An analysis of remote sensing land subsidence data in the Netherlands

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Introduction

Land subsidence is a major challenge in many parts of the Netherlands. To develop plausible scenarios and pathways for possible mitigation and adaptation measures under inclusive governance, it is necessary to prepare a comprehensive damage risk map by studying and analysing all available historical and predicted land subsidence data in the Netherlands. One important source of the historical land subsidence data in the Netherlands is the remote sensing subsidence data of the surface and object motion (SOM) map 2.0 from the Dutch ground motion service online "Bodemdalingskaart.nl" which provides land subsidence data from Sentinel-1 every twelve days for five consecutive years from October 2017 to October 2022.

Motivation

A sustainable vision and five future targets have been set for the land subsidence scenario development process within a backcasting approach that has been selected for the LOSS project. To know where each subsidence-related strategy or measure can be implemented to reach these future targets, a comprehensive damage risk map should first be developed through a robust framework using a statistical method to identify high, medium, and low comprehensive damage risk areas of subsidence in each of the urban and rural areas. This comprehensive damage risk map should be developed based on all available predicted and observed land subsidence data, elevation data (below sea level and above sea level), lithology (peat/clay with thicknesses), and land cover / land use data in order to include all of the flood-risk and GHG emission components for rural areas, and with the Fragility Curve data on top of that, the damage probability for buildings in urban areas can be included. Analysing of the observed remote sensing land subsidence data and comparing it with the predicted land subsidence data is an important step to knowing the advantages and disadvantages of both data types. It is also an important step to know the best way of using these data in developing the comprehensive damage risk map, which is, as previously stated, an essential step in choosing some case studies that can be used to test and monitor tailored intervention of water and land use management scenarios and pathways prior to the assessment stage. As a result, the optimal way of dealing with land subsidence in each area type can be defined and the final sustainable vision of minimum subsidence, minimum GHG emissions, and minimum future damage can be reached in both urban and rural areas.

Methods

The subsidence points data from "Bodemdalingskaart.nl" [Fig. 1] were statistically classified as low subsidence rate (equal to or less than 3 mm/year) and high subsidence rate (more than 3 mm/year) and combined with the Sentinel-2 10m Land Use / Land Cover map from ArcGIS Living Atlas of the World to disentangle urban areas from rural areas. Also, the high subsidence rates from the observed remote sensing data were compared with the predicted subsidence rate values of the Atlantis model (Bootsma et al. 2020) for both the low climate change scenario [Fig. 3] and the high climate change scenario [Fig. 4] to enable for visual comparison and statistical analysis of trends and degree of correlations.

