



Deliverable 4.2

PILOT DESCRIPTION AND ASSESSMENT

Recharge map (Finland)

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This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation programme under grant agreement number 731166.



Deliverable Data	
Deliverable number	D4.2
Dissemination level	Public
Deliverable name	Pilots description and assessment report for recharge and groundwater vulnerability
Work package	WP4
Lead WP	BRGM, BGS
Deliverable status	
Version	Version 3
Date	17/03/2021

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LIST OF ABBREVIATIONS & ACRONYMS

CC Climate change

EPIR Effective Precipitation Infiltration Ratio

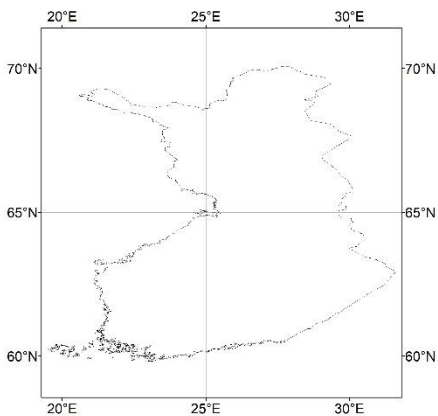
GSOs The Geological Survey Organisations

GTK Geologian Tutkimuskeskus (Geological Survey of Finland)

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1 EXECUTIVE SUMMARY

Pilot name	Recharge map	
Country	Finland	
EU-region	Northern Europe	
Area (km ²)	336 805	
Aquifer geology and type classification	Porous glacial sand and gravel deposits. To lesser extent fractures, faults and fissures in crystalline bedrock	
Primary water usage	Drinking water / Industry	
Main climate change issues	Risk of high precipitation causing groundwater flooding. Risk of drought.	
Models and methods used	Recharge map following methods used by GSI	
Key stakeholders	Government. Research institutes. Water companies.	
Contact person	Geological Survey of Finland. Olli Sallasmaa	

Geological Survey of Finland (GTK) took part in GeoERA TACTIC project WP4 by making an estimation of potential groundwater recharge in Finland.

Most of the groundwater is in shallow aquifers, which are typically sand and gravel formations on top of the bedrock. 150 largest Finnish water utilities provide water for 90% of households and 75% of that is groundwater or it is from managed aquifer recharge. Finland has crystalline bedrock, which has only relative small fractures enabling groundwater forming. Groundwater is extracted from bedrock, as well, but to a lesser extent than from shallow aquifers. Changes in climate are rapidly reflected in shallow groundwater formations.

In order to estimate potential groundwater recharge, statistical climate/weather data (daily weather data from years 1981-2010, FMI) and geological data (Surficial geology map, GTK) was collected. Daily temperature, precipitation and snow cover data was used to calculate effective precipitation. Geological surficial map by GTK was used to estimate effective precipitation infiltration ration (EPIR). Estimated effective precipitation and effective precipitation infiltration ratio were multiplied to calculate potential amount of precipitation to infiltrate to the ground.



In TACTIC project two climatic scenarios were chosen to represent conditions of low/high precipitation of 1 and 3 °C global change estimates.

In Finland the given scenarios suggest warmer winters with increased precipitation, which results in diminishing seasonal snow cover. In these scenarios the summers are warmer and drier. The potential groundwater recharge was calculated with the estimated temperature and precipitation values of both 1 and 3 °C scenarios. Resulting maps didn't show changes in the overall amount of potential groundwater recharge in Finland.

This study was a simplified first step to estimate potential groundwater recharge in Finland and it was only carried out using a set of existing data. Local studies and measurements are still needed to verify and clarify the actual groundwater recharge.

2 INTRODUCTION

Climate change (CC) already have widespread and significant impacts in Europe, which is expected to increase in the future. Groundwater plays a vital role for the land phase of the freshwater cycle and have the capability of buffering or enhancing the impact from extreme climate events causing droughts or floods, depending on the subsurface properties and the status of the system (dry/wet) prior to the climate event. Understanding and taking the hydrogeology into account is therefore essential in the assessment of climate change impacts. Providing harmonised results and products across Europe is further vital for supporting stakeholders, decision makers and EU policies makers.

The Geological Survey Organisations (GSOs) in Europe compile the necessary data and knowledge of the groundwater systems across Europe. In order to enhance the utilisation of these data and knowledge of the subsurface system in CC impact assessments the GSOs, in the framework of GeoERA, has established the project “Tools for Assessment of Climate change Impact on Groundwater and Adaptation Strategies – TACTIC”. By collaboration among the involved partners, TACTIC aims to enhance and harmonise CC impact assessments and identification and analyses of potential adaptation strategies.

TACTIC is centred around 40 pilot studies covering a variety of CC challenges as well as different hydrogeological settings and different management systems found in Europe. Knowledge and experiences from the pilots will be synthesised and provide a basis for the development of an infrastructure on CC impact assessments and adaptation strategies. The final projects results will be made available through the common GeoERA Information Platform (<http://www.europe-geology.eu>).

The report describes the work undertaken by the Geological Survey of Finland (GTK) as a part of TACTIC WP4 to create a Potential recharge map of Finland. The whole land area of Finland was chosen as a pilot area because of the need to have an estimation of the potential of groundwater recharge in the area.

Geological Survey of Finland is a national research centre and it has been studying groundwater formations for both groundwater and aggregate extraction aspects. Tactic project involved geologists Olli Sallasmaa and Nina Hendriksson.

3 PILOT AREA

3.1 Location and topography

The pilot area covers land area of Finland. It is located between the 60th and 70th northern parallels in the Eurasian continent's coastal zone. Length of the coastline against the Baltic Sea is 1250 km. (Statistics Finland 2019). In total, Finnish region covers 336 805 km² excluding the sea water area (52 456 km²). Lakes cover 34 533 km² of Finnish land area. There are estimated 168 000 lakes with the size larger than 500 m². (Statistics Finland 2019). Most of Finland is plain area with the elevation no higher than 200 m (Figure 1). Coastal area is characterized with lowlands, less than 50 m above sea level. In the middle of Finland, at the main water divide uplands, hilly landscape may reach the elevation level of 300 m above sea level. This is also the case in the hilly eastern Finland. Majority of Lapland (North Finland), except river and lake valleys, is hill and fell area in altitude of 200 – 600 m. The highest point, up to 1324 m a.s.l., located in the northwestern most branch of Finland.

