Migratory patterns of white-fronted goose in northern Europe

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1. Introduction

The medium-sized, heavy-bodied white-fronted goose, *Anser albifrons*, has brown and white feathers with an orange beak and feet and can geographically be found residing across Europe and northern Asia (Cornell University, 2019). This species is known to breed in the arctic and Siberia of Russia during the warmer season in areas of wetlands, ponds and rivers, and winter in agricultural, wetland areas, as well as marshes of Europe (Cornell University, 2019). Their ecosystem role is wetland management and restoration, as they aid in seed dispersal during migration and provide a food source for predators (Schellinger, 2014). They are primarily herbivorous, particularly during wintering, and eat mostly crops and grains, as well as grasses and berries. However, during breeding season, the birds are recorded foraging for aquatic insects and mollusks (Schellinger, 2014). During migration between the wintering and summering months, the species tend to mimic 'V' shaped formations during flight and have stopovers in groups to forage in lake areas and agricultural fields (Cornell University, 2019).

White-fronted geese form monogamous and life-long pairs (Cornell University, 2019). They participate in cooperative breeding, meaning the offspring remain with the parents for an extended time after birth, and in the case of this species, the next one or two breeding seasons (Schellinger, 2014). The younglings learn how to rear their own clutch during the next mating season, as they do not become independent from the parents until 1.5 or 2 years of age (Schellinger, 2014). Breeding occurs once per year, with clutch sizes ranging from 4 to 7 eggs, which incubate over an average of 27 days (Schellinger, 2014). Sexual maturity is reached for white-fronted geese around the age of 3 (Schellinger, 2014). Oftentimes their eggs are predated, however the cooperative breeding works in the family's favor as the early younglings protect the nests while the parents forage (Schellinger, 2014). Additionally, they are predated by humans during hunting seasons as a food source and on agricultural lands, as they can be seen as a nuisance by the crop damage and overgrazing that they cause (Schellinger, 2014). Nonetheless, at this moment in time, the white-fronted goose possesses a stable population and is considered a least concern for extinction (Ely et al., 2020; Schellinger, 2014).

Although research has been performed on the preferred land-use for these geese (Schellinger, 2014; Cornell University, 2019), the proportions of each land-use utilized by white-fronted geese for wintering, migratory stopovers and breeding together has not been explicitly stated. The aim for the research is to determine the habitat most favorable to white-fronted geese throughout their seasonal movements across Europe and northern Asia by proportion. The research objectives aim to determine the preferred habitats proportionally by extracting the land use type (USGS, 1992) of stopovers from movement data of a white-fronted geese sample population collected between 2007 and 2008 (Wilkelski, 2020) and plotting them by speed and distance thresholds.

2. Methodology

As the first step of the project, a GitHub repository was created to share scripts and required files within the group to allow concurrent work (see Appendix 1). The workflow utilized the Python programming language along with the open-source QGIS software, allowing implementation of geospatial functions and plotting. A diagram of the workflow carried can be understood in Figure 1.