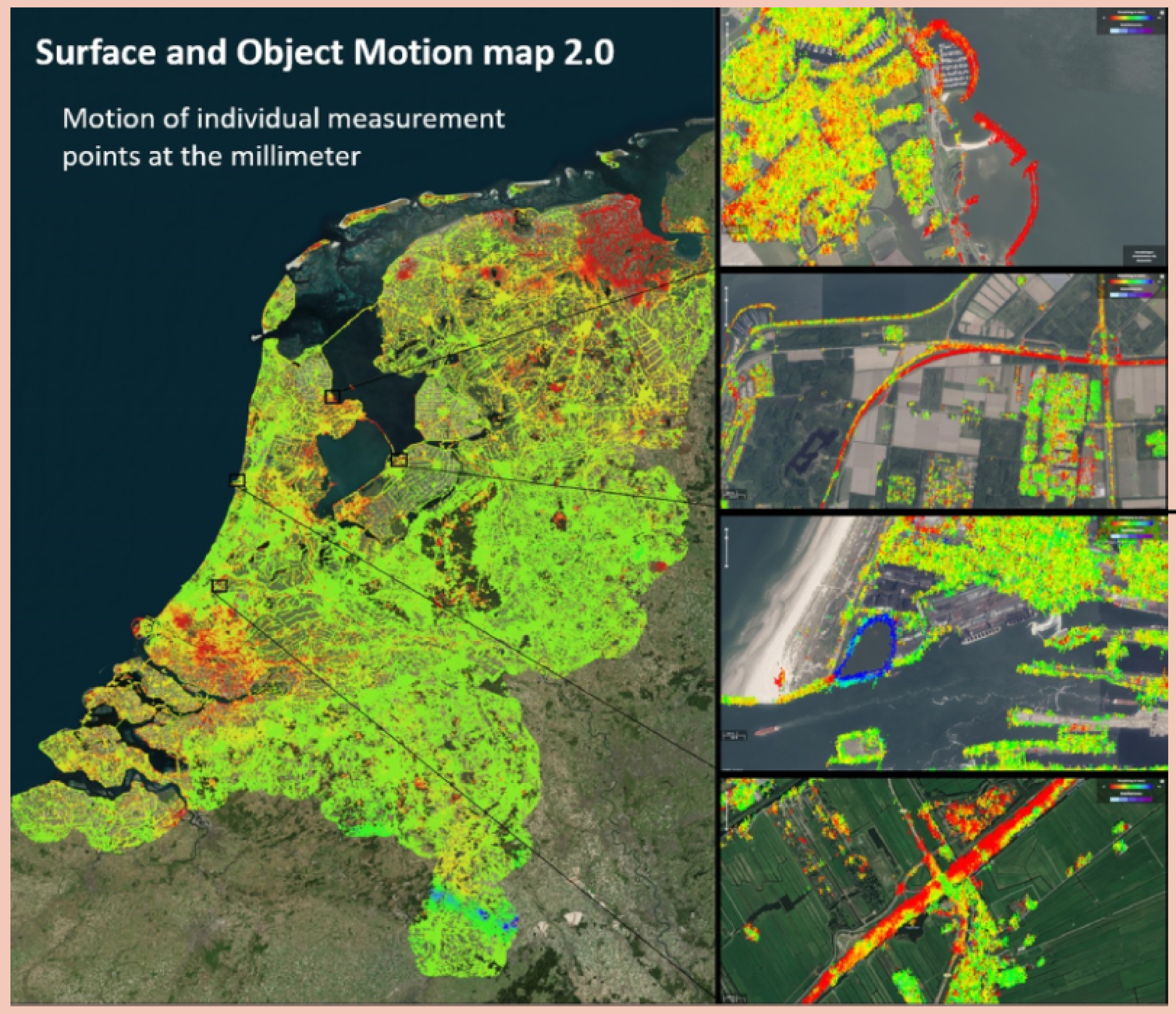

Fig.1: The land subsidence object-based motion map 2.0 from The Dutch Ground Motion Service [*Bodemdalingskaart.nl*].