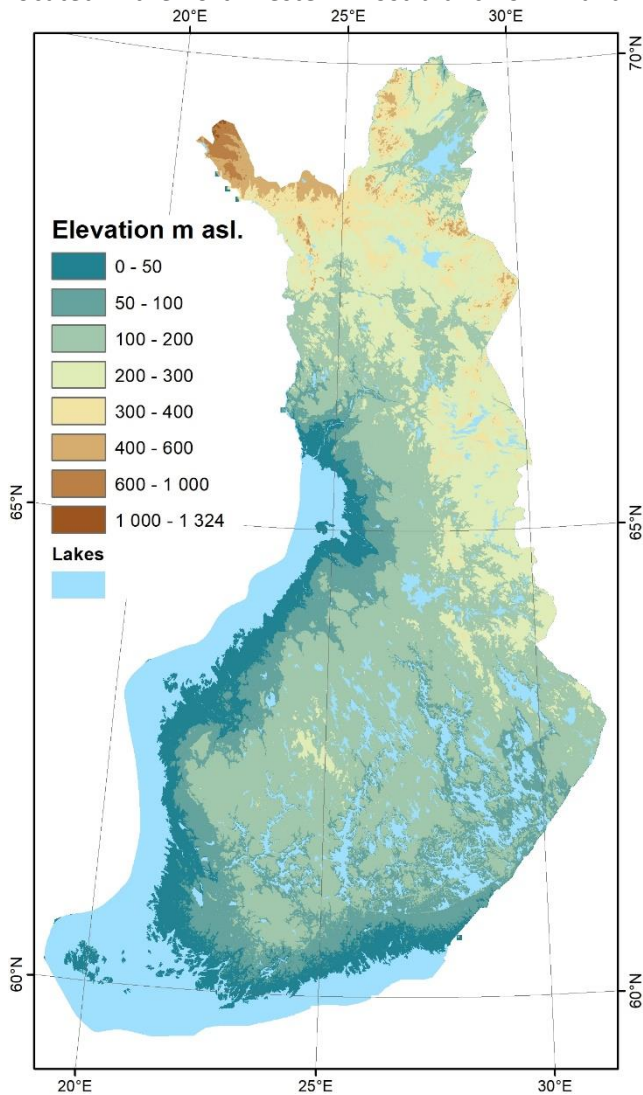


Figure 1 Topography of Finland © National Land Survey of Finland

3.2 Land use

Finland is a sparsely populated country with only metropolitan area of Helsinki exceeding population of one million. Only 1.4% of the land area is covered by artificial surfaces, this including cities and villages. 74.4% of the land area is forests and semi-natural areas (Figure 2). Water bodies cover 10% and agricultural areas 8,3%. (Finnish Environment Institute 2018)

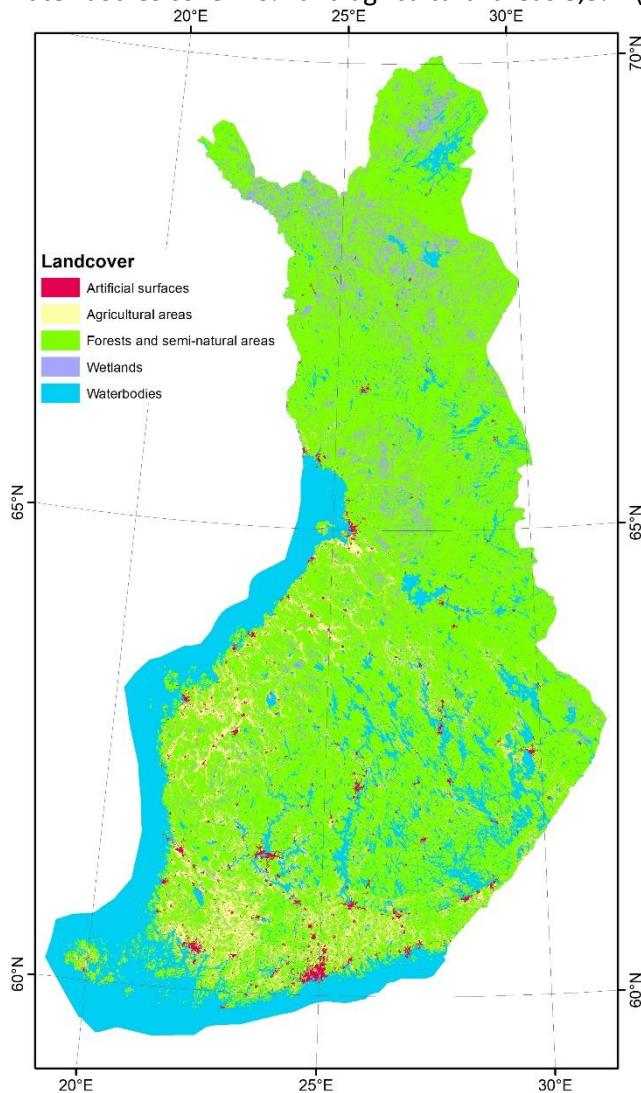


Figure 2 Land use according Corine land cover of Finland (Finnish Environment Institute 2018)

3.3 Hydrogeology of the pilot area

Geological media holding groundwater in Finland contains predominantly unconsolidated Quaternary till and glaciofluvial deposits and as a minor role the underlying crystalline basement with igneous and metamorphic rocks (Tarvainen et al. 2001). Due to repeated glaciations the surficial deposits are composed only of deposits such as till, sand and gravel, glacial and postglacial clay and silt. Hydrogeological properties of the soil deposits, especially porosity and



grain size and shape, dominate the groundwater recharge rate. Highest hydraulic conductivity is attained in coarse grained glacial sorted sand and gravel deposits such as eskers and ice-marginal formations (Salpausselkä). Where, approximately 30 – 60 % of local precipitation is infiltrated to form groundwater (Hatva et al. 2008). These formations are the economically most important Finnish groundwater reserves, despite the fact that they represent only 3 – 4 % area in Finland (Tarvainen et al. 2001). Most common soil sediment type in Finland is till and various moraine deposits (Figure 3). Till is characterized by non-sorted texture of varying grain sizes from very fine to very coarse grained material. Generally only 10 – 30 % of precipitation is infiltrated to coarse grained moraine deposits and even less in fine-grained sediments, such as silt and clay (Hatva et al. 2008). Heterogeneity of the soil material and discontinuity of the sedimentary units within a groundwater formation is common in Finland and this affects both the recharge rates and the groundwater velocities in the system. Groundwater table exists commonly in the depth of 2 – 4 m in Finland. However, in the topographically elevated esker and ice-marginal formations the groundwater table may reach a depth of 30 - 50 meters from the ground surface (Hatva et al. 2008).

Crystalline basement in Finland is characterized by rock types with very low porosity and hydraulic conductivity. In bedrock, groundwater recharge and flow are mainly controlled by the fractures, faults and fissures of the basement and the groundwater flow takes place in the depths of tens to hundreds (even thousands) of meters. Despite of typically smaller volumes of exploitable bedrock groundwater, it has a significant role both in potable water and geothermal energy purposes in Finland.

Aquifer types vary regionally depending on the dominating topographical and Quaternary geological features. Thereby, Finland may be divided into four hydrogeological provinces to characterize the groundwater formation types of certain region: 1. Coastal and archipelago regions in South and Southwest Finland; 2. West coast; 3. Central Finland; and 4. Northeast and North Finland (Figure 3) (Lahermo et al. 2002).

1. The southern coastal belt of Finland is characterized by wide variation of different aquifer types from clay covered, confined aquifers to bedrock, till and glaciofluvial aquifers. Unique to the coastal belt are low-lying areas with numerous river basins and bedrock outcrops (Alalammi, 1986; Karlsson, 1986). The southern Finland coastal belt stretches up to the northern border of the Salpausselkä ice-marginal formations with scattered esker deposits.
2. Western coastal belt areas reach to the northern end of the Bothnian and in East stretches to the water divide where terrain is higher and where relative height differences are larger. The broad coastal plain, cut by numerous rivers, is dominated by clay and silt deposits and bounteous peat lands while till deposits are more common eastward.
3. The central Finland encompasses the main part of the large lake basin characterized by variable topography with structurally controlled valleys (Alalammi, 1986). Numerous lakes, overburden till and small peat lands, lesser deposits are the typical features of the area. The area includes three major river basins and the surface coverage of lakes and

ivers generally ranges from 10% to 20%. The most frequent aquifer types in this area are till deposits (ca. 50%).

4. Northeast and North Finland is the most hilly and mountainous area in Finland. It is characterized by till-covered, broad elevated areas with locally comparatively steep slopes (Alalammi, 1986). Here the till-covered hills are often peaked by broken bedrock and rock fields and separated from each other by large flat peat lands. Large rivers flow in broad and flat river valleys flanked frequently by extensive sand deposits.

