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A Step Toward Resolving Spatiotemporal Distribution of Suspended Sediment Concentration Using Remote Sensing

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Abstract

It is critical to study Suspended Sediment Concentration (SSC) to improve our understanding of the impacts of wildfires, climate, and anthropogenic on the riverine environments. The processes that contribute to SSC occur over a range of spatiotemporal scales making it difficult to continuously measure and monitor. Traditional methods (e.g., field measurement) require significant resources and often lack the spatial and temporal resolution that is needed for important yet smaller-scale systems like streams. In this study, we create an open-source and low-cost method to estimate SSC using remotely sensed data. Our study aims to elucidate if a machine learning (ML) model is capable of estimating SSC from multispectral imagery using a dataset collected in the laboratory. Another objective is to determine which ML model most accurately estimates SSC. Our methods involve testing and comparing two Machine Learning (ML) models: Random Forest and Linear Regression. Preliminary results indicate that the Random Forest model has the capability of extracting the SSC signal from the imagery and providing superb agreement between experimental and ML-generated data (R2=0.99). Further, our results from the Linear Regression model indicate that the relationship between multispectral imagery and SSC is non-linear and requires a more robust ML model (low correlation of R2= -.71). Continuing work will compare these results with other ML models to develop a cross-validated method for widespread usage in SSC detection. This study contributes to a larger framework, and with a validated model we will be able to quantify the effects of SSC on the entire Snake and Columbia River system. Implications of this research include improving our understanding of SSC and detection methods that augment existing methodologies as tools for stakeholders, government agencies, land managers, and citizen scientists.

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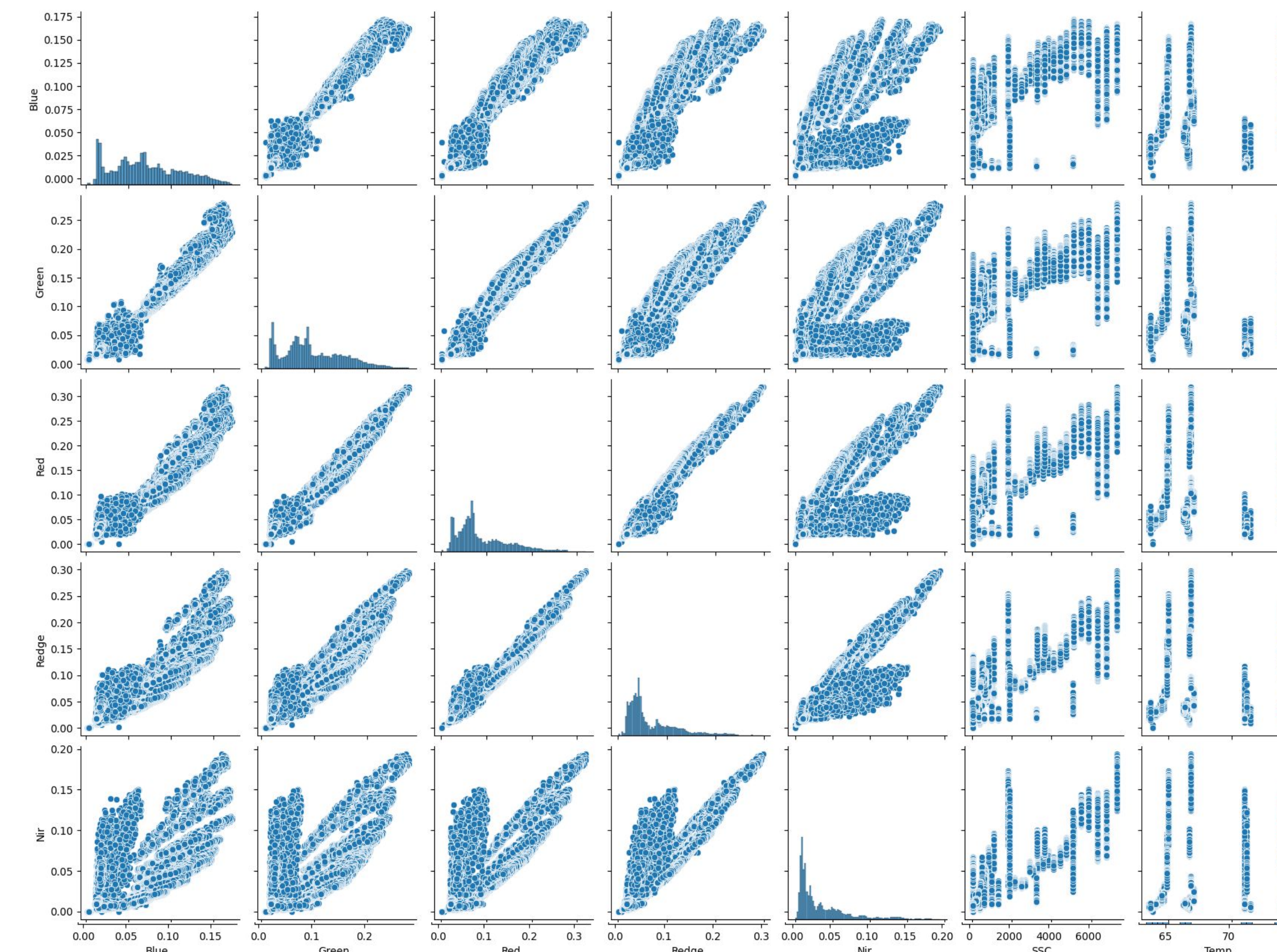
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ABSTRACT

