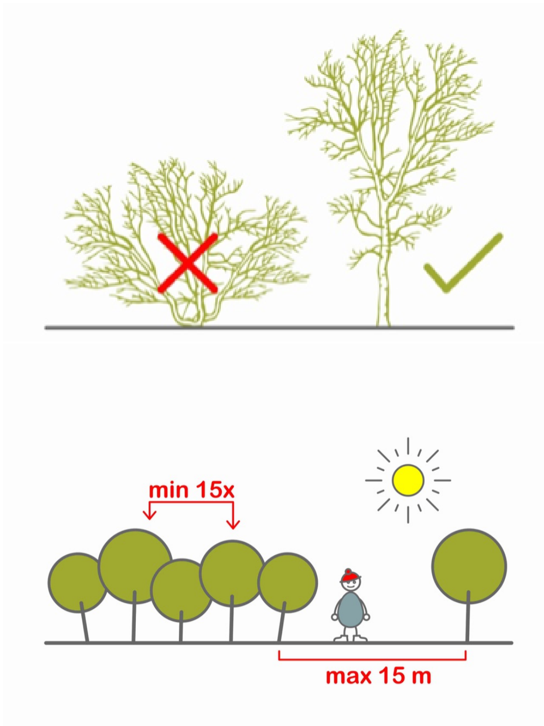


Figure 1.2: The guidelines of the mobile application used by *Natur i Endring* are followed by illustrations. These illustrations are showing the difference between a bush and a tree and the definition of forest. Illustration by Zuskinová 2018.

The mobile application includes guidelines for the participants, it runs on iOS and Android, and is available in English and Norwegian. The application is free for download and use, but the users need to log on and provide an e-mail address to be activated. The project has been undertaken in partnership with The Norwegian Trekking Association (hereafter abbreviated DNT), which has more than 300.000 members. DNT has actively promoted the project to it's members, as well as to the society in general.

1.3 Common challenges with citizen science, and a potential framework for solving such complex challenges

There are many challenges with citizen science projects (Irwin 2018). Common challenges mentioned in papers treating citizen science are recruitment of new citizen scientists and reliability of obtained data. Studies show that reliability of collected data is highly variable and dependable on the kind of data that is collected(Aceves-Bueno et al. 2017). According to Dickinson, Zuckerberg and Bonter 2010, the ability of citizen scientists to produce valid data sets are poorly understood. But often, when users are provided with clear guidelines, parity of quality with professional researchers can be reached (Kosmala et al. 2016). Recruitment of new citizen scientists is highly dependable on advertisement of the project as well as motivation of participants who contribute to the project (Land-Zandstra et al. 2016). Participants usually contribute to the project because they feel good about helping science, enjoy the participation process, have a chance to get involved with community or have a chance to win valuable prices (Land-Zandstra et al. 2016).

The last decade, in accordance with increasing sampling through citizen science projects, there has been considerable discussion and research into different uncertainties, biases and errors (Tye et al. 2017). In particular, there has been a focus on the difference between citizen science data and professionally collected species occurrence data (Tye et al. 2017; Van der Wal et al. 2015). This is probably related to the easy access of large datasets through web-portals such as GBIF (*GBIF* 2019). Such databases enable research on large data sets. However, the quality of such data has been questioned (Tye et al. 2017; Van der Wal et al. 2015). In particular, spatial bias towards already established walking paths and roads is common. Studies identified the tendency to collect more data points in more developed areas, giving spatially biased distribution of observations.

In addition, it is often problematic to get the public engaged in citizen science projects (Irwin 2018). Main problems are in persuading new people to participate in the projects and keeping participants active over time.

General consensus about methods for evaluating citizen science projects have not yet been reached, but Kirkpatrick evaluation taxonomy model (Kirkpatrick 1979) which is commonly used in business and industry training setting is a good starting point for any evaluation of this sort (West 2015).

This model categorizes evaluation into four parts: Reaction, Learning, Behavior and Results evaluation.

- Reaction evaluation focusses on the ways public was engaged and how effective was the outreach strategy.

- Learning evaluation focusses on feedback analysis after certain time the project is running. Main goal is to identify if participants learned something new and what is the overall sentiment about the project.
- Behavior evaluation focusses on users engagement patterns and activity in the field.
- Results evaluation focusses on analysis of actual data provided by citizen scientists and assessment of data quality.

1.4 Aims of the study

The main aim of this study is thus to evaluate how effective this method of data collection is and identify possible pathways to improvements. Four specific research questions where given specific focus:

- Which was the most effective outreach method for attracting new users and what was the general distribution of participants in regard to age and gender?
- What did the participants learn while taking part in this project and how did participation in this project affect their perception of citizen science projects in general?
- What were the behavioral patterns of users in regard to their activity and spatial coverage of study area?
- How precise were the individual aspects of data provided by citizen scientist?

1.5 Study area

Data were collected from the whole of Norway with filtering of points based on the area of expected forest line boundary published by Bryn and Potthoff 2018. For LiDAR evaluation we used all the data points and for field test we focused on the part of Norway south of Trondheim. The CS data included where sampled by participants between 15.05.2018 and 30.11.2018. All the data included in this study, and the study areas can be seen in Figure 1.3.

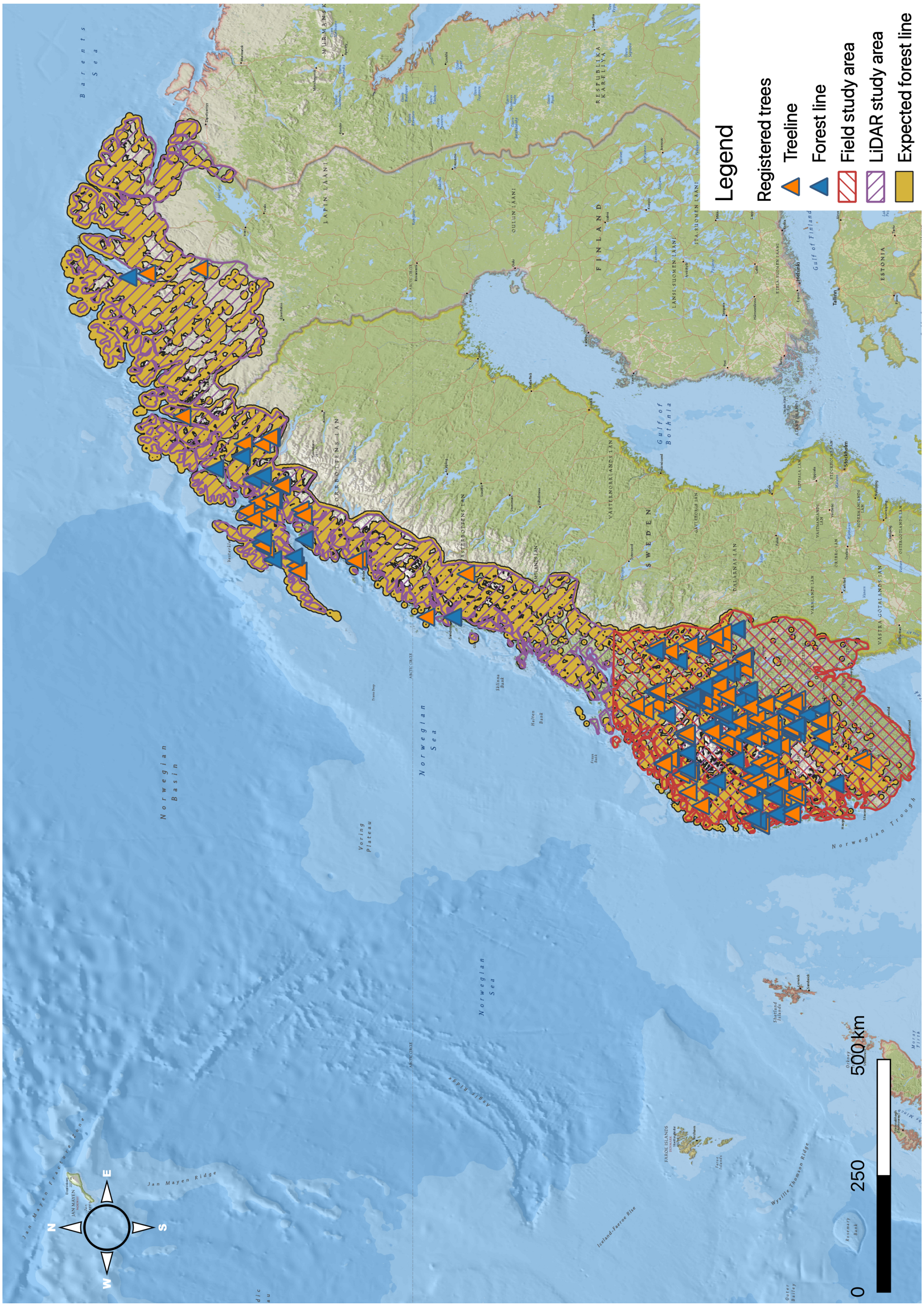


Figure 1.3: Map of study area and collected reports

2 Methods

In order to improve the CS project *Natur i Endring* in it's whole, the evaluation process was divided into four main steps, following the aims of this study. The diagram below 2.1 depicts workflow of the project. Each of the evaluation processes feeds back to the development workflow of the project and the information will be used to improve individual parts of the project in the upcoming field season.

1. Reaction - identification of the most effective outreach strategy and distribution of gender and age of registered users.
2. Learning - using survey to gain insight into sentiment of users and identification of possible user-facing problems of *Natur i Endring* CS project.
3. Behavior - analysis of individual users activity in the project.
4. Results - precision analysis of all aspects of the data set we obtained from citizen scientist.

To identify precision and asses reliability of individual aspects of data we obtained from citizen scientists, we employed a multitude of analysis tools all of which were open-source software. To generate maps we used QGIS 3.6, for general statistics we used Python 3.7 and R 3.5.2. All of the data used in this study is publicly available (*Natur i Endring - Results* 2019).

For this study we removed from our data set all registrations made by three scientists involved in *Natur i Endring* project design and development. This was done to avoid biased results in terms of the expected higher quality of professionals compared with ordinary citizens.

2.1 Data collection

Participants were encouraged to collect data in the field through a mobile app. The app was released on 15.5.2018. The release was reported in national newspapers (Haugen 2018). Participants were guided through a learning process by following a tutorial within the app. The tutorial was developed to introduce the general aspects of the CS project and introduce the user to the registration process for the first time. The data reports that we studied were collected from 15.5.2018 to 30.11.2018 by participants from all around Norway. There were no prerequisites for citizen scientists to participate in data collection and children were especially encouraged to take part in the project (Busterud 2019). Before every registration, the user could state that following registration is to be done in the name of a child to identify that it belongs to a separate competition with prices adapted to children.

