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# Surface Soil Moisture Estimation for Temperate Forests with the Application of Remote Sensing Techniques


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# Introduction

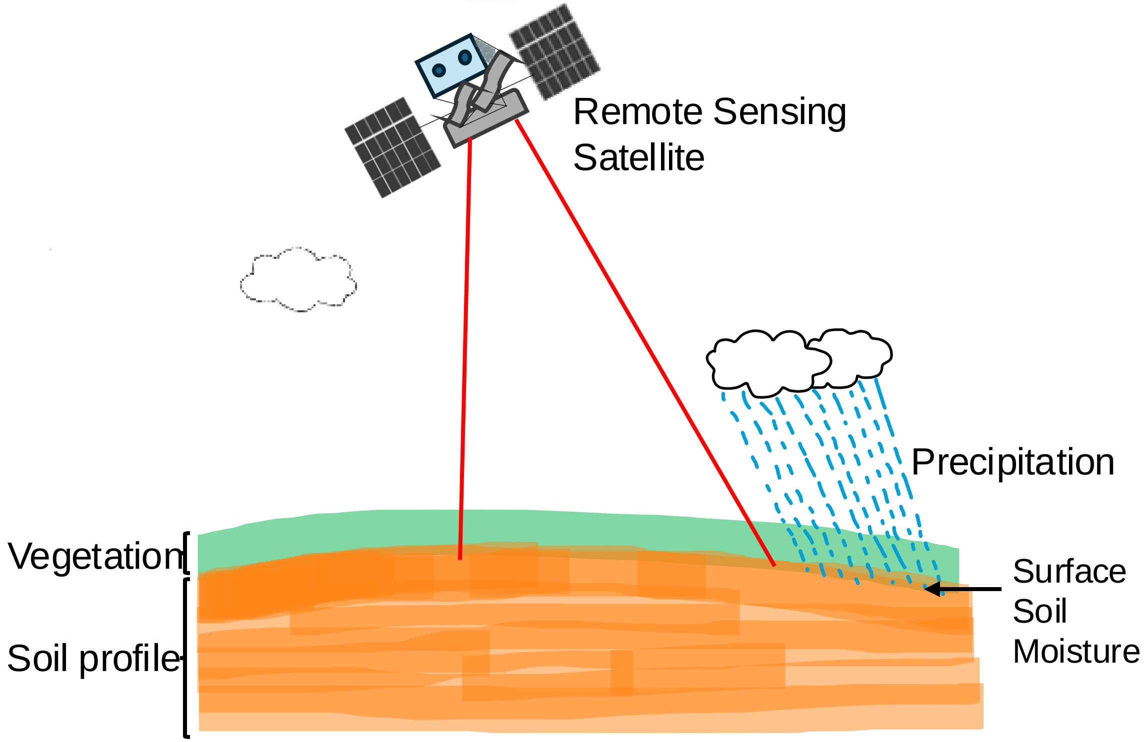
Surface soil moisture:

- ✓ key component of terrestrial ecosystems (Peng et al. 2021, Sabaghy et al. 2018)
- ✓ refers to the water content of the topsoil layer (~5–15 cm) (Wang et al. 2009)
- ❑ SSM estimation with high spatial resolution is urgently required for practical applications in the forestry field.
- ❑ This study adopts synergistic approaches to recommend the most suitable approach for SSM estimation.

**Objective**

- ❑ to estimate surface soil moisture (SSM) for temperate forests with a variety of forest types of central Japan through remote sensing techniques