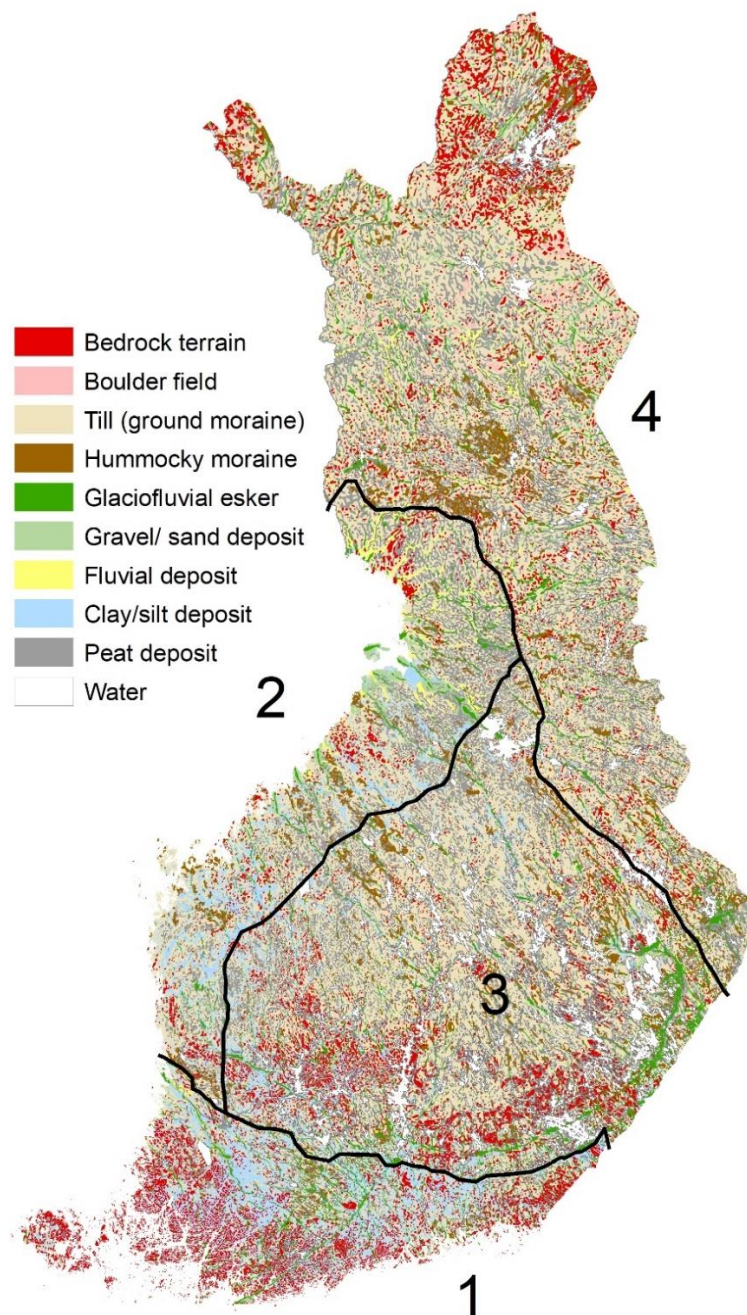


Figure 3 Hydrogeological provinces in Finland by Lahermo et al. (2002): 1. Coastal and archipelago regions in South and Southwest Finland; 2. West coast; 3. Central Finland; 4. Northeast and North Finland. Background: Quaternary deposits of Finland 1:1 000 000 (Kujansuu & Niemelä 1984). Picture modified from Lahermo et al. (2002).

3.4 Climate

Finland belongs mainly in cold (D) climate on the basis of the Köppen-Geiger climate classification (Peel et al. 2007). Predominant climate type in Finland is subarctic (Dfc). Only in the southernmost coast, warm-summer humid continental climate (Dfb) prevails.

The mean annual temperature during the latest long term monitoring period of 1981 – 2010 varies from +5.9 °C (Helsinki) in the south to -0.4 °C (Sodankylä) in the north (Figure 4; FMI 2019). Airflows from the Atlantic Ocean warmed by the Gulf Stream produce a climate that is more temperate compared to other areas at similar latitudes. The precipitation is mainly derived from one vapor source in the North Atlantic Ocean (Alalammi, 1987). Also the vapor from the Baltic Sea serves as an additional moisture source causing increasing precipitation in coastal areas in early winter. The proximity of the Barents Sea in the North has a similar effect in northern Finland. Regionally, the mean annual precipitation varies from 655 mm (Helsinki, 1981 – 2010) to 520 mm (Sodankylä, 1981 – 2010) (Figure 4; FMI 2019). Highest precipitation rates are found in southern and eastern Finland and in the water divide area of central Finland. The lowest precipitation rates are recorded along the north western coast and in northern Finland due to the proximity of the Caledonian mountain range.

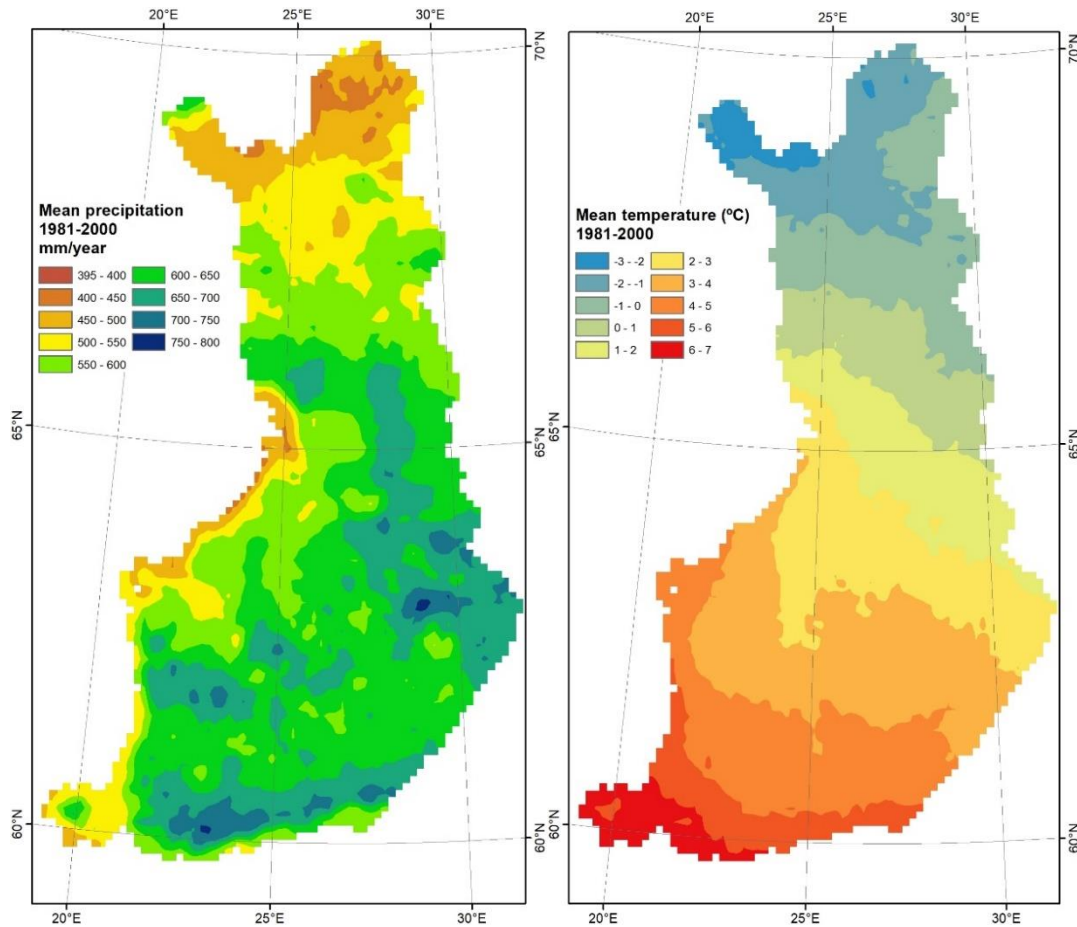


Figure 4 Mean annual precipitation and temperature 1981-2010.