Reports were collected using mobile app and for each registration, citizen scientist was guided through following steps:

1. Check if tree fits definition the definition of a tree. We defined trees to be at least 2.5 m tall, heaving one stem and not being bendable at breast height. This was done to avoid unwanted registrations of bushes instead.
2. Choose whether this report registration of the treeline or the forest line. We defined the treeline to be the highest tree in the the area and the forest line as the highest tree in the forest while the forest is a collection of at least 15 trees where each tree has distance to the nearest neighbor of maximum 15 meters.
3. Input tree height using slider with distinct values. To aid the estimation, there was a visual animation showing relative height of the selected value compared with 1.75 m tall human silhouette (Figure 2.1).
4. Input tree diameter using slider with distinct values. To aid the measurement, there was an on-screen ruler spanning height of the screen as seen in Figure 2.1.
    - Report location was finalized in the background during this step. The app tried to obtain GNSS coordinates fix since the beginning of the procedure in order to increase accuracy. We used a 10 m threshold for coordinate precision, and until this threshold was reached, it was impossible to continue the data input process.
5. Choose tree species from the list of options. These options were chosen from previous studies to be the only possible species to occur in this environment (Bryn and Potthoff 2018) namely mountain birch, Scots pine, Norway spruce, willow (*Salix sp*) and rowan.
6. Take picture of the tree. Users were requested to take a picture with the whole tree in the frame.

Once the reporting process was successfully finished, data was stored in local SQLite database of the device and subsequently synchronized to our server database when internet connection of the device was favorable.

When the new report arrived to our server, it was checked according to the following criteria:

- it falls within our expected boundary seen on Figure 1.3
- the registration is obviously not depicting a tree/forest (trial registration in the living room)

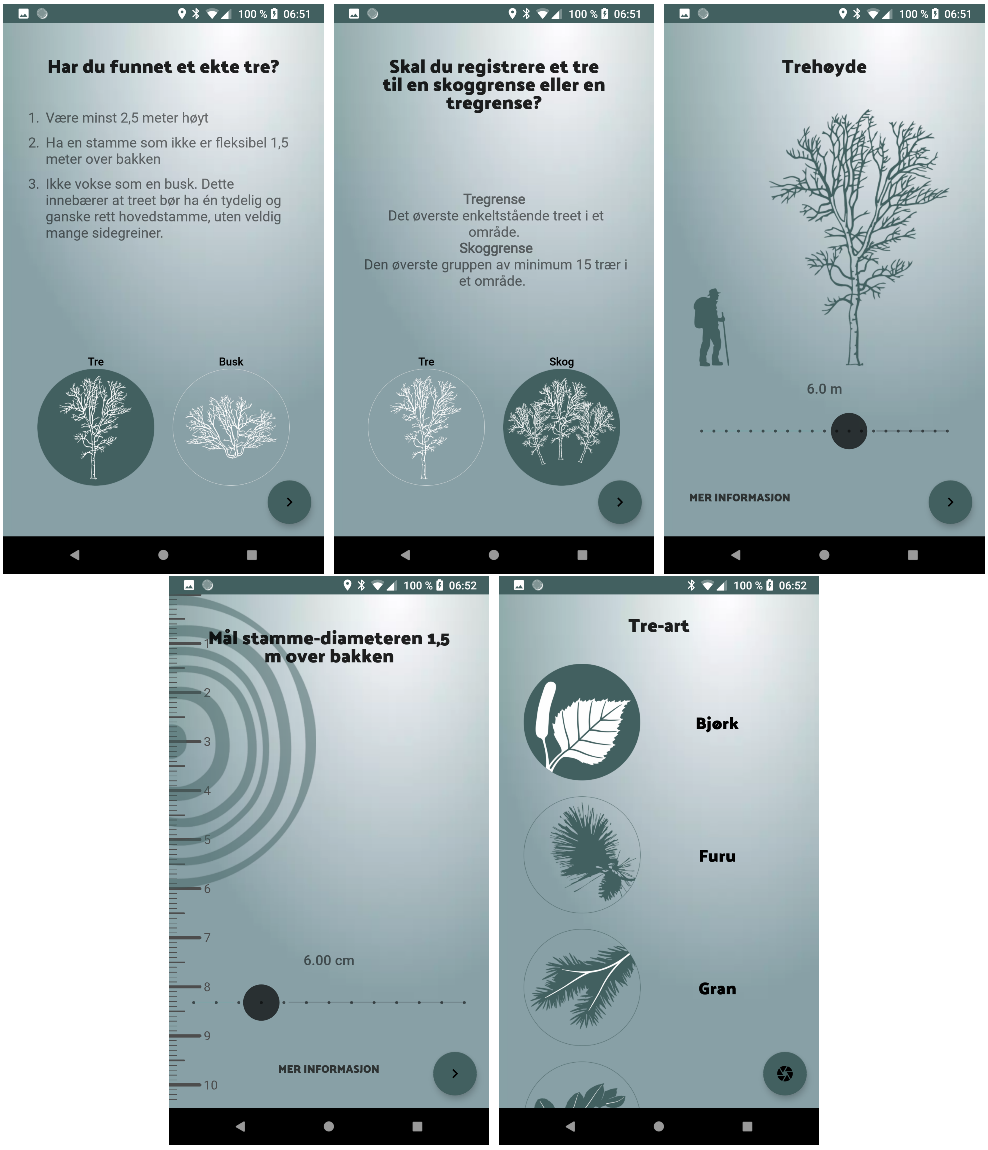


Figure 2.1: Mobile app - New report data input procedure

After this process was finished, we manually checked the report and decided whether to approve it or not. The approved data remained flagged in the database and became visible on the project website. Altitude from mobile GNSS sensor is highly unreliable (Zandbergen and Barbeau 2011). Therefore an additional altitude measurement of the registration was derived from the standard digital elevation model of Norway (*Geonorge*

DTM 10m 2019). The database finally included the attributes that can be seen in Figure 2.1

Column name	Description	Data type
uuid	Id of the user who submitted the registration	TEXT
ts	Timestamp of when the registration was taken	LONG
ts_up	Timestamp of when the registration was uploaded	LONG
lat	Latitude of the registration in WGS 84 projection	REAL
lon	Longitude of the registration in WGS 84 projection	REAL
acc	Accuracy of location measurement	REAL
alti	Altitude from on-device GNSS	REAL
is_forest	Boolean value identifying treeline or forest line registration	BOOL
tree_height	Height of the tree	REAL
tree_dbh	DBH of the tree	REAL
tree_spec	Tree species	TEXT
photo_path	Path to the photo taken	TEXT
g_alti_dem	Altitude derived from Digital Elevation Model (DEM)	REAL
g_fylke	County to which the registration belongs to	TEXT
g_aspect	Aspect of the registration derived from DEM	REAL
valid	Boolean value of manual validity check	BOOL

Table 2.1: Table of database entries for each registration

During the registration process of new participants, we stored the time of creation of the new account. We also asked for optional input of age and gender of a user (Figure 2.2)

Column name	Description	Data type
uuid	Unique user id	TEXT
timestamp	Timestamp of account creation	LONG
age	Optional age of the user	INT
gender	Female/male/other	TEXT

Table 2.2: Table of users

2.2 Reaction analysis

For reaction analysis we used data obtained from new user registration process where users were asked to input their age and gender. Particularly we used attributes age and gender in table 2.2. We also stored time and date of every new registrations which we could consequently corelate with our outreach activities to get insight into the most effective methods of advertisement. The methods of advertising/ outreach we used were the following:

- Outreach activities consisting of seminars in Oslo botanical gardens and on DNT cabins.
- “Walk and talk” presentation of a project on *Vinjerock* music festival (23.7.2018)
- TV interviews (20.7.2018, 8.5.2018)
- Newspaper articles

For correlation analysis we used smoothed z-score based peak detection algorithm (Perkins and Heber 2018) to identify when the number of registrations per day spiked. After series of testing we used 10 days lag time for mean and choose $10 \times SD$ as a threshold. Subsequently we matched the time of our outreach activities with corresponding spikes if possible.

We used gender and age data (Table 2.2) to identify average age of the users and gender ratio. We than compared age distribution of males and females using z-test to find out if they differ significantly.

2.3 Learning analysis

During the project *Natur i Endring*, the participants were encouraged to learn about one of challenges Norwegian ecosystems are facing due to climate change – altitudinal changes of the treeline and forest-line. Participants were encouraged through different means to get insight into these challenges through the following activities:

- Seminars
- Tutorial included in the mobile application
- Website[1]

To enquire about the learning process of participants, we created a survey, which was sent out to all the participants who have downloaded the app (and given a correct contact email address). The survey was available in booth English and Norwegian using Google Forms [2]. Full content of the survey can be seen in figure 2.2.

[1] https://www.naturiendring.no/
[2] https://docs.google.com/forms

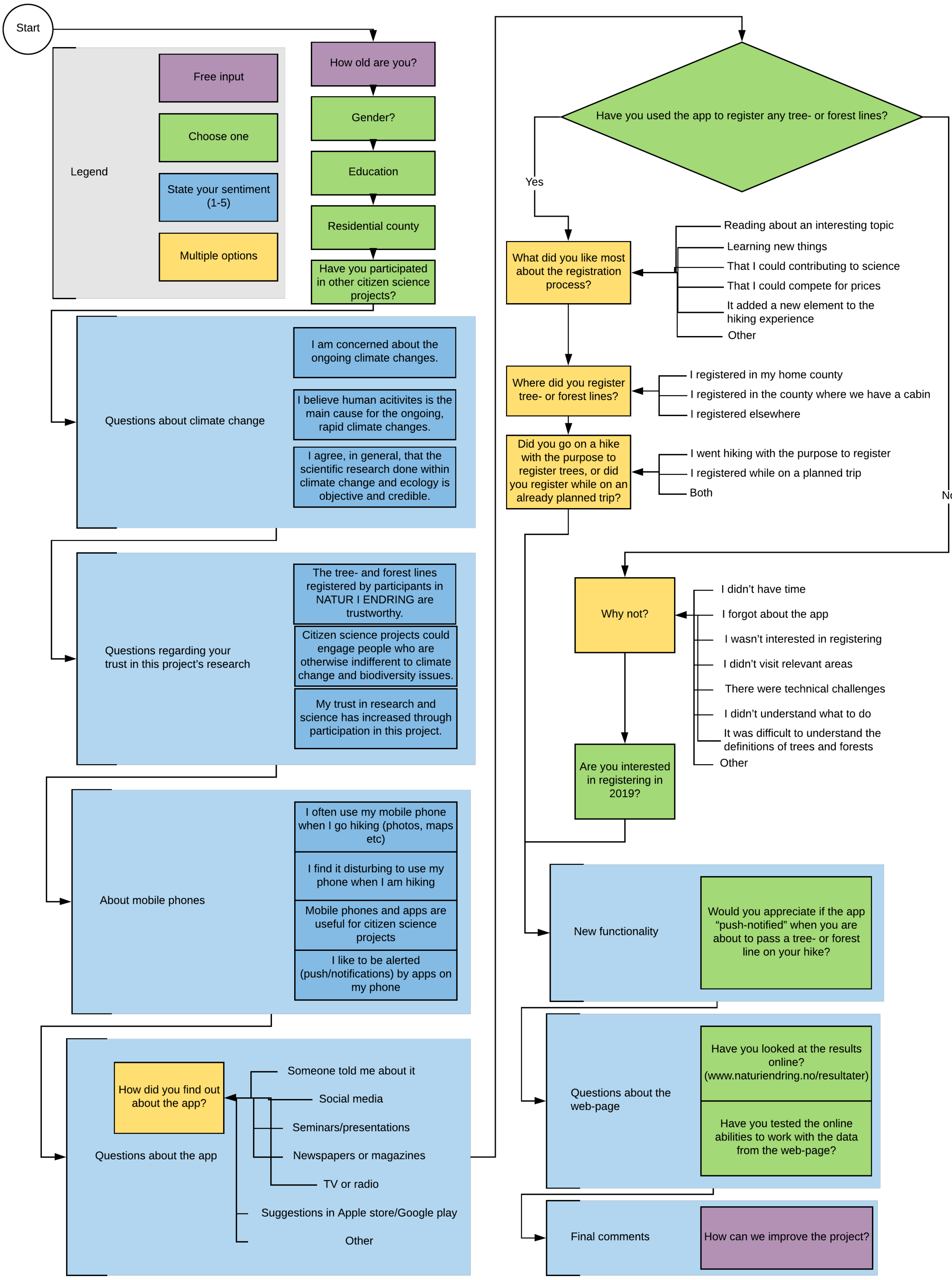


Figure 2.2: Survey questions in a form of flowchart

Within two weeks of spreading the survey we obtained answers from 251 responders. Firstly we merged results from the two language options with using the *pandas* library in Python and consequently plotted the results using the *plotly* library[3].