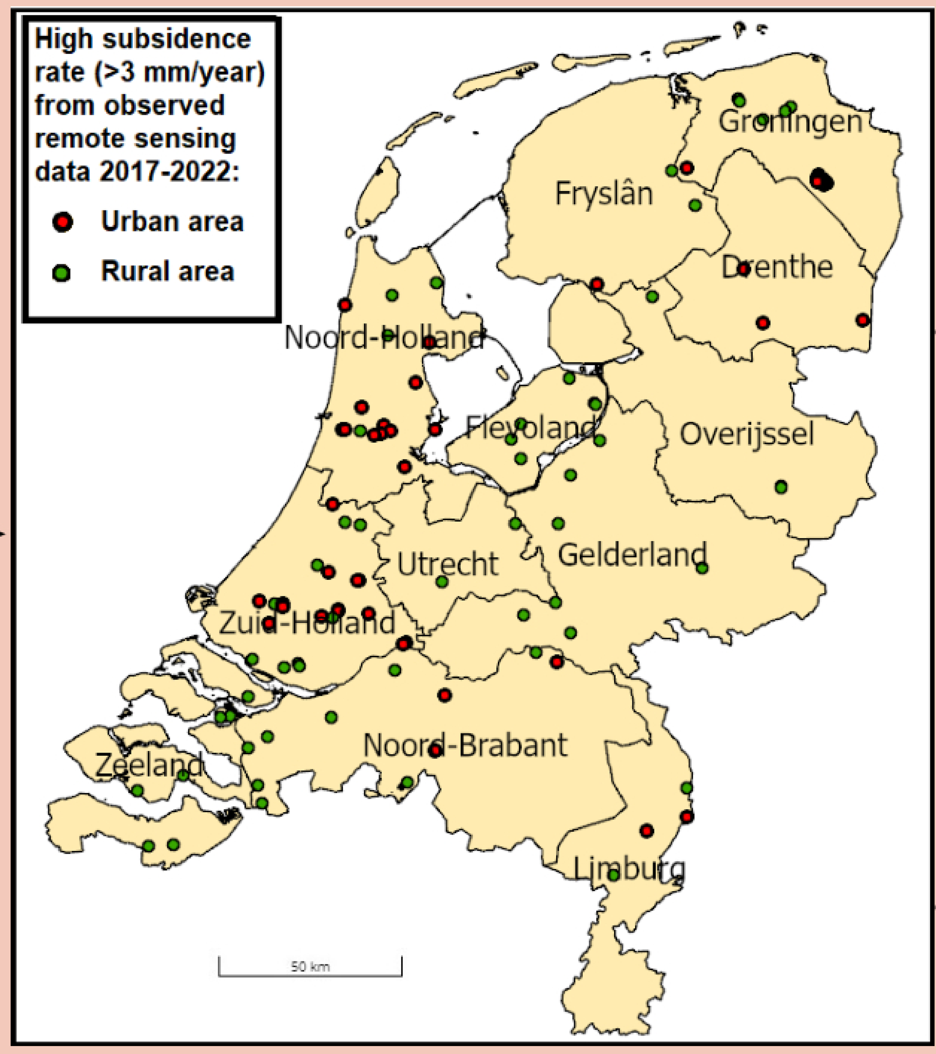

Fig.2: High land subsidence rates of observed remote sensing data from Sentinel-1 between 2017-2022.