It is critical to study Suspended Sediment Concentration (SSC) to improve our understanding of the impacts of wildfires, climate, and anthropogenic on riverine environments. The processes that contribute to SSC occur over a range of spatiotemporal scales making it difficult to continuously measure and monitor. Traditional methods (e.g., field measurement) require significant resources and often lack the spatial and temporal resolution that is needed for important yet smaller scale systems like streams. In this study we create an open-source and low-cost method to estimate SSC using remotely sensed data. Our study aims to elucidate if a machine learning (ML) model is capable of estimating SSC from multispectral imagery using a dataset collected in the laboratory. Another objective is to determine which ML model most accurately estimates SSC. Our methods involve testing and comparing two Machine Learning (ML) models: Random Forest and Linear Regression. Preliminary results indicate that the Random Forest model has the capability of extracting the SSC signal from the imagery and providing superb agreement between experimental and ML-generated data ($R2=0.99$). Further, our results from the Linear Regression model indicate that the relationship between multispectral imagery and SSC is non-linear and requires a more robust ML model (low correlation of $R2=-0.71$). Continuing work will compare these results with other ML models to develop a cross-validated method for widespread usage in SSC detection. This study contributes to a larger framework, and with a validated model we will be able to quantify the effects of SSC on the entire Snake and Columbia River system. Implications of this research include improving our understanding of SSC and detection methods that augment existing methodologies as tools for stakeholders, government agencies, land managers, and citizen scientists.
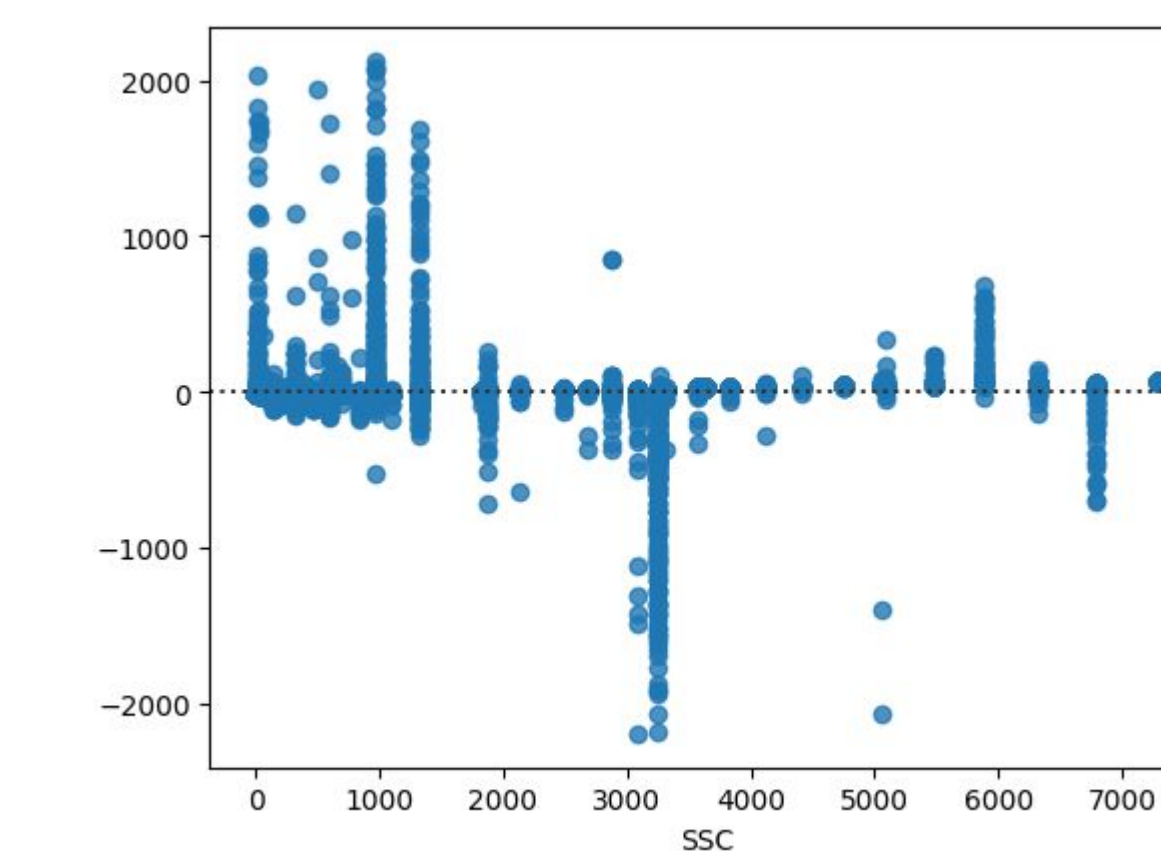
MULTISPECTRAL DATA