3.5 Climate change challenge

3.5.1 Climatic control of groundwater recharge

In the northern latitudes, the infiltration of precipitation to form groundwater is controlled by the variation between the hydrological processes dominating during four distinct seasons. In Finland, the main two periods of the groundwater recharge are: 1) after snow melt in spring and 2) autumn before developing soil frost. In the winter time, the precipitation is received as snow and infiltration largely ceases in frozen soil. In the South it is known that most of snowmelt is lost by surface flow and evaporation, and in the North by surface flow but less by evaporation. In southern Finland, 10 – 20% of the precipitation is in the form of snow, but in northern and eastern Finland the proportion of snow reaches 20 – 35% (Karlsson, 1986). In the East shallow and discontinuous frost during winter may cause higher rates of recharge in spring time (Karlsson, 1986). As a consequence of evolving climatic conditions, oscillation of the autumn-winter-spring boundaries may also extend the period of groundwater recharge throughout the winter if soil frost is not properly developed. This is recorded especially from the southern and western coastal areas in Finland. The land area of Finland is covered by vegetation and forests, and therefore transpiration by plants is significant during the growing season in summer.



Groundwater recharge by summer precipitation has been considered to be of minor importance for the formation of groundwater in Finland (Karlsson, 1986).

3.5.2 Future climate and challenges

Higher evapotranspiration during summer season, declined groundwater table and local droughts are expected in changing climate. Moreover, extreme weather events may cause e.g. flooding of seawater on coastal areas and surface runoff floods on made grounds as referred in Figure 5.

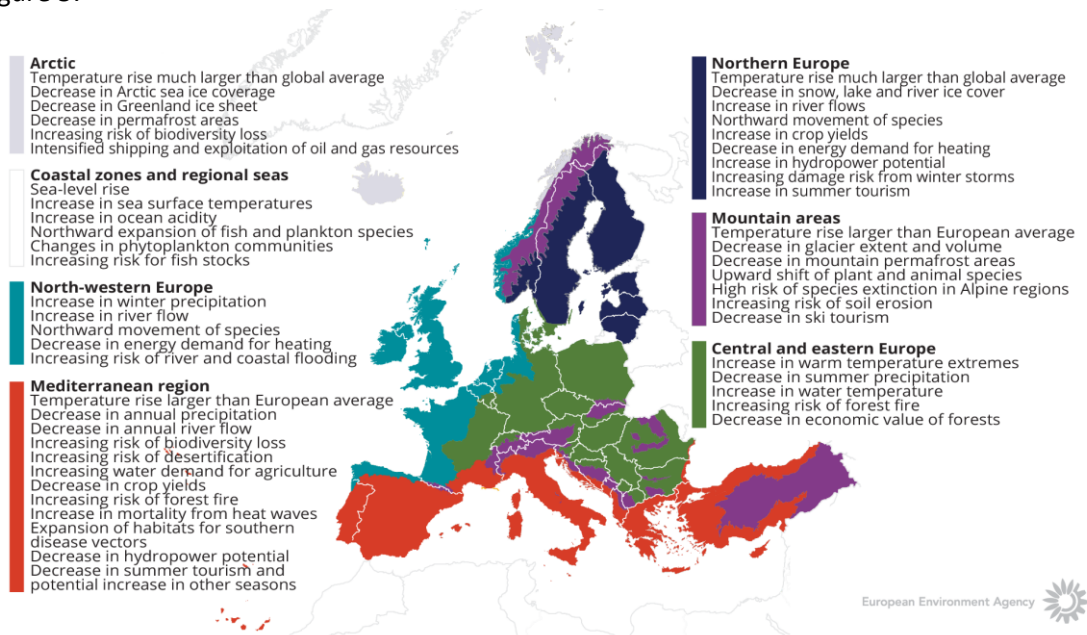


Figure 5 How is climate expected to change in Europe. The European Environment Agency map

4 METHODOLOGY

The methodology applied to assess the potential groundwater recharge is:

$$\text{Recharge} = \text{EPIR} * \text{Effective Precipitation},$$

where EPIR = Effective Precipitation Infiltration Ratio as discussed below in Section 4.3. This approach is applied to evaluate both present and future groundwater recharge.

4.1 Climate data

4.1.1 Meteorological data

The applied meteorological data from years 1981-2010 was all publicly available open data from Finnish Meteorological Institute (FMI 2019). Data consisted of daily precipitation, mean temperature and thickness of snow cover. Data was interpolated to raster format of grid cell size of 10×10 km.

4.1.2 TACTIC standard Climate Change scenarios

The TACTIC standard scenarios were developed based on the ISIMIP (Inter Sectoral Impact Model Intercomparison Project, see www.isimip.org) datasets. The resolution of the data is 0.5°x0.5° global grid and at daily time steps. As part of ISIMIP, much effort has been made to standardise the climate data (a.o. bias correction). Data selection and preparation included the following steps:

1. Fifteen combinations of RCPs and GCMs from the ISIMIP data set were selected. RCPs are the Representative Concentration Pathways determining the development in greenhouse gas concentrations, while GCMs are the Global Circulation Models used to simulate the future climate at the global scale. Three RCPs (RCP4.5, RCP6.0, RCP8.5) were combined with five GCMs (noresm1-m, miroc-esm-chem, ipsl-cm5a-lr, hadgem2-es, gfdl-esm2m).
2. A reference period was selected as 1981 – 2010 and an annual mean temperature was calculated for the reference period.
3. For each combination of RCP-GCM, 30-years moving average of the annual mean temperature were calculated and two time slices identified in which the global annual mean temperature had increased by +1 and +3 °C compared to the reference period, respectively. Hence, the selection of the future periods was made to honour a specific temperature increase instead of using a fixed time-slice. This means that the temperature changes are the same for all scenarios, while the period in which this occurs varies between the scenarios.
4. To represent conditions of low/high precipitation, the RCP-GCM combinations with the second lowest and second highest precipitation were selected among the 15 combinations for the +1 and +3 °C scenarios. This selection was made on a pilot-by-pilot basis to accommodate that the different scenarios have different impact in the various parts of Europe. The scenarios showing the lowest/highest precipitation were avoided, as these endmembers often reflect outliers.
5. Delta change values were calculated on a monthly basis for the four selected scenarios, based on the climate data from the reference period and the selected future period. The delta change values express the changes between the current and future climates, either as a relative factor (precipitation and evapotranspiration) or by an additive factor (temperature).

6. Delta change factors were applied to local climate data by which the local particularities are reflected also for future conditions.

Figure 6 shows all the monthly delta change factors for Finland from TACTIC standard Climate Change scenarios. Monthly precipitation multiplication factors are shown in left side of the figure 6 and same data in numbers in table 2. Both 1 and 3 °C scenarios had minimum and maximum calculations from which average values were used in calculations by GTK. Monthly temperature additive factors are shown in the right side of the figure 6 and same data in numbers in table 1. Average values were used in calculations by GTK.