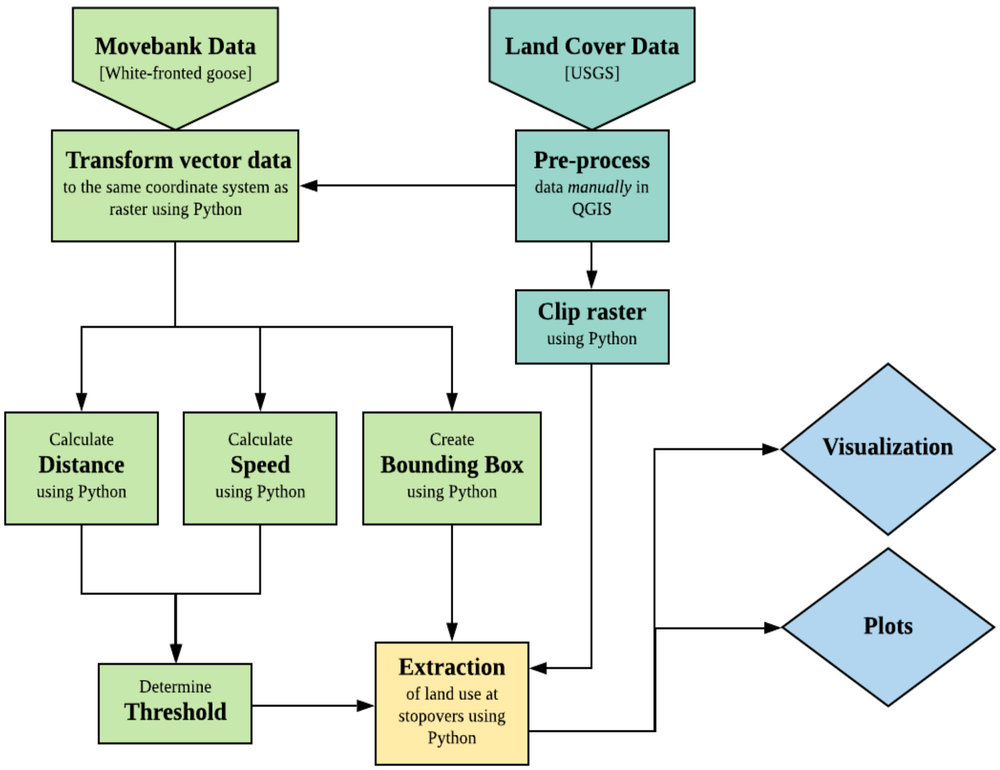

Figure 1
A diagram illustrating the workflow of the project in terms of data pre-processing, processing, plotting and visualization.

2.1. Data and study variables

The movement data for the white-fronted goose, hosted by the Max Planck Institute for Ornithology, was chosen as the primary data source for the project (Wilkelski, 2020). This dataset consisted of two shapefiles: a point shapefile representing the locations of white fronted goose stopovers and a line shapefile representing their migratory routes (see Fig. 2). The timeframe of the white-fronted goose movement data ranged from 2007 to 2008 from a sample population of seven geese. The land use classes used for extraction came from open-source official data provided by the United States Geological Survey (USGS) for Eurasia (USGS, 1992). The land-use data was preprocessed manually in QGIS to transform it into Europe Lambert Conformal Conic projection. The movebank vector data was transformed to match the projection of the raster data using Python.

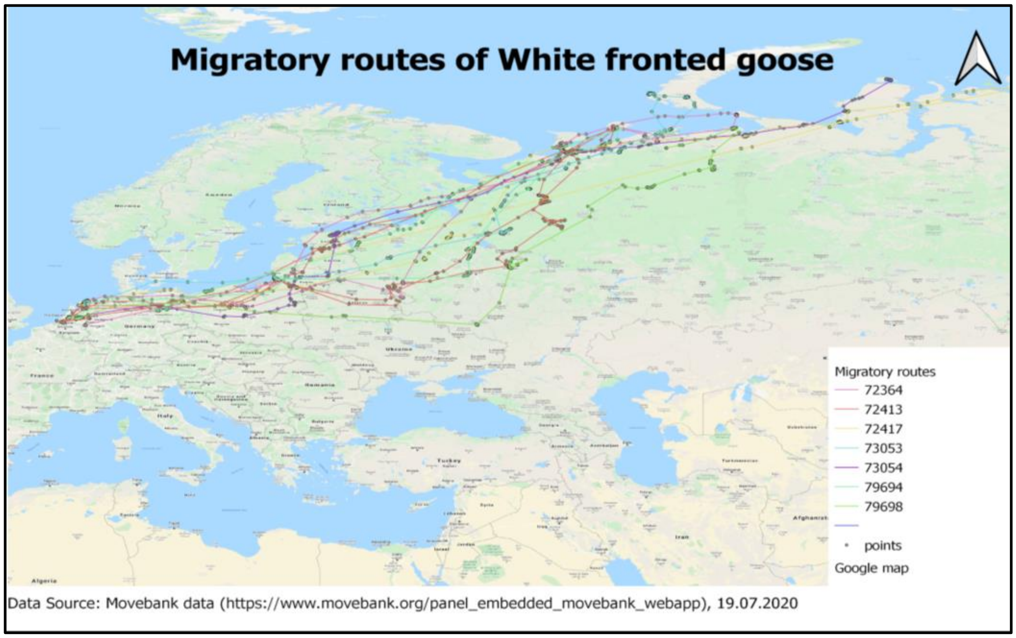

Figure 2

A map displaying the white-fronted goose movement data with a timeframe ranging from 2007 to 2008 from a sample population of seven geese.