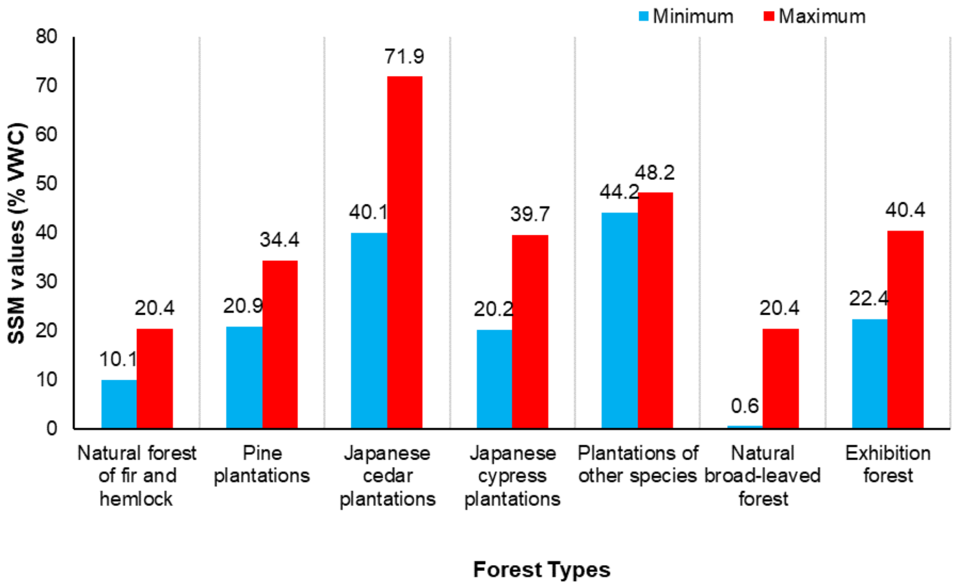
Traditional technique

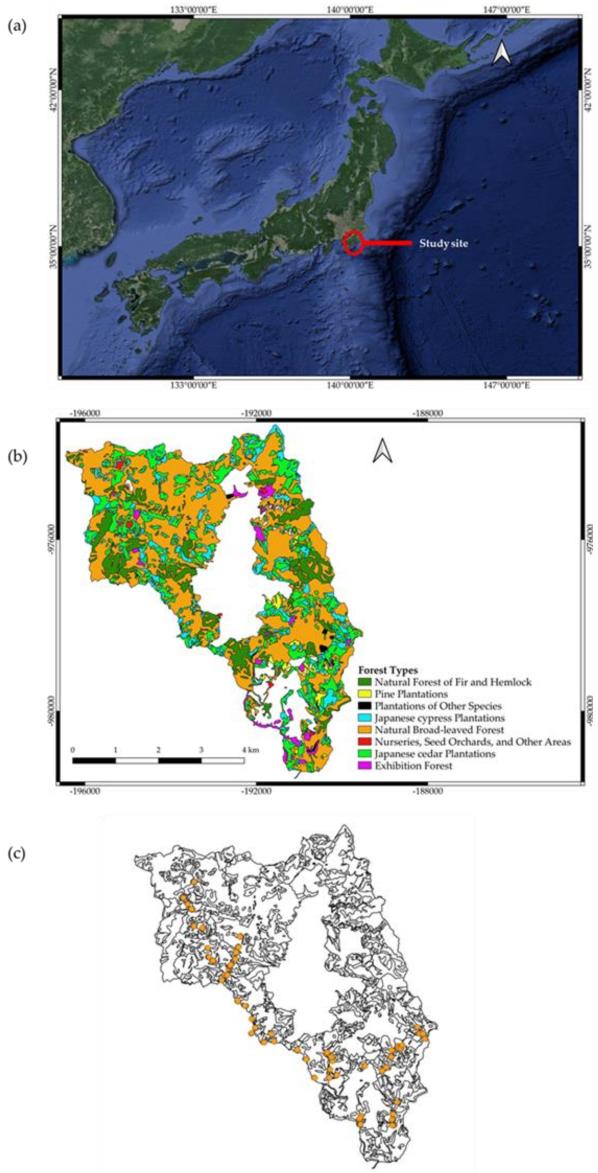



Remote sensing technique

# Methodology

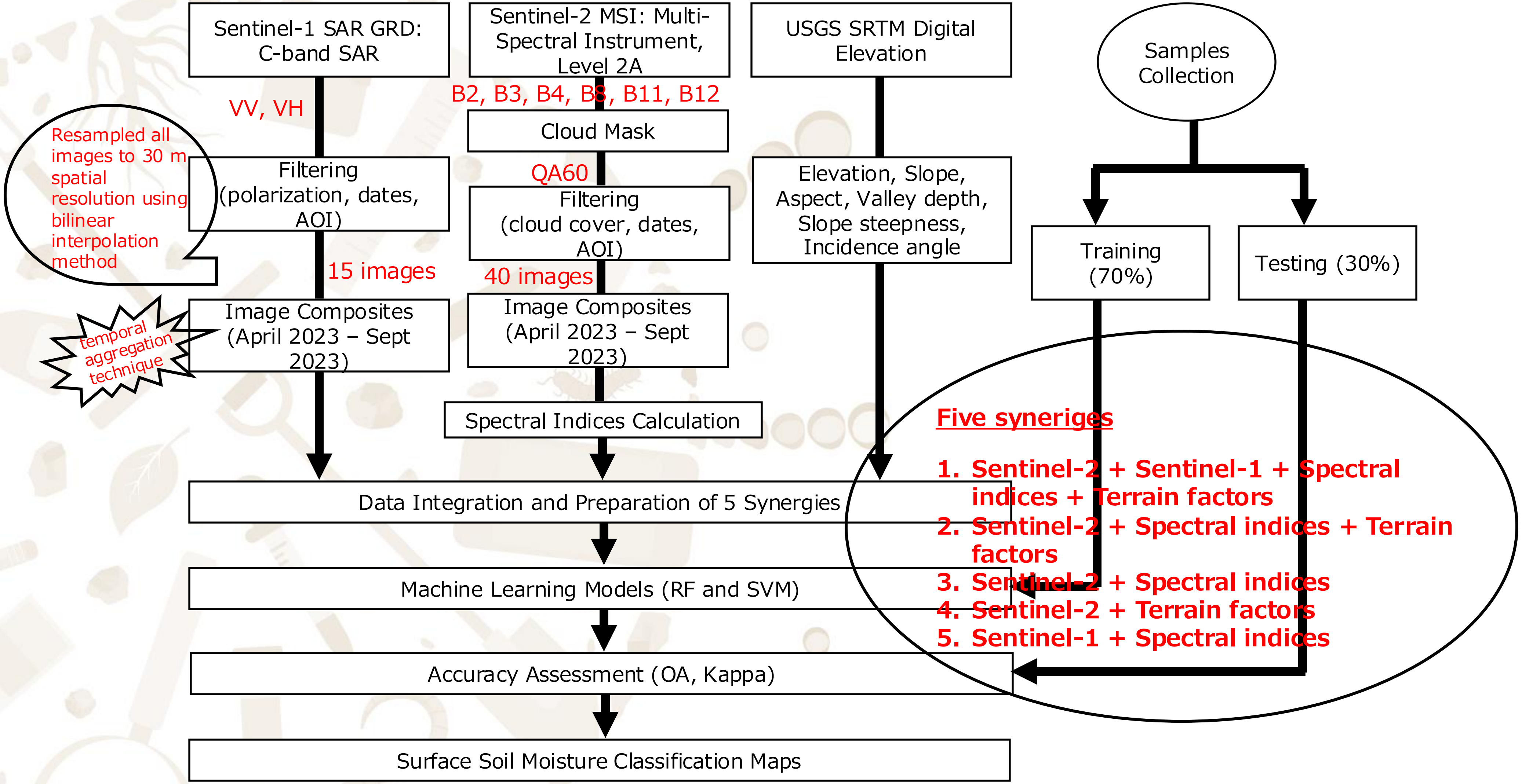
- Use TDR sensor to measure SSM data
- Use stratified random sampling design
- the values of SSM ground-truth data ranged from 0.6 to 71.9% VWC among different forest types
- classified these values as three levels of SSM ground-truth data: (1) <20% VWC, (2) 20-40% VWC, and (3) >40% VWC