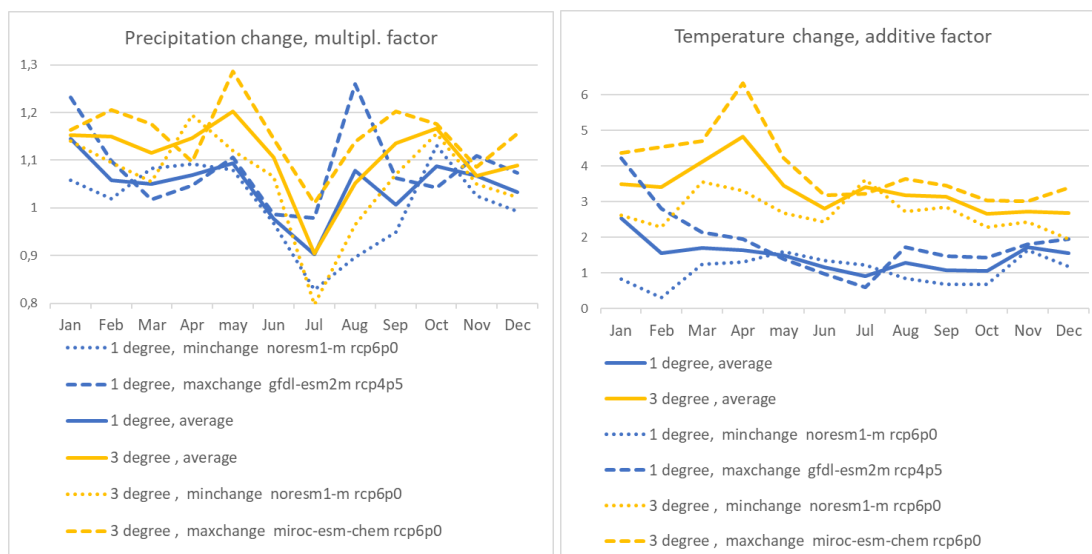


Figure 6 Monthly delta change factors for Finland from TACTIC standard Climate Change scenarios.

Table 1 Monthly temperature delta change additive factors for Finland from TACTIC standard Climate Change scenarios.

3 degree			Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
minchange	noresm1-m	rcp6p0	2,62	2,28	3,55	3,3	2,67	2,42	3,61	2,72	2,84	2,28	2,42	1,96
maxchange	miroc-esm-chem	rcp6p0	4,36	4,53	4,7	6,33	4,21	3,18	3,21	3,63	3,45	3,03	3,02	3,39
average			3,49	3,405	4,125	4,815	3,44	2,8	3,41	3,175	3,145	2,655	2,72	2,675
1 degree			Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
minchange	noresm1-m	rcp6p0	0,82	0,31	1,25	1,31	1,6	1,35	1,22	0,84	0,67	0,69	1,63	1,18
maxchange	gfdl-esm2m	rcp4p5	4,23	2,8	2,13	1,95	1,38	0,98	0,6	1,72	1,47	1,42	1,81	1,94
average			2,525	1,555	1,69	1,63	1,49	1,165	0,91	1,28	1,07	1,055	1,72	1,56



Table 2 Monthly precipitation delta change multiplication factors for Finland from TACTIC standard Climate Change scenarios.

3 degree			Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
minchange	noresm1-m	rcp6p0	1,1405	1,0952	1,0550	1,1954	1,1200	1,0654	0,7970	0,9653	1,0701	1,1563	1,0500	1,0226
maxchange	miroc-esm-chem	rcp6p0	1,1639	1,2056	1,1765	1,0968	1,2857	1,1457	1,0106	1,1383	1,2023	1,1761	1,0854	1,1563
average			1,1522	1,1504	1,1158	1,1461	1,2029	1,1055	0,9038	1,0518	1,1362	1,1662	1,0677	1,0894
1 degree			Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
minchange	noresm1-m	rcp6p0	1,0579	1,0190	1,0826	1,0920	1,0800	0,9673	0,8274	0,8960	0,9490	1,1312	1,0250	0,9925
maxchange	gfdl-esm2m	rcp4p5	1,2328	1,0980	1,0179	1,0465	1,1064	0,9863	0,9794	1,2597	1,0633	1,0424	1,1098	1,0741
average			1,1453	1,0585	1,0502	1,0692	1,0932	0,9768	0,9034	1,0779	1,0062	1,0868	1,0674	1,0333

4.2 Effective precipitation calculation

Daily evaporation was estimated using daily mean temperature as was described in Swedish work of Groundwater formation in Swedish type soil, "Grundvattenbildning i svenska typjorlar - översiktlig beräkning med en vattenbalansmodell." (Rodhe et al 2006).

$$E_{pot} = B(t) \cdot T \text{ for } T > 0^{\circ}C$$

$$E_{pot} = 0 \text{ for } T \leq 0^{\circ}C$$

$$B(t) = (1 + A \cdot \sin(2\pi \frac{t+\psi}{365} - \frac{\pi}{2})) \cdot C_E$$

t = number of the day in a year

A = amplitude

E_{pot} = potential evaporation

Ψ = phase shift (days)

C_E = evaporation parameter ($\text{mm d}^{-1}^{\circ}\text{C}^{-1}$)

The resulting map of effective precipitation calculations by GTK were compared with the provisional calculations made for TACTIC WP4 by Grith Martinsen and Simon Stisen from GEUS. Figure 7 shows the three different effective precipitation calculation maps Peff RRe(GTK), Peff NetRR(GTK) and Peff (TACTIC). The map Peff NetRR(GTK) shows high effective precipitation in south-east Finland and lowest in the north. Peff NetRR(GTK) has the assumption, that effective precipitation does not occur while snow cover is present and that melting snow goes totally as a surface run-off. This seems to be significantly different from the estimations by Martinsen and Stisen. In the map Peff RRe (GTK) there is a sum of Peff for every day, including wintertime with



snow-cover. In Figure 8 there are cell by cell comparison between Peff RRe(GTK) and Peff NetRR(GTK) with Peff (TACTIC).

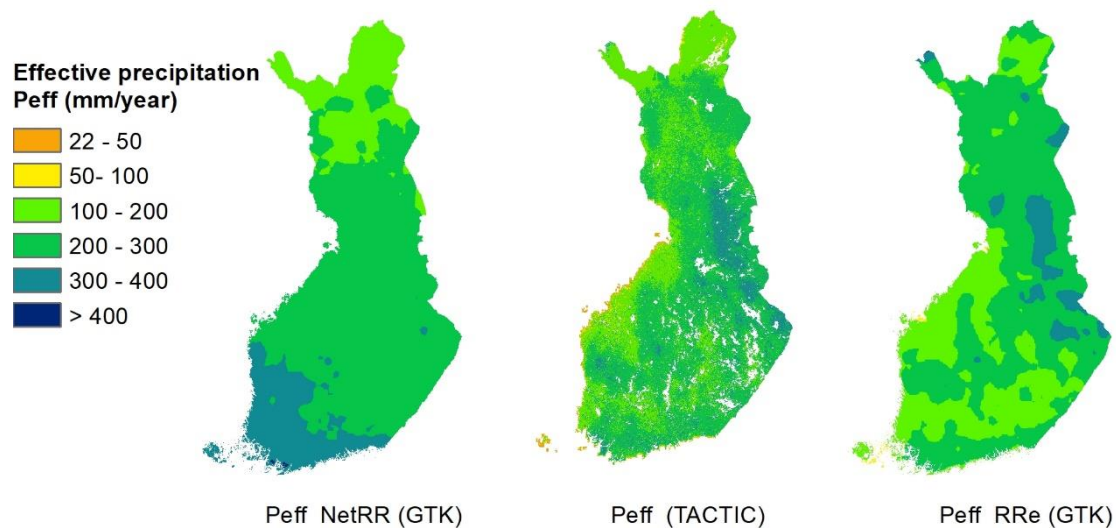


Figure 7 Three different effective precipitation estimation maps Peff RRe(GTK), Peff NetRR(GTK) and Peff (TACTIC).