Two variables, the speed of the birds and the distances between successive locations during the migration routes, were selected to determine stopover points of the white-fronted goose. Since there were no attributes representing speed or distance between successive locations during the migration routes present in the shapefiles, they had to be calculated. The study used Euclidean distance to calculate the span between two consecutive locations (a, b) (see Eq. 1). For calculating the speed of the birds during flight, a function based on the distance between successive locations and the time it took to move between the two points was calculated (see Eq. 2).

(1) Equation 1

$$Distance = \sqrt{(a_1 - b_1)^2 + (a_2 - b_2)^2}$$

(2) Equation 2

$$Speed = Distance / Time$$

2.2. Threshold determination

After calculating the distance and speed, the next task was to define the classification threshold as to what constitutes a stopover. To accomplish this, first an exploratory analysis was conducted by formulating a table of the descriptive statistics and plotting distributions with histograms (see Table 1). By considering the distributions of each variable, the threshold could be determined, and the observed positions were classified into two classes: stopover versus non-stopover. The selection of the thresholds was based on testing, trial and error and visual interpretation.

Table 1
A table of the descriptive statistics and threshold determinations for two variables, speed and distance.

Variable	Distance (Km)	Speed(Km/h)
Mean	7.710869	1.694909
Median	0.377957	0.0816820
Variance	7.528177	66.880937
Standard Deviation	47.770802	8.178077
Threshold	1.644151 (Mean- Variance)	1.694909 (Mean)

2.3. Land use extraction

Using the determined threshold values, a new shapefile was created with selected stopovers to extract the land use at those locations. First, the land-use data was imported into QGIS and then it was clipped to the extent of the bounding box using Python, which was defined from the extent of the Movebank data. Then, using the new stopover shapefile and clipped land use raster, Python programming was used to extract the land use classes white-fronted geese used during their migrations.

3. Results

Using the bounding box of the vector data, the raster file was clipped using Python. The land use raster originally had 24 classes of possible land uses (see Appendix 2), and after clipping, narrowed down the possible land-uses to 20 classes. A pie chart was developed to understand the proportions of land uses occurring within the bounding box (see Fig. 3). Of those, more than half of the bounded territory is made up of water bodies. The next most prevalent land uses in closer proportions are 'evergreen needleleaf forest', 'dryland, cropland and pasture', 'cropland/woodland mosaic' and 'deciduous broadleaf forest'.

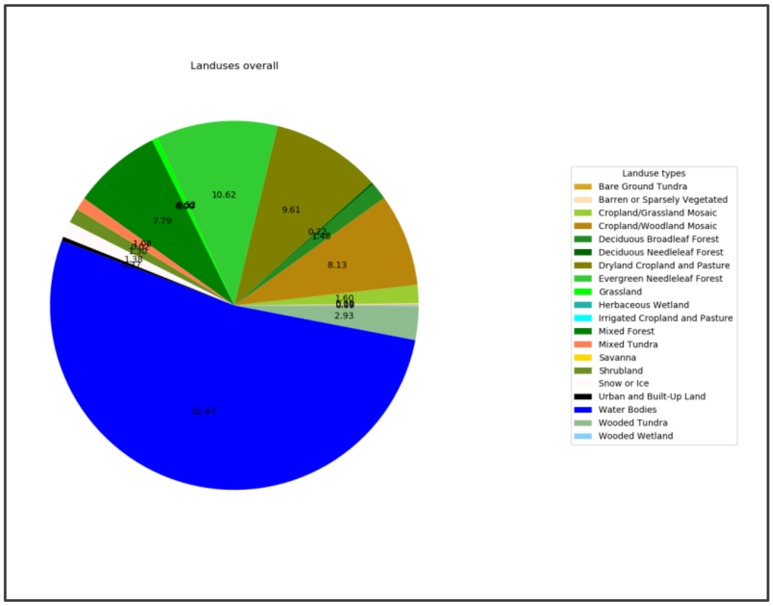

Figure 3
Histograms displaying values for speed (km/h) and distance (km) plotted using Python programming.

Two variables, speed and distance, were calculated to determine stopovers for the white-fronted goose. The distributions for speed show that about 90 percent of the flights occurred at 0.2 km/h or below, and for distance, 90 percent of the flights ranged between 0 to 2 kilometers (see Fig. 4).