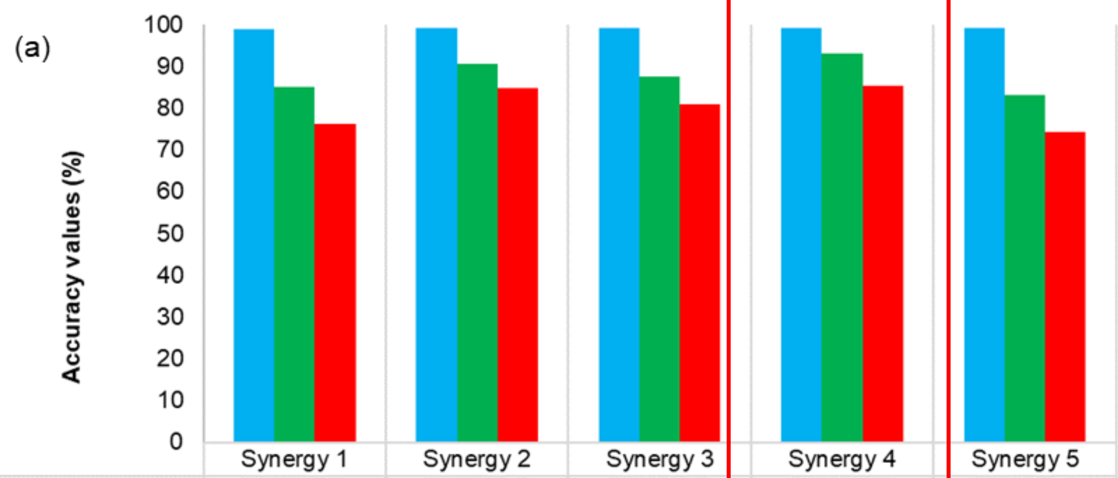




| Forest Types | Areas (ha) | | No of Ground Truth Points |
|---|---|---|---|
| Natural forest of fir and hemlock | 387 | | 40 |
| Plantations | 825 | Pine plantations | 5 |
| | | Japanese cedar plantations | 95 |
| | | Japanese cypress plantations | 90 |
| | | Plantations of other species | 5 |
| Natural broad-leaved forest | 949 | | 120 |
| Exhibition forest | 56 | | 20 |
| Nurseries, seed orchards, and other areas | 8 | | 0 |
| Total | 2225 | | 375 |

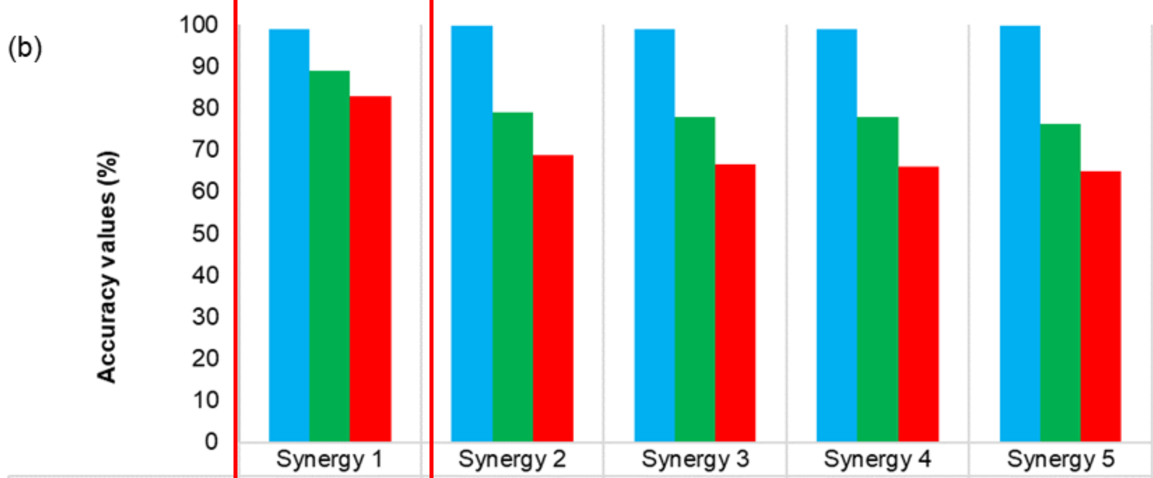
# Research Flowchart



# Accuracy Results of Five Synergies by (a) RF and (b) SVM

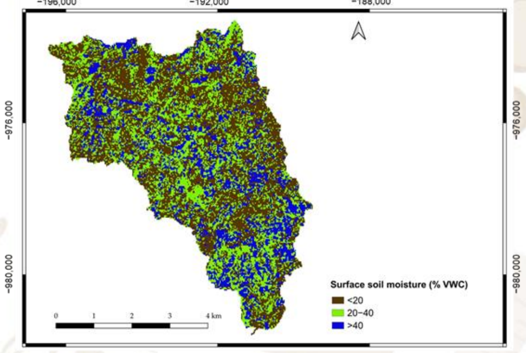



| | Synergy 1 | Synergy 2 | Synergy 3 | Synergy 4 | Synergy 5 |
|---|---|---|---|---|---|
| OA for training (%) | 98.94 | 99.26 | 99.24 | 99.26 | 99.24 |
| OA for testing (%) | 84.95 | 90.48 | 87.61 | 92.97 | 83.19 |
| Kappa (%) | 76.29 | 84.67 | 80.80 | 85.45 | 74.23 |