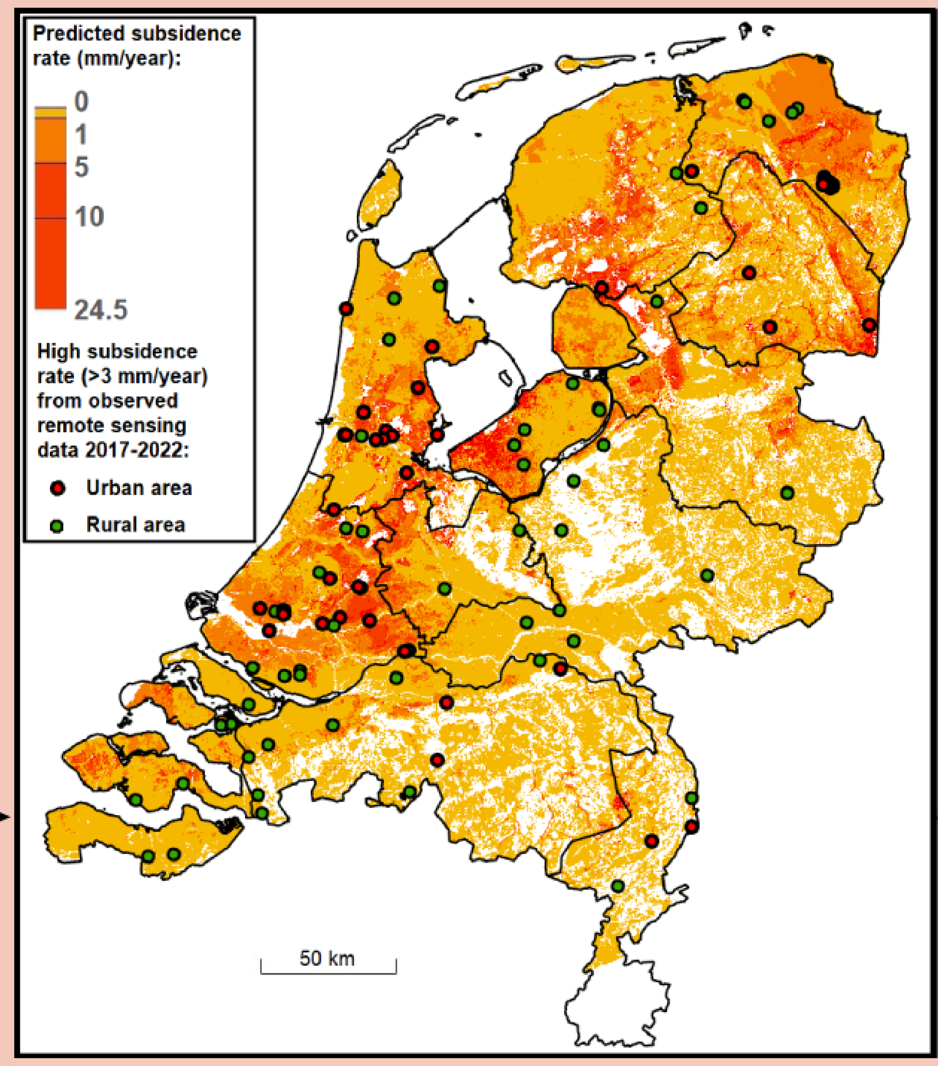

Fig.3: Predicted subsidence rate map of Atlantis 2050 for the low climate change scenario.