The lab used a MicaSense camera, a multispectral camera, which combines a panchromatic sensor with five narrow bands to produce high-resolution multispectral and RGB from one flight,

Data was collected by H. Spero in summer 2021 in a laboratory setting using a MicaSense RedEdge camera. Example of dataset on right.

	Blue	Green	Red	Redge	Nir	SSC	Temp	Exp
0	0.049006	0.063901	0.058663	0.039747	0.015381	327.937875	64.5	10_180g_Clay_2021_24_05
1	0.053875	0.068805	0.063535	0.042557	0.017758	327.937875	64.5	10_180g_Clay_2021_24_05
2	0.060301	0.073612	0.068871	0.047324	0.019706	327.937875	64.5	10_180g_Clay_2021_24_05
3	0.064790	0.080350	0.073851	0.050390	0.020997	327.937875	64.5	10_180g_Clay_2021_24_05
4	0.069004	0.085702	0.078428	0.053268	0.021784	327.937875	64.5	10_180g_Clay_2021_24_05
...	...	...	...	...	...	...	...	...
48495	0.012944	0.018293	0.021511	0.018387	0.010959	1329.970270	71	6_730g_Clay_2021_02_06b
48496	0.012763	0.018609	0.021234	0.017865	0.010474	1329.970270	71	6_730g_Clay_2021_02_06b
48497	0.012506	0.018247	0.021035	0.017788	0.010169	1329.970270	71	6_730g_Clay_2021_02_06b
48498	0.012194	0.018081	0.021175	0.017543	0.009943	1329.970270	71	6_730g_Clay_2021_02_06b
48499	0.011808	0.017787	0.020862	0.017378	0.009786	1329.970270	71	6_730g_Clay_2021_02_06b

48500 rows × 8 columns

DATA

RESULTS

Random Forest

- Mean squared error: 34610.71
- Mean absolute error: 40.58
- Coefficient of determination: 0.99