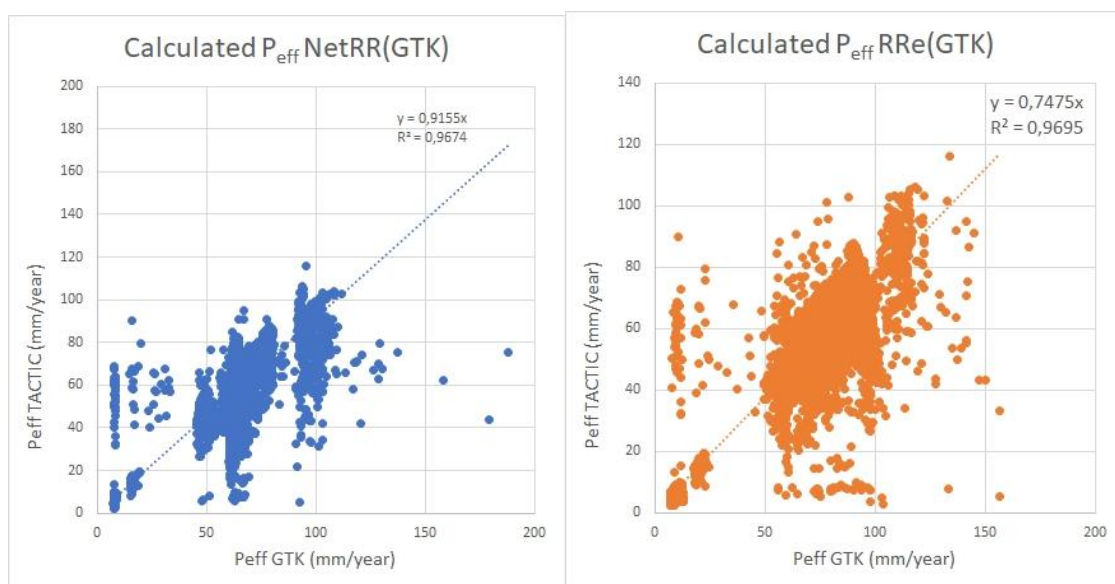


Figure 8 Cell by cell comparison with calculated values (GTK) to calculations of pan-european Peff (TACTIC).



4.3 Effective Precipitation Infiltration Ratio

Effective Precipitation Infiltration Ratio (EPIR) was estimated using the soil type of the Superficial deposits of Finland 1:200 000 (sediment polygons, GTK). It included soil type at depths from 0 to 1 m. The Superficial deposits of Finland 1:1 000 000 (GTK) was also used to distinguish different types of till in various parts of Finland. EPIR for respective soil types was estimated using K-values from literature.

The effective precipitation infiltration ratios for different soil types are shown in Figure 9. Value means how much of the effective precipitation could infiltrate in the ground. This calculation doesn't take into account transpiration through vegetation. Its purpose is to give general view of the groundwater potential and what happens under changing climate.

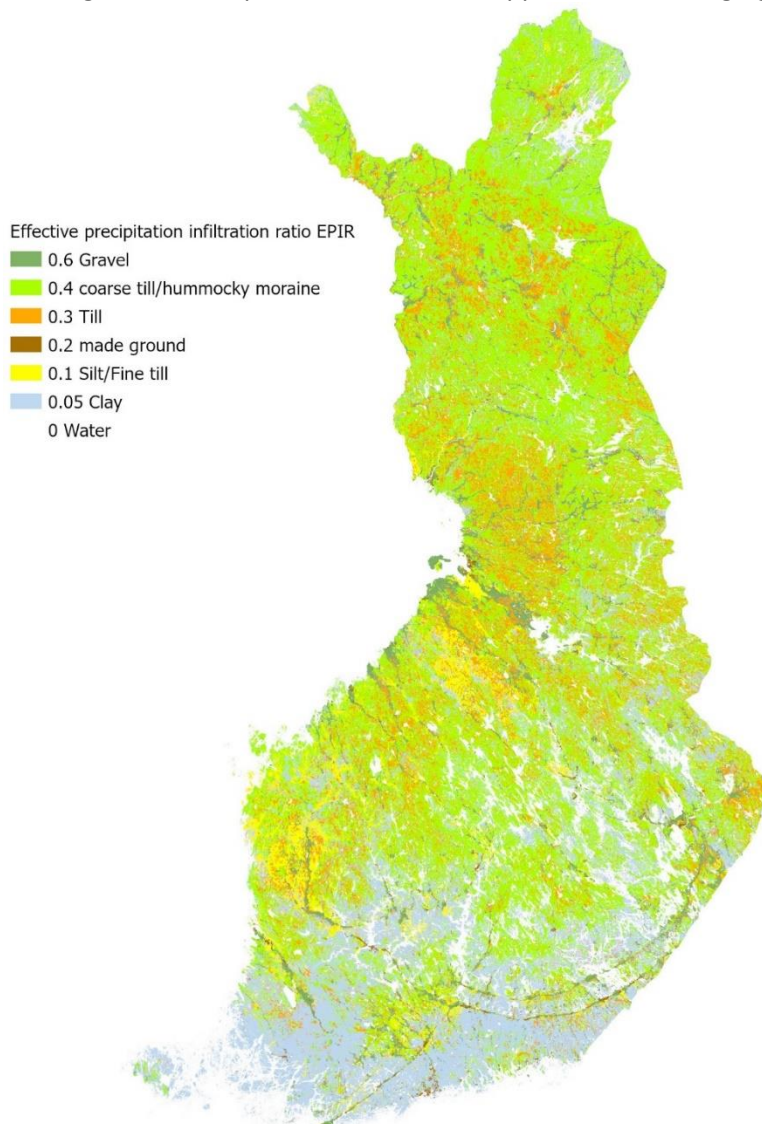


Figure 9 Effective precipitation infiltration ratio and major soil types



4.4 Model calibration

4.4.1 Observation data

Calculated values were compared with estimated values of groundwater formation in groundwater area database provided by (SYKE 2020). Figure 10 shows comparison charts and linear regression estimation. Calculation was done in ArcGIS Pro program with zonal statistics function.

Linear regression was calculated for the entire Finland and also within areas of 13 ELY-centers separately. Finland is divided in ELY-centers, which are “The Centers for Economic Development, Transport and the Environment” and they are responsible for the regional implementation and development tasks of the central government. ELY-Centres are shown in in figure 11. Figure 10 shows linear regression chart for both NetRR and RRe calculations for entire country. Slope of line (Y) shows the relationship between the calculated values and the values in the database by SYKE. Calculated recharge values are in average 60 % of the values that were estimated by SYKE. Different ELY-centers show variation between 53.8 % in 90.6%, as shown in Table 3. Slope-values for each ELY-center are also shown in column Y in Table 3. Potential recharge map for Finland was decided to be calculated using Peff NetRR (GTK) recharge values as they have better correlation with the estimated recharge values of groundwater areas by SYKE.

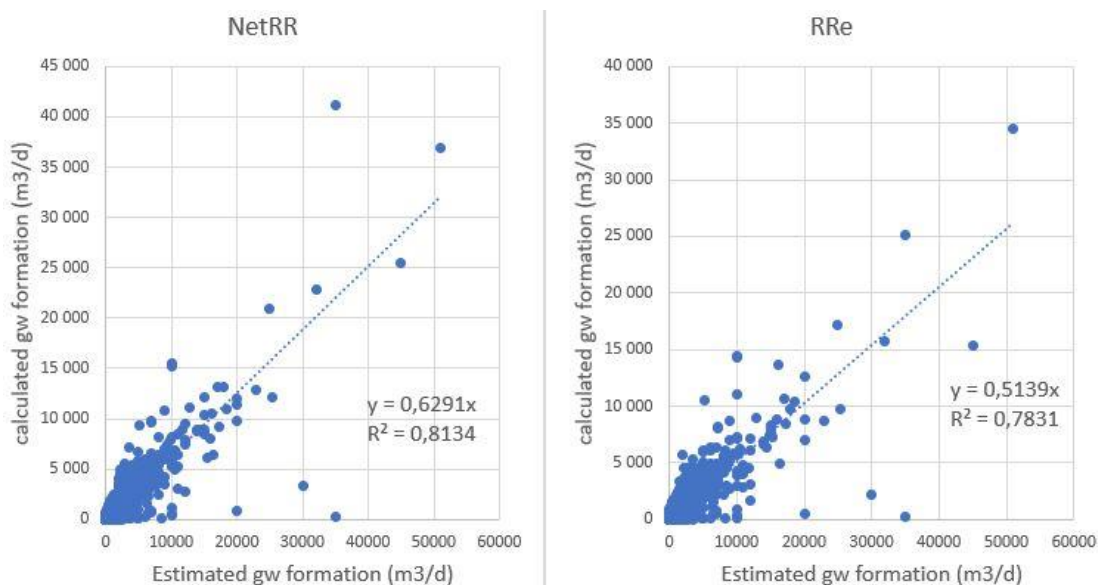


Figure 10 Comparison between calculated and previously estimated groundwater formation values