For plotting single answer question we used pie chart. For plotting multiple answers questions we first decoupled the individual answers as separate votes and used pie chart to visualize individual answers separately. Lastly, for visualization of questions asking for sentiment about the statement we used bar chart with individual bar for each of five available sentiments. Possible sentiments available in these questions were following:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

2.4 Behavior analysis

For behavioral analysis of our users we compared active users count with overall registered users count. Basic activity trends for active users were identified by identifying mean number of registrations per user. We also analysed when the reports were taken in respect to the day of the week. We work with the hypothesis that users would be more likely to register during the weekends as opposed to weekdays. We also identified how registrations from different counties of Norway were represented in the data set.

To identify spatial bias of collected reports we generated 10000 random points in the area where we expected to find a treeline (Bryn and Potthoff 2018) to occur using random points inside a polygon function in QGIS. Then we computed distance to the nearest hiking track, ski track or a road (*Geonorge Tur- og friluftsruter* 2019; *Geonorge Vbase* 2019) using distance to nearest hub function in QGIS. We used the same approach with all the valid reports collected by citizen scientists. Then, we compared these two distributions using z-test and mean distance to the tracks comparison.

[3] https://plot.ly

2.5 Results analysis

We used two methods for checking validity of registrations obtained throughout the first year of running *Natur i Endring* project. First, a field test of randomly selected registrations where we checked all the metadata of each registration. Second, a LiDAR analysis of all the registrations, where we were constrained to test the reliability of the treeline/forest line sampling conducted by the participants.

2.5.1 Field test

To check the ground truth, we went to the field and visited 10 random treeline and 10 random forest line registrations in the area of Norway south of Trondheim using random selection function in QGIS. Resulting points can be seen in figure 2.3. Due to conditions of the field season (reduced accessibility of mountainous areas in the winter) and feasibility of the field work (limiting the amount of traveling), we had to constrain the study area of the field test to South Norway. We also checked all the registrations in the vicinity of these randomly chosen sites altogether checking 50 reports. At all the selected field points, we checked if the treeline or forest line registered were in accordance with the sampling scheme (provided by the guidelines). If a registration didn't correspond with the definition, we collected the location of the nearest point (treeline or forest line) that was in accordance with the sampling scheme. Subsequently, we measured tree height, DBH and collected location coordinates using a Garmin eTrex x20 GPS device with accuracy of ± 3 m. Each of these measurements were consequently compared with the measurements provided by citizen scientists. We used the mean distance between these pairs of points and compared with the expected variability based on the "Accuracy of location measurement" (*acc*, see table 2.1).

To compare tree height and DBH metadata of visited registrations we used Bland–Altman plot to visually compare measurement of researchers versus citizen scientists (Myles and Cui 2007; Carkeet 2015).

2.5.2 LiDAR validation

LiDAR mapping is a high-precision remote sensing technique that is used for elevation mapping using laser distance measurements from an airplane. Thanks to the high resolution of the LiDAR, it is possible to identify forest structures remotely (Lim et al. 2003). We used the existing coverage of LiDAR in Norway (*Høydedata* 2019) to manually verify which registrations were valid within the reasonable expectations of error. For every sample, if covered by LiDAR measurement, we decided weather it seems valid based on it's surroundings. We also identified any mismatched registrations of treeline as forest

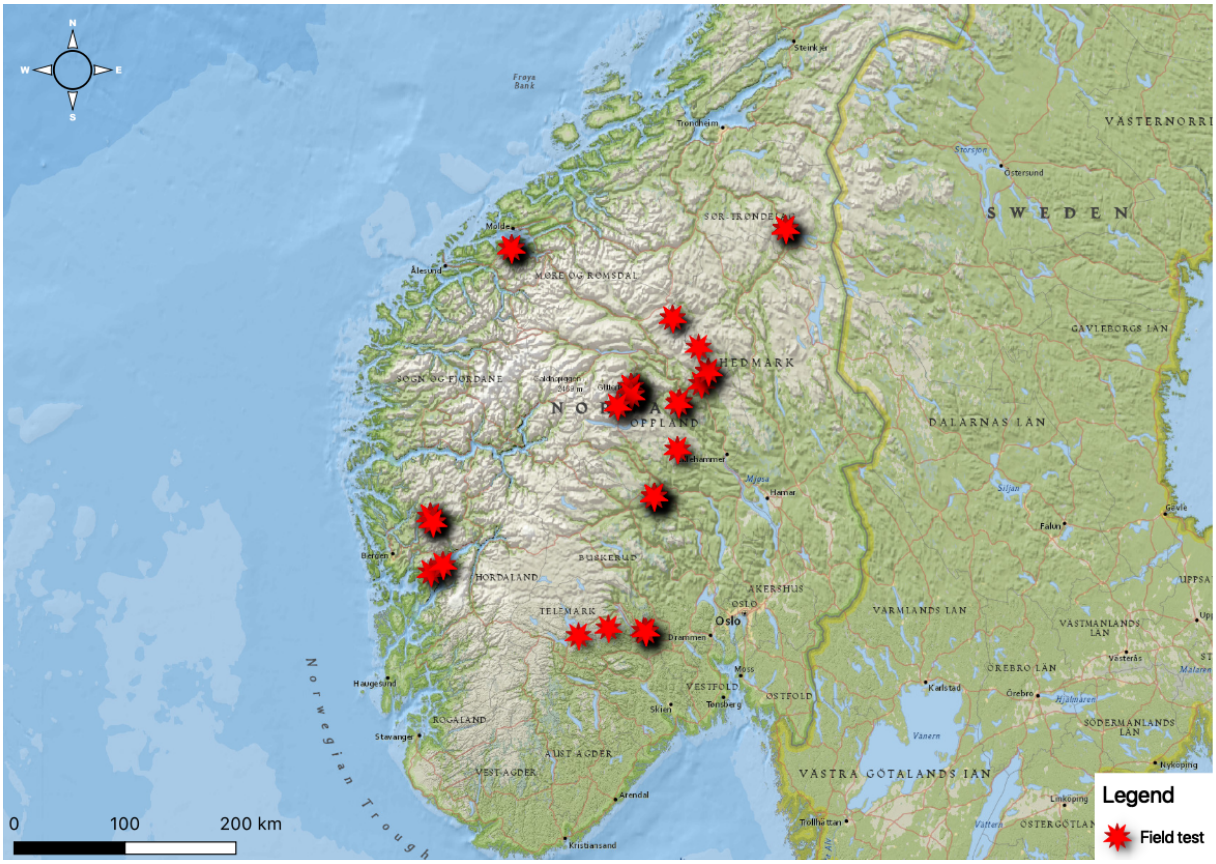


Figure 2.3: Field test - random reports

line and vice versa in case there was sufficient evidence in photo taken by citizen scientist and LiDAR measurement. To make decision process faster and more objective, we wrote a Python application that shows LiDAR data with accurate tree location and photo of the tree as well as an input for our assessment of the reports (see Figure 2.4). After this manual decision process, the data was saved in a table and the ratio of valid registrations was evaluated for subsets of treeline and forest line registrations separately.

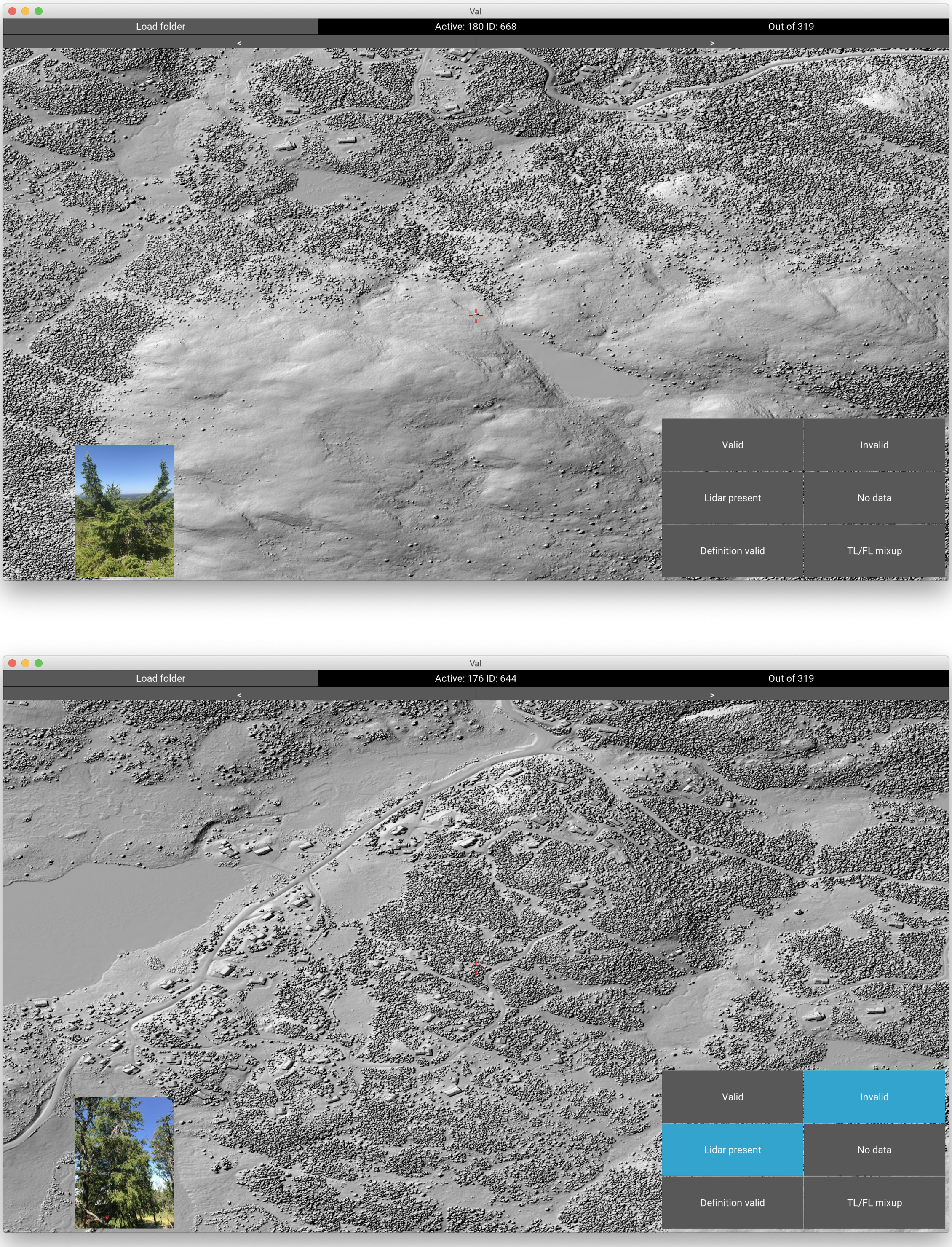


Figure 2.4: LiDAR validation interface

3 Results

3.1 Reaction analysis

During our study period of the first year of running *Natur i Endring* project we registered 3147 new user accounts created. Out of these 40% were female, 59.4% were male and 0.6% identified as other or did not register any information about gender question during the registration. Average age of registered users was 45.2 ($SD = 15.46$) years (Figure 3.2) which is higher than national mean age of 39.3 years(*CIA factbook* 2019). We compared female and male age distribution using z-test, and found that the groups have significantly different age ($z - value = 8.64$, $p = 5.6 \times 10^{-18}$).