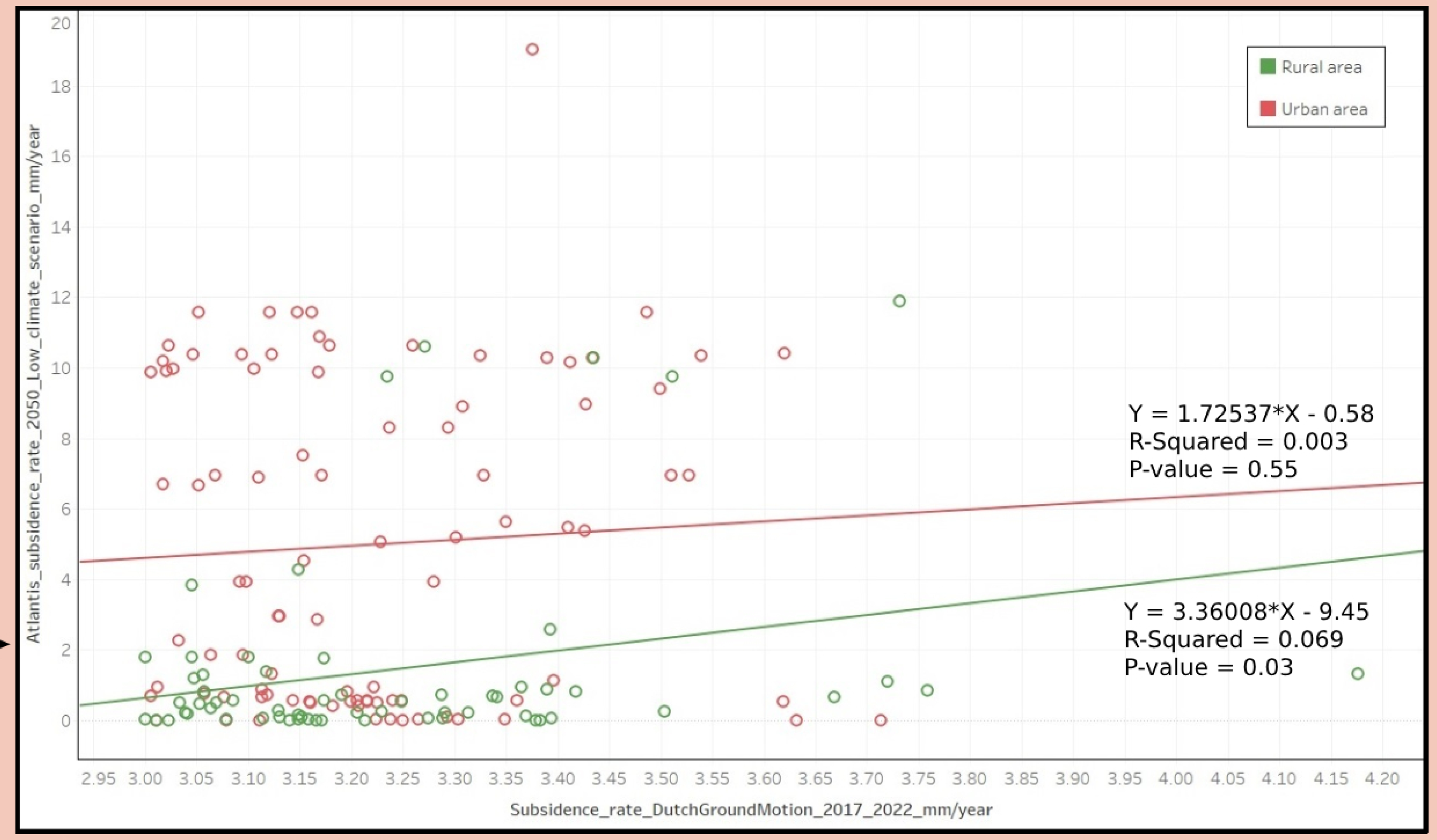

Fig.5: A scatter plot with the trends for urban and rural areas of the remote sensing subsidence data on the X axis and the Atlantis predicted subsidence data for the low climate scenario 2050 on the Y axis.