Table 3 Slope values of the linear regression analysis for each ELY Centres

ID	Area	Count	Calculated/Estimated(SYKE) Y	R ²
EPO	Etelä-Pohjanmaa, Keski-Pohjanmaa and Pohjanmaa	319	0,7615	0,7472
ESA	Etelä-Savo	184	0,6408	0,9327
HAM	Kanta-Häme	297	0,5385	0,6828
KAI	Kainuu	231	0,562	0,9178
KAS	Kymenlaakso and Etelä-Karjala	293	0,6497	0,9461
KES	Keski-Suomi	1,6462	0,7655	0,5575
LAP	Lappi	1744	0,608	0,7059
PIR	Pirkanmaa	144	0,6371	0,8791
POK	Pohjois-Karjala	1,6156	0,8389	0,6171
POP	Pohjois- Pohjanmaa	350	0,6946	0,8774
POS	Pohjois-Savo	1,3114	0,906	0,4836
UUD	Uusimaa	302	0,6419	0,6273
VAR	Varsinais-Suomi and Satakunta	245	0,876	0,895
Sum all		4856	0,6034	0,7188

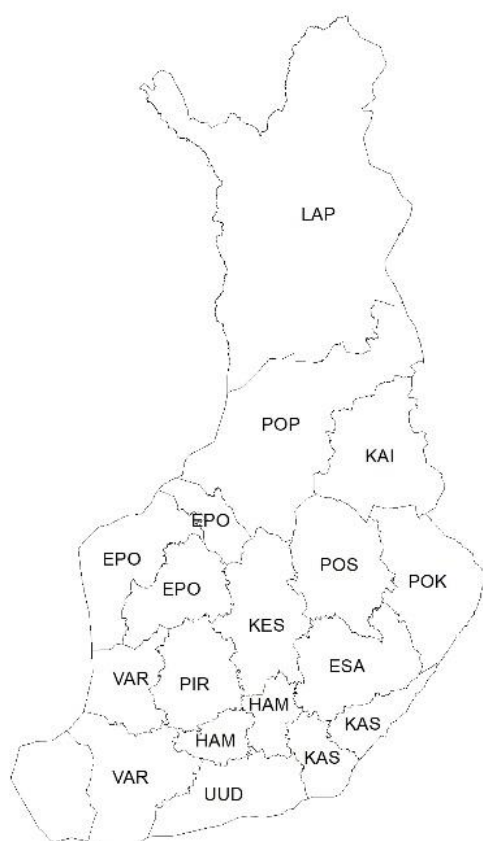


Figure 11 ELY -Centres in Finland



4.4.2 *Uncertainty*

Estimating groundwater recharge in the whole country is certainly challenging. In general estimating evaporation and thus effective precipitation leaves room to errors. Snow cover has appeared in all over Finland every winter in years 1981-2010, nearly half a year in the north and perhaps only a few days in the southwest Finland. Future climate change scenarios predict shorter periods with snow cover. Thick snow cover can keep ground unfrozen and allow infiltration during the snow melting period. On the other hand, absence of snow could lead the ground to freeze, which prevents the water infiltration. These questions remain unanswered in a nation scale approach.

5 RESULTS AND CONCLUSIONS

5.1 Climate data

Monthly temperature delta change additive factors (Table 1) were added to meteorological temperature data and monthly precipitation delta change multiplication factors (table2) were multiplied to monthly precipitation data. Meteorological data and simulated prediction are shown in Figure and Figure 13. Temperature and precipitation are changing according the given delta change factors, as showed in Figure 6 and Table 1 and Table 2 (Chapter 4.1.1). Warm winters and increasing precipitation can change the periods when the groundwater infiltration can take place. Potential groundwater recharge estimations for present and 1 °C scenario and 3 °C scenarios are shown in Figure 14.

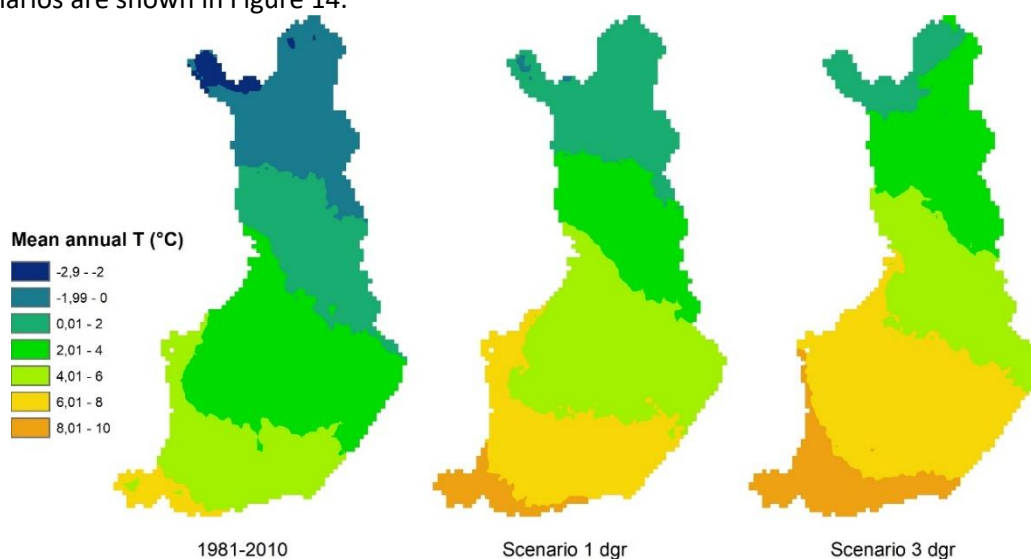


Figure 12 Observed present and predicted temperature values according given scenarios.

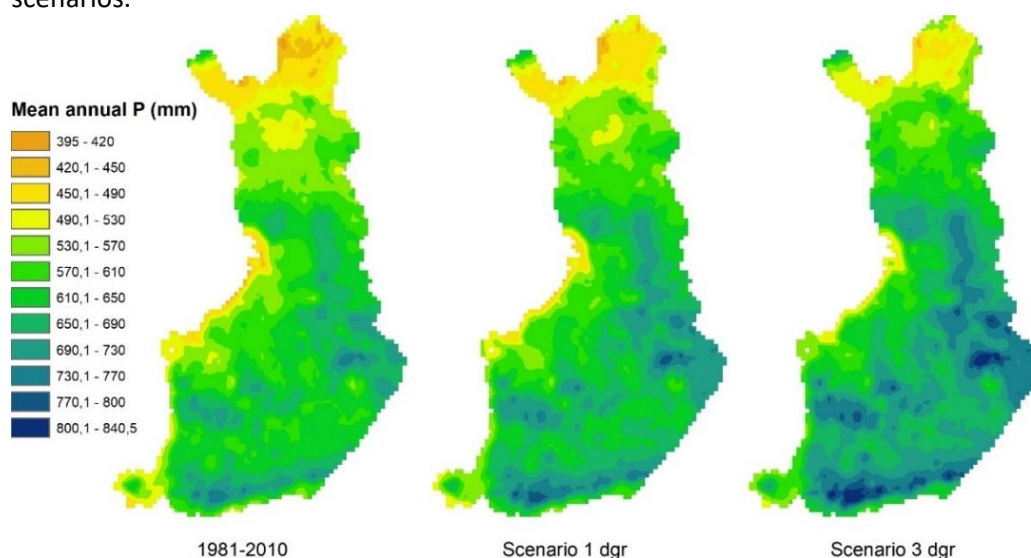


Figure 13 Observed present and predicted precipitation values according given scenarios.