We used multiple promotion techniques and smoothed z-score based peak detection algorithm on the timeline of new users registrations (Figure 3.1). By these methods we could identify the five most notable peaks in registrations(Table 3.1). After correlation of these peaks with our calendar we identified corresponding events:

1. 15.5.2018 - Official start of the project which was done as a part of a morning seminar organized by Natural History Museum in Oslo university's botanical gardens. The same day, the newspaper Aftenposten presented the project in the form of an interview (Haugen 2018), and DNT posted an article on their webpage (Langen 2018).

2. 7.6.2018 - Not identified, but from 7.6.2018 to 22.7.2018 the project were presented in more than 25 double-page newspaper interviews. During this period, the project also had advertisements in the newspaper Morgenbladet (4 times in June).

3. 20.7.2018 - This can be most likely attributed to promotion by Anders Bryn in *Monsen minutt for minutt* program on Norwegian national television (NRK TV), however it is not possible to disentangle this from the outreach activity on the "Vinjerock" festival, which took part during the same dates.

4. 5.8.2018 - Promotion by Inger Kristine Volden on *TV 2 Nyhetskanalen* TV channel.

5. 6.12.2018 - Not clearly identified, but probably related to the key-note project presentation at the national conference "Forskning i friluft" on the 6th of December.

ID	Date	Number of new registrations
1	2018-05-15	138
2	2018-06-07	32
3	2018-07-20	869
4	2018-08-05	567
5	2018-12-06	15

Table 3.1: Table of number of registrations for days where z-score based peak finding algorithm was triggered

The conference hosted more than 300 participants. The second most effective advertising method is probably through newspapers, but see the effect of social media (twitter, facebook etc) in the survey results (subchapter 3.2).

Our results show that among the most effective advertising methods is Television broadcasting. Out of all the accounts created 1589 accounts were established within a day after one of the abovementioned activities.

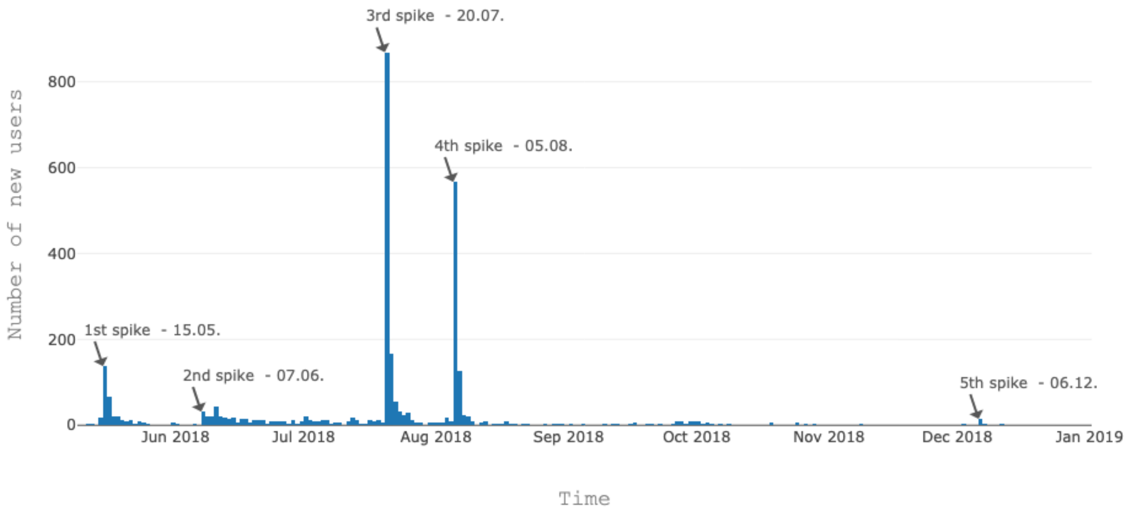


Figure 3.1: New user's registrations over time

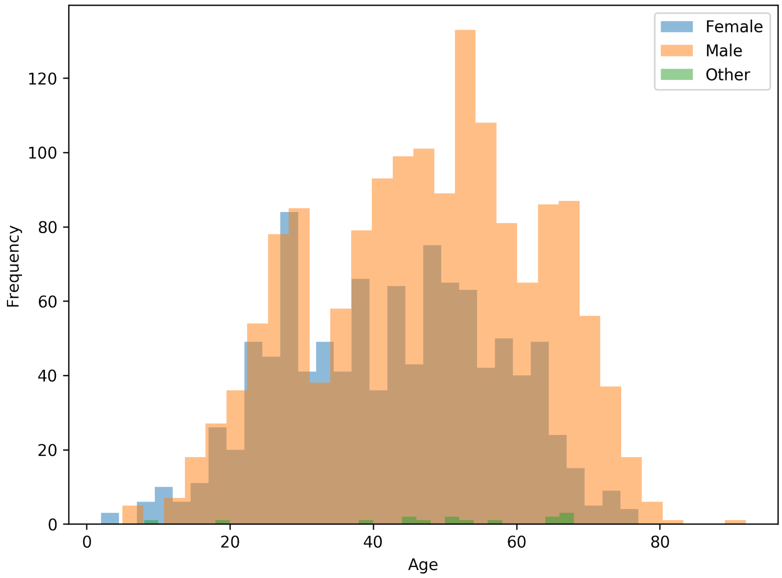


Figure 3.2: New user's age distribution

3.2 Learning analysis

Results from the survey provided valuable insight into the opinion of participants about the *Natur i Endring* project. We found out that 98.2% of responders chose Norwegian language to fill in the survey, opposed to 1.78% that chose English (Figure 3.3a). Mean age of a responder was 46 years ($SD = 15.97$) (Figure 3.3b). Gender distribution was 56.4% male, 43.1% female and 0.5% of responders preferred not to say (Figure 3.3c). Most of the responders finished bachelor degree education (30.8%) with master degree close second (30.4%). Others followed high school (19.2%), other (11.6%), PhD (4.46%) and primary school (3.57%) (Figure 3.4a). Out of all responders, 94.6% had not participated in any other citizen science project before (Figure 3.4b).

Users also mostly strongly agreed that they are concerned about the affects ongoing climate change (92.44% agreed or strongly agreed, see figure 3.4c) and mostly strongly agreed or agreed that human activities are causing climate change (82.67% agreed or strongly agreed, see figure 3.4d).

In respect to *Natur i Endring* citizen science project, responders mostly agreed that treeline and forest line registered by users are trustworthy (Figure 3.5b). Responders also mostly agreed that citizen science projects could engage people who are otherwise indifferent to climate change and biodiversity issues (Figure 3.5c). Survey participants mostly neither agreed nor disagreed that participation in *Natur i Endring* project increased their trust in research and science (Figure 3.5d).

When it comes to mobile phone use, participants in our survey mostly agreed and strongly agreed that they often use mobile phone while hiking (for taking photos, maps etc.) (Figure 3.6a). Responders also mostly disagreed that using their phone while hiking is disturbing, but sentiment here was very variable (Figure 3.6b). Responders also mostly agree that mobile phones are useful for citizen science projects (Figure 3.6c). Most of the responders also disagree with the statement that they like to be notified by the apps on their phone (Figure 3.6d).

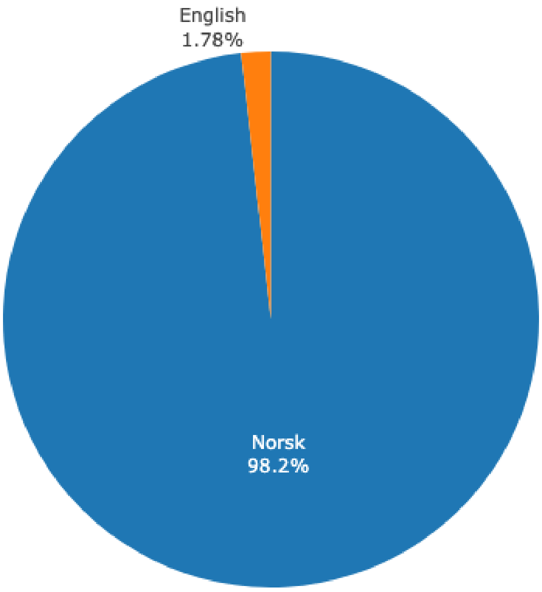
Responders identified that they found out about our app mainly on social media (36.9%) closely followed by newspapers and magazines (23%), somebody told them about it (13.9%), seminars and presentations (7.54%), by suggestions in Apple store or Google play store (7.14), other means (6.75%) and by TV or radio (4.76%) (Figure 3.7a).

Most of our responders (68.4%) did not register any tree during the last season (Figure 3.7b). Those who did register, mostly enjoyed that they could contribute to science (48.5%), liked learning new things (19.7%), enjoyed the fact that citizen science adds new element to the hiking experience (17.4%), enjoyed reading about interesting topic (6.82%) or liked that they could compete for prices (5.3) (Figure 3.7c). Most of our active responders also registered treeline or forest line in the county where they have a cabin (46.5%) (Figure 3.7d). Those who didn't register in their cabin county, registered either in their home county (26.8%) or elsewhere (26.8%). Mostly respondents submitted their registrations while being on already planed hikes (81.7%). Only 2.82% of the users went hiking with the purpose to register and rest did booth (15.5%) (Figure 3.8a).