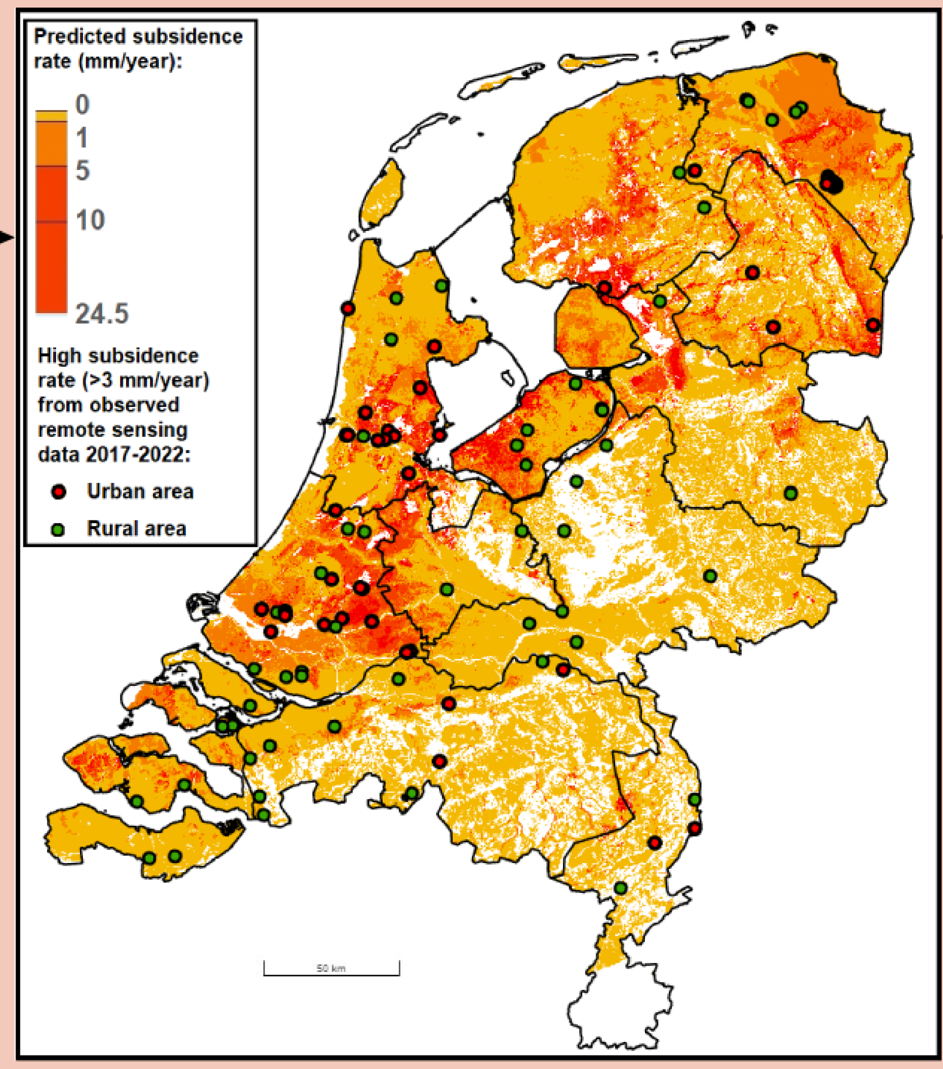

Fig.4: Predicted subsidence rate map of Atlantis 2050 for the high climate change scenario.