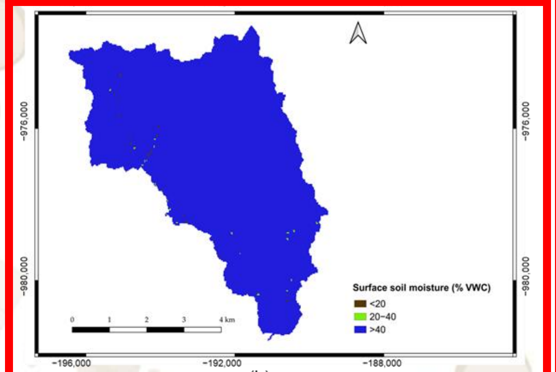



| | Synergy 1 | Synergy 2 | Synergy 3 | Synergy 4 | Synergy 5 |
|---|---|---|---|---|---|
| OA for training (%) | 98.95 | 99.62 | 98.85 | 98.83 | 99.63 |
| OA for testing (%) | 88.89 | 78.89 | 77.88 | 77.97 | 76.19 |
| Kappa (%) | 82.82 | 68.66 | 66.55 | 66.09 | 64.83 |

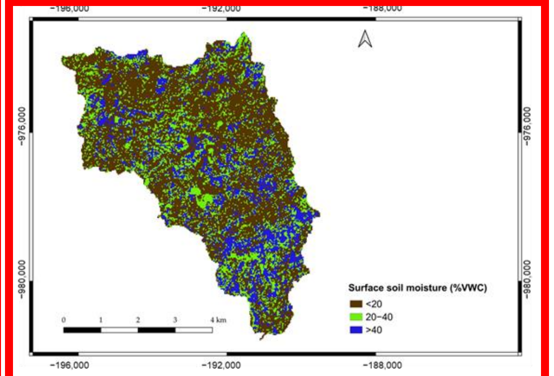
- **Synergy 4 – the best accuracy**
- **Synergy 1 – the best accuracy**



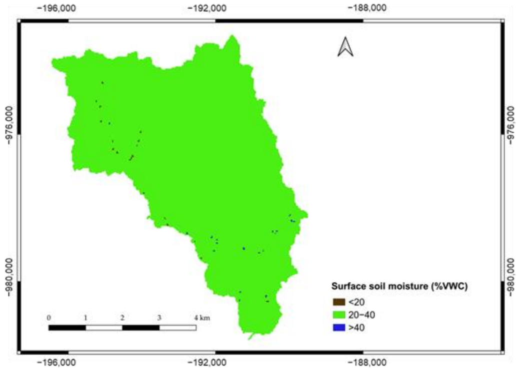
(a)



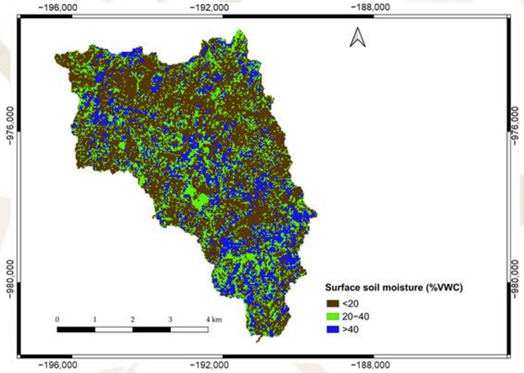
(b)



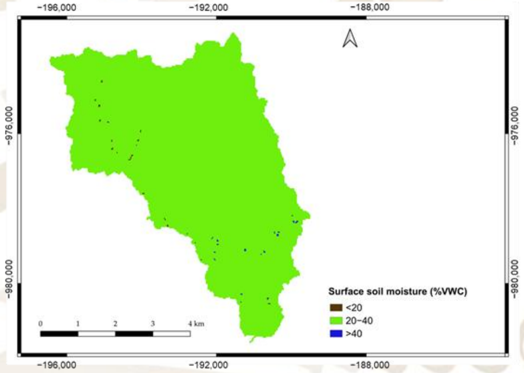
(g)



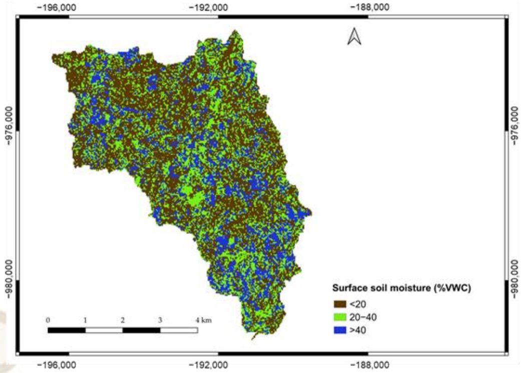
(h)