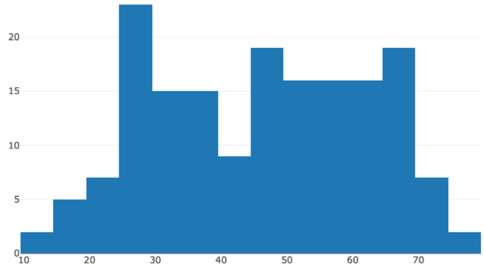
Responders that did not register any treeline or forest line stated that the main reason was the fact that they forgot to do so (42.1%). The rest stated that the didn't visit relevant areas (21.3%), didn't understand the definitions of trees and forests (8.91%), didn't understand what to do (6.93%), had some sort of technical challenges (5.94%), didn't have time (4.95%) or were not interested in registering (1.98%) (Figure 3.8b). Most of the inactive users (60.4%) stated that they are interested in registering in the 2019 season, 35.1% stated maybe and 4.55% said no (Figure 3.8c).

When asked, 55.8%of the responders would appreciate if the app "push-notified" when they are about to pass a treeline or a forest line on their hike, while 27.5% did not like the idea (Figure 3.8d).

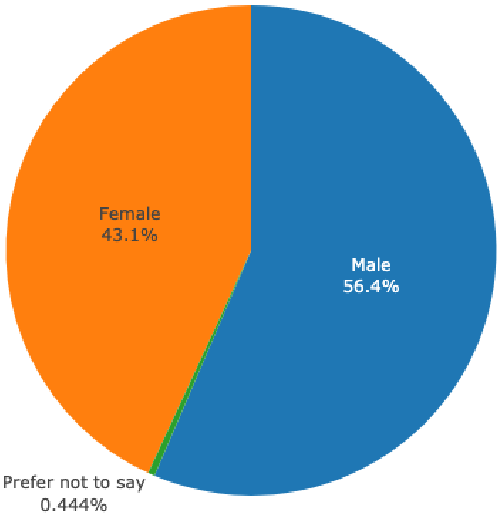
When asked about interaction with the project webpage, providing the results, the survey showed that 68.4% of users did not visit our webpage and that 81.8% of the users did not test online ability to work with the data on our webpage (Figures 3.9a and 3.9b).



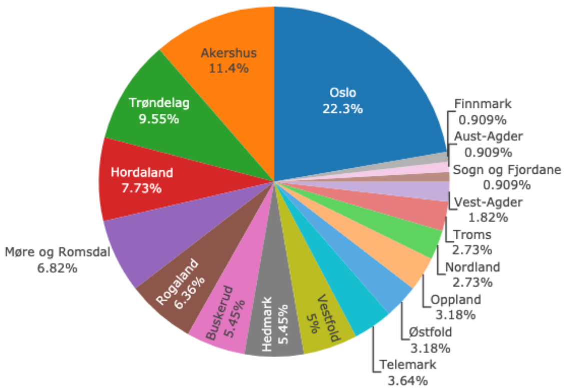
(a) Language



(b) Age

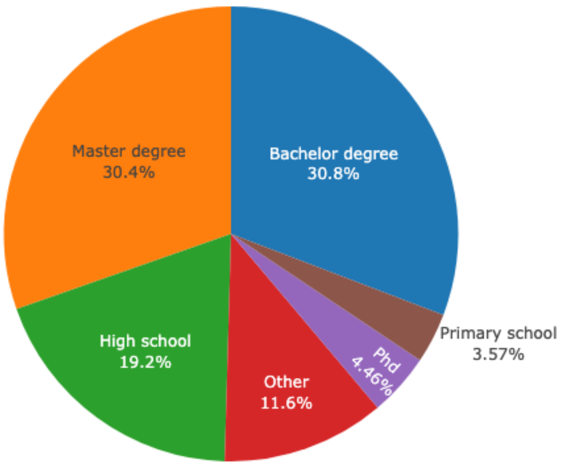


(c) Gender

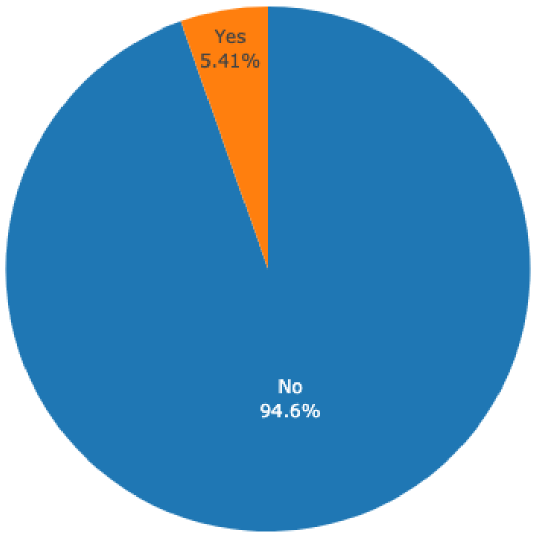


(d) Residential county

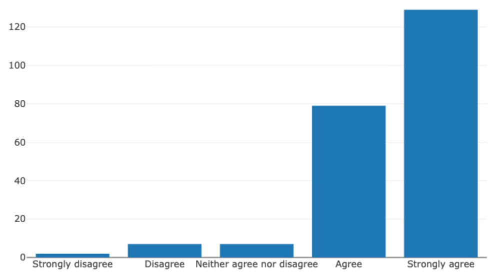
Figure 3.3: Survey results - general questions



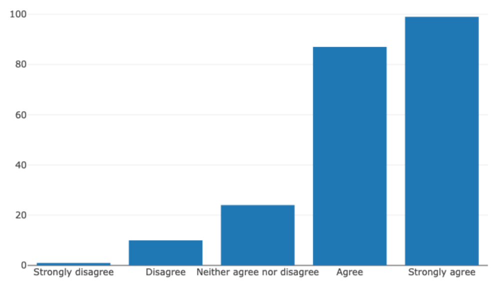
(a) Education



(b) Have you participated in other citizen science projects?

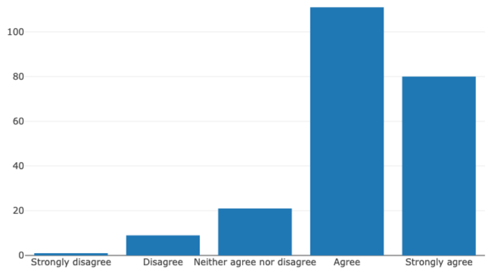


(c) I am concerned about the ongoing climate changes.

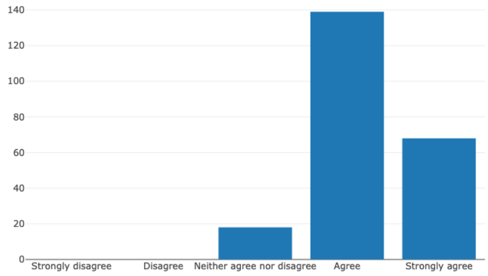


(d) I believe human activities is the main cause for the ongoing, rapid climate changes.

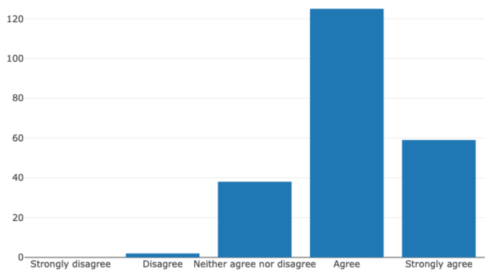
Figure 3.4: Survey results - general questions and questions concerning climate change



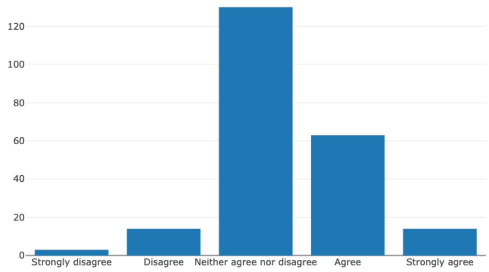
(a) I agree, in general, that the scientific research done within climate change and ecology is objective and credible.



(b) The tree- and forest lines registered by participants in *Natur i Endring* are trustworthy.

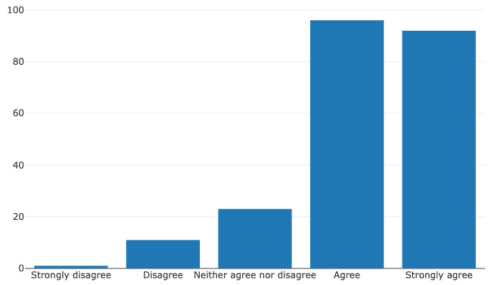


(c) Citizen science projects could engage people who are otherwise indifferent to climate change and biodiversity issues.

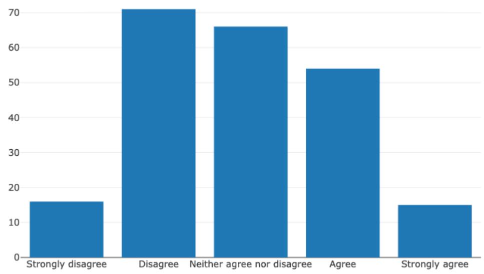


(d) My trust in research and science has increased through participation in this project.

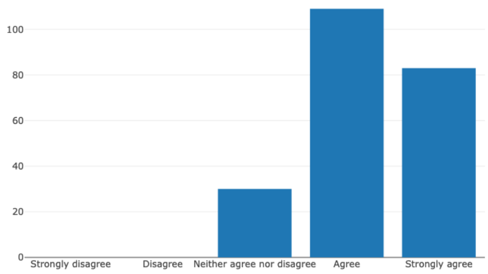
Figure 3.5: Survey results - questions concerning climate change and trust in *Natur i Endring* project



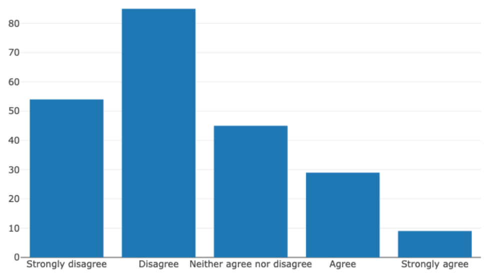
(a) I often use my mobile phone when I go hiking (photos, maps etc)