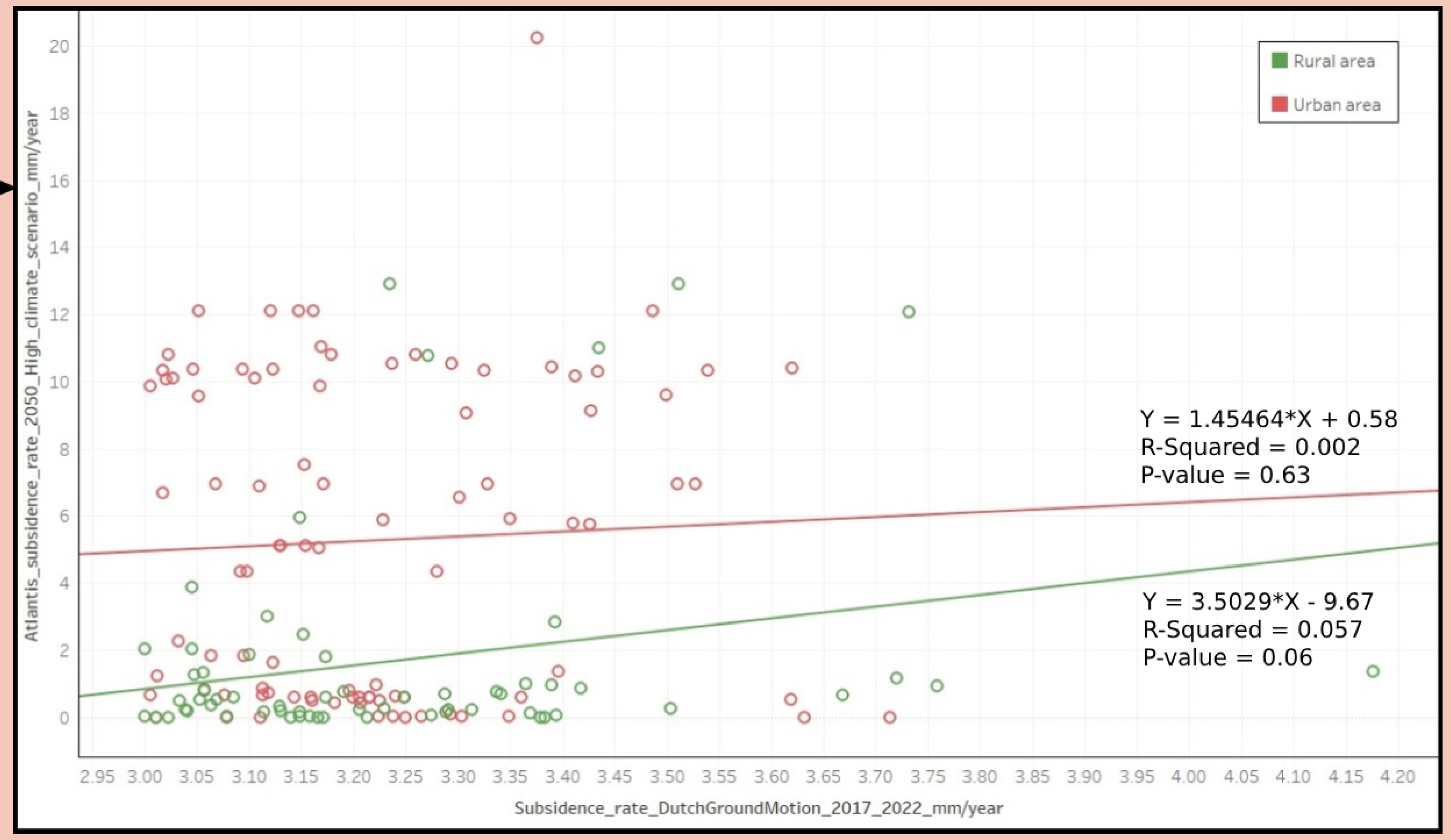

Fig.6: A scatter plot with the trends for urban and rural areas of the remote sensing subsidence data on the X axis and the Atlantis predicted subsidence data for the high climate scenario 2050 on the Y axis.

Results

In total, 155 scatterer points out of more than 4 million scatterer points from the Surface and Object Motion (SOM) map 2.0 were recognized as having significant land subsidence rate values (> 3 mm/year) [Fig. 2]. The 155 identified locations were distributed among all 12 provinces. Also, 66 locations of the 155 identified locations were in urban areas and 89 locations were in rural areas according to the Sentinel-2 10m Land Use/Land Cover map. Moreover, 60 of the 155 locations were in areas below sea level. By comparing the high subsidence rates of remote sensing data with each of the land subsidence predicted rates from the Atlantis model of 2050 for the low climate change scenario [Fig. 3] and for the high climate change scenario [Fig. 4], it was found that the majority urban area points of predicted and subsidence values from the Atlantis model were greater than those in the observed remote sensing data. As for rural areas, the majority of predicted subsidence rate values in the Atlantis model were slightly lower than those in the observed remote sensing subsidence data. Finally, the trend lines for rural areas in both climate scenarios indicate low weak positive correlation while the trend lines for urban areas in both climate scenarios indicate high weak positive correlation [Fig. 5] [Fig. 6].

Discussion

- In urban areas, the weak correlation between both data types, where the large values of predicted subsidence rates do not accurately match the observed subsidence rates of remote sensing Sentinel-1 data, can be due to limitations of Sentinel-1 short radar wavelength (C-band, 5.6 cm) which is known as the phase decorrelation limit. This decorrelation arises from the high complexity and diverse scattering characteristics of urban structures, which can result in signal interference and reduced coherence (Yonezawa et al. 2002).
- In rural areas, the weak correlation between both data types, where the observed subsidence rates of remote sensing data are higher compared to the predicted subsidence rates of Atlantis model, can be due to acceleration of climate change and increased severity of drought periods in the Netherlands during the last 5 years.
- In both urban and rural areas, uncertainties and possible errors in each of both data types can also be contributing reasons behind the differences between the observed remote sensing subsidence data and the predicted Atlantis subsidence data.

Conclusion

Even with differences in the amount of land subsidence values in urban and rural areas, both the observed subsidence data of remote sensing radar data and the predicted subsidence data of the Atlantis model can identify locations with high subsidence rates in both urban and rural areas. The high correlation between both data in urban areas is an indicator that the remote sensing subsidence data can increase the reliability of the comprehensive damage risk map that will be developed for the scenario development process within the LOSS project.

Refgerences: H. Bootsma, H. Kooi and G. Erkens (2020). Atlantis, a tool for producing national predictive land subsidence maps of the Netherlands. TISOLS: the Tenth International Symposium On Land Subsidence – living with subsidence.

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