NDVI Exploration for Lead-Zinc Deposits in Southern Missouri

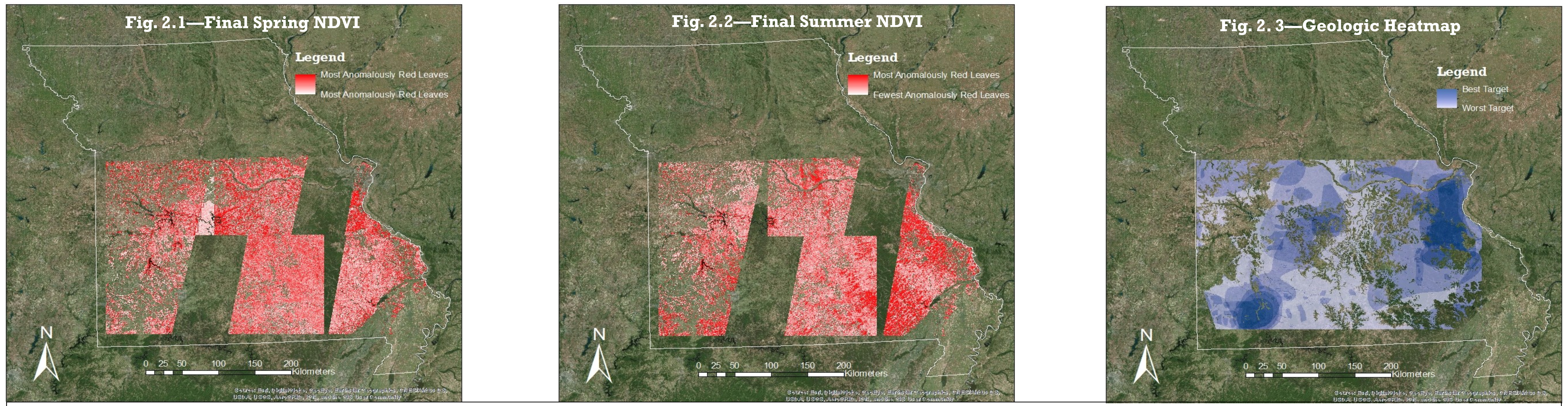


Figure 2— The final maps. They were produced using the component maps (Fig. 1) and used to create the proof of concept overlays (Fig. 3).

Introduction

Exploration is the most crucial phase of any mining operation. However, it requires economically and environmentally costly boots-on-the-ground work, which can lead to the degradation of local ecosystems. The exploration phase also involves high financial risk, and even well-funded projects can be bankrupt by unforeseen issues. It is therefore crucial to narrow down exploration targets as much as possible before beginning fieldwork.

Exploration teams have increasingly relied on remote sensing – the manipulation of spectral bands in satellite images – to identify metals and minerals in the soil that indicate the presence of an underlying ore deposit[1]. However, this methodology is limited to areas with minimal plant cover, which renders it near-useless for exploration in mineral-rich but heavily forested regions such as Canada and Alaska.

This project attempts to address these shortcomings by instead using remotely-sensed forest data, through which deep root systems offer an even better picture of what metals rest beneath the surface. Lead-zinc deposits are the ideal test subjects, since high zinc levels can cause a characteristic reddening of younger leaves[2], while excess lead stunts root growth, leading to a rapid decline in plant health. Both of these qualities can be measured using the Normalized Difference Vegetation Index (NDVI) which uses the ratio of red and near-infrared light reflected by a plant to determine its health. Southern Missouri was selected as the research site because it offers an abundance of lead-zinc deposits and hardwood forests, which allows for the examination of young leaves in the spring, and mature leaves in the summer.

Methodology

This project is focused on comparing objective geological data to results obtained via remote sensing, in search of spatial agreement between the two.

Aggregating the geological data:

- Soil data from the United States Geological Survey was used to create point maps of lead and zinc values measured in soils throughout the study area. Each map was then interpolated using the Natural Neighbor method to create continuous rasters (*Fig. 1.1,1.2*).
- A U.S. Geological Survey map was used to isolate areas with dolomite or limestone bedrock, as those rocks are the known hosts of lead-zinc deposits in the region. Faults serve as structural controls on mineral deposits, and thus the map's faults were isolated and buffered to 100 meters, after Madani, 2011[4] (*Fig. 1.3*).
- A Missouri DNR map of lead-zinc mining districts and mining regions was georeferenced and digitized to constrain areas of known lead-zinc deposits (*Fig. 1.4*).