(b) I find it disturbing to use my phone when I am hiking

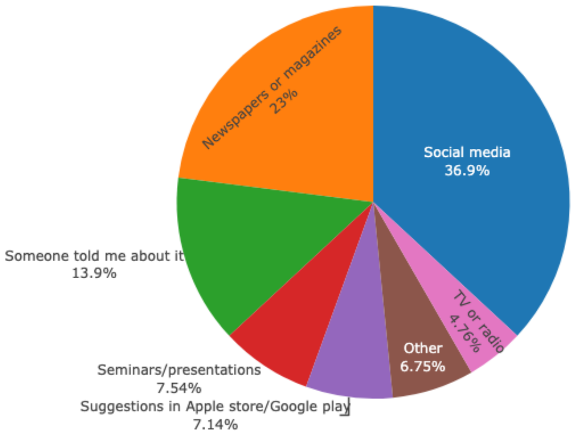


(c) Mobile phones and apps are useful for citizen science projects

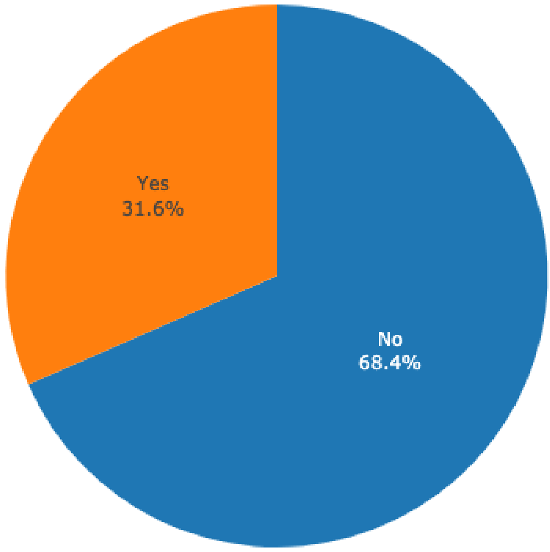


(d) I like to be alerted (push/notifications) by apps on my phone

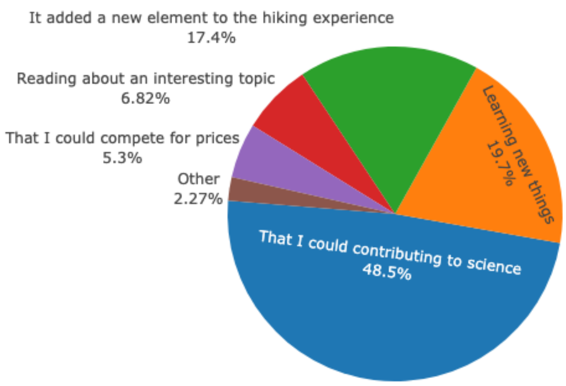
Figure 3.6: Survey results - questions about mobile phone usage while hiking



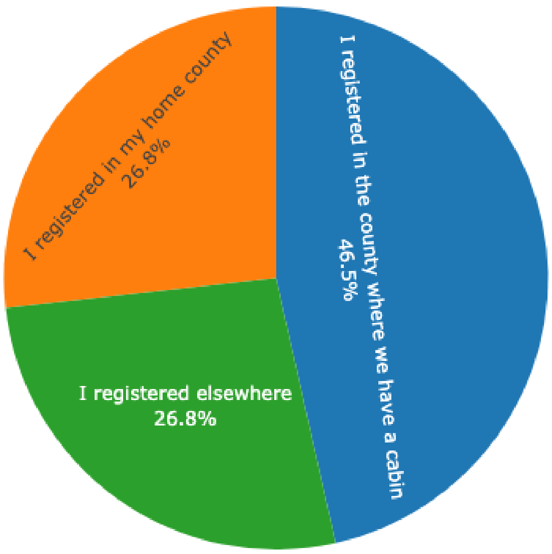
(a) How did you find out about the app?



(b) Have you used the app to register any tree- or forest lines?

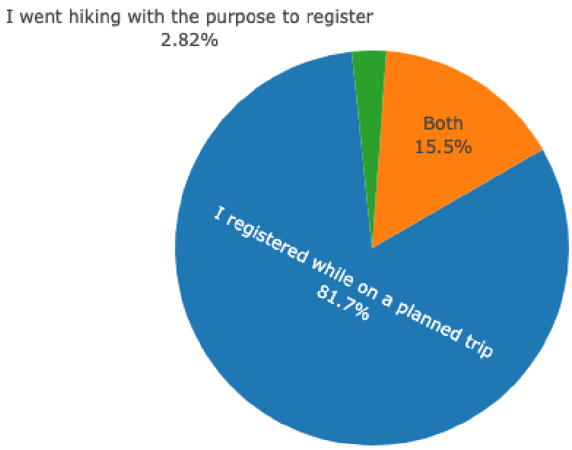


(c) What did you like most about the registration process? (For users that did take registration)

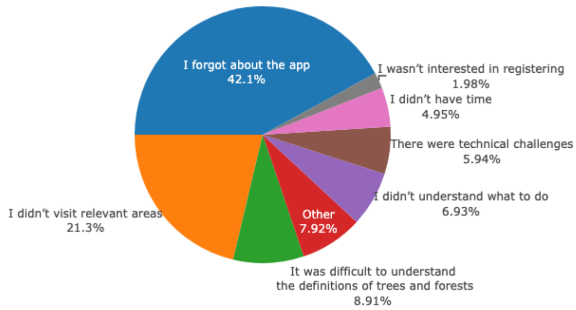


(d) Where did you register tree- or forest lines? (For users that did take registration)

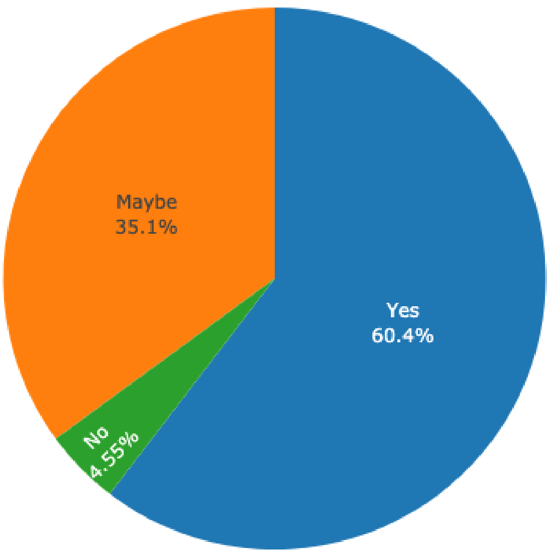
Figure 3.7: Survey results - questions about app discovery, participant's activity and registration process



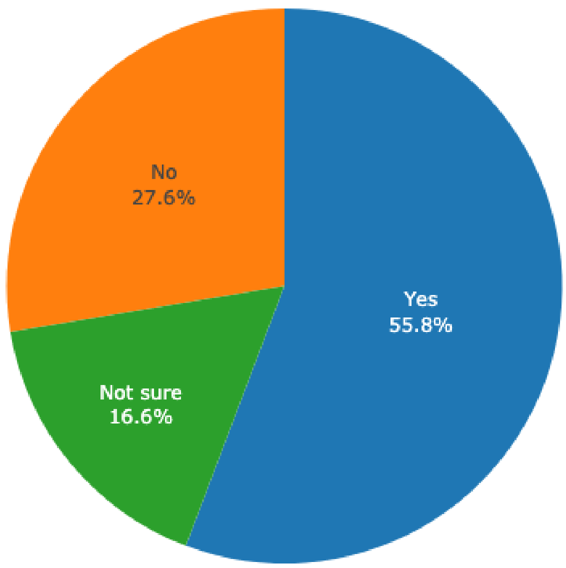
(a) Did you go on a hike with the purpose to register trees, or did you register while on an already planned trip?



(b) Reasons for not registering



(c) Are you interested in registering in 2019?



(d) Would you appreciate if the app "push-notified" when you are about to pass a tree- or forest line on your hike?

Figure 3.8: Survey results - questions about reasons for not registering

3.3 Behavior analysis

Out of 3147 registered users that downloaded the app and went trough the user registration process, 102 users actually submitted valid registration giving us active users ratio of 3.27%. On average each active user contributed with 3.29 ($SD = 3.66$) valid registrations. Median number of registrations was one and maximum registrations per user was 25 (Figure 3.10)

64.9% of registrations we received were of treelines, whereas 35.1% were of forest lines. We received registration from all the counties of Norway with most registration being from Oppland (31.7%), Buskerud(13%) and Sogn og Fjordane (10.6%). Least represented counties were Rogaland, Aust-Agder and Finnmark, all with less than 1% representation in our data set (Figure 3.11). Overall distribution in booth latitude and altitude of individual registrations can be seen in figure 3.12

We identified high spatial bias (z-value = -8.94, p-value = 4.06×10^{-19}) towards hiking tracks, ski tracks and roads, as can be seen in Figure 3.13 histogram. Mean distance to the tracks of registered reports was 1717.86 m whereas mean random distance to the tracks was 4698.84 m. From this result we can conclude that citizen science spatial data collection is heavily biased towards collecting reports close to already established hiking tracks, ski tracks and roads.

We assumed that registrations would be more prevalent during the weekends because that's when people usually hike. We plotted registration distribution for days of the week (Figure 3.14) and compared Monday to Friday versus the weekend with t-test and didn't get significant difference (t-value = -1.56, p-value = 0.18). When we included Friday to the weekend, the difference was significant (t-value = -3.20, p-value = 0.024).

3.4 Results analysis

Using the field test as validation method, we identified that 57.7% of treeline and 63.2% of forest line registrations were properly identified treelines and forest lines. 11.5% of the treeline and 4.3% of the forest line registrations were mixups where users identified treeline but selected forest line or vice versa. 30.8% of treeline and 30.4% of forest line registrations were invalid (Figure 3.15). For invalid registrations of treeline, mean distance to the nearest proper treeline was 91.61 m ($SD = 91.29$) and mean altitude difference was 14.64 m ($SD = 12.36$). For forest line the mean distance to nearest proper forest line was 71.67 m ($SD = 41.16$) and mean altitude difference was 8.84 m ($SD = 7.95$).

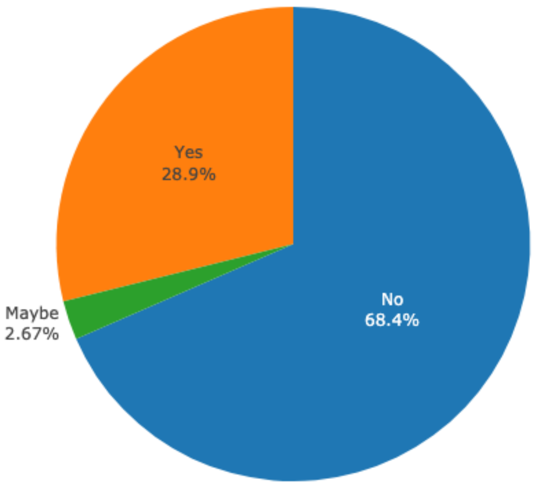
Using LiDAR as validation method, we were able to asses 75.86% of the treeline and 74.14% of the forest line registration, represented in areas with sufficient LiDAR coverage. We identified that for treeline 83.1% of the treeline registrations were valid, 3.3% were mixups and 13.6% were invalid. For the forest line, 82.2% of the registrations were valid, 3.9% were mixups and 14% were invalid (3.16).

When we compared tree height measurement of trees made by citizen scientist and the data from the field test then plotted the comparison of measurements using Bland–Altman plot (Figure 3.17), we could see that except of two outliers, all the measurements fall within expected boundaries of $\pm 1.96 \times SD$ of measurement (Myles and Cui 2007; Carkeet 2015). This shows us that 96% of tested tree heights measurements were reasonably accurate.

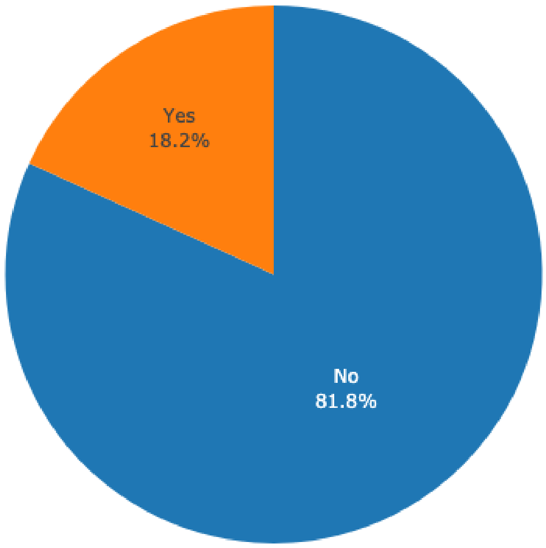
We compared three DBH measurements using Bland–Altman plot and there was only one outlier from the expected boundaries which means that 98% of measurements were reasonably accurate (Figure 3.18).