This robust and simplified approach doesn't show major changes in calculated potential groundwater recharge. However, detailed local studies are needed to understand properly the water infiltration dynamics under snow cover and frozen ground.

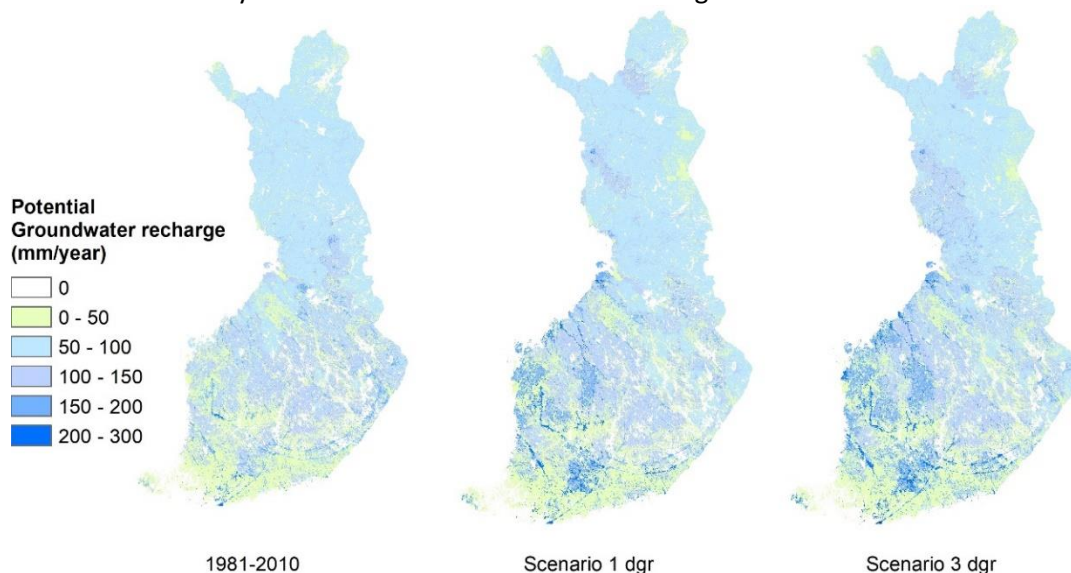


Figure 14 Calculated potential groundwater recharge for present (1981-2010) and for the two future scenarios.

5.1.1 Performance to historical data

This model shows potential groundwater recharge decreasing in eastern Finland in both 1 °C scenario and 3 °C scenario. Small increase is calculated in western part of middle Finland (Figure 155).

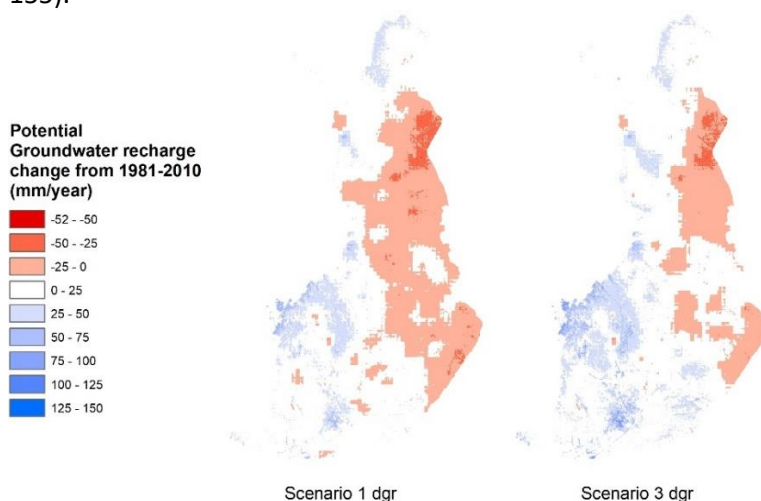


Figure 15 Difference between present values and predicted values of potential groundwater recharge for Climate change scenarios 1 and 3 °C.



5.2 Potential groundwater recharge map of Finland

Potential groundwater recharge was obtained by multiplying EPIR values by effective precipitation. In lakes the potential groundwater recharge was estimated as zero. Resulting map is shown in Figure 116 and chart of the results in Figure 127. Mean recharge value is 68 mm/year.

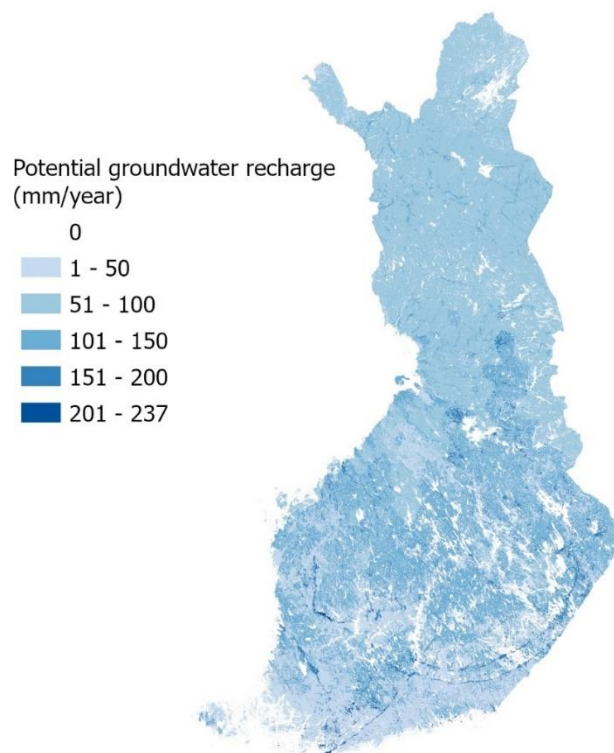


Figure 116 Potential groundwater recharge in Finland as estimated during years 1981-2010.

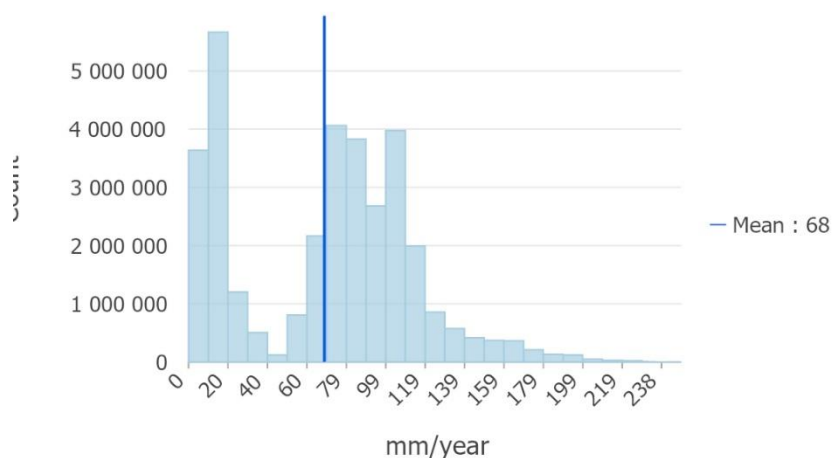


Figure 127 Potential groundwater recharge in Finland as estimated during years 1981-2010.



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