Each of these maps were each reclassified to a scale of 1 through 5 (with binary maps reclassified to 5 and NoData) and combined to create the aggregate Geological Pb-Zn Heatmap via a Weighted Sum. The sum weights were as follows: Bedrock: 0.5, Faults: 2.0, Mining Regions: 0.5, Mining Districts: 1.0, Soil Lead: 1.5, Soil Zinc: 1.5 (*Fig. 2.3*).

Performing the remote sensing analysis :

Recent Landsat 8 Top-of-Atmosphere corrected images were used, with early May and mid-July images for the spring and summer analyses respectively. Next, an NDVI analysis was performed for each image, selecting Band 5 as the near-infrared band, and Band 4 as the red light band. These images were classified to exclude NDVI values below 0.65, in order to increase the visibility of weakened trees.

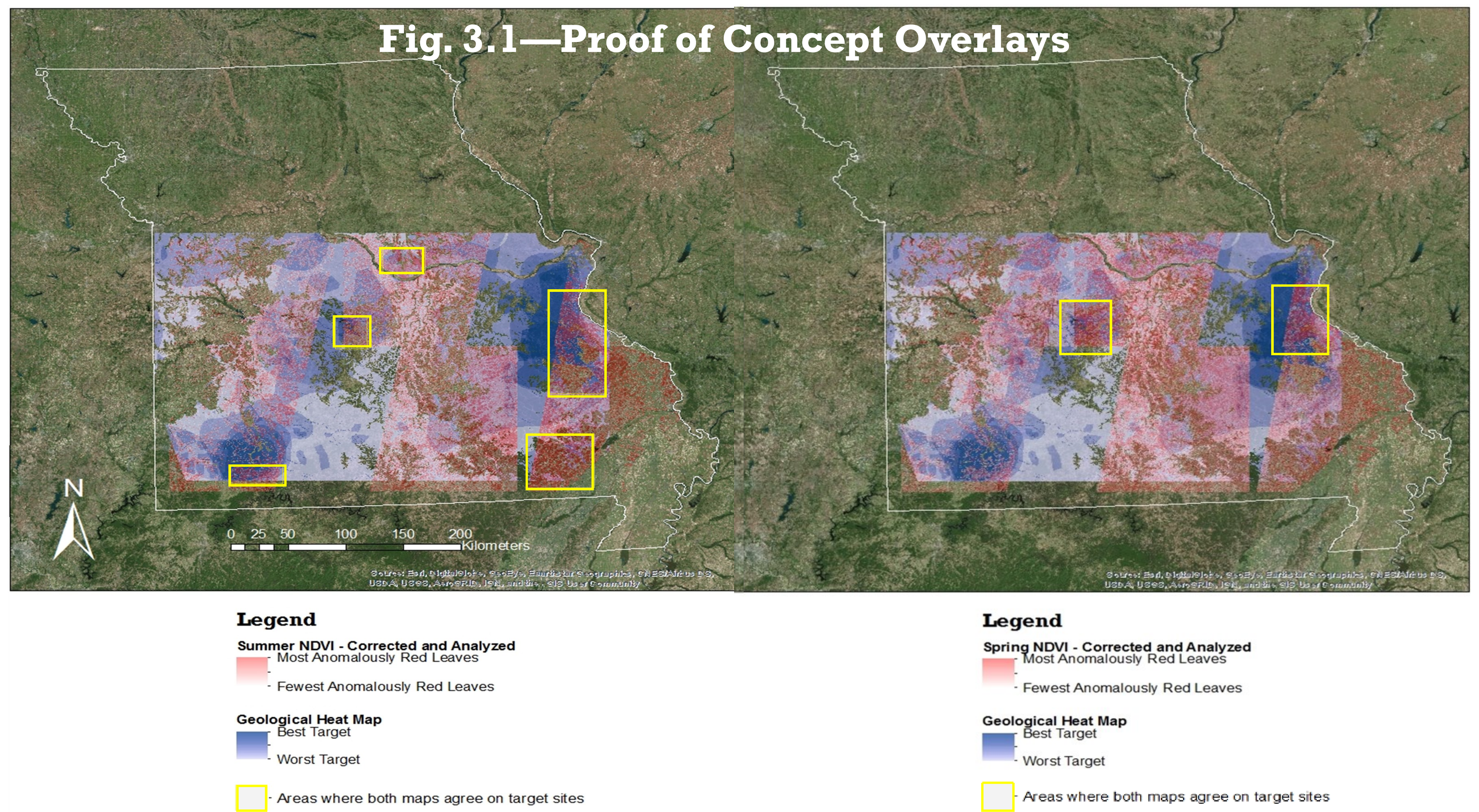
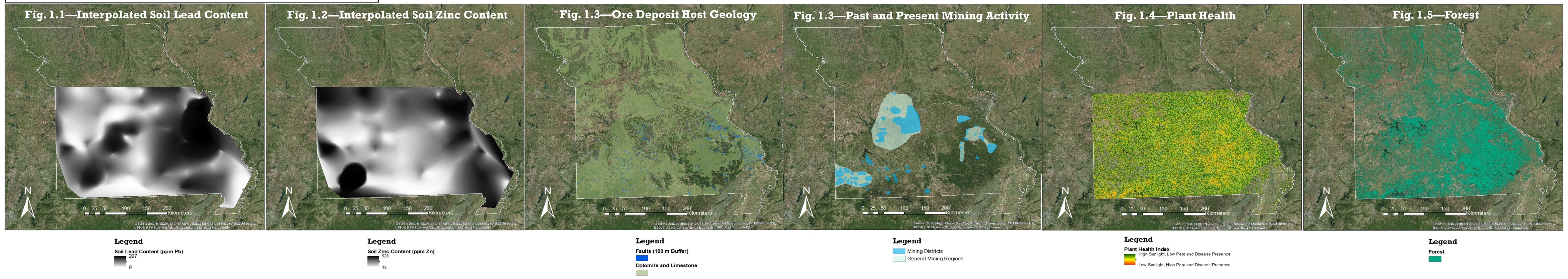