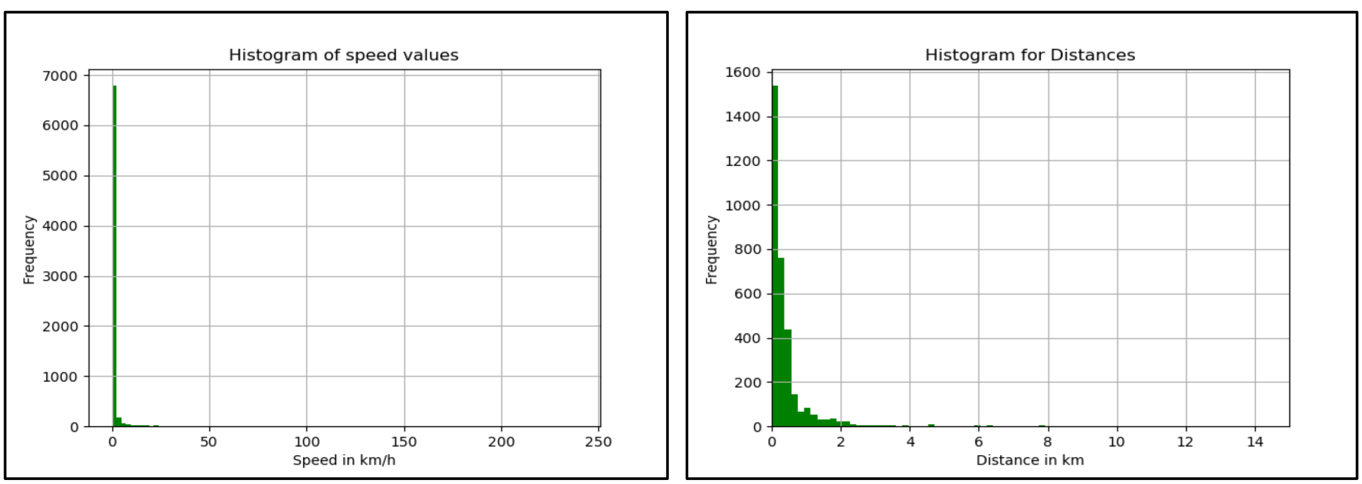

Figure 4
Histograms displaying values for speed (km/h) and distance (km) plotted using Python programming.

Land use stopovers for speed and distance were plotted separately but provided similar results. For speed, the most prevalent land use class used fell under 'wooded tundra' at 30.13 percent and second 'dryland, cropland and pasture' at 16.2 percent (see Fig. 5). The third most important land use type using the speed threshold was 'wooded wetland' at 10.31 percent.

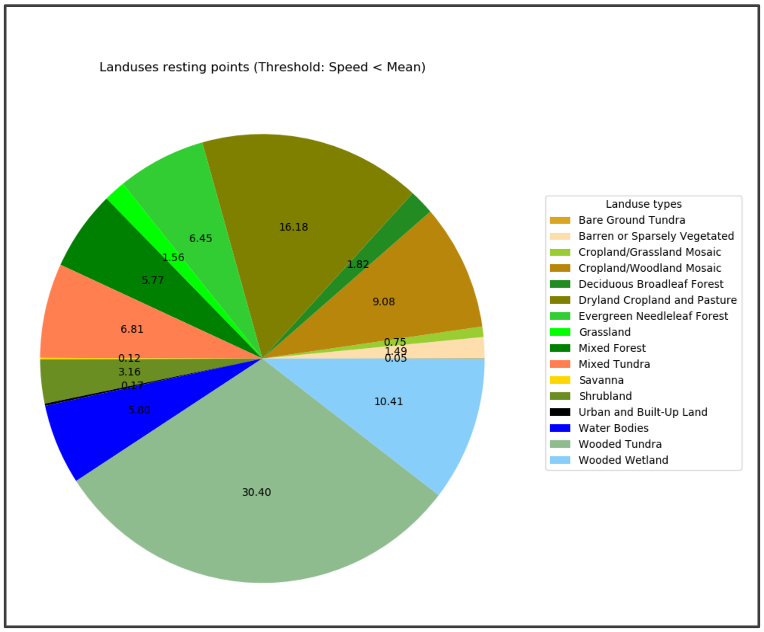

Figure 5
A pie chart illustrating the land use class at stopovers using the speed threshold (speed < mean).

For distance, the most prevalent land use class was also 'wooded tundra' at 36.55 percent and second 'wooded wetland' at 14.28 percent (see Fig. 6). The third most important land use type using the distance threshold was 'dryland, cropland and pasture' at 11.91 percent.