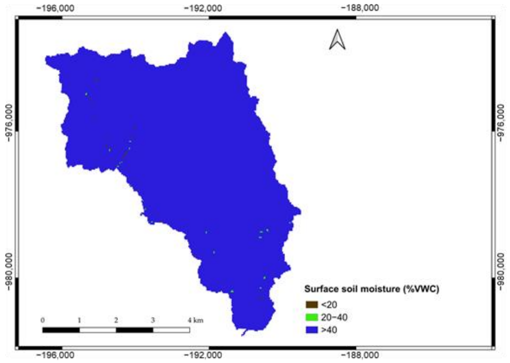
(c)



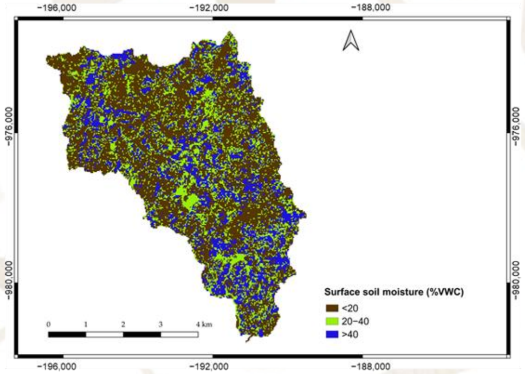
(d)



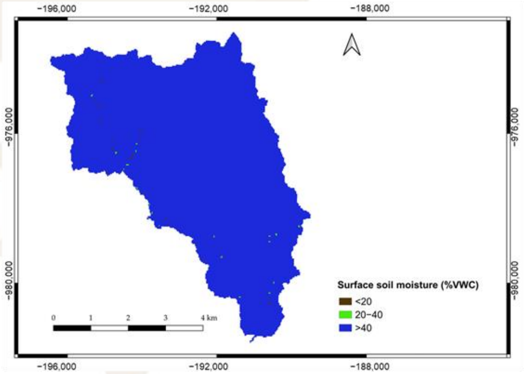
(i)



(j)



(e)



(f)

Spatial distribution of SSM in temperate forests of UTCBF: (a) synergy 1 by RF, (b) synergy1 by SVM, (c) synergy 2 by RF, (d) synergy 2 by SVM, (e) synergy 3 by RF, (f) synergy 3 by SVM, (g) synergy 4 by RF, (h) synergy 4 by SVM, (i) synergy 5 by RF, and (j) synergy 5 by SVM

# Assessment of Best Model Performance for Each Synergy among RF and SVM

| | Random Forest (RF) | | | Support Vector Machine (SVM) | | |
|---|---|---|---|---|---|---|
| **Synergies** | **$R^2$** | **RMSE** | **MAE** | **$R^2$** | **RMSE** | **MAE** |
| Synergy 1 | 0.933 | 0.022 | 0.019 | 0.918 | 0.063 | 0.050 |
| Synergy 2 | 0.954 | 0.035 | 0.031 | 0.900 | 0.009 | 0.008 |
| Synergy 3 | 0.923 | 0.045 | 0.039 | 0.766 | 0.175 | 0.142 |
| Synergy 4 | 0.954 | 0.033 | 0.029 | 0.885 | 0.035 | 0.035 |
| Synergy 5 | 0.896 | 0.051 | 0.045 | 0.912 | 0.014 | 0.011 |

- **Synergy 4 by RF – the most suitable approach**

# Correlation between observed SSM and predicted SSM from five synergies by RF and SVM

| | Synergy 1 | Synergy 2 | Synergy 3 | Synergy 4 | Synergy 5 |
|---|---|---|---|---|---|
| | Predicted SSM by RF Model | | | | |
| Observed SSM | 0.96 | 0.97 | 0.96 | 0.98 | 0.95 |
| | Predicted SSM by SVM Model | | | | |
| Observed SSM | 0.95 | 0.94 | 0.87 | 0.94 | 0.95 |

- **Synergy 4 by RF – the most suitable approach**

# Conclusions

- ❑ The study demonstrated the effectiveness of integrating multi-source remote sensing data and two machine learning models (RF and SVM) for accurate SSM mapping in temperate forests of Central Japan.
- ❑ RF model achieved the better performance in terms of accuracy and reliability compared with the application of the SVM model.
- ❑ In RF model, the synergy of Sentinel-2 and terrain factors was the most suitable approach.
- ❑ This finding contributes to advancing our understanding of SSM dynamics in temperate forests and has practical implications for managing land and water resources as part of forest management practice.

# Relative Publication

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