Figure 3—Final proof of concept overlays of the Geologic Heatmap and the spring and summer NDVI maps.

Digital Elevation Models (DEMs) of southern Missouri were imported from the National Map and analyzed for slope direction with the Aspect tool. Aspects were reclassified into sun-exposure categories under the assumption that south-facing slopes would receive the most light, while north-facing slopes would receive the least. Then, this sunlight map was combined with U.S. Forest Service composite pest and disease maps to create a plant health index via Weighted Overlay, which was in turn converted to a correction factor for the NDVI maps. (*Fig. 1.4*). Next, land-use-land-cover data from the National Map were used to ensure the NDVI analysis only considered hardwood forests (*Fig. 1.5*). Lastly, the corrected NDVI maps were then analyzed using the standard deviation function of the Focal Statistics tool, in order to highlight areas of anomalously poor tree health (Fig. 2.1, 2.2). These final maps were then superimposed on the Geological Heatmap for proof of concept comparison (*Fig. 3.1*).

Figure 1—Component maps, used to generate the final maps



Discussion

Perhaps the biggest limitation to this study is the lack of available data. Landsat 8 images did not cover large swaths of Missouri, and often had significant cloud cover or atmospheric distortion. Soil samples were taken far apart, and do not necessarily offer a complete picture of soil chemistry. Additionally, the forests of the study region are disturbed, which may have a significant impact on forest health in some areas. In the same vein, different species may respond differently to specific stressors, which is a difficult factor to control for. Hydrologic variance – both seasonal and local – was not considered. Finally, exploration programs in remote locations may not have access to important control data such as pest and disease maps.

Results and Conclusions

While this analysis is by no means an exact science, it does show promise as a tool for exploration geologists to use in conjunction with other methods. Both proof of concept maps show significant areas of agreement between the NDVI analyses and the Geologic Heatmap. The summer NDVI clearly shows stronger and more frequent agreement, however, especially in the historically zinc-rich southwestern region of Missouri, suggesting that summertime imaging would produce the best results, despite the springtime effects attributed to zinc.

Future efforts should focus on refining this analysis methodology by better constraining the correction factors and overlay weights, and through consideration of additional variables, as well as the degree of each variables' statistical correlation. Most important would be developing accurate solar radiation and hydrological models, and furthering our understanding of the way leaf reflectance values of different species change when exposed to different metals.

Cartographer: Jack Baer, A18

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Data Sources

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