We compared tree species identification provided by citizen scientists with our the field test data we gathered. In all 50 reports that were checked, 100% were correctly identified.

In the location precision analysis, where we compared location provided by the *Natur i Endring* mobile application with our in situ measurement, the mean distance between those two measurements was 13.93 m ($SD = 12.15$).



(a) Have you looked at the results online?



(b) Have you tested the online abilities to work with the data from the web-page?

Figure 3.9: Survey results - questions about results impact

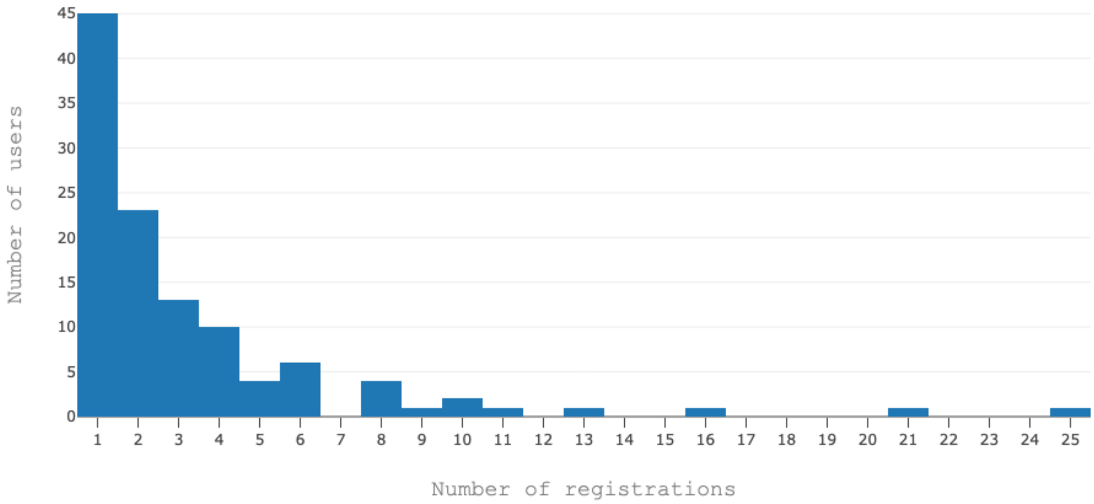


Figure 3.10: Number of registrations per user

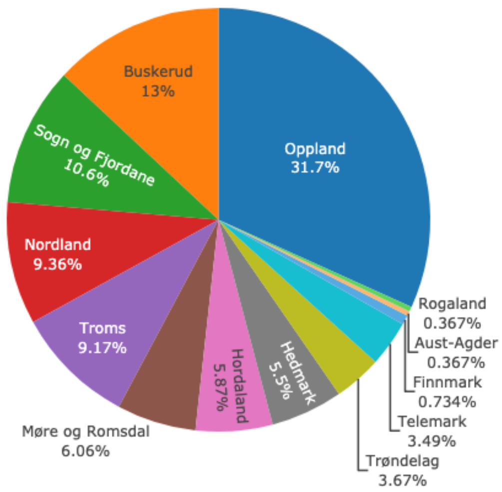


Figure 3.11: Registration distribution for each county

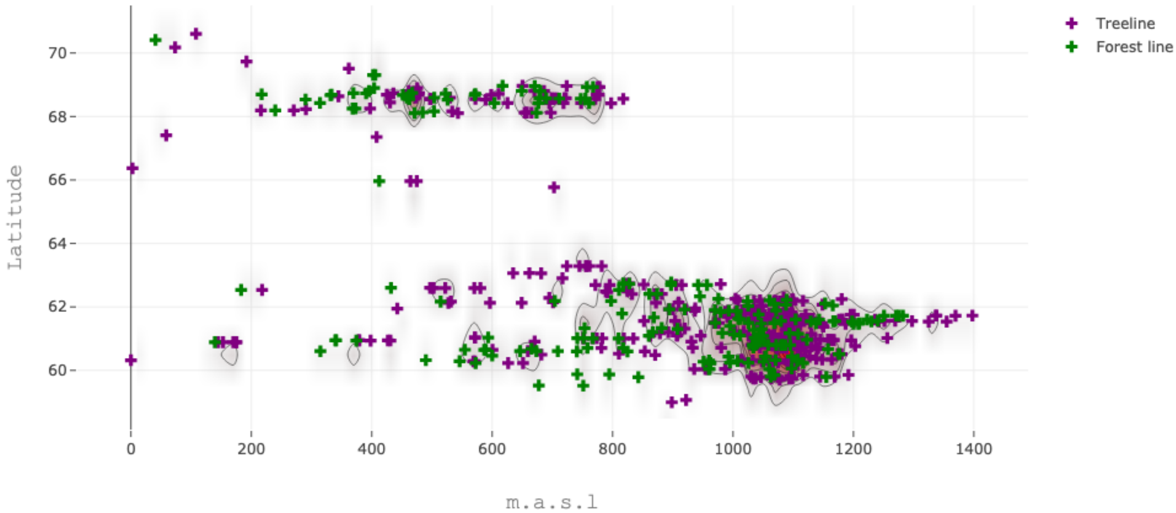


Figure 3.12: Altitudinal and longitudinal distribution of registrations

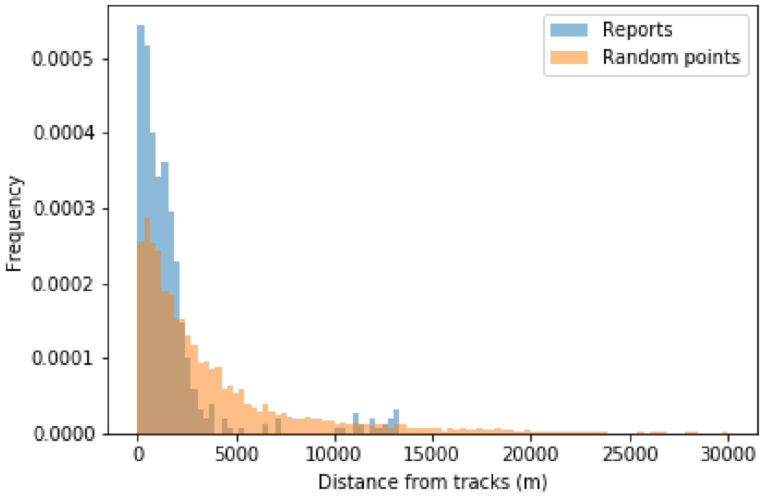


Figure 3.13: Distance to tracks, roads and ski tracks distribution of obtained reports compared to random points in area of expected forest line