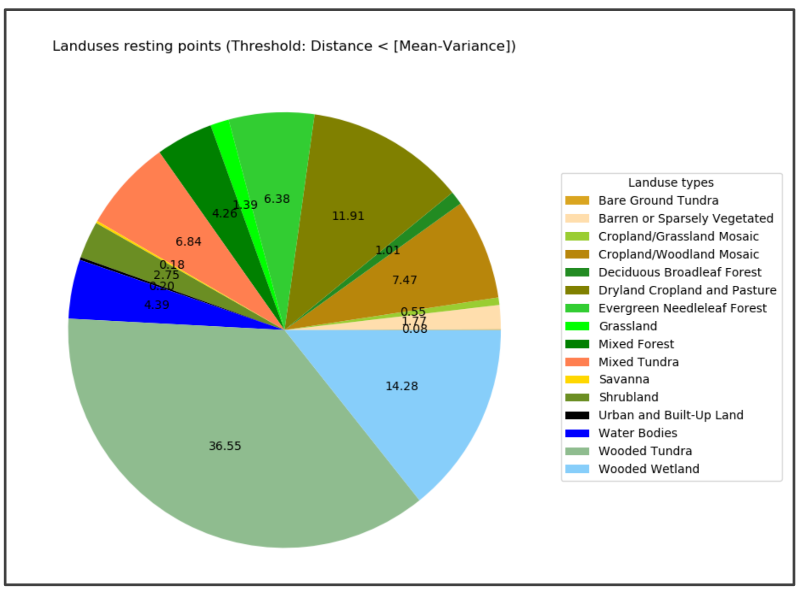

Figure 6
A pie chart illustrating the land use class at stopovers using the distance threshold (distance < mean-variance).

To compare the land use types for stopovers between the speed and distance thresholds, a bar chart was created to display the distributions side-by-side (see Fig. 7). The frequency of stopovers for the speed threshold was slightly more than the distance threshold in every case.

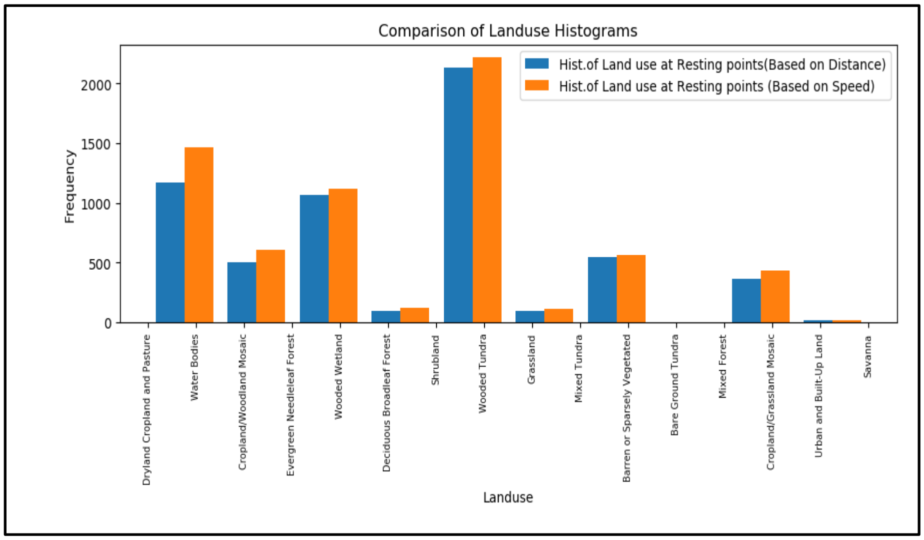

Figure 7
A bar chart illustrating the land use class at stopovers using two methods (distance-based thresholding and speed-based thresholding).

The most prominent stopover land uses for both the distance and speed thresholds were 'wooded tundra', 'wooded wetland' and 'dryland, cropland and pasture'. However, this outcome does not completely correspond with the largest proportions of the overall land-uses present in the bounded territory, which included 'water bodies' at 52.67 percent, 'evergreen needleleaf forest' at 10.62 percent and 'dryland, cropland and pasture' at 9.61%. The most popular land use classes for white-fronted geese at stopovers only makes up 12.57 percent of the total available land use in the bounded territory.