Linear Regression

- Mean squared error: 5557240.83
- Mean absolute error: 738.74
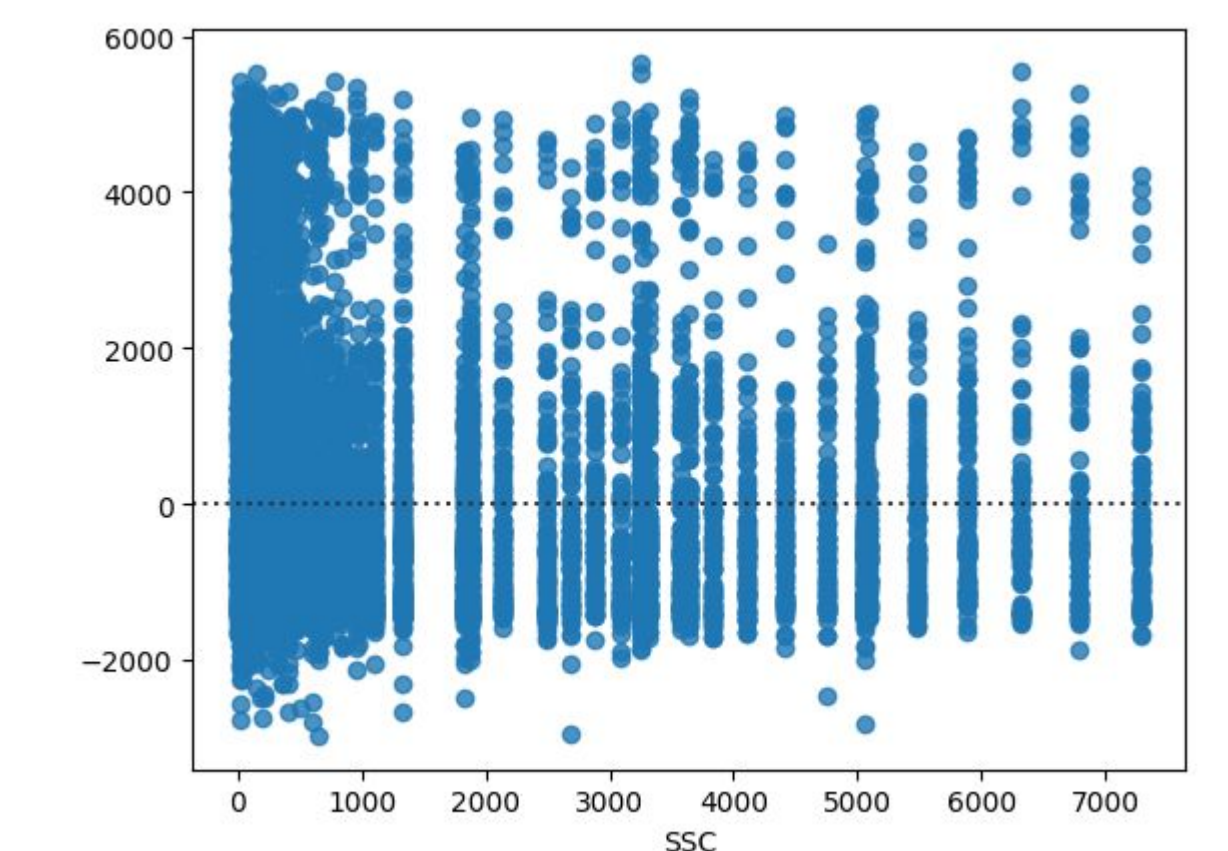- Coefficient of determination: -0.71