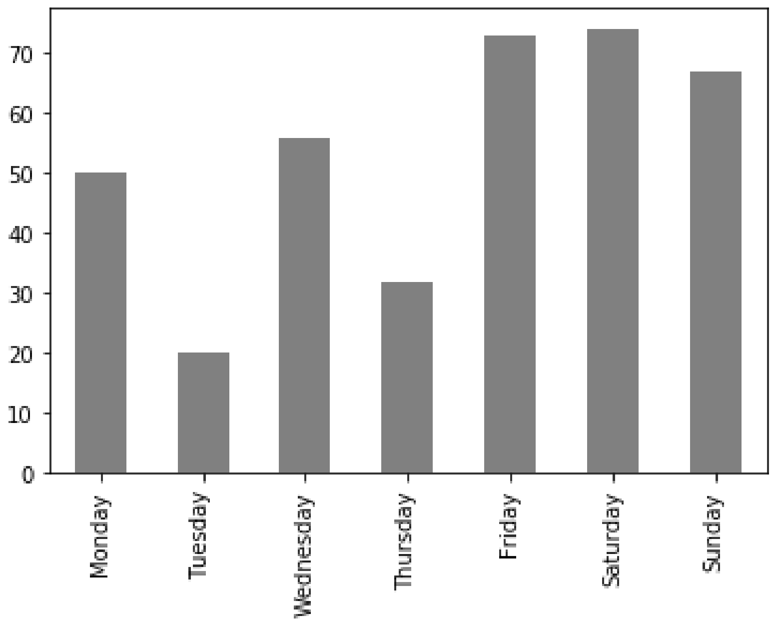


Figure 3.14: Registrations distribution for days of the week

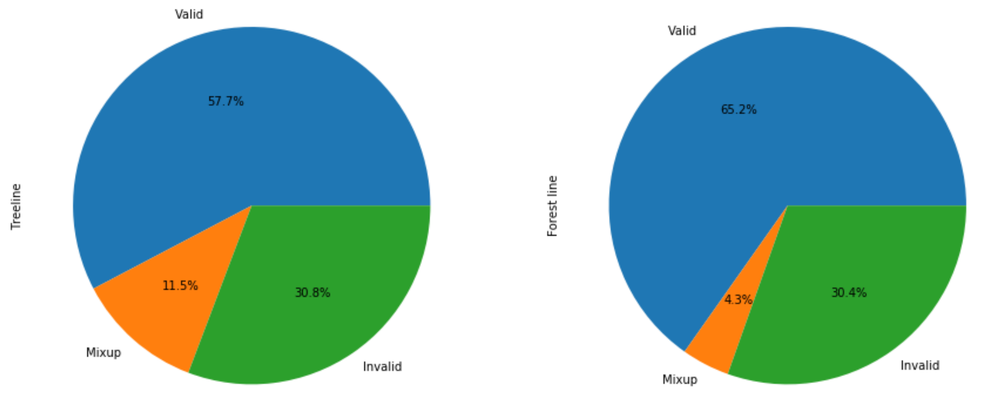


Figure 3.15: Field validation results

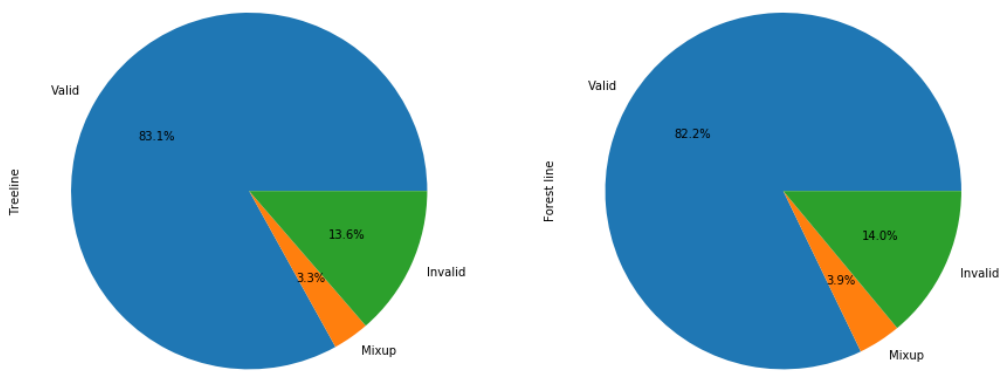


Figure 3.16: LiDAR validation results

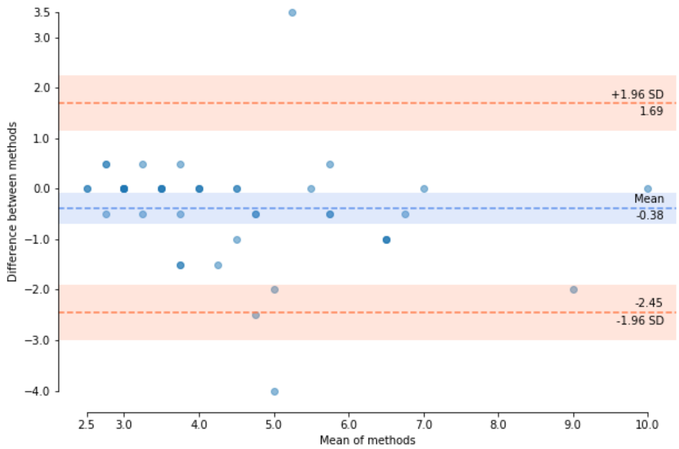


Figure 3.17: Bland–Altman plot of tree height measurement comparison

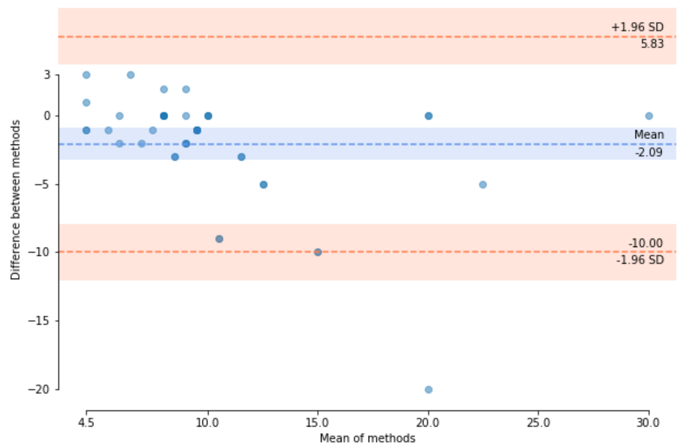


Figure 3.18: Bland–Altman plot of tree DBH measurement comparison

4 Discussion

4.1 Reaction

Which was the most effective outreach method for attracting new users and what was the general distribution of participants in regard to age and gender?

One of the main hurdles with citizen science projects is attracting new participants and keeping them active (Irwin 2018). Here, we investigated which was the most effective outreach method for attracting new users. In our project we attracted quite substantial attention and registered influx of new users mainly after TV promotions. Our results show that among the most effective advertising methods for our app was Television broadcasting, as majority of the total accounts were created within a day after one of the TV outreach activities. One of the possible explanations could be that the TV is still the main channel how to reach and engage Norwegian public, however this seems not so probable with the todays influencing power of the internet (Moe, Poell and Dijck 2016). The other reason for this result could be that we either underestimated other outreach activities, or we focused our outreach attention to small groups (Inger Kristine Volden's evening presentation series at DNT cabins), which had narrow implications on our user base.

We should not underestimate other outreach techniques (Seminars, Presentations, Walk & Talk), even though they seemingly didn't get as much attention as the TV ads. The reason is that the base of users, that participate in such activities might be much more committed to contributing to CS projects than a "shallow" TV spectator (Soni 2017). However, our data doesn't allow us to check for this, as we have no way of disentangling the amount of active users vs. the advertising strategy they used for downloading the app.

Another interesting dilemma is that the results about success of our TV outreach does not correspond with the results that we got from our survey, where only 4.76% of respondents identified that they found out about the project through the TV promotion. From this we can conclude that users who got to know about our project were less likely to become active users. Other possibility is that users, who installed the app after watching TV ads did not to a large extent participate in the survey.

Many CS projects achieve to attract participants in the beginning phase of the project, however, it is much more challenging to retain the interest of users throughout a longer time-frame. Different motivation incentives have been tested in CS projects (Geoghegan et al. 2016). We had several competitions to motivate our participants (Best photo competition, highest tree competition, most registrations per user competition (Langen 2018)). Despite these incentives were the numbers of active participants quite low (3.27% of the total registered). Similar challenges were reported by other CS studies (Segal et al. 2015; Land-Zandstra et al. 2016).

According to the study of National Academies of Sciences, Medicine et al. 2018 demographic analysis of CS, majority of citizen scientist are female (64%). On a contrary in our study 59.4% of our registered users and 56.4% of survey respondents were male. This divergence is difficult to interpret because there are many contributing factors that could be at play. Age distribution on the other hand is within expectations, with female median being 41 and male median 47 in the study, and our mean age being 45.2.

4.2 Learning

What did the participants learn while taking part in this project and how did participation in this project affect their perception of citizen science projects in general?

One of the main aims of CS projects is not only to gain data from the participants, but also to educate them, in order to achieve a reciprocal flow of information. Out main means of providing education about the problem of treeline and forest line creeping into higher altitudes were by tutorial in the app, webpage, seminars and presentations, TV promotions and articles in newspapers and magazines. According to our survey, 92.44% of respondents are concerned about ongoing climate change which is remarkably close to 93% respondents in Steentjes et al. 2017 study.

The project was meant to engage young generation (kids, youth). From the results of the survey this seems not to be so successful (as majority of respondents were Bc and MSc students, see figure 3.4a). But survey results might be misleading in this way, as children and youth might have registered through the app on behalf of their parents and therefore could not be directly contacted.

Users identified that the most common reason for not submitting the registration was the fact that they forgot. We attribute this to the nature of the treeline since user needs to remember to make a registration while passing the treeline and there is only a small window of opportunity to do so. To address this problem, we thought of a improvement within the app, which would notify the users when approaching the treeline and forest line area. This could possibly dampen the effect of people forgetting to remember the app in the critical moment. We investigated the attitude of our users to such improvement. In the survey we first asked the users about the desire to get notifications within their apps in general. Then, we also asked whether they would be keen on being notified, when passing the treeline and forest line. Surprisingly these two questions yielded contradictory answers. While people tend to be skeptical to receiving notifications from their apps, more than half of the respondents would be interested to be notified by *Natur i Endring* app. This indicates that people have become engaged by the project. This is further supported by the fact that we have built a substantial base of users that are interested in using the app further in the 2019, with over 60% interest.

The project *Natur i Endring* has also created a lot of attention in the research environment. Results show that 34.86% of the accounts registered were with education level MSc and PhD. This hints that *Natur i Endring* app is being used by students interested in ecology & climate sciences. Interviews with researchers at University of Oslo (Bryn, 2019, pers.comm) indicates that there is a need for tools enabling easier data collection in the field, as well as storing and visualization of such data. The app that we have developed through *Natur i Endring* project seems to be a good indicator of how future data will be collected also in the research environment.

A valuable feedback from the survey indicates a general under-usage of the web resources of *Natur i Endring* project. When asked about our webpage, 68.4% of users did not visit our webpage and 81.8% of users did not test online ability to work with the data. This suggests a great potential for improvement and possible viability of mirroring results directly into the app to make the user experience more streamlined.

4.3 Behavior

What were the behavioral patterns of users in regard to their activity and spatial coverage of study area?

Behavioral analysis showed us that only 3.27% of our registered users were active and according to the survey the main reason was the fact that users forgot about it. To improve this, according to (Bowser et al. 2013), we should consider gamification of the project to provide more incentives for participants. Also implementing notifications could lead to increased awareness about the app and therefore yield better results in the future.

Distribution of registrations along latitude and altitude shows a clustering in the low latitudes (south Norway) and high latitudes (north Norway) (Figure 3.12). There is a gap in registrations over the central latitudes of Norway, namely the Nordland and Trondelag counties. Explanation to this might be the sparser population density in these large counties of Norway. In the future, we need to concentrate on outreach activities in these under-sampled areas and establishing a collaboration with the main partners for CS projects in Nordland and Trondelag (NHM and NTNU). Moreover the participant registrations confirm also the decreasing altitudinal trend of tree and forest lines along a latitudinal gradient (Figure 3.12). This in line with Bryn and Potthoff 2018 study and shows that the treeline and the forest line decreases in altitude with increasing latitude.

It was expected that weekend registrations would be more abundant than weekday registrations. We assumed that registrations would be more prevalent during the weekends because that's when people usually hike, but this was the case only when Friday was included as a weekend day. This is very likely because Norwegians usually leave for their cabins on Friday and therefore had the possibility to register when they arrive to the cabin on Friday afternoon. It is also common to leave work early on Friday (Norway 2019).

4.4 Results

How precise were the individual aspects of data provided by citizen scientist?

The evaluation of *Natur i Endring* citizen science project, renders overall surprisingly accurate results about data quality, even though the success rates of participants depends on the complexity of the task required. For example, an easy task of species identification rendered a 100% success rate among citizens. This result is higher then the one achieved in Crall et al. 2011 study where citizen scientists reached 82% accuracy for "easy" tree species identification. Our result is closer to Bloniarz and Ryan 1996 study where volunteers accurately identified 94% of genus of street trees. Reasons for this surprisingly high accuracy could be limited pool of possibilities (only five species to choose from) and application design with visual aids (Figure 2.1).

More complex tasks like measuring tree height and DBH did fare really well also, providing measurements within the reasonable margin of error 96% and 98% of the time respectively. We attribute this to the fact that trees along the treeline and forest line are usually smaller in height due to the conditions they endure (Paulsen, Weber and Körner 2000) therefore it's easier to estimate the height in reference to how tall is the observer or their possible companion. Design of the app could have played a role here as well, with visual aid of tree resizing in ratio with human silhouette (Figure 2.1).

However, a more complicated task such as classifying a proper treeline had lower accuracy of 57.7% based on the field test and 75.86% based on the LiDAR analysis. Similarly, forest line registrations had accuracy of 63.2% based on the field test and 74.14% based on LiDAR analysis. Such results are not unexpected, in other studies, where complexity of the tasks required from citizen scientists reflects the success of their participation (Aceves-Bueno et al. 2017). The obvious disparity between our field test and LiDAR analysis shows the limitation of LiDAR when it comes to accurate identification of singular trees. Since the average altitudinal error introduced by wrong treeline registrations was 14.64 m (8.84 m for forest line) we still consider this data to be relevant and something that can be improved over time.

Accuracy of localization data provided by mobile phones in our study was on par with expectations we had based on Zandbergen and Barbeau 2011. Other CS projects differentiate between the localization accuracy of the gathered data. For example, GBIF has the possibility of filtering the records based on coordinate precision. Our study collected data that are always tagged with coordinates, moreover at a precision not worse than 10 meters. Therefore the data collected through *Natur i Endring* project are precise enough for being input into GBIF databases as tree species data for individual species. But more importantly, this type of data can also be used in future studies of forest and treeline, and in studies of advancement of treeline and forest line (Bryn and Potthoff 2018; Cudlín et al. 2017; Hagedorn et al. 2014; Harsch et al. 2009).

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