4. Discussion

According to movement the data provided by the white-fronted goose sample population, the geese mostly stop in land use classes 'wooded tundra', 'dryland, cropland and pasture' and 'wooded wetland' during their seasonal migrations between Europe and Siberia, according to distance and speed-based thresholding (see Fig. 5; Fig 6). These results are supported by the claims of the informational web pages by Cornell University (2019) and Schellinger (2014) stating that white-fronted geese prefer agricultural lands and wetlands and breed in arctic areas of Asia. The most prevalent land uses available to the white-fronted goose in its bounded territory, differ somewhat from the land uses exploited by the bird. This is to show that the stopover locations for the bird are not random but rather intentional, based on some sort of instinctual preference. As the bird is stated to aid in seed dispersal (Schellinger, 2014) and act as a food source for predators, the bird's presence in their favored land use areas is critical. In addition, the nuisance caused by the bird on agricultural lands (Schellinger, 2014) is additionally supported, as they are evidently taking advantage of the human crop production system, being the bird's second favored habitat.

The speed threshold calculations show that the geese are very slow-flying birds compared to other migratory birds (Ehrlich et al., 1988). This explains the relatively shorter distances flown by the birds between stopovers. The map of the movement data shows that white-fronted geese tend to migrate along the trend of the coastline in the north Europe and Asia (see Fig. 2). In addition, their bounded territory is made up of more than half water bodies (see Fig. 3), so this may indicate that the birds pattern their flights, treating the northern coastline of Europe and Asia as if it were to orient their migration path. The birds also appear to prefer flying across land mass rather than large open bodies of water.

Limitations to the study are present in that the speed and distance thresholds have bias as they were determined by testing, trial and error. The sample population, consisting of seven geese, may not be enough to generalize about the entire white-fronted goose population across Europe and Siberia. However, it was noted that the white fronted-goose fly and forage in groups (Cornell University, 2019), so despite the sample population accounting for seven geese, the results may represent a larger sample. Future research could classify the stopovers for wintering, migration and breeding separately to understand how land use types differ between each migratory phase of white-fronted geese, using a larger sample population.

5. Conclusion

The favored land use for the white-fronted goose was successfully modelled in QGIS and Python using the goose movement and land use data to determine threshold and extract information by coincidental point and land use type. For the speed threshold, the most prevalent land use classes were 'wooded tundra' at 30.13 percent, 'dryland, cropland and pasture' at 16.2 percent and 'wooded wetland' at 10.31 percent, proportionally. For the distance threshold, the most prevalent land use classes were 'wooded tundra' at 36.55 percent, 'wooded wetland' at 14.28 percent and 'dryland, cropland and pasture' at 11.91 percent, proportionally. The speed and distance thresholds indicate the white-fronted goose is a slow-flying bird and travels short distances at a time.

6. References

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7. Appendices

Appendix 1

Click here to access the project data and code via GitHub.

Appendix 2

USGS land use/land cover system legend (Modified level 2)

Value	Description
1	Urban and Built-Up Land
2	Dryland, Cropland and Pasture
3	Irrigated Cropland and Pasture
4	Mixed Dryland/Irrigated Cropland and Pasture
5	Cropland/Grassland Mosaic
6	Cropland/Woodland Mosaic
7	Grassland
8	Shrubland
9	Mixed Shrubland/Grassland
10	Savanna
11	Deciduous Broadleaf Forest
12	Deciduous Needleleaf Forest
13	Evergreen Broadleaf Forest
14	Evergreen Needleleaf Forest
15	Mixed Forest

16	Water Bodies
17	Herbaceous Wetland
18	Barren or Sparsely Vegetated
19	Herbaceous Tundra
20	Wooded Tundra
21	Mixed Tundra
22	Bare Ground Tundra
23	Bare Ground Tundra
24	Snow or Ice

Appendix 3
The allocation of tasks amongst members of group 7.

Task	Members
Planning and Preparation	
Proposal	Ilka, Prasadi, Jannis and Gabrielle
Data Acquisition	Gabrielle
Raster preprocessing (manual)	Gabrielle
Python and Coding	
Bounding Box	Ilka
Vector Transformation	Gabrielle
Raster Clip	Gabrielle and Jannis
Speed	Prasadi
Distance	Prasadi
Extraction	Jannis
Analysis	
Code Integration	Jannis

Plots	Jannis and Prasadi
Visualizations	Jannis and Prasadi
Deliverables	
Presentation	Ilka and Gabrielle
Final Report	Ilka, Gabrielle and Prasadi