CONCLUSION

- The Random Forest model is reasonably accurate at detecting SSC from multispectral imagery data collected in an ideal setting
- Trends and patterns for SSC detection cannot be made by using a simple model, such as the Linear Regression model demonstrated by a negative R2
- Both results point to further testing of more robust models being needed
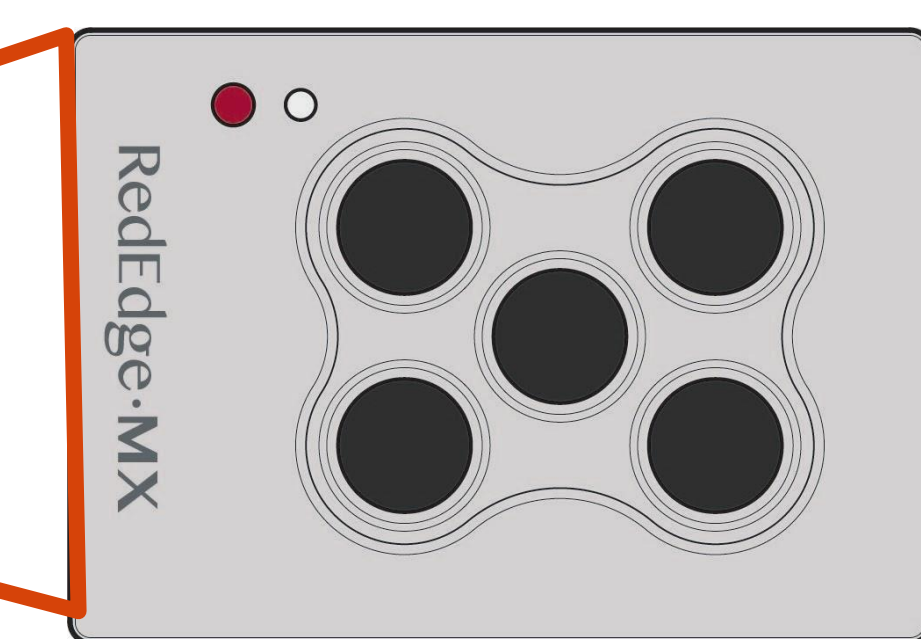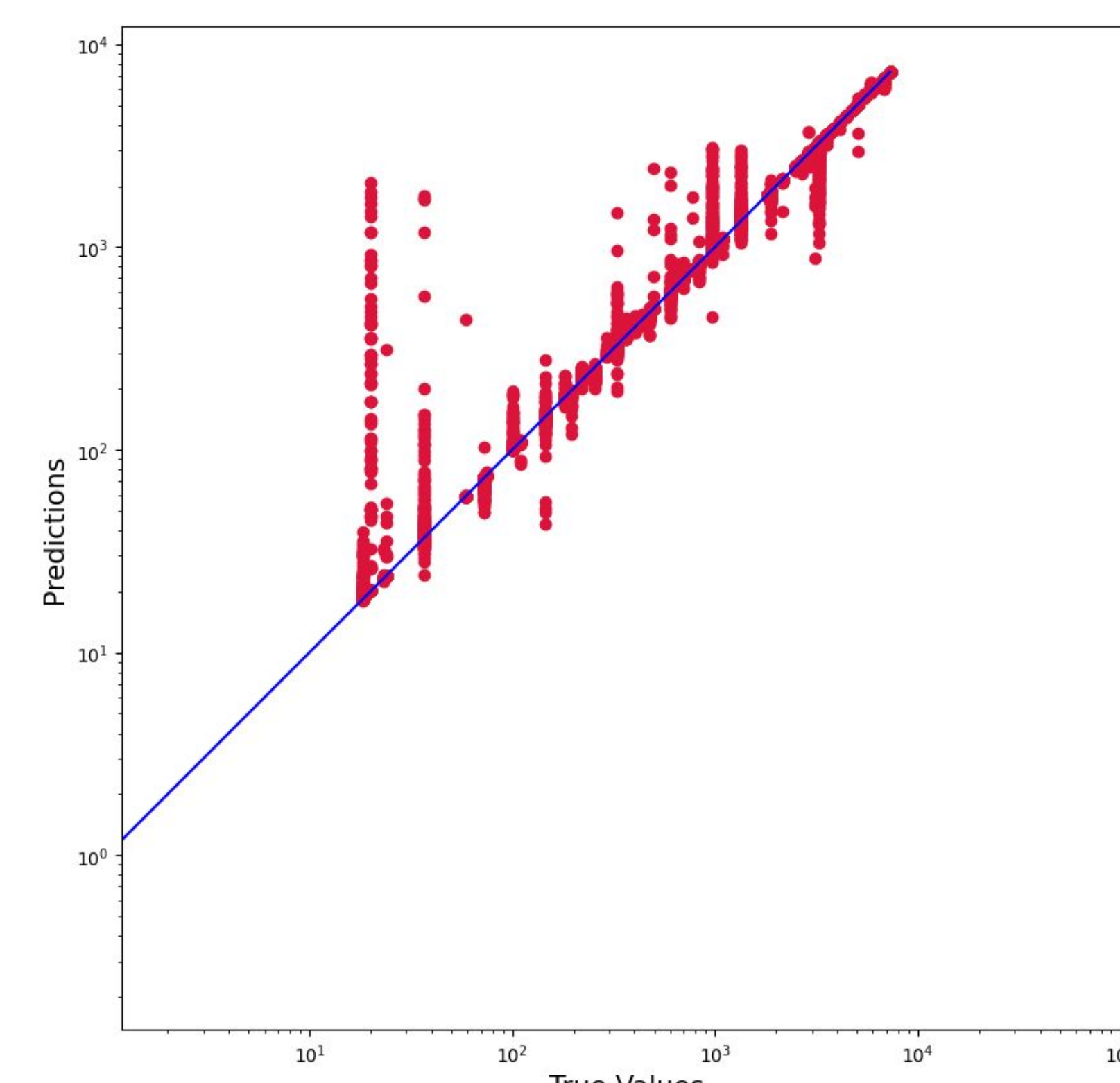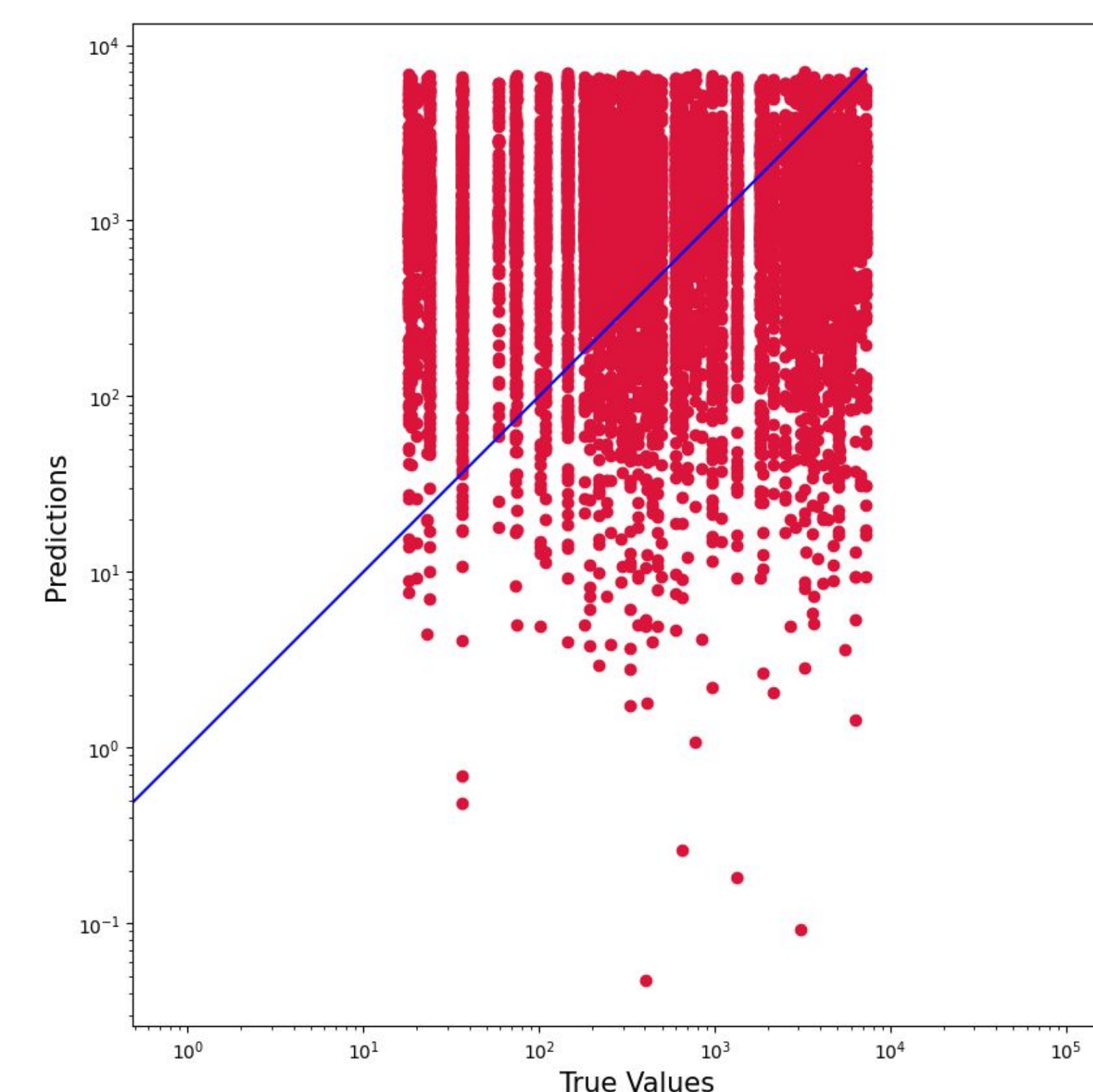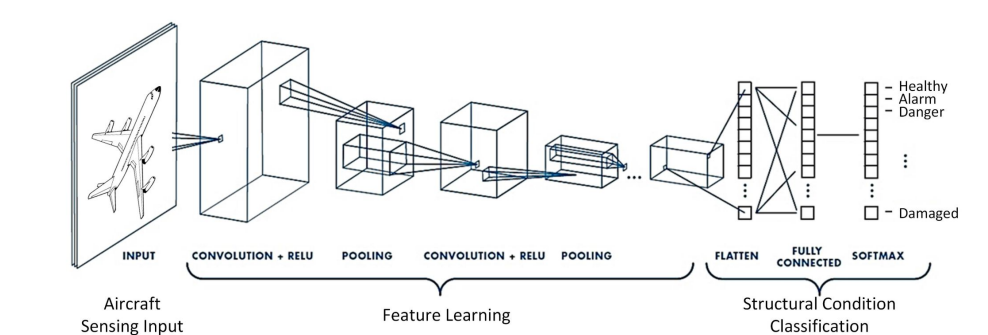
Random Forest

