Prior Well Depletion or Interwell Spacing? Isolating the Causes of Spacing Degradation in the Williston Basin

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Abstract

A major question for operators in shale basins is the number of wells to complete in a given acreage. Several tests have attempted to maximize the value of acreage by downspacing wells to capture a high fraction of available hydrocarbons, or even to achieve constructive interference between wells. There are numerous examples of downspacing tests leading to poor well performance, but the exact effects and relationships between geology, completions, interwell spacing, and parent-child relationships are difficult to isolate. In order to determine the effects of tight spacing and parent-child relationships, we first compute 45 different spacing and timing variables for ~10,000 horizontal wells in North Dakota. Spatially, these variables include absolute horizontal, vertical, and tangent distances between well bores at the time of initial production. In order to account for parent-child relationships, we also compute the number of parent wells, and distance between parents and children. Finally, we compute the prior production of these parents, to determine the magnitude of damage to a child well as a function of prior well depletion. Next, we construct a tree-based machine learning model using these features, along with geology and completions, to predict the production of oil, gas, and water at 30 day increments out to 2 years. The utility of this machine learning model is two-fold. First, we use it to generate simulated pads at varying spacing, timing, and completion scenarios and observe variations in predictions as a function of these controllable parameters across the basin. Second, we build a surrogate model and compute SHAP (Shapley Additive Prediction) values, which estimate the impact of each variable on a well prediction, in units of

barrels or MCF. The results of this modeling approach show that interwell spacing is much less important than timing effects such as number of parents and prior well depletion. For example, we see that parent-child features impact 2-year cumulative oil predictions by roughly 20% as we move from true parent wells to child wells with at least 4 parents in a 2000 foot radius. We also see a strong difference between exterior and interior wells. On this timescale, the effect of interwell spacing on co-developed interior wells is much less pronounced. Predictions on both unseen test set wells as well as synthetic planned wells show degradations of less than 10% moving from 440ft to 880ft spacing for simultaneously developed wells on the same pad. These results show the value of an explainable machine learning model to decouple effects of geology, completions, spacing, and prior well depletion. Historical development trends leads to confounding of these variables, limiting the effectiveness of traditional data analysis and type curve methods. Using a machine learning model to isolate the effects of parent-child effects can lead directly to improved well planning decisions.

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