Chapter 4

Leveraging Quantum Machine Learning for Precision Nutrient Management in Sustainable Crop Production

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ABSTRACT

Contemporary agriculture is having major difficulties in assuring nutrient delivery and caring for the environment. The paper proposes integrating quantum machine learning (QML) techniques with precision agriculture tools to bring improvements to nutrient management. Predicting the correct amount, timing and distribution of fertilizer works much better with our new quantum-based strategy than with established ones. Analyzing the interactions among soil, plants and the atmosphere with quantum variational circuits and quantum kernel methods allows us to predict how much fertilizer is needed with an accuracy of 94.7% and helps lower waste by 38.2%. With QAOA implementation, real-time adjustments can be done in variable-rate systems. This type of research aims to overcome important problems with current

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algorithms unable to work with high-dimensional datasets in agriculture. This work creates the base for new agriculture systems that help achieve high crop yields while keeping the environment safe through quick and effective methods of optimization.

1. INTRODUCTION

1.1 Global Agricultural Challenges and Food Security

The world faces an unprecedented challenge in feeding a projected global population of 9.7 billion by 2050 while simultaneously addressing environmental degradation, climate change, and resource scarcity (FAO, 2017). To satisfy food requirements of future generations, agricultural systems will have to become more productive, nearly 70 percent more productive, but present activities fashion systems that reduce sustainability in the long term by overusing fertilizers, degrading soil composition, and polluting the environment (Godfray et al., 2010).

The modernized form of agriculture is faced with a paradoxical situation whereby more production has to be achieved without altering the environment. Conventional nutrient control systems normally lay fertilizer across all fields regardless of spatial and temporal differences in the soil, crop needs, and environmental conditions (Zhang et al., 2002). The net outcome of this one-size-fits-all method is that the efficiency of using nitrogen in the production of cereals around the world is only 33 percent on average (Ladha et al., 2005). Environmental impacts are grave such as water body eutrophication, emission of greenhouse gases, and biodiversity degradation (Sutton et al.,2011).

1.2 The Promise and Limitations of Precision Agriculture

Precision Agriculture has come out as a solution to all these issues by offering the opportunity to manage a site under real time scenarios using advanced analytics and data (Stafford, 2000). Variable rate technology (VRT) enables farmers to apply inputs in specific location and time to reduce wastage without affecting or enhancing the yield (Blackmore et al., 2003). Nonetheless, agricultural systems are highly complex, and as such, their computation poses a challenge to the application of modern precision agriculture strategies.

Agricultural decision making encompasses many interacting factors such as soil characteristics, weather, bio-genetic characteristics of crops, presence of pests, and market (Jones et al., 2017). These variables have relationships that are non-linear, non-contextual and increasingly optimization problems as the number of variables to consider increases exponentially. On this account, classical machine learning

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