Linear Regression

Residual plots for both ML models

FURTHER PLANS

- Compare these results with other ML models such as U-Net, Extreme Gradient Boosting, and Convolutional Neural Network.
- Develop more robust method with the ability to quantify the effects of SSC on entire river systems such as the Snake and Columbia River.
- Create open source, easily accessible detection methods
- Provide stakeholders, government agencies, land managers, and citizen scientists with tools to augment existing methodologies.
- Complement concurrent studies on sediment deposition caused by the increased frequency and intensity of wildfires.
- Complement studies on effects of SSC on anadromous fish
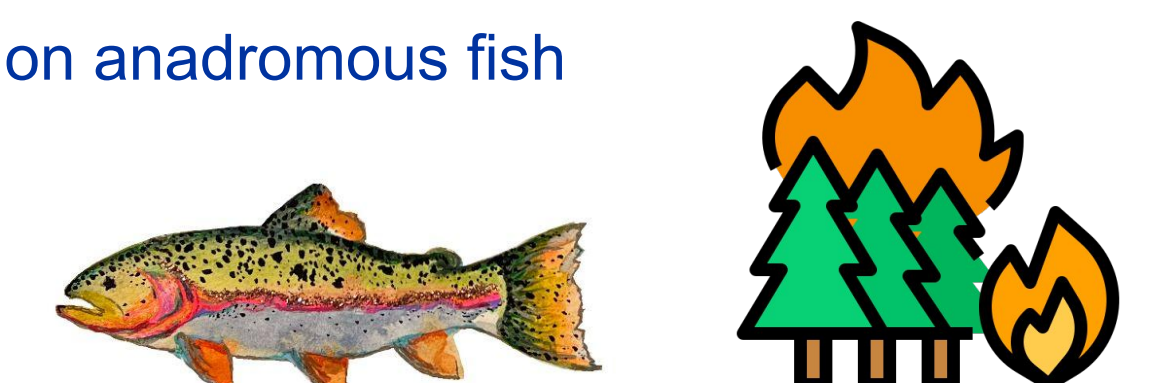
ACKNOWLEDGEMENTS

Idaho